Chapter 5.4

Macroalgae Abundance and Distribution in the Maryland Coastal Bays

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Abstract
In order to understand potential changes in primary production in Maryland's Coastal Bays, the distribution and abundance of macroalgae were investigated in tidal locations as part of the Coastal Bays Fisheries Investigation Trawl and Beach Seine Surveys. While macroalgae abundance was highly variable, the embayments north of the Ocean City Inlet had higher abundance when compared to the southern embayments over an eight year time series (2006-2013). Most embayments were dominated by Rhodophyta, specifically *Agardhiella* and *Gracilaria,* with the exception of Chincoteague Bay, where *Polysiphonia* was the most prevelant. When environmental conditions such as water temperature, salinity or clarity were right, *Chlorophyta*, specifically *Ulva* and *Chaetomorpha*, appeared able to compete with the Rhodophytes.

Introduction
Macroalgae are a part of a healthy estuarine ecosystem, and variations in abundance, distribution, or composition of macroalgae are affected by natural environmental changes. An increase in macroalgae abundance or change in composition may be indicative of eutrophication (Doctor *et al.* 2013). It can provide cover, produce oxygen, and serve as a food source for many species in the Coastal Bays. Interestingly, macroalgae are not considered an essential habitat for fish because it is variable and ephemeral (Sogard and Able, 1991). Additionally, sea lettuce (*Ulva sp.*) produces exudates which can be toxic to winter flounder (*Pseudopleuronectes americanus*) and many invertebrates (Sogard and Able 1991).

Macroalgae abundance and composition could play an important role in fish and invertebrate composition and diversity. Several species of fishes (blennies, gobies, sticklebacks, pipefishes, and tautog (*Tautoga onitis*) have been observed using macroalgae as refuge (Olla *et al.* 1979; Stoner and Livingston, 1980; Gore *et al.* 1981, Wilson *et al*. 1990, Sogard and Able 1991, Raposa and Oviatt 2000). Macroalgae also provide habitat and foraging opportunities for several species of decapods (Wilson *et al*. 1990, Sogard and Able 1991).

Williams and Grosholz (2008) define introduced species as having been introduced outside its native range through human activities; invasive species are a subset that are likely to, or cause economic harm or ecological harm. The Mid-Atlantic Panel on Aquatic Nuisance Species lists two out of the 20 macroalgae collected in the Coastal Bays Fisheries Investigation on their Invasive Species "Of Interest" List; *Gracilaria* and *Codium*. *Gracilaria* was the dominant macroalgae in the Coastal Bays which has declined in the most recent years. *Codium* has been

encountered in all but Assawoman Bay. Fortunately, *Codium* abundance (catch per unit effort, CPUE, L/ha) has remained low over the time series (Table 5.4.1). Often times, invasive species are known for steady increases in abundance, which has not been the case for *Codium* or *Gracilaria*.

Data Sets
During each Coastal Bays Fisheries Investigation (CBFI) Trawl and Beach Seine Survey, macroalgae were identified by genus and measured volumetrically (liters, L) using calibrated containers with small holes in the bottom to drain the excess water. Community composition was estimated to the nearest percent. The seine sampling was conducted at 19 fixed beach sites during June and September. The trawl sampling was conducted at 20 fixed sites throughout Maryland's Coastal Bays on a monthly basis from April through October (Figure 5.4.3).

Analyses
To summarize macroalgae presence in the CBFI, statistical analyses were conducted on each genus and the combined total abundance from 2006 to 2013. The measure of abundance (CPUE) for the trawl and seine was mean liters per hectare (L/ha). An analysis of variance (ANOVA) was performed to determine relationships in CPUE (L/ha) by year, embayment and genus. Annual CPUE (L/ha) was compared to the time series grand mean. Macroalgae diversity was calculated by the Shannon-Weaver index.

Management Objective
CBFI has been monitoring macroalgae distribution and abundance since 2006 to provide data for potential management measures.

Results
Twenty genera of macroalgae have been collected since 2006 as part of the CBFI in Maryland's Coastal Bays (Table 5.4.1). *Rhodophyta* (Red macroalgae), *Chlorophyta* (Green macroalgae), *Phaeophyta* (Brown macroalgae) and *Xanthophyta* (Yellow-Green macroalgae) were represented in the survey collections. Rhodophytes have dominated the Coastal Bays since 1998 (McGinty *et al.*, 2002, Doctor *et al* 2013). *Ulva* and *Chaetomorpha* were the most abundant green macroalgae. *Vaucheria* were the only yellow-green genera; brown macroalgae were represented in very low abundance, most likely due to the sampling design which was focused on collecting fish and not macroalgae.

Macroalgae abundance (CPUE) across Maryland's Coastal Bays during the 2006-2013 time series has been variable for both the Trawl and Beach Seine Surveys. The Trawl Survey peak year was 2008; however, this abundance was not different than the grand mean. The years that were different than the grand mean were 2006, 2007 and 2013, of which all were below the grand mean. The Shannon Index was variable over the time series without trend (Figure 5.4.1). The macroalgae abundance (CPUE) for the Beach Seine Survey was highly variable due to the lower sample size. The years that were different than the grand mean were 2006, 2007 and 2009, of which all were below the grand mean. The Shannon Index was variable over the time series without trend (Figure 5.4.2).

Mean CPUE was higher in the embayments north of Ocean City Inlet for both Surveys. The Shannon index values were variable for the Trawl Survey, but higher in the embayments south of the inlet for the Beach Seine Survey (Figures 5.4.3; 5.4.4; 5.4.5)

Assawoman Bay

The Assawoman Bay (trawl n=21/year) has been the most productive macroalgae area in the Trawl Survey time series (Figure 5.4.4). Abundance (CPUE) was not different than the grand mean except for three years of low abundance (2006, 2007 and 2013; Figure 5.4.6). *Agardhiella* (45.6%), *Gracilaria* (38.9%) and *Ulva* (9.4%) were the prominent macroalgae in the time series. Diversity was the highest in 2013 (H = 1.29; Figure 5.4.6) due a decrease in *Agardhiella* that year. The Beach Seine Survey for Assawoman Bay (beach seine n=6/year) resulted in moderate abundance and high variability in 2008 and 2013. Four of the eight years in the time series were below the grand mean. *Agardhiella* (51.2%), *Chaetomorpha* (20.9%) and *Enteromorpha* (6.4%) were the prominent macroalgae in the time series. Diversity decreased in 2013 (H= 0.77) due to the increased abundance of *Agardhiella* (78.6%) in the littoral zone (Figure 5.4.7).

St. Martin River

The St. Martin River (trawl n=14/year) has had moderate macroalgae abundance in the Trawl Survey time series (Figure 5.4.4). Abundance (CPUE) has been below the grand mean since 2011. *Agardhiella* (44.9%), *Gracilaria* (32.7%) and *Ulva* (20.4%) were the prominent macroalgae in the time series. Diversity was low in 2013 (H = 0.82) due to the increased abundance of *Ulva* (70.6%) that year (Figure 5.4.8). The Beach Seine Survey for St. Martin River (beach seine n=2/year) resulted in high abundance and high variability in 2007 and 2010. Two of the eight years in the time series were below the grand mean. *Agardhiella* (80.2%) and *Enteromorpha* (10.1%) were the prominent macroalgae in the time series. Diversity decreased in 2013 (H= 0.33) due to the increased abundance of *Agardhiella* (92.0%) in the littoral zone (Figure 5.4.9).

Isle of Wight Bay

Isle of Wight Bay (trawl n=14/year) was the second most productive area for macroalgae the Trawl Survey time series (Figure 5.4.4). Abundance (CPUE) was below the grand mean in four of the eight years in the time series (Figure 5.4.10). *Agardhiella* (59.4%), *Gracilaria* (32.0%) and *Ulva* (5.8%) were the prominent macroalgae in the time series. Diversity increased in 2013 (H = 1.15) due to the increased abundance of *Chaetomorpha* (32.3%) that year (Figure 5.4.10). The Beach Seine Survey for Isle of Wight Bay (beach seine n=6/year) resulted in high abundance and high variability in 2010. Three of the eight years in the time series were below the grand mean. *Agardhiella* (48.3%) *Gracilaria* (14.2%) and *Cladophora* (13.5%) were the prominent macroalgae in the time series. Diversity increased in 2013 (H= 1.33) due to the increased abundance of *Chaetomorpha* (34.9%) in the littoral zone (Figure 5.4.11).

Sinepuxent Bay

Sinepuxent Bay (trawl n=21/year) had low macroalgae abundance in the Trawl Survey time series (Figure 5.4.4). Abundance (CPUE) was below the grand mean in two of the eight years in the time series (Figure 5.4.12). *Agardhiella* (41.1%), *Ulva* (28.8%) and *Gracilaria* (10.7%) were the prominent macroalgae in the time series. Diversity decreased in 2013 (H = 1.41) due to the increased abundance of *Agardhiella* (40.6%) that year (Figure 5.4.12). The Beach Seine Survey

for Sinepuxent Bay (beach seine n=6/year) resulted in increasing abundance and high variability in 2013. All years in the time series were not different than the grand mean. *Agardhiella* (56.5%) and *Gracilaria* (32.6%) were the prominent macroalgae in the time series. Diversity has been low in the littoral zone (Figure 5.4.13).

Newport Bay

Newport Bay (trawl n=14/year) had low macroalgae abundance in the Trawl Survey time series (Figure 5.4.4). Abundance (CPUE) was below the grand mean in three of the eight years in the time series (Figure 5.4.14). *Agardhiella* (22.4%), *Gracilaria* (22.9%), *Polysiphonia* (19.2%) and *Ulva* (13.8%) and were the prominent macroalgae in the time series. Diversity has remained stable during the time series (Figure 5.4.14). The Beach Seine Survey for Newport Bay (beach seine n=4/year) resulted in increasing abundance and high variability over the time series. Four of eight years in the time series were below the grand mean. *Agardhiella* (47.0%), *Gracilaria* (23.7%) and *Spyridia* (13.1%) were the prominent macroalgae in the time series. Diversity has been low in the littoral zone, except in 2011 (Figure 5.4.15).

Chincoteague Bay

Chincoteague Bay (trawl n=56/year) had low macroalgae abundance in the Trawl Survey time series (Figure 5.4.16). Abundance (CPUE) was below the grand mean in two of the eight years in the time series (Figure 5.4.16). *Agardhiella* (20.4%), *Polysiphonia* (19.2%) *Chaetomorpha* (16.7%) *Vaucheria* (9.2%) and *Ulva* (7.8%) and were the prominent macroalgae in the time series. Diversity has remained stable and above the other embayments. The Beach Seine Survey for Chincoteague Bay (beach seine n=12/year) resulted in increasing abundance and high variability in 2012-2013. Six of eight years in the time series were below the grand mean. *Polysiphonia* (60.0%), *Agardhiella* (20.0%) and *Vaucheria* (9.8%) were the prominent macroalgae in the time series. Diversity has been high and variable in the littoral zone, except in 2006 (Figure 5.4.17).

Summary

Macroalgae in Maryland's Coastal Bays were investigated consistently over eight years as a supplement to the Coastal Bays Fisheries Investigation Trawl and Beach Seine Surveys. The results of this investigation show distribution and abundance of macroalgae encountered by each survey. These data are highly variable and the survey designs were not developed to perform a population assessment for macroalgae. Abundances of *Rhodophyta*, *Chlorophyta*, *Phaeophyta* and *Xanthophyta* may not be accurate because the Trawl and Beach Seine Surveys did not sample macroalgae habitat such as rocks, jetties and bulkheads where macroalgae has been observed. However those data show that *Rhodophyta* and *Chlorophyta* were present at high levels in the embayment's closest to high density human population.

Table 5.4.1 Macroalgae catch per unit effort (L/ha) from the CBFI Trawl and Beach Seine Survey, 2006-2013.

Macroalgae	Gear	2006	2007	2008	2009	2010	2011	2012	2013	Mean
Agardhs Red Weed (*Agardhiella sp.*)	Trawl	9.72	26.65	131.79	167.31	223.68	145.04	59.95	26.42	98.82
	Seine	0.07	87.12	16.73	82.80	352.41	139.06	192.66	346.91	152.22
Banded Weeds (*Ceramium sp.*)	Trawl	0.18	0.97	2.28	1.16	0.12	1.13	2.71	2.11	1.33
	Seine	5.77	2.15	0.44	0.15	0.00	4.76	0.02	1.02	1.79
Barrel Weed (*Champia sp.*)	Trawl	2.18	0.95	16.19	2.71	0.33	2.07	1.55	0.16	3.27
	Seine	0	1.12	2.75	3.11	0	0.49	1.10	2.12	1.34
Brittlewort (*Nitella sp.*)	Trawl	0	0	0	0	0	0	0	0	0
	Seine	0	0	0	0.32	0	0	0	0	0.04
Brown Bubble Algae (*Colpomenia sp.*)	Trawl	0	0	0	0	0	0	0.04	0.01	0.01
	Seine	0	0	0	0	0	0	0	0	0
Common Southern Kelp (*Laminaria sp.*)	Trawl	0	0	0	0	0	0.67	0.01	0.04	0.09
	Seine	0	0	0	0	0	0	0	0	0
Ectocarpus Genus (*Ectocarpus sp.*)	Trawl	0	0	0	0	0	0	0	0	0
	Seine	0	0	1.67	0	0	0	0	0	0.21
Graceful Red Weed (*Gracilaria sp.*)	Trawl	37.80	26.35	175.94	25.55	41.34	202.37	129.93	0.52	79.98
	Seine	66.25	33.41	81.17	17.45	84.02	15.32	0.67	1.24	37.44
Green Fleece (*Codium fragile*)	Trawl	0	0.21	0.75	0.67	0.09	0.21	1.54	0.40	0.49
	Seine	2.81	0	0	1.37	0	6.45	16.11	5.48	4.03
Green Hair Algae (*Chaetomorpha sp.*)	Trawl	0.91	1.17	4.38	26.12	14.95	2.66	0.06	10.20	7.56
	Seine	4.17	0.00	88.64	6.61	1.12	15.40	0.31	49.69	20.74
Green Sea Fern (*Bryopsis sp.*)	Trawl	0	0	0	0	0	0.01	0	0.06	0.01
	Seine	0	0	0	0.58	0	0	0	0.62	0.15
Green Tufted Seaweed (*Cladophora sp.*)	Trawl	0.79	0.06	1.06	0.00	0.00	0.52	8.32	0.54	1.41
	Seine	16.26	0.27	81.64	0.04	59.94	1.61	1.07	0.77	20.20
Hairy Basket Weed (*Spyridia sp.*)	Trawl	0	0	0	0.35	0.19	0.24	2.93	0.49	0.52
	Seine	0	0	0	0.20	0.83	16.90	1.03	18.36	4.66
Hollow Green Weed (*Enteromorpha sp.*)	Trawl	0.03	0.37	2.50	1.08	1.09	1.36	5.05	0.47	1.49
	Seine	10.43	0.02	34.60	13.21	31.36	10.80	0.66	20.42	15.19
Hooked Red Weed (*Hypnea sp.*)	Trawl	0	0	0.04	0	0	0.08	0.03	0	0.02
	Seine	0	0	2.00	0	0	0	0	0	0.25
Rockweed (*Fucus sp.*)	Trawl	0.01	0.01	0	0.15	0.10	0	0	0	0.03
	Seine	0.21	0.01	1.01	0	0	0	0	0	0.15
Sea Lettuce (*Ulva sp.*)	Trawl	4.50	11.39	43.12	43.96	17.49	17.58	7.72	12.67	19.80
	Seine	2.01	8.81	10.04	2.21	27.81	4.74	12.28	23.28	11.40
Sour Weeds (*Desmarestia sp.*)	Trawl	0	0	9.81	0	0	2.41	0.03	0.03	1.54
	Seine	0	0	1.45	0	0	0.03	0.01	0	0.19
Tubed Weeds (*Polysiphonia sp.*)	Trawl	0.10	14.98	0.01	0.70	1.79	10.45	31.13	12.23	8.92
	Seine	1.19	0.78	0.54	0.03	0.20	1.41	46.66	115.11	20.74
Water Felt (*Vaucheria sp.*)	Trawl	0	0	0.59	10.09	0.71	1.59	2.75	6.11	2.73
	Seine	0	0	0.60	2.08	6.95	11.60	8.94	19.64	6.22

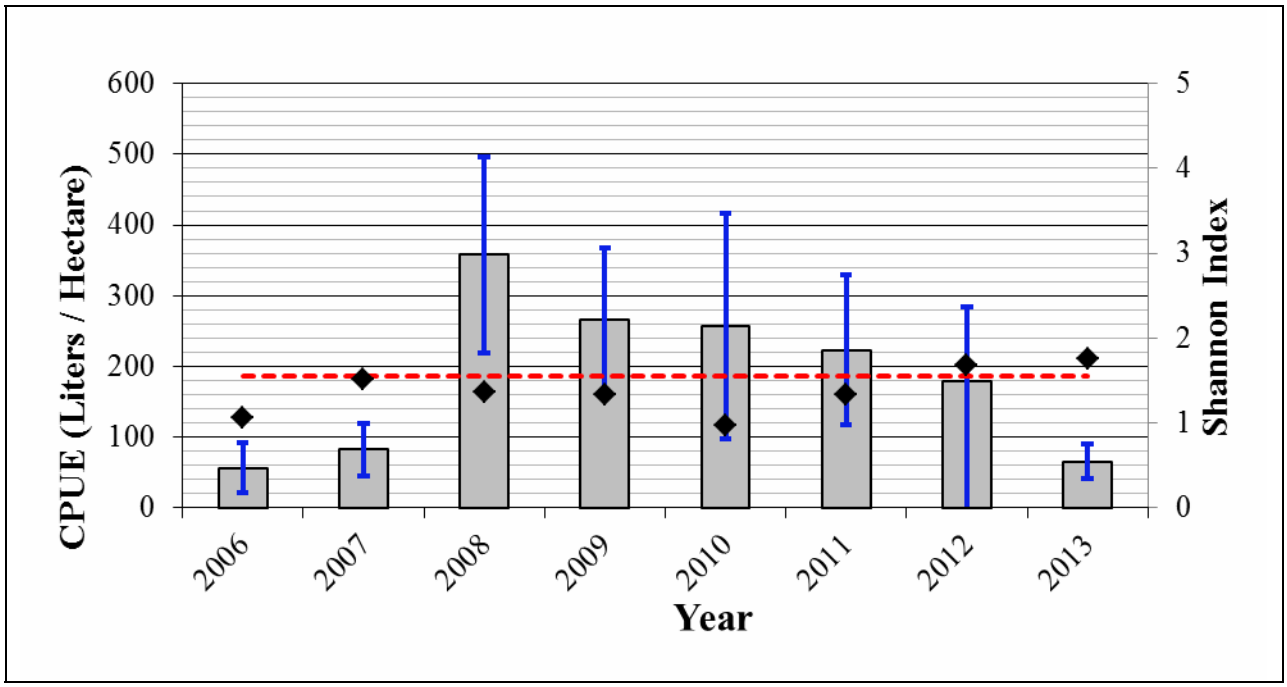

Figure 5.4.1 Coastal Bays Fisheries Investigation Trawl Survey Index of macroalgae relative abundance (CPUE; L/ha) in ALL BAYS with 95% confidence intervals (2006-2013). Black diamond represents the 2006-2013 time series Shannon index of diversity.

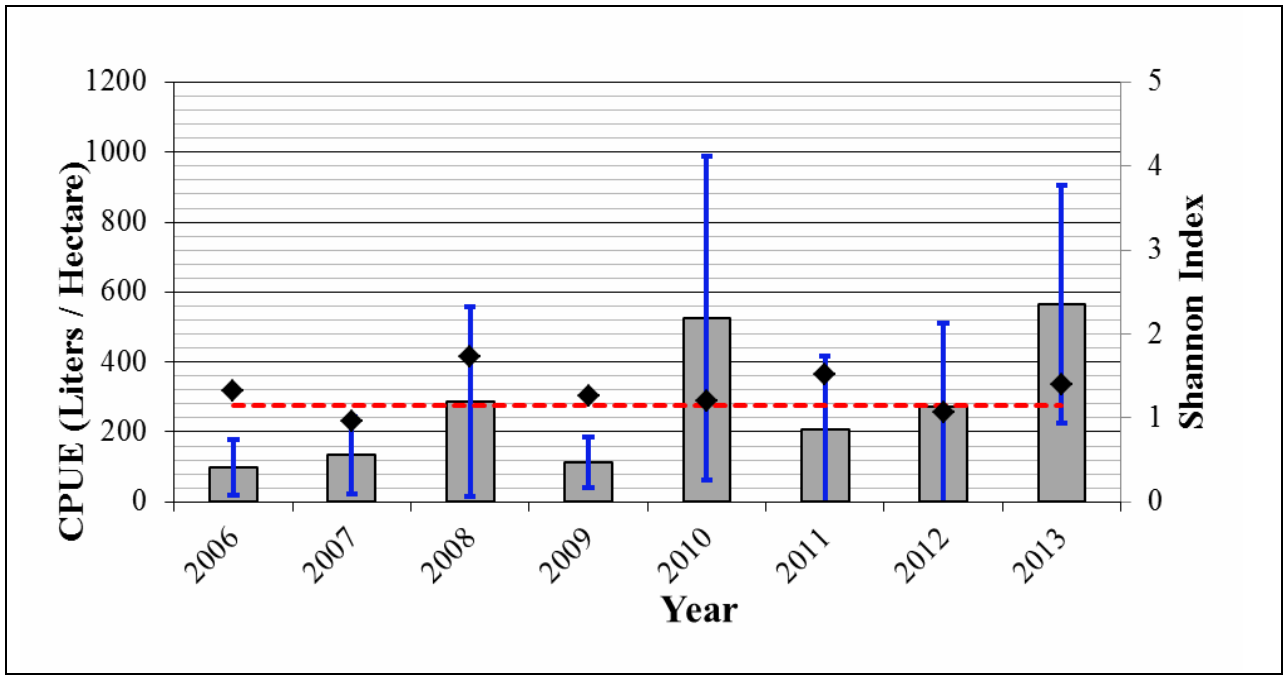

Figure 5.4.2 Coastal Bays Beach Seine Survey index of macroalgae relative abundance (CPUE; L/ha) in ALL BAYS with 95% confidence intervals (2006-2013). Black diamond represents the 2006-2013 time series Shannon index of diversity.

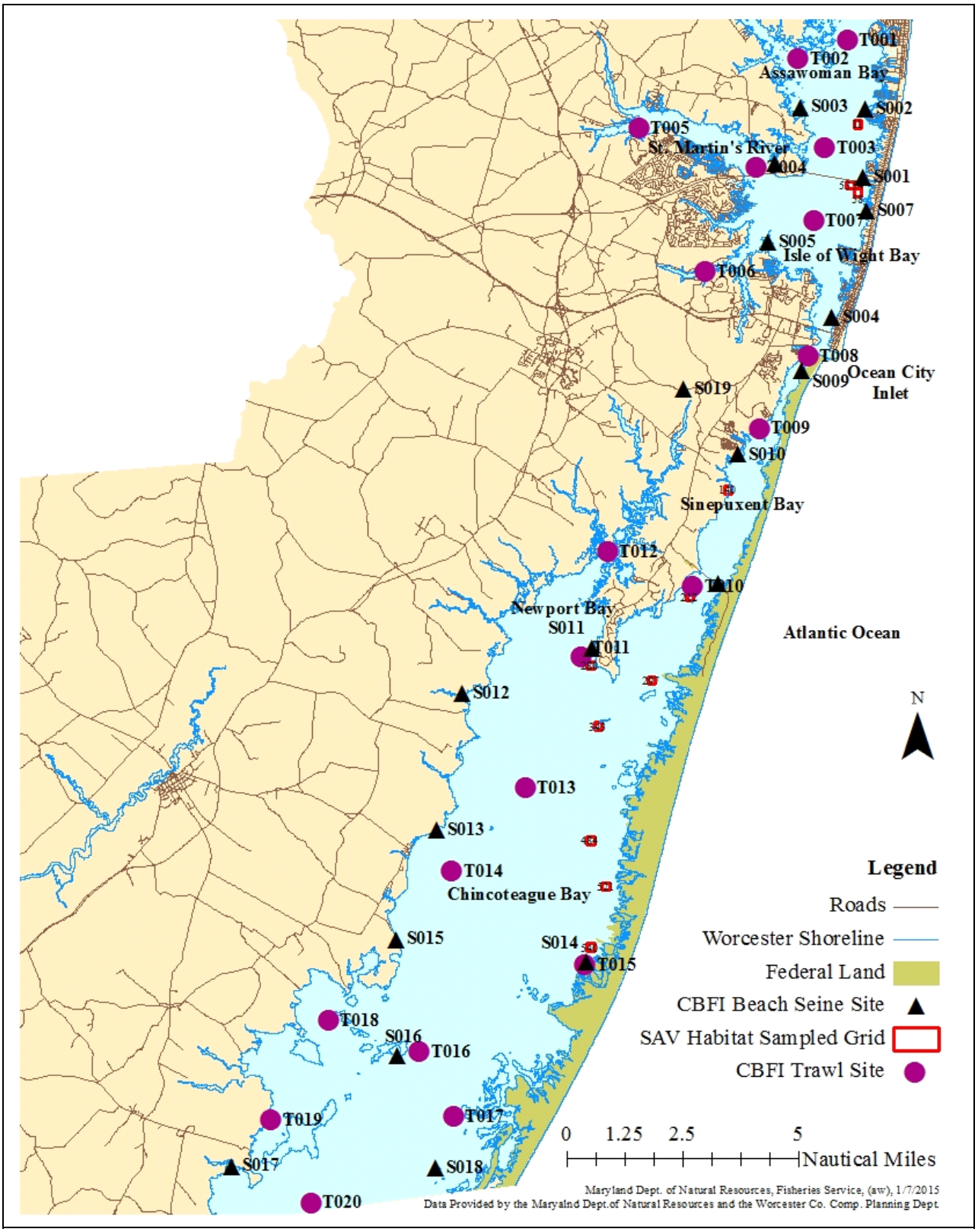

Figure 5.4.3 Coastal Bay Fisheries Investigation Trawl and Beach Seine Survey sample sites (2013).

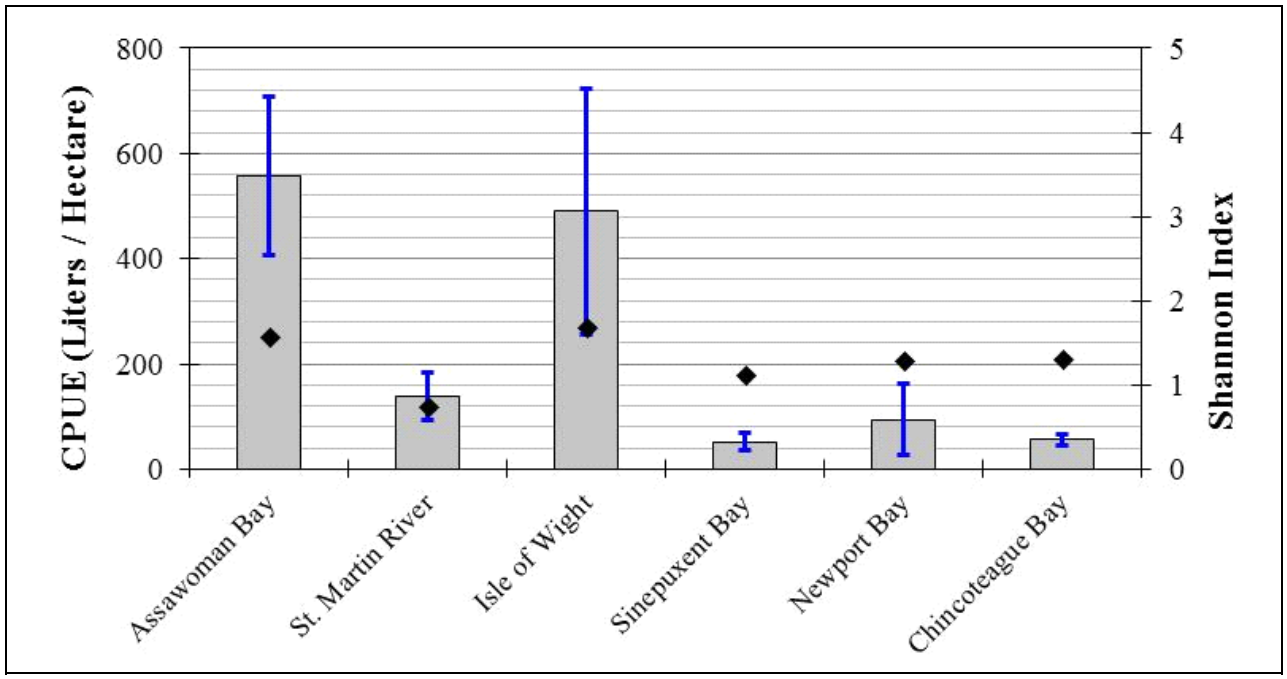

Figure 5.4.4 Coastal Bays Fisheries Investigation Trawl Survey index of macroalgae relative abundance (CPUE; L/ha) by sub-watershed with 95% confidence intervals (2006-2013). Black diamond represents the 2006-2013 time series Shannon index of diversity.

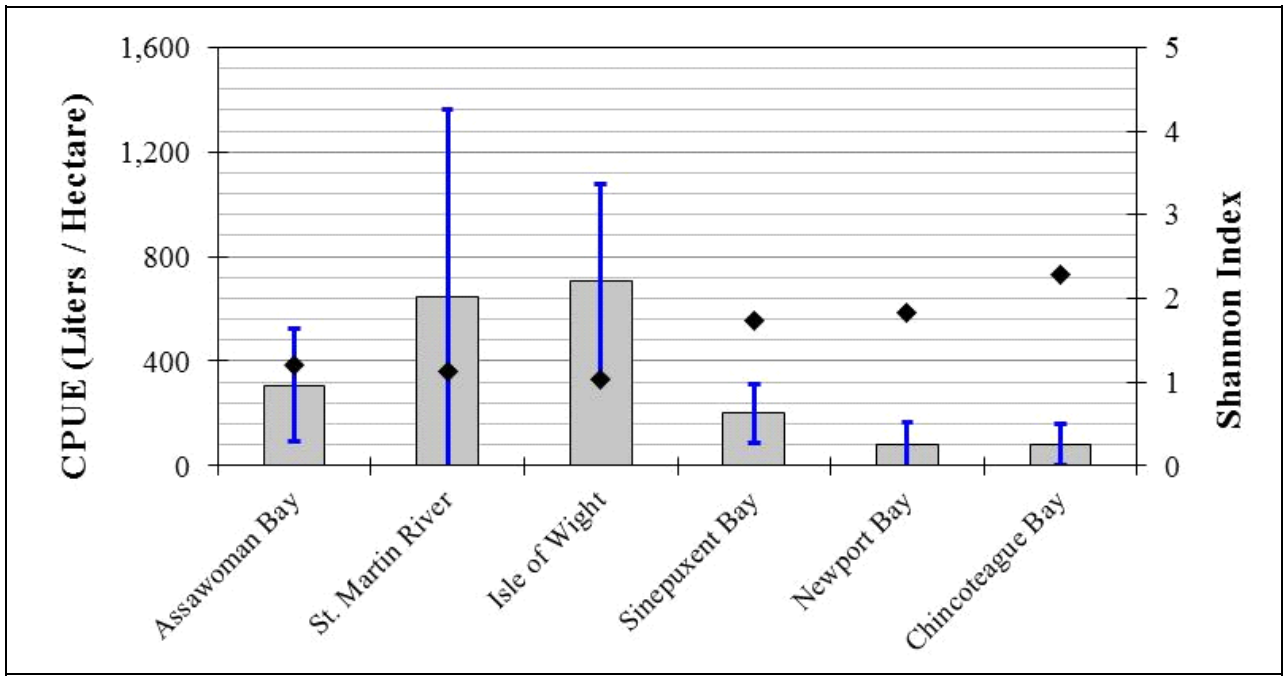

Figure 5.4.5 Coastal Bays Fisheries Investigation Beach Seine Survey index of macroalgae relative abundance (CPUE; L/ha) by sub-watershed with 95% confidence intervals (2006-2013). Black diamond represents the 2006-2013 time series Shannon index of diversity.

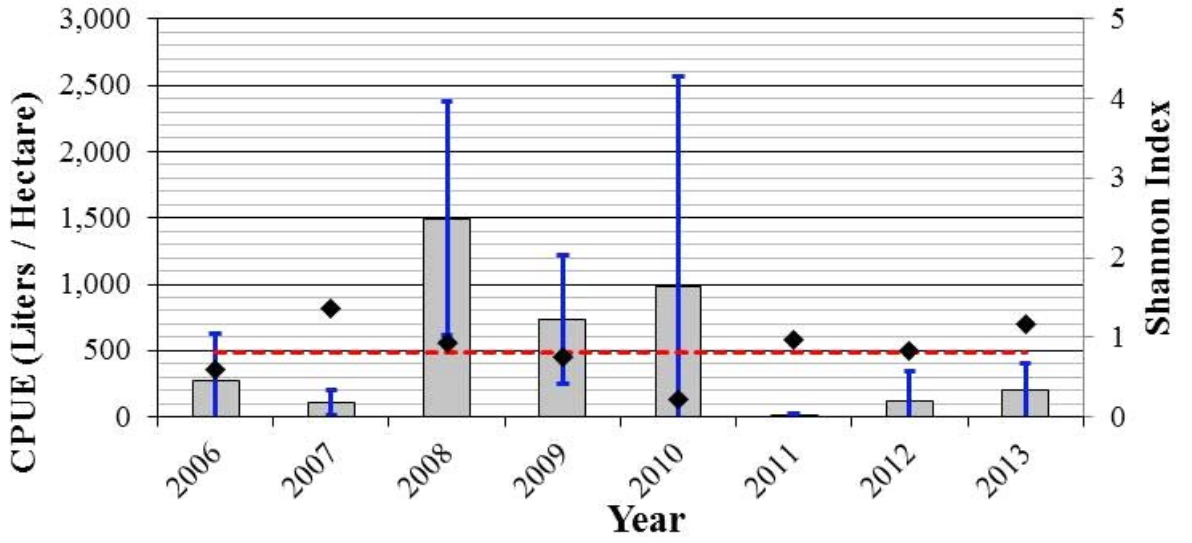

Figure 5.4.6 Coastal Bays Fisheries Investigation Trawl Survey index of Assawoman Bay macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006-2013). Red line represents the 2006-2013 time series CPUE grand mean, (n=21/year). Black diamond represents the Shannon index of diversity.

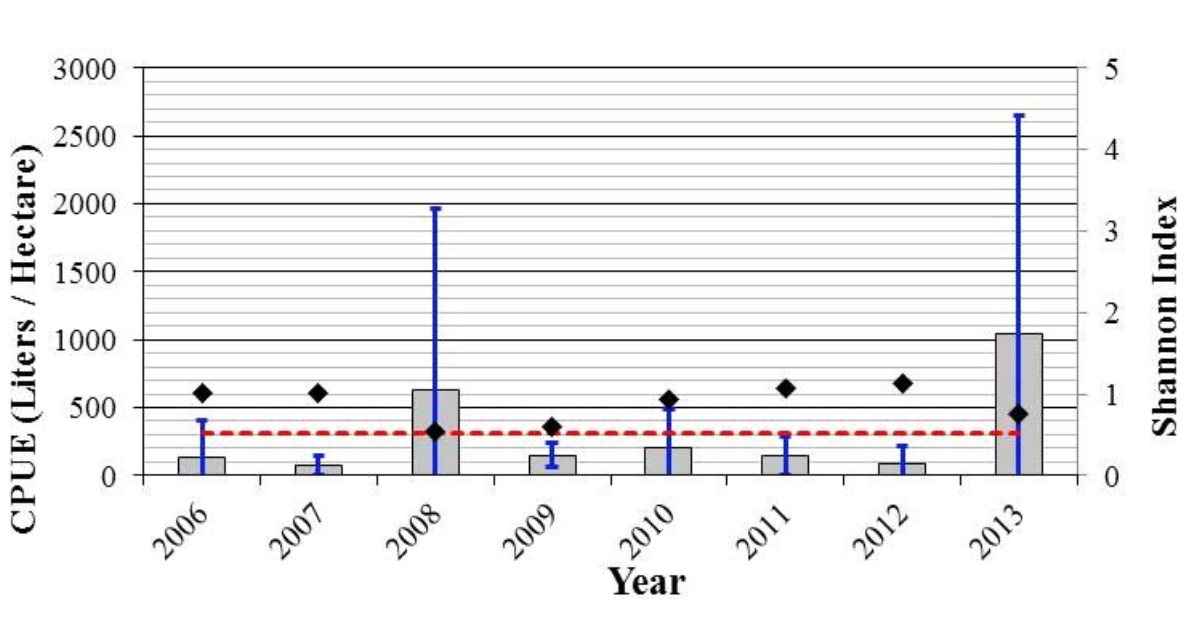

Figure 5.4.7 Coastal Bays Fisheries Investigation Beach Seine Survey index of Assawoman Bay macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006-2013).

Dotted line represents the 2006-2013 time series CPUE grand mean, (n=6/year). Black diamond represents the Shannon index of diversity.

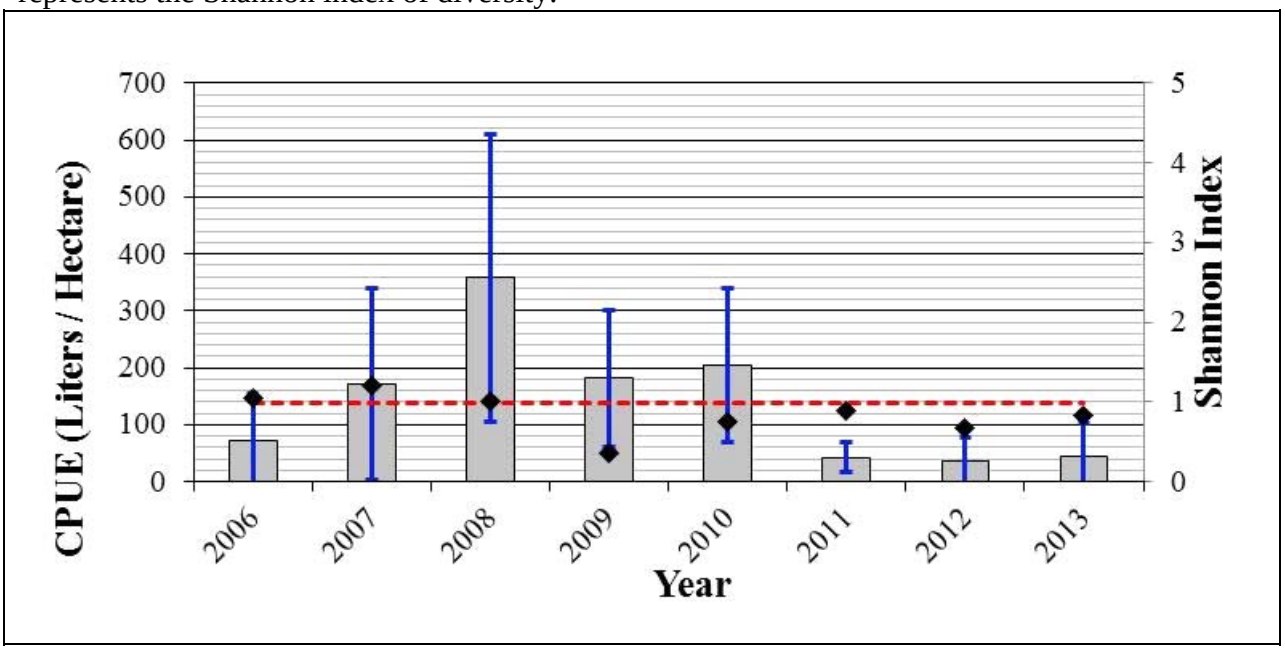

Figure 5.4.8 Coastal Bays Fisheries Investigation Trawl Survey index of St. Martin River macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006-2013). Red line represents the 2006-2013 time series CPUE grand mean, (n=14/year). Black diamond represents the Shannon index of diversity.

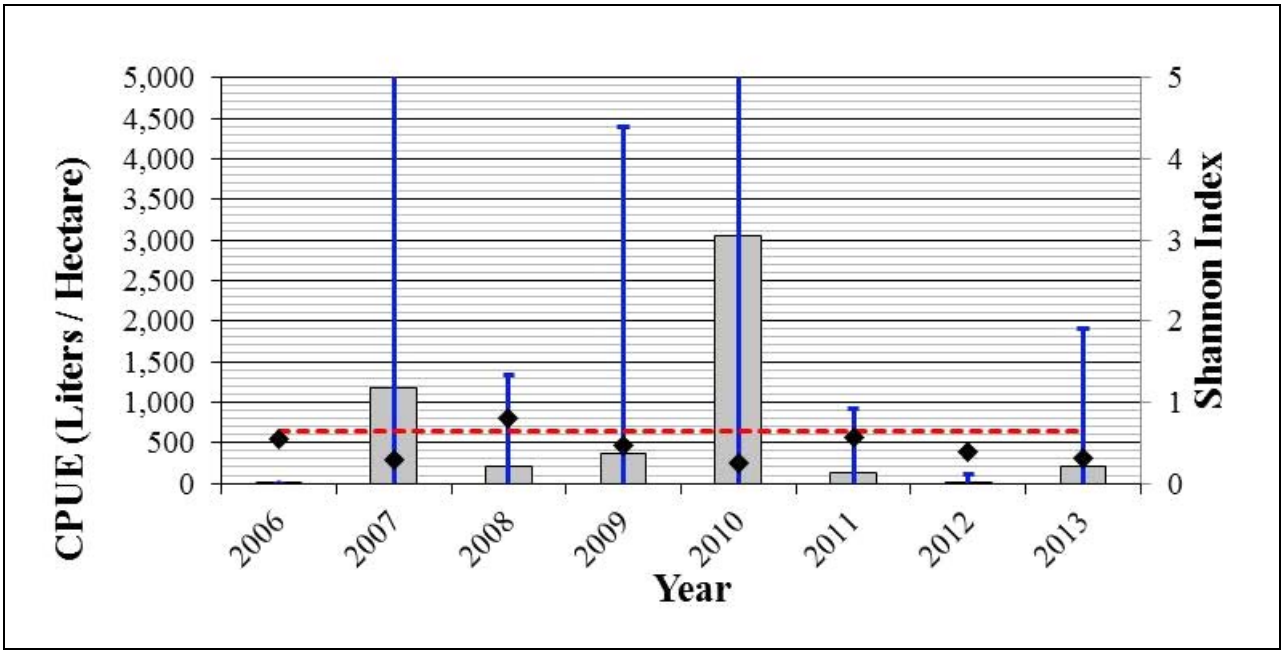

Figure 5.4.9 Coastal Bays Fisheries Investigation Beach Seine Survey index of St. Martin River macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006-2013). Red line represents the 2006-2013 time series CPUE grand mean, (n=2/year). Black diamond represents the Shannon index of diversity

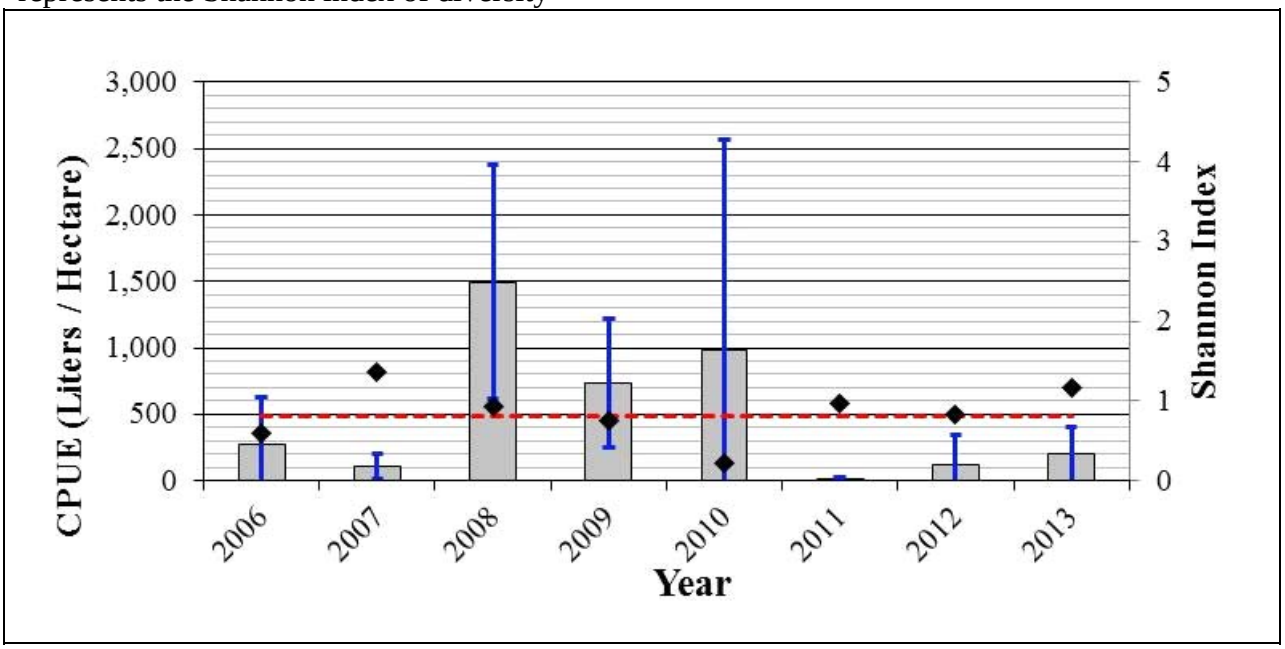

Figure 5.4.10 Coastal Bays Fisheries Investigation Trawl Survey index of Isle of Wight Bay macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006-2013). Red line represents the 2006-2013 time series CPUE grand mean, (n=14/year). Black diamond represents the Shannon index of diversity.

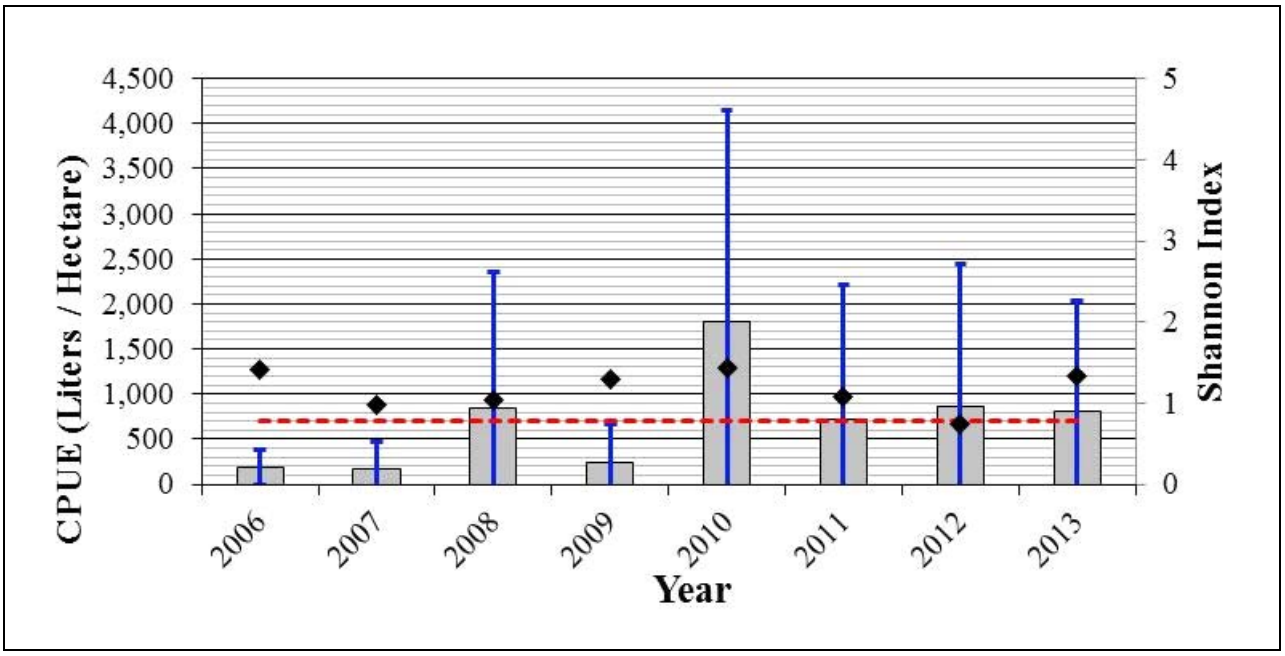

Figure 5.4.11 Coastal Bays Fisheries Investigation Bay Beach Seine Survey index of Isle of Wight macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006-2013). Red line represents the 2006-2013 time series CPUE grand mean, (n=4/year). Black diamond represents the Shannon index of diversity.

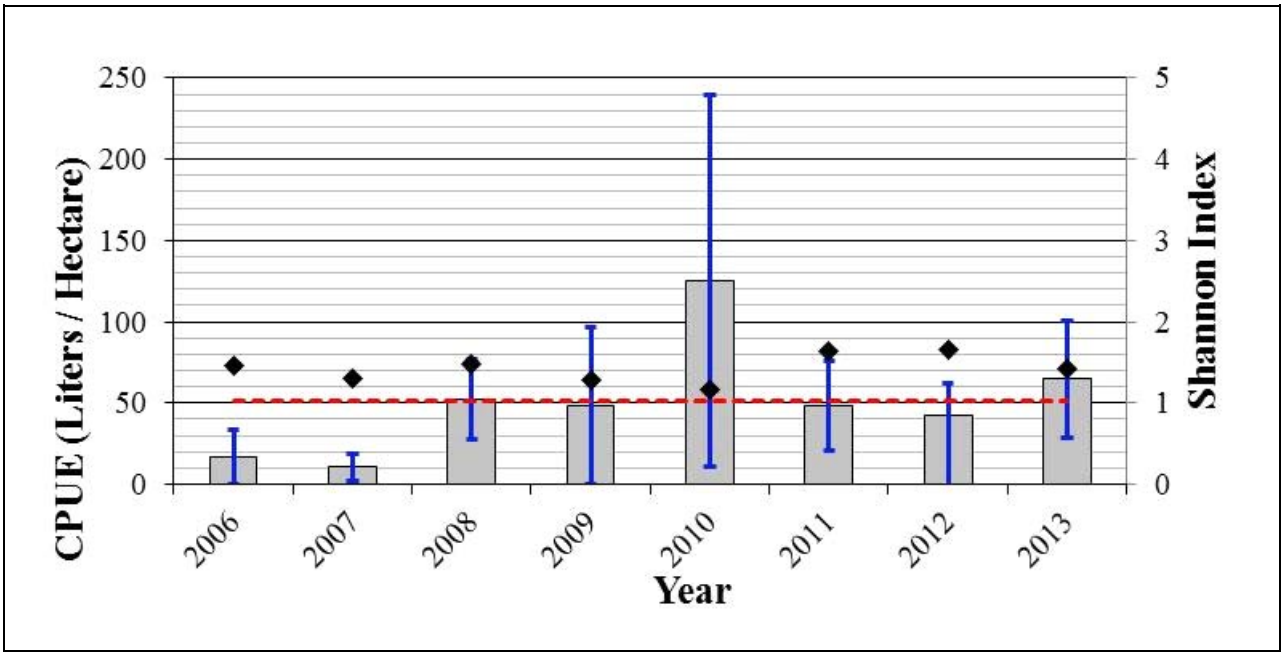

Figure 5.4.12 Coastal Bays Fisheries Investigation Trawl Survey index of Sinepuxent Bay macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006-2013). Red line represents the 2006-2013 time series CPUE grand mean, (n=21/year). Black diamond represents the Shannon index of diversity.

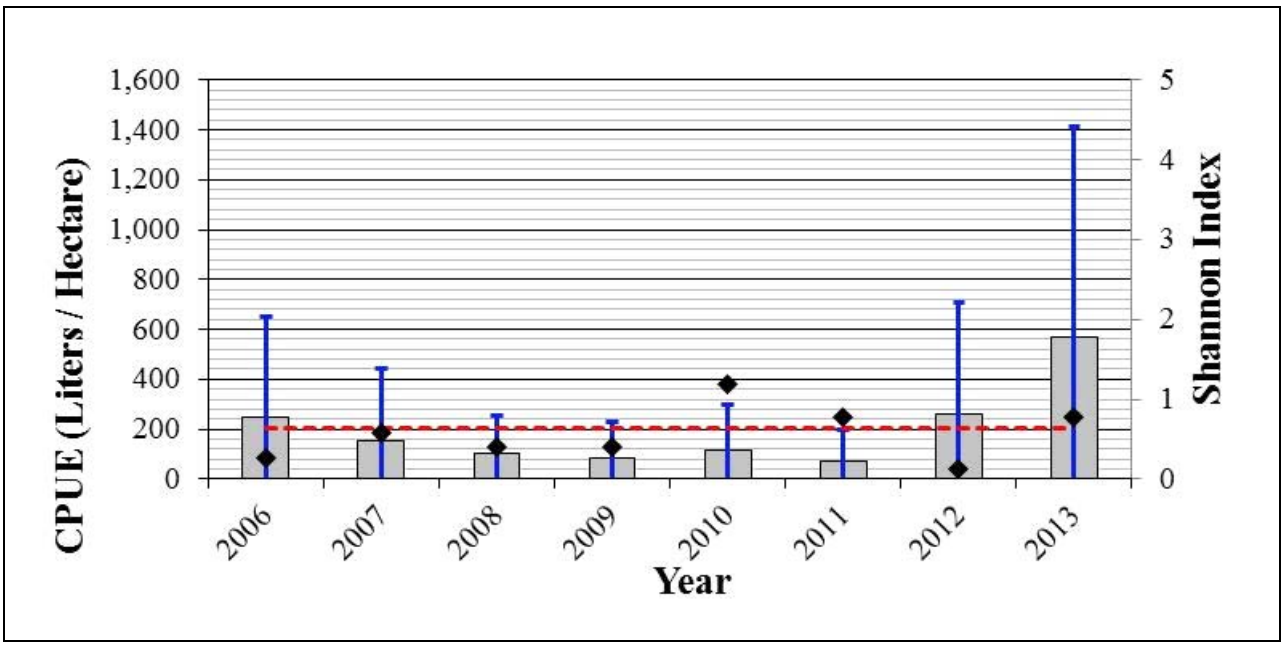

Figure 5.4.13 Coastal Bays Fisheries Investigation Beach Seine Survey index of Sinepuxent Bay macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006-2013). Red line represents the 2006-2013 time series CPUE grand mean, (n=6/year). Black diamond represents the Shannon index of diversity.

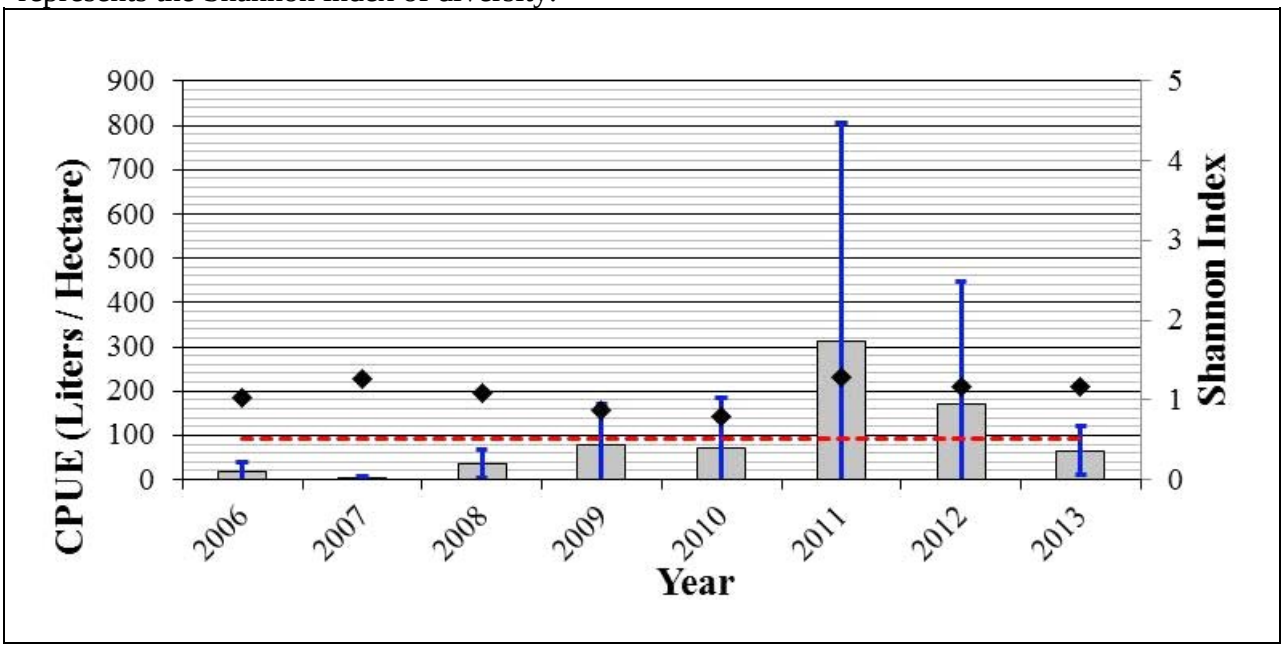

Figure 5.4.14 Coastal Bays Fisheries Investigation Trawl Survey index of relative Newport Bay macroalgae abundance (CPUE; L/ha) with 95% confidence intervals (2006-2013). Red line represents the 2006-2013 time series CPUE grand mean, (n=14/year). Black diamond represents the Shannon index of diversity.

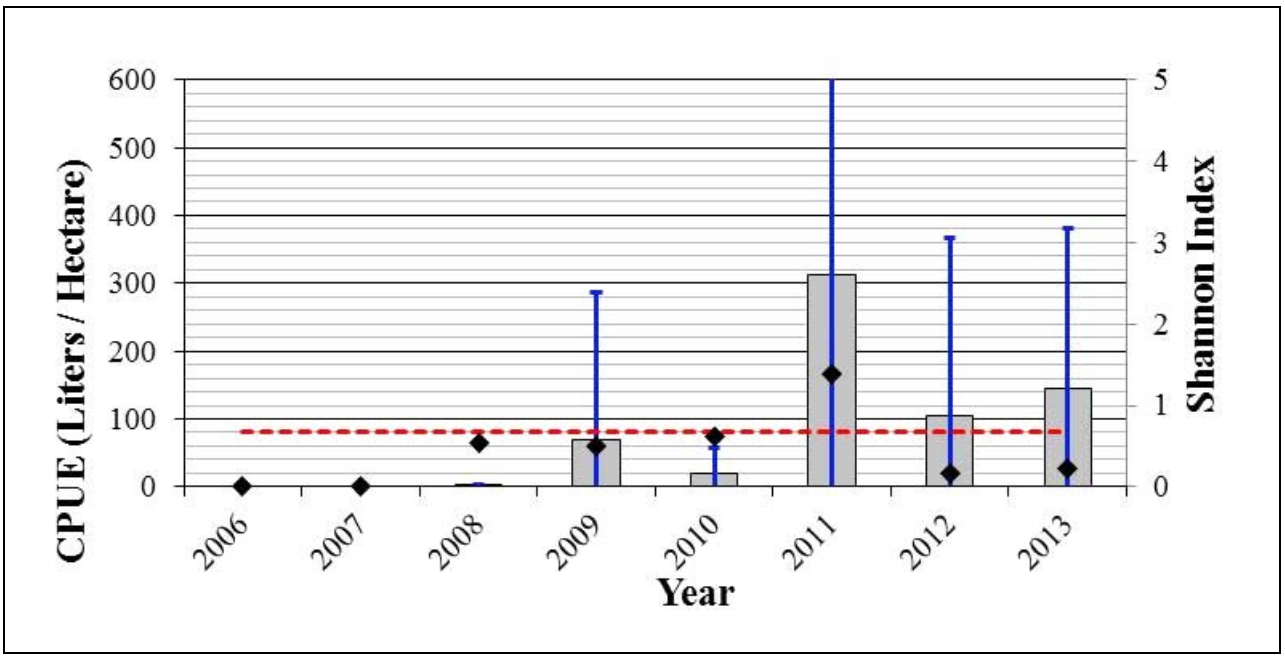

Figure 5.4.15 Coastal Bays Fisheries Investigation Beach Seine Survey index of Newport Bay macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006-2013). Red line represents the 2006-2013 time series CPUE grand mean, (n=4/year). Black diamond represents the Shannon index of diversity.

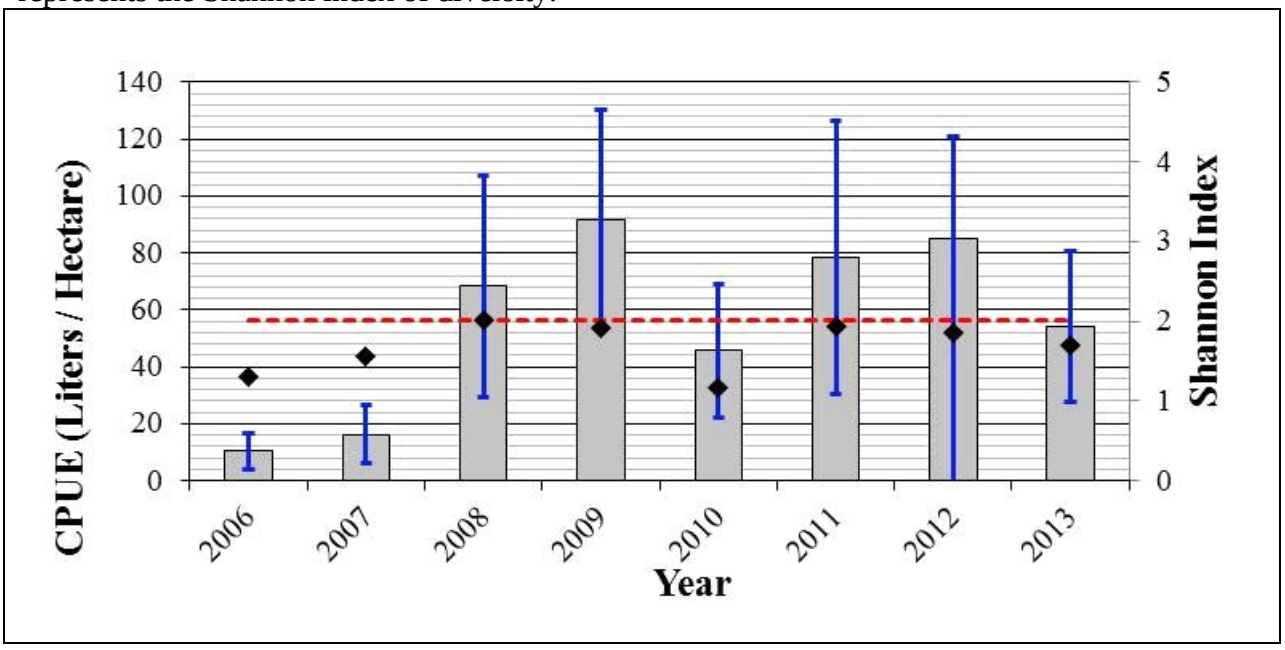

Figure 5.4.16. Coastal Bays Fisheries Investigation Trawl Survey index of Chincoteague Bay macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006-2013). Dotted line represents the 2006-2013 time series CPUE grand mean, (n=56/year). Black diamond represents the Shannon index of diversity.

Figure 5.4.17 Coastal Bays Fisheries Investigation Beach Seine Survey index Chincoteague Bay of macroalgae relative abundance (CPUE; L/ha) with 95% confidence intervals (2006-2013). Red line represents the 2006-2013 time series CPUE grand mean, (n=12/year). Black diamond represents the Shannon index of diversity.

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