Fisheries-independent data for Scamp (*Mycteroperca phenax*) from reef-fish visual surveys in the Florida Keys and Dry Tortugas, 1999-2018

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Fisheries-independent data for Scamp (*Mycteroperca phenax*) from reef-fish visual surveys in the Florida Keys and Dry Tortugas, 1999-2018.

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Introduction:

The Florida Keys reef tract is one of the longest barrier reefs in the world supporting over 500 species of fish and thousands of invertebrate species (Ault et al. 2005). Not only does the reef tract support an important ecosystem, but it also helps support the economy of Florida by creating thousands of jobs in the fishing and tourism industries (Ault et al. 2005). However, like many coral reefs worldwide the Florida reef tract is declining due to the cumulative effects of climate change, poor water quality, and the over exploitation of many fish species. In order to monitor and asses changes along the Florida reef tract, , the reef visual census (RVC) was implemented in 1979 in the Florida Keys, Florida to monitor and provide long term data for reef fish populations in south Florida (Bohnsack et al. 1999). In 1999, the Dry Tortugas were included in the monitoring plan. The RVC is a multi-agency effort that uses trained scientific divers to conduct underwater visual surveys to record the abundance and size of reef fishes on shallow water reef habitats. These data can be used to provide abundance indices for stock assessments. Therefore, these data were used to provide indices of abundance for Scamp, *Mycteroperca phenax*, in the Florida Keys and the Dry Tortugas.

Methods:

Methods follow those initially outlined by Herbig et al. (2019), for yellowtail snapper for SEDAR 64. Reef visual surveys in the Florida Keys (Biscayne National Park to Key West) and Dry Tortugas regions were typically conducted from May through October. Sampling was based on a two-stage stratified sampling design, focusing on hard bottom shallow reef habitat, typically less than 30m. From 1999-2012, hardbottom habitat in the Florida Keys and the Dry Tortugas was divided into 200x200m grid cells, or primary sampling units (PSUs). After 2012, sampling was conducted biennially, and the PSUs were divided into 100x100m grids. Each PSU was assigned a habitat stratum based on depth, protection (open or closed to fishing), habitat type (isolated, continuous, spur and groove), and substrate relief (Brandt et al. 2009). The habitat strata in the Florida Keys were defined as inshore patch reef, mid-channel patch reef, offshore patch reef, high relief reef, shallow forereef, mid-forereef, and deep forereef (Figure 1). In the Dry Tortugas, habitat strata were defined as continuous low-relief reef, continuous mid-relief reef, continuous high-relief reef, isolated low-relief reef, isolated mid-relief reef, isolated high-relief reef, spur and grove low-relief reef, and spur and groove high-relief reef (Figure 2). The number of PSUs sampled in each stratum was based on the area of each strata within the sampling region and variance in estimated abundance (Smith et al. 2011). Strata with higher variance were allocated more samples to increase survey accuracy. Once the estimated number of PSUs needed to achieve a 20% coefficient of variation (CV) were allocated to each stratum, PSUs were randomly chosen for each stratum.

Within each PSU, two secondary sampling units (SSUs) were selected based on the location of hard bottom habitat. At each SSU, a pair of divers would secure a float with a GPS marker, swim 7.5m in opposite directions, and conduct stationary point counts within a cylinder of water with a 7.5 m radius. Each point count survey recorded the abundance and lengths of fish species present and basic benthic habitat variables. Since diver cylinders at SSUs were adjacent and sometimes overlapped, the counts were not independent and were averaged for each SSU.

For this report, data from RVC surveys from 1999-2018 were used. Fish surveys have been collected in the Florida Keys since 1979, however the above methods were not adopted until 1999 and until the two-stage stratified random sampling design and the increased stratification were implemented, there was much higher variability in survey estimates (O'Hop et al. 2012). Data from the 1999-2018 surveys

were used to estimate density, abundance, occurrence, occupancy, and length frequencies for the Florida Keys (Biscayne Bay through Key West) and the Dry Tortugas. Samples that occasionally occurred on non-reef habitat (like seagrass or artificial reef) were excluded from analyses, along with surveys conducted in poor visibility (<3.5m). Occurrence was calculated as the percent of SSUs where Scamp was present. Occupancy was calculated as the weighted average of the strata occurrence. Density (fish/cylinder) was calculated by taking the average density per PSU, calculating a stratum density by averaging the PSU densities in that stratum, and calculating the final population density (within the sampling domain) by summing the weighted stratum densities. Stratum densities were weighted by the number of PSUs found within each stratum. The abundance estimates were extrapolated from the densities by multiplying the densities for each stratum by the number of PSUs per stratum and the number of SSUs possible in a PSU. Estimates were calculated for juvenile fish and mature fish, greater than or equal to 33 cm FL. More in-depth information about sampling design and analysis can be found in Ault et al. (2002, 2005, 2006), Brandt et al. (2009), and Smith et al. (2011).

Results/Discussion:

Florida Keys:

The Florida Keys were sampled yearly from 1999-2018, after which they were sampled biennially. During this time 5630 PSUs were sampled from Biscayne Bay to the Marquesas (Figure 3, Table 1). During the 2004 sampling year several hurricanes caused a disruption to the survey schedule and two strata (inshore patch reef and mid-channel patch reef) were not sampled. Therefore, data from 2003 and 2005 were averaged and used as a proxy for the missing strata values for 2004.

During the entire RVC sampling history, mean overall Scamp density was never above 0.1 fish/cylinder in the Florida Keys (Table 1, Figure 4). Adult density was particularly low, rarely above zero, while juvenile density had two small peaks in 2005 and 2011. Scamp abundance (extrapolated from densities) for the Florida Keys therefore followed a similar pattern with very low adult abundances and slightly higher juvenile abundances with peaks in 2005 and 2011 (Table 2, Figure 5). The coefficient of variance and standard error values are high for both density and abundance due to the low number of surveys where Scamp were present, and this should be considered when using this data.

Scamp occupancy was also low, never more than five percent. Occupancy was lowest in 2003 and 2004, when it was almost zero (Figure 6). When occupancy was divided into occurrence by habitat strata the average occurrence for juvenile fish was highest at mid-channel patch reefs and deep forereefs and average occurrence for adult fish was highest at deep forereefs (Figure 7). The low occupancy in 2003 and 2004 could be because fewer deep forereef and mid-channel patch reef habitats were sampled in those years compared to others. Scamp have been documented in deep water (20-100m) at low relief sites, often near slopes or drop offs, and aggregating at high relief sites to spawn (Gilmore & Jones 1992, Manooch et al. 1998, Coleman et al. 2011). If Scamp, particularly adults, prefer deep forereef habitat, they are likely occurring deeper than the RVC program samples, explaining the low density, abundance, and occupancy throughout the years. The increased presence of Scamp at forereef habitats could be due to habitat preference of deeper sites or early signs of ontogenetic shifts into deeper water. It could also be due to competition of space and territoriality as other grouper species in the Florida Keys have been found to have particular habitat preferences (Sluka et al. 2001).

A breakdown of the recorded Scamp lengths in the Florida Keys suggested that there was some digit bias with multiples of five having higher counts (Figure 8). Therefore, fish lengths were binned by 2cm for observed length frequencies (Figure 9). In general, there were more juvenile fish (n =118) observed than adult (n = 54). The increase of observed juveniles compared to adults is likely due to sampling depth. Juveniles are more abundant than adults in the shallower (<30m) coral reef habitats of the Florida Keys and are likely moving to deeper habitat as they mature.

Dry Tortugas:

The Dry Tortugas were sampled from 1999-2000, and then biennially beginning in 2004. During this time, 3028 PSUs were sampled (Figure 10, Table 3). The average density of Scamp in the Dry Tortugas was higher than in the Florida Keys for both adults and juveniles (Tables 1 & 3), but average overall density was never above 0.2 fish/cylinder. Peaks in density over the years were not as distinct compared to the Florida Keys, but overall densities were lowest in 2011, 2016 and 2018 compared to other years, largely influenced by juvenile density (Table 3, Figure 11). Abundance followed a similar pattern, with a lower abundance of adults compared to juveniles and the lowest overall abundances in 2016 and 2018 (Table 4, Figure 12). Again, the standard error and coefficient of variance values are high for both density and abundance due to the low number of surveys where Scamp were present, and this should be considered when using this data.

Occupancy in the Dry Tortugas was higher throughout the time series, between 3-12%, than it was the in the Florida Keys (Figure 13). The relative high occupancy could be due to the network of large marine reserves encompassing almost pristine reef habitat that make up the Dry Tortugas. When occupancy was divided into occurrence by habitat type, juvenile Scamp did not exhibit a strong habitat preference (Figure 14). The average occurrence for adult Scamp was highest at continuous low relief and low relief spur and grooves followed by isolated low relief and continuous high relief habitats (Figure 14). Although the RVC sampling is shallower than where most Scamp are documented, they have been shown to prefer low relief live-bottom habitat (Manooch et al. 1998) and occur at undercuts of ledges in 14 -21m depths (Kendall et al. 2008). However, RVC sampling sites are likely not capturing preferred habitat of Scamp, particularly of adults, as remotely operated vehicle (ROV) surveys have recorded scamp at depths up to 100 m at Pulley Ridge and Miller's ledge (Reed et al. 2017), both of which are close to the Dry Tortugas.

A breakdown of the recorded Scamp lengths in the Dry Tortugas suggested that there was also some digit bias with multiples of five having higher counts (Figure 15). Therefore, fish lengths were binned by 2cm for observed length frequencies (Figure 16). In general, there were more juvenile Scamp (n=716) observed and their length distribution was a little more evenly distributed compared to adult Scamp (n=180). The increase of observed juveniles compared to adults is again likely due to the depth of sampling. Juveniles are more abundant than adults in the shallower (<30m) coral reef habitats of the Dry Tortugas and are likely moving to deeper habitat as they mature.

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Table 1. The number of primary sampling units (PSUs) surveyed, average densities (Scamp per cylinder) and associated standard error (SE) and coefficient of variance (CV) values by sampling year for the Florida Keys.

Year	Number of PSU	Average Density	Average Density SE	Average Density CV (%)	Average Adult Density	Average Adult Density SE	Average Adult Density CV(%)	Average Juvenile Density	Average Juvenile Density SE	Average Juvenile Density CV (%)
1999	161	0.0114	0.0061	53.90	0.0000	0.0000	--	0.0114	0.0061	53.90
2000	221	0.0108	0.0043	40.06	0.0007	0.0005	72.06	0.0100	0.0042	42.05
2001	305	0.0205	0.0077	37.56	0.0115	0.0058	50.54	0.0090	0.0054	59.43
2002	343	0.0113	0.0047	41.70	0.0055	0.0040	72.35	0.0057	0.0025	43.30
2003	237	0.0009	0.0007	81.78	0.0000	0.0000	--	0.0009	0.0007	81.78
2004	127	0.0006	0.0006	103.09	0.0002	0.0001	69.42	0.0005	0.0006	140.21
2005	243	0.0416	0.0193	46.45	0.0075	0.0052	68.70	0.0341	0.0190	55.83
2006	319	0.0187	0.0071	38.17	0.0033	0.0023	68.96	0.0153	0.0067	44.00
2007	316	0.0229	0.0063	27.55	0.0077	0.0037	47.80	0.0152	0.0048	31.67
2008	376	0.0351	0.0092	26.07	0.0139	0.0045	31.97	0.0212	0.0064	30.19
2009	516	0.0264	0.0067	25.53	0.0101	0.0044	43.71	0.0163	0.0049	30.19
2010	379	0.0157	0.0073	46.59	0.0024	0.0017	71.07	0.0133	0.0063	47.19
2011	401	0.0637	0.0295	46.28	0.0112	0.0046	41.12	0.0525	0.0256	48.77
2012	416	0.0123	0.0054	43.67	0.0025	0.0014	56.38	0.0098	0.0049	49.49
2014	431	0.0153	0.0052	34.32	0.0049	0.0019	38.54	0.0104	0.0046	44.76
2016	405	0.0151	0.0109	72.18	0.0118	0.0108	91.28	0.0033	0.0016	50.67
2018	434	0.0063	0.0031	49.27	0.0037	0.0025	68.72	0.0026	0.0020	76.20

Table 2. Extrapolated abundance estimates and standard errors (SE) for Scamp in the Florida Keys.

	Abundance	Abundance SE	Adult Abundance	Adult Abundance SE	Juvenile Abundance	Juvenile Abundance SE
1999	43,457	23,423	0	0	43,457	23,423
2000	41,095	16,463	2,764	1,992	38,331	16,116
2001	78,231	29,383	43,749	22,110	34,481	20,492
2002	43,003	17,934	21,155	15,305	21,849	9,461
2003	3,345	2,735	0	0	3,345	2,735
2004	2,401	2,475	664	461	1,737	2,435
2005	158,880	73,801	28,662	19,691	130,218	72,705
2006	71,287	27,213	12,764	8,801	58,524	25,750
2007	87,497	24,105	29,347	14,028	58,151	18,414
2008	134,087	34,960	53,152	16,993	80,935	24,433
2009	100,726	25,718	38,481	16,820	62,245	18,794
2010	60,104	28,002	9,302	6,611	50,802	23,973
2011	243,357	112,630	42,851	17,618	200,507	97,796
2012	46,850	20,460	9,419	5,310	37,431	18,525
2014	58,750	20,162	18,782	7,238	39,968	17,889
2016	58,090	41,928	45,561	41,589	12,529	6,349
2018	24,086	11,866	14,231	9,779	9,856	7,510

Table 3. The number of primary sampling units (PSUs) surveyed, average densities (Scamp per cylinder) and associated standard error (SE) and coefficient of variance (CV) values by sampling year for the Dry Tortugas.

Year	Number of PSU	Average Density	Average Density SE	Average Density CV (%)	Average Adult Density	Average Adult Density SE	Average Adult Density CV (%)	Average Juvenile Density	Average Juvenile Density SE	Average Juvenile Density CV (%)
1999	170	0.072	0.021	28.37	0.022	0.009	39.33	0.051	0.016	30.92
2000	207	0.144	0.031	21.22	0.012	0.004	37.02	0.133	0.029	21.93
2004	310	0.101	0.022	21.54	0.018	0.005	28.55	0.083	0.019	23.34
2006	249	0.111	0.027	24.83	0.010	0.005	52.10	0.101	0.027	27.19
2008	338	0.078	0.013	17.16	0.022	0.006	28.14	0.056	0.011	19.35
2010	364	0.046	0.011	23.80	0.009	0.003	35.18	0.037	0.010	26.84
2012	416	0.112	0.015	13.62	0.020	0.007	36.33	0.092	0.014	14.87
2014	351	0.065	0.011	17.60	0.016	0.005	30.83	0.050	0.010	20.11
2016	286	0.020	0.004	20.58	0.005	0.002	33.06	0.014	0.004	24.20
2018	337	0.024	0.007	30.66	0.011	0.006	53.51	0.013	0.004	31.23

Table 2. Extrapolated abundance estimates and standard errors (SE) for Scamp in the Dry Tortugas.

Year	Abundance	Abundance SE	Adult Abundance	Adult Abundance SE	Juvenile Abundance	Juvenile Abundance SE
1999	144,402	40,970	43,760	17,209	100,642	31,121
2000	287,795	61,078	23,768	8,800	264,026	57,905
2004	200,855	43,255	35,837	10,230	165,017	38,515
2006	220,658	54,791	20,344	10,600	200,314	54,466
2008	156,005	26,774	44,460	12,513	111,545	21,587
2010	91,014	21,664	17,910	6,300	73,104	19,623
2012	222,852	30,355	39,772	14,450	183,080	27,219
2014	115,836	20,386	27,767	8,561	88,069	17,708
2016	34,645	7,131	8,972	2,966	25,673	6,213
2018	42,564	13,050	18,993	10,163	23,571	7,362

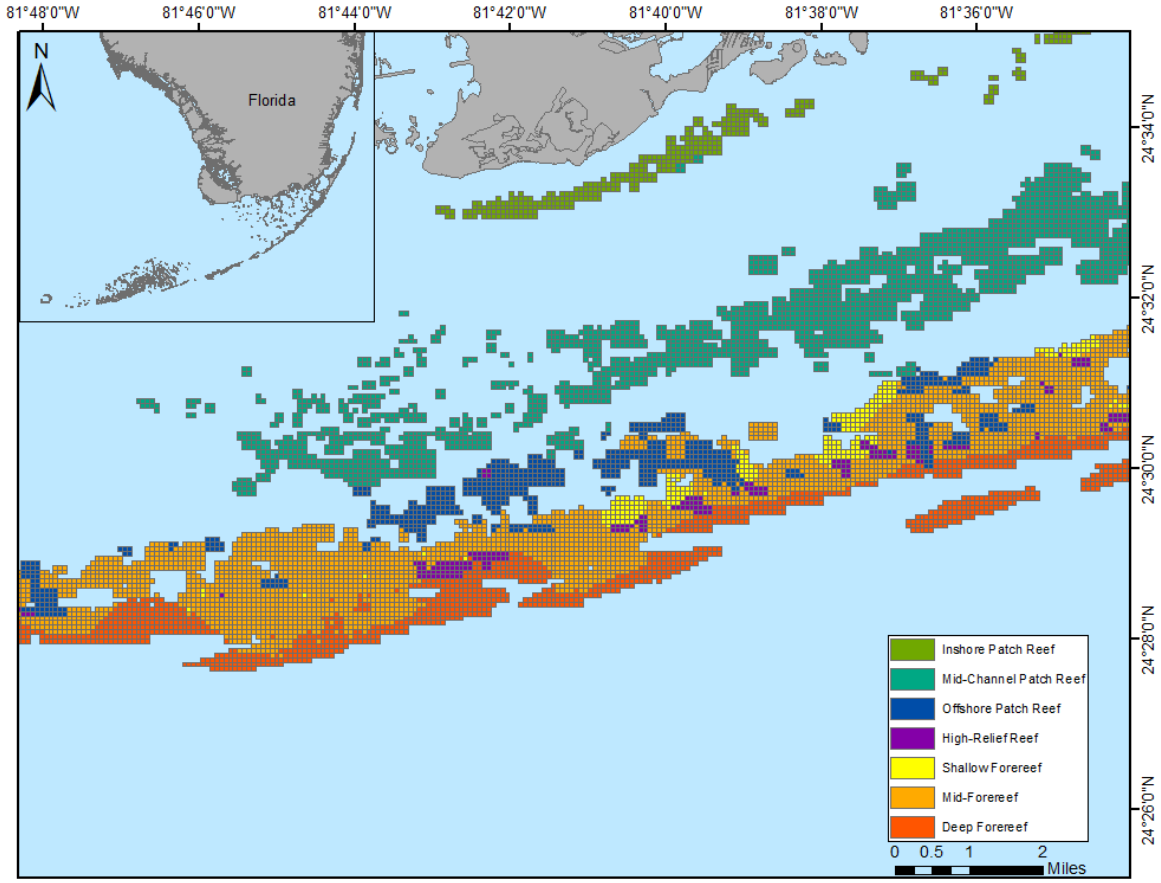

Figure 1. An example of habitat strata within the 100x100m grid for the RVC Florida Keys sampling scheme.

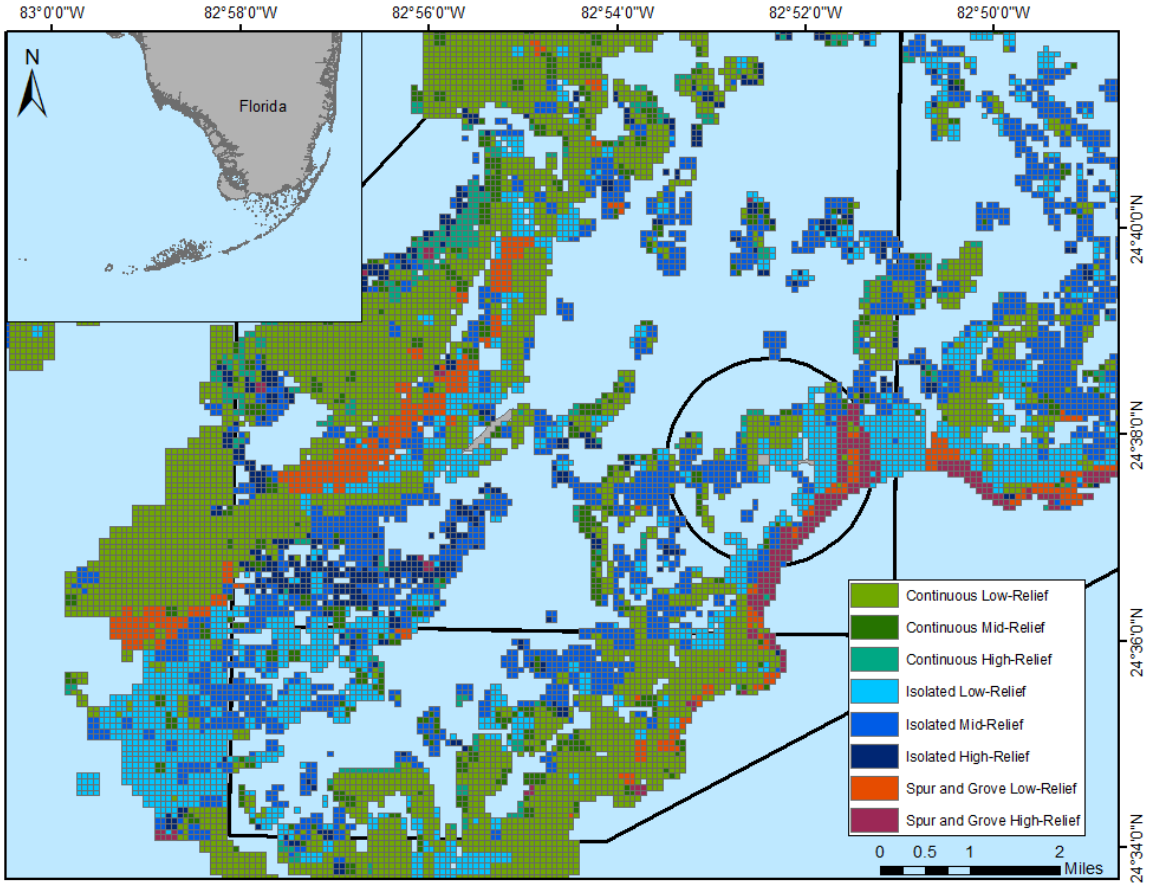

Figure 2. An example of habitat strata within the 100x100m grid for the RVC Dry Tortugas sampling scheme.

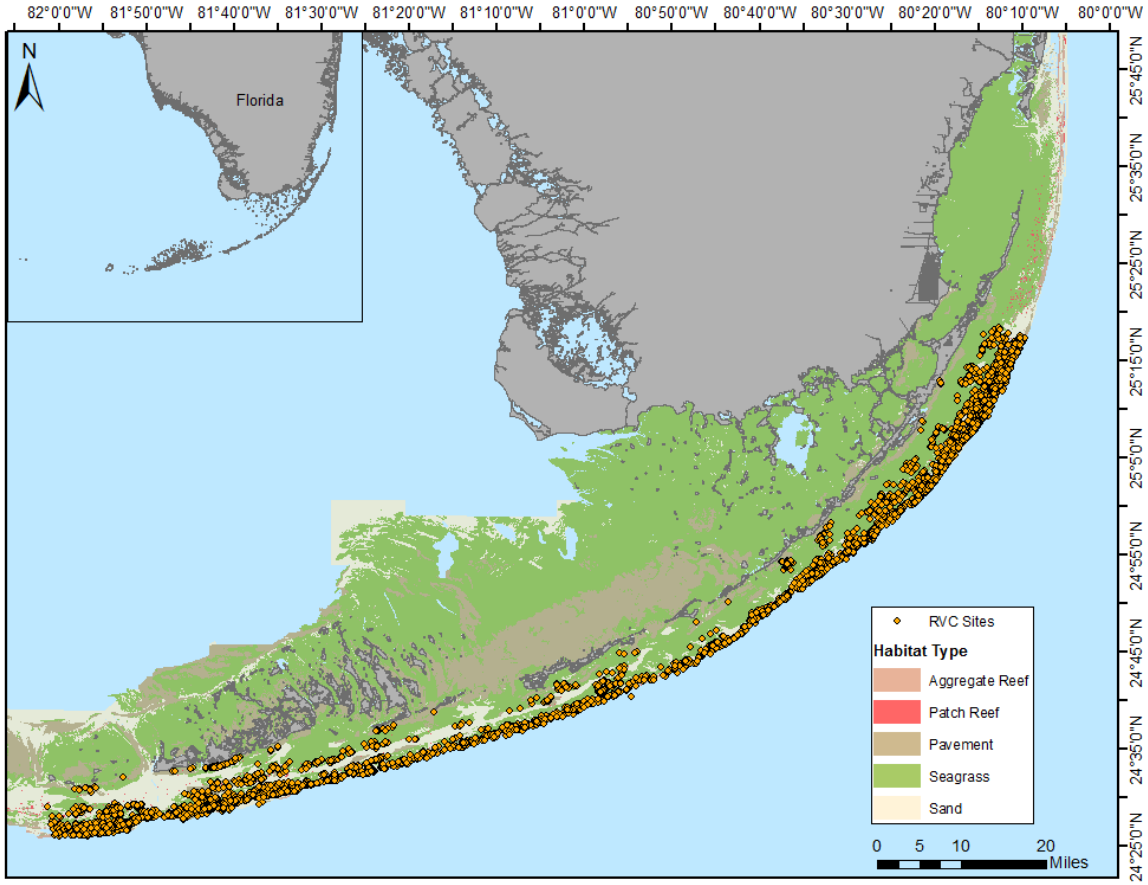

Figure 3. A map of the Reef Visual Census (RVC) primary sampling units (PSUs) surveyed from Biscayne Bay to the Marquesas from 1999 through 2018.

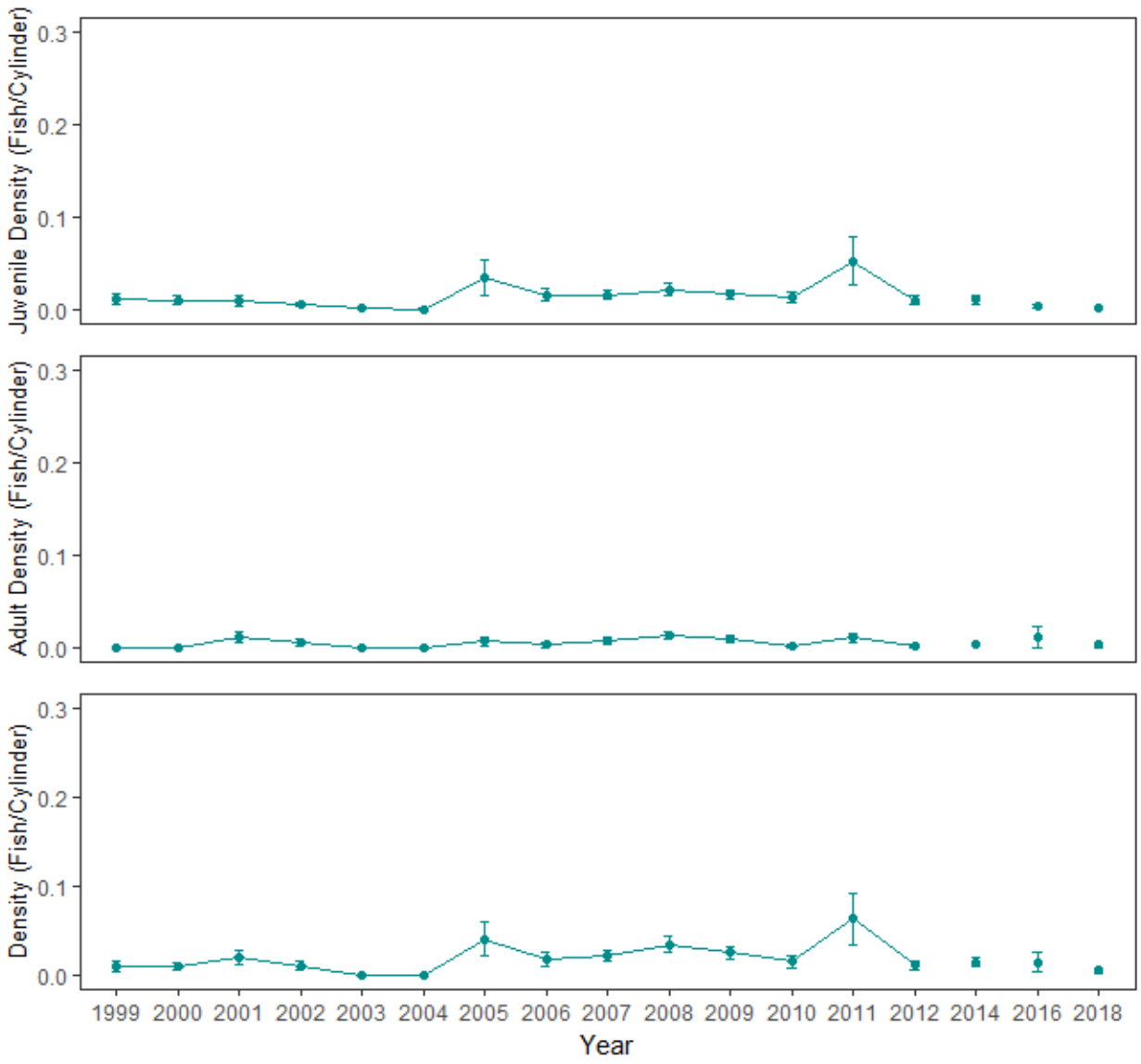

Figure 4. Densities of Scamp (juvenile, adult, and both life stages combined) from RVC surveys in the Florida Keys. Error bars represent the standard error.

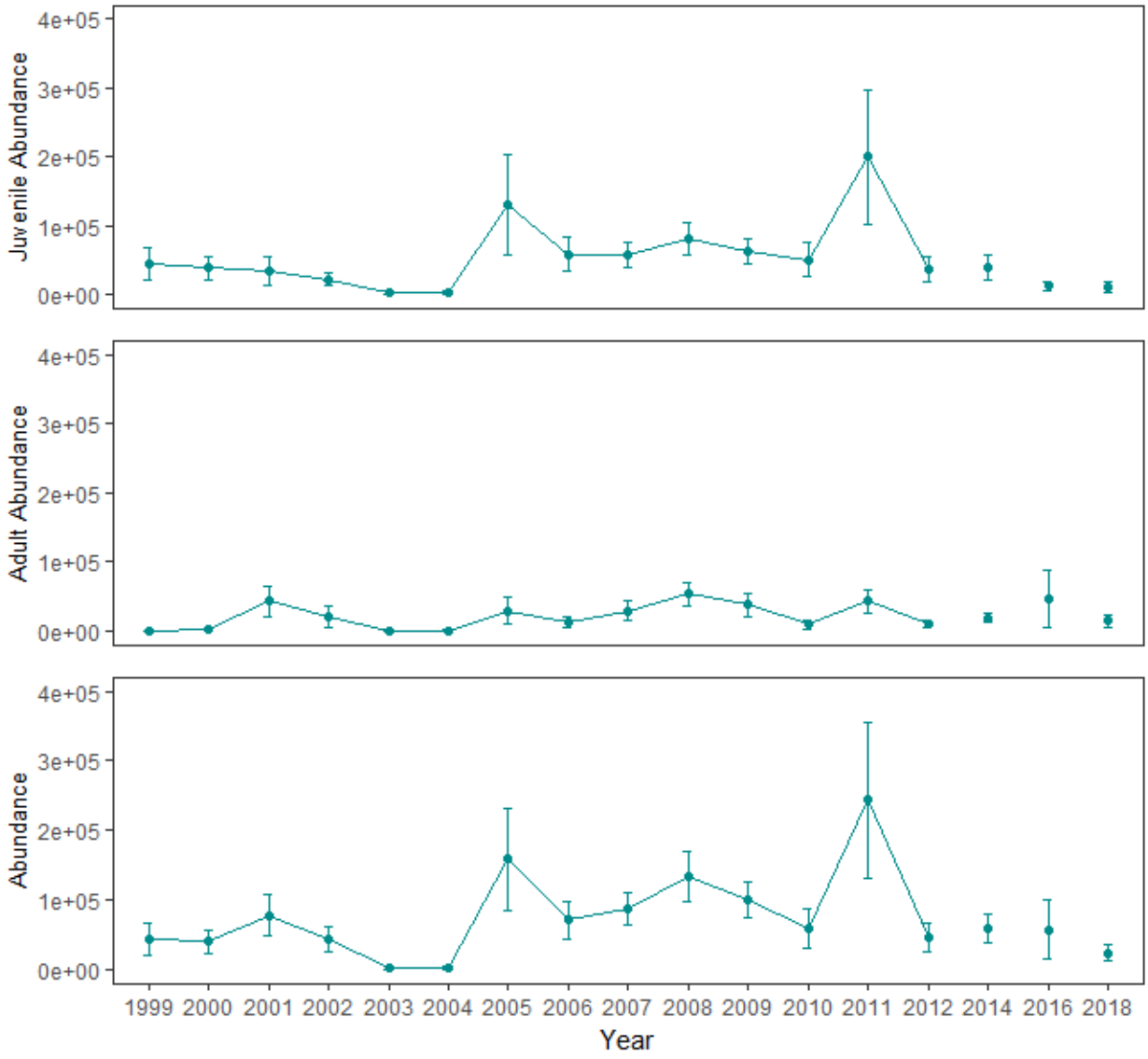

Figure 5. Survey-estimated abundance of Scamp (juvenile, adult, and both life stages combined) in the Florida Keys. Error bars represent the standard error.

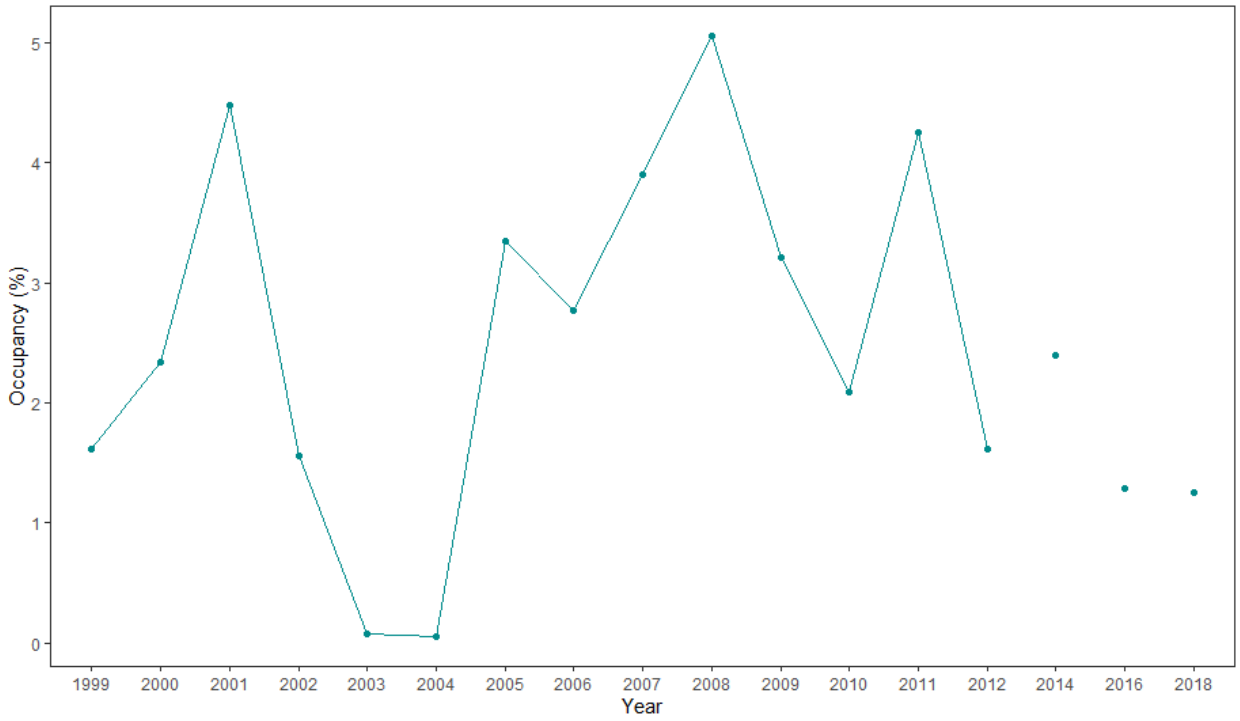

Figure 6. The occupancy rate of Scamp (juvenile and adult combined) over time in the Florida Keys. Occupancy was calculated as the weighted average of the strata occurrence.

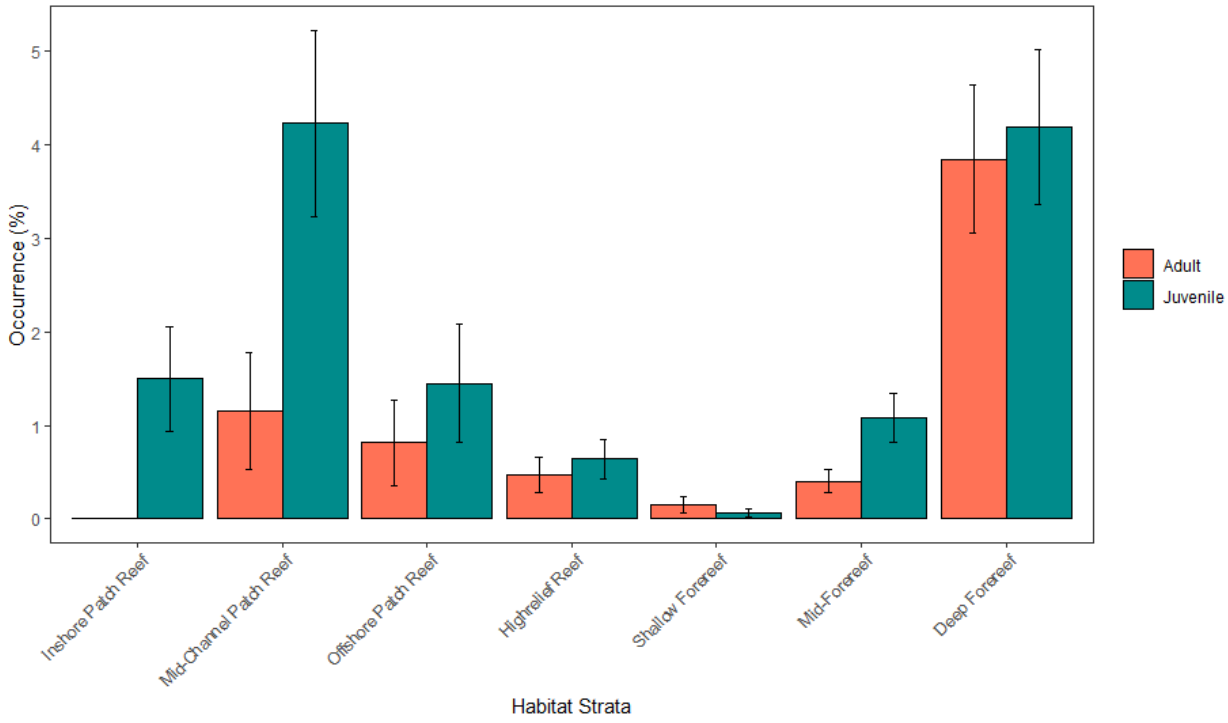

Figure 7. Occurrence by life stage (juvenile or adult) and strata for Scamp in the Florida Keys averaged across all years. Error bars represent the standard error. Occurrence was calculated as the percent of secondary sampling units (SSUs) when Scamp was present.

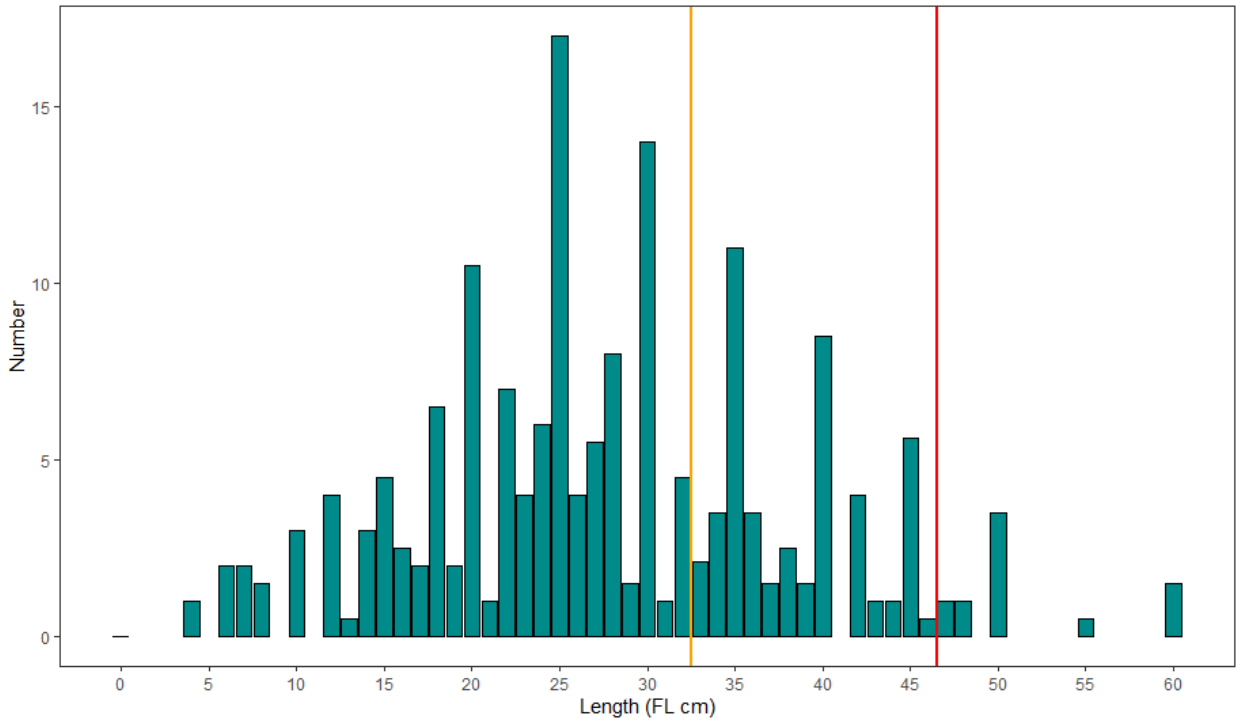

Figure 8. The observed length frequency for all Scamp surveyed in the Florida Keys RVCs (n=172). The orange vertical line represents the length at maturity (33 cm FL) and the red vertical line represents the minimum size limit in Florida Atlantic State waters (20 in TL) converted from inches total length to centimeter fork length (46.5 cm FL).

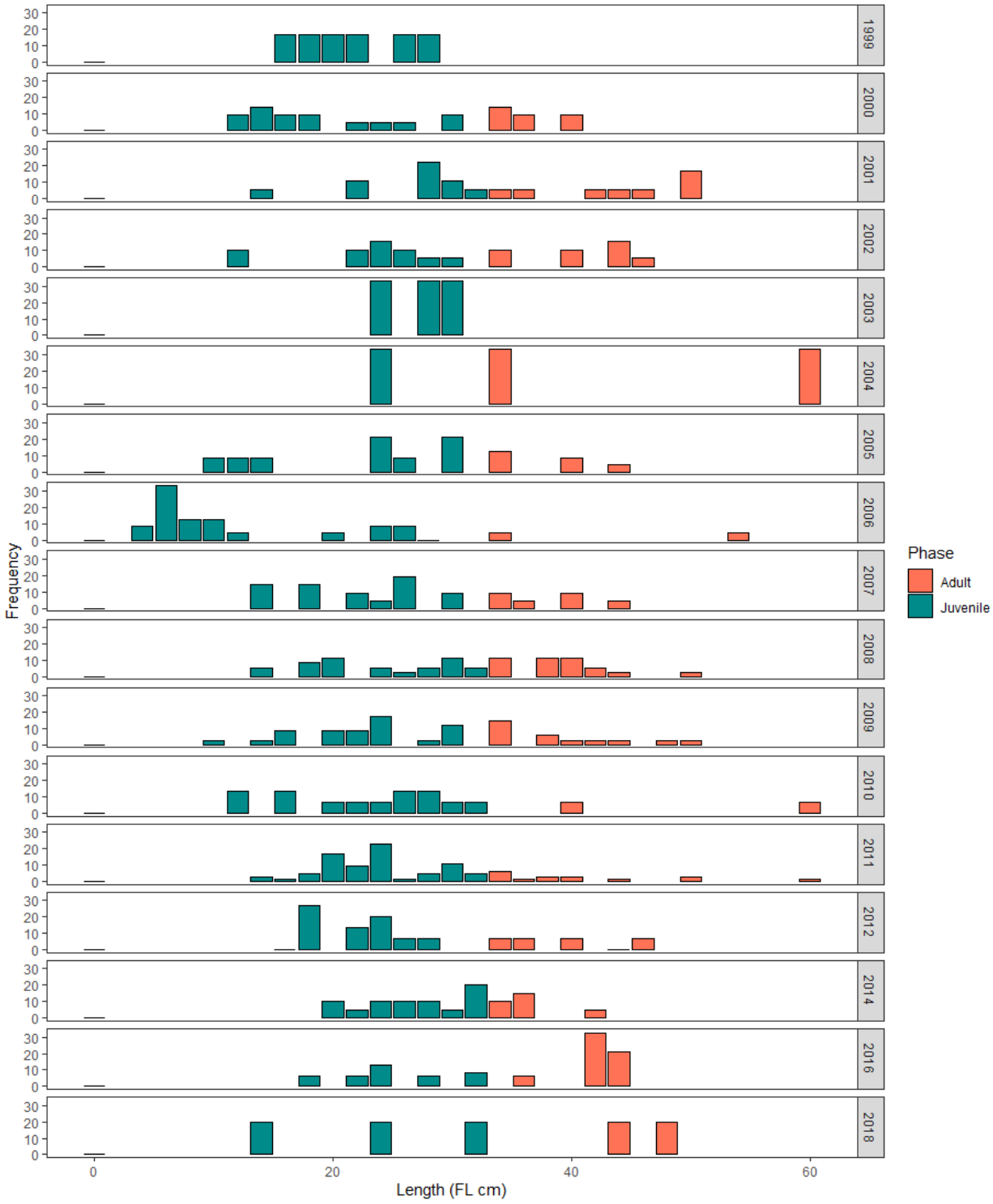

Figure 9. Observed length frequency by year for juvenile (n=118) and adult Scamp (n=54) in the Florida Keys. Fish lengths were binned into 2cm bins with closed intervals on the right.

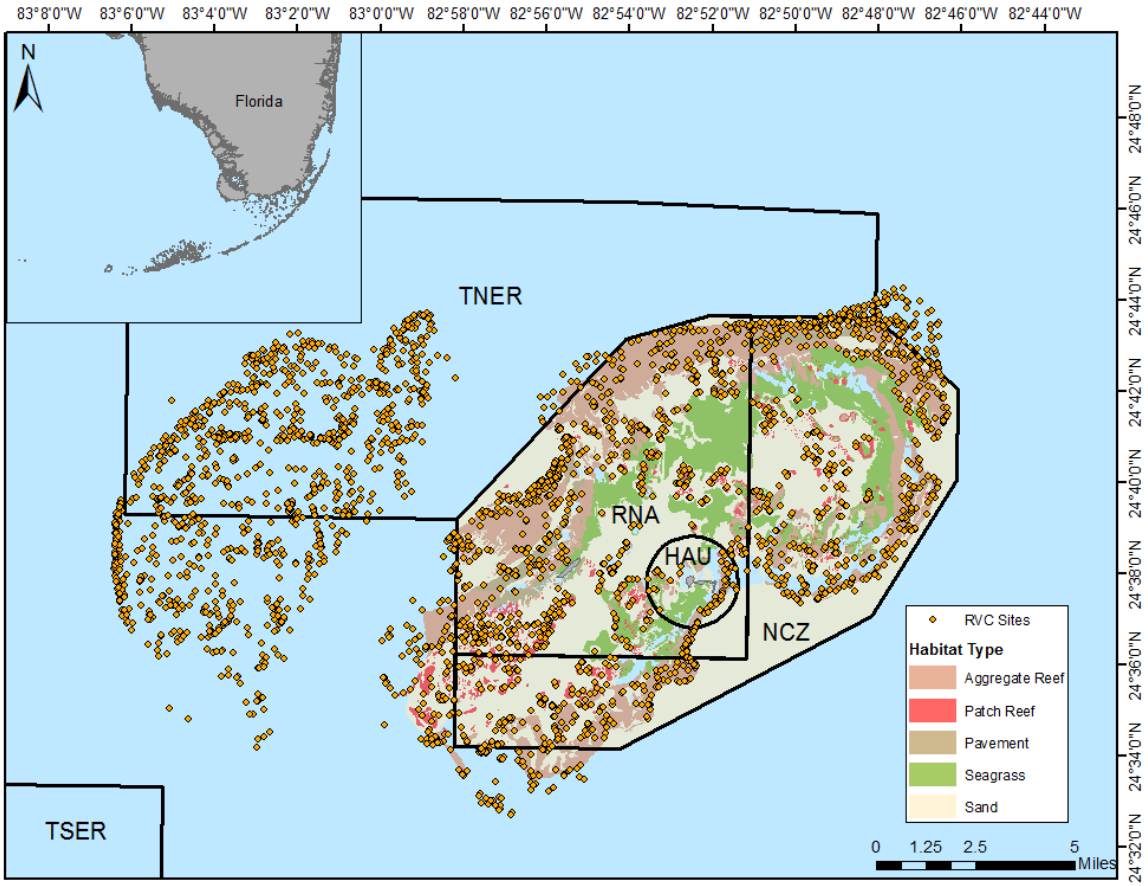

Figure 10. A map of the Reef Visual Census (RVC) primary sampling units (PSUs) surveyed In the Dry Tortugas from 1999 through 2018. The South Ecological Reserve (TSER), North Ecological Reserve (TNER), the Research Natural Area (RNA), the Historic Preservation and Adaptive Use area (HAU), and the Natural Cultural Zone (NCZ) are all marine reserves with closed or limited fishing. Areas outside these reserves are open to fishing.

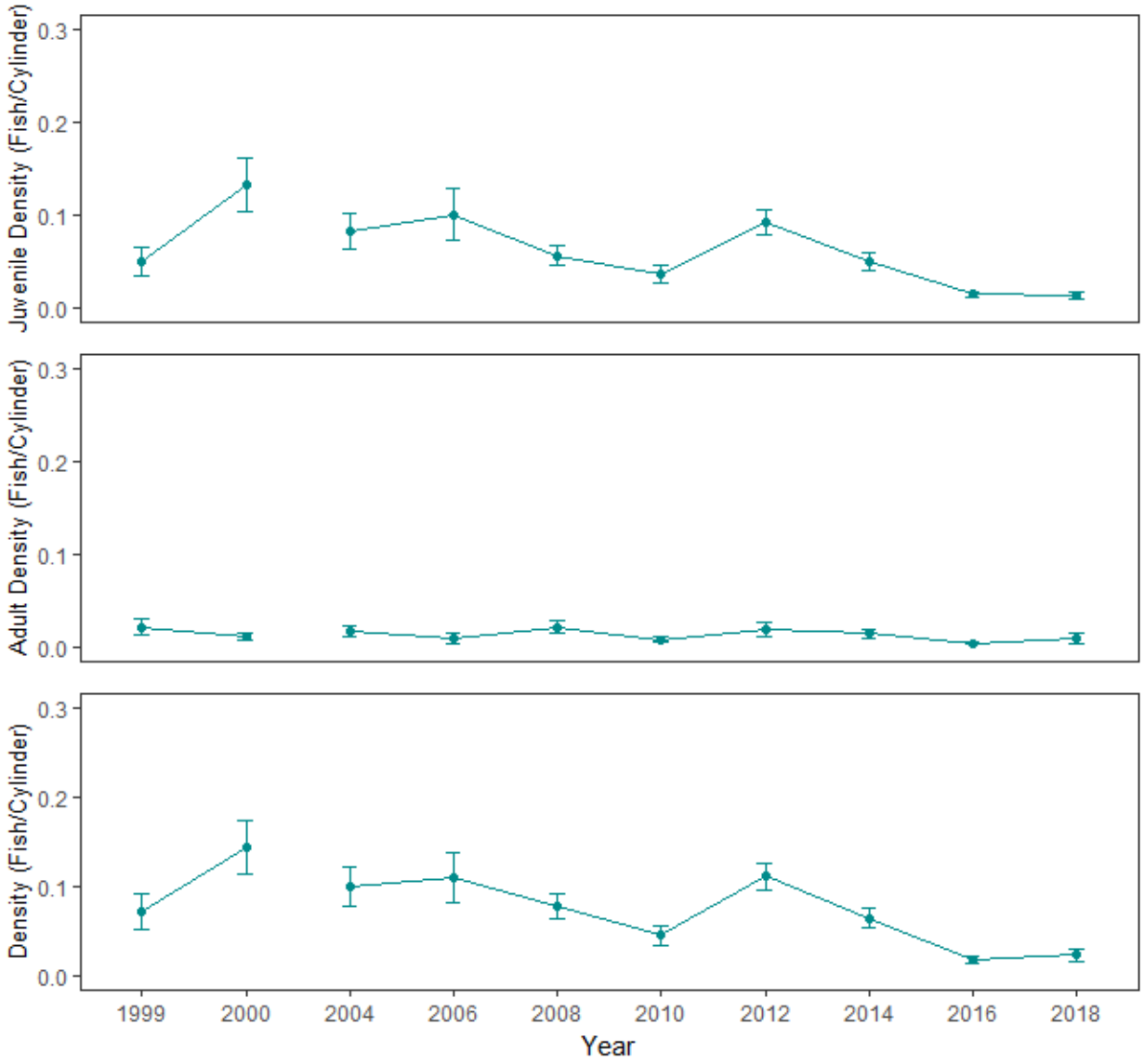

Figure 11. Densities of Scamp (juvenile, adult, and both life stages combined) from RVC surveys in the Dry Tortugas. Error bars represent the standard error.

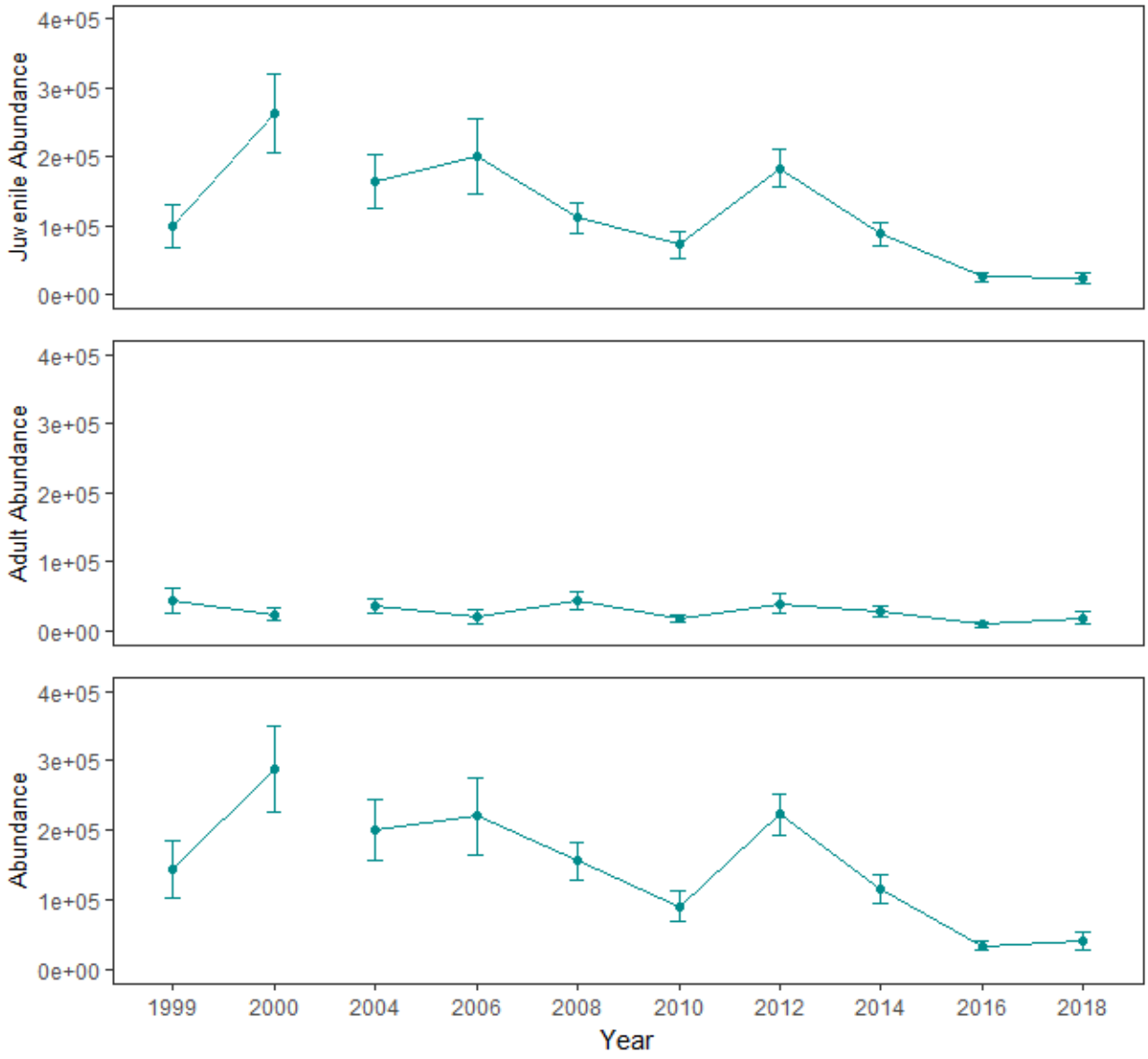

Figure 12. Survey-estimated abundance of Scamp (juvenile, adult, and both life stages combined) in the Dry Tortugas. Error bars represent the standard error.

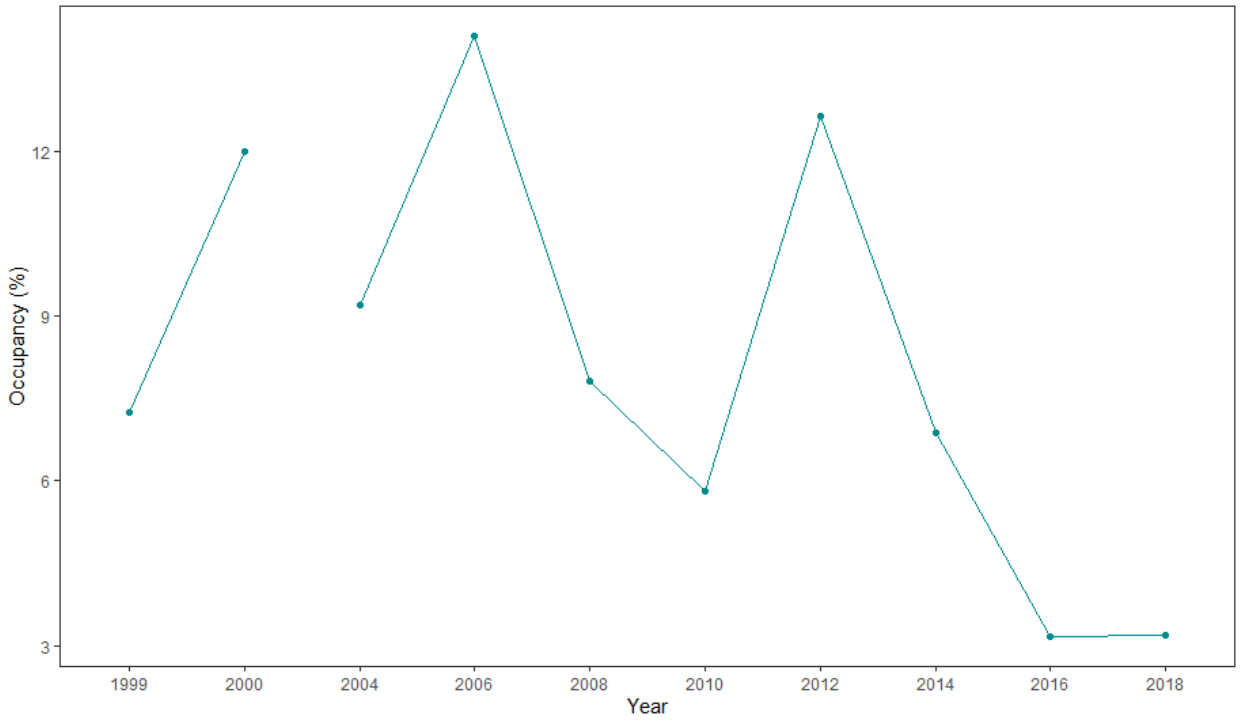

Figure 13. The occupancy rate of Scamp (both juvenile and adult) over time in the Dry Tortugas. Occupancy was calculated as the weighted average of the strata occurrence.

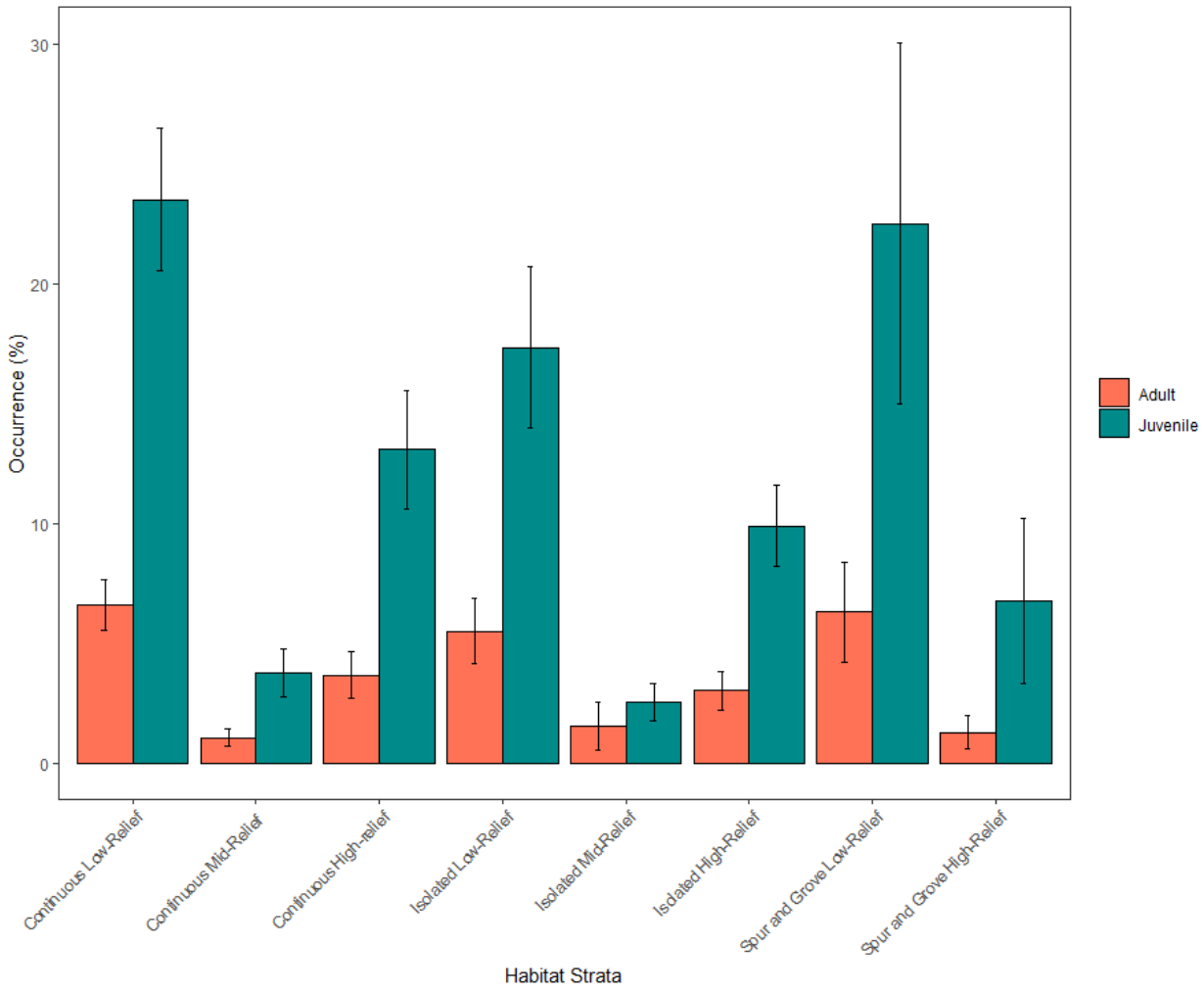

Figure 14. Figure 5. Occurrence by life stage (juvenile or adult) and strata for Scamp in the Dry Tortugas averaged across all years. Error bars represent the standard error. Occurrence was calculated as the percent of secondary sampling units (SSUs) when Scamp was present.

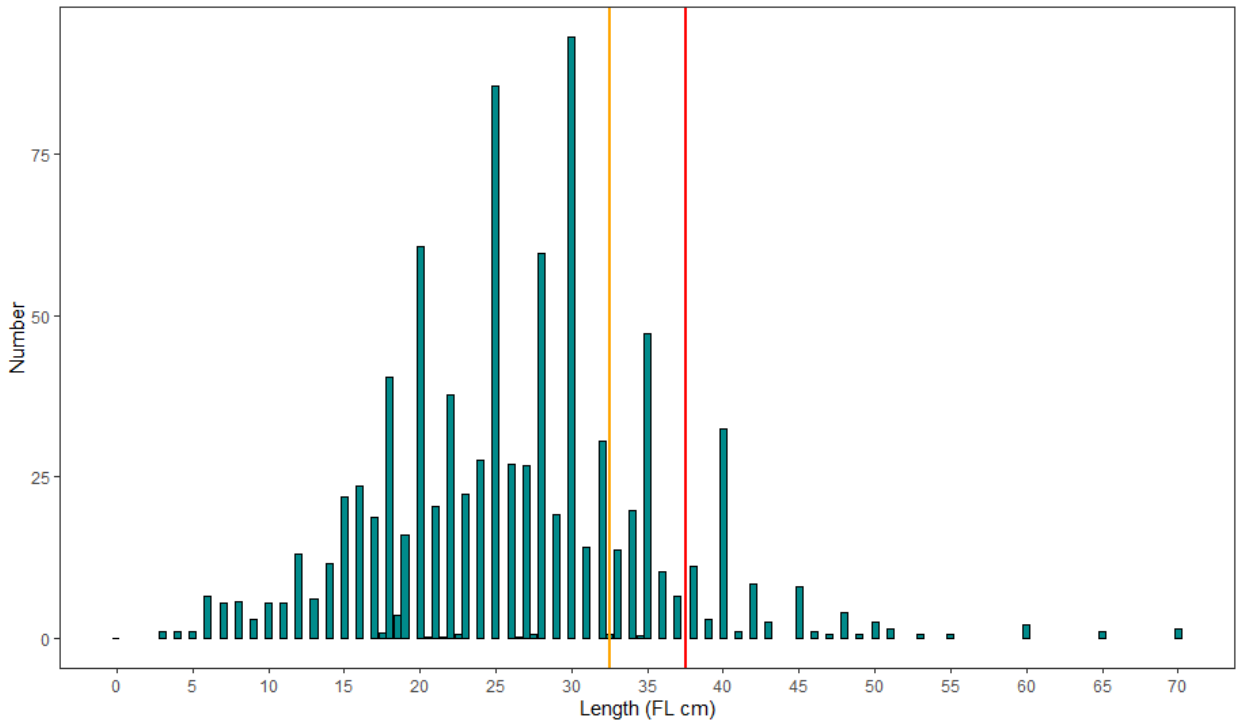

Figure 15. The observed length frequency for all Scamp surveyed in the Dry Tortugas RVCs (n=896). The orange vertical line represents the length at maturity (33 cm FL) and the red vertical line represents the minimum size limit in Florida Atlantic State waters (20 in TL) converted from inches total length to centimeter fork length (46.5 cm FL).

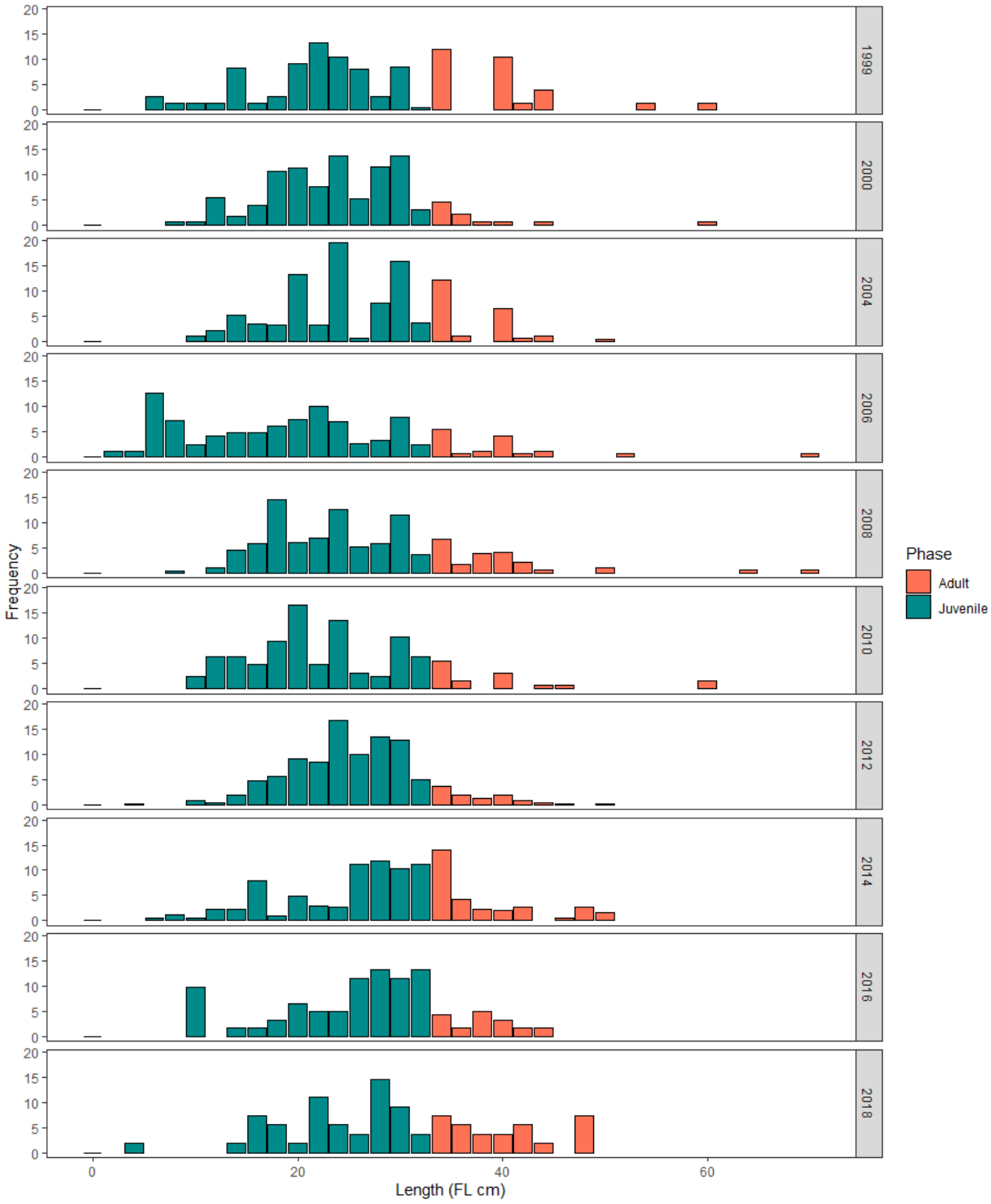

Figure 16. Observed length frequency by year for juvenile (n=716) and adult Scamp (n=180) in the Dry Tortugas. Fish lengths were binned into 2cm bins with closed intervals on the right.