Seasonal estimates of relative abundance of penaeid shrimp in Coastal Georgia

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Introduction

The Georgia Department of Natural Resources has been monitoring the shrimp populations of Coastal Georgia since the late 1960's. In 1970, a comprehensive project was initiated to assess marine and estuarine invertebrate and finfishes of Georgia using trawls, gillnets, and seines in six of the nine major sounds (Mahood et al, 1974). The survey design and trawl sampling methods established on that project became the basis for the present trawl survey conducted by the Department's Coastal Resources Division and has remained relatively unchanged since its inception.

The Mahood study examined two sound systems each for a period of one year (October – September): South: St. Simons and St. Andrews (1970-1971); Central: Sapelo and Doboy (1971-1972); and North: Wassaw and Ossabaw (1972-1973). Five (5) fixed location stations were determined for each system in each of 3 sectors: large creeks and rivers, sounds, and nearshore ocean waters (beaches 0-3nm), for a total of 15 stations monthly per sound system per gear. A fourth sector, marsh and small creeks, was sampled exclusively with seine nets. The trawl sampling gear (40 ft flat net) and other methodologies were similar to the present survey (same vessel – R/V *Anna*), however, trawl durations were typically 30 minutes. At the conclusion of that project in 1974, recommendations were made that continue as part of the present survey. Initially, called the Shrimp Assessment Survey (SAS), its name was changed to the Ecological Monitoring Trawl Survey (EMTS) in 2003 when a more comprehensive approach of processing all invertebrates and finfishes was established (Page, 2011) .

Methods

Trawl sampling is conducted monthly aboard the Department's 18.3 m (60 ft) Research Vessel *Anna* in six of Georgia's estuarine systems: Wassaw, Ossabaw, Sapelo, St. Simons, St. Andrew, and Cumberland. Each system has been historically stratified into one of three sectors: 1) large creeks and rivers; 2) open sounds; and 3) nearshore ocean waters associated with the state's territorial waters from the beaches to three miles offshore (Table 1). In March 2005 six ancillary stations were added further upstream in lower saline waters in response to continued issues with the blue crab fishery (Table 1). A total of 42 stations are sampled each

month, 35 of which are long-term sites sampled since 1976 (Figure 1 and Tables 1 and 2). Two of the primary sampled sites were discontinued in recent years due to shoaling that prohibited successful trawling (Table 1). Nearby ancillary or alternative sampling sites were selected as replacements based on proximity, depth, and bottom type. These sites were sampled concurrently with the historic sites to be discontinued for at least one year. Species' catch rates, size, and composition were examined to ensure similar characteristics between sites.

At all locations, standardized fifteen-minute tows, (defined as beginning when winch was dogged off and ending when net retrieval began), are conducted with a 12.2 m (40 ft) flat trawl with 4.8 cm (1 7/8 inch) stretch-mesh webbing for the body and bag, with attached tickler chain and 152 x 71 cm (60x 28 inch) trawl doors, to obtain targeted species. Environmental information recorded at each station included: station location, tide stage, moon phase, wind direction and speed, surface air temperature, surface and bottom water temperatures (^{o}C), surface and bottom dissolved oxygen in mg/L, and surface and bottom water salinity in parts per thousand (ppt).

Cruises are typically scheduled and conducted during the first half of the month on neap tides when possible for standardization purposes. Although some deviation occasionally occurred due to inclement weather, mechanical problems, and other unforeseen events, field sampling is typically completed within this two-week window.

From each trawl sample, quantitative and life history data are collected for each target species (Geer and Roberson, 2003). Total weight is obtained for each shrimp species, and a 1361 g (~3 lbs) subsample is obtained, total number counted, and a representative sample of 30 shrimp is taken for further detailed processing. Individual lengths (TL in millimeters, rostrum to telson), sex, state of ovarian development, occurrence and type of diseased individuals is recorded for each of the 30 specimens. Number per pound (count size – heads on) is determined from the number of whole individuals in the three-pound subsample. In samples less than three pounds, number per pound values were calculated by dividing the total number of individuals collected by the total weight of the sample. In samples where only one specimen was collected, or when total weights represented one gram or less, a length/weight conversion table, prepared from previous commercial fisheries investigations, was used to obtain heads-on counts (Table 3). Ovarian development was classified and recorded in five distinct stages of maturity (King, 1948): UN = undeveloped; D = developing; Y = yellow; R = ripe; and S = spent.

Survey data is routinely analyzed on both a monthly and annual basis to track abundance versus long-term trends. The survey has a commendable track record in regards to consistency (same gear, vessel, and stations) over its 39 year history (Table 2) with only a few months with no sampling during the early 1980's due to budget cuts.

Data are presently being entered and stored in a customized Microsoft Access database. All historic data (back to 1976) are regularly evaluated for correctness and completeness. Data collected from this study continue to be used to determine population abundance, availability for harvest, relative economic value of stocks, and formulate fishery management recommendations.

Estimating Relative Abundance

Given the short life history of the species, annual estimates on several cohorts (seasons) can be established for the penaeids inhabiting Georgia's waters. White shrimp typical spawn from April to July (peaking in May and June), with post larvae recruiting to the estuaries within two weeks. The fall (September – December) has the highest and most consistent catch rates. Overwintering white shrimp are the upcoming spawning stock, its abundance impacted primarily by winter water temperatures. Temperatures below 8.3 ^{o}C for more than 18 days during the winter has been shown to have an adverse impact on the spawning stock and spring commercial harvest (D. Whitaker (SCDNR), per. comm.). Brown shrimp are typically only vulnerable to the survey gear during the summer months. It is believed they spawn in October and November and post larvae do not recruit to the estuaries until late spring to summer the following year.

White Shrimp

Abundance is highly variable on both a monthly (Figure 2a) and annual basis (Figure 2b). There are two modes in the monthly abundance. Winter CPUEs are dependent in part to winter temperatures resulting in high inter-annual variability (Figures 2a and 2b). Catches are lowest during the spring spawning season and highest during the fall months (Figures 2a and 2b). The temporal (months) and spatial (sounds and sectors) catch rates are examined to develop season estimates. White shrimp abundance is typically highest in the Sapelo and St. Simons Sound systems, followed by St. Andrew and Cumberland Sounds (Figure 3). The northern sound systems of Wassaw and Ossabaw have the lowest catch rates (Figure 3). The estuarine stations (creek and sounds) have significantly higher catch rates than the nearshore coastal waters as well as the upriver locations added in 2005 (Figure 4). The upriver stations have been excluded from these analyses due to the short time series. Even though the nearshore estimates are significantly lower than those in the estuaries, they have been included since they represent a geographic area directly related to the commercial trawl fishery.

The spawning stock estimates are derived from April to June sampling. Although April CPUEs are more similar to the January through March period than May – June (Figure 2a), 10.09% of all female white shrimp processed had observed gonadal development in the latter stages of maturity (yellow or beyond) (Figure 6). Gonadal development is driven by water

temperature and during milder winters is consistently observed during April cruises. Earlier estimates of white shrimp spawning stock used a temporal component of May through July since catch rates were more similar. However, abundance is low and gonadal development sporadic during July (< 5% overall) warranting further examination. Additionally, other spawning stock estimates by DeLancey et al. (2005) and Belcher and Jennings (2004) used the April to June window to define white shrimp spawning stock. The long-term annual spawning stock estimates are 1.31 kg/trawl. Following two recent cold winters (2010 and 2011), the spawning stock was near record lows, significantly below the long-term average (Figure 7). Both 2012 and 2013 were just below the average, with 2014 estimates not yet complete.

Catch rates are typically highest during the fall months and coincides with the peak commercial trawl harvest in State coastal waters (Figure 2a). Using similar temporal components as DeLancey et al. (2005) and Belcher and Jennings (2004), August to December defines the fall white shrimp cohort (Figure 7). The inclusion of August may be of discussion since CPUEs that month are significantly lower than the four proceeding months, all of which are not statistically different (Figure 2a). Estimates for the fall range from a minimum of 1.86 kg/trawl (1984) to 10.85 kg/trawl (1977) with an overall average$_{76\text{-}13}$ of 4.08 kg/trawl (Figure 7). Unfortunately, of the ten years significantly below the 38 year average, five have occurred since 2004, including the past three years: 2011-2013 (Figure 7).

The overwintering stock has been defined as the months January to March. Catch rates are similar during that time period and water temperatures are at their lowest (Figures 2a and 5). Additional natural mortality due to freeze kill is highest during January and February and could impact spawning stock in the spring. Freeze kills observed in late December to mid-January in 1984, 1990, and 2001 significantly reduced over-winter shrimp populations and had a direct impact on the spring spawning stock as well (Figure 7). Although there were no observed freeze kills in the winter of 2011, it is postulated cold winter temperatures pushed shrimp offshore and south resulting in the lowest spawning stock biomass observed in over 30 years (1977 and 1978) (Figure 7).

Brown Shrimp

Catches first appear in June, peak in July, and are negligible by September (Figure 8a and 8b). Similar to the spatial catches of white shrimp, abundance is highest in Sapelo and St. Simons Sounds, but higher in the northern sounds of Wassaw and Ossabaw than the sounds bordering with Florida (Cumberland and St. Andrew) (Figure 9). The sound stations have significantly higher catches than all other sectors, with creek stations significantly higher than both upriver and beach locations (Figure 10). The annual brown shrimp estimates are clearly based on the months of June through August (Figure 8a). The long-term CPUE$_{76\text{-}13}$ is 0.95

kg/trawl but varies from 0.1 (1981) to 2.88 kg/trawl (2003) (Figure 7). Estimates for 2013 were significantly higher than the long-term at 1.72 kg/trawl (Figure 7).

Issues and Concerns

Researchers have known for years the effect prolonged cold temperatures could have on overwinter white shrimp and the proceeding spring spawning stock. Management has developed to close state and federal waters when low water temperatures persist (SAFMC, 2012). No such management action exists to manage the fall white shrimp fishery. White shrimp abundance is typically highest in the fall, but no management actions exist to protect the population during very poor recruitment years (Figure 7). Many in the industry blame black gill for these declines in the fall. Black gill is caused by a ubiquitous ciliated protozoan which results in melanization and destruction of the gills. It typically first appears in catches in northern portion of the state in August, spreading coastwide in September and October, before dissipating with cooler December temperatures (Figures 11 and 12). Other factors may be contributing to these lower than normal fall crops, including precipitation and the ensuing run off and stream flow. 2013 was the third wettest year ever recorded in Georgia, and the wettest overall summer. Environmental factors and disease and their relationship with shrimp abundance needs to be further explored to better understand recruitment success and failure.

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Table 1. GADNR Ecological Monitoring Trawl Survey Stations. Northern Coast

System	Station	Sector	Lat	Lon	N	First Date	Latest Date	AvgDepth (ft)	Location
Wassaw	111[a]	Creek	31.97156	-80.96162	340	14-Jan-76	10-Jan-06	17.5	Halfmoon River
	112	Creek	31.99463	-81.00285	440	14-Jan-76	10-Jun-14	22.9	Wilmington River
	113	Creek	31.99121	-81.02367	112	21-Mar-05	10-Jun-14	21.5	Skidaway River at Grimball Creek
	114	Creek	31.94241	-80.98127	51	21-Mar-05	12-May-09	37.7	Wilmington River at Priest Landing
	115[b]	Creek	31.97956	-80.92651	110	21-Mar-05	10-Jun-14	24.8	Bull River below Lazaretto Creek
	121	Sound	31.95393	-80.93331	439	14-Jan-76	10-Jun-14	22.9	N. side of Bull River
	122	Sound	31.92125	-80.96477	441	14-Jan-76	10-Jun-14	26.2	S. Wassaw at Saltpond
	131	Beach	31.90685	-80.91055	432	14-Jan-76	10-Jun-14	28.6	ENE of Wassaw Sea Buoy
	132	Beach	31.90619	-80.91216	433	14-Jan-76	10-Jun-14	28.4	West of R2W Buoy
Ossabaw	211	Creek	31.91225	-81.10114	386	15-Jan-76	9-Jun-14	16.7	Vernon River
	212	Creek	31.82518	-81.1595	385	15-Jan-76	10-Jun-14	14.8	Mouth of Cane Patch Creek
	221	Sound	31.86564	-81.07597	389	15-Jan-76	9-Jun-14	16.4	N. of Racoon Key
	222	Sound	31.83819	-81.05057	385	15-Jan-76	10-Jun-14	24.3	S. of Racoon Key
	231	Beach	31.79071	-80.99734	383	14-Jan-76	10-Jun-14	20.8	E. of Ossabaw Sea Buoy
	232	Beach	31.78449	-80.98157	382	14-Jan-76	10-Jun-14	16.2	S. of Ossabaw Channel
Sapelo	411	Creek	31.5868	-81.19904	441	15-Jan-76	9-Jun-14	11.9	Wahoo River
	412	Creek	31.48468	-81.29781	442	16-Jan-76	9-Jun-14	9.8	Mud River
	421	Sound	31.52879	-81.28143	442	16-Jan-76	9-Jun-14	18.4	N. side of Dog Hammock
	422	Sound	31.53486	-81.23254	439	16-Jan-76	9-Jun-14	14.3	Off Sapelo High Point
	431	Beach	31.52886	-81.1701	435	16-Jan-76	9-Jun-14	27.6	Off S. St. Catherine Island
	432	Beach	31.52641	-81.1625	440	16-Jan-76	9-Jun-14	17.8	Off N. end of Blackbeard Island

a: Discontinued in Feb 2006 due to depth issues - replaced with station 115

b: Replaced Station 111 Feb 2006

c: Discontinued in Jan 2011 due to tow duration restrictions, replaced by Station 923 effective Dec 2009

d: Replaced station 922 effective Dec 2009

Stations shaded gray were initially added in response to blue crab issues (2005-2006)

Table 1(continued). GADNR Ecological Monitoring Trawl Survey Stations. Southern Coast

System	Station	Sector	Lat	Lon	N	First Date	Latest Date	AvgDepth (ft)	Location
St. Simons	711	Creek	31.19763	-81.41449	440	5-Jan-76	16-Jun-14	14.2	Mouth of Frederica River
	712	Creek	31.15042	-81.44537	441	5-Jan-76	16-Jun-14	27.9	Back River
	713	Creek	31.2116	-81.4259	111	1-Mar-05	16-Jun-14	24.1	Mackay River South of Jove Creek
	714	UpRiver	31.16829	-81.52655	111	2-Mar-05	12-Jun-14	29.9	Turtle River at Andrews Island
	715	UpRiver	31.21701	-81.55676	112	1-Oct-84	12-Jun-14	24.3	Turtle River at Cowpen
	716	UpRiver	31.2095	-81.60914	111	2-Mar-05	12-Jun-14	18.3	Turtle River West of Buffalo
	721	Sound	31.15706	-81.42123	443	5-Jan-76	16-Jun-14	11.2	Towers of St Simons
	722	Sound	31.10151	-81.43189	442	5-Jan-76	16-Jun-14	22.4	Lower Jekyll Cove
	731	Beach	31.1132	-81.36081	439	12-Jan-76	6-Jun-14	20.6	E. of Sea Island
	732	Beach	31.10203	-81.34747	437	12-Jan-76	6-Jun-14	17.3	S. of St Simons Sea Buoy
St. Andrew	811	Creek	31.05078	-81.46812	442	20-Jan-76	3-Jun-14	24.5	Joiner Creek
	812	Creek	30.93195	-81.48278	440	20-Jan-76	3-Jun-14	22.9	Floyd Creek
	813	UpRiver	30.99418	-81.6368	96	2-May-06	3-Jun-14	17.3	Satilla R. at Crow Harbor
	821	Sound	30.96729	-81.51219	440	20-Jan-76	3-Jun-14	20.4	Satilla R. at Todd Creek
	822	Sound	30.95027	-81.43233	442	20-Jan-76	3-Jun-14	25.5	Off Cumberland High Pt.
	831	Beach	30.99586	-81.41559	439	12-Jan-76	6-Jun-14	17.5	St Andrew Channel
	832	Beach	30.961	-81.31114	438	12-Jan-76	6-Jun-14	26.8	N. of Cumberland Lighthouse
Cumberland	911	Creek	30.86932	-81.48057	435	20-Jan-76	4-Jun-14	14.9	Brickhill River
	912	Creek	30.83126	-81.5051	433	21-Jan-76	4-Jun-14	17.2	S. Crooked River
	921	Sound	30.7731	-81.46999	432	21-Jan-76	4-Jun-14	21.5	Cumberland R. W of Stafford Shoals
	922[c]	Sound	30.75228	-81.47605	391	21-Jan-76	2-Dec-10	16.6	Cumberland River
	923[d]	Sound	30.72989	-81.49023	55	11-Dec-09	4-Jun-14	24.6	W. of Marker #2
	931	Beach	30.90184	-81.32971	426	12-Jan-76	6-Jun-14	18.5	Off Whitney River
	932	Beach	30.88611	-81.34251	426	12-Jan-76	6-Jun-14	17.6	S. of Stafford Shoal

a: Discontinued in Feb 2006 due to depth issues - replaced with station 115

b: Replaced Station 111 Feb 2006

c: Discontinued in Jan 2011 due to tow duration restrictions, replaced by Station 923 effective Dec 2009

d: Replaced station 922 effective Dec 2009

Stations shaded gray were initially added in response to blue crab issues (2005-2006)

Table 2. History of the GADNR Ecological Monitoring Trawl Survey (1976 to present).
Gray cells represent samples outside present sampling scheme.

Year	Total	MONTH												SOUND SYSTEM						SECTOR				StatType		Tow Time			Sample Type			
		J	F	M	A	M	J	J	A	S	O	N	D	WA	OS	SP	SS	SA	CU	Creek	Sound	Beach	UpRiv	Acc	Prim	15	30	OT	1	2	3	4
1976	432	36	36	36	36	36	36	36	36	36	36	36	36	72	72	72	72	72	72	144	144	144	0	0	432	40	391	1	432	0	0	0
1977	433	37	36	36	37	36	36	35	36	36	36	36	36	72	72	73	72	72	72	144	145	144	0	0	433	31	401	1	433	0	0	0
1978	647	54	54	54	54	54	54	54	54	54	54	53	54	73	70	72	72	72	72	215	217	215	0	0	647	199	446	2	647	0	0	0
1979	523	54	54	54	55	59	55	54	54	54	0	0	30	62	55	61	60	60	54	177	174	172	0	0	523	321	196	6	523	0	0	0
1980	150	0	0	32	0	30	0	0	0	28	0	30	30	30	0	30	30	30	0	50	50	50	0	0	150	144	3	3	150	0	0	0
1981	271	0	18	0	34	40	36	0	34	0	36	37	36	42	0	46	47	46	44	95	94	82	0	0	271	271	0	0	271	0	0	0
1982	235	1	30	0	36	36	0	36	0	30	0	32	34	38	0	41	40	42	38	82	82	71	0	0	235	235	0	0	235	0	0	0
1983	343	22	36	0	36	34	36	19	36	36	28	30	30	60	1	59	63	63	54	117	120	106	0	0	343	342	0	1	343	0	0	0
1984	377	16	0	36	36	36	36	36	36	36	36	36	37	59	0	63	66	65	64	125	127	124	1	0	377	377	0	0	377	0	0	0
1985	432	37	35	36	36	36	35	37	36	36	36	36	36	72	0	72	72	73	71	145	144	143	0	0	432	432	0	0	432	0	0	0
1986	432	36	36	36	36	36	36	36	36	36	36	36	36	72	72	72	72	72	72	144	144	144	0	0	432	431	0	1	432	0	0	0
1987	433	36	36	36	37	36	36	36	36	36	36	36	36	72	72	73	72	72	72	144	144	145	0	0	433	433	0	0	433	0	0	0
1988	432	36	36	36	36	36	36	36	36	36	36	36	36	72	72	72	72	72	72	144	144	144	0	0	432	430	0	2	432	0	0	0
1989	432	36	36	36	36	36	36	36	36	36	36	36	36	72	72	72	72	72	72	144	144	144	0	1	431	432	0	0	432	0	0	0
1990	432	36	36	36	36	36	36	36	36	36	36	36	36	72	72	72	72	72	72	144	144	144	0	0	432	430	0	2	432	0	0	0
1991	432	36	36	36	36	36	36	36	36	36	36	36	36	72	72	72	72	72	72	144	144	144	0	0	432	432	0	0	432	0	0	0
1992	432	36	36	36	36	36	36	36	36	36	36	36	36	72	72	72	72	72	72	144	144	144	0	0	432	430	0	2	432	0	0	0
1993	432	36	36	36	36	36	36	36	36	36	36	36	36	72	72	72	72	72	72	144	144	144	0	0	432	428	0	4	432	0	0	0
1994	432	36	36	36	36	36	36	36	36	36	36	36	36	72	72	72	72	73	71	144	144	144	0	0	432	431	0	1	432	0	0	0
1995	432	36	36	36	36	36	36	36	36	36	36	36	36	72	72	72	72	72	72	144	144	144	0	0	432	432	0	0	144	0	288	0
1996	433	37	36	36	36	36	36	36	36	36	36	36	36	72	73	72	72	72	72	144	145	144	0	0	433	433	0	0	37	0	396	0
1997	432	36	36	36	36	36	36	36	36	36	36	36	36	72	72	72	72	72	72	144	144	144	0	0	432	432	0	0	179	0	253	0
1998	433	36	36	36	36	36	36	36	36	36	36	36	37	72	72	72	73	72	72	144	144	145	0	0	433	433	0	0	325	0	108	0
1999	432	36	36	36	36	36	36	36	36	36	36	36	36	72	72	72	72	72	72	144	144	144	0	0	432	432	0	0	0	432	0	0

Table 2. continued.

Year	Total	MONTH												SOUND SYSTEM						SECTOR				StatType		Tow Time			Sample Type			
		J	F	M	A	M	J	J	A	S	O	N	D	WA	OS	SP	SS	SA	CU	Creek	Sound	Beach	UpRiv	Acc	Prim	15	30	OT	1	2	3	4
2001	432	36	36	36	36	36	36	36	36	36	36	36	36	72	72	72	72	72	72	144	144	144	0	0	432	432	0	0	0	432	0	0
2002	432	36	36	36	36	36	36	36	36	36	36	36	36	72	72	72	72	72	72	144	144	144	0	0	432	432	0	0	0	432	0	0
2003	432	36	36	36	36	36	36	36	36	36	36	36	36	72	72	72	72	72	72	144	144	144	0	0	432	428	0	4	0	72	0	360
2004	432	36	36	36	36	36	36	36	36	36	36	36	36	72	72	72	72	72	72	144	144	144	0	0	432	432	0	0	0	0	0	432
2005	502	36	36	43	43	43	43	43	43	43	43	43	43	102	72	72	112	72	72	184	144	144	30	70	432	499	0	3	3	0	0	499
2006	513	43	42	42	42	43	43	43	43	43	43	43	43	97	72	72	120	80	72	181	144	144	44	81	432	508	0	5	0	0	0	513
2007	516	43	43	43	43	43	43	43	43	43	43	43	43	96	72	72	120	84	72	180	144	144	48	84	432	507	0	9	4	0	0	512
2008	516	43	43	43	43	43	43	43	43	43	43	43	43	96	72	72	120	84	72	180	144	144	48	84	432	502	0	14	0	0	0	516
2009	509	43	43	43	43	43	42	42	42	42	42	42	42	89	72	72	120	84	72	173	144	144	48	77	432	484	0	25	0	0	0	509
2010	515	43	43	43	43	43	43	43	43	43	43	43	42	84	72	71	120	84	84	168	156	143	48	84	431	471	0	44	0	0	0	515
2011	504	42	42	42	42	42	42	42	42	42	42	42	42	84	72	72	120	84	72	168	144	144	48	72	432	486	0	18	0	0	0	504
2012	494	42	42	42	42	42	38	42	42	42	36	42	42	82	70	72	118	82	70	168	144	134	48	72	422	476	0	18	0	0	0	494
2013	469	27	42	42	34	41	40	42	42	39	42	38	40	74	64	69	115	79	68	162	138	126	43	66	403	452	0	17	0	0	0	469
2014	249	41	42	41	42	41	42							42	34	36	60	41	36	84	69	72	24	36	213	232	0	17	0	0	0	249
Key:	Sound: WA: Wassaw, OS: Ossabaw, SC: St. Catherines, SP: Sapelo, DB: Doboy, AL: Altamaha, SS: St Simons, SA: St. Andrew, CU: Cumberland																															
	Sector: Crk: Creeks, Snd: Sounds, Off: Beaches out 3 nm, UpR: Upriver - added in 2005.																															
	Station Type: ACC: Ancillary, PRIM: Primary																															
	Sample Type: 1: Shrimp and blue crab, 2: Shrimp, blue crab, and horseshoe crab, 3: Shrimp, blue crab, hsc, and fishes, 4: All invertebrates and fishes																															

Table 3. Lengths versus mean count size for Georgia white shrimp. Length taken from tip of rostrum to tip of telson. (S.A. Stevens and A. Kvaternik, GA DNR, per. comm.). Adapted from an unpublished manuscript, Length-weight relationships for white shrimp in Georgia waters. 7 pp.

Length (mm)	Heads-On No./lb	Length (mm)	Heads-On No./lb	Length (mm)	Heads-On No./lb	Length (mm)	Heads-On No./lb	Length (mm)	Heads-On No./lb	Length (mm)	Heads-On No./lb
51	480	76	140	101	58	126	30	151	17	176	11
52	452	77	135	102	57	127	29	152	17	177	10
53	426	78	130	103	55	128	28	153	16	178	10
54	403	79	125	104	53	129	27	154	16	179	10
55	380	80	120	105	52	130	27	155	16	180	10
56	360	81	115	106	50	131	26	156	15	181	10
57	341	82	111	107	49	132	26	157	15	182	10
58	323	83	107	108	48	133	25	158	15	183	9
59	306	84	103	109	46	134	24	159	14	184	9
60	291	85	99	110	45	135	24	160	14	185	9
61	276	86	96	111	44	136	23	161	14	186	9
62	263	87	93	112	42	137	23	162	14	187	9
63	250	88	89	113	41	138	22	163	13	188	9
64	238	89	86	114	40	139	22	164	13	189	8
65	227	90	83	115	39	140	21	165	13	190	8
66	217	91	81	116	38	141	21	166	13	191	8
67	207	92	78	117	37	142	20	167	12	192	8
68	198	93	75	118	36	143	20	168	12		
69	189	94	73	119	35	144	20	169	12		
70	181	95	71	120	34	145	19	170	12		
71	173	96	68	121	33	146	19	171	12		
72	166	97	66	122	33	147	18	172	11		
73	159	98	64	123	32	148	18	173	11		
74	152	99	62	124	31	149	18	174	11		
75	146	100	60	125	30	150	17	175	11		

Figures

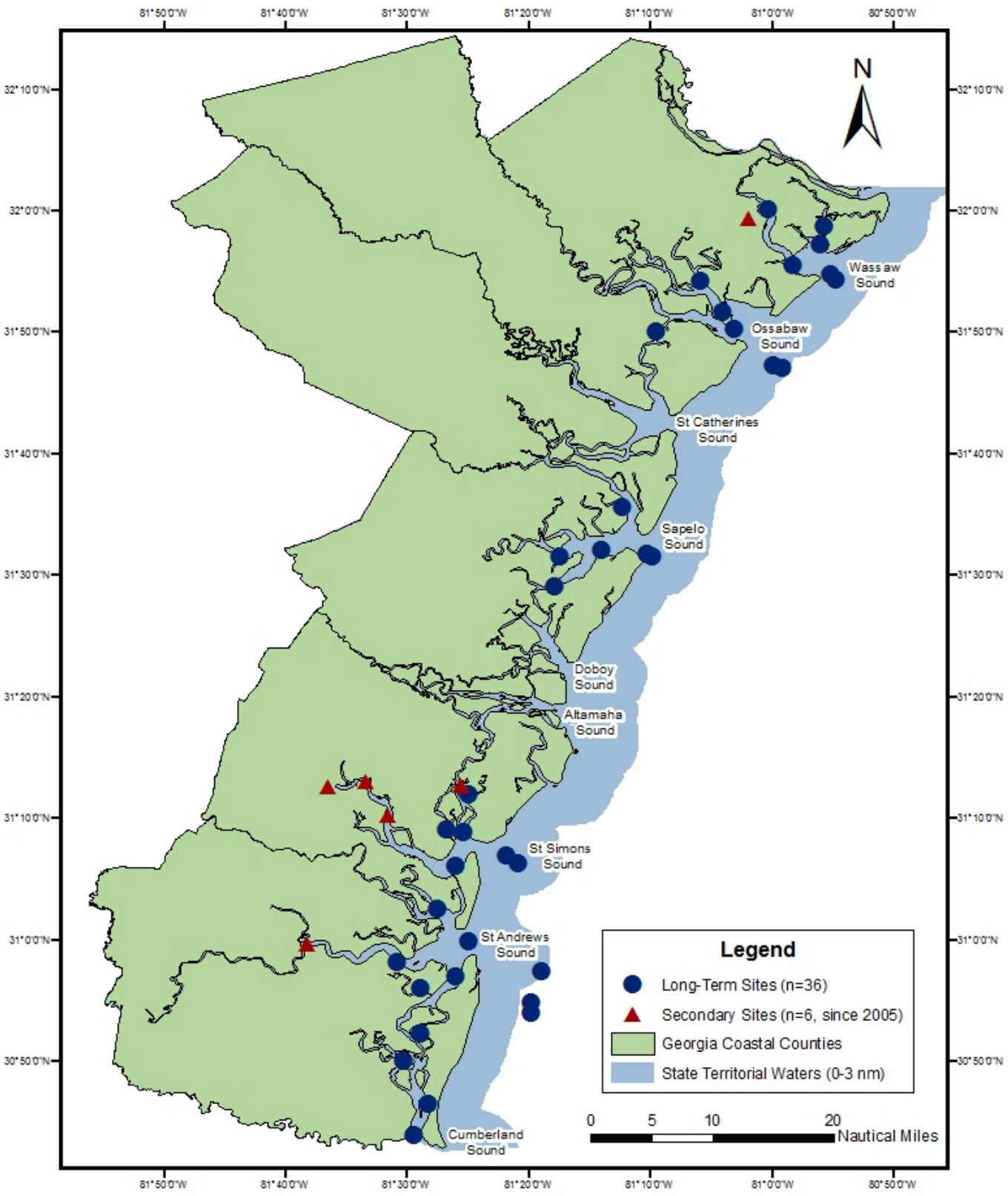


Figure 1. GA DNR Ecological Monitoring Trawl Survey sampling locations.

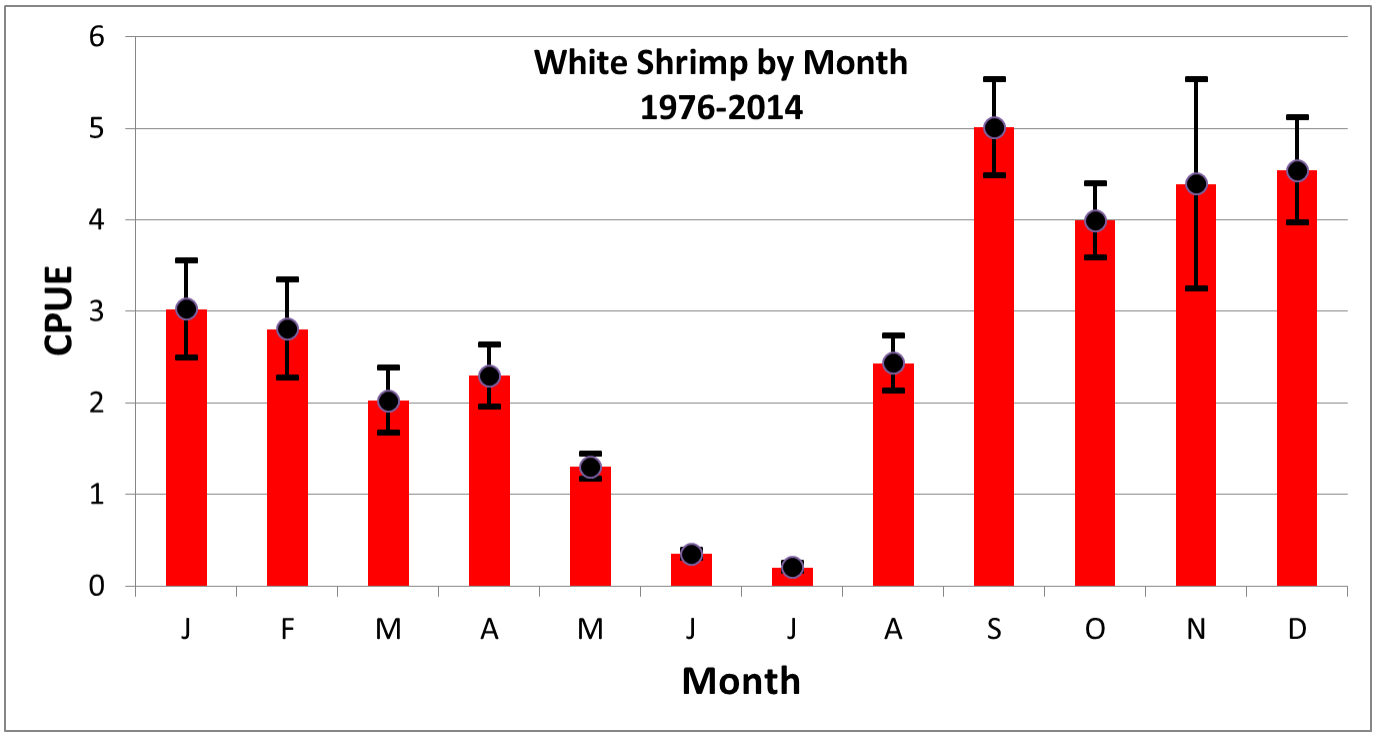


Figure 2a. White shrimp CPUE and 95% confidence intervals by month, 1976-2013. CPUE is kg / trawl.

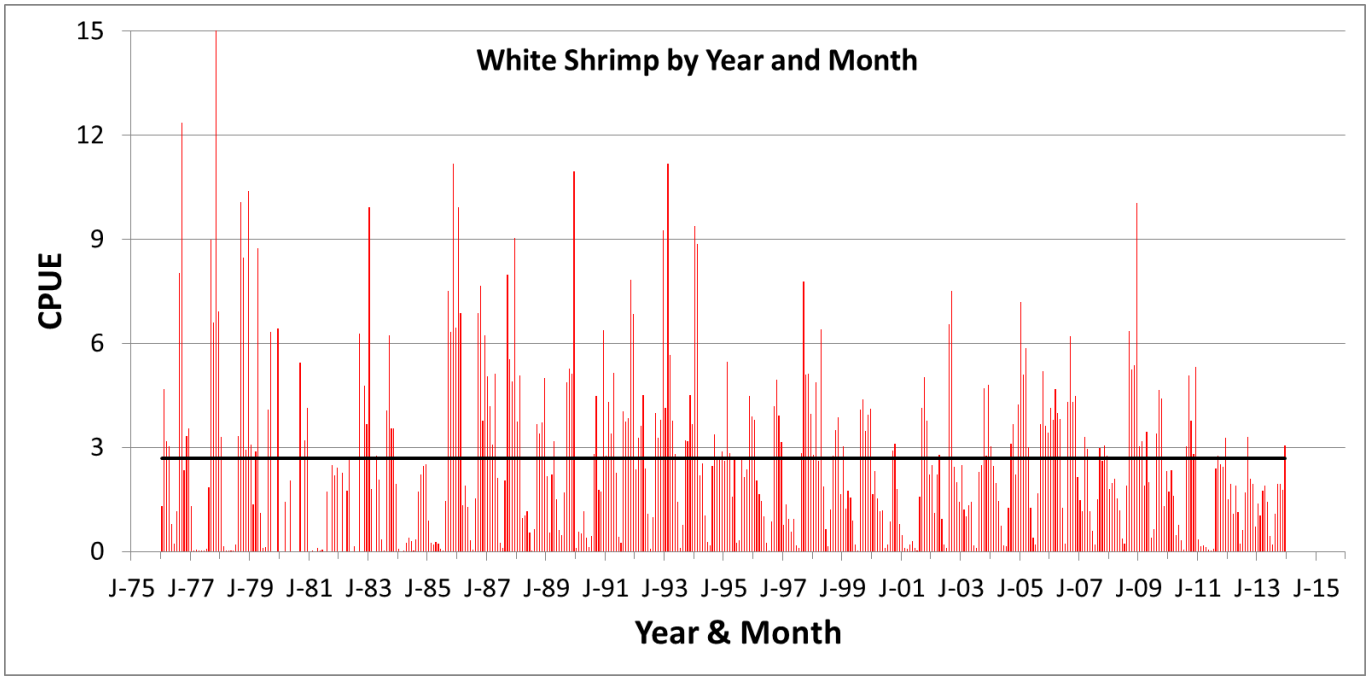


Figure 2b. White shrimp CPUE (as kg/15 minute trawl) by year and month (1976 - June 2014).

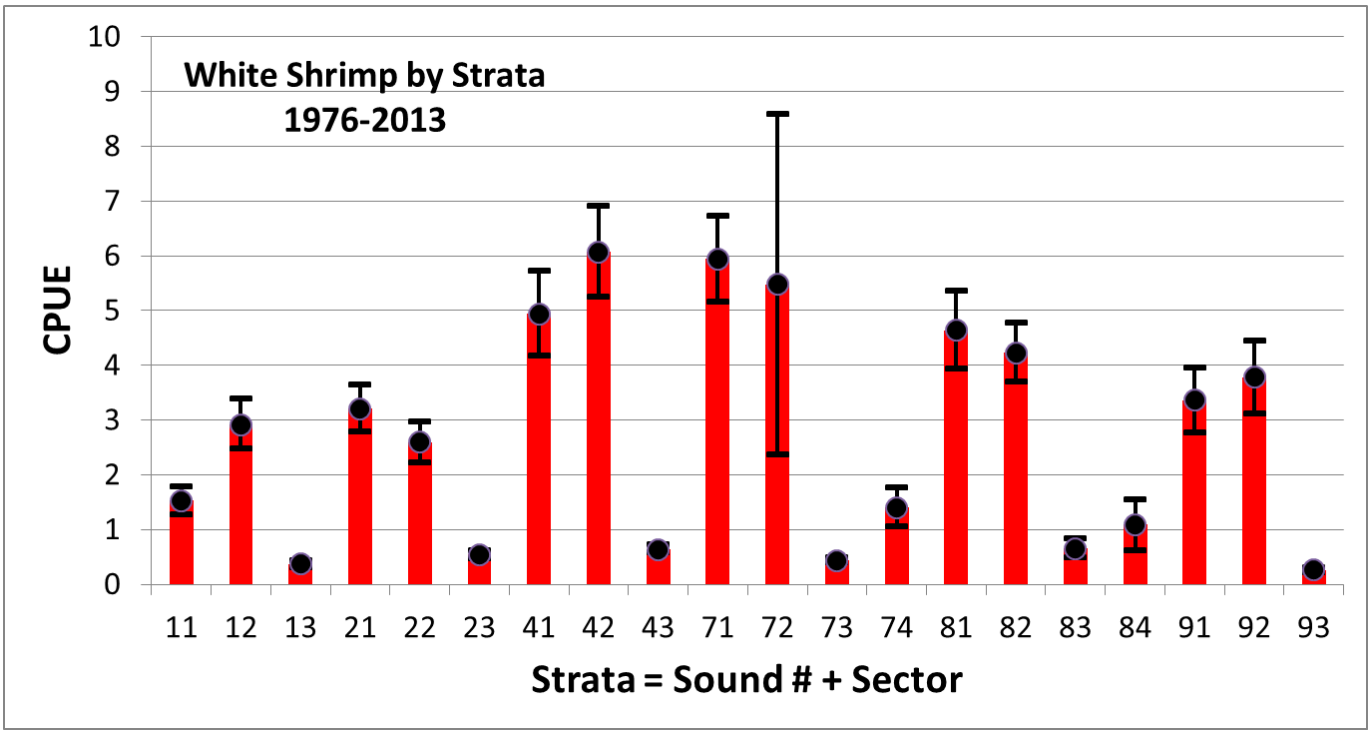


Figure 3. White shrimp CPUE and 95% confidence intervals by sound and sector, 1976-2013. CPUE is kg / trawl.

Key: Sound: 1: Wassaw, 2: Ossabaw, 4: Sapelo, 7: St. Simons, 8: St. Andrew, 9: Cumberland.
Sector: 1: Creek, 2: Sound, 3: Beach (0-3nm), 4: Upriver

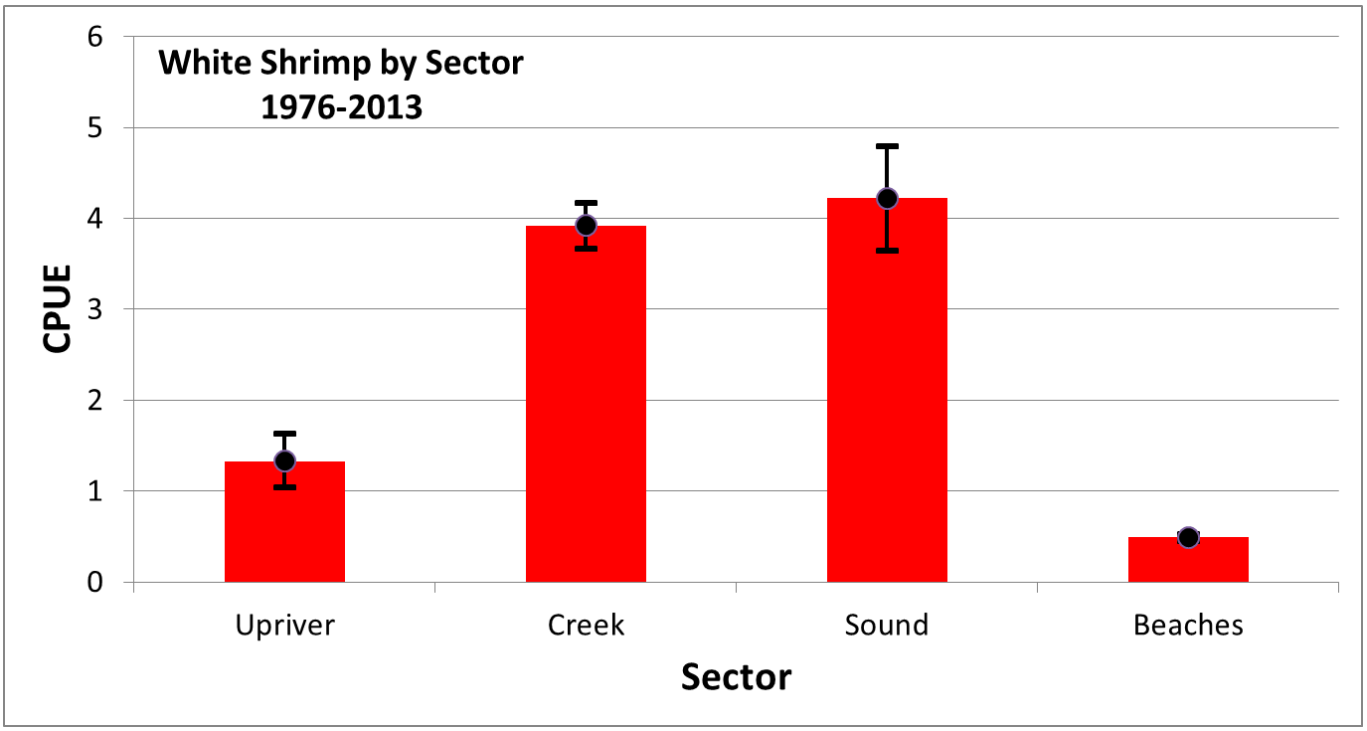


Figure 4. White shrimp CPUE and 95% confidence intervals by sector, 1976-2013. CPUE is kg / trawl.

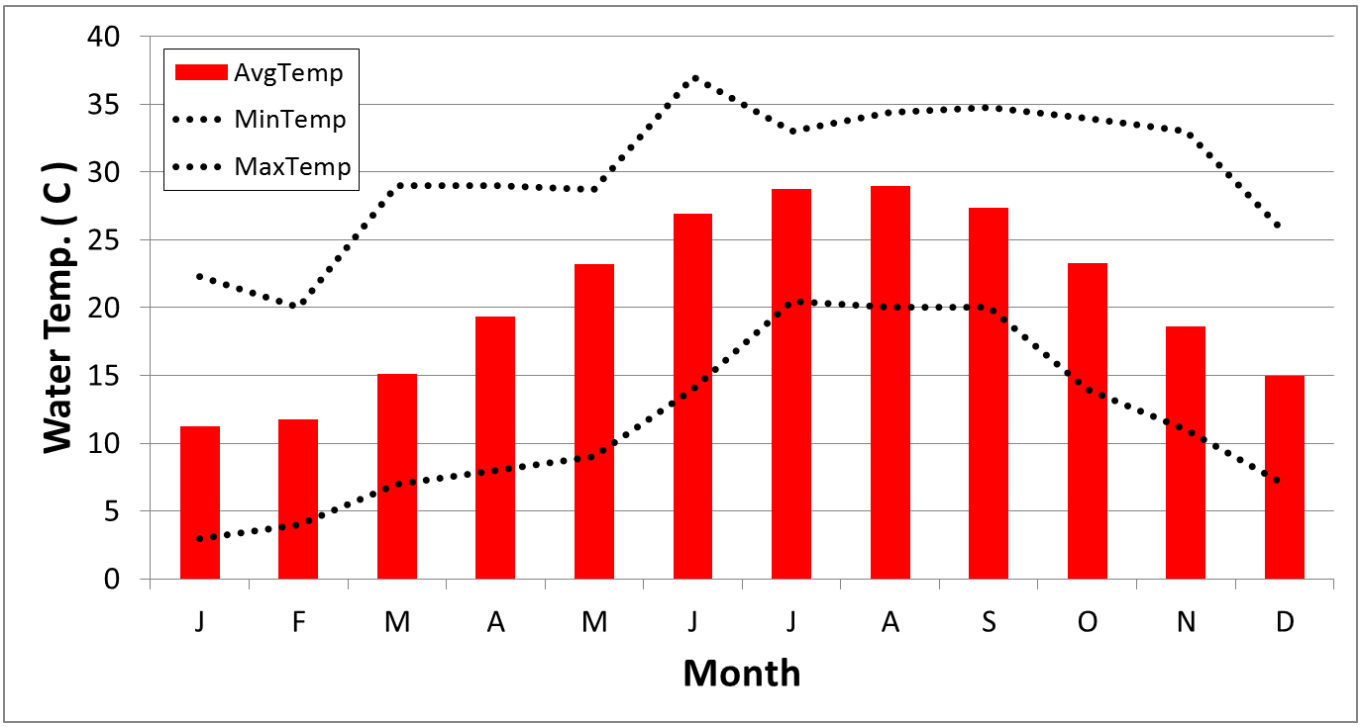


Figure 5. Average, minimum, and maximum water temperatures by month, 1976 - 2013.

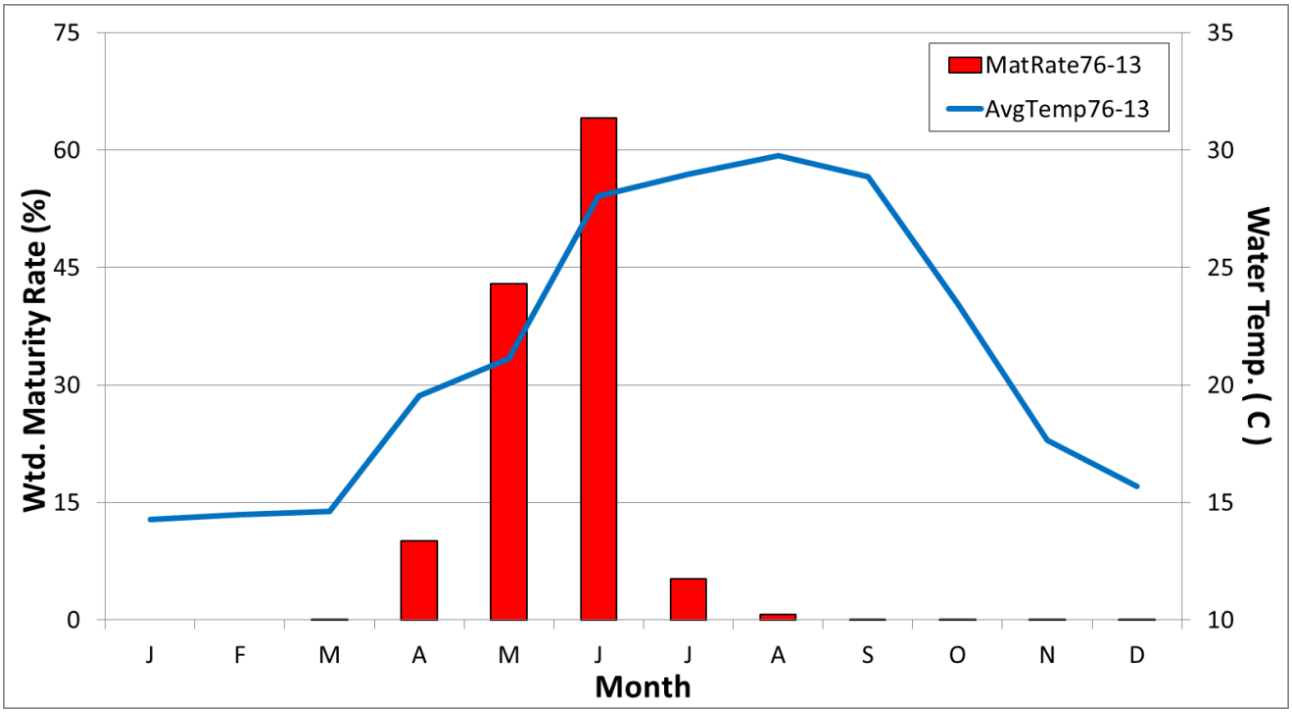
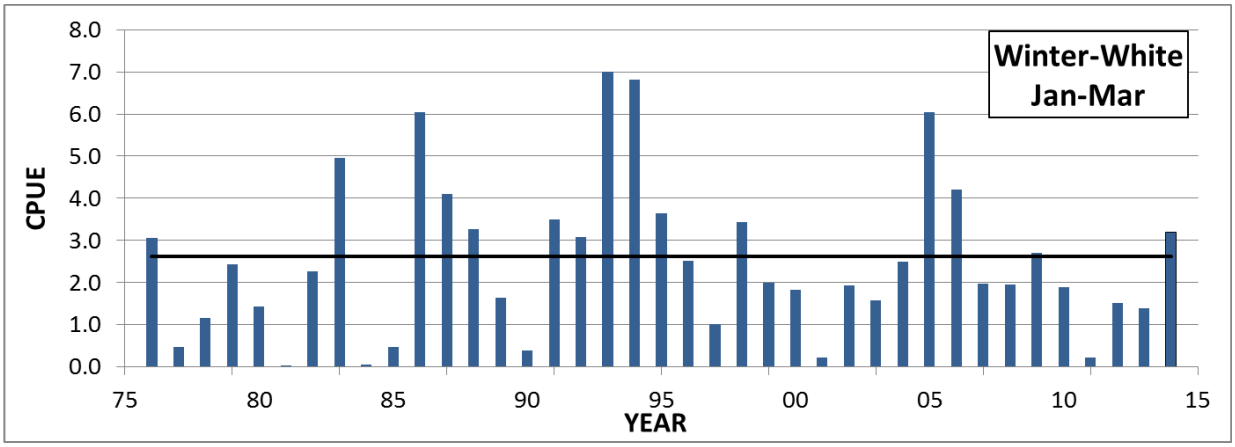
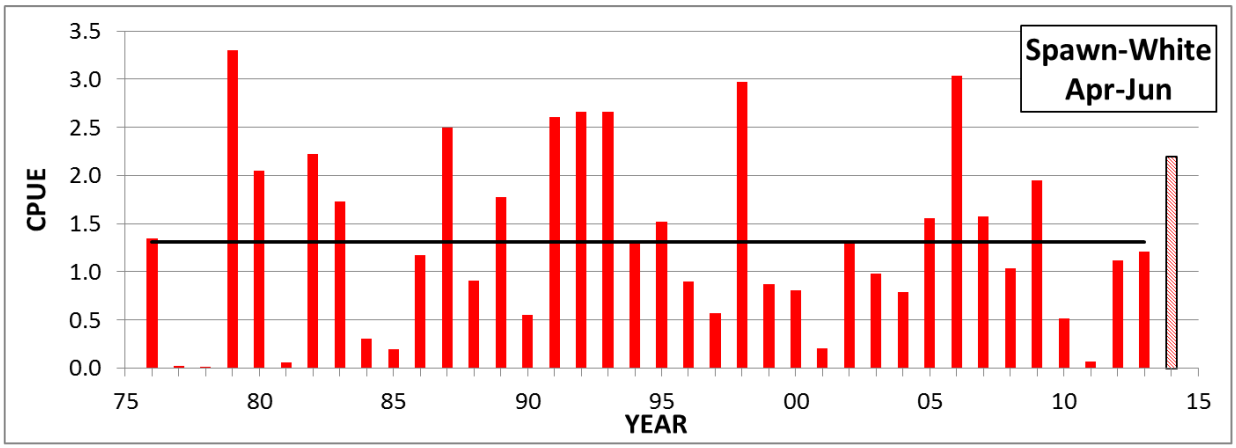
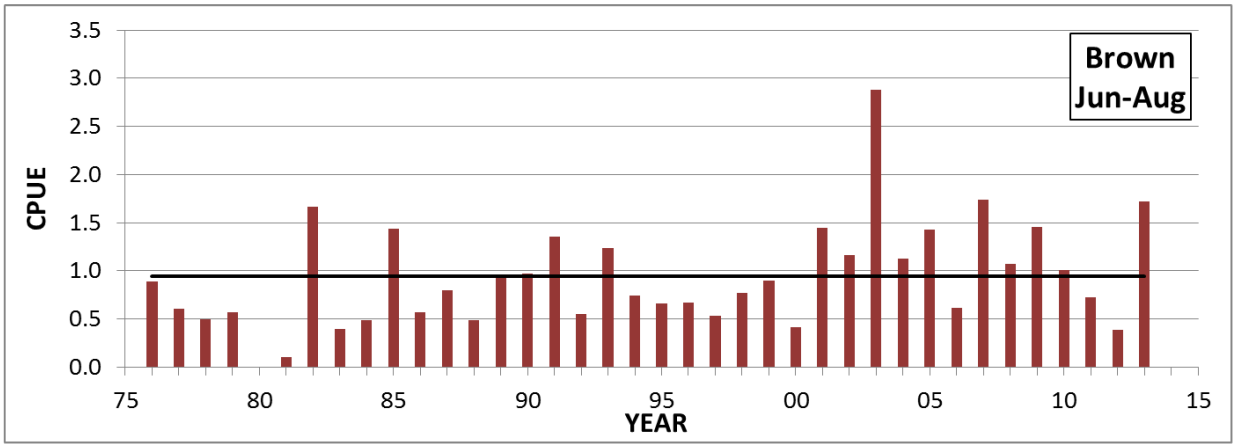


Figure 6. Gonadal maturity rate as a percent of female white shrimp with advanced development (yellow stage and greater) in comparison to monthly average water temperatures (1976-2013).







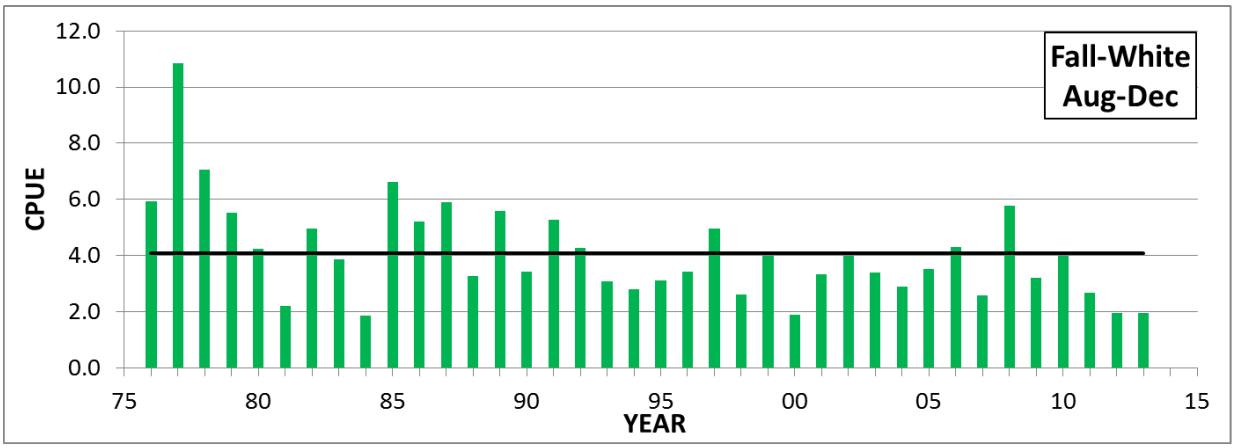


Figure 7. Georgia annual shrimp estimates by season.
CPUE is in kg per standard 15 minute trawl.
The 2014 white shrimp spawn index is incomplete at this time.

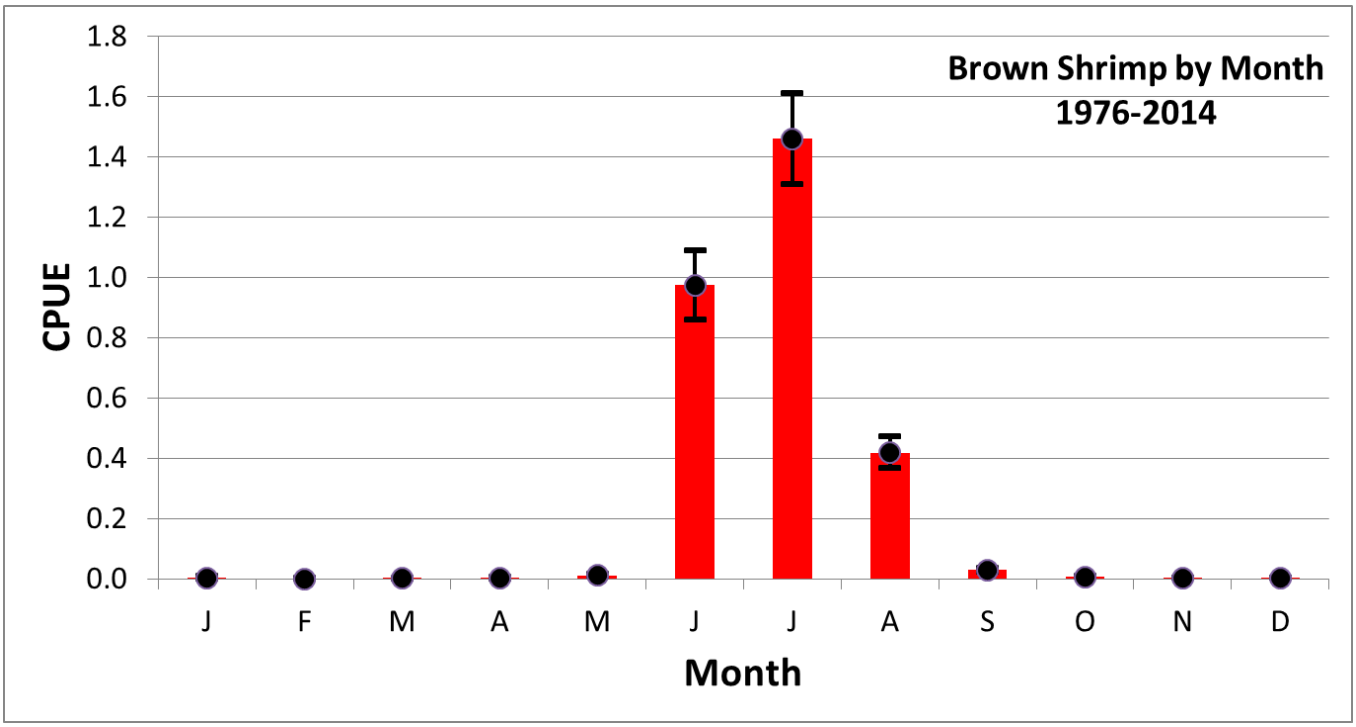


Figure 8a. Brown shrimp CPUE and 95% confidence intervals by month, 1976-2013. CPUE is kg / trawl.

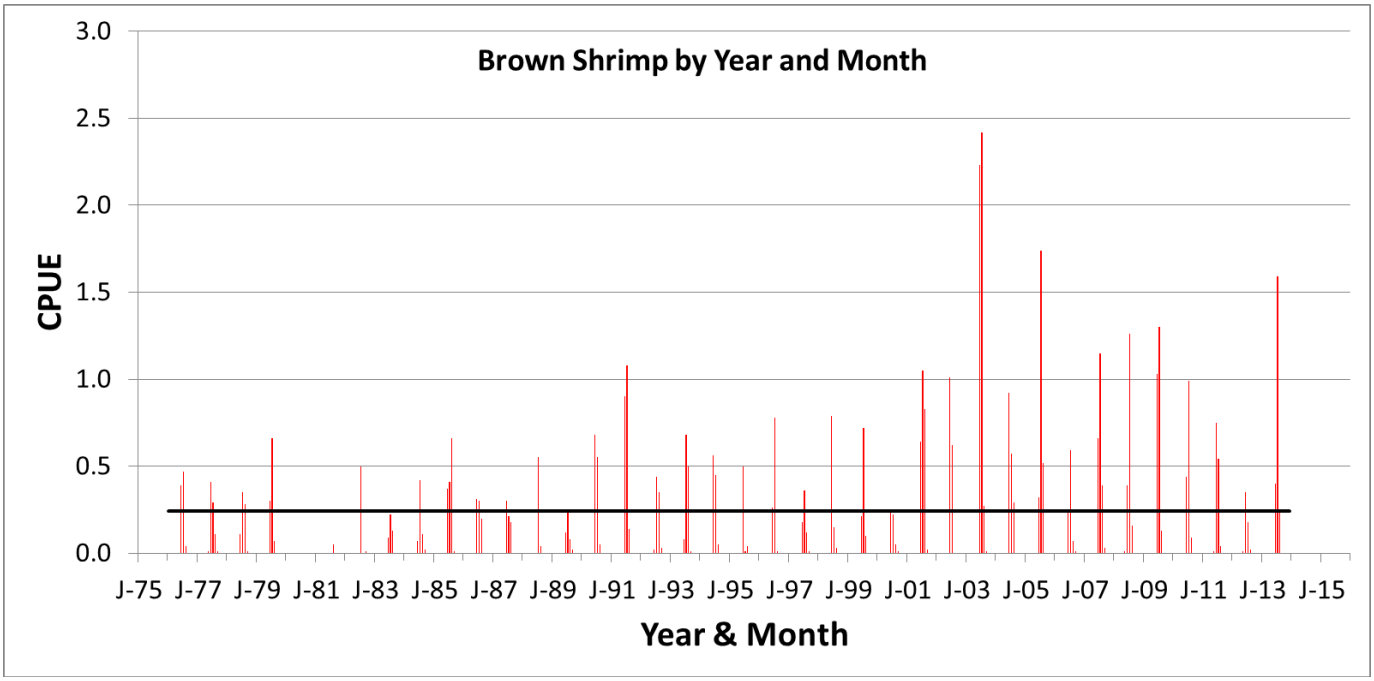


Figure 8b. Brown shrimp CPUE (as kg/15 minute trawl) by year and month (1976 - June 2014).

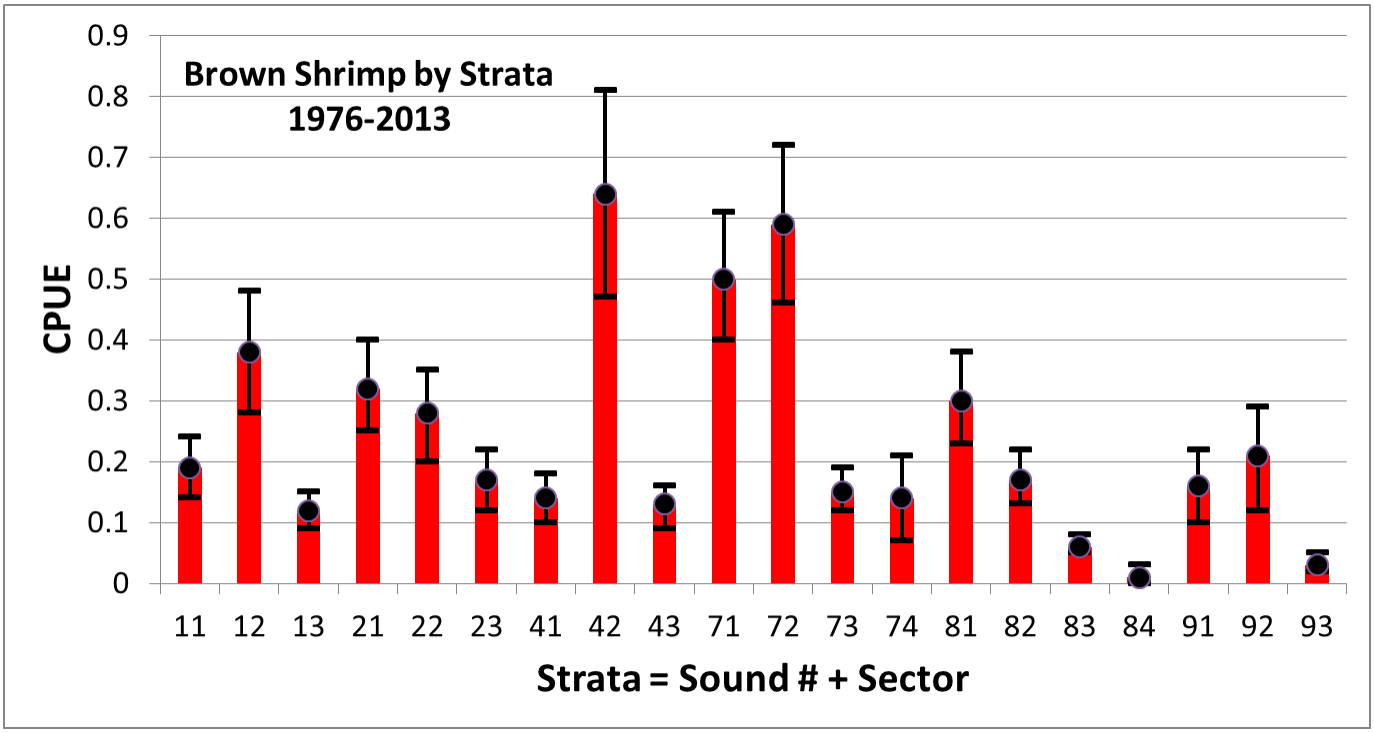


Figure 9. Brown shrimp CPUE and 95% confidence intervals by sound and sector, 1976-2013. CPUE is kg / trawl.

Key: Sound: 1: Wassaw, 2: Ossabaw, 4: Sapelo, 7: St. Simons, 8: St. Andrew, 9: Cumberland.
Sector: 1: Creek, 2: Sound, 3: Beach (0-3nm), 4: Upriver

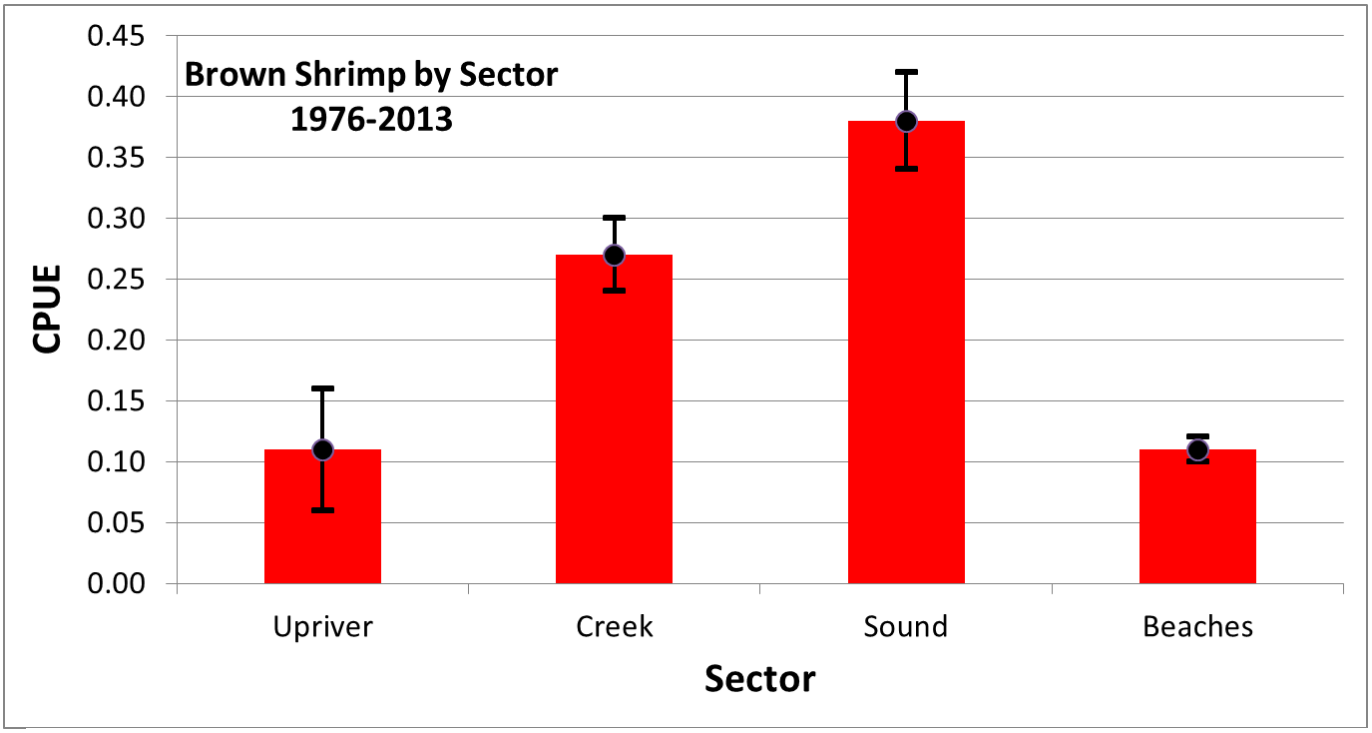


Figure 10. Brown shrimp CPUE and 95% confidence intervals by sector, 1976-2013. CPUE is kg / trawl.

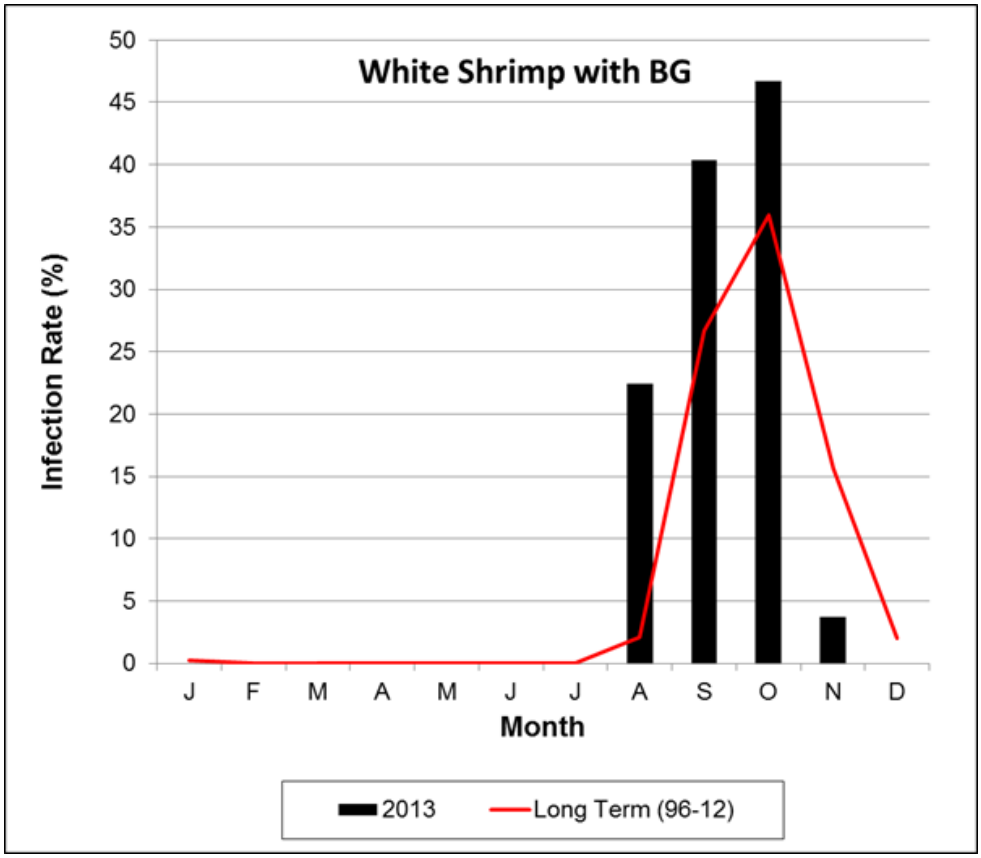


Figure 11. Monthly black gill infection rate in white shrimp.

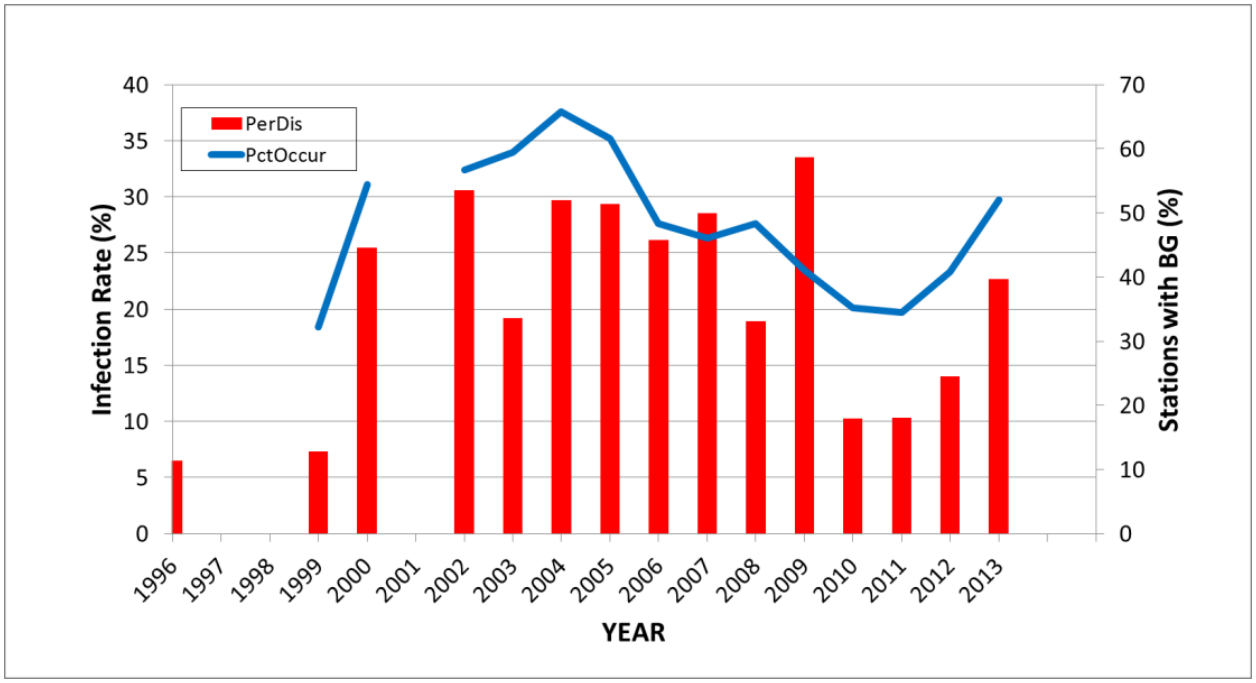


Figure 12. White shrimp annual black gill infection rate and frequency of occurrence (percent of stations with black gill).