Distribution and abundance of juvenile intertidal bivalves in the San Juan Islands, WA

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Zoobots

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Abstract

Adult distribution of intertidal bivalve communities is dependent on larval success and juvenile survival. Finding and predicting juvenile presence is crucial to understanding the mechanisms determining adult abundance. I sampled seven intertidal areas on San Juan Island, representing various wave exposures, sediment compositions, and beach slope to determine where juveniles are present and what factors might predict their presence. Juvenile clams were found at six of the seven sites sampled, in highest abundance at British Camp and Bell Point on the northeastern tip of the island, dominated by *Nutricola* spp. Juveniles of *Mysella tumida*, *Saxidomus giganteus, Protothaca staminea, Macoma inquinata,* and *Macoma nasuta* were also found. Clam assemblages seem to be site-specific, rather than being driven by tidal height or other individual environmental factors. Within sites, shell hash, mud and granules the best predictors of presence or absence of juveniles.

Introduction

Quantifying distribution and abundance of species is essential for the understanding of community structure and ecological interactions, and maintenance of these systems. Soft-sediment intertidal zones are ecologically, economically, and recreationally important interfaces between life on land and sea. The infauna of these areas provide a vital food source to shore birds and other intertidal predators, and appeal to humans as a relatively easily accessible fishery (Beukema et al. 2010, Hunt and Scheibling 1997). Soft-sediment species, especially clams and other common shellfish, are sought for commercial and individual consumption, driving an interest in their management and conservation. Bivalves act as ecosystem engineers, as their shells can be colonized by epibiotic communities, and affect species diversity in the soft-sediment system overall (Gribben et al. 2009).

Abundance and diversity of adult infaunal organisms can vary with location, wave exposure, and sediment type, but these distributions may be determined before an individual reaches adulthood (Hunt and Sheibling 1997). Populations of intertidal infauna follow a progression of larval recruitment and settlement before reaching the juvenile stage, and finally the adult stage (Beukema 1993, Beukema et al. 2010, Hunt and Sheibling 1997). Site selection and settlement success of larvae can depend on substrate type, wave action, feeding strategies, and a number of biotic factors, such as predation and competition (Beukema et al. 2010, Hunt and Sheibling 1997). The juvenile stage, however, is considered a crucial juncture. Thorson (1966) estimated that more than 98% of juvenile intertidal bivalves die before reaching adulthood. A later review confirmed juvenile mortality exceeded 90% in two-thirds of the infaunal species reviewed (Gosselin & Quain 1997).

In Puget Sound, Washington, adult infaunal diversity varies along an estuarine gradient, but this variation is not reflected in larval recruitment along the sound (Dethier 2010). Understanding distribution of juveniles may offer insight into the factors influencing this disconnect between the larval and adult distributions. These insights would inform harvest or conservation efforts of these valuable infaunal organisms (Hunt and Scheibling 1997).

This study will focus on intertidal bivalves as a key player in soft-sediment intertidal communities, and investigate the juvenile stage as an intermediate between settlement and adulthood. Intertidal clam populations have received more attention elsewhere in the Salish Sea, but the distribution of juvenile bivalves remains undescribed in the San Juan Islands. This study will quantify the distribution and abundance of juvenile intertidal bivalves in the San Juan region. Target species will include *Clinocardium nuttallii, Saxidomus giganteus, Protothaca staminea, Mysella tumida, Nutricola* spp. and *Macoma* spp. This data will provide a basis for comparison to the distribution and abundance of adult populations and may offer insight into the ecological structure of these infaunal communities.

Methods

I sampled seven beaches on San Juan Island for the presence of juvenile clams, with sites representing various wave exposures, sediment types, and beach slopes (Fig. 1). At each site (excluding False Bay), I collected five sediment samples haphazardly along 30-m transects at three tidal heights (-1, 0, 1 ft). Sediment was scooped from the surface of an 8 x 13 cm plot, to the depth of approximately 5 cm, with total sample size standardized by surface area rather than volume. Most samples were approximately 120 ml. I characterized sediment composition in three location at each tidal height by percent cover of various grain sizes (cobble 6-25 cm, pebble 4 mm-6 cm, granule 2-4 mm, sand <2 mm, shell hash, mud) at both the surface and subsurface (3-5 cm deep), 0.1 m^2 quadrats. Tidal height and beach slope were determined using predicted tide tables and laser level surveying equipment. False Bay, a mosaic mudflat that can reach 1 km^2 at low tide, required an altered sampling plan. Samples were taken from four regions of the flat: East Sand, West Sand, High Cobble, and Middle Earth. East Sand, West Sand, and High Cobble were along a transect at 4.1 ft, and Middle Earth was at 3.3 ft.

I sieved the sediment samples on a 1-mm mesh, preserving clams in isopropyl alcohol. Live clams were identified to species, when possible, by external characteristics.

I used crystal violet dye (aka. Gentian violet) to clarify the pallial line for distinguishing *Saxidomus giganteus* and *Nutricola* spp.

I used the Shannon-Weiver index to compare diversity of juvenile communities. I calculated the index for each site, summed across tidal heights, and for each tidal height, summed across all sites (excluding False Bay) to evaluate the affect of these groupings on diversity.

Results

The seven sample sites represent a range of sediment types and beach slopes (Table 1). Jackson Beach, the site which experiences the highest wave energy, is dominated by granules at the surface and subsurface (Tables 2 & 3). Fourth of July Beach, a wave-exposed eelgrass bed, has mostly sand at lower tidal heights, and granules at +1 ft. All samples were collected above the eelgrass line but the lower tidal levels had substantial ulvoid cover. Bell Point and British Camp, adjacent sites on the northeastern tip of San Juan Island, have similar sediment composition: sand and shell hash at the surface, and mud and sand at the subsurface level. British Camp has a steeper slope (14°) than Bell Point (3°), but Bell Point is more wave-exposed, positioned at the mouth of Garrison Bay. The Argyle site, a pebble and sand beach located inside a narrow bay, is protected by a small peninsula separating it from Jackson Beach. Beaverton Cove, a relatively protected site inside Friday Harbor, has mostly pebble and cobble cover at the surface, with pebble and sand at the subsurface level. The lower tidal levels are covered by substantial ulvoid growth. False Bay is a broad mudflat with a braided freshwater input and several distinct regions of sediment composition. East Sand and West Sand at

False Bay are primarily sand at both the surface and subsurface levels. The High Cobble region abuts a freshwater stream and is dominated by pebbles. Middle Earth is at a lower tidal height than the other three False Bay locations and has a mixture of pebble and sand at both the surface and subsurface levels (Tables 2 & 3).

Juvenile clams were present at six of the seven sites sampled (there were no juveniles at any tidal heights at Jackson Beach; Figs. 1 & 2). Juveniles ranged in size from 1-14 mm and represented at least six species: *Mysella tumida*, *Saxidomus giganteus, Protothaca staminea, Macoma inquinata, Macoma nasuta,* and *Nutricola* spp. (likely *Nutricola tantilla* and *N. confusa*). The majority of individuals were 2-3 mm. *Nutricola* spp. individuals were the most abundant overall, with hugely disproportionate abundances at all tidal heights at Bell Point, a mid-exposure site on the northeaster side of the island (Fig. 2).

Those sites with low overall abundances (5-15 total individuals per site; Argyle, Beaverton) were generally dominated by *Mysella tumida (*Fig. 2). Fourth of July Beach and British Camp, with mid-range abundances (26 and 62 total individuals per site) showed the highest diversity of species, as ranked by the Shannon-Wiener diversity index (Fig. 3). Bell Point, despite its high abundances, had the lowest diversity because of the dominance of a single species (*Nutricola tantilla*).

The highest abundances of juveniles were present at -1 and 0 tidal heights (Fig. 4), but there was no difference in diversity between heights (ANOVA, P = 0.1, Fig. 5). Multidimensional scaling analysis (PRIMER) confirmed that clam assemblages were not different among tidal levels, but that there were substantial differences in clam assemblages among sites (ANOSIM, R = 0.42, P = 0.001, Fig. 7). MDS analysis also identified subsurface shell hash, mud, and granules as the environmental factors most strongly correlated to the presence or absence of juvenile clams (BEST analysis, corr = 0.565). Subsurface shell hash and mud were indicators of clam presence, while subsurface granules generally corresponded to samples with no juveniles, as seen at Jackson Beach (Fig. 8).

Discussion

The sites at either extreme of the wave exposure gradient had the lowest abundance and diversity of clams, suggesting that both extreme high and extreme low wave-energy has a negative impact on the presence of juveniles. While water flow is important to these filter feeders, high wave-energies may wash juveniles out of the sediment, or deposit grain sizes that are unsuitable to habitation. The granules present at Jackson Beach were basically free of any macroscopic infauna, and granules at other sites were indicators of bivalve absence. Conversely, the low wave-energy environments, like False Bay, may experience insufficient water exchange and potentially hypoxic conditions, hindering bivalves directly or via community interaction. Limited water exchange may also prevent dispersal of the larval stage to these areas. False Bay, however, may be an exceptional example of this wave exposure extreme, as its conditions are further confounded by the input of freshwater. The moderate wave exposures bounded by these extremes contained maximum abundances and diversity of juveniles, revealing a range of optimal wave-energies for juvenile survival.

Subsurface shell hash and mud were strongly correlated to the presence of juvenile clams at a particular site and tidal height despite their slight proportion. Shell hash and mud were only major components of sediment composition at Bell Point and British Camp. While these sites contributed disproportionately to the absolute abundance of clams in the analysis, more moderate percentages of shell hash and mud corresponded to more moderate abundances of clams. The presence of shall hash and mud in any quantity were indicators of juvenile presence. Shell hash and mud, as low-density components, are indicative of low wave-energy environments. Shell hash, in particular may signify sediment retention, if shell fragments are of intertidal origin. Sediment stability would favor the maintenance of juvenile populations.

Despite typical zonation trends in the intertidal, juvenile community composition in this study was not predictable by tidal height, but was site specific. For distinguishing between areas with clams and without clams, or determining which clams were present, site was the predicting locator. Within a site, however, abundances were generally greater at the lower tidal heights, suggesting a physical limitation is dispersal or survival up beaches. Environmental conditions were also more similar among tidal heights at a single site than at a single tidal height across multiple sites. Local conditions at tidal heights at a single site, therefore, are likely responsible for differences within a site.

This study did not consider the possible biological factors influencing distribution and abundance of intertidal bivalves. The severe dominance of *Nutricola* at Bell Point compared to the high diversity at the adjacent site, British Camp, may indicate competition among species, as this difference was not explained by environmental factors alone. The composition of these infaunal communities, including the habitat engineering of tube-dwelling annelids and predation pressure by crustaceans, may also play a role in the presence of juveniles and resulting distribution of adult bivalves. Further studies tracking the survival of bivalves through adulthood and investigating the effects of various biological interactions may elucidate the ultimate success or failure of soft-sediment infauna.

This study identified field sources for juvenile clams, for possible comparison to adult populations or further investigation of the ecological challenges faced during this developmental stage. Using the factors illuminated by the MDS analysis, we can also predict other sites that would likely have juvenile clams, those with subsurface shell hash and mud, and without granules.

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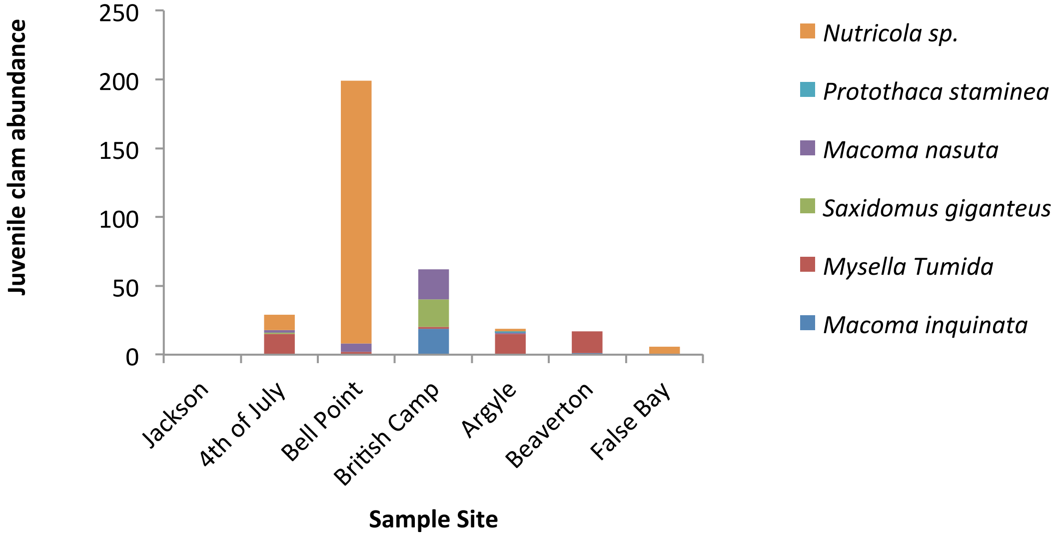
Figures

Figure 1. Seven locations sampled for juvenile clams on San Juan Island.

Table 1. Summary of environmental factors, beach slope, wave exposure rank, and dominant surface and subsurface sediment grain sizes at each sample site.

Site	Beach slope (°)	Wave exposure rank	Dominant surface sediment grain size	Dominant subsurface sediment grain size
Argyle	5	5	pebble, sand	pebble, sand
Jackson Beach	5	1	granule	granule
British Camp	14	4	sand, shell hash	mud, sand
Bell Point	6	3	sand, shell hash	mud, sand
4th of July Beach	3	2	sand	sand
False Bay (E & W)	0	7	sand	sand
False Bay (Middle)	0	7	pebble, sand	sand, pebble
False Bay (High)	0	7	pebble	pebble
Beaverton	13	6	pebble, cobble	sand, pebble



Figures 2. Juvenile clam abundance at the seven sample sites (summed across all samples and tidal heights) arranged from most to least wave exposure (Jackson = most exposed, False Bay = least exposed).

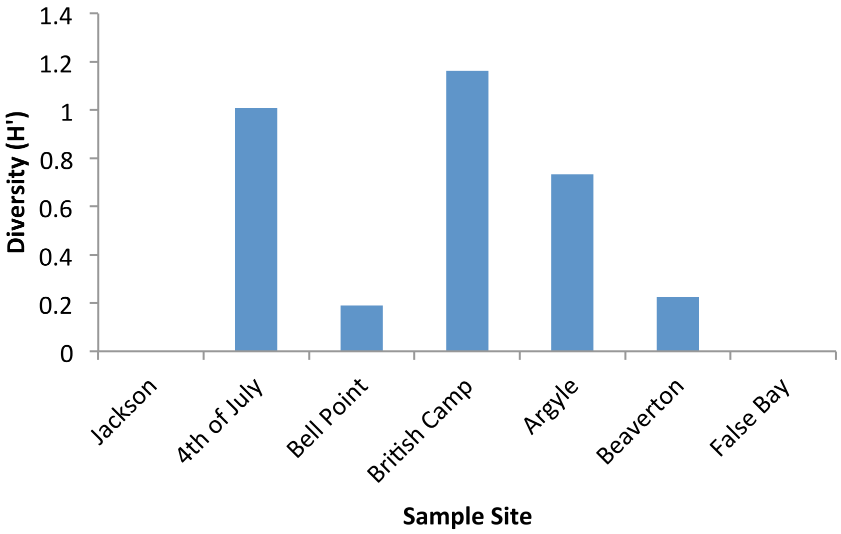


Figure 3. Bivalve diversity (Shannon-Weiner index) at each of the seven sites (summed across all samples and tidal heights) arranged from most to least wave exposure (Jackson = most exposed, False Bay = least exposed).

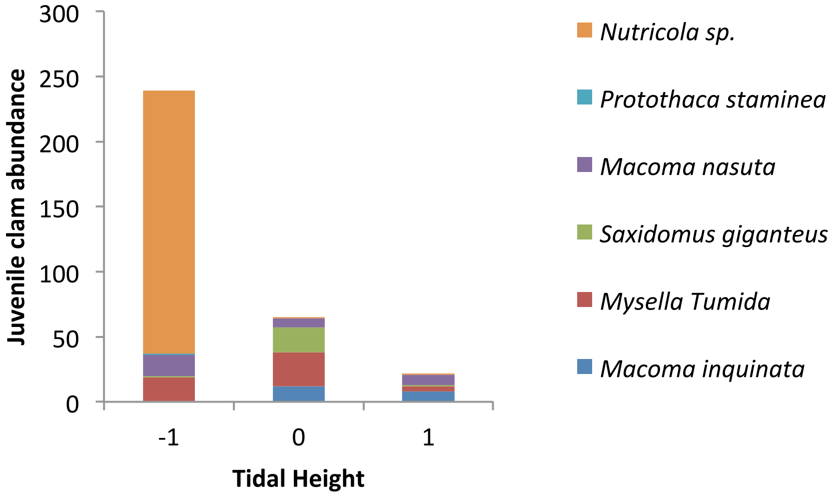


Figure 4. Juvenile clam abundance was greatest at the lower tidal heights.

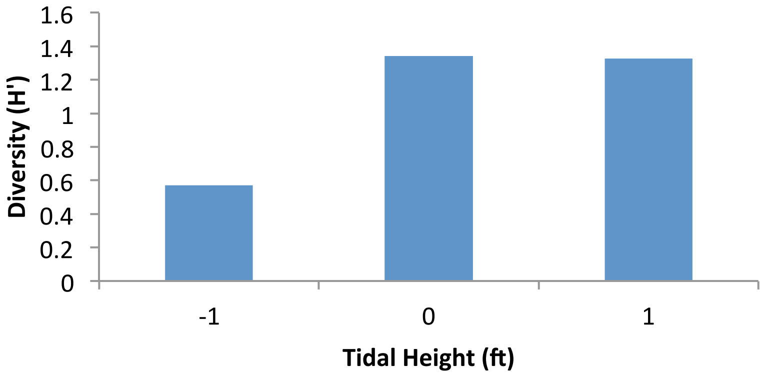


Figure 5. Bivalve diversity (Shannon-Wiener index), summed across all sites, did not differ among tidal heights (1-way ANOVA, P = 0.10).

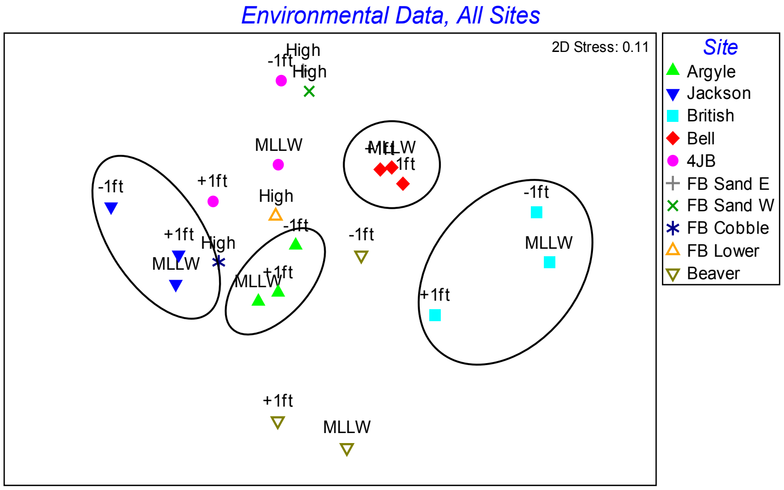


Figure 6. MDS (PRIMER) representation of the relative similarity of environmental factors (sediment size, beach cline, and wave exposure) between points. Each point represents a single tidal height at a single site. Points clustered by site.

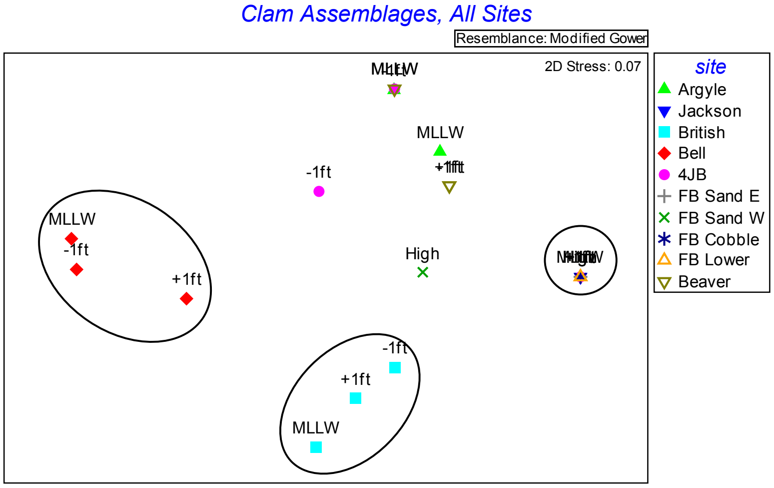


Figure 7. Clam assemblages, visualized in MDS by PRIMER. Each point represents the multispecies clam assemblage at each site and tidal height; points closer together have more similar assemblages. The cluster of points on the right all indicate sites and levels with no clams (ANOSIM, R = 0.42, P = 0.001).

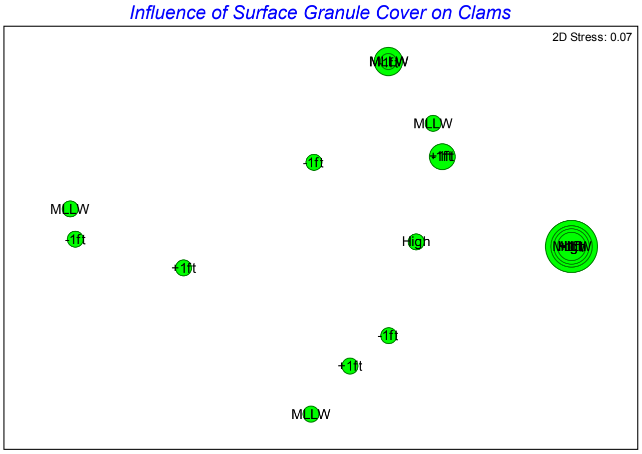


Figure 8. 2D bubble representation of the disproportionate influence of surface granule cover on the presence of juvenile clams. Bubble size indicates strength of influence. The cluster of large bubbles contains the sample locations with zero clams present.

Table 2. Average surface sediment composition at each tidal height at each site, measured by percent cover.

Site	Tidal Height	Surf Cobble (6-25 cm)	Surf Pebble (4 mm-6 cm)	Surf Granule (2-4 mm)	Surf Sand (<2 mm)	Surf Shell hash	Surf Mud
Argyle	-1.0	0.0	47.3	0.0	50.0	8.0	0.0
Argyle	0.0	8.0	71.3	0.0	26.0	0.0	0.0
Argyle	1.0	0.0	71.7	0.0	26.7	5.0	0.0
Jackson	-1.0	0.0	21.7	45.0	33.3	0.0	0.0
Jackson	0.0	0.0	76.7	18.3	7.5	0.0	0.0
Jackson	1.0	0.0	46.7	26.7	26.7	0.0	0.0
British Camp	-1.0	0.0	0.0	0.0	20.0	20.0	66.7
British Camp	0.0	0.0	0.0	0.0	15.0	31.7	53.3
British Camp	1.0	0.0	41.7	0.0	13.3	25.0	20.0
Bell Point	-1.0	0.0	0.0	0.0	50.0	11.7	38.3
Bell Point	0.0	0.0	0.0	0.0	50.0	5.0	45.0
Bell Point	1.0	0.0	0.0	0.0	51.7	5.0	43.3
4th of July	-1.0	0.0	0.0	0.0	98.3	5.0	0.0
4th of July	0.0	0.0	18.3	10.0	73.3	5.0	0.0
4th of July	1.0	0.0	31.7	26.7	40.0	5.0	0.0
False Bay	E	0.0	0.0	0.0	99.3	2.0	0.0
False Bay	W	0.0	0.0	0.0	90.0	0.0	10.0
False Bay	High	0.0	58.3	18.3	21.7	5.0	0.0
False Bay	Middle	0.0	33.3	10.0	36.7	0.0	23.3
Beaverton	-1.0	20.0	30.0	0.0	51.7	7.5	6.7
Beaverton	0.0	20.0	50.0	0.0	30.0	7.5	5.0
Beaverton	1.0	36.7	51.7	7.5	6.7	0.0	0.0

Table 3. Average sediment composition at each tidal height of each site, measured by percent cover at the subsurface level (3-5 cm).

Site	Tidal Height	Surf Cobble (6-25 cm)	Surf Pebble (4 mm-6 cm)	Surf Granule (2-4 mm)	Surf Sand (<2 mm)	Surf Shell hash	Surf Mud
Argyle	-1.0	0.0	48.3	0.0	50.0	5.0	0.0
Argyle	0.0	0.0	60.0	0.0	40.0	0.0	0.0
Argyle	1.0	0.0	61.7	0.0	36.7	5.0	0.0
Jackson	-1.0	0.0	13.3	53.3	33.3	0.0	0.0
Jackson	0.0	0.0	36.7	36.7	26.7	0.0	0.0
Jackson	1.0	0.0	46.7	31.7	21.7	0.0	0.0
British Camp	-1.0	0.0	5.0	0.0	20.0	23.3	58.3
British Camp	0.0	0.0	10.0	0.0	33.3	36.7	26.7
British Camp	1.0	0.0	43.3	0.0	20.0	26.7	10.0
Bell Point	-1.0	0.0	0.0	0.0	50.0	12.5	41.7
Bell Point	0.0	0.0	0.0	0.0	50.0	6.7	43.3
Bell Point	1.0	0.0	0.0	0.0	55.0	5.0	40.0
4th of July	-1.0	0.0	0.0	0.0	98.3	5.0	0.0
4th of July	0.0	0.0	16.7	15.0	71.7	5.0	0.0
4th of July	1.0	0.0	15.0	40.0	50.0	0.0	0.0
False Bay	E	0.0	0.0	0.0	98.3	2.5	0.0
False Bay	W	0.0	0.0	0.0	90.0	0.0	10.0
False Bay	High	0.0	30.0	40.0	30.0	0.0	0.0
False Bay	Middle	0.0	35.0	23.3	46.7	0.0	20.0
Beaverton	-1.0	0.0	11.7	0.0	68.3	11.7	8.3
Beaverton	0.0	30.0	36.7	10.0	35.0	13.3	5.0
Beaverton	1.0	10.0	30.0	20.0	23.3	13.3	0.0