Indices of relative abundance for Pink Shrimp, and summary of data availability for Pink, Brown, and White Shrimp, from inshore surveys of Florida's Gulf coast estuaries

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SEDAR87-DW-11

21 September 2023
Updated: 30 November 2023

Please cite this document as:

Edwards, Dwayne D., Derek M. Tremain, Meagan N. Schrandt, and Theodore S. Switzer. 2023. Indices of relative abundance for Pink Shrimp, and summary of data availability for Pink, Brown, and White Shrimp, from inshore surveys of Florida's Gulf coast estuaries. SEDAR87-DW-11. SEDAR, North Charleston, SC. 60 pp.

Indices of relative abundance for Pink, Brown, and White Shrimp from surveys conducted in several Florida Gulf coast estuaries

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Abstract

Fisheries-Independent Monitoring (FIM) surveys have been conducted by the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWRI) since 1989. Monthly fixed stations and Fall/Spring seasonal sampling were conducted from 1989–1995 in estuarine systems along Florida's Gulf of Mexico coast. Beginning in 1996, the FIM survey transitioned to a monthly stratified-random sampling design. In 2008, these surveys were expanded to include a seasonal (June–November) polyhaline seagrass survey developed to increase data for estuarine-dependent reef species. Three commercially important shrimp species were captured within these surveys: Pink Shrimp (*Farfantepenaeus duorarum*), Brown Shrimp (*F. aztecus*), and White Shrimp (*Litopenaeus setiferus*). For each species, catch data were subset into three size classes – Size 1 (≤110 mm, 116 mm, 108 mm Total Length [TL] for Pink Shrimp, Brown Shrimp, and White Shrimp, respectively), Size 2 (111–144 mm, 117–150 mm, 109–143 mm TL), and Size 3 (≥ 145 mm, 151 mm, 144 mm TL) – to explore potential development of indices of relative abundance. For all species, catch data from all sampled estuarine systems were explored for potential index development. Data for each estuary and size class were only included if the species and size class was commonly collected. When a size class and species was abundant in multiple estuaries, data was combined by using a weighting factor to account for differences between the proportion of available habitat within each sampling universe and the proportion of sets completed. Single estuary indices were developed for size classes and species where data were spatially limited. Based on data workshop evaluations, four indices of abundance were developed and recommended for potential use in the assessment: 1) Size 1 Pink Shrimp from the long-term FIM Survey (1998–2022), 2) Size 1 Pink Shrimp from the polyhaline seagrass survey (2008–2022), 3) Size 1 Brown shrimp from the long-term FIM survey (1998–2022), and 4) Size 1 White Shrimp from the long-term FIM survey (1998–2022). Indices of relative abundance for Size 2 and Size 3 Pink, Brown, and White Shrimp were not developed due to the limited number of these individuals collected in FWRI FIM surveys.

Survey Designs

<u>FWRI fishery-independent monitoring (FIM) long-term survey</u>

A multi-gear, stratified-random sampling design was used in monthly collections of fishes and selected macroinvertebrates from four estuaries along Florida's Gulf coast: Apalachicola Bay, Cedar Key, Tampa Bay, and Charlotte Harbor. Sampling effort was allocated into spatial zones that emphasized geographic coverage, natural boundaries, and environmental distinctions that could isolate meaningful differences in faunal assemblages. Sampling effort was further stratified by habitat with deference to estuary and gear type deployed. Effort for habitat strata was allocated proportionately with respect to the number of available sampling sites within each zone. The stratified random selection of sample sites was conducted without replacement monthly (1996–2022) in Apalachicola Bay, Cedar Key, Tampa Bay, and Charlotte Harbor and (Figure 1, Flaherty et al. 2014). Prior to 1996 (1989–1995) all sampling was conducted seasonally within a 10-week window each fall and spring.

Gear:

- 21.3-m × 1.8-m center-bag haul seine with 3.2-mm nylon mesh.
    - Bay deployment: Deployed in shallow (≤1.5 m) shoreline (gr=19) and offshore (gr=20) habitat, the 21.3-m seine sampled a 9.1 m by 15.5 m site with an approximate area of 140 m^2. Shoreline seines were deployed with one side on an array of shoreline habitats, including mangroves, emergent vegetation, urbanized areas with seawalls, hardened structures (i.e., rocks, rubble), adjacent docks and pulled parallel to the shoreline. Offshore seines (>5 m from a shoreline) were stratified by presence or absence of submerged aquatic vegetation (≥25% SAV cover) and deployed in seagrass meadows, mixed SAV areas, and open sand or mud substrates.
    - River deployment (gr=23): 21.3-m seine deployed in a semi-circular (68 m^2) set from the stern of a vessel that was retrieved along the shoreline. Seines were deployed along river shorelines with steeply sloping benthos to sample areas with mangroves, terrestrial vegetation, emergent vegetation, and hardened structures. In 2016, in Charlotte Harbor, monthly effort was expanded to include tidal creeks and tributaries, which are an important juvenile habitat for some fish species.

- 6.1-m otter trawl (38-mm stretched mesh) with a 3.2-mm mesh liner in the cod end. Trawl gear was used to sample soft bottom habitats 1.8 m to 7.6 m in water depth.
    - Bay deployment: Each tow was conducted for 10 minutes towing along a path approximately 0.2 nautical miles (370 m) and sampling an area of approximately 1,482 m^2. Actual distance towed was measured by differential GPS from the start and end points of the tow. In 2005, monthly sampling effort was increased to improve abundance estimates for various species. In 2021, this gear type was transitioned from monthly to quarterly sampling, with sampling occurring in January, April, July, and October.

- River deployment: Each tow was conducted for 5 minutes towing along a path approximately 0.1 nautical miles (185 m) and sampling an area of approximately 741 m^2. Actual distance towed was measured by differential GPS from the start and end points of the tow. This gear type was transitioned from monthly to bimonthly sampling in 2021, with sampling occurring in January, March, May, July, September, and November.

FWRI FIM polyhaline seagrass surveys

Results from multiple studies in the eastern Gulf (Koenig and Coleman 1998; Fitzhugh et al. 2005; Casey et al. 2007) were used to inform the implementation (2008) of a FWRI FIM survey to augment the characterization of populations of juvenile groupers and snappers. Seagrass habitats, like those sampled in this survey, have been identified through stable isotope analysis as a major source of Pink Shrimp migrating to offshore fishing grounds (Fry et al. 1999). Bathymetry and submerged aquatic vegetation coverage (Yarbro 2013) data were used to detail a sampling universe consisting of 0.2-km × 0.2-km discrete units containing SAV. From these available SAV units, monthly sites were randomly selected, and survey requirements were verified at time of sampling. This survey samples polyhaline seagrass habitats (>18 PSU and ≥50% SAV bottom coverage), which were underrepresented in FIM surveys prior to 2008 (Switzer et al. 2012, Flaherty-Walia et al. 2015). This survey is conducted (June–November) in St. Andrew Bay, Apalachicola Bay, the Big Bend region, Tampa Bay, and Charlotte Harbor (Figure 1, Flaherty et al. 2014).

Gear:

- 6.1-m otter trawl (38-mm stretched mesh) with a 3.2-mm mesh liner in the cod end. Trawl gear was used to sample polyhaline seagrass habitats 1.0 m to 7.6 m in water depth. Each tow was conducted for 5 minutes towing along a path approximately 0.1 nautical miles (185 m) and sampling an area of approximately 741 m^2. Actual distance towed was measured by differential GPS from the start and end points of the tow. In water <1.8 m in depth, the trawl was towed in a shallow arc to reduce disturbance of sampled substrates by prop wash. Sampling was conducted monthly from June through November coinciding with peak estuary use by juvenile reef fish (Switzer et al. 2012; Flaherty et al. 2014).

For all gear types, deployments, and surveys, all fish and selected macroinvertebrates were identified, counted, and a subset were randomly measured. In the northern estuaries, *Farfantepenaeus* spp. shrimp have been identified at the genus level for shrimp <15 mm post-orbital head length (69 mm total length) since 2010. Pink, Brown, and White Shrimp were enumerated and a subset of at least 10 individuals were randomly selected and measured for post-orbital head length, which is equivalent to carapace length (CL). Carapace lengths were then converted to total length (TL) following the equations for Pink (1), Brown (2), and White (3) Shrimp from Diaz et al. (2001) and Brown et al. (2013).

$$TL = 1.616 + 4.503*CL \quad (1)$$

$$TL = 0.28 + 4.5*CL \quad (2)$$

$$TL = 0.53 + 5.06*CL \quad (3)$$

Sample location (GPS), date, time, and depth at the center bag for seines or start and end depths for trawls were recorded. Habitat variables documented were shoreline types (e.g., mangroves, emergent vegetation, hardened structures), SAV composition by species, SAV area of coverage, and substrate composition. Temperature (°C) and salinity (PSU) were measured from the surface (0.2 m) to the bottom in 1.0-m depth intervals; these water conditions were averaged for a single water column value for each site.

Data

A total of 50,784 stations (1998–2022) were sampled with the 21.3-m seine (Tables 1-2) and 21,575 stations were sampled (1998–2022) with the 6.1-m otter trawl during FWRI FIM long-term sampling in Charlotte Harbor, Tampa Bay, Cedar Key, and Apalachicola Bay (Table 3). A total of 6,784 stations were sampled (2008–2022) with the 6.1-m otter trawl during polyhaline seagrass surveys in Charlotte Harbor, Tampa Bay, Big Bend, Apalachicola Bay, and St. Andrew Bay (Table 4).

Data Exclusions

Data from long-term FIM surveys were subset to the years of consistent survey design and methodology among Gulf coast estuaries. Indices developed with Charlotte Harbor and Tampa Bay data were subset to 1998–2022. Indices developed with Apalachicola data were subset to 2001–2022.

Pink Shrimp Size 1 (≤24 mm CL, 110 mm TL) indices were developed with catch data from Tampa Bay and Charlotte Harbor as these estuaries had the greatest catch of Pink Shrimp in FIM surveys and *Farfantepenaeus* spp. shrimp have been identified to species at all sizes in these estuaries. In the northern estuaries (St. Andrew Bay, Apalachicola Bay, Big Bend, and Cedar Key), *Farfantepenaeus* spp. shrimp were identified at the genus level for shrimp <15 mm CL (69 mm TL) since 2010; therefore, data records of *Farfantepenaeus* spp. were excluded from the analyses. For Size 1 Pink Shrimp, three potential index models were explored to examine whether temporal or spatial changes in survey effort influenced index results. The first potential index model included all long-term survey efforts in Tampa Bay and Charlotte Harbor, including bay trawl data in both estuaries (1998–2022) and the tidal creek and tributary expansion in Charlotte Harbor (2016–2022). The second potential index model excluded data from the tidal creek and tributary expansion in Charlotte Harbor. The third potential index model excluded data from the tidal creek and tributary expansion in Charlotte Harbor and bay trawl data in Tampa Bay and Charlotte Harbor. Trends were similar among the three models, so the decision was made to proceed with the model that excluded both tidal tributary expansion, and bay deployed trawls because it had the most consistent long-term data with the lowest coefficient of variation (Figure 1A). Indices for Size 2 and 3 (25–32 mm CL, 111–144 mm TL and ≥33 mm CL, 145 mm TL) Pink Shrimp were explored, however, data for these sizes were sparse and indices were not further developed (Tables 1A-8A).

A Brown Shrimp Size 1 (≤26 mm CL, 116 mm TL) index was developed with catch data from Apalachicola Bay long-term FIM surveys. Brown Shrimp were limited in catch to Apalachicola Bay and St. Andrew Bay (Tables 5-8). Size 2 (27-32 mm CL, 117-150 mm TL) and Size 3 (≥33 mm CL, 151 mm TL) Brown Shrimp indices were not developed due to low catch of the respective size classes (Figure 4).

A White Shrimp Size 1 (≤21 mm CL, 116 mm TL) index was developed from Apalachicola Bay long-term FIM surveys. Apalachicola Bay accounted for 97% of all White Shrimp caught in Florida's Gulf Coast estuaries (Tables 9-12). Size 2 (22-27 mm CL, 117-143 mm TL) and Size 3 (≥28 mm CL, 144 mm TL) White Shrimp indices were not developed due to low catch of the respective size classes.

Brown and White Shrimp indices from FWRI FIM Polyhaline Seagrass surveys were not developed due to low catch of these species (Tables 8, 12). Reductions in effort occurred in 2020 due to the COVID-19 pandemic, and again in 2021 with the transition to seasonal and bi-monthly sampling in bay and river 6.1-m otter trawls, respectively (Tables 1-11).

Index Construction

For each of the species, Pink, Brown, and White Shrimp, three size classes based on market categories, were defined to help facilitate economic evaluations. During FWRI FIM long-term surveys, Size 1 (≤24 mm CL, 110 mm TL) Pink Shrimp were collected between June and February of the following year (first recruitment pulse to age out of size class), Size 2 (25–32 mm CL, 111–144 mm TL) were collected January–December, and Size 3 (≥33 mm CL, 145 mm TL) were collected January–December. During FWRI FIM polyhaline seagrass surveys, all three size classes were collected within the June–November sampling window.

During FWRI FIM long-term surveys, Size 1 (≤26 mm CL, 116 mm TL) Brown Shrimp occurred May-October, coinciding with the first recruitment pulse to age out of the size class. Size 2 (27-32 mm CL, 117-150 mm TL) and Size 3 (≥33 mm CL, 151 mm TL) Brown Shrimp indices were not developed because of low catches. No indices were developed for any of the three size classes of Brown Shrimp from FWRI FIM polyhaline seagrass surveys because of low catches. During FWRI FIM long-term surveys, Size 1 (≤21 mm CL, 108 mm TL) White Shrimp occurred June-November, coinciding with the first recruitment pulse to age out of the size class. Size 2 (22-27 mm CL, 109-143 mm TL) and Size 3 (≥28 mm CL, 144 mm TL) White Shrimp indices were not developed because of low catches. No indices were developed for any of the three size classes of White Shrimp from FWRI FIM polyhaline seagrass surveys because of low catches.

Annual Indices of Abundance (IOA) of Size 1 Pink, Brown, and White Shrimp collected during FWRI FIM long-term and seagrass surveys were constructed using generalized linear modeling analyses. Indices combining multiple estuarine systems (Pink Shrimp) were calculated as individuals per haul using a weighting factor that represented a ratio of the proportion of total area sampleable that occurred within each estuarine sampling area to the proportion of total sampling effort that occurred within each area to account for non-proportional sampling across estuarine areas (weighting factor = (estuarine sampling area/total sampling area)/(sets per estuary/total sets)). No weighting factor was used for single estuary indices (Brown, White

Shrimp). Class variables initially considered included year, month, bay system (estuary, for combined indices only), sampling zone (within each bay system), gear, shore type (overhanging vegetation, emergent vegetation, terrestrial vegetation, manmade structure, none), bottom type (mud, sand, other), bottom vegetation (SAV, algae, none), SAV percentage (divided into bins of 10%), and quartiles of water depth, temperature, and salinity as calculated by the reduced dataset. When more than one gear type was included in the model, area sampled (effort) per 100 m^2 was incorporated as a covariate. The relative abundance of Pink, Brown, and White Shrimp represents count data, the distribution of which is bound by zero and therefore often highly nonnormal. Accordingly, generalized linear models based on the Poisson distribution and the negative binomial distribution were fit to the data, and residual diagnostics and goodness-of-fit statistics were examined to determine the most appropriate model. For all indices, the model based on the negative binomial distribution was the most appropriate. Apart from year, variables that were not significant ($\alpha = 0.05$) and did not improve model fit based on the Akaike's information criterion (AIC) value were removed, and the analysis was repeated until the most parsimonious model remained. For each species, size class, and survey combination, annual least square means (± SE) and annual coefficients of variation were calculated. All analyses were conducted using the GLIMMIX procedure and SAS software (SAS Institute 2006).

Results and Discussion

Distribution and Size

The size distribution of Pink Shrimp collected during FIM long-term surveys and polyhaline seagrass surveys is presented in Figures 6-17. Pink Shrimp of all sizes were captured in all of Florida's Gulf Coast estuaries during long-term surveys (Figure 2). In polyhaline seagrass surveys, all sample areas captured all sizes except Apalachicola Bay, where Size 3 Pink Shrimp were not captured (Figure 3). The distribution of Size 1 Brown Shrimp is presented in Figure 18. Size 2 and 3 Brown Shrimp were few, and their distribution was not developed. Brown shrimp of all sizes were captured only in Apalachicola Bay during long-term surveys (Figure 4). In polyhaline seagrass surveys, Size 1 Brown Shrimp were captured in Apalachicola Bay and St. Andrew Bay. No Size 2 or 3 Brown shrimp were captured in polyhaline seagrass surveys (Figure 4). The distribution of Size 1 White Shrimp is presented in Figure 19. Size 2 and 3 White Shrimp were few, and their distribution was not developed. White Shrimp of all sizes were captured in Apalachicola Bay and Cedar Key during long-term surveys (Figure 5). In polyhaline seagrass surveys, Size 1 White Shrimp were captured in Apalachicola Bay and Big Bend. No Size 2 or 3 White Shrimp were captured in polyhaline seagrass surveys (Figure 5).

Indices of Abundance

For the Pink Shrimp Size 1 long-term survey index, year, month, bay, gear, SAV percentage, shore type, bottom type, salinity quartile, temperature quartile, and depth quartile were retained in the model (Table 13). For the Pink Shrimp Size 1 polyhaline seagrass survey index, year, month, bay, SAV percentage, shore type, bottom type, salinity quartile, and temperature quartile were retained in the model (Table 14). For the Brown Shrimp Size 1 long-term survey index, year, month, zone (within estuary), effort (area over 100 m^2), SAV presence, salinity

quartile, and depth quartile were retained in the model (Table 15). No Brown Shrimp indices were developed for the polyhaline seagrass surveys. For the White Shrimp Size 1 long-term survey index, year, month, gear, effort (area over 100 m^2), shore type, bottom type, SAV presence, salinity quartile, and depth quartile were retained in the model (Table 16). No White Shrimp indices were developed for the polyhaline seagrass surveys. A summary of all Type III fixed effects retained, and their statistical significance, can be found in Tables 13–16, below. Tables 17–20 summarize the annual abundance and coefficients of variation for all indices, as illustrated in Figures 20-23.

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Table 1. Annual sampling effort (number of nets), occurrence, and number (N) of Pink Shrimp collected during FWRI FIM long-term surveys (1998–2022) using a 21.3-m bay seine (gr = 19 and 20 combined) within Charlotte Harbor (CH), Tampa Bay (TB), Cedar Key (CK), and Apalachicola Bay (AB). Note, after 2010, CK and AB identified Pink Shrimp <69 mm TL to genus level.

	Bay											
	CH			TB			CK			AB		
Year	Effort	Occurrence	N	Effort	Occurrence	N	Effort	Occurrence	N	Effort	Occurrence	N
1998	288	0.507	4894	300	0.320	1926	144			76		
1999	288	0.618	3012	300	0.380	2159	144			96		
2000	288	0.611	3232	300	0.340	1217	144			96	0.010	1
2001	288	0.590	3544	300	0.307	1439	243	0.255	354	240	0.075	61
2002	288	0.510	2862	300	0.327	2404	252	0.159	198	240	0.146	126
2003	332	0.599	3576	300	0.357	1114	252	0.206	189	240	0.117	73
2004	552	0.518	6265	300	0.350	2451	252	0.202	243	240	0.100	66
2005	552	0.507	4456	408	0.132	205	252	0.179	155	240	0.079	46
2006	552	0.504	6557	408	0.211	1394	252	0.234	515	240	0.063	40
2007	552	0.496	2634	408	0.250	1363	252	0.286	432	240	0.017	7
2008	480	0.519	3813	408	0.262	736	252	0.194	272	240	0.013	3
2009	480	0.469	2486	408	0.297	1067	252	0.198	196	240	0.029	9
2010	408	0.409	1787	408	0.289	2080	252	0.258	291	240	0.033	11
2011	408	0.554	2988	408	0.331	1410	252	0.083	39	240	0.046	17
2012	408	0.461	1705	408	0.292	1206	252	0.036	10	240	0.029	8
2013	408	0.478	1967	408	0.350	1058	252	0.016	8	240	0.025	8
2014	408	0.525	3065	408	0.380	2094	252	0.024	7	240	0.025	13
2015	408	0.544	3917	408	0.387	2979	252	0.060	22	240	0.054	37
2016	408	0.532	3228	408	0.382	2705	252	0.040	21	240	0.042	18
2017	408	0.463	2821	408	0.360	2476	252	0.032	10	240	0.025	8
2018	408	0.407	1592	408	0.324	1533	252	0.032	10	240	0.013	5
2019	408	0.451	4501	408	0.304	1676	252	0.024	8	240	0.042	12
2020	377	0.507	1503	374	0.350	2253	231	0.022	5	225	0.040	10
2021	408	0.370	1484	408	0.248	601	252	0.032	17	240	0.038	13
2022	408	0.377	2636	408	0.311	1713	252	0.056	25	240	0.038	10
Total	10213		80525	9410		41259	5946		3027	5533		602

Table 2. Annual sampling effort (number of nets), occurrence, and number (N) of Pink Shrimp collected during FWRI FIM long-term surveys (1998–2022) using a 21.3-m seine deployed along river shorelines (gr = 23) within Charlotte Harbor (CH), Tampa Bay (TB), Cedar Key (CK), and Apalachicola Bay (AB). Note, after 2010, CK and AB identified Pink Shrimp <69 mm TL to genus level.

	Bay											
	CH			TB			CK			AB		
Year	Effort	Occurrence	N	Effort	Occurrence	N	Effort	Occurrence	N	Effort	Occurrence	N
1998	96	0.375	582	212	0.392	480	108					
1999	96	0.552	412	264	0.595	1434	108					
2000	96	0.615	314	264	0.455	728	108			42		
2001	96	0.250	217	264	0.326	353	163	0.239	213	168	0.030	7
2002	96	0.323	628	264	0.375	1051	168	0.179	198	168	0.024	9
2003	142	0.169	89	264	0.208	132	168	0.089	33	156		
2004	372	0.180	511	264	0.386	695	168	0.161	96	156		
2005	372	0.097	117	264	0.121	71	168	0.095	78	156	0.006	1
2006	372	0.172	327	264	0.246	210	168	0.196	148	156		
2007	372	0.223	281	264	0.386	617	168	0.292	234	155		
2008	180	0.294	199	288	0.306	277	168	0.173	137	156		
2009	180	0.172	91	288	0.333	438	168	0.095	33	156		
2010	96	0.292	168	312	0.330	652	168	0.167	91	156	0.013	2
2011	96	0.458	144	312	0.343	531	168	0.036	10	156		
2012	96	0.156	23	312	0.343	293	168	0.018	6	156	0.013	2
2013	96	0.125	32	312	0.292	226	168	0.006	1	156		
2014	96	0.344	260	318	0.308	296	168	0.018	3	156	0.006	1
2015	96	0.302	71	336	0.351	355	168	0.006	1	156		
2016	504	0.306	720	432	0.208	181	168	0.012	3	156	0.032	10
2017	504	0.288	904	432	0.215	255	168	0.036	6	156		
2018	504	0.198	260	432	0.157	159	168	0.012	2	156		
2019	504	0.367	1081	432	0.206	219	168			156	0.006	1
2020	471	0.357	622	423	0.260	400	154			77		
2021	504	0.214	394	432	0.111	83	168			84		
2022	378	0.228	537	324	0.259	524	168			84		
Total	6415		8984	7973		10660	4001		1293	3274		33

Table 3. Annual sampling effort (number of nets), occurrence, and number (N) of Pink Shrimp collected during FWRI FIM long-term surveys (1998-2022) using a 6.1-m otter trawl (bay and river combined) within Charlotte Harbor (CH), Tampa Bay (TB), Cedar Key (CK), and Apalachicola Bay (AB). Otter trawl sampling transitioned to quarterly sampling in bay habitats and bimonthly sampling in rivers in 2021. Note, after 2010, CK and AB identified Pink Shrimp <69 mm TL to genus level.

	Bay											
	CH			TB			CK			AB		
Year	Effort	Occurrence	N	Effort	Occurrence	N	Effort	Occurrence	N	Effort	Occurrence	N
1998	72	0.569	2457	129	0.473	873				64	0.203	39
1999	72	0.694	377	162	0.568	1429				96	0.240	117
2000	72	0.694	497	156	0.609	818				138	0.159	104
2001	72	0.681	316	156	0.526	1372	165	0.285	261	228	0.180	124
2002	72	0.556	663	156	0.500	1486	180	0.239	344	228	0.320	341
2003	108	0.287	110	156	0.353	641	180	0.211	132	228	0.294	267
2004	288	0.448	1117	156	0.449	1160	180	0.328	1508	228	0.303	346
2005	516	0.432	2817	336	0.307	395	180	0.289	270	228	0.303	258
2006	516	0.391	4277	336	0.369	1151	180	0.272	272	228	0.377	404
2007	516	0.403	1901	336	0.440	903	180	0.272	530	228	0.219	186
2008	420	0.400	1125	336	0.438	1049	180	0.244	152	228	0.268	235
2009	420	0.376	932	336	0.435	961	180	0.217	285	228	0.346	348
2010	360	0.447	1488	336	0.423	969	180	0.200	165	222	0.230	177
2011	360	0.383	694	336	0.408	687	180	0.194	102	228	0.281	187
2012	360	0.336	806	336	0.298	451	180	0.139	57	228	0.338	248
2013	360	0.281	557	336	0.399	666	180	0.178	103	228	0.368	570
2014	360	0.444	963	336	0.417	772	180	0.189	164	228	0.329	429
2015	360	0.508	1611	336	0.420	1158	180	0.233	580	228	0.298	306
2016	360	0.481	1631	348	0.339	973	180	0.228	105	228	0.368	422
2017	360	0.564	3196	348	0.460	985	180	0.194	107	228	0.276	217
2018	360	0.500	1147	348	0.402	677	180	0.150	87	228	0.311	230
2019	360	0.628	5124	348	0.382	870	180	0.189	88	228	0.333	244
2020	213	0.592	842	240	0.425	1020	75	0.173	22	115	0.296	762
2021	132	0.432	664	144	0.257	159	45	0.289	71	72	0.403	159
2022	132	0.371	983	144	0.438	609	40	0.400	121	72	0.444	609
Total	6957		36295	6399		22234	3480		5526	4739		7329

Table 4. Annual sampling effort (number of nets), occurrence, and number (N) of Pink Shrimp collected during FWRI FIM polyhaline seagrass surveys (2008–2022) using a 6.1-m otter trawl within Charlotte Harbor (CH), Tampa Bay (TB), Big Bend (BB), Apalachicola Bay (AB), and St. Andrew Bay (SA). Note, after 2010, BB and AB identified Pink Shrimp <69 mm TL to genus level. Note, due to the COVID-19 pandemic no sampling occurred in SA in 2020.

	Bay														
	CH			TB			BB			AB			SA		
Year	Effort	Occurrence	N	Effort	Occurrence	N	Effort	Occurrence	N	Effort	Occurrence	N	Effort	Occurrence	N
2008	70	0.086	8	90	0.378	147	276	0.293	196	56	0.179	15	42	0.167	23
2009	56	0.357	58	70	0.400	122	210	0.262	155	56	0.250	23	42	0.262	33
2010	56	0.268	54	70	0.400	138	210	0.305	266	56	0.286	60	42	0.262	89
2011	56	0.446	92	70	0.400	239	210	0.276	95	56	0.286	26	42	0.333	57
2012	56	0.179	39	70	0.314	61	210	0.310	357	56	0.196	33	39	0.205	45
2013	56	0.250	39	70	0.329	93	210	0.338	350	56	0.250	53	42	0.095	11
2014	56	0.321	269	70	0.471	210	210	0.357	252	56	0.286	84	42	0.286	52
2015	56	0.339	68	70	0.429	110	210	0.357	200	56	0.482	83	42	0.167	20
2016	48	0.188	27	60	0.283	59	180	0.289	100	48	0.375	44	36	0.306	24
2017	48	0.438	117	60	0.333	156	180	0.339	136	48	0.229	23	36	0.167	10
2018	48	0.604	284	60	0.350	529	180	0.522	424	48	0.333	33	30	0.233	13
2019	120	0.483	270	144	0.375	341	180	0.383	152	96	0.240	43	72	0.278	50
2020	60	0.333	81	72	0.347	109	90	0.444	86	48	0.229	22			
2021	119	0.286	101	144	0.549	1979	180	0.572	300	96	0.323	62	72	0.181	44
2022	120	0.425	371	144	0.403	546	180	0.278	91	96	0.229	42	72	0.278	27
Total	1025		1878	1264		4839	2916		3160	928		646	651		498

Table 5. Annual sampling effort (number of nets), occurrence, and number (N) of Brown Shrimp collected during FWRI FIM long-term surveys (1998–2022) using a 21.3-m bay seine (gr = 19 and 20 combined) within Charlotte Harbor (CH), Tampa Bay (TB), Cedar Key (CK), and Apalachicola Bay (AB). Note, after 2010, CK and AB identified Brown Shrimp <69 mm TL to genus level.

	Bay											
	CH			TB			CK			AB		
Year	Effort	Occurrence	Number	Effort	Occurrence	Number	Effort	Occurrence	Number	Effort	Occurrence	Number
1998	288			300			144			76	0.118	371
1999	288			300			144			96	0.115	30
2000	288			300			144			96	0.094	90
2001	288			300			243			240	0.133	137
2002	288			300			252			240	0.038	31
2003	332			300			252			240	0.021	12
2004	552			300			252			240	0.017	7
2005	552			408			252			240	0.008	2
2006	552			408			252			240	0.021	11
2007	552			408			252			240	0.013	8
2008	480			408			252			240	0.013	4
2009	480			408			252			240	0.025	8
2010	408			408			252			240	0.013	5
2011	408			408			252			240	0.008	2
2012	408			408			252			240	0.004	1
2013	408			408			252			240	0.008	9
2014	408			408			252			240		
2015	408			408			252			240	0.013	22
2016	408			408			252			240	0.004	1
2017	408			408			252			240	0.029	35
2018	408			408			252			240	0.017	8
2019	408			408			252			240	0.017	5
2020	377			374			231			225	0.036	26
2021	408			408			252			240		
2022	408			408			252			240	0.013	3
Total	10213			9410			5946			5533		828

Table 6. Annual sampling effort (number of nets), occurrence, and number (N) of Brown Shrimp collected during FWRI FIM long-term surveys (1998–2022) using a 21.3-m seine deployed along river shorelines (gr = 23) within Charlotte Harbor (CH), Tampa Bay (TB), Cedar Key (CK), and Apalachicola Bay (AB). Note, after 2010, CK and AB identified Brown Shrimp <69mm TL to genus level.

	Bay											
	CH			TB			CK			AB		
Year	Effort	Occurrence	Number	Effort	Occurrence	Number	Effort	Occurrence	Number	Effort	Occurrence	Number
1998	96			212			108					
1999	96			264			108					
2000	96			264			108			42	0.048	2
2001	96			264			163			168	0.006	1
2002	96			264			168			168	0.018	4
2003	142			264			168			156		
2004	372			264			168			156		
2005	372			264			168			156	0.006	1
2006	372			264			168			156		
2007	372			264			168			155	0.006	1
2008	180			288			168			156	0.006	1
2009	180			288			168			156		
2010	96			312			168			156	0.006	1
2011	96			312			168			156		
2012	96			312			168			156		
2013	96			312			168			156		
2014	96			318			168			156	0.006	1
2015	96			336			168			156		
2016	504			432			168			156		
2017	504			432			168			156	0.006	1
2018	504			432			168			156		
2019	504			432			168			156	0.006	1
2020	471			423			154			77		
2021	504			432			168			84		
2022	378			324			168			84	0.012	1
Total	6415			7973			4001			3274		15

Table 7. Annual sampling effort (number of nets), occurrence, and number (N) of Brown Shrimp collected during FWRI FIM long-term surveys (1998–2022) using a 6.1-m otter trawl (bay and river combined) within Charlotte Harbor (CH), Tampa Bay (TB), Cedar Key (CK), and Apalachicola Bay (AB). Otter trawl sampling transitioned to quarterly sampling in bay habitats and bimonthly sampling in rivers in 2021. Note, after 2010, CK and AB identified Brown Shrimp <69 mm TL to genus level.

	Bay											
	CH			TB			CK			AB		
Year	Effort	Occurrence	Number	Effort	Occurrence	Number	Effort	Occurrence	Number	Effort	Occurrence	Number
1998	72			129						64	0.422	425
1999	72			162						96	0.354	252
2000	72			156						138	0.232	129
2001	72			156			165			228	0.215	376
2002	72			156			180			228	0.184	402
2003	108			156			180			228	0.101	164
2004	288			156			180			228	0.066	48
2005	516			336			180			228	0.101	178
2006	516			336			180			228	0.127	464
2007	516			336			180			228	0.132	298
2008	420			336			180			228	0.189	442
2009	420			336			180			228	0.145	160
2010	360			336			180			222	0.104	198
2011	360			336			180			228	0.075	76
2012	360			336			180			228	0.061	53
2013	360			336			180			228	0.101	89
2014	360			336			180			228	0.079	81
2015	360			336			180			228	0.140	214
2016	360			348			180			228	0.158	265
2017	360			348			180			228	0.215	650
2018	360			348			180			228	0.167	354
2019	360			348			180			228	0.202	199
2020	213			240			75			115	0.191	210
2021	132			144			45			72	0.139	88
2022	132			144			40			72	0.042	3
Total	7221			6687			3565			4883		5818

Table 8. Annual sampling effort (number of nets), occurrence, and number (N) of Brown Shrimp collected during FWRI FIM polyhaline seagrass surveys (2008–2022) using a 6.1-m otter trawl within Charlotte Harbor (CH), Tampa Bay (TB), Big Bend (BB), Apalachicola Bay (AB), and St. Andrew Bay (SA). Note, after 2010, BB and AB identified Brown Shrimp <69 mm TL to genus level. Note, due to the COVID-19 pandemic no sampling occurred in SA in 2020.

	Bay														
	CH			TB			BB			AB			SA		
Year	Effort	Occurrence	Number	Effort	Occurrence	Number	Effort	Occurrence	Number	Effort	Occurrence	Number	Effort	Occurrence	Number
2008	70			90			276			56	0.071	11	42		
2009	56			70			210			56	0.018	1	42		
2010	56			70			210			56	0.054	9	42		
2011	56			70			210			56	0.018	2	42		
2012	56			70			210			56			39		
2013	56			70			210			56	0.071	7	42		
2014	56			70			210			56			42		
2015	56			70			210			56			42		
2016	48			60			180			48			36		
2017	48			60			180			48			36		
2018	48			60			180			48	0.021	1	30		
2019	120			144			180			96			72	0.014	1
2020	60			72			90			48					
2021	119			144			180			96	0.010	1	72	0.014	2
2022	120			144			180			96	0.010	1	72	0.014	1
Total	1025			1264			2916			928		33	651		4

Table 9. Annual sampling effort (number of nets), occurrence, and number (N) of White Shrimp collected during FWRI FIM long-term surveys (1998–2022) using a 21.3-m bay seine (gr = 19 and 20 combined) within Charlotte Harbor (CH), Tampa Bay (TB), Cedar Key (CK), and Apalachicola Bay (AB).

	Bay											
	CH			TB			CK			AB		
Year	Effort	Occurrence	Number	Effort	Occurrence	Number	Effort	Occurrence	Number	Effort	Occurrence	Number
1998	288			300			144			76	0.105	114
1999	288			300			144			96	0.115	170
2000	288			300			144			96	0.042	6
2001	288			300			243			240	0.100	647
2002	288			300			252			240	0.113	216
2003	332			300			252			240	0.088	1248
2004	552			300			252			240	0.188	2063
2005	552			408			252			240	0.142	663
2006	552			408			252			240	0.092	657
2007	552			408			252			240	0.092	217
2008	480			408			252			240	0.121	2430
2009	480			408			252			240	0.125	1046
2010	408			408			252			240	0.154	8215
2011	408			408			252			240	0.129	1105
2012	408			408			252			240	0.138	290
2013	408			408			252			240	0.088	652
2014	408			408			252			240	0.171	872
2015	408			408			252			240	0.108	479
2016	408			408			252			240	0.138	788
2017	408			408			252			240	0.142	1818
2018	408			408			252			240	0.121	1005
2019	408			408			252	0.020	17	240	0.183	3385
2020	377			374			231	0.052	55	225	0.178	2222
2021	408			408			252	0.091	434	240	0.150	2627
2022	408			408			252	0.099	222	240	0.225	2044
Total	10213			9410			5946		728	5533		34979

Table 10. Annual sampling effort (number of nets), occurrence, and number (N) of White Shrimp collected during FWRI FIM long-term surveys (1998–2022) using a 21.3-m seine deployed along river shorelines (gr = 23) within Charlotte Harbor (CH), Tampa Bay (TB), Cedar Key (CK), and Apalachicola Bay (AB).

	Bay											
	CH			TB			CK			AB		
Year	Effort	Occurrence	Number	Effort	Occurrence	Number	Effort	Occurrence	Number	Effort	Occurrence	Number
1998	96			212			108					
1999	96			264			108					
2000	96			264			108			42	0.024	7
2001	96			264			163			168	0.054	39
2002	96			264			168			168	0.042	8
2003	142			264			168			156	0.006	1
2004	372			264			168			156	0.032	34
2005	372			264			168			156	0.032	44
2006	372			264			168			156	0.147	394
2007	372			264			168			155	0.123	180
2008	180			288			168			156	0.186	360
2009	180			288			168			156	0.083	166
2010	96			312			168			156	0.109	314
2011	96			312			168			156	0.173	212
2012	96			312			168			156	0.090	56
2013	96			312			168			156	0.051	30
2014	96			318			168			156	0.096	68
2015	96			336			168			156	0.026	8
2016	504			432			168			156	0.167	246
2017	504			432			168	0.006	1	156	0.064	60
2018	504			432			168			156	0.032	23
2019	504			432			168	0.048	36	156	0.141	369
2020	471			423			154	0.013	2	77	0.091	51
2021	504			432			168	0.107	158	84		
2022	378			324			168	0.226	1671	84	0.119	32
Total	6415			7973			4001		1868	3274		2702

Table 11. Annual sampling effort (number of nets), occurrence, and number (N) of White Shrimp collected during FWRI FIM long-term surveys (1998–2022) using a 6.1-m otter trawl (bay and river combined) within Charlotte Harbor (CH), Tampa Bay (TB), Cedar Key (CK), and Apalachicola Bay (AB). Otter trawl sampling transitioned to quarterly sampling in bay habitats and bimonthly sampling in rivers in 2021.

	Bay											
	CH			TB			CK			AB		
Year	Effort	Occurrence	Number	Effort	Occurrence	Number	Effort	Occurrence	Number	Effort	Occurrence	Number
1998	72			129						64	0.359	195
1999	72			162						96	0.271	316
2000	72			156						138	0.167	1292
2001	72			156			165			228	0.215	604
2002	72			156			180			228	0.259	401
2003	108			156			180			228	0.189	419
2004	288			156			180			228	0.272	3815
2005	516			336			180			228	0.259	650
2006	516			336			180			228	0.246	5233
2007	516			336			180			228	0.215	2089
2008	420			336			180			228	0.237	8454
2009	420			336			180			228	0.259	2365
2010	360			336			180			222	0.351	4190
2011	360			336			180			228	0.303	5320
2012	360			336			180			228	0.338	5234
2013	360			336			180			228	0.158	1511
2014	360			336			180			228	0.320	4751
2015	360			336			180			228	0.294	3270
2016	360			348			180			228	0.404	3300
2017	360			348			180			228	0.294	2998
2018	360			348			180			228	0.193	1391
2019	360			348			180	0.044	65	228	0.355	4545
2020	213			240			75	0.107	40	115	0.252	669
2021	132			144			45	0.200	66	72	0.333	479
2022	132			144			40	0.400	748	72	0.403	972
Total	7221			6687			3565		919	4883		64463

Table 12. Annual sampling effort (number of nets), occurrence, and number (N) of White Shrimp collected during FWRI FIM polyhaline seagrass surveys (2008–2022) using a 6.1-m otter trawl within Charlotte Harbor (CH), Tampa Bay (TB), Big Bend (BB), Apalachicola Bay (AB), and St. Andrew Bay (SA). Note, due to the COVID-19 pandemic no sampling occurred in SA in 2020.

	Bay														
	CH			TB			BB			AB			SA		
Year	Effort	Occurrence	Number	Effort	Occurrence	Number	Effort	Occurrence	Number	Effort	Occurrence	Number	Effort	Occurrence	Number
2008	70			90			276			56			42		
2009	56			70			210			56	0.018	2	42		
2010	56			70			210			56			42		
2011	56			70			210			56			42		
2012	56			70			210			56			39		
2013	56			70			210			56	0.018	1	42		
2014	56			70			210			56	0.054	12	42		
2015	56			70			210			56	0.018	1	42		
2016	48			60			180			48	0.021	2	36		
2017	48			60			180			48	0.021	2	36		
2018	48			60			180			48	0.042	8	30		
2019	120			144			180			96	0.104	25	72		
2020	60			72			90			48					
2021	119			144			180			96	0.104	388	72		
2022	120			144			180			96	0.052	6	72		
Total	1025			1264			2916			928		447	651		

Table 13. Type III tests of fixed effects for the negative binomial model for Size 1 Pink Shrimp collected in FWRI FIM long-term surveys from June–February the following year, 1998–2022, within Tampa Bay and Charlotte Harbor.

Type III Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
SAV percentage	10	22836	209.31	<.0001
Gear	3	22836	115.15	<.0001
Bottom type	4	22836	103.53	<.0001
Month	8	22836	75.55	<.0001
Bay	1	22836	61.9	<.0001
Salinity quartile	3	22836	60.44	<.0001
Year	24	22836	51.47	<.0001
Depth quartile	3	22836	38.74	<.0001
Temperature quartile	3	22836	37.16	<.0001
Shore type	6	22836	12.77	<.0001

Table 14. Type III tests of fixed effects for the negative binomial model for Size 1 Pink Shrimp collected in FWRI FIM polyhaline seagrass surveys from June–November 2008–2022, within Tampa Bay and Charlotte Harbor.

Type III Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Bay	1	1985	34.65	<.0001
Salinity quartile	3	1985	11.86	<.0001
Bottom type	1	1985	10.81	0.001
Year	14	1985	7.54	<.0001
Shore type	2	1985	3.3	0.0371
Month	5	1985	3.9	0.0016
Temperature quartile	3	1985	4.36	0.0046
SAV percent	5	1985	2.84	0.0148

Table 15. Type III tests of fixed effects for the negative binomial model for Size 1 Brown Shrimp collected in FWRI FIM long-term surveys from May–October 2001–2022, within Apalachicola Bay.

Type III Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Zone	2	4386	27.96	<.0001
Bottom type	1	4386	25.69	<.0001
Salinity quartile	3	4386	17.68	<.0001
Month	5	4386	16.59	<.0001
Effort (area over 100-m^2)	1	4386	13.46	0.0002
SAV Presence	1	4386	6.57	0.0104
Year	21	4386	5.6	<.0001
Depth quartile	3	4386	3.02	0.0286

Table 16. Type III tests of fixed effects for the negative binomial model for Size 1 White Shrimp collected in FWRI FIM long-term surveys from June–November 2001–2022, within Apalachicola Bay.

Type III Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Salinity quartile	3	3958	99.48	<.0001
Gear	3	3958	53.24	<.0001
Bottom type	1	3958	18.28	<.0001
Shore Type	1	3958	11.27	0.0008
Month	5	3958	7.81	<.0001
Effort (area over 100-m^2)	1	3958	5.76	0.0164
Year	21	3958	4.96	<.0001
Depth quartile	3	3958	4.92	0.0021
SAV Presence	1	3958	1.53	0.2161

Table 17. Index of abundance developed using the negative binomial model for Size 1 Pink Shrimp collected in FWRI FIM long-term surveys from June–February the following year, 1998–2022, within Tampa Bay and Charlotte Harbor. The nominal frequency of occurrence, the number of samples (N), the least squares mean (Mean, number per set) and standard error (SE), the coefficient of variation on the mean (CV), lower and upper confidence limits (LCL and UCL).

Year	Frequency	N	Mean	SE	CV	LCL	UCL
1998	0.53069	7615	10.1583	0.9944	0.09789	8.3848	12.307
1999	0.59038	6626	13.5988	1.3085	0.096222	11.2614	16.4214
2000	0.55755	5246	10.3545	1.0272	0.099203	8.5248	12.5769
2001	0.44324	5313	8.5634	0.8361	0.097636	7.072	10.3695
2002	0.50182	6687	21.256	2.1124	0.099379	17.4938	25.8272
2003	0.42174	3914	6.1446	0.5699	0.092748	5.1232	7.3695
2004	0.54839	8890	15.0503	1.2454	0.082749	12.7968	17.7005
2005	0.25706	2108	2.3697	0.2028	0.08558	2.0037	2.8024
2006	0.42412	4905	6.3177	0.5091	0.080583	5.3946	7.3987
2007	0.42787	4203	6.0859	0.5051	0.082995	5.1721	7.161
2008	0.46628	3932	5.6833	0.4869	0.085672	4.8047	6.7225
2009	0.39804	3912	4.3859	0.3671	0.0837	3.7223	5.1679
2010	0.453	4748	6.7311	0.5809	0.086301	5.6837	7.9717
2011	0.47694	4942	6.1548	0.5186	0.084259	5.2178	7.26
2012	0.4311	3583	4.641	0.3986	0.085887	3.9219	5.4918
2013	0.39882	2912	3.4216	0.3032	0.088614	2.8761	4.0706
2014	0.47925	5984	7.5408	0.6353	0.084248	6.3929	8.8948
2015	0.47021	7349	7.6852	0.6502	0.084604	6.5109	9.0714
2016	0.42586	6479	5.943	0.4717	0.079371	5.0869	6.9433
2017	0.45909	6772	9.0299	0.7215	0.079901	7.7209	10.561
2018	0.26804	2549	2.8035	0.2371	0.084573	2.3752	3.3089
2019	0.44549	6887	7.8079	0.6288	0.080534	6.6678	9.1429
2020	0.41139	4655	6.1342	0.5075	0.082733	5.216	7.214
2021	0.2333	1752	1.9986	0.1761	0.088112	1.6815	2.3754
2022	0.45897	5321	6.4491	0.573	0.08885	5.4184	7.6759

Table 18. Index of abundance developed using the negative binomial model for Size 1 Pink Shrimp collected in FWRI FIM polyhaline seagrass surveys from June–November, 2008-2022, within Tampa Bay and Charlotte Harbor. The nominal frequency of occurrence, the number of samples (N), the least squares mean (Mean, number per set) and standard error (SE), the coefficient of variation on the mean (CV), lower and upper confidence limits (LCL and UCL).

Year	Frequency	N	Mean	SE	CV	LCL	UCL
2008	0.2193	66	0.9911	0.5047	0.509232166	0.365	2.6907
2009	0.30556	138	1.8346	0.986	0.537446855	0.6394	5.264
2010	0.33333	184	2.7853	1.4627	0.525149894	0.9945	7.8009
2011	0.37963	302	4.2127	2.2453	0.532983597	1.4812	11.9813
2012	0.24074	89	1.3689	0.7361	0.537731025	0.4768	3.9299
2013	0.26852	124	1.7685	0.9503	0.537348035	0.6165	5.0733
2014	0.39815	447	6.4282	3.3935	0.527908279	2.2828	18.1014
2015	0.36111	150	2.4918	1.3455	0.539971105	0.8642	7.1848
2016	0.24074	97	1.42	0.7541	0.531056338	0.5012	4.0232
2017	0.37963	290	2.048	1.0673	0.521142578	0.737	5.6913
2018	0.40741	650	6.8946	3.7051	0.537391582	2.4032	19.7798
2019	0.42424	645	3.6299	1.8315	0.504559354	1.3494	9.7641
2020	0.34091	211	2.0111	1.0574	0.52578191	0.7172	5.6397
2021	0.40304	1758	6.778	3.4393	0.507421068	2.5057	18.335
2022	0.41288	946	4.6518	2.3428	0.503633002	1.7325	12.4903

Table 19. Index of abundance developed using the negative binomial model for Size 1 Brown Shrimp collected in FWRI FIM long-term surveys from May–October 2001–2022, within Apalachicola Bay. The nominal frequency of occurrence, the number of samples (N), the least squares mean (Mean, number per set) and standard error (SE), the coefficient of variation on the mean (CV), lower and upper confidence limits (LCL and UCL).

Year	Frequency	N	Mean	SE	CV	LCL	UCL
2001	0.17300	487	1.58070	0.50210	0.31764	0.84810	2.94640
2002	0.10900	305	0.45250	0.15370	0.33967	0.23250	0.88060
2003	0.06000	130	0.15410	0.06166	0.40013	0.07035	0.33770
2004	0.04100	40	0.07395	0.03040	0.41109	0.03303	0.16560
2005	0.05300	157	0.10520	0.03926	0.37319	0.05058	0.21860
2006	0.07300	404	0.39060	0.12670	0.32437	0.20680	0.73790
2007	0.07100	266	0.32290	0.10540	0.32642	0.17030	0.61210
2008	0.09900	455	0.25610	0.08449	0.32991	0.13410	0.48900
2009	0.08400	169	0.20490	0.07412	0.36174	0.10080	0.41650
2010	0.05600	211	0.18420	0.06863	0.37258	0.08873	0.38240
2011	0.04100	74	0.04581	0.01989	0.43418	0.01956	0.10730
2012	0.03200	56	0.05237	0.02203	0.42066	0.02295	0.11950
2013	0.05300	107	0.15300	0.05639	0.36856	0.07425	0.31510
2014	0.03800	86	0.07076	0.02869	0.40546	0.03196	0.15670
2015	0.07500	209	0.19010	0.06583	0.34629	0.09645	0.37480
2016	0.07700	258	0.23360	0.07953	0.34045	0.11990	0.45540
2017	0.12000	672	0.43450	0.13640	0.31392	0.23470	0.80420
2018	0.09000	346	0.15770	0.05431	0.34439	0.08029	0.30980
2019	0.10700	216	0.28030	0.09242	0.32972	0.14690	0.53500
2020	0.08900	214	0.75630	0.29210	0.38622	0.35470	1.61250
2021	0.03200	44	0.07737	0.04119	0.53238	0.02724	0.21970
2022	0.01900	13	0.07971	0.04655	0.58399	0.02537	0.25050

Table 20. Index of abundance developed using the negative binomial model for Size 1 White Shrimp collected in FWRI FIM long-term surveys from June–November 2001–2022, within Apalachicola Bay. The nominal frequency of occurrence, the number of samples (N), the least squares mean (Mean, number per set) and standard error (SE), the coefficient of variation on the mean (CV), lower and upper confidence limits (LCL and UCL).

Year	Frequency	N	Mean	SE	CV	LCL	UCL
2001	0.15500	684	0.31170	0.15130	0.48540	0.12030	0.80740
2002	0.18800	217	0.25040	0.12540	0.50080	0.09380	0.66820
2003	0.13200	1206	0.22130	0.09645	0.43583	0.09416	0.52010
2004	0.20800	5319	1.02930	0.42800	0.41582	0.45550	2.32580
2005	0.19000	1019	0.36730	0.16210	0.44133	0.15460	0.87240
2006	0.21800	5662	1.74010	0.68770	0.39521	0.80180	3.77660
2007	0.20400	2854	0.47010	0.19450	0.41374	0.20890	1.05790
2008	0.25100	8736	3.40970	1.32860	0.38965	1.58830	7.31960
2009	0.20500	4745	1.76620	0.72180	0.40867	0.79270	3.93560
2010	0.27300	10492	4.58940	1.80490	0.39328	2.12270	9.92240
2011	0.27800	4827	1.24710	0.53200	0.42659	0.54030	2.87840
2012	0.27000	3332	0.52260	0.21380	0.40911	0.23430	1.16550
2013	0.13900	1218	0.49500	0.20940	0.42303	0.21590	1.13470
2014	0.28500	7338	1.51390	0.58410	0.38582	0.71060	3.22570
2015	0.21100	2253	0.54150	0.21440	0.39594	0.24920	1.17670
2016	0.30700	3372	1.86560	0.71820	0.38497	0.87710	3.96810
2017	0.23000	3020	0.91700	0.36880	0.40218	0.41680	2.01740
2018	0.15800	743	0.58480	0.25570	0.43724	0.24810	1.37840
2019	0.27900	6773	3.62540	1.42230	0.39232	1.68000	7.82360
2020	0.24800	634	0.36540	0.19080	0.52217	0.13120	1.01720
2021	0.19000	2624	0.56900	0.30760	0.54060	0.19720	1.64200
2022	0.29200	2312	1.40730	0.73070	0.51922	0.50850	3.89480

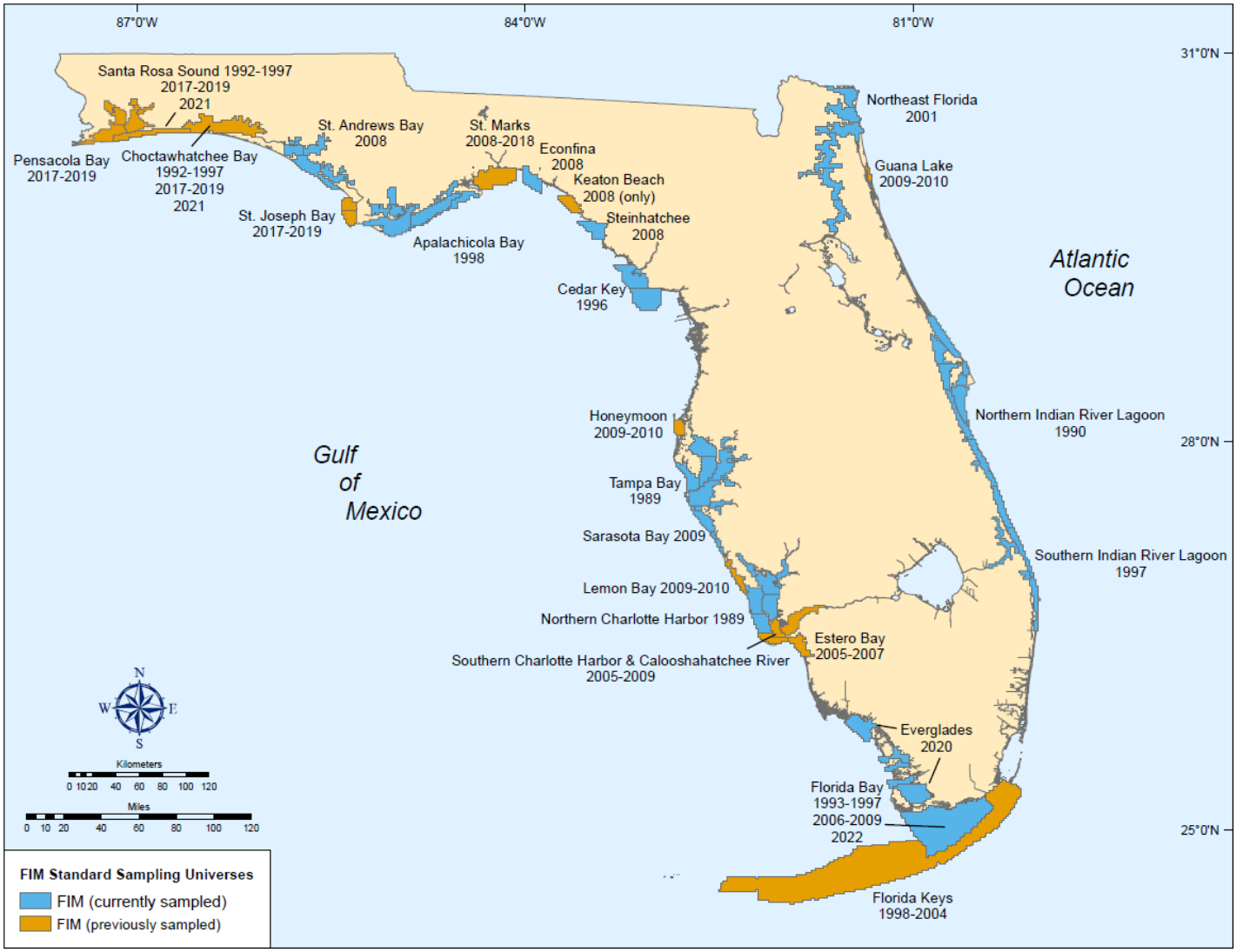

Figure 1. Estuaries where Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute conducted seine and trawl surveys. Pink Shrimp indices were developed with data from Charlotte Harbor and Tampa Bay. Brown and White Shrimp indices were developed with data from Apalachicola Bay.

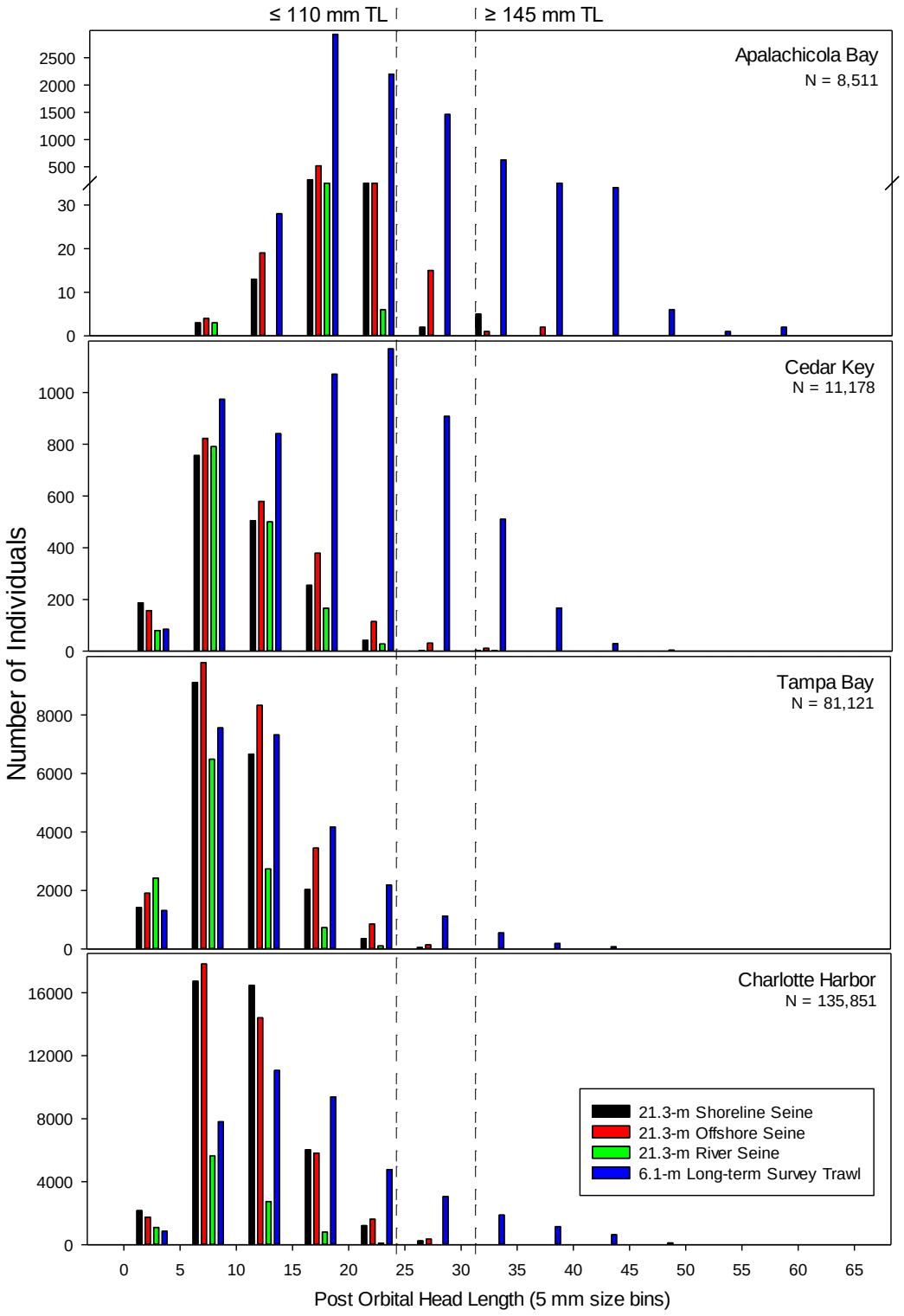

Figure 2. Length frequency of Pink Shrimp (*Farfantepenaeus duorarum*) captured in FWRI FIM long-term surveys from 1998–2022. Dashed line denotes size bins for SEDAR 87 assessment. Note break in y-axis for Apalachicola Bay panel. Note, after 2010, *Farfantepenaeus* spp. shrimp <15 mm post orbital head length (69 mm total length) were identified to genus in Cedar Key and Apalachicola Bay.

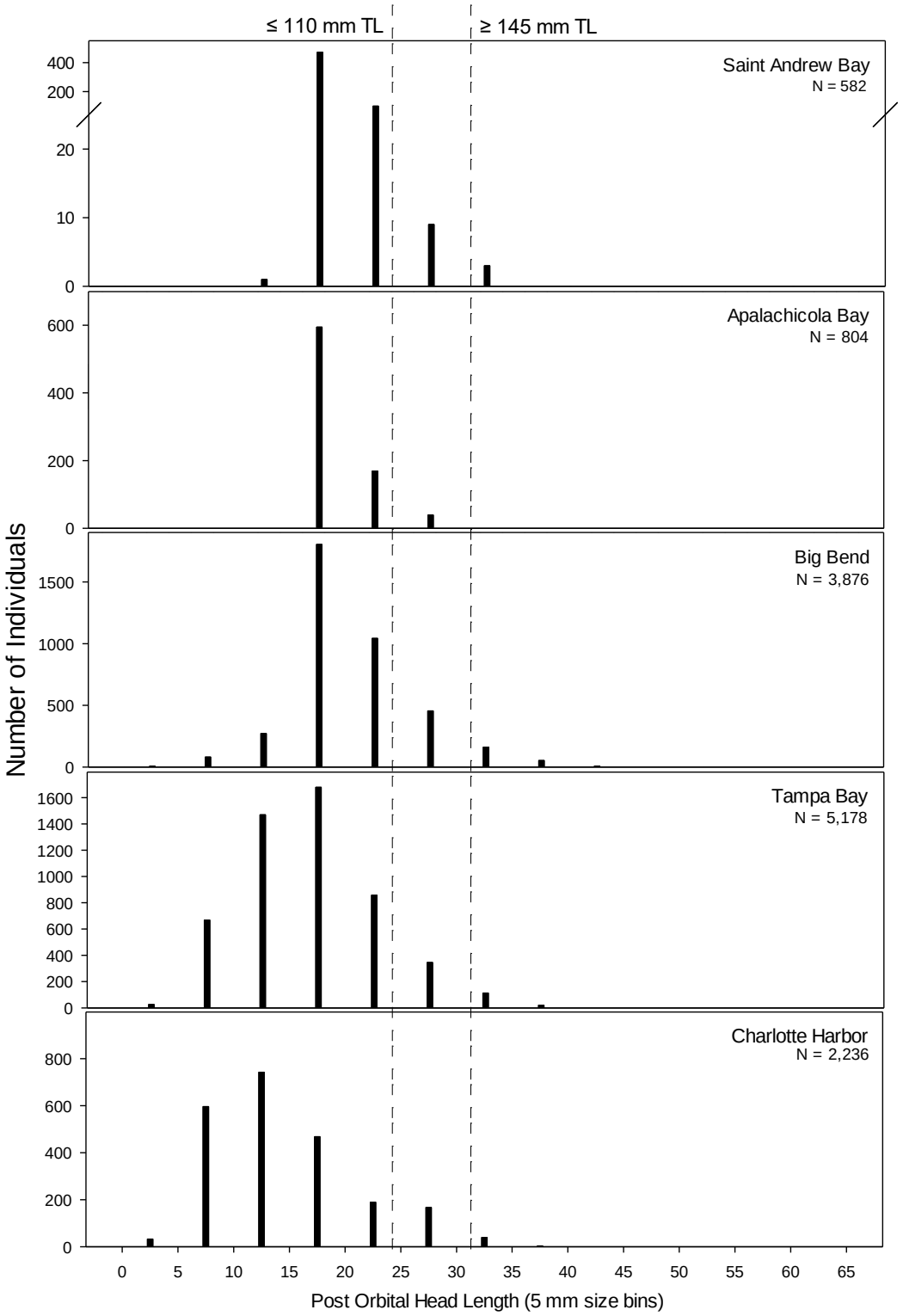

Figure 3. Length frequency of Pink Shrimp (*Farfantepenaeus duorarum*) captured in FWRI FIM polyhaline seagrass surveys from 2008–2022. Dashed line denotes size bins for SEDAR 87 assessment. Note break in y-axis for St. Andrew Bay panel. Note, after 2010, *Farfantepenaeus* spp. shrimp <15 mm post orbital head length (69 mm total length) were identified to genus in Big Bend, Apalachicola Bay, and St. Andrew Bay.

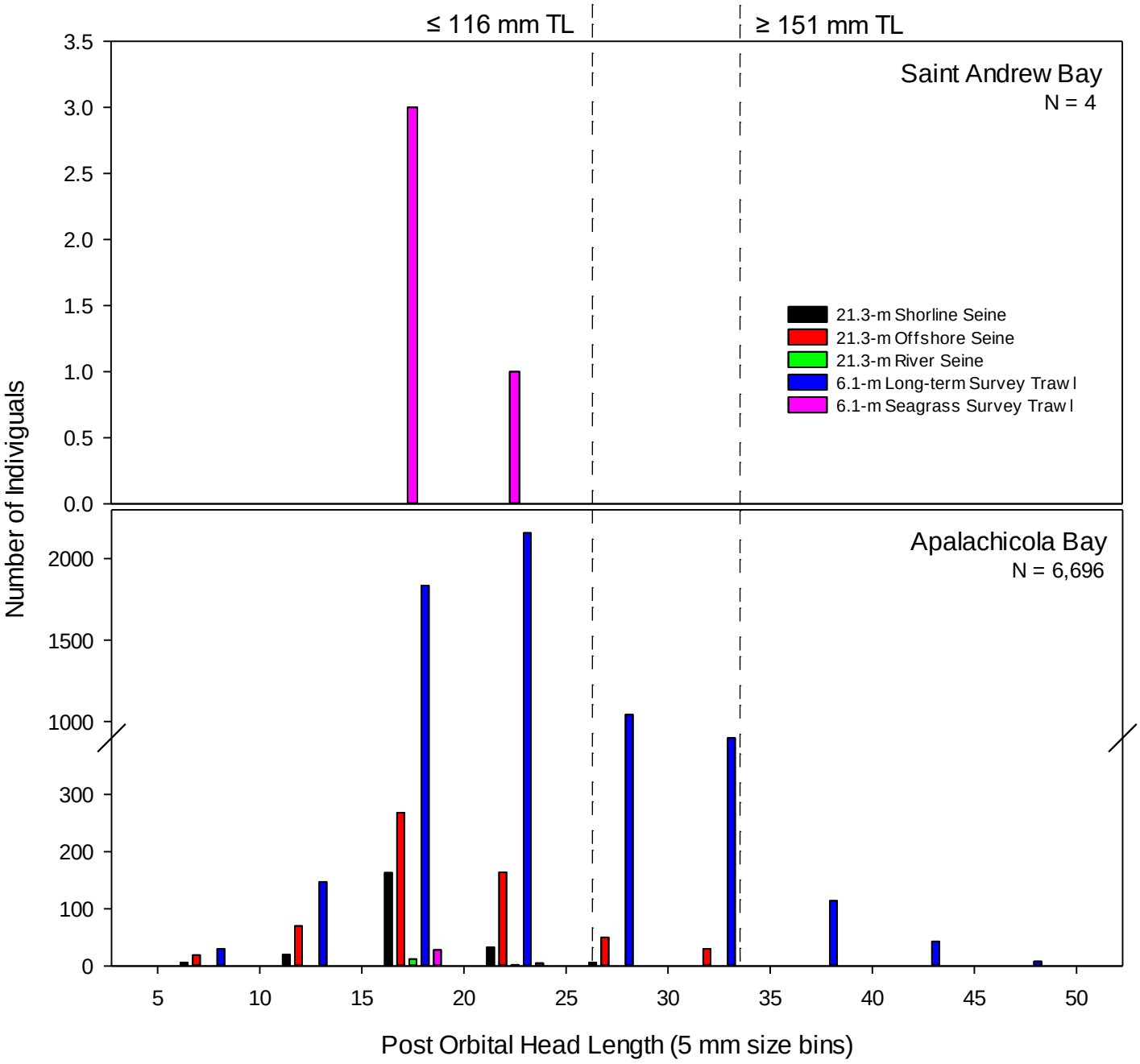

Figure 4. Length frequency of Brown Shrimp (*Farfantepenaeus aztecus*) captured in FWRI FIM long-term (1998–2022) and polyhaline seagrass (2008–2022) surveys. Dashed line denotes size bins for SEDAR 87 assessment. Note, break in y-axis in Apalachicola Bay panel. Note, after 2010, *Farfantepenaeus* spp. shrimp <15 mm post orbital head length (69 mm total length) were identified to genus in Apalachicola Bay and St. Andrew Bay.

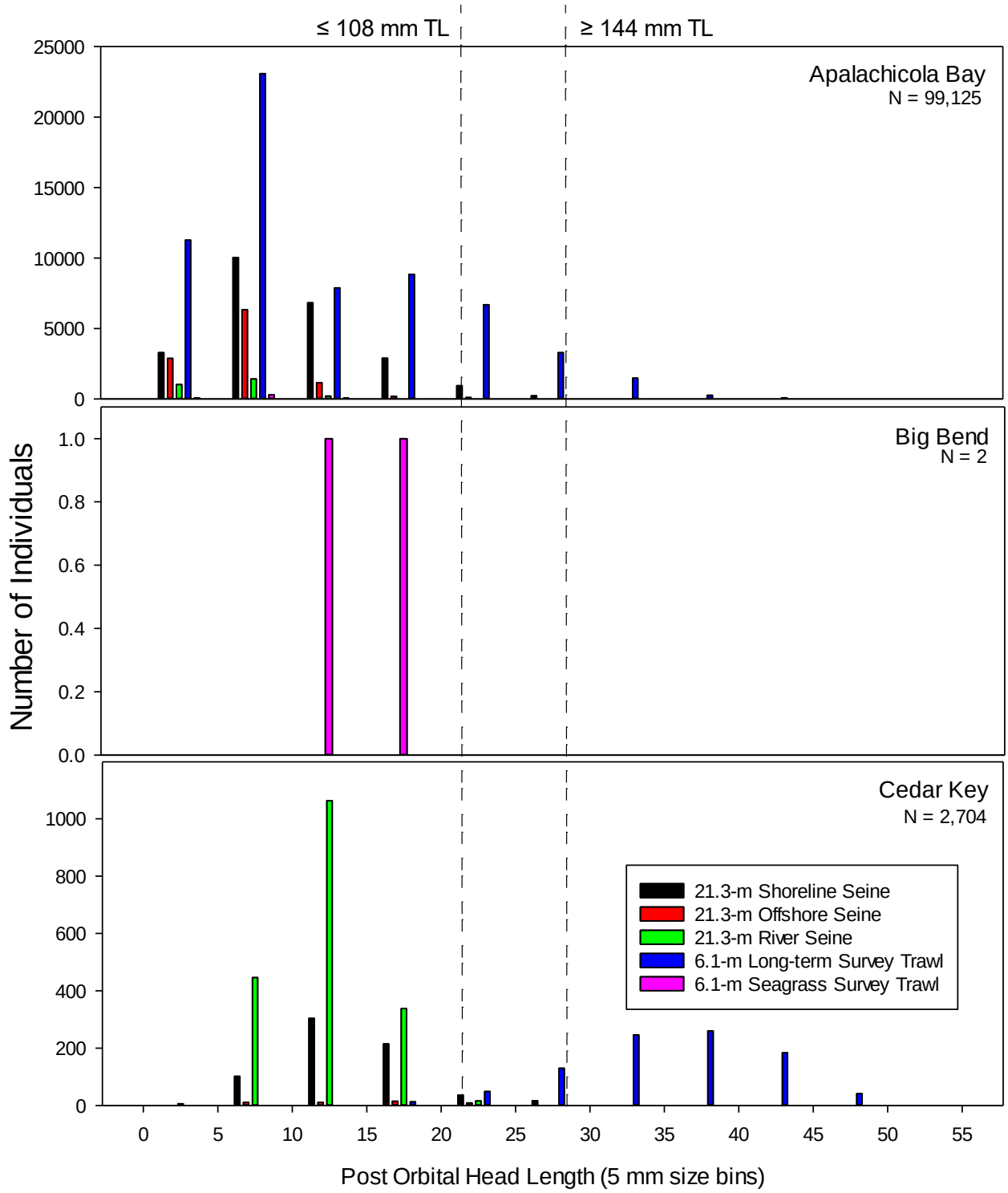

Figure 5. Length frequency of White Shrimp (*Litopenaeus setiferus*) captured in FWRI FIM long-term (1998–2022) and polyhaline seagrass (2008–2022) surveys. Dashed line denotes size bins for SEDAR 87 assessment.

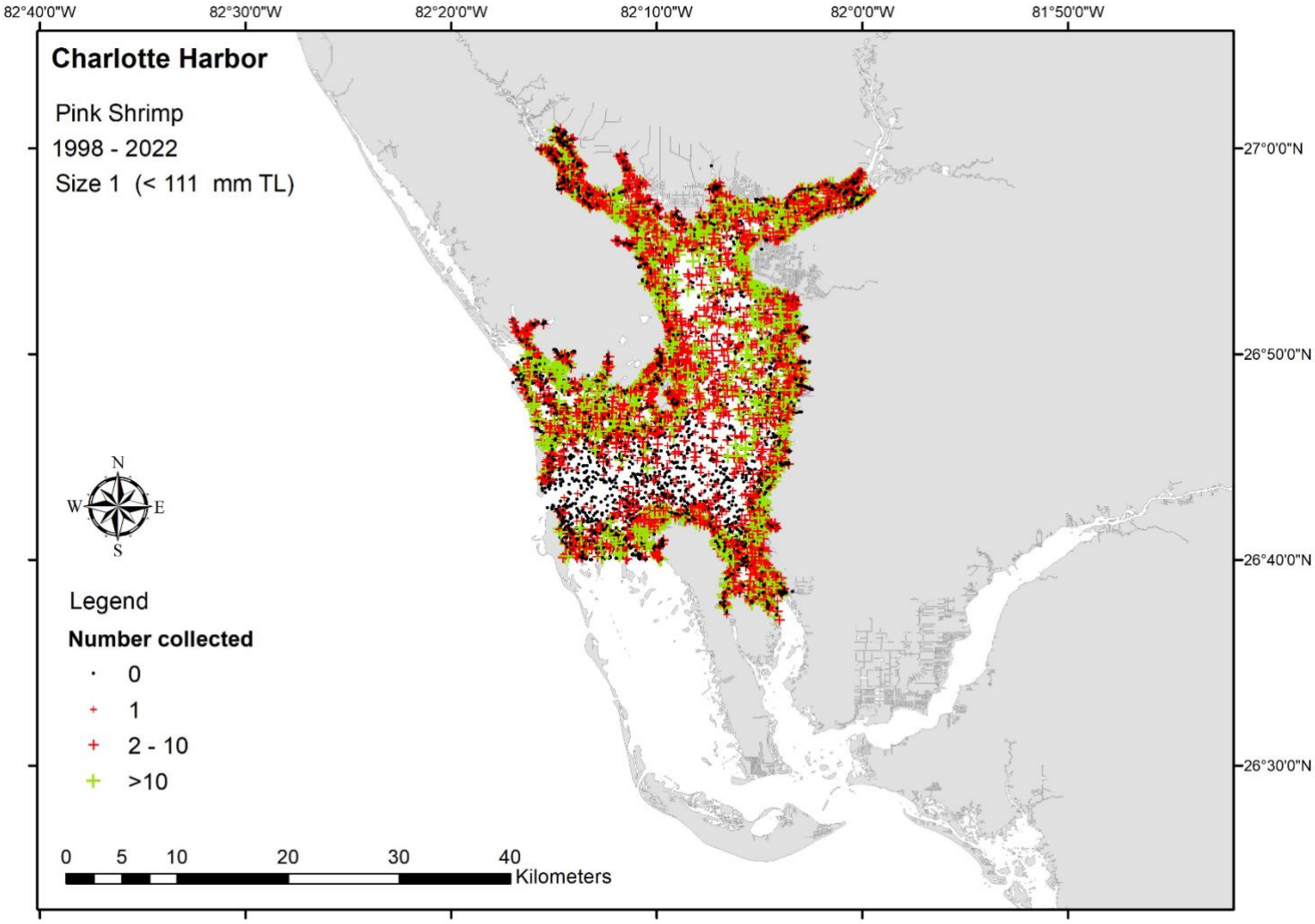

Figure 6. Stations sampled in Charlotte Harbor in FWRI FIM long-term surveys (1998–2022) using 21.3-m seines and 6.1-m otter trawls. Symbols represent the number of Size 1 Pink Shrimp per set.

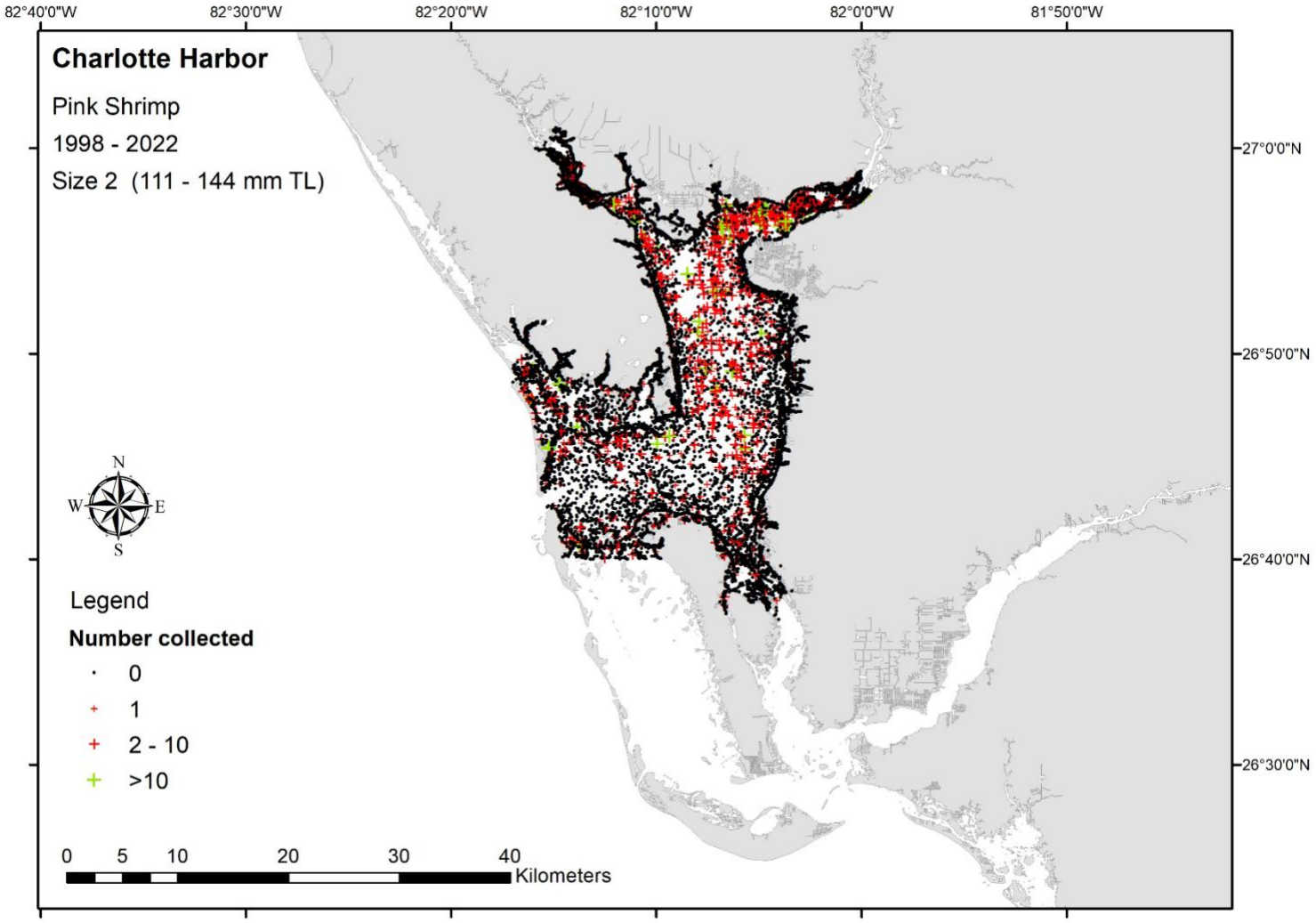

Figure 7. Stations sampled in Charlotte Harbor in FWRI FIM long-term surveys (1998–2022) using 21.3-m seines and 6.1-m otter trawls. Symbols represent the number of Size 2 Pink Shrimp per set.

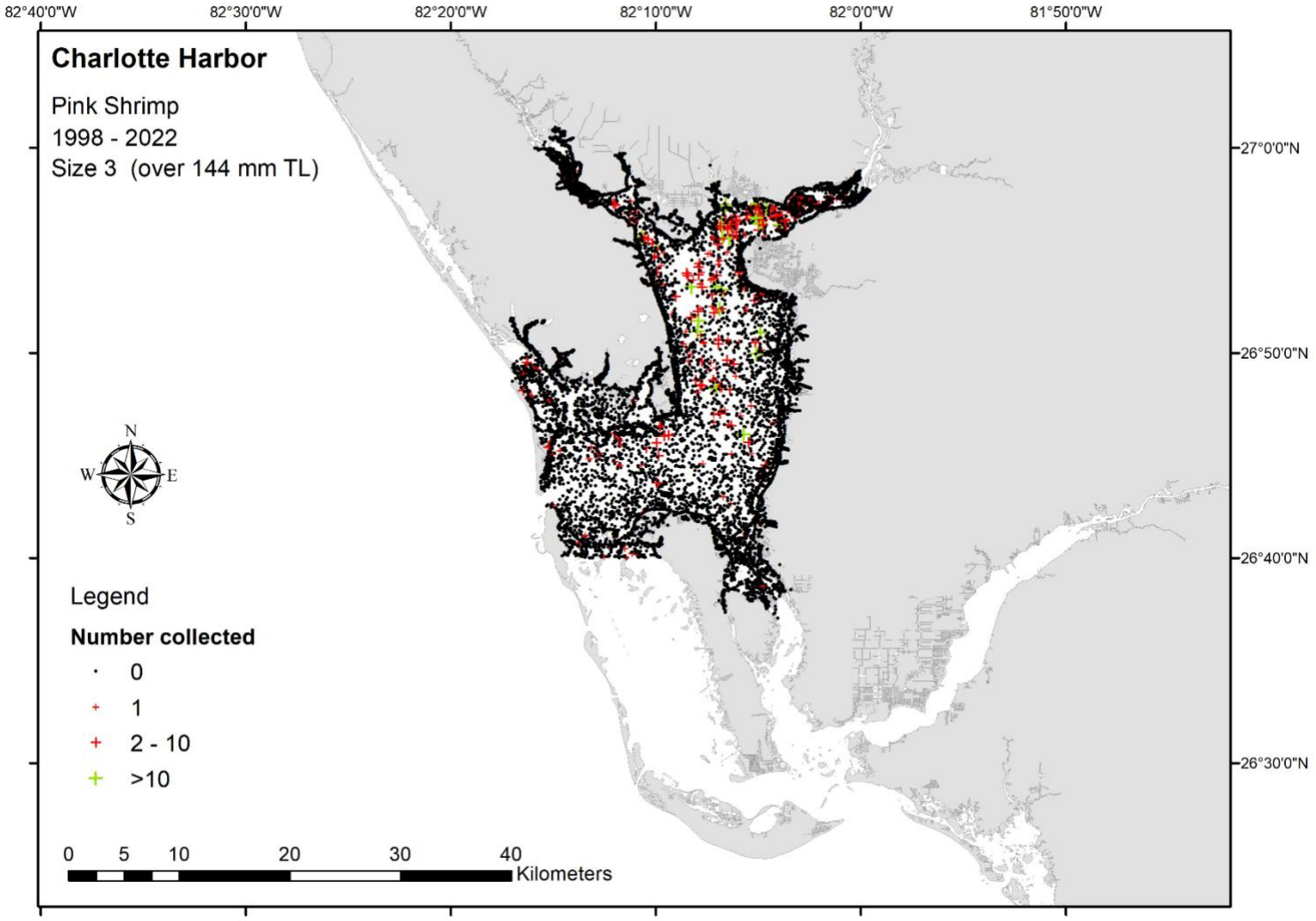

Figure 8. Stations sampled in Charlotte Harbor in FWRI FIM long-term surveys (1998–2022) using 21.3-m seines and 6.1-m otter trawls. Symbols represent the number of Size 3 Pink Shrimp per set.

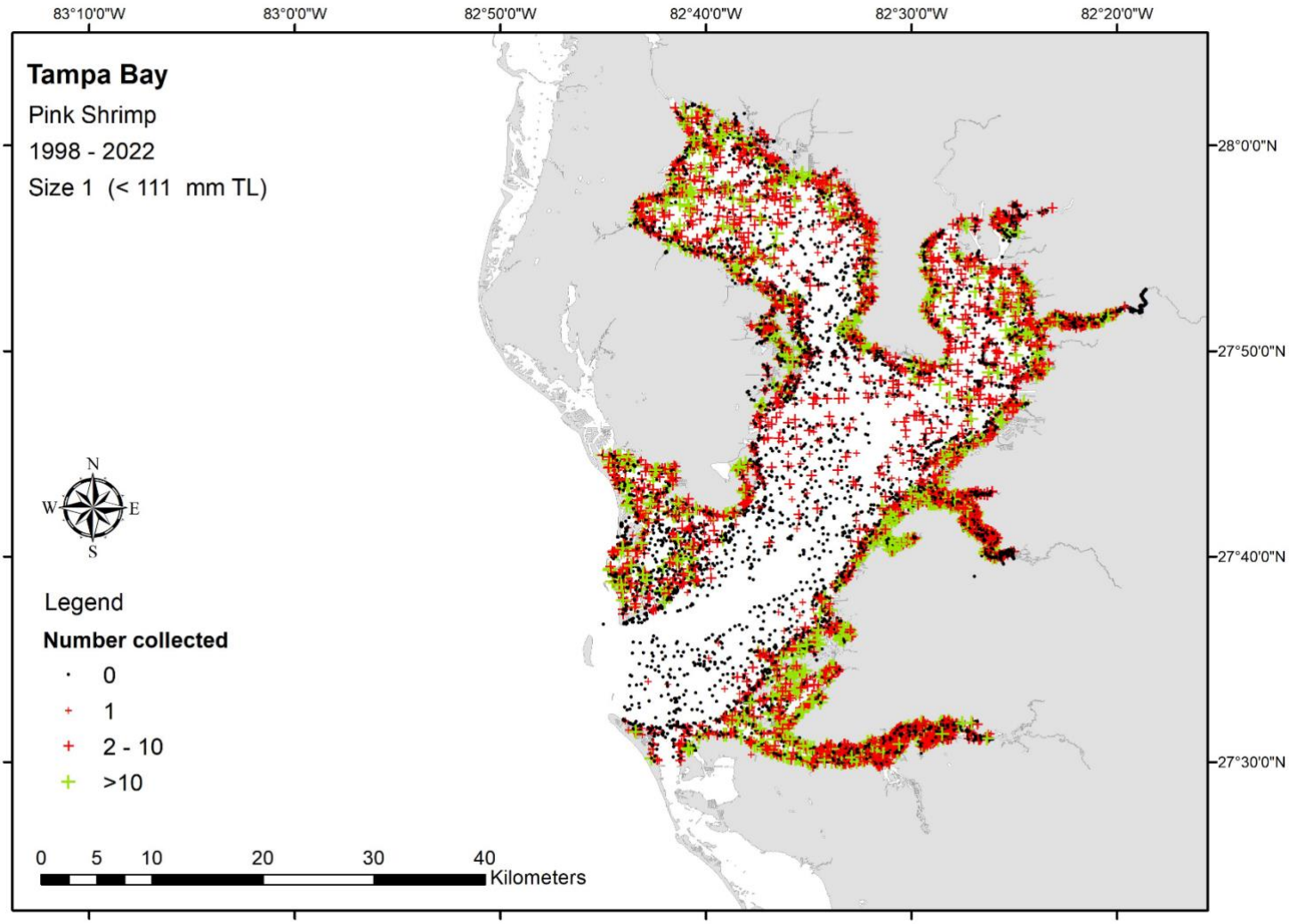

Figure 9. Stations sampled in Tampa Bay in FWRI FIM long-term surveys (1998–2022) using 21.3-m seines and 6.1-m otter trawls. Symbols represent the number of Size 1 Pink Shrimp per set.

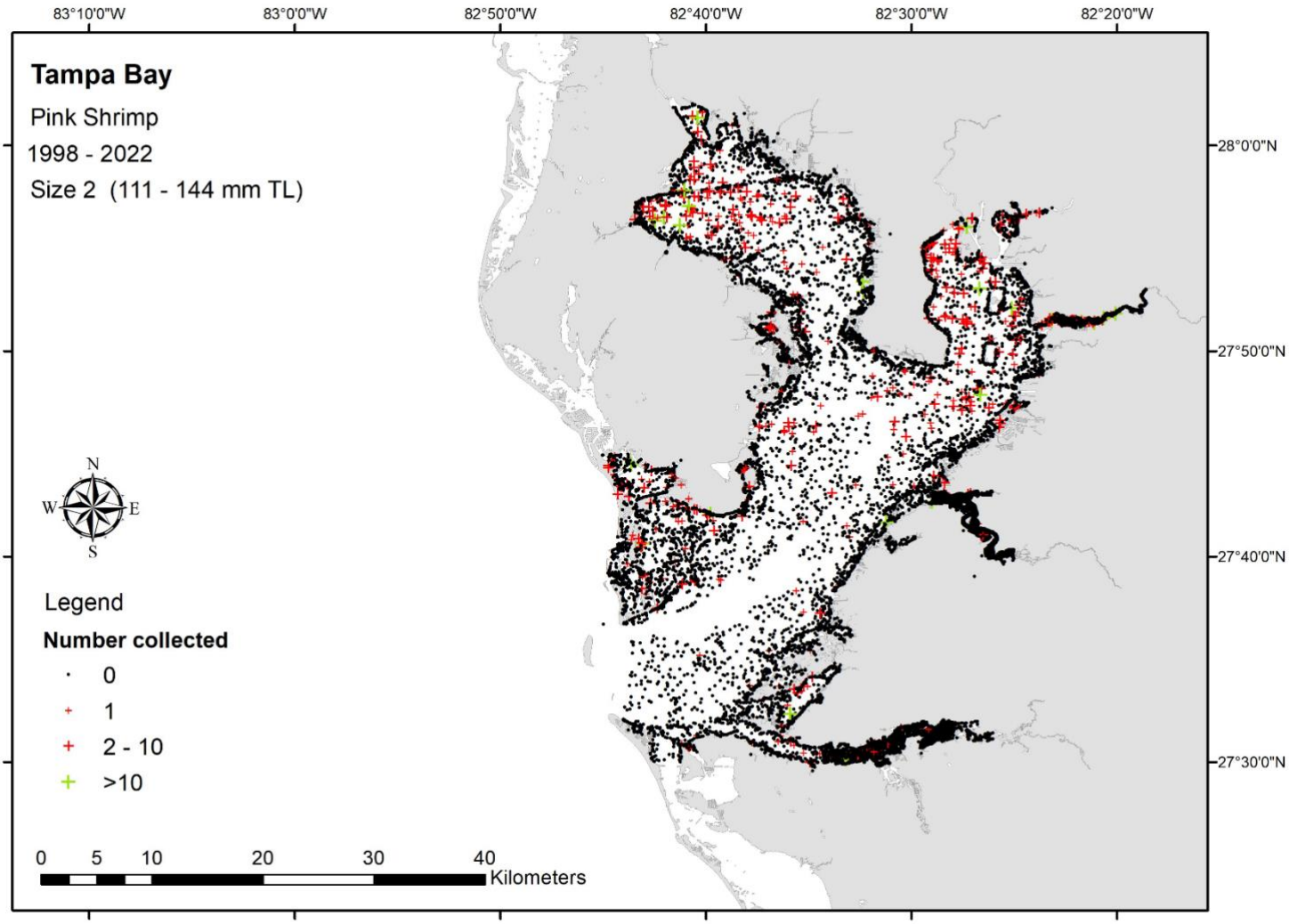

Figure 10. Stations sampled in Tampa Bay in FWRI FIM long-term surveys (1998–2022) using 21.3-m seines and 6.1-m otter trawls. Symbols represent the number of Size 2 Pink Shrimp per set.

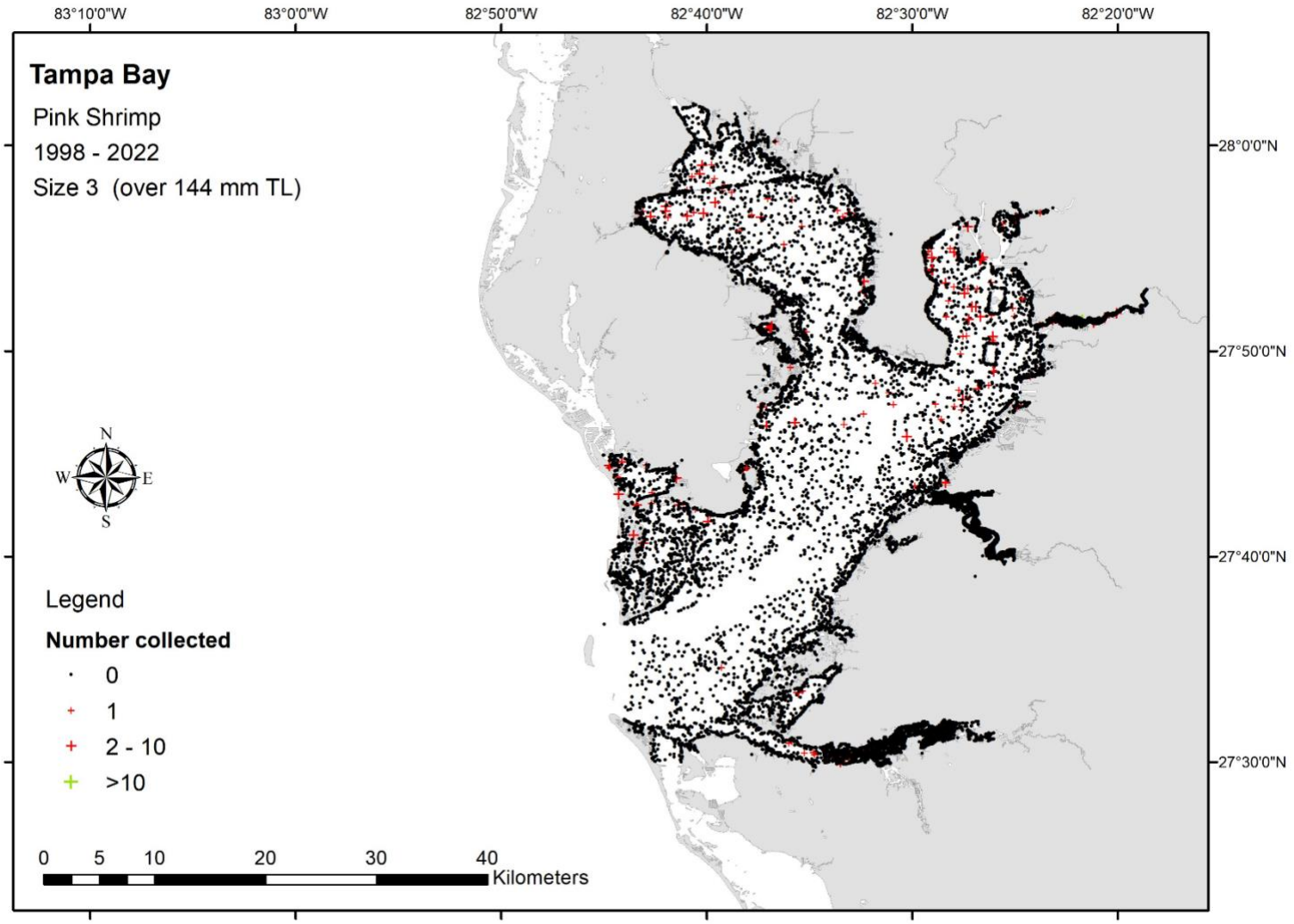

Figure 11. Stations sampled in Tampa Bay in FWRI FIM long-term surveys (1998–2022) using 21.3-m seines and 6.1-m otter trawls. Symbols represent the number of Size 3 Pink Shrimp per set.

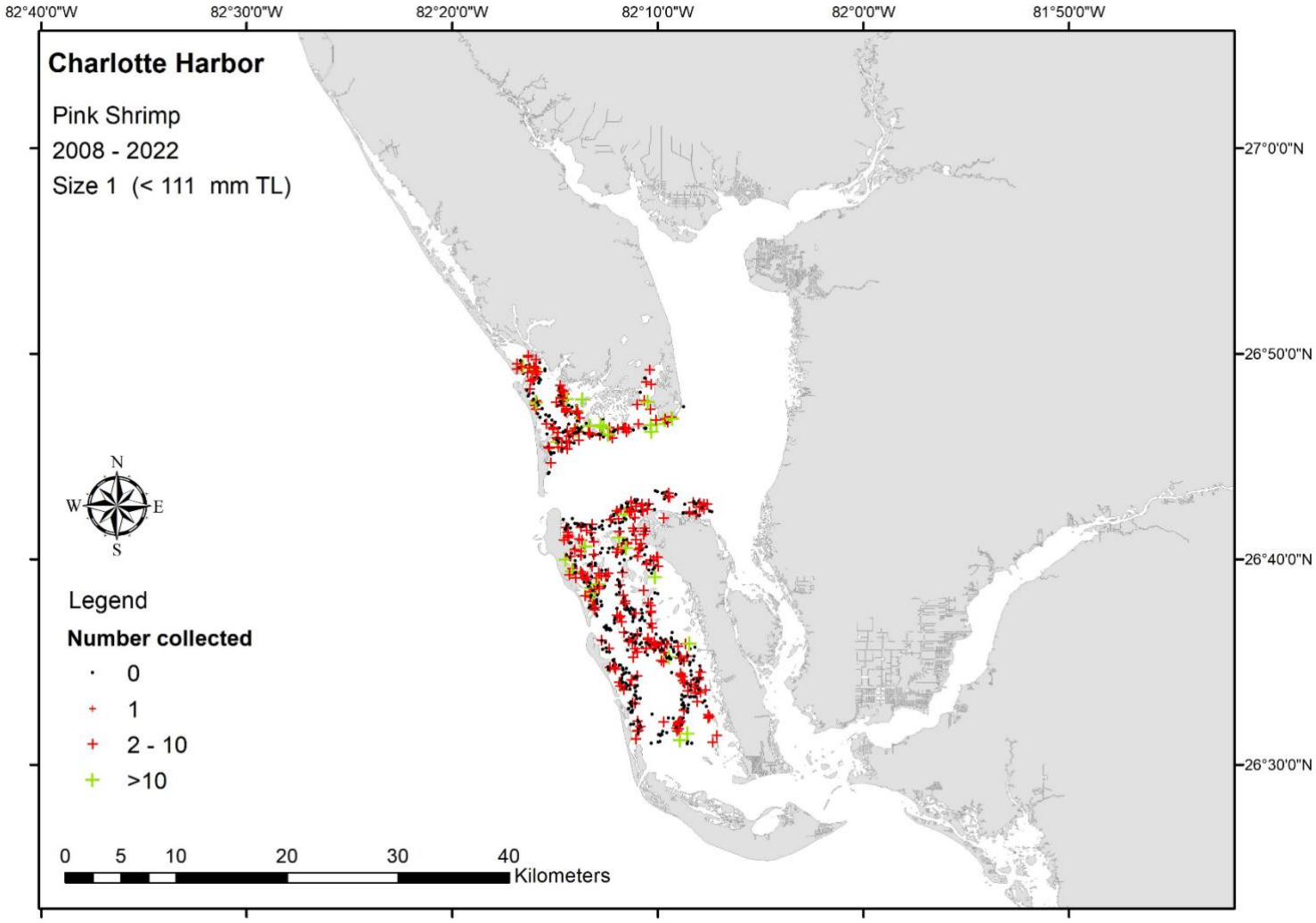

Figure 12. Stations sampled in Charlotte Harbor in FWRI FIM polyhaline seagrass surveys (2008–2022) using 6.1-m otter trawls. Symbols represent the number of Size 1 Pink Shrimp per set.

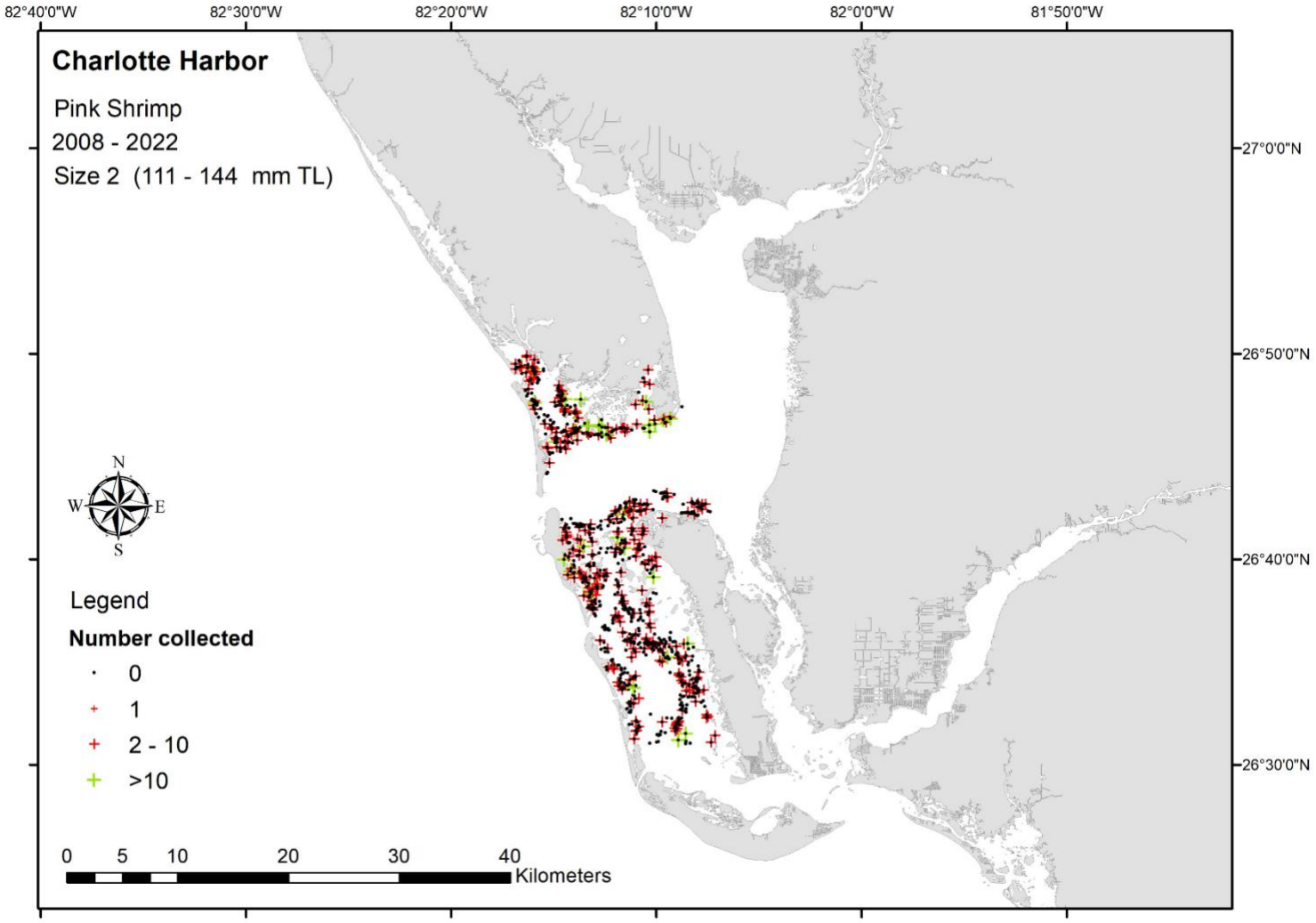

Figure 13. Stations sampled in Charlotte Harbor in FWRI FIM polyhaline seagrass surveys (2008–2022) using 6.1-m otter trawls. Symbols represent the number of Size 2 Pink Shrimp per set.

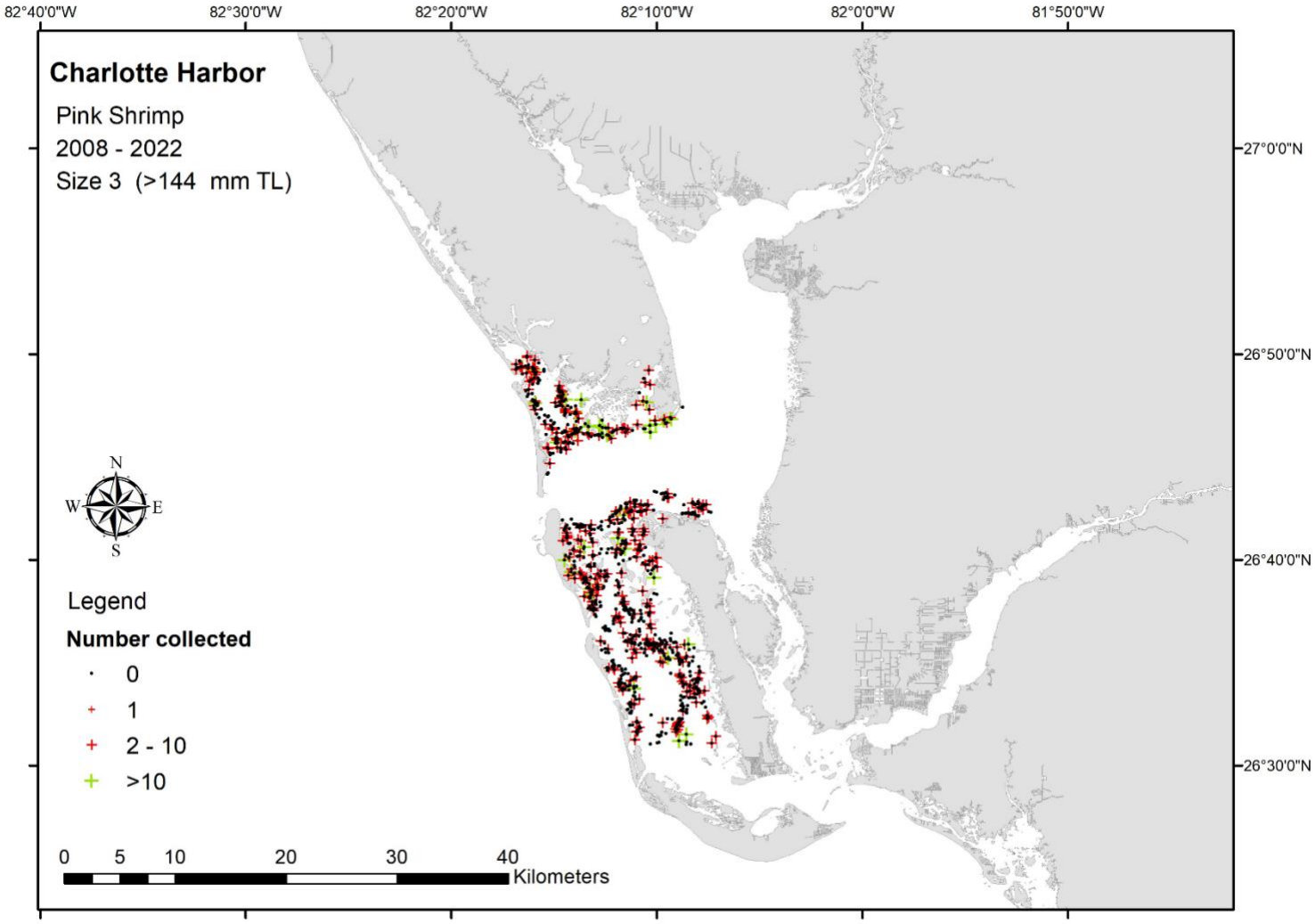

Figure 14. Stations sampled in Charlotte Harbor in FWRI FIM polyhaline seagrass surveys (2008–2022) using 6.1-m otter trawls. Symbols represent the number of Size 3 Pink Shrimp per set.

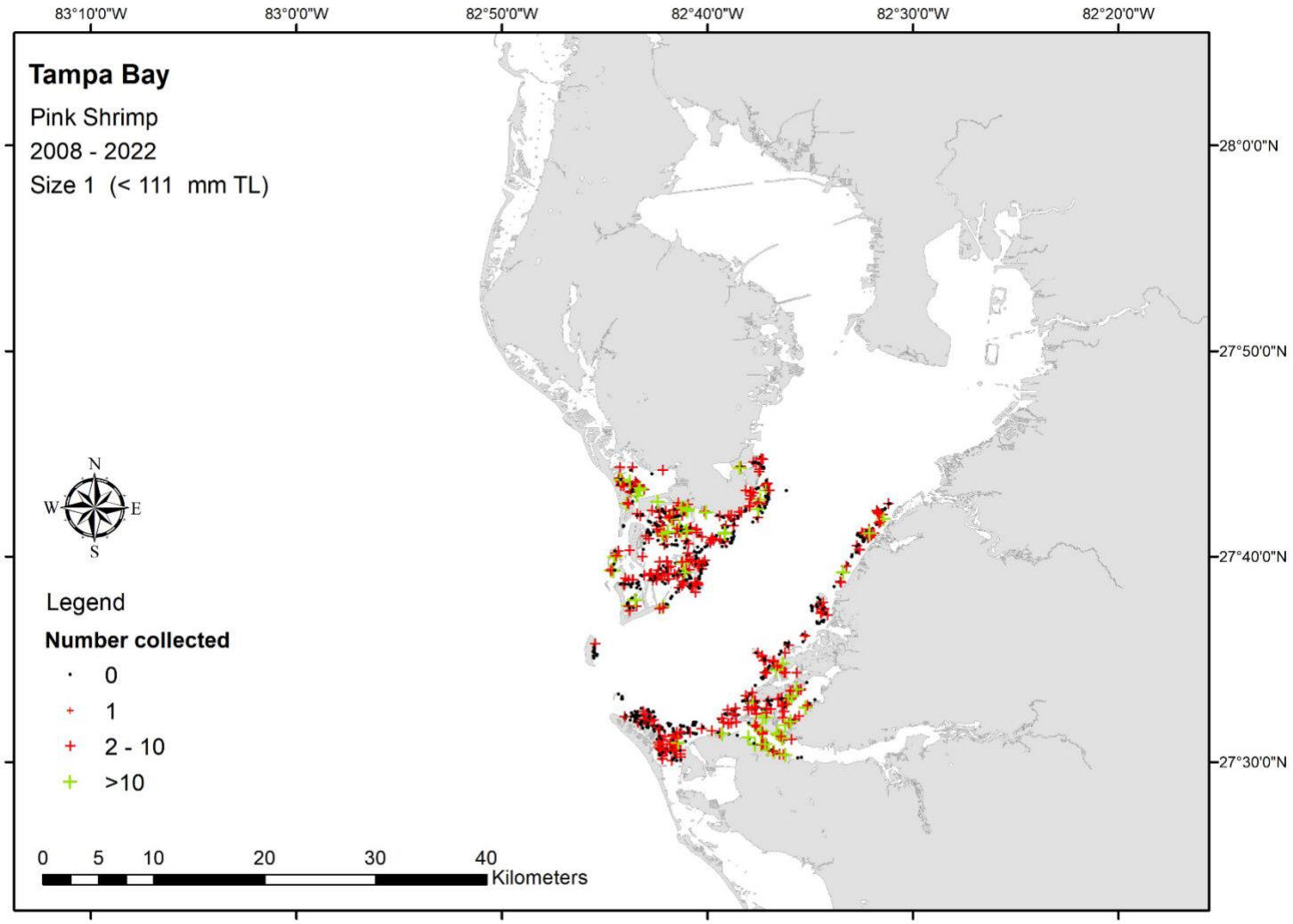

Figure 15. Stations sampled in Tampa Bay in FWRI FIM polyhaline seagrass surveys (2008–2022) using 6.1-m otter trawls. Symbols represent the number of Size 1 Pink Shrimp per set.

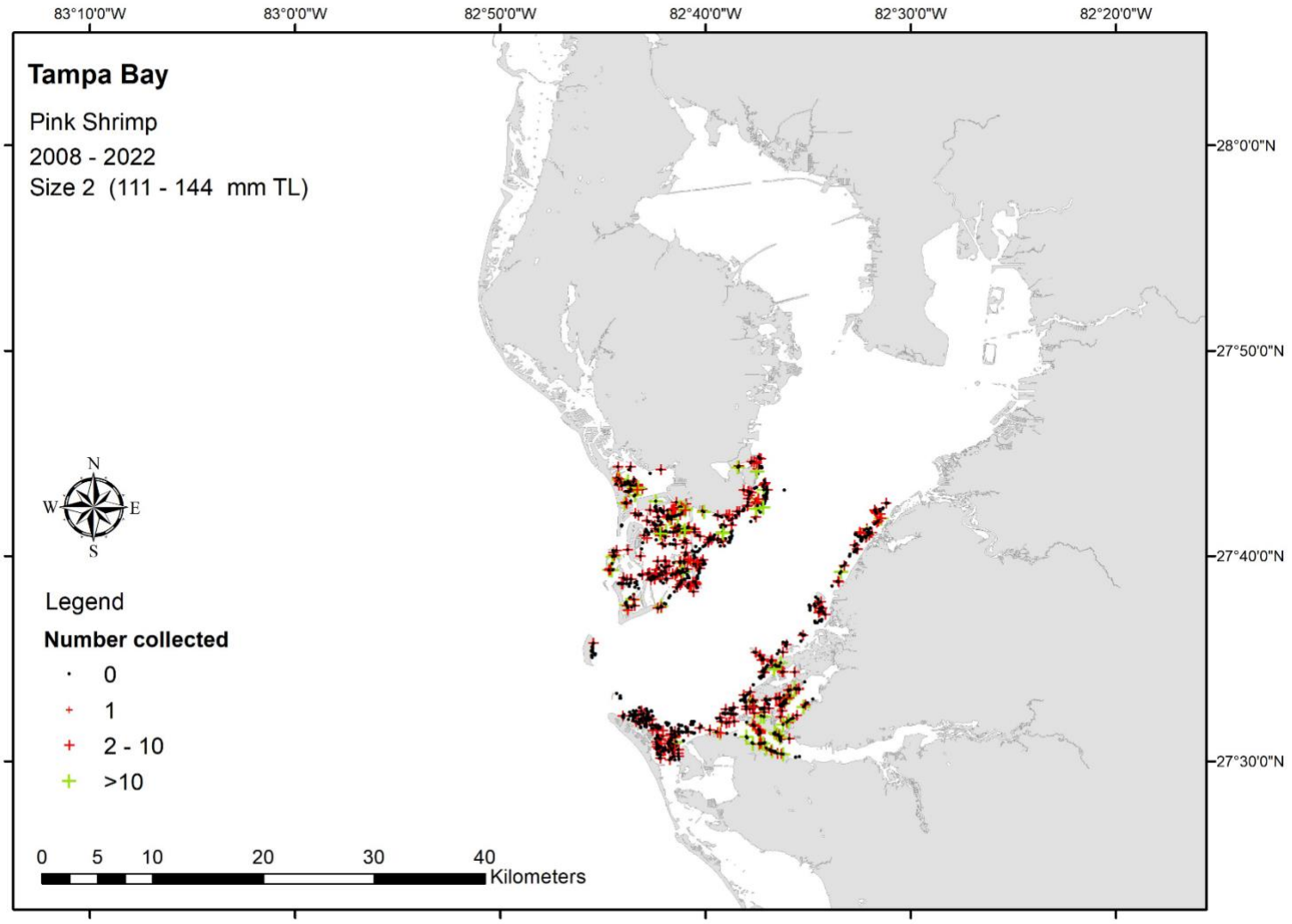

Figure 16. Stations sampled in Tampa Bay in FWRI FIM polyhaline seagrass surveys (2008–2022) using 6.1-m otter trawls. Symbols represent the number of Size 2 Pink Shrimp per set.

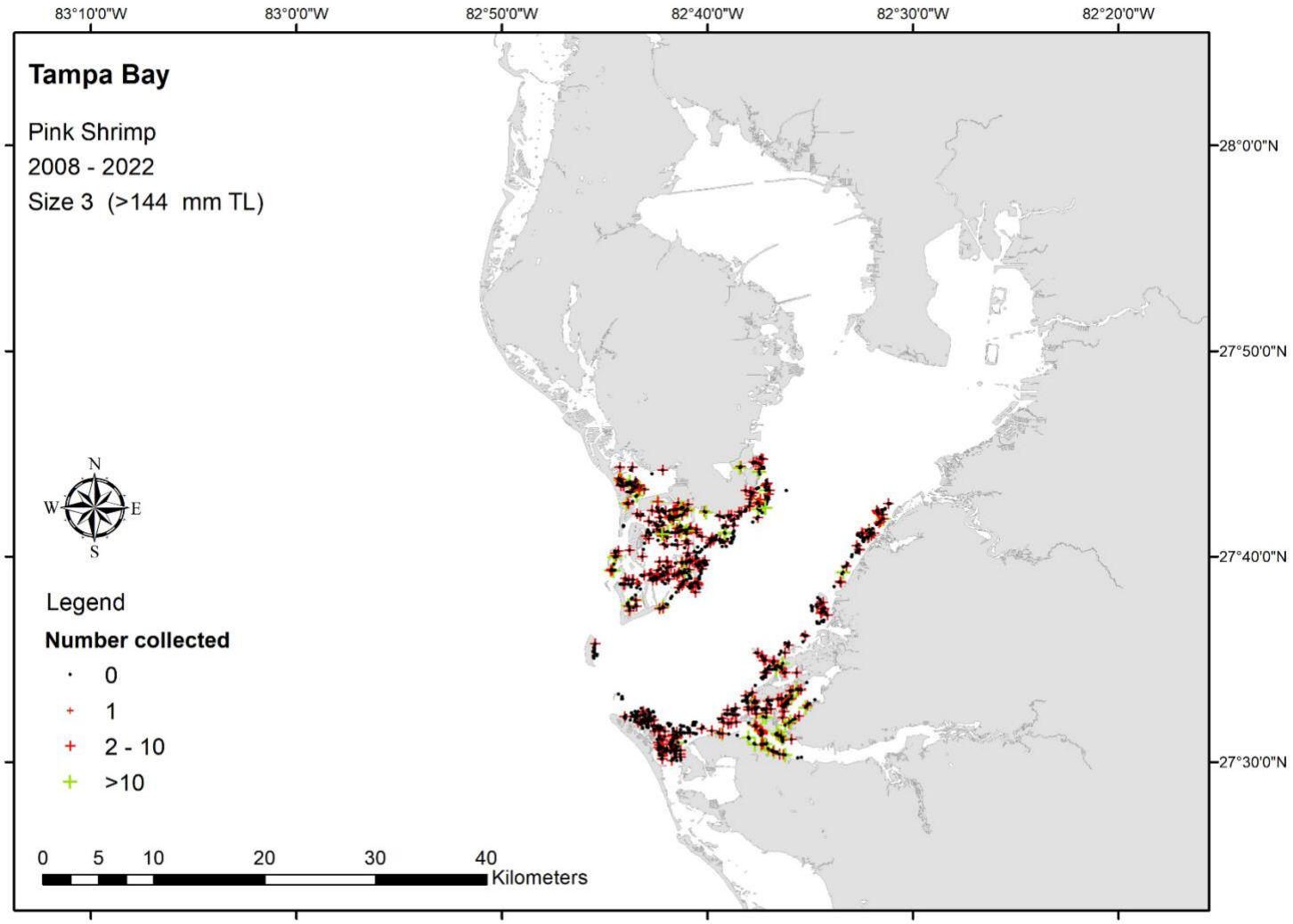

Figure 17. Stations sampled in Tampa Bay in FWRI FIM polyhaline seagrass surveys (2008–2022) using 6.1-m otter trawls. Symbols represent the number of Size 3 Pink Shrimp per set.

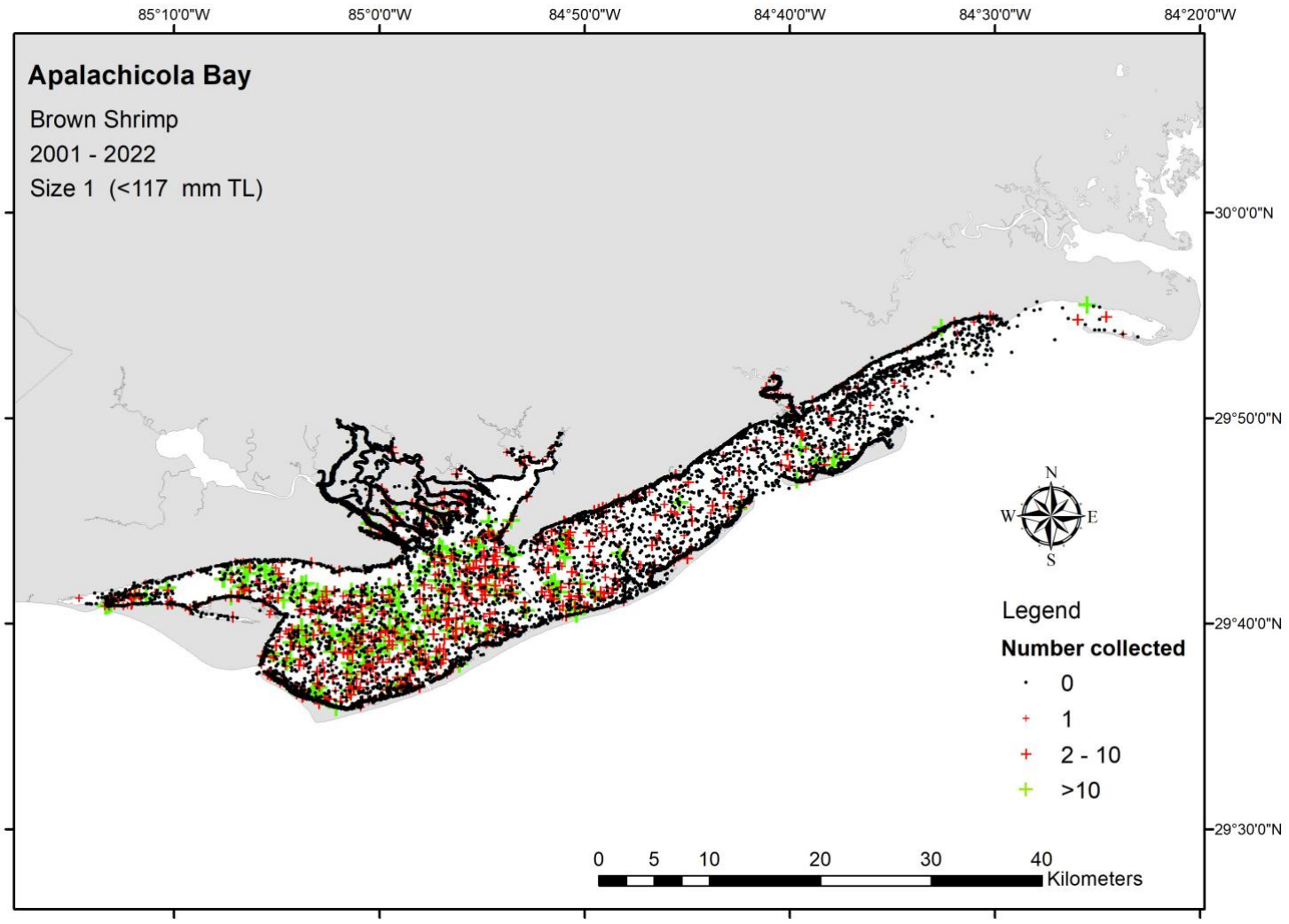

Figure 18. Stations sampled in Apalachicola Bay in FWRI FIM long-term surveys (2001–2022) using 21.3-m seines and 6.1-m otter trawls. Symbols represent the number of Size 1 Brown Shrimp per set.

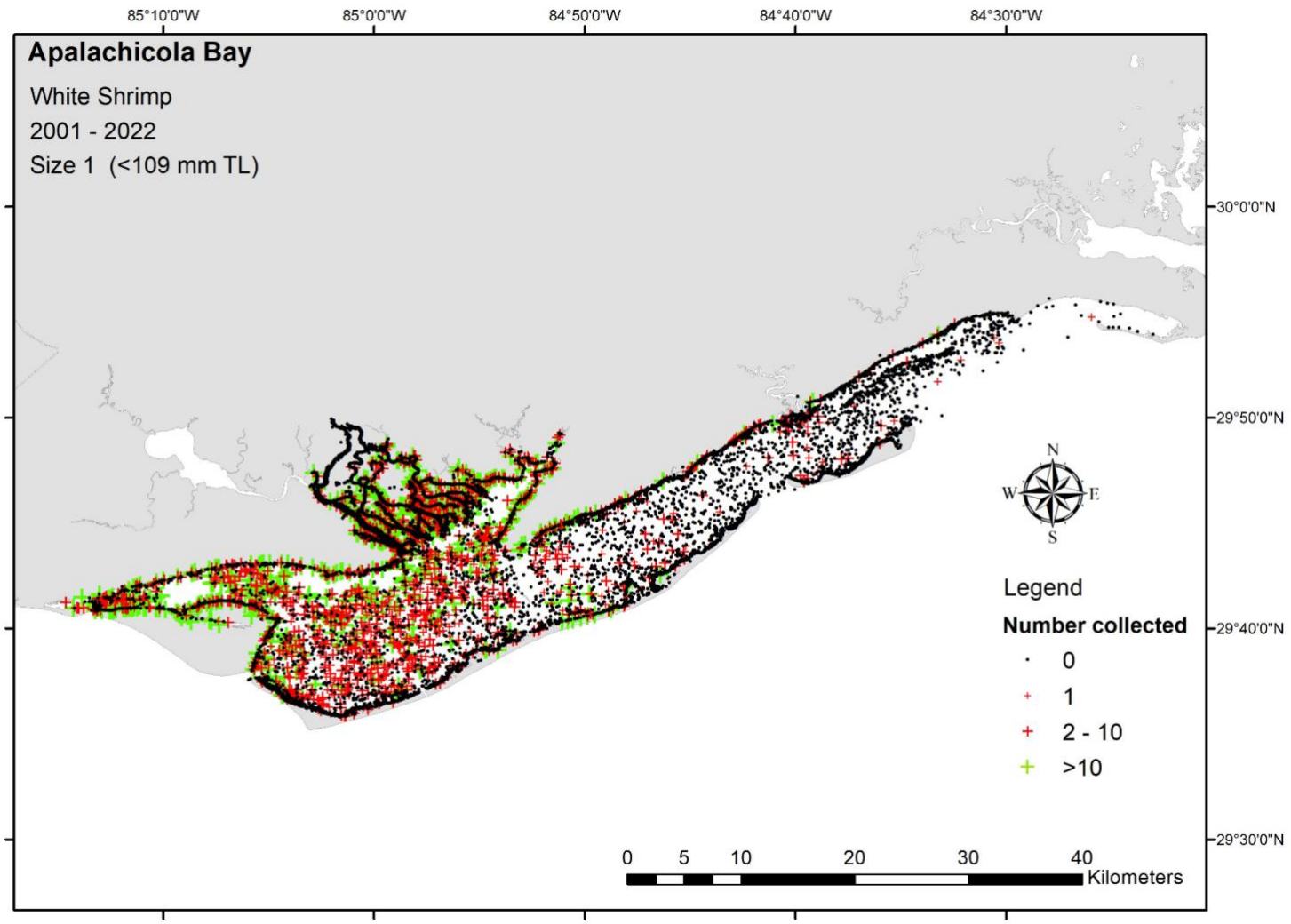

Figure 19. Stations sampled in Apalachicola Bay in FWRI FIM long-term surveys (2001–2022) using 21.3-m seines and 6.1-m otter trawls. Symbols represent the number of Size 1 White Shrimp per set.

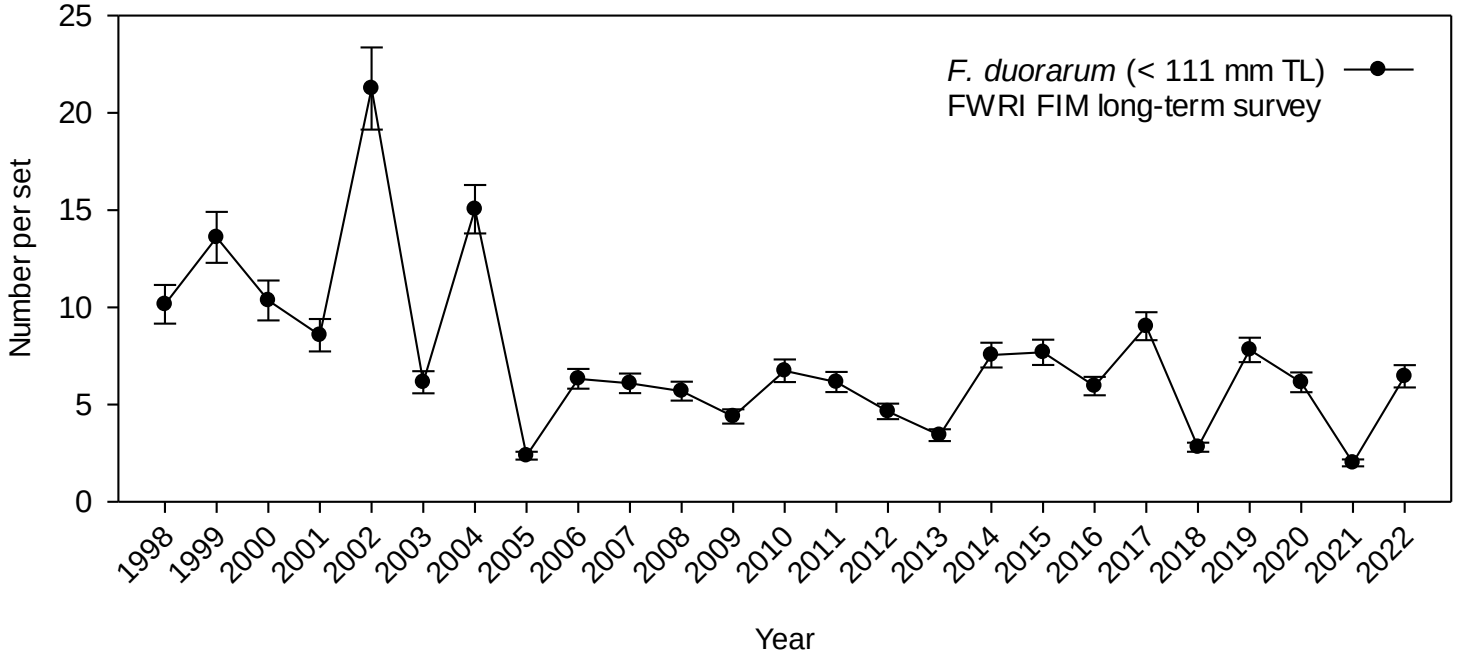

Figure 20. Index of abundance (least square means) for Size 1 Pink Shrimp collected during FWRI FIM long-term surveys (1998-2022) in Tampa Bay and Charlotte Harbor. Error bars represent standard error.

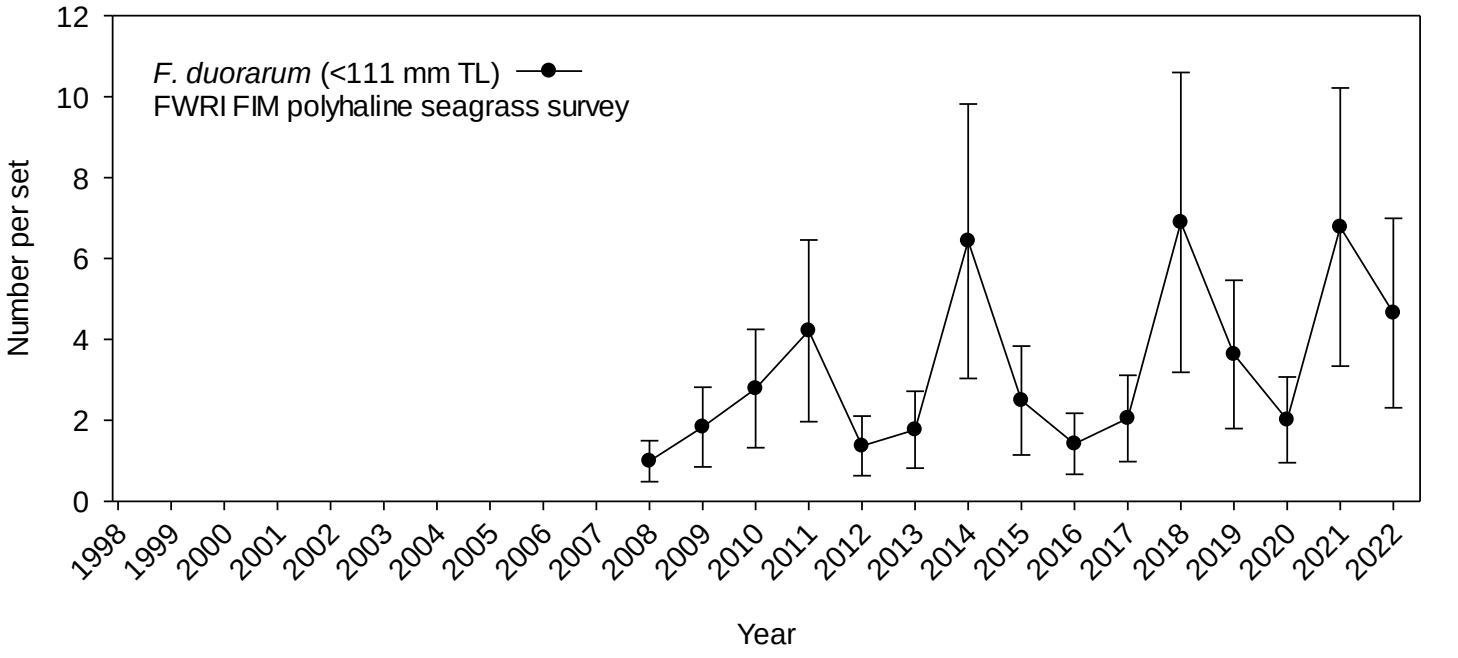

Figure 21. Index of abundance (least square means) for Size 1 Pink Shrimp collected during FWRI FIM polyhaline seagrass surveys (2008-2022) in Tampa Bay and Charlotte Harbor. Error bars represent standard error.

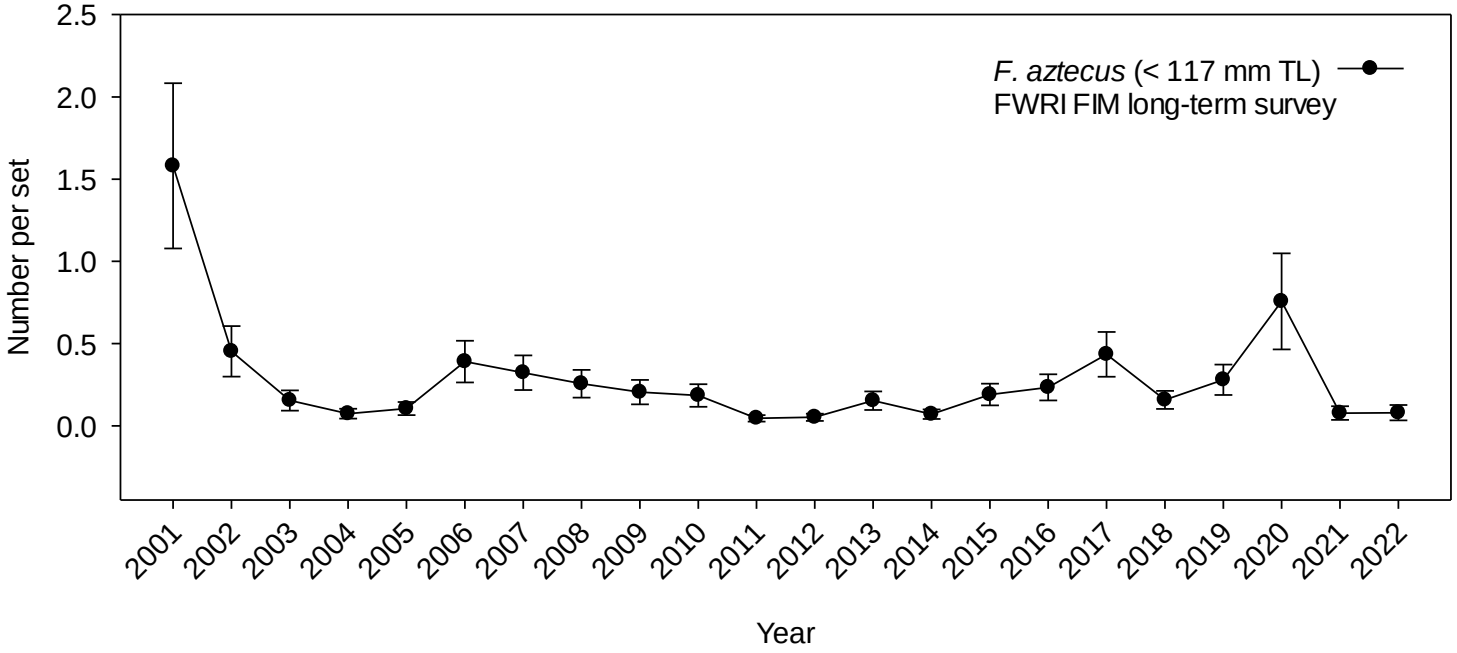

Figure 22. Index of abundance (least square means) for Size 1 Brown Shrimp collected during FWRI FIM long-term surveys (2001-2022) in Apalachicola Bay. Error bars represent standard error.

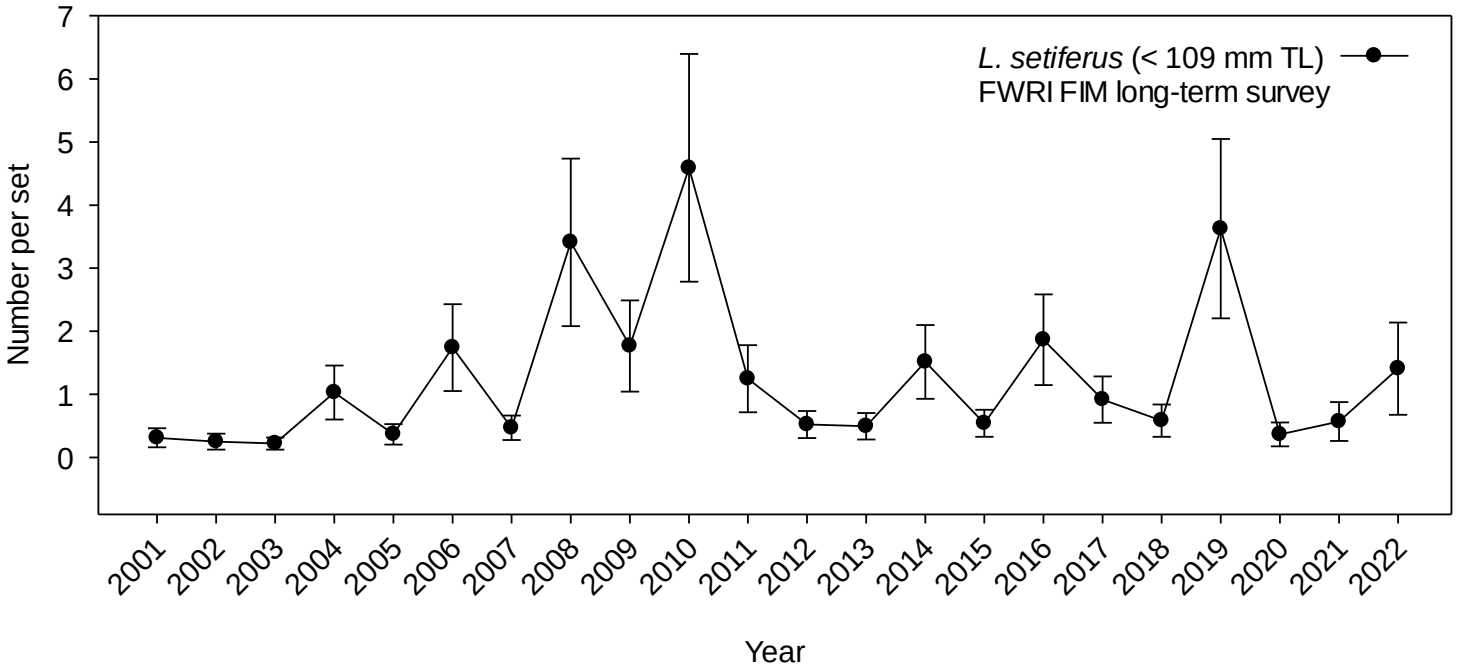

Figure 23. Index of abundance (least square means) for Size 1 White Shrimp collected during FWRI FIM long-term surveys (2001-2022) in Apalachicola Bay. Error bars represent standard error.

Appendix

Table A1. Type 3 tests of fixed effects for the negative binomial model for Size 2 Pink Shrimp collected in FWRI FIM long-term surveys from January-December, 1998-2022, within Tampa Bay and Charlotte Harbor.

Type III Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Year	24	32686	15.11	<.0001
Gear	3	32686	31.27	<.0001
SAV Percent	10	32686	10.33	<.0001
Bottom type	2	32686	41.67	<.0001
Depth quartile	3	32686	7.9	<.0001
Month	11	32686	22.79	<.0001
Salinity quartile	3	32686	7.91	<.0001
Shore	8	32686	3.36	0.0007
Effort	1	32686	21.45	<.0001
SAV presence	1	32686	7.55	0.006

Table A2. Type 3 tests of fixed effects for the negative binomial model for Size 3 Pink Shrimp collected in FWRI FIM long-term surveys from January-December, 1998-2022, within Tampa Bay and Charlotte Harbor.

Type III Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Effort	1	32706	16.31	<.0001
Bottom type	2	32706	20.16	<.0001
Gear	3	32706	14.38	<.0001
Salinity quartile	3	32706	6.37	0.0003
Year	24	32706	7.4	<.0001
Month	11	32706	6.92	<.0001
Temperature quartile	3	32706	3.4	0.017

Table A3. Type 3 tests of fixed effects for the negative binomial model for Size 2 Pink Shrimp collected in FWRI FIM polyhaline seagrass surveys from June-November, 2008-2022, within Tampa Bay and Charlotte Harbor.

Type III Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Month	5	2000	3.93	0.0015
Year	11	2000	4.54	<.0001

Table A4. Type 3 tests of fixed effects for the negative binomial model for Size 3 Pink Shrimp collected in FWRI FIM polyhaline seagrass surveys from June-November, 2008-2022, within Tampa Bay and Charlotte Harbor.

Type III Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Year	14	2005	0.24	0.9982

Table A5. Index of abundance developed using the negative binomial model for Size 2 Pink Shrimp collected in FWRI FIM long-term surveys from January-December, 1998-2022, within Tampa Bay and Charlotte Harbor. The nominal frequency of occurrence, the number of samples (N), the least squares mean (Mean, number per set) and standard error (SE), the coefficient of variation on the mean (CV), lower and upper confidence limits (LCL and UCL).

Year	Frequency	N	Mean	SE	CV	LCL	UCL
1998	0.02439	148	0.001701	0.001074	0.631393	0.000493	0.005861
1999	0.040799	143	0.01012	0.005262	0.51996	0.003653	0.02804
2000	0.037587	106	0.00893	0.004744	0.531243	0.003152	0.0253
2001	0.068223	227	0.01081	0.005398	0.499352	0.004064	0.02877
2002	0.03176	104	0.004583	0.002422	0.528475	0.001627	0.01291
2003	0.031365	93	0.004863	0.002478	0.509562	0.001791	0.0132
2004	0.035939	244	0.02213	0.01093	0.4939	0.008404	0.05826
2005	0.064151	429	0.003983	0.001979	0.496862	0.001504	0.01055
2006	0.057935	251	0.006057	0.003042	0.502229	0.002264	0.01621
2007	0.058642	217	0.002705	0.001382	0.510906	0.000994	0.007364
2008	0.043024	151	0.001784	0.000931	0.521861	0.000641	0.004963
2009	0.04118	210	0.002724	0.001393	0.51138	0.001	0.007424
2010	0.040498	176	0.000755	0.000379	0.501987	0.000282	0.002021
2011	0.034848	119	0.001666	0.000848	0.509004	0.000614	0.004518
2012	0.041121	159	0.001854	0.000935	0.504315	0.00069	0.004983
2013	0.028607	107	0.001065	0.000547	0.513615	0.000389	0.002916
2014	0.053955	213	0.00237	0.001196	0.504641	0.000882	0.006372
2015	0.057579	368	0.00267	0.001353	0.506742	0.000989	0.007207
2016	0.039572	355	0.003912	0.001949	0.498211	0.001474	0.01039
2017	0.05007	446	0.003328	0.00166	0.498798	0.001253	0.008845
2018	0.041667	182	0.001377	0.000708	0.514161	0.000502	0.003772
2019	0.022535	108	0.000915	0.000476	0.520219	0.00033	0.002536
2020	0.028185	156	0.000817	0.00043	0.526316	0.000291	0.002294
2021	0.013442	49	0.001214	0.000665	0.547776	0.000415	0.003552
2022	0.010996	29	0.00036	0.000227	0.630556	0.000105	0.001236

Table A6. Index of abundance developed using the negative binomial model for Size 3 Pink Shrimp collected in FWRI FIM long-term surveys from January-December, 1998-2022, within Tampa Bay and Charlotte Harbor. The nominal frequency of occurrence, the number of samples (N), the least squares mean (Mean, number per set) and standard error (SE), the coefficient of variation on the mean (CV), lower and upper confidence limits (LCL and UCL).

Year	Frequency	N	Mean	SE	CV	LCL	UCL
1998	0.000903	1	0.00000019	0.0000055	28.111168	2.27E-31	1.66E+17
1999	0.013021	50	0.000172	0.000269	1.563953	8.01E-06	0.0037
2000	0.013112	27	0.000917	0.001196	1.304253	0.000071	0.01182
2001	0.021544	46	0.00052	0.000647	1.244231	0.000046	0.005947
2002	0.010889	20	0.000365	0.000481	1.317808	0.000028	0.004833
2003	0.00738	14	0.00007	0.000096	1.371429	4.80E-06	0.001028
2004	0.016173	566	0.001782	0.002183	1.225028	0.000161	0.01967
2005	0.030818	261	0.00021	0.000258	1.228571	0.000019	0.002326
2006	0.035264	133	0.000197	0.000242	1.228426	0.000018	0.002193
2007	0.033333	126	0.000128	0.00016	1.25	0.000011	0.001481
2008	0.014136	43	0.000048	0.000062	1.291667	3.65E-06	0.00062
2009	0.014136	60	0.000126	0.000158	1.253968	0.000011	0.001483
2010	0.013707	50	0.000011	0.000015	1.363636	7.90E-07	0.000152
2011	0.011823	41	0.000066	0.000083	1.257576	5.67E-06	0.000776
2012	0.011838	81	0.000185	0.000229	1.237838	0.000016	0.002082
2013	0.010572	22	0.000025	0.000032	1.28	2.09E-06	0.000303
2014	0.011649	59	0.00007	0.000088	1.257143	6.06E-06	0.000814
2015	0.016451	110	0.000052	0.000065	1.25	4.37E-06	0.000608
2016	0.010242	85	0.000088	0.00011	1.25	7.70E-06	0.001013
2017	0.01669	89	0.000087	0.000109	1.252874	7.53E-06	0.001014
2018	0.003704	10	0.00001	0.000013	1.3	7.51E-07	0.000137
2019	0.002817	8	0.00000754	0.00001	1.326788	5.52E-07	0.000103
2020	0.005073	20	0.00000572	0.0000083	1.445745	3.37E-07	0.000097
2021	0.000584	5	0.000028	0.000038	1.357143	1.93E-06	0.000399
2022	0.000647	1	0.00000001	0.0000003	18.364419	3.28E-24	59347942

Table A7. Index of abundance developed using the negative binomial model for Size 2 Pink Shrimp collected in FWRI FIM polyhaline seagrass surveys from June-November, 2008-2022, within Tampa Bay and Charlotte Harbor. The nominal frequency of occurrence, the number of samples (N), the least squares mean (Mean, number per set) and standard error (SE), the coefficient of variation on the mean (CV), lower and upper confidence limits (LCL and UCL).

Year	Frequency	N	Mean	SE	CV	LCL	UCL
2008	0.00877	3	0.008946	0.00926	1.035099486	0.001175	0.06811
2009	0.03704	8	0.02793	0.02298	0.822771214	0.005559	0.1403
2010	0.02778	6	0.1182	0.1149	0.972081218	0.01758	0.7952
2011	0.01852	4	0.01558	0.01511	0.969833119	0.002325	0.1044
2012	0.01852	9	0.06024	0.04847	0.804614874	0.01243	0.2919
2013	0.03704	10	0.02595	0.02191	0.844315992	0.004954	0.1359
2014	0.06481	35	0.172	0.1255	0.729651163	0.04113	0.7196
2015		0	0.000000002	0.000000001	0.608395062	6E-10	0.000000007
2016	0.01852	4	0.0173	0.01604	0.92716763	0.002806	0.1066
2017		0	0.000000002	0.000000001	0.608374384	6E-10	0.000000007
2018	0.07407	219	1.5439	1.1173	0.723686767	0.3735	6.3829
2019	0.01515	9	0.01015	0.007237	0.713004926	0.002506	0.0411
2020		0	0.000000002	0.000000001	0.608740895	6E-10	0.000000006
2021	0.11407	404	1.036	0.4707	0.454343629	0.425	2.5253
2022	0.01515	18	0.0618	0.0376	0.608414239	0.01874	0.2038

Table A8. Index of abundance developed using the negative binomial model for Size 3 Pink Shrimp collected in FWRI FIM polyhaline seagrass surveys from June-November, 2008-2022, within Tampa Bay and Charlotte Harbor. The nominal frequency of occurrence, the number of samples (N), the least squares mean (Mean, number per set) and standard error (SE), the coefficient of variation on the mean (CV), lower and upper confidence limits (LCL and UCL).

Year	Frequency	N	Mean	SE	CV	LCL	UCL
2008		0	0.00000006	0.000023	1.22629136	0	
2009	0.007937	2	0.00000006	0.000024	0.92202501	0	
2010	0.015873	4	0.02121	0.02648	1.255445307	0.001834	0.2454
2011	0.007937	2	0.02132	0.02696	1.160760751	0.001787	0.2545
2012		0	0.00000006	0.000023	0.932837756	0	
2013	0.015873	6	0.04289	0.04899	0.935550891	0.004566	0.4029
2014		0	0.00000006	0.000024	0.804095255	0	
2015		0	0.00000006	0.000023	0.631395405	0	
2016		0	0.00000006	0.000024	1.152931289	0	
2017		0	0.00000006	0.000024	0.620459619	0	
2018	0.027778	6	0.05058	0.05613	0.777900867	0.005738	0.4458
2019		0	0.00000006	0.000015	0.747818992	8.13E-231	4.07E+215
2020		0	0.00000006	0.000021	0.639403042	0	
2021	0.022814	52	0.1532	0.1044	0.450067813	0.04025	0.5829
2022		0	0.00000006	0.000015	0.637699723	4.71E-233	7.02E+217

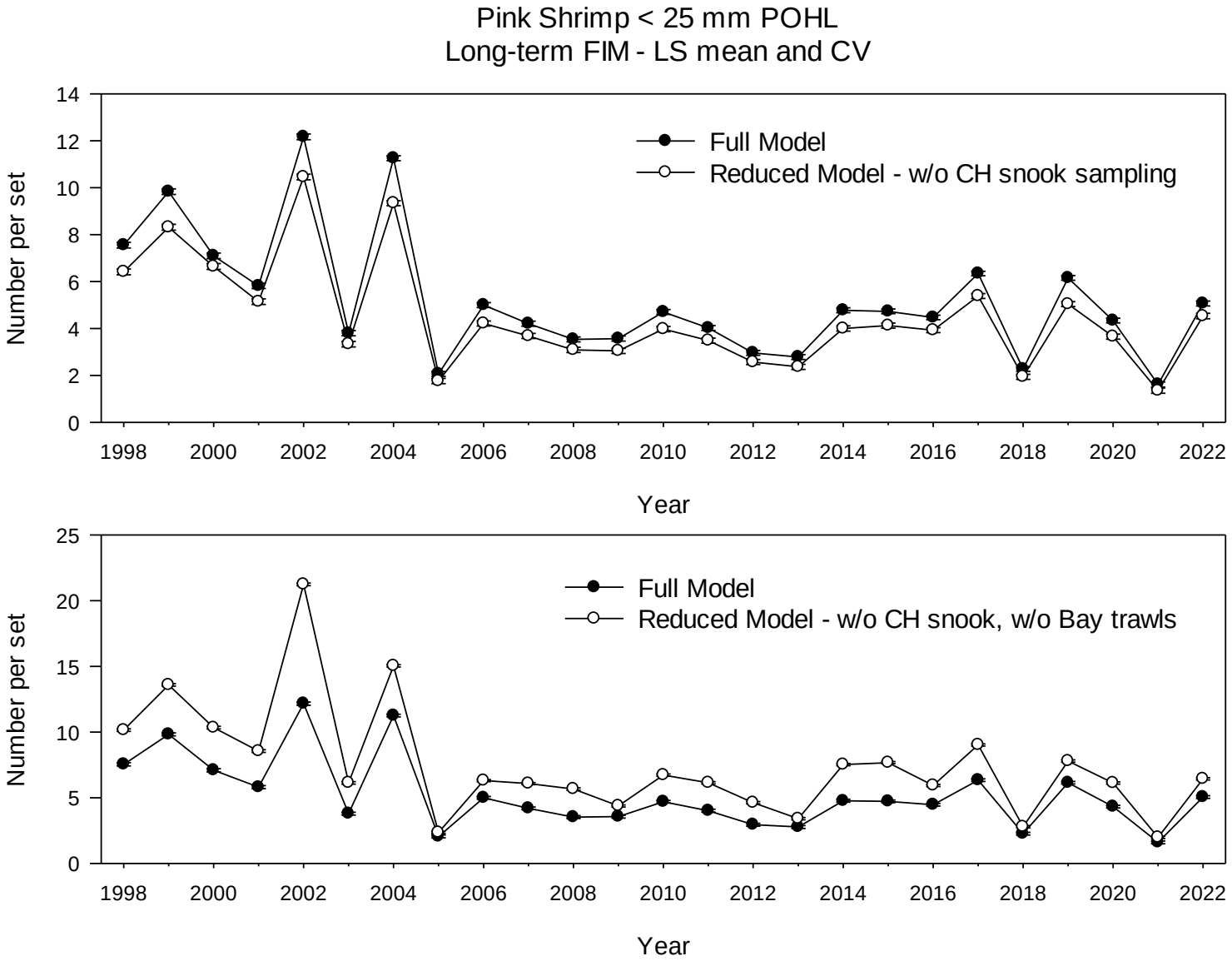

Figure 1A. Model comparisons of indices of abundance (least square means) for Size 1 Pink Shrimp collected during FWRI FIM long-term surveys (1998-2022) in Tampa Bay and Charlotte Harbor. Error bars represent the coefficient of variation.

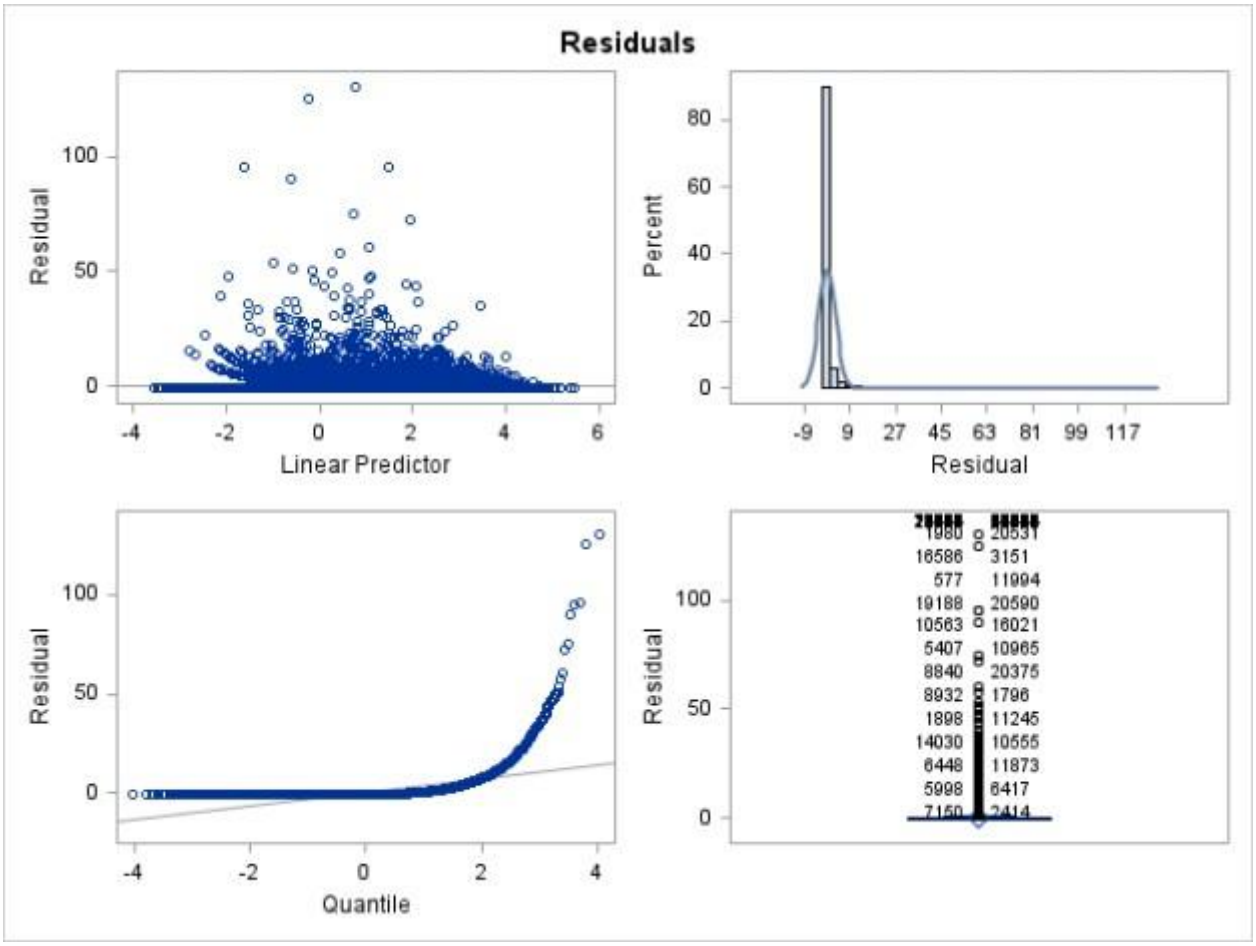

Figure 2A. Diagnostic plots from the generalized linear model of Size 1 (< 111 mm TL) Pink Shrimp for FWRI FIM long-term surveys in Charlotte Harbor and Tampa Bay.

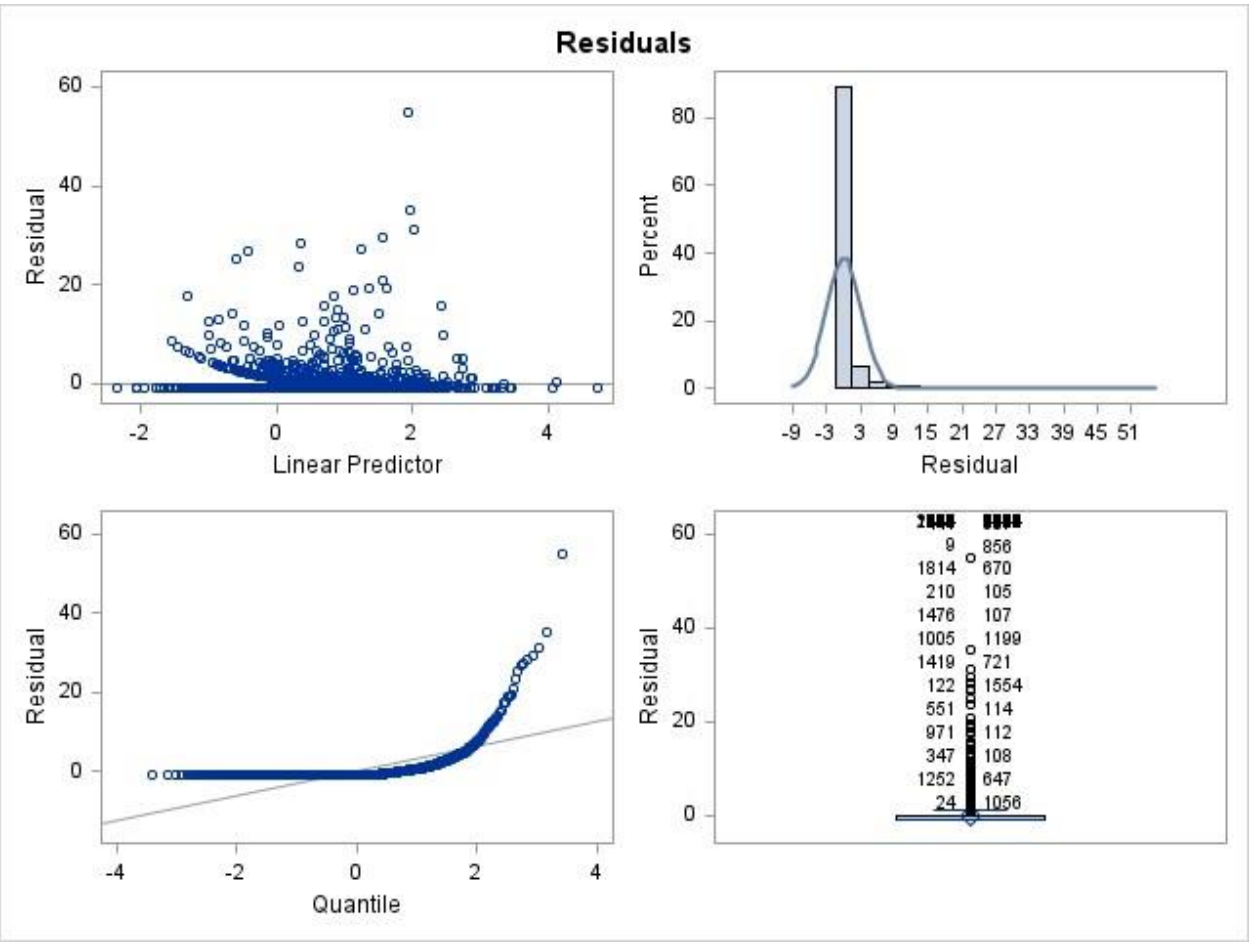

Figure 3A. Diagnostic plots from the generalized linear model of Size 1 (< 111 mm TL) Pink Shrimp for FWRI FIM polyhaline seagrass surveys in Charlotte Harbor and Tampa Bay.

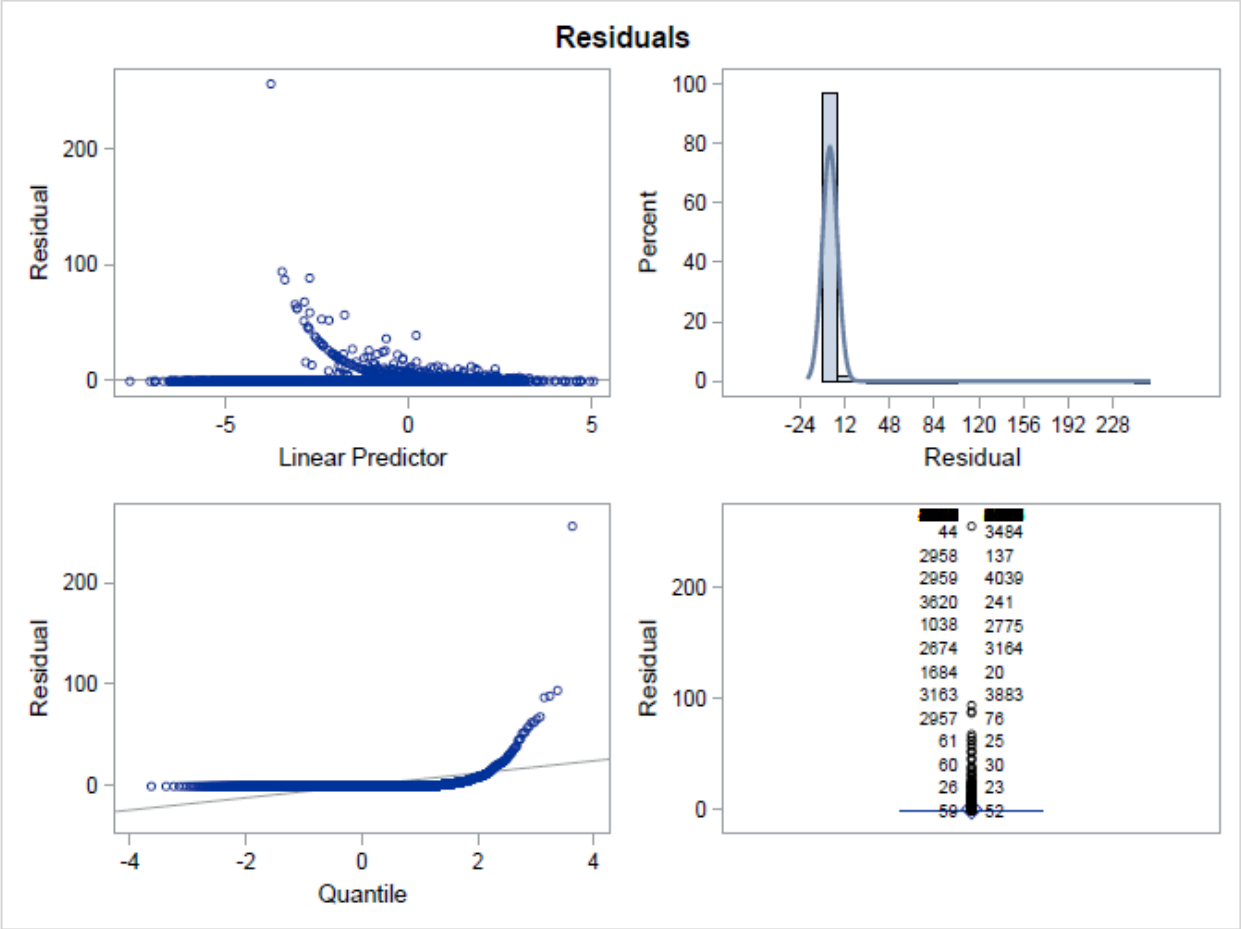

Figure 4A. Diagnostic plots from the generalized linear model of Size 1 (< 117 mm TL) Brown Shrimp for FWRI FIM long-term surveys in Apalachicola Bay.

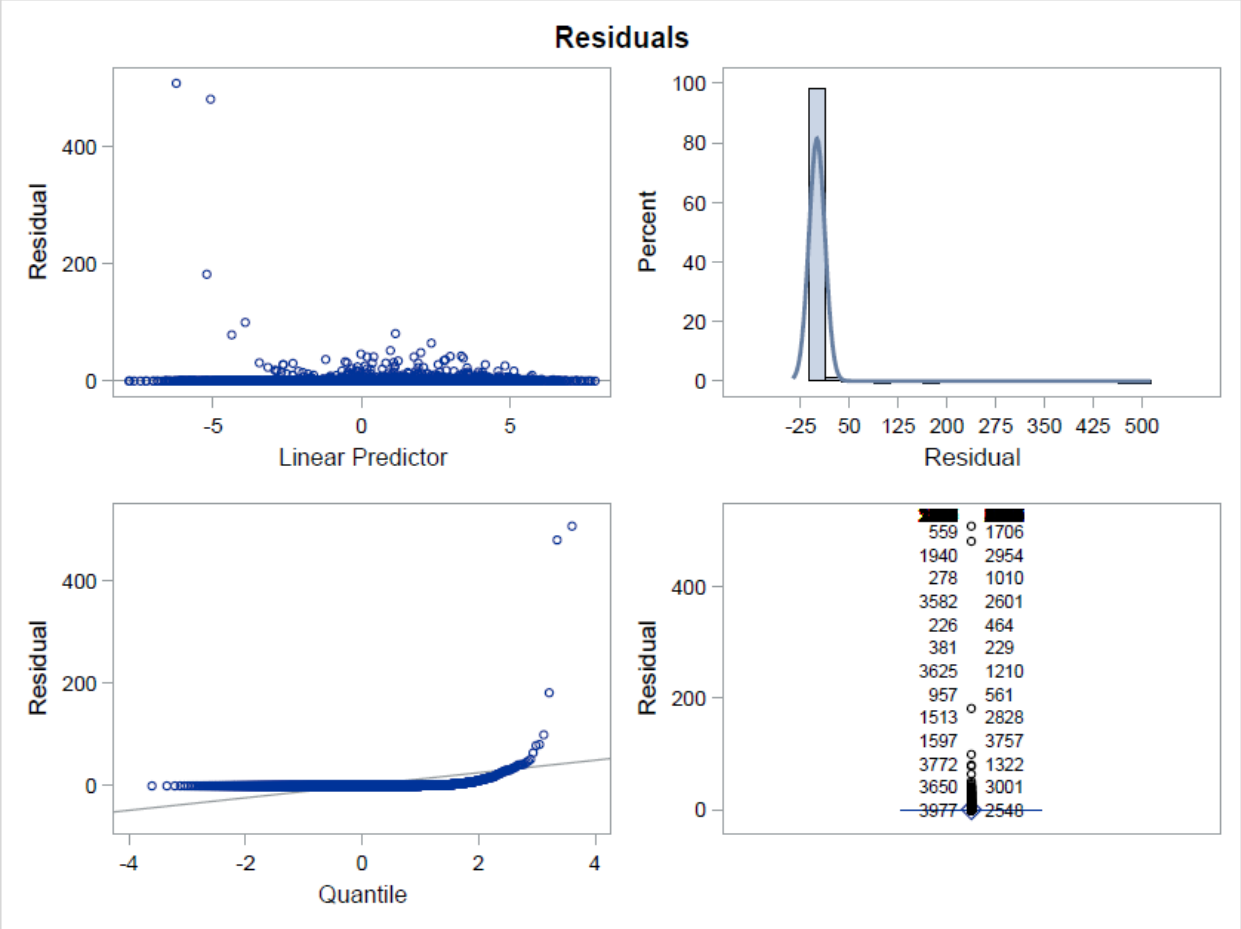

Figure 4A. Diagnostic plots from the generalized linear model of Size 1 (< 109 mm TL) White Shrimp for FWRI FIM long-term surveys in Apalachicola Bay.