Assessment of high marsh occupation by populations of the fiddler crab *Uca pugnax* across salt marsh system on the CT shore

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Abstract

Changes in salt marsh structure due to sea level rise and increasing tidal inundation appear to be associated with *U. pugnax* expanding its habitat range from low to high salt marsh tidal zones (Luk and Zajac 2013). Ten Connecticut salt marsh systems were field surveyed between June and July 2013 to determine the extent of this phenomenon. *U. pugnax* was found occupying high marsh habitats in several Connecticut marsh systems in addition to the sites researched by Luk and Zajac (2013). At sites where *U. pugax* abundances were present, counts per 1.0 m^2 crab corrals ranged from 0.71 ± 5.98 to 43.25 ± 7.91 and 1.16 ± 0.16 to 2.60 ± 0.23 per 0.25 m^2 video transect quadrats. Highest abundances were associated with bare ground patches, however no trends were found among vegetative patch types, burrow counts, mussel counts, or distances from low marsh habitats. Surveyed high marsh sites without *U. pugnax* presence had steeply sloped and narrow low marsh habitats. These patterns reveal that the habitat expansion of *U. pugnax* is a complex phenomenon among salt marsh systems. The presence of bare ground in the high marsh and the site-specific low marsh habitat availability appear to be linked to the habitat expansion of *U. pugnax* populations in Connecticut salt marsh systems.

Introduction

Uca pugnax is a common fiddler crab species of the North American Atlantic coast and is regularly found within *Spartina alterniflora* low marsh habitat (Teal, 1958). Changes in salt marsh structure due to increased tidal inundation may be allowing *U. pugnax* populations in the northeast portions of its range to expand from low to high salt marsh tidal zones (Luk and Zajac 2013). The burrowing preference of *U. pugnax* for mud substrate with roots in *Spartina alterniflora* (Teal, 1958; Bertness and Miller, 1984) may not limit population expansion in response to increased tidal inundation.

Relatively high numbers of *U. pugnax* burrows and live individuals were recorded in Luk and Zajac's study in high marsh habitats containing *Distichlis spicata*, *Spartina patens*, and *Phragmites australis*. These plants are typical dominants of dryer high marsh substrates (Niering and Warren, 1980), and generally unfavorable for *U. pugnax* burrowing (Teal, 1958; Jaramilo, 1988). Luk and Zajac (2013) also found live *U. pugnax* to be active in high marsh patches dominated by short *S. alterniflora* and associated plants. The presence of live *U. pugnax* with low numbers of burrows in high marsh habitats could be a result of tidal inundation on CT Long Island Sound (LIS) salt marshes (Luk and Zajac, 2013).

Over the past several years, Zajac and undergraduate and graduate students substantiated the use of high marsh habitats by significant numbers of fiddler crabs in one marsh system in Branford Connecticut. However it is not known to what extent this potential habitat expansion is taking place in other marsh systems. The objective of this study was to assess the abundance of *U. pugnax* in high marsh habitats at several marshes along the CT coast to determine whether the trends found by Luk and Zajac (2013) are pervasive across salt marsh systems in different geographic locations.

Materials and Methods

To assess to extent at which *U. pugnax* occupy high marsh habitat, field surveys were conducted at ten salt marsh systems along the Connecticut coast (Figure 1). Field data were acquired between June and late July of 2013. Marsh surveys were conducted during the day around low slack tide. The marsh sites studied were Lordship Boulevard (Stratford), Farm River, Pleasant Point North/West, Banca Back/Upper (Branford), Chaffinch, Trolley Road (Guilford), and Barn Island (Stonington). A Niantic marsh system off Old Black Point Road was surveyed but no quantitative data was obtained because no crabs were found in the high marsh (Figure 1).

Quadrats/Crab Corrals

A 1.0 m^2 quadrat with 10cm high walls (referred to as a crab corral) was deployed at multiple random points to trap crabs. Crabs were counted, sex determined and gravid females were recorded. For some corrals, the sizes of the crabs were also measured using carapace width. Burrows and live mussels (*Geukensia demissa*) attached to substrate were counted in each quadrat. Photos and GPS coordinates of the quadrats were obtained. Photos were analyzed by CPCe software (www.nova.edu/ocean/cpce/) to quantify the vegetation types per quadrat using percent cover based on 50 random points superimposed on the image. GPS coordinates were used to calculate distances to the nearest creek and mosquito ditches using ArcGIS. One-way analysis of variance (ANOVA) tested differences in crab abundances among patch types to determine if the habitat expansion of *U. pugnax* is dependent on vegetative species. To analyze differences in high marsh structure and characteristics, crab abundances, mussels, burrows and percent cover of dominant patch types were tested with an ANOVA by site. Regressions were performed to find a correlation of crab abundance, mussels and burrows by mosquito ditch and creek distances. All statistical analyses were conducted using NCSS software.

Video Transects

Crab abundances were also estimated using video transects at six study sites (Figs. 1 and 6). Video data were obtained using a GoPro camera fixed to a 2.30 meter pole in order to minimize crab scattering as the transects were videoed. High marsh sites were surveyed prior to transect path recordings to choose routes with a diverse set of habitats modeling bare ground, pool and vegetated areas. Before recording a transect line, the camera pole apparatus was held over a $0.25m^2$ quadrat for reference. Transect walking speed was 0.898 ± 0.04 mph (mean ± S.E.) and the distances of transects ranged from 18m (Lordship Boulevard, Stratford) to 83 m (Banca Back, Branford). Video transects were later analyzed using VLC media player (www.videolan.org/vlc/index.html) at slow playback speeds. The border dimensions of the recorded reference quadrat were traced on a clear plastic sheet that was affixed to the computer monitor to count crabs and identify presence/absence of bare ground, pool, and vegetative species per every incremental $0.25m^2$ quadrat from each transect. Abundances of crabs among sites, patch types, and patch groups were analyzed using ANOVA.

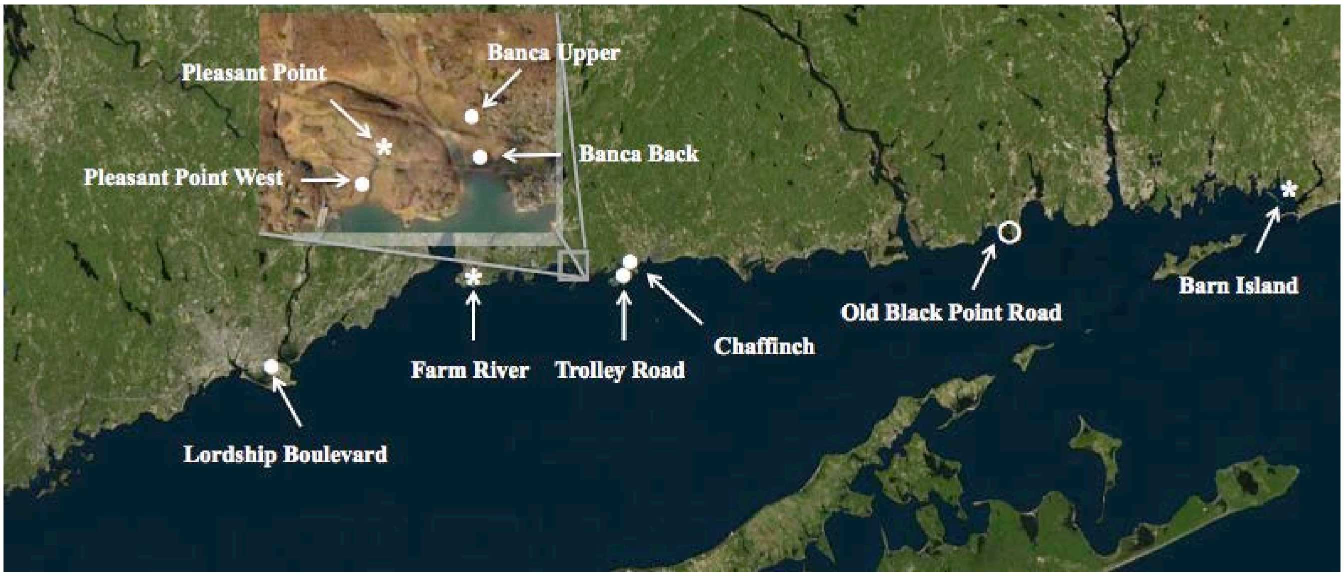

Figure 1: All surveyed marsh locations. Solid circle indicates that both corrals and transect(s) were conducted, an asterisk (*) where only corrals were completed with the exception of video transects, and the open circle signifies that neither corrals nor video transects were utilized.

Results

Quadrats/Crab Corrals

Mean *U. pugnax* counts per 1.0 m^2 among marsh sites were significantly different ($P < 0.05$) ranging from 0.71 ± 5.98 (Barn Island) to 43.25 ± 7.91 (Banca Upper) (Table 1 and Fig. 2). Dominant patch types (Fig 4) and mean mussel and burrow counts (Fig. 3) were also significantly different between all sites surveyed (Table 1). *Spartina alterniflora*, *Spartina patens*, *Distichlis spicata*, and bare ground were the major patch types present within the quadrats (Table 1 and Fig. 4). Mean crab abundances were significantly different among patch types (Fig. 5), however linear regressions with distances from marsh creeks and mosquito ditches showed no relationship. Mean burrow and mussel counts were not significantly different among patch type and creek/mosquito ditch distance variables. However, it should be noted that the number of crab burrows on the high marsh was usually considerably lower than the abundance of *Uca (*Figs. 2 and 3).

Video Transects

Based on video transect data, mean *U.pugnax* counts per $0.25m^2$ were significantly different among sites (Fig. 6) with means ranging from 1.16 ± 0.16 (Banca Back) to 2.60 ± 0.23 (Trolley Road). Thirty-eight small-scale patch types were identified in the videos and mean *U. pugnax* abundance was determined in these patch types (Fig. 7). Significant differences were found among these patch types as well. The small-scale patch types were grouped more broadly based on presence of bare ground, pools, or just vegetated (Fig. 8). The criteria of patch type designation for each quadrat was as follows: 1.) >60% = single dominant patch type, 2.) two patches between 30-60% = shared patch type and 3.) three or more patch types between 20-50% = MIX. The highest mean abundances of *U. pugnax* were found in patches that had bare areas, followed by patches that had pools, and lowest in wholly vegetated patches (Fig. 8).

Location	Site	Quadrats	Dominant Patch Types Mean % per 1.0m² ± S.E.				Mean Count per 1.0m² ± S.E.		
			Spartin alterniflora (short)	*Spartina patens*	*Distichlis spicata*	Bare Ground	Mussels	Burrows	*U. pugnax*
		n	P-value < 0.01	P-value < 0.01	P-value < 0.01	P-value < 0.01	P-value < 0.01	P-value < 0.01	P-value < 0.01
Stratford	Lordship Blvd.	8	84.88 ± 7.62	0.00	0.00	15.12 ± 5.41	1.13 ± 1.33	0	1.25 ± 5.59
Branford	Farm River	4	10.50 ± 10.77	71.0 ± 14.96	4.0 ± 7.17	14.50 ± 7.65	0.75 ± 1.88	42.5 ± 4.15	18.50 ± 7.91
	Pleasant Pt. West	9	42.36 ± 7.18	21.11 ± 9.97	0.00	35.14 ± 5.10	3.33 ± 1.26	3.11 ± 2.77	23.89 ± 5.27
	Pleasant Pt.	10	47.14 ± 7.18	9.95 ± 9.97	0.00	42.90 ± 5.10	3.9 ± 1.19	0.4 ± 2.62	21.70 ± 5.0
	Banca Back (6/5/2013)	5	39.33 ± 9.63	32.40 ± 13.38	0.00	26.60 ± 6.84	11 ± 1.69	1.60 ± 3.71	34.40 ± 7.08
	Banca Back (7/24/2013)	3	66.71 ± 12.44	0.00	0.00	33.29 ± 8.83	0.67 ± 2.18	1.67 ± 4.79	39.33 ± 9.14
	Banca Upper	4	54.23 ± 12.44	8.64 ± 17.27	0.00	36.46 ± 8.83	0.25 ± 1.88	1.25 ± 4.15	43.25 ± 7.91
Guilford	Trolley Rd.	3	65.31 ± 12.44	0.00	0.00	34.69 ± 5.41	38.67 ± 2.18	27 ± 4.79	34.33 ± 9.14
	Chaffinch	10	6.32 ± 6.81	47.09 ± 9.46	35.82 ± 4.53	10.16 ± 4.84	0.5 ± 1.19	2.40 ± 2.62	4.0 ± 5.0
Stonington	Barn Island	7	49.30 ± 8.14	40.20 ± 11.31	0.00	6.16 ± 5.78	1.29 ± 1.42	1.14 ± 3.4	0.71 ± 5.98

Table 1: Mean *U.pugnax* and mussel counts per 1.0 m^2 ± S.E. (p-values below) gathered at nine separate marsh systems. Dominant patch type data from CPCe 50 random point analysis was calculated as mean % per 1.0m^2 ± S.E. (P-values below) for each site. All displayed data was statistically significant (p<0.05) through an ANOVA test.

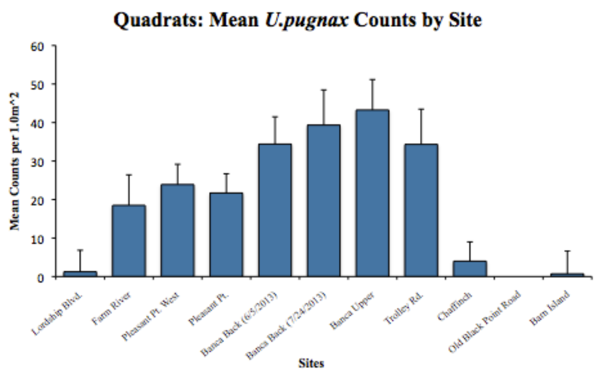

Figure 2: Mean ± S.E. *U.pugnax* from 1.0m^{-2} quadrat crab corrals at all marsh systems (Table 1). Sites on the x-axis are ordered georgrahically west to east.

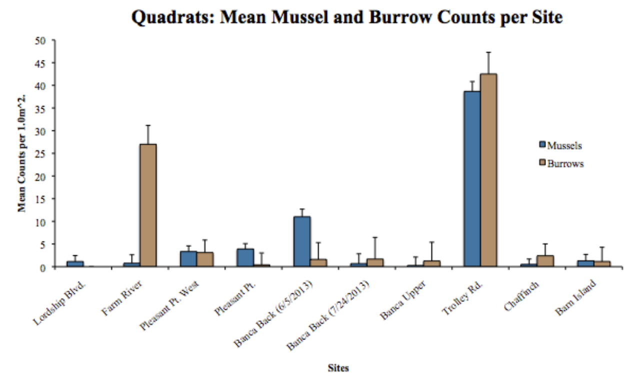

Figure 3: Mean ± S.E. mussel (*G. demissa*) and burrow counts per 1.0 m^2 for all sites.

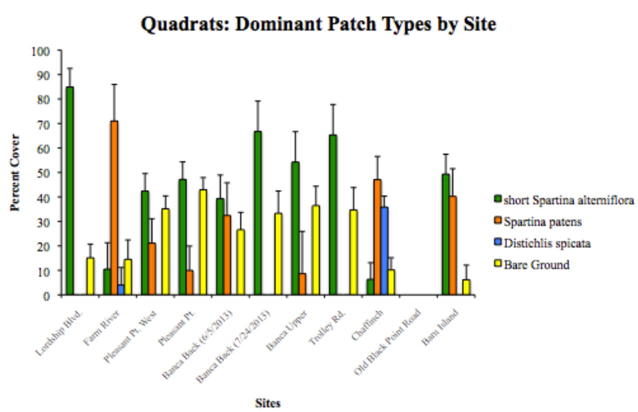

Figure 4: Dominant vegitation types. Mean % cover ± S.E. per 1.0 m^2 at each marsh site (Table 1).

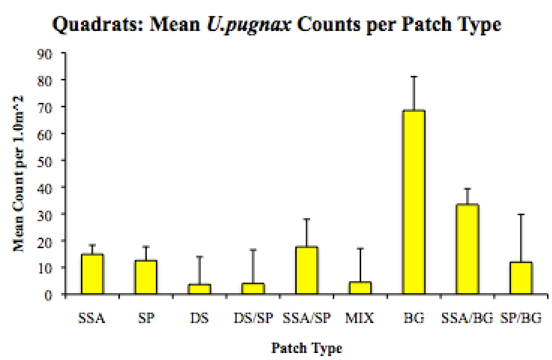

Figure 5: Mean ± S.E. *U.pugnax* counts by patch type for all marsh sites (p = 0.0019). Similar to Figure 4, patch types are displayed here from the same CPCe data. The categorical patch type abreviations refer to: short *Spartina alterniflora* (SSA), *Spartina patens* (SP), *Distichlis spicata* (DS), mixture of 3+ types (MIX) and bare ground (BG).

Location	Site	Transects n	Mean Quadrat Count ± S.E.	Mean Crab Count per 0.25m^2 ± S.E. P - value < 0.01
Stratford	Lordship Blvd.	1	71	1.52 ± 0.48
Branford	Farm River	-	-	-
	Pleasant Pt. West	4	167.75 ± 10.62	1.70 ± 0.16
	Pleasant Pt.	-	-	-
	Banca Back (6/5/2013)	-	-	-
	Banca Back (7/24/2013)	2	332.5 ± 10.5	1.16 ± 0.16
	Banca Upper	3	270 ± 123.54	2.52 ± 0.14
Guilford	Trolley Rd.	2	152.50 ± 59.5	2.60 ± 0.23
	Chaffinch	3	179.33 ± 7.67	1.72 ± 0.17
Stonington	Barn Island	-	-	-

Table 2: Mean crab counts ± S.E per 0.25m^2 quadrats and for transects completed on six sites.

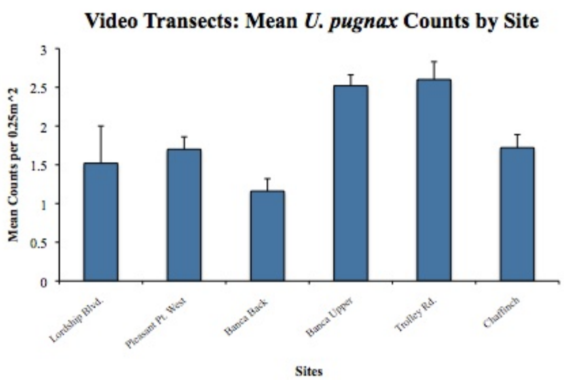

Figure 6: Mean ± S.E. *U. pugnax* counts per 0.25m^2 quadrats (Table 2) from transect videos (ANOVA test, P < 0.01).

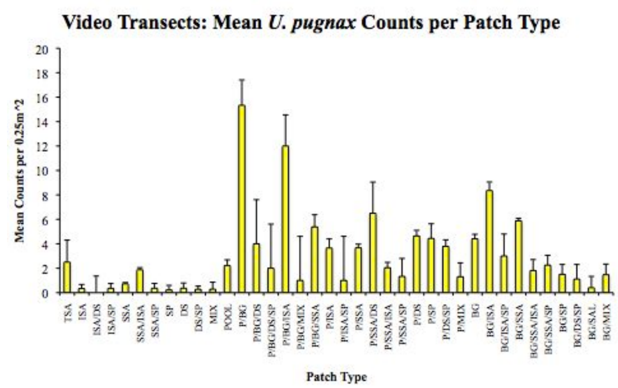

Figure 7: Mean *U.pugnax* counts per 0.25m^2 ± S.E. for patch types recorded in fifteen total transects (ANOVA test, P < 0.01). Patch types were determined by presence/absence within incremental quadrats of video transects. Common patch type abreviations are the same as in Figure 5, with the exception of “MIX” refereing to three or more vegetative species. Additional types present are as follows: tall *Spartina alterniflora* (TSA), intermediate *Spartina alterniflora* (ISA), *Salicornia europaea* (SAL) and pool (P).

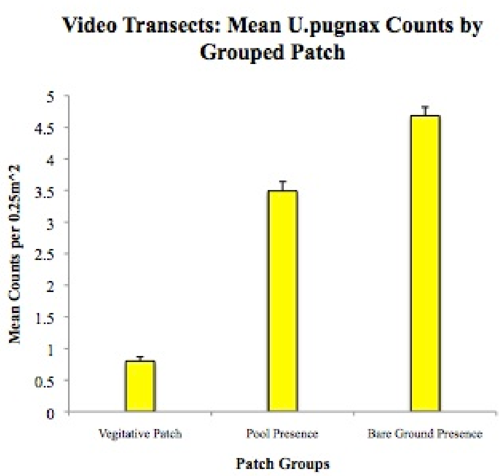

Figure 8: All data from Figure 7, divided into three groups of vegetative patch, pool, and bare ground (ANOVA test, p < 0.01). Patches signified as pool and bareground (Figure 7, “P/BG..etc.”), were designated as “Pool Presence”.

Discussion

U. pugnax is occupying high marsh habitats in several Connecticut marsh systems in addition to the sites surveyed by Luk and Zajac (2013). However, sparse *U. pugnax* at Barn Island, Lordship Boulevard and Old Black Point Road show the marsh-specific variability in the expansion of *U. pugnax* from low marsh habitat. Both corral and video transect methodology showed the same trends in terms of broad-scale patterns and patch preferences of *U. pugax* abundances. However, to reveal the marsh dynamics that correspond with high marsh crab abundances, it is essential to first compare the corral and video transect data and methodology.

The general approach of both methods was similar in this study, but *U. pugnax* abundances are considerably different between both datasets (Tables 1 and 2). Both the corrals and transects resulted with significantly different *U. pugnax* abundances by site, however the larger and physically searched 1.0 m^2 corrals contained greater mean crabs counts than 0.25 m^2 incremental video transect quadrats. Evident from Figure 8, crabs in video transects were efficiently quantified in bare ground and pool patch types, seemingly facilitating crab identification by exposing movement of individuals without visual obstruction by vegetation. This may appear as a visual bias, but the corral data coincide with highest *U. pugnax* counts also favoring the bare ground patch type (Fig. 5). Discrepancies do exist between corral and transect methods and the variables they offer, but the data they provide can be used to assess crab occupation of high marsh habitats.

A site not studied by Luk and Zajac (2013) was Trolley Road. This site contained comparable high marsh *U. pugnax* abundances to previously studied Banca and Pleasant Point marshes (Figs. 2 and 6). Trolley Road also had the highest mussel and burrow counts in this study (Fig. 3). The filter feeding mechanism of mussels indicates that the Trolley Road marsh is subject to regular tidal flooding. Bertness (1984) suggests that although *U. pugnax* prefer intermediate muddy substratum for burrowing, they are unable to maintain burrows in frequently flooded areas without vegetation. The Trolley Road site had short *S. alteriflora* at 65.31% cover as its one vegetative type (rest as bare ground) (Table 1 and Fig. 4), but the high density of mussels and burrows per 1.0 m^2 demonstrates it is a flooded area with substratum for burrowing. Short *S. alterniflora* was prevalent at Lordship Boulevard (84.88% cover) and Banca Back (66.71% cover) (Table 1 and Fig. 4), but mean mussel and burrow counts were much lower than at Trolley Road (Fig. 3). As do the other marsh sites, Trolley Road appears to support Warren and Neirring's (1993) finding of high marsh conversion to *S. alterniflora* forbs as a result of increasing tidal range at another CT marsh. Salt marshes subject to this change may have slower sedimentation rates that result in longer periods of flooded high marsh (Warren and Niering, 1993), providing intermediate muddy substratum that may allow for burrowing by *U. pugnax* (Bertness, 1984). Trolley Road is a site that appears to be experiencing low marsh expansion from increased tidal inundation. This could explain the higher mean *U. pugnax* counts found at Trolley Road than systems with similar vegetative assemblages (Tables 1 and 2).

The high numbers of burrows at Trolley Road were in areas that appeared to be converting to low marsh habitat, however the high burrow counts at Farm River were not (Fig. 3) and suggest that *U. pugnax* can expand readily into different types of high marsh habitat. *S. patens*, a mid-high marsh species favoring dryer substratum than *S. alterniflora* (Niering and Warren, 1980), had an average of 71.0% cover on the high marsh at Farm River (Table 1). Luk and Zajac (2013) also found habitat expansion and residency of *U. pugnax* in *S. patens* high marsh habitats. The *S. patens* at Farm River were observed to be very wet and this may allow for increased burrowing. The vegetation assemblages of all other sites were more mixed with respect to plant composition (Fig. 4).

None of the dominant % per 1.0 m^2 patch types (Figure 4) had a correlation with mean *U. pugnax* counts. However, the high marsh plant community structure was highly variable. *D. spicata* was not a prevalent vegetation type across all marshes,; it was only found in a high percent cover at Farm River and Chaffinch (Table 1). Short *S. alterniflora*, *S. patens* and bare ground were common in nearly all marshes with significantly different percent cover (Table 1). Significantly different mean *U. pugnax* counts by patch type reveals that their abundances are widespread and varied in high marsh habitats (Figs 5, 7 and 8).

Bare ground patch type contributed to the greatest abundances of *U. pugnax* (Figs. 5, 7 and 8). Mean *U. pugnax* was highest in corrals where bare ground was >60% (Fig. 5) and video transect quadrats where bare ground was present (Figs. 7 and 8). It can be concluded by crab corral and video transect data of this study that bare ground areas in high marsh systems are favored by greater abundances of *U. pugnax* over pool and vegetated patches (Figs. 5 and 8). There were significant differences among patch types in mussel and burrow counts but no relationships between crab abundance and distances to creek/mosquito ditches. The reasoning behind the preference of bare ground by *U. pugnax* at these marsh systems is not clear, but may be tied to herding or other behaviors, and needs further study.

Transects were not conducted on marsh sites where either the high marsh was limited and/or *U. pugnax* were found to be sparse based on visual observations (Fig. 1). Observations of the Barn Island system revealed that the low marsh habitats along mosquito ditches and creeks areas were narrow and steeply sloped. This characteristic was also found at the Old Black Point Road salt marsh system where neither quadrats nor transects were conducted because of the scarcity of *U. pugnax* in low marsh habitats; none were found on the high marsh. It is possible that the area and physical configuration / geomorphology of low marsh habitats is a limiting factor affecting the size of *Uca* populations on marshes; in turn any habitat expansion that may occur as high marsh areas become altered due to increased tidal inundation

Conclusion

U. pugnax populations were found in high marsh habitats in several Connecticut salt marsh systems in addition to sites researched by Luk and Zajac (2013). High marsh *U. pugnax* abundances were greatest within bare ground patches (Figs. 5 and 8). This suggests that habitat expansion by *Uca* may be more prevalent in high marsh zones that have large amounts of bare area. Significant differences in burrows, mussels and vegetation types between all sites demonstrate that no one salt marsh system is identical to another. The habitat expansion of *U. pugnax* appears to be a complex phenomenon, likely influenced by multiple marsh characteristics and dynamics, some of which were not addressed in this study.

Further research should target salt marsh characteristics that were not looked at in this study. How steeply sloped and narrow expanses of low marsh, observed at Barn Island and Old Black Point Road, affect the ability of crabs to occupy high marsh habitat should be further researched. These sites had considerably low or no *U. pugnax* in the high marsh (Fig. 2). Also, additional data should be collected to determine the extent of available low marsh habitat areas and the abundances of *U. pugnax* in the low marsh in other systems in order to compare them to adjoining high marsh habitats. Although it is known that high abundances of *Uca* are found in the low marsh, these types of data would provide a more detailed context for the significance of high marsh expansion of *U. pugnax*, particularly since high marsh areas are generally much greater in extent than low marsh zones

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Background

Sam Gurr is currently a senior anticipating graduation in May 2014 from the University of New Haven with a B.Sc. in Marine Biology and Chemistry minor. He has high hopes to pursue graduate education at a laboratory specializing in the research of ocean acidification. The SURF program provided him with a strong research background that will be utilized in his career future.

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