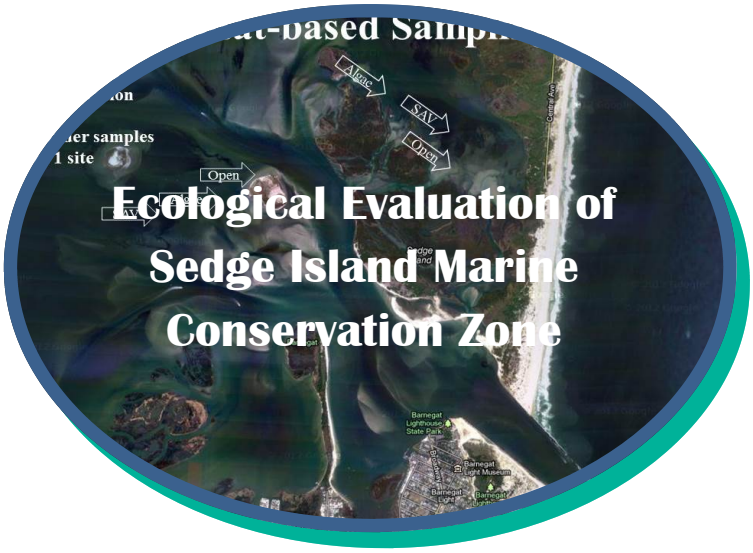
Barnegat Bay—Year 1



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Final Report

Project Title: Ecological Evaluation of Sedge Island Marine Conservation Area in Barnegat Bay

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Executive Summary

Conservation zones are important for maintaining the sustainability of ecosystems and populations of economically important species. The relative ecological value, especially for economically important species, of the Sedge Island Marine Conservation Zone (SIMCZ) in Barnegat Bay, NJ was assessed by comparing the following inside the SIMCZ with areas outside the conservation zone: (1) abundance and species diversity of fish and select decapod crustaceans in three habitats (seagrass, macroalgae, and unvegetated) using throw traps, (2) population structure of adult blue crabs using commercial-style traps, and (3) brood production of adult female blue crabs. Throw trap sampling indicates that blue crabs are most abundant in seagrass as compared to unvegetated habitats. Overall, blue crabs are more abundant outside the SIMCZ than inside but the difference does not apply to each habitat, suggesting the habitats inside and outside the SIMCZ are at least equivalent. Inside and outside the conservation area, species diversity is enhanced in both structured habitats as compared to unvegetated areas and is similar inside the SIMCZ as compared to outside. Again, this suggests the SIMCZ is at least equivalent to a comparative area outside the conservation zone. The SIMCZ has greater

abundance of adult blue crabs, a sex ratio that is more skewed towards males, and a greater proportion of ovigerous females that are about to spawn and show signs of recent spawning. This suggests that the SIMCZ may provide refuge from fishing, particularly for male blue crabs, and may be an important area for spawning females.

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Introduction & Problem Statement

The Sedge Island Wildlife Management Area in Barnegat Bay is located within New Jersey's first Marine Conservation Zone, just off Island Beach State Park. Despite its designation as a Marine Conservation Zone by the Tidelands Council there has been no significant scientific inventory of this environmentally sensitive area, nor an assessment of the essential estuarine habitats in the surrounding conservation zone. Blue crabs are an excellent model organism for assessing the ecological value of the Sedge Island Marine Conservation Zone (SIMCZ). Blue crabs are known to use some of the critical estuarine habitats, such as seagrass, found within the SIMCZ as nursery areas (Jivoff and Able 2001). Fishing and hunting are allowed in NJ's Wildlife Management Areas (NJDEP) during certain seasons and the SIMCZ is adjacent to Barnegat Inlet, where adult female blue crabs potentially congregate in order to spawn (Jivoff, unpublished data); therefore this area may offer minimally disturbed habitats for post-larval crabs and an important refuge from fishing pressure for males and females representing the spawning stock.

The overall goal of the project is to assess the value of the SIMCZ to sustain a key recreational and commercially important species by comparing the following inside the SIMCZ with areas outside the conservation zone: (1) population structure (abundance, size, sex ratio) of adult crabs, (2) adult female reproductive success (size, number and viability of broods produced) and (3) species diversity, abundance and size characteristics of fish and selected decapods (e.g., crabs and shrimp) in three shallow-water habitats (seagrass, macroalgae, and unvegetated).

Blue crabs are one of the most important commercial and recreational fisheries in New Jersey (Kennish et al. 1984; Stehlik et al. 1998) and throughout the mid-Atlantic region (Jordan 1998). Over the past decade, as crab catches continue to decline in the Delaware portion of Delaware Bay (Jivoff, unpublished data), the relative importance of blue crab populations in coastal bays like Barnegat Bay increases (NJDEP data). Therefore it is critical to gather information about the population status and key indicators of population sustainability in blue crab populations in estuaries like Barnegat Bay. This project examines facets of the population structure of adult crabs and aspects of adult female reproductive success inside the SIMCZ relative to similar areas outside the SIMCZ to determine the relative importance of the SIMCZ in contributing to population sustainability of blue crabs in Barnegat Bay.

Factors influencing female reproductive output in blue crabs are still not understood. Female blue crabs may produce several broods of fertilized eggs during their reproductive lifetime; however the actual number is still unknown and may be influenced by a variety of factors including female size, food availability and stored sperm supplies (Hines 1982; Prager et al. 1990; Jivoff 2003; Wolcott et al. 2005). Therefore, the seasonal and lifetime fecundity (number of fertilized eggs produced by a female) of blue crabs in New Jersey, near the northern limit of the blue crab range, may vary from that in other locations, requiring different decisions

to effectively manage New Jersey blue crabs. In Chesapeake Bay, managers established a marine protected area and corridor, specifically to protect adult female blue crabs enroute and within their traditional spawning grounds, that provides a refuge from fishing pressure for a considerable portion of the spawning stock (Lipcius et al. 2003). It is unknown whether the SIMCZ provides the same service in Barnegat Bay. This project examines various aspects of brood production of females in the field and experimentally determines the influence of female size, food level and female location (inside the SIMCZ versus outside the SIMCZ) on various measures of female reproductive output.

Factors influencing post-larval recruitment and the success of juvenile crabs reaching adulthood (i.e., recruiting to the fishery) have been well studied (Wilson et al. 1990; Lipcius et al. 2005; Moksnes and Heck 2006). While some of this work on the success of juvenile crabs has occurred in Little Egg Harbor, the lower portion of Barnegat Bay, there is little to no information on post-larval recruitment of blue crabs in Barnegat Bay proper. One critical factor is the presence of nursery habitats that provide refuge from predation as well as adequate food resources. Many of these habitats including seagrass beds and near-shore shallows are negatively impacted by a variety of human-induced sources including physical impacts (Eckrich and Holmquist 2000) from boat and personal watercraft traffic. Comparing post-larval crab abundance in common habitats inside the SIMCZ (where boat traffic is minimal) with a similar area outside the SIMCZ provides the opportunity to assess the role of the SIMCZ in providing critical habitats for post-larval blue crabs as well as to examine human-induced impacts on blue crab habitat use. This project examines species diversity, as well as the abundance and size characteristics of fish and selected decapods (e.g., crabs and shrimp) in three shallow-water habitats (seagrass, macroalgae, and unvegetated) both inside and outside the SIMCZ.

Project Design & Methods

Sampling Techniques: Adult Blue Crabs

The objective is to examine the temporal and spatial variation in population characteristics of adult blue crabs including a comparison of population characteristics inside versus outside the SIMCZ. Sampling is done using baited (with menhaden) commercial-style traps sampled daily for four consecutive days during each month (May-August 2012). Traps have consistent "soak times" and bait is replaced daily. Sampling occurs in 3 areas that span the width of Barnegat Bay (inside the SIMCZ on the eastern shore of the Bay, in mid-Bay, and on the western shore of the Bay) (Figure 1). Each of the three sampling areas contains 4 replicate sampling sites (Figure 1). Each sampling day, three traps are randomly assigned to one of the four sampling sites within each area and placed at least 50m apart from one another. Crabs are separated by trap in moistened burlap bags, returned to the Rutgers University Marine Field Station, and measured for carapace width, sex, age-class, sexual maturity, molt stage, limb loss (i.e., a non-regenerated limb) and regeneration (i.e., presence of a limb bud), and ovigerous stage (adult females). Sexual maturity and molt stage are determined using previously established methods (Jivoff

1997). Physical characteristics including depth, salinity, temperature, and dissolved oxygen are taken with a hand-held YSI datalogger (model 6820) at the first and last trap in each sampling location. Depth is also be measured with a depth pole marked at 10cm increments and verified using the YSI 6820. The time and tidal stage are also noted.

Sampling Techniques: Field Experiment

The objective is to examine the factors influencing the number, size and timing of broods produced by adult female blue crabs including female size, food, and if captured inside or outside the SIMCZ. Ovigerous females (i.e., those carrying fertilized eggs) were collected in May (thus presumably carrying their first brood of eggs) and held individually in field enclosures partially submerged in the sediment and accessible at low tide (Dickinson et al. 2006) to assess the following factors on the incidence, size, and timing of broods produced: capture location (inside SIMCZ versus outside SIMCZ), carapace width (small, $\leq$125mm; medium, 130-140mm; and large $\geq$145mm), and food level (low=fed once per week or high=fed three times per week). Food levels were based on crabs receiving approximately 100g of fish, from various species, at each feeding. The enclosures were checked three times per week; fouling organisms (e.g., algae) were removed when necessary and females were examined for the presence of a new brood of eggs. The size of each new brood was assessed using previously established techniques (Dickenson et al. 2006 [pp 274-276]). Briefly, the size of broods was assessed by measuring the dimensions of the overall brood: width (laterally at the middle of the brood), length (vertically at the middle of the brood) and depth (thickness of the brood between the ventral surface of the female's carapace and the inside of the ventral flap).

Sampling Techniques: Species Diversity, Abundance and Size of Selected Decapods

The objective is to examine the temporal and spatial variation in population characteristics of juvenile blue crabs (as well as other crustaceans and fish) among three common estuarine habitats existing inside and outside the SIMCZ. Sampling is performed using quantitative samplers (i.e., throw traps) deployed daily for four consecutive days during each month (May-August 2012). Sampling is performed in two areas: inside the SIMCZ and outside the SIMCZ (Figure 2). Each area contains four replicate sampling sites with each site containing the three habitats: seagrass, macroalgae, and unvegetated (Figure 2). Each sampling day, one of the sampling sites in each area is chosen at random and two throw trap sets are performed in each habitat. Throw traps are circular (1.12m diameter x 0.84m tall) and enclose a 1.0m^2 area. Long-handled dip nets with fine mesh are used to sweep the benthos (and nekton) enclosed by the throw trap. Sweeps end when nothing is captured after five successive sweeps. The catch is processed in the field: fish and shrimp are identified to species and total length (of 21 individuals) is measured; crabs are measured for carapace width, sex, age-class, sexual maturity, molt stage, limb loss and regeneration, and ovigerous stage (adult females). Physical characteristics including depth, salinity, temperature, and dissolved oxygen are taken with a hand-held YSI datalogger (model 6820) at each throw trap set. Depth is also measured with a

depth pole marked at 10cm increments and verified using the YSI 6820. The time and tidal stage are also noted.

Sampling Techniques: Reproductive Potential Studies
A daily sample of adult crabs ($n \geq 12$ of each sex) and of ovigerous females ($n \geq 12$) across 6 size classes (100-109, 110-119, 120-129, 130-139, 140-149 and ≥150) from each site are combined in a plastic bag with a label indicating the date, sampling location and site of collection and placed in a freezer (located at the Rutgers Field Station) for subsequent dissection and measurement of reproductive potential using previously established techniques: sperm stores and seminal fluid weight in males; sperm stores, ovarian weight and developmental stage, brood stage and egg number in females.

Quality Assurance
The YSI 6820 handheld data logger, which records temperature, salinity, and dissolved oxygen, is calibrated before and after each field sampling. All water quality testing is performed by a New Jersey laboratory certified person under the requirements of N.J.A.C. 7:18 or laboratories which have formal approval from the NJDEP-Office of Quality Assurance. Certificates of formal approval are specific to the QAPP related analytical testing and are effective until June 30th of every year.

Results & Discussion

Results: Trap Sampling (Adult Blue Crabs)
For the entire sampling period (June-August), more adult blue crabs were captured in the SIMCZ than either location outside the SIMCZ and more male blue crabs, relative to females, were captured inside the SIMCZ as compared to either location outside the SIMCZ (Figure 3). On average the size of adult females was not significantly different among the three sampling areas ($F_{2,166}=0.85$, $P=0.43$), however males did vary significantly in size among the sampling areas ($F_{2,338}=6.03$, $P=0.003$) with males in the west area being significantly larger than males from the mid area and SIMCZ (Tukey HSD, $P<0.05$ for both comparisons) (Figure 4). There was significant variation among the locations in the egg stages of ovigerous females which provide a temporal proxy to the time of spawning (Figure 5). There was a greater percentage of females with early stage eggs (furthest from spawning) in the west area compared to the other areas, whereas a greater percentage of females with mid stage eggs (closer to spawning) and females showing signs of recent spawning (egg remnants) were captured in the SIMCZ (Figure 5). There was significant variation in temperature ($F_{2,78}=21.48$, $P<0.0001$), salinity ($F_{2,78}=20.92$, $P<0.0001$), and depth ($F_{2,78}=28.36$, $P<0.0001$) among the locations during the sampling period. The west area was warmer (Tukey HSD, $P<0.001$ for both comparisons) and lower in salinity (Tukey HSD, $P<0.001$ for both comparisons) than either the mid or SIMCZ. The combination of warmer temperature and lower salinity may increase molting frequency and enhance the size

increment at molting, however, on average, the absolute magnitude of these differences (~3°C, ~1ppt, respectively) and the range of salinity values among the locations (28-29ppt) suggest these physical differences may not adequately explain variation in abundance, sex ratio or size of adult crabs among the locations. Consistent with the cylinder sampling (see below), the SIMCZ was shallower than both areas outside the SIMCZ (Tukey HSD, $P<0.001$ for both comparisons). However, on average, the absolute magnitude of these differences (~50cm) and the range of depths among locations are well within those used by adult blue crabs.

Results: Throw Trap Sampling (Species Diversity, Abundance and Size of Selected Decapods)
A total of 11 species of fish and 11 species of decapods were captured in the SIMCZ as compared to 17 species of fish and 13 species of decapods outside the SIMCZ (Table 1). Both inside and outside the SIMCZ, structured habitats (algae and SAV) contained a greater number of species (Figure 6A) and had larger Shannon-Weiner Indexes (Figure 6A) than the open habitat. Only inside the SIMCZ did the structured habitats differ in the number of species present with SAV containing more species than algae (Figure 6A). Only when the measure of species diversity is the number of species (i.e., species richness) were there diversity differences between the locations. In open and algae habitats, there were more species present outside the SIMCZ as compared to inside the conservation zone (Figure 6A). These differences disappear when the Shannon-Weiner Index is used as a measure of diversity (Figure 6B) because this index incorporates both species richness (number of species) and evenness (relative abundance of each species). Therefore, the indexes of the open habitats are relatively low compared to the other habitats because several species may have been captured in open habitats, but only one or two numerically dominate that habitat whereas the relative abundance of the different species in structured habitats was more uniform.

The abundance of blue crabs varies significantly among the habitats ($F_{2,164}=8.35$, $P<0.0001$) and between the locations ($F_{1,164}=6.88$, $P=0.01$). Both inside and outside the conservation zone, more blue crabs were captured in SAV as compared to either the algae or open habitats (Figure 7). On average, more blue crabs were captured outside the SIMCZ as compared to inside (Figure 7). However, pairwise comparisons of similar habitats between locations did not reveal significant differences between the locations, perhaps because of the variation in the abundance of crabs per sample.

With the exception of depth, none of the physical variables varied significantly between locations or among habitats (Figure 8). Depth varied among habitats with open habitats shallower than the structured habitats, particularly inside the SIMCZ (Figure 8). However, the absolute differences are, on average, no more than 20cm (Figure 8) suggesting the presence of structure is more important than depth in explaining differences among the habitats and between locations. This suggests that physical variation does not explain the differences observed in species diversity and in the abundance of blue crabs. I propose that habitat differences in these response variables are probably due to biological features, such as differences in recruitment to these areas, rather than physical features. Sampling results from September support this hypothesis. The average size of crabs captured in throw traps markedly decreased in September

as compared to August in both structured habitats inside (August=28.7mm $\pm$ 25.2 SD vs September=13.3mm $\pm$ 6.4 SD) and outside (August=22.6mm $\pm$ 23.0 SD vs September=6.9mm $\pm$ 4.7 SD) the SIMCZ, suggesting recruitment of first year blue crabs to these areas. If only the abundance of first year crabs ($\leq$ 10mm) is considered, more of these recruits were captured outside the SIMCZ (67) as compared to inside (10).

Results: Reproductive Potential Studies

A delay in getting the field experiment established as well as mortality of adult females limited the amount of data collected on brood production from this experiment. Several females produced broods during the experiment but we have no data on individual females producing multiple broods.

In adult females, measures of reproductive potential include ovary weight (a proxy of available eggs for future brood production) and seminal receptacle weight (a proxy of available sperm for future egg fertilization). A female's ovigerous status may help explain variation in both of these measures, therefore ovigerous females were distinguished from non-ovigerous females. Indeed, ovary weight did not vary according to location ($F_{2,79}$=1.13, P=0.33), however non-ovigerous females had significantly heavier ovaries than ovigerous females ($F_{1,79}$=41.21, P<0.0001) and this occurred in each location (SIMCZ, $F_{1,7}$=66.97, P<0.0001; mid, $F_{1,39}$=18.19, P<0.0001; west, $F_{1,33}$=12.54, P=0.0001) (Figure 9). Female seminal receptacle weight did not vary by ovigerous status ($F_{1,79}$=3.41, P=0.07) or location ($F_{2,79}$=0.62, P=0.54) but non-ovigerous females had significantly heavier seminal receptacles than ovigerous females in the mid ($F_{1,39}$=5.43, P=0.03) and west ($F_{1,33}$=5.21, P=0.03) locations (Figure 10). There were more non-ovigerous females in the mid and west locations that showed signs of recent mating as compared to the SIMCZ suggesting the SIMCZ may be more important for spawning than for mating.

In adult males, measures of reproductive potential include weights of the vas deferens components that are passed to females during copulation; spermatophores and seminal fluid. Male seminal fluid weight did not vary among the locations ($F_{2,132}$=1.46, P=0.24) but male spermatophore weight did ($F_{2,132}$=6.72, P=0.002) with males in the west containing significantly more spermatophores than both the mid (Tukey HSD, P=0.008) and the SIMCZ (Tukey HSD, P=0.004) (Figure 11). On average, males in the west (136.2 $\pm$ 13.8SD) were larger than males in the mid (136.2 $\pm$ 13.8SD) and SIMCZ (136.2 $\pm$ 13.8SD), however this difference was not statistically significant.

Conclusions and Recommendations for Future Research

Trap sampling revealed some potentially interesting differences in adult blue crabs inside the SIMCZ as compared to areas outside the SIMCZ, including overall greater abundance of crabs and particularly more male-biased sex ratios. One potential impact of the lack of commercial fishing inside the SIMCZ (especially during the summer) may be a preponderance of males since more males are taken by the commercial fishery at this time of year. Thus, relaxed fishing pressure may benefit male blue crabs and skew the adult sex ratio inside the SIMCZ. The results

indicate that adult female blue crabs do not accumulate in the SIMCZ, similar to spawning grounds in other estuaries, however adult females in the SIMCZ are indeed closer to spawning and more often show signs of recent spawning compared to areas outside the SIMCZ. Thus, the SIMCZ may represent an important area for the spawning stock of blue crabs in Barnegat Bay.

Throw trap sampling suggests the SIMCZ is at least equivalent to a comparative area outside the conservation zone in terms of species diversity (especially when both species richness and evenness are accounted for) but, overall the abundance of blue crabs is greater outside the conservation zone. The physical characteristics are similar inside and outside the SIMCZ, but one factor that may influence the abundance of blue crabs and other species in these areas is recruitment to these areas. The area outside the SIMCZ is inundated directly with water entering the estuary via Barnegat Inlet whereas this water must travel through marsh channels of various sizes to reach much of the SIMCZ (see Figure 2). As a result, early life history stages of organisms carried into the estuary via the inlet may have more direct access to the area outside the conservation zone. To test this idea, in the future, the relative abundance of early life history stages (e.g., megalopae) of blue crabs being delivered to the sampling areas will be assessed. Both inside the SIMCZ and outside, structured habitats help enhance species diversity and provide important habitats for blue crabs. Algae habitats tend to show more variation in species diversity and the abundance of blue crabs compared to the other habitats and both the degree and type of vegetative cover may help explain some of this variation. In the future, estimates of the degree of vegetative cover and the type of cover present will be noted.

Recommendations and Application and use by NJDEP

Given the potential for both within and between year variation in the dependent as well as independent variables in this study, recommendations and application for use of these results should be tempered by the fact that this represents only one year of a (planned) three year study. The results of the first year of this project suggest that the SIMCZ is at least ecologically equivalent to a comparative area outside the conservation zone, thus providing NJ-DEP some quantitative justification for designating the area around the Sedge Islands a conservation zone.

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Appendices

Results from this research were presented at the annual Fall meeting of the Atlantic Estuarine Research Society as an oral presentation entitled: "The relative ecological value of the Sedge Island Marine Conservation Zone in Barnegat Bay, NJ." by Jivoff, P., Kels, J., McCarthy, J. Moritzen, L, Young, A.

Figures & Tables

Table 1. Abundance of each species captured via throw trap in each habitat inside and outside of the SIMCZ, May-September 2012.

		Inside SIMCZ			Outside SIMCZ			
		Habitat			Habitat			
Common Name	**Species Name**	**open**	**algae**	**sav**	**open**	**algae**	**sav**	**Total**
Fish								
4-spine stickleback	*Apeltes quadracus*	7	227	551	7	90	281	1163
American eel	*Anguilla rostrata*			3		1	1	5
bay anchovy	*Anchoa mitchilli*					1		1
black sea bass	*Centropristis striata*					2	1	3
cunner	*Tautogolabrus adspersus*			6		17	8	31
feather blenny	*Hypsoblennius hentz*		1					1
mummichog	*Fundulus heteroclitus*		1	2				3
naked goby	*Gobiosoma bosc*	1	1		1	25	9	37
oyster toadfish	*Opsanus tao*						1	1
pinfish	*Lagodon rhomboides*						1	1
pipefish	*Syngnathus fuscus*		5	8	1	4	26	44
seahorse	*Hippocampus erectus*					1		1
silver hake	*Urophycis regia*				1			1
silver perch	*Bairdiella chrysoura*		2	7			4	13
silverside	*Menidia menidia*	7	55	4	5		1	72
summer flounder	*Paralichthys dentatus*			1	3		2	6
tautog	*Tautoga onitis*					5	1	6
tomcod	*Microgadus tomcod*					1		1
winter flounder	*Pleuronectes americanus*	8	14	25	4	6	13	70
Decapods								
blue crab	*Callinectes sapidus*	3	32	59	5	127	152	378
grass shrimp	*Palaemonetes pugio*		260	615	1	133	496	1505
green crab	*Carcinus maenas*		21	26		65	18	130
green shrimp	*Hippolyte sp.*		112	245	2	159	187	705
horseshoe crab	*Limulus polyphemus*					1		1
Japanese shore crab	*Hemigrapsus sanguineus*						1	1
lady crab	*Ovalipes ocellatus*	4	1		2			7
long nose spider crab	*Libinia dubia*					1	1	2
mud crab	*Neopanopeus sayii*	1	122	140		133	339	735
mud shrimp	*Callianassa atlantica*		1					1
pea crab	*Pinnixia sp.*	1	1	1		2	1	6
rock crab	*Cancer irroratus*	10	58	15	2	170	12	267
sand shrimp	*Crangon septemspinosa*	220	412	94	300	288	155	1469
spider crab	*Libinia emarginata*	1	8	8	3	36	15	71
Habitat Total		**263**	**1334**	**1810**	**337**	**1268**	**1726**	**6738**

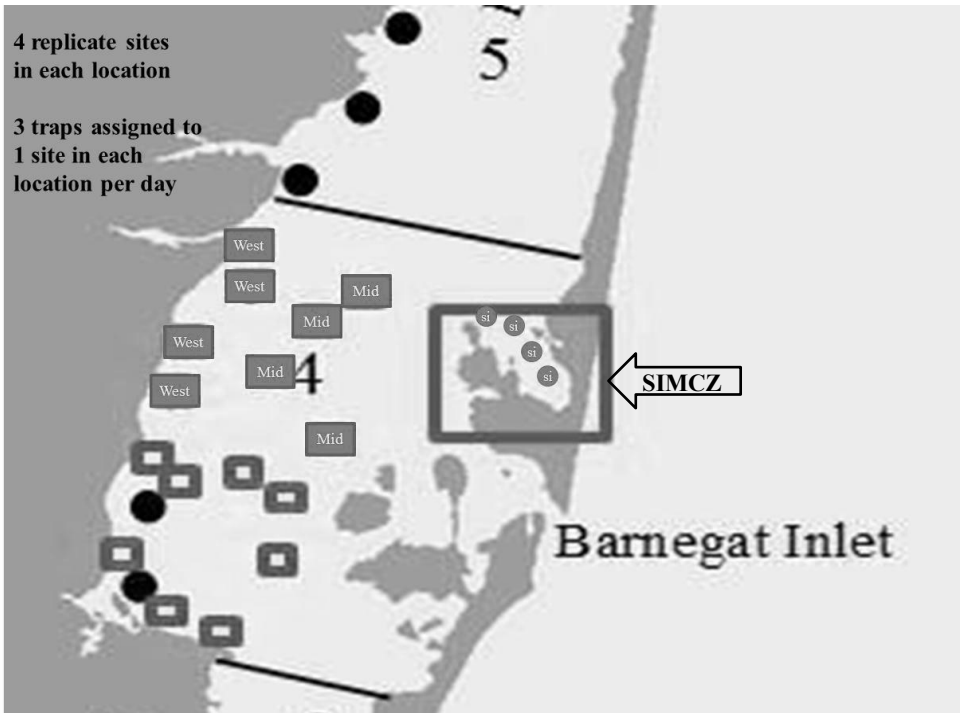

Figure 1. Approximate locations of trap sampling sites. The three locations are "west", "mid" and "si". The other symbols do not pertain to this study. The arrow indicates the SIMCZ.

Figure 2. Approximate locations of throw trap sampling sites inside and outside the SIMCZ. s=SAV, a=Algae, o=Open.

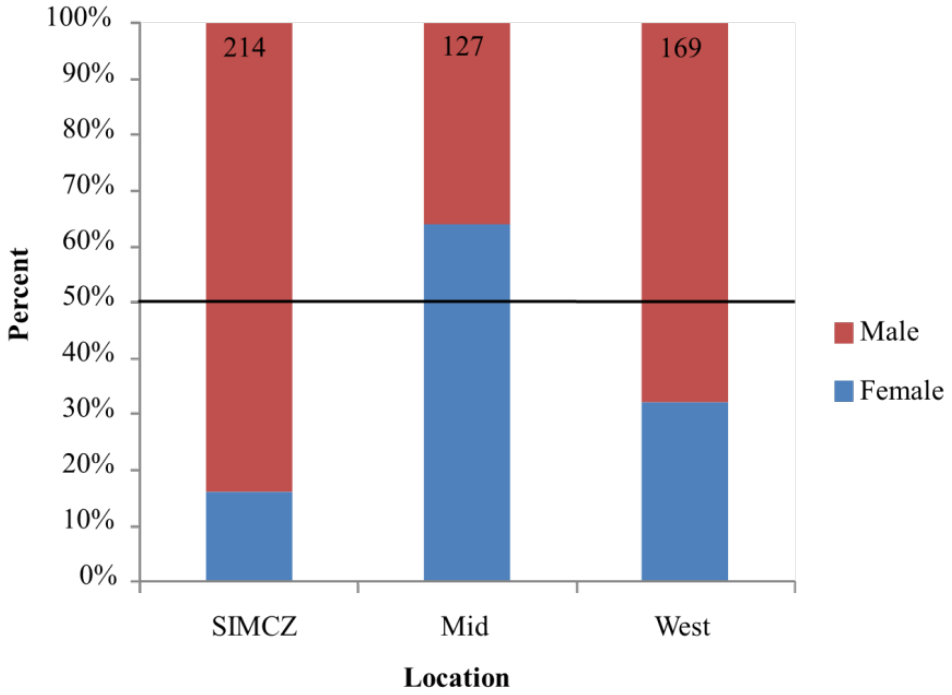

Figure 3. Abundance of blue crabs (numbers inside the bars) and percentage of each sex captured in the SIMCZ, mid, and west areas of the bay, June-August 2012. The horizontal line indicates a 1:1 sex ratio.

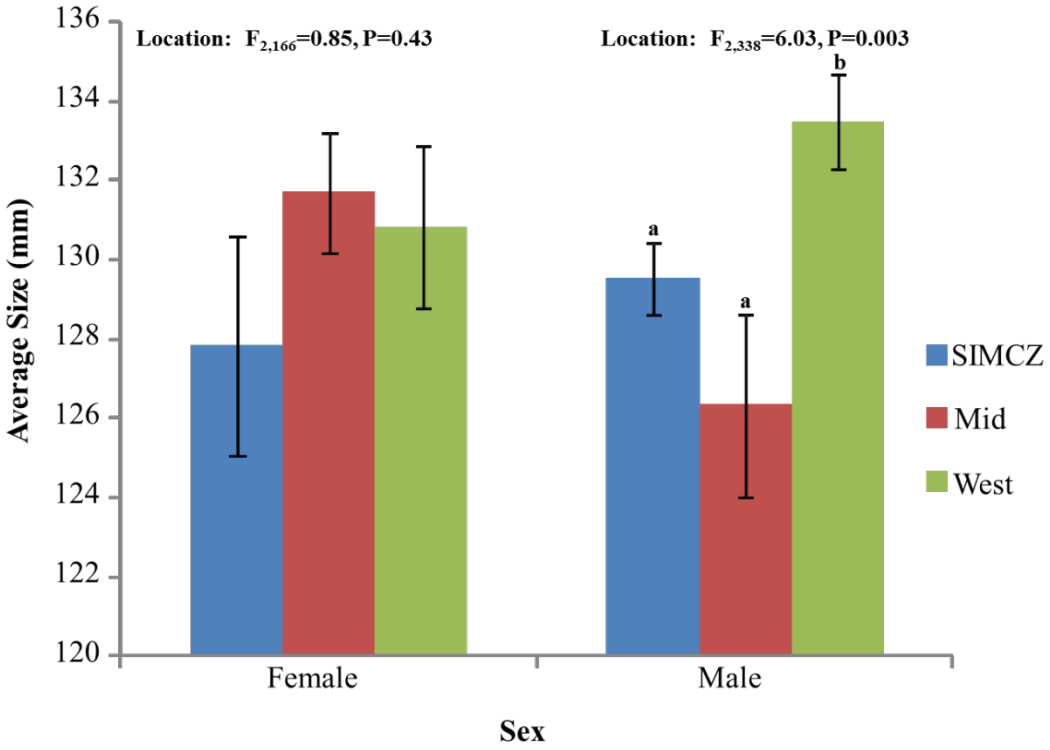

Figure 4. Average (± 1 SE) size of male and female blue crabs captured in the SIMCZ, mid, and west areas of the bay, June-August 2012. Bars within each sex sharing the same letter are not significantly different.

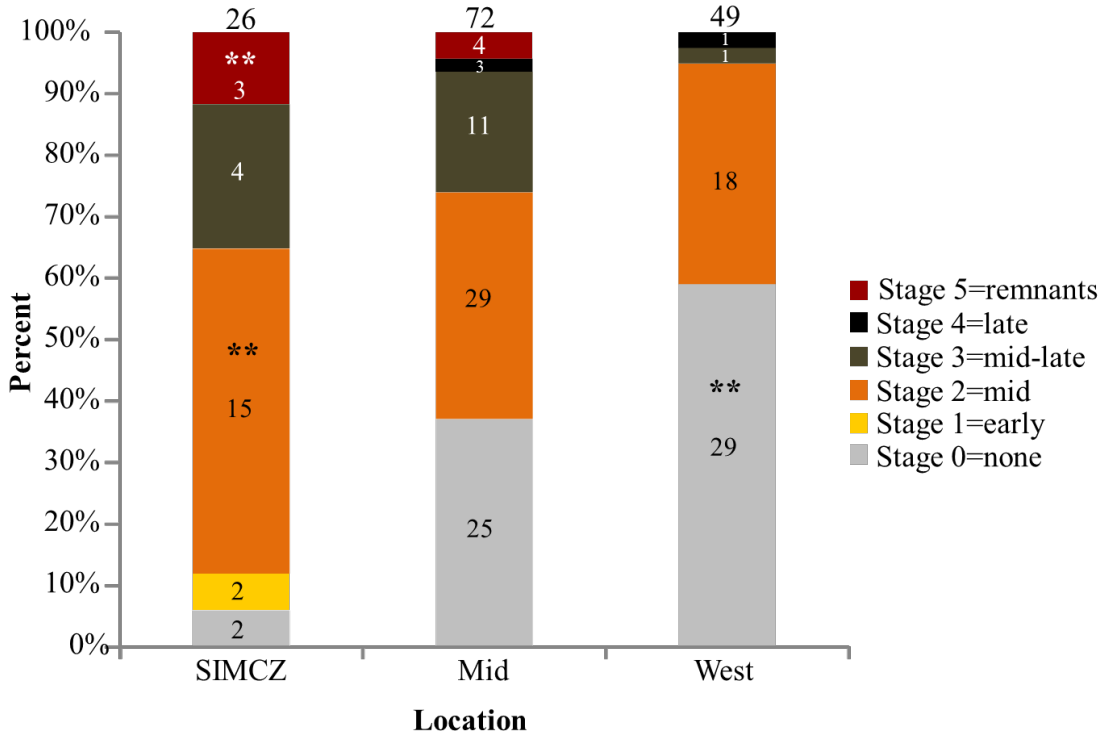

Figure 5. Percentage of females in various stages of egg development captured in the SIMCZ, mid, and west areas of the bay, June-August 2012. Numbers above the bars indicate sample size of females in each area. Numbers inside each stage correspond to sample size of females in each stage. **P<0.001 within stage comparisons among locations.

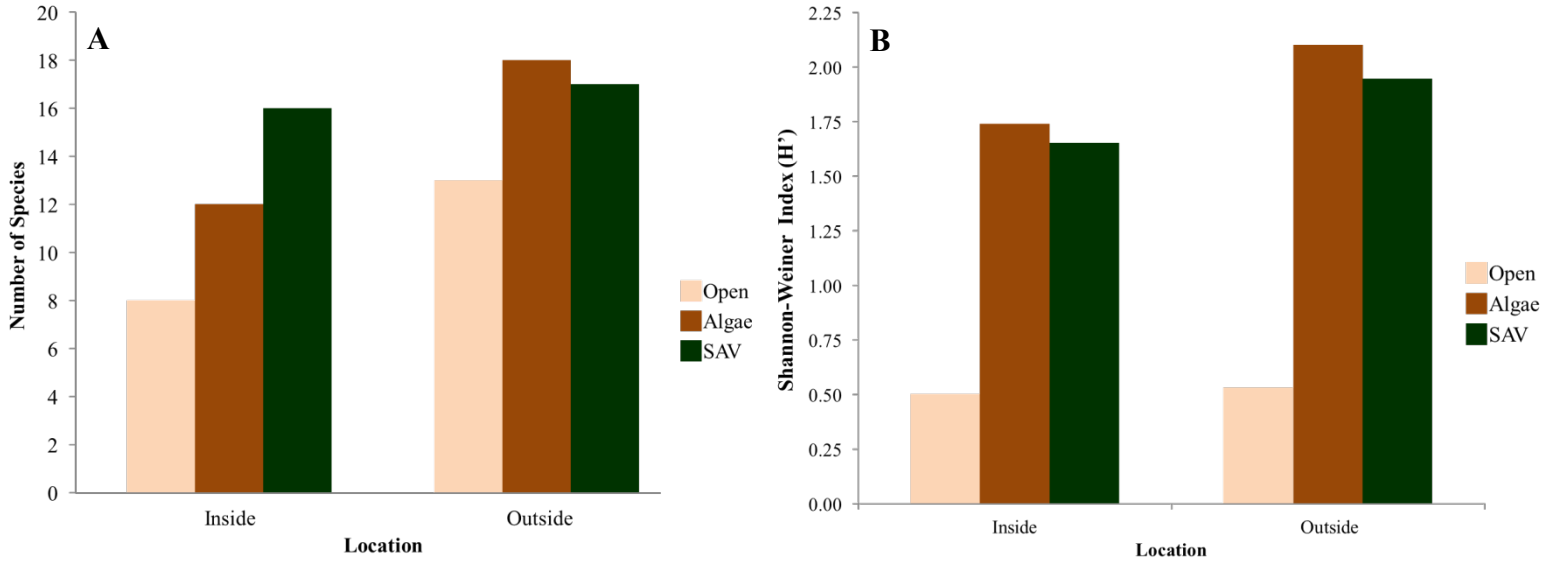

Figure 6. A. Number of species; B. Shannon-Weiner Index in three habitats inside and outside the SIMCZ, June-August 2012.

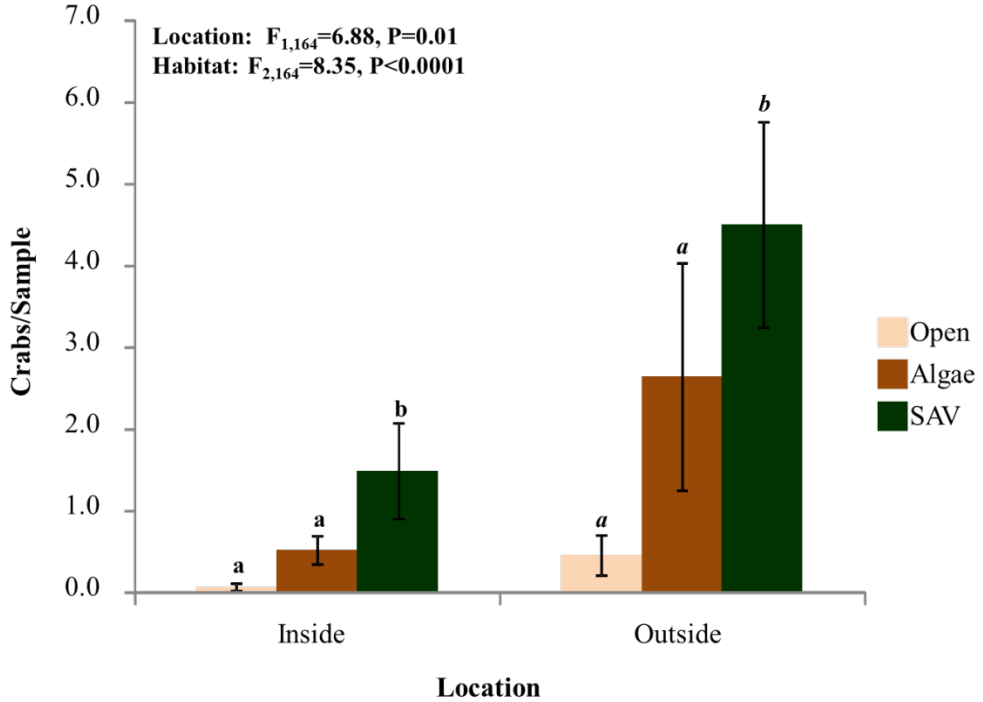

Figure 7. Average (± 1 SE) number of blue crabs per sample in three habitats inside and outside the SIMCZ, June-August 2012. Bars within a location sharing the same letter are not significantly different.

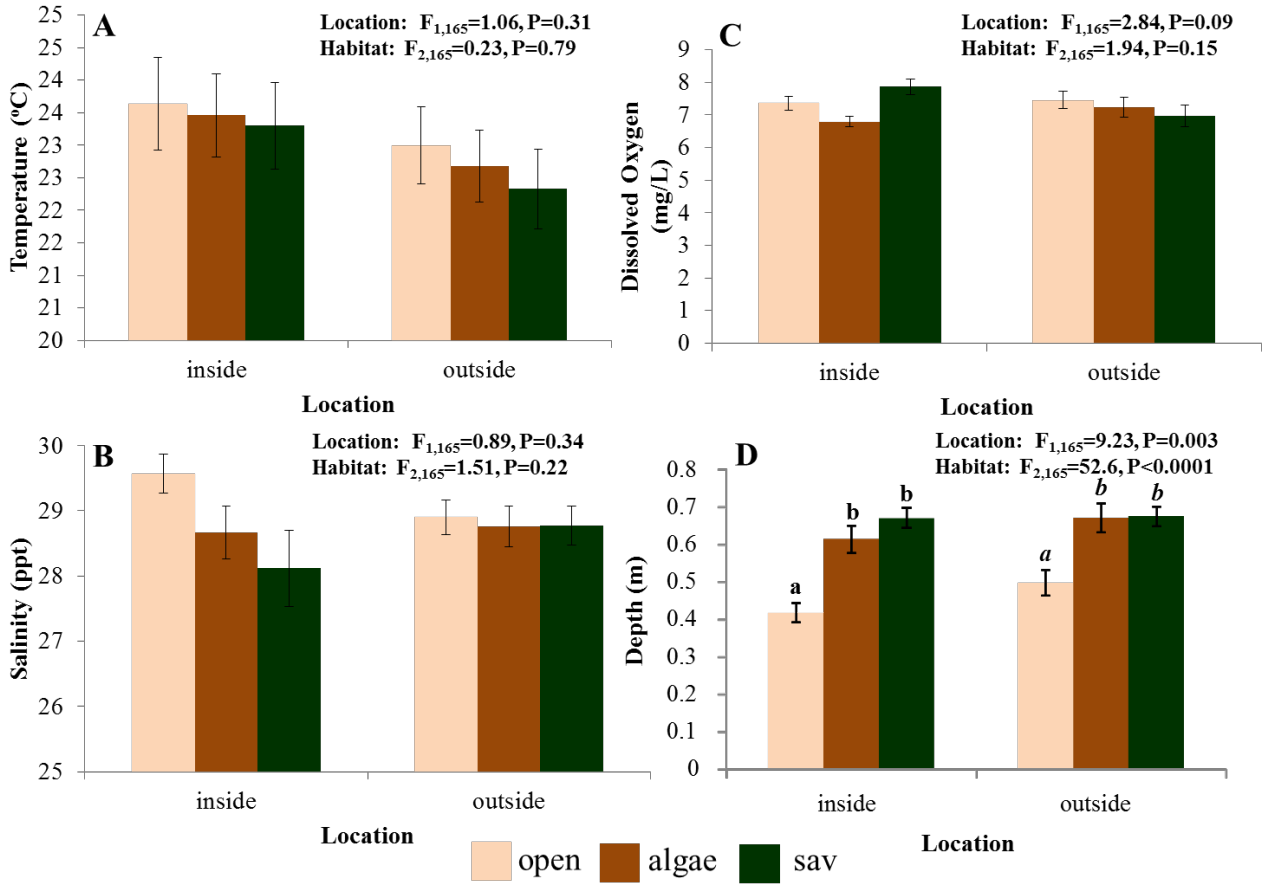

Figure 8. Average (± 1 SE) physical variables in three habitats inside and outside the SIMCZ, June-August 2012: A. Temperature, B. Salinity, C. Dissolved Oxygen, D. Depth. Bars within locations sharing the same letter are not significantly different.

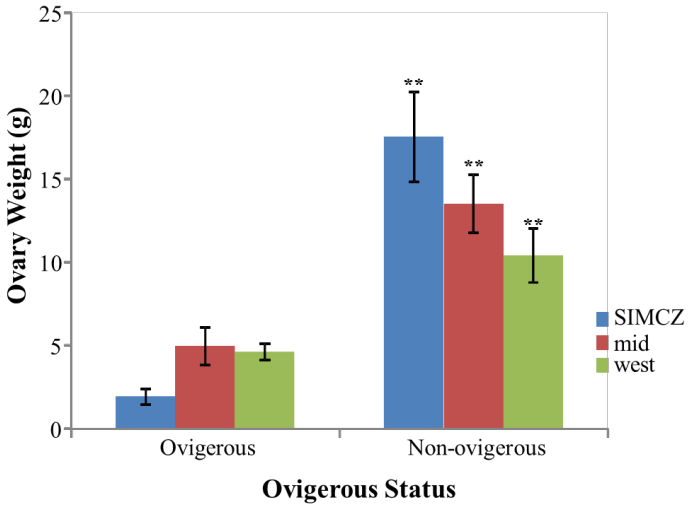

Figure 9. Average (± 1 SE) ovary weight of ovigerous and non-ovigerous female blue crabs in the SIMCZ, mid and west areas of the bay. Asterisks indicate comparisons between ovigerous versus non-ovigerous females within each location. **P<0.001.

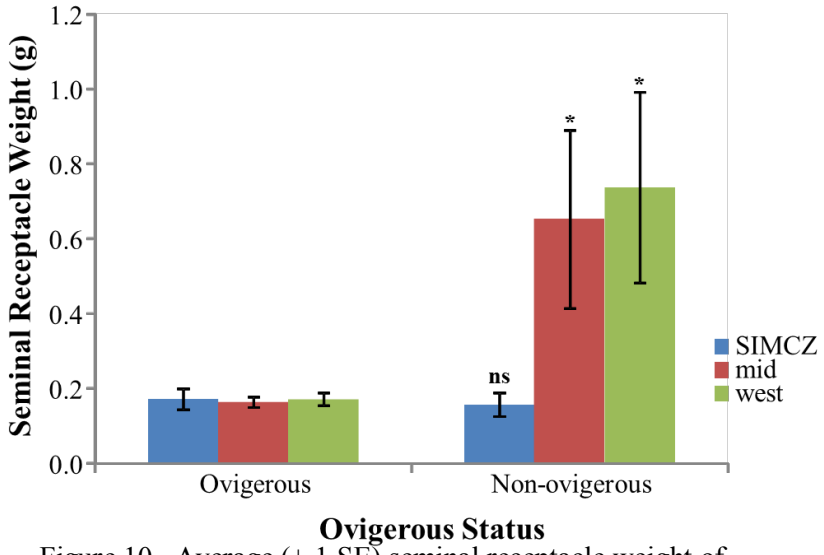

Figure 10. Average (± 1 SE) seminal receptacle weight of ovigerous and non-ovigerous female blue crabs in the SIMCZ, mid and west areas of the bay. Asterisks indicate comparisons between ovigerous versus non-ovigerous females within each location. *P<0.05.

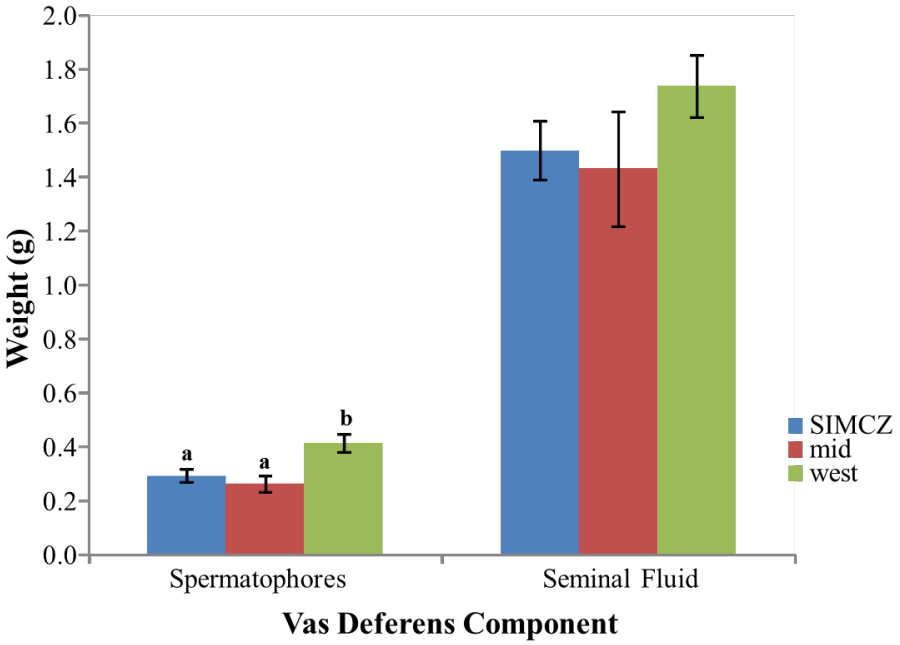

Figure 11. Average (± 1 SE) weight of spermatophore and seminal fluid components of male vas deferens in the SIMCZ, mid and west areas of the bay. Letters above bars indicate comparisons of component weight among locations. Bars sharing the same letter are not significantly different, P<0.01.