

The Abundance, Habitat Selection, and Feeding Behavior of the Brittle Star, *Ophioderma brevispinum*, in Eelgrass- vs. Algae-Dominated Habitats in a Nutrient Enriched Estuary

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Abstract

Eutrophication is a common problem among shallow estuarine systems that greatly affects the diversity of organisms from fish to small benthic invertebrates. This study addresses the changes in abundance, population size, and diet of the brittle star, *Ophioderma brevispinum*, in response to a shift from pristine eelgrass meadows to drifting algae mats that induce episodic hypoxia. To understand the lifestyle and role of this elusive animal, I sampled the abundance within eelgrass, algae, mud, and sandy bottom habitats in West Falmouth Harbor, measured and weighed collected individuals, conducted habitat and feeding selection experiments, and determined $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for *O. brevispinum* and its food sources. Abundance was highest in eelgrass beds (213 individuals/m²), and none were found in bare habitats, results that were supported by observed habitat preferences. Size frequency revealed the algae population as significantly larger than that of the eelgrass, but isotopic analysis suggests a similar diet on an upper trophic level in the two populations. This suggests that their larger size may be more dependent on decreased predation within the algae mats as opposed to differential food sources. The unique physical characteristics and behavioral tendencies of *O. brevispinum* may ensure successful survival as eelgrass habitats decline with increasing nutrient enrichment from the watershed.

Keywords and Phrases: Ophiuroids, *Ophioderma brevispinum*, benthic invertebrates, abundance, size frequency, eelgrass, algae colonization, eutrophication, West Falmouth Harbor.

INTRODUCTION

A natural community of diverse organisms is like a community of humans: every species has a specific niche or service they perform related to how they live that contributes to the functioning of the whole. Species are tied to one another and to the physical environment, forming a complex network of intricate relationships that can shape the ecosystem. The sediment - water interface of an estuarine system supports an astonishingly diverse community of benthic organisms. Imagine an underwater rainforest teeming with life: thousands of species ranging from top predators, tiny herbivores, and

an array of plants. Each one of these species has a unique life history as it eats, grows, reproduces, and lives habitually in accordance with the daily and seasonal shifts in physical conditions and nutrient availability.

However, not all of the changes these communities experience are natural. Eutrophication is an increasingly problematic and common phenomenon among Cape Cod estuaries that has been proven to cause declining eelgrass meadows, algae colonization, episodic anoxia leading to fish kills, an overall decrease in biodiversity, and suffering fishery populations (Cummins et al 2004; Deegan et al 2002; Valiela et al 1997). Eelgrass habitats are deemed essential for healthy fish populations and highly influential for benthic community structure because they provide nurseries for juvenile fish, habitat complexity, large amounts of organic matter, more stability, and increased food availability (Bostrom and Bonsdorff 1997). Despite the overwhelming evidence documenting the negative effects of eutrophication, algae colonization may not be devastating for all benthic species. The brittle star *Ophioderma brevispinum* (*O. brevispinum*) is highly prevalent in many estuarine systems and has been documented in large numbers within algae and mud dominated systems (Gage 1990). This study examines whether there are any discernible behavioral characteristics that allow these animals to thrive in areas where other species cannot. This starfish relative may be a hardy ophiuroid species remaining unaffected by eutrophic conditions or it may be another sensitive species indicating eutrophication.

Ophiuroids are highly variable in appearance, size, and habitat, where *O. brevispinum* is just one species of two thousand. Ophiuroid populations have a wide range in abundance, anywhere from 10 to beds of up to several thousand individuals/m² reported by Warner (1980), Broom (1975), and Allen (1998) inhabiting coral reefs and deep ocean floors around the world. These animals are flexible, highly mobile, and are easily concealed by plant and detritus material. Light sensitivity (Johnsen 1994) and active shade-seeking behavior (Johnsen and Kier 1999) combined with high flexibility may explain successful populations within dark, dense algal mats.

Feeding is one of the most important behavioral characteristics of animal species yet remains relatively mysterious for ophiuroids: nearly every possible feeding strategy imaginable has been hypothesized for different species. Ophiuroids have been called opportunistic omnivores (Reimer and Reimer 1975), suspension feeders (Davoult and Gounin 1995, Allen 1998), detritivores, deposit feeders (Thayer et al 1978), and predaceous scavengers (Aronson and Harms 1985). The feeding habits of such an abundant organism can greatly affect ecosystem function and have potential feedbacks to declining fishery populations. It is possible that *O. brevispinum* are the sharks of the sediment surface, or that they passively filter feed and clear the water column of organic particles, or even feed on detritus and effectively accelerate nutrient recycling.

West Falmouth Harbor is a unique estuary in that it has resisted eutrophication due to large tidal exchange with the clean water of Buzzards Bay while other estuaries on Cape Cod have long since been devoid of eelgrass. However, within the last twenty years, nutrient loading has doubled and eelgrass beds have drastically receded only to be replaced by fast growing algae mats. For the diverse community of benthic organisms frequenting the estuary floor, this shift is akin to having your rainforest replaced by grasslands. A change of this magnitude could elicit strong responses in the abundance, size, habitat, and feeding of *O. brevispinum* populations. If brittle stars are more

abundant within an algae bed, is this the result of an altered habitat structure that leads to decreased predation? Or might abundance be more correlated with feeding and thus dependent on the organic matter content of eelgrass and algal detritus? And are these habitat and diet changes large enough to cause a significant difference in body size? Understanding *O. brevispinum* survival strategies in different habitats will contribute to our knowledge and ability to predict whether researchers' best efforts to minimize nutrient enrichment can balance the increasing population density and development within the watershed.

Study Site

West Falmouth Harbor (WFH) is a relatively small (80 ha), shallow, enclosed embayment on Cape Cod, MA receiving freshwater inputs from Mashapaquit Creek and tidal exchange at the inlet to Buzzards Bay with a range of 1.5m (Fig. 1). This estuarine system is composed of several separate inlets and harbors and has an average depth of 1.8m with 3.4m depth along the main channel. Salinity varies from 20 ppt in Snug Harbor at the mouth of the Mashapaquit Creek to 30 ppt in the Outer Harbor. WFH receives nutrients from groundwater, runoff, and Wastewater Treatment Facility effluent. Eelgrass (*Z. marina*), algae (*S. filipendula*), and sandy bottom habitats were sampled in the Outer Harbor basin while a muddy habitat was sampled in Snug Harbor.

METHODS

Abundance and Size

To assess the abundance of *O. brevispinum* in WFH, eelgrass, algae, muddy, and sandy bottom habitats were surveyed by snorkeling and scuba diving in November. Brittle stars were collected in four randomly placed 0.02m quadrats within each habitat in Outer Harbor. Divers extracted sediment core samples using 60mL syringes (3cm diameter) next to each transect for CN analysis on a PE2400 Elemental Analyzer. I gathered eelgrass, algae, and detritus samples from each habitat for isotopic analysis. Qualitative brittle star sampling was conducted through exploration and using an Ekman grab.

In the lab, brittle stars were kept in aquaria (14 x 16 x 2 in.) in a continuous flow of unfiltered seawater (17mL/s) with an average temperature of 13°C. I measured disk diameter (mm), leg length (mm), and wet weight (g/individual) of individuals collected from eelgrass (n= 55) and algae (n=35). Disk diameter was defined as the distance from the base of one leg to the perpendicular disk edge (Warner 1971).

Habitat Selection

To learn more about the behavior and habitat preferences of *O. brevispinum*, I conducted a series of binary habitat selection experiments that simulated their natural environment. Twenty brittle stars were placed in aquaria between combinations of the following habitats: bare sand and mud (4 cm deep), shells, detritus, algae, and eelgrass (n=5). To control for possible escape behavior, each batch was slid from a small bowl

into a bare space between the habitat choices. I noted the number of individuals in each habitat at 1, 5, 10, 30, and 60 minutes. To account for the tendency to seek out corners for safety, the number clinging to the edges or clumping in the corners was subtracted from the total number on that side of the tank to attain the number of individuals within each habitat. I acclimatized each batch in the dark for ten minutes or until settled and made sure that no batch entered the same binary choice twice consecutively.

To test *O. brevispinum* light sensitivity and defensive behavior, observations were made in high and low light. I placed twenty individuals into exposed and covered aquaria (control) to emulate potential conditions in the natural environment and noted the number of “clumped” individuals (defined as in a corner or having two or more legs up against the wall) after 1, 5, 10, 30, and 60 minutes (n=5).

Food Choice

To determine whether a difference in abundance or size could be attributed to differential feeding in the different habitats, brittle star (4 bodies), vegetation, and detritus samples from each habitat were prepared for isotopic analysis. Samples were washed in tap water, oven dried (48 hrs, ~60°C), and ground with a mortar and pestle. I acidified brittle star and eelgrass samples with 10% HCl as Davoult et al (1992). To observe feeding in the lab, a single brittle star was placed in a large glass bowl for twenty minutes (20cm diameter) with 1 small piece of fish carrion, 5 dead amphipods, detritus, mud, and live vegetation (n=10). Special care was taken to orient each individual differently in relation to the food sources. I noted the sequence that each brittle star consumed the available choices.

Data Analysis

The student T-test assuming equal variance was used to determine the significance in the difference between means of abundance and all habitat selection experiments. Brittle star productivity was estimated using average biomass and a Production: Biomass ratio for invertebrates (Banse and Mosher 1980). Brittle star carbon and nitrogen content was estimated from disk diameter (Davoult et al 1992).

RESULTS

Abundance and Size

Field sampling and laboratory work indicated that brittle stars collected from the eelgrass meadow were more abundant but smaller than those collected from the algae bed. Within the eelgrass, brittle stars were found in the base of the eelgrass stands and among the thick layer of eelgrass detritus. In the algae bed, brittle stars were found both underneath and within the dense mat. Abundance was highest in the eelgrass bed (213/m²), followed by algae (88/m²) (p=0.1), with none in sandy or muddy bottom habitats (Fig. 2). Based on this density, I estimated total estuary *O. brevispinum* population to reach approximately 43 million. Biomass and estimated production do not differ significantly between habitats (p=0.35) (Fig. 3). Size frequency showed the

average disk diameter in the algae population to be significantly larger than that of the eelgrass population with a normal size distribution within both populations (Fig. 4). Size-weight correlation confirmed that *O. brevispinum* from algae beds are 25% larger and 60% heavier than those from the eelgrass with both populations allometrically scaled along an exponential curve ($p < 0.0001$, $R^2 = 0.92$) (Fig. 5). Average biomass of the algal population (0.92g) is 60% greater than that of the eelgrass population (0.56g). Disk diameter ranged from 4.5 to 12 mm and 8.8 to 13 mm in eelgrass and algal populations, respectively. The fitted curve shows that increases in disk diameter for the algae population leads to a larger increase in biomass than in the eelgrass population. Sediment carbon content did not vary significantly but highest N content was found in muddy sediment (Fig. 6). *O. brevispinum* abundance did not correlate to the C:N ratio of the sediment samples ($R^2 = 0.24$) (Fig. 7). *O. brevispinum* has a low C:N ratio of 4 while the vegetation has a ratio ~25 (Fig. 8). The algae detritus has significantly more nitrogen than that of the eelgrass detritus, and the detritus is higher in carbon than the live vegetation (Fig. 8).

Habitat Choice

Brittle stars are cryptic animals that search for protective hiding places. Whether it was a shell, aquarium corner, vegetation, detritus, or another animal, *O. brevispinum* significantly preferred any three dimensional object to a bare substrate. Based on observations, when placed on a bare substrate such as sand or a cleared aquarium, the individual would be still for a few seconds while systematically sweeping its arms around and then move in a direction until it found a structural object. Binary habitat selection experiments resulted in the following preference scheme:

Detritus > eelgrass/algae > shells > mud > sand

Sand was least preferred of all the substrates ($p < 0.0001$) while detritus was chosen even over eelgrass ($p < 0.0001$) (Table 1). A noticeable trend was that although individuals collected from eelgrass showed no preference for the different vegetation choices ($p = 1$), brittle stars from the algae significantly chose the algae over the eelgrass ($p < 0.05$) (Table 2). Light-dark experiments showed a negative light response in *O. brevispinum* with many fewer individuals clumped in the corners of dark aquaria than in those exposed to light ($p = 0.001$) (Fig. 9).

Food Choice

Isotopic analysis reveals *O. brevispinum* as a top predator among benthic invertebrates with each population having a different carbon source composition. Brittle stars from the eelgrass bed had a $\delta^{13}\text{C}$ value of $\sim -15\text{‰}$, algae from both habitats was -19.2‰ , but detritus composition differed strongly in the eelgrass and algae as -10.7‰ and -14.9‰ , respectively (Fig. 10). Live and dead eelgrass did not have similar composition with a suspicious live eelgrass ^{13}C value of -7.5‰ . High $\delta^{15}\text{N}$ values of brittle stars in both eelgrass and algae (12.6‰ and 11.5‰ , respectively) indicate an intermediate trophic transfer between *O. brevispinum* and vegetation or detritus that ranged from 6-7‰ (Fig 10).

Laboratory observations and experiments revealed *O. brevispinum* to be opportunistic omnivores, eating anything from algae flotation bulbs to bits of twine, with an acute sense for animal meat. Fifty percent of the tested individuals consumed the fish

meat first and then finished off the majority of the amphipods, while the other half ate the amphipods followed by the fish, showing that animal matter was preferred by all of the tested individuals. Detritus (organic matter, non-plant) was a common third choice followed by mud. No vegetation was consumed during the experiment although individuals had been commonly observed eating eelgrass blades and or algae leaves throughout the study. All objects were swallowed whole, and if the object was larger than the individual, half remained outside the body for hours. Within a day, several of the consumed fish pieces had been egested relatively intact.

Three feeding methods were observed depending on the type and location of the food source. When eating or trapping animal pieces, an arm would grasp the prey, coil around it, and then lift the body and move the arm underneath to bring the prey directly to the mouth. When deposit feeding on mud or detritus, the individual moved directly over the food source and stretched its mouth open while the podia, or tube feet, slowly pushed the prey through the mouth. Another observed feeding mode was that small particles such as sand grains were carried by the podia down to the base of the arm, where the body would lift and the arm would bend slightly to get the food source closer to the mouth.

DISCUSSION

Abundance and Size

The abundance of *O. brevispinum* was higher in eelgrass than algae but the algal population was significantly larger (Fig. 2, 4, 5). The distribution and abundance of an organism is determined by food availability and whether the physical conditions are conducive to a protective habitat. Both of these factors differ significantly in eelgrass and algal habitats. The size of an organism is also a factor in determining abundance. One explanation for the difference in abundance and size of *O. brevispinum* within these two habitats is that algae mats support larger individuals so there cannot be as many.

The size of an organism is directly related to its food source, growth efficiency, and predation pressures. Algae mats differ from eelgrass in that it grows and decomposes quickly. This alone has two important implications for benthic invertebrates: the high organic matter content of the detritus and the hypoxia induced during decomposition. The rich detritus can directly and indirectly enhance *O. brevispinum* diet and consumption by stimulating small invertebrate prey populations and by being easier for brittle stars to assimilate than eelgrass detritus that decomposes slowly due to high cellulose content. Additionally, if *O. brevispinum* is tolerant to hypoxic events, low oxygen levels may be beneficial by causing burrowing infaunal invertebrates to migrate out of the sediments where they are available for consumption. Hypoxia and the complex structure of *S. filipendula* may strongly decrease predation pressure, allowing brittle stars to live longer. If predaceous crabs or fish managed to find a brittle star within the tangled algae mat, the extensive surface area provides many places where *O. brevispinum* can effectively grab hold and escape.

Few studies have examined ophiuroid size in eutrophic estuaries but algal mats have been studied as a viable, alternative habitat for benthic invertebrates capable of

colonizing algae (Norkko et al 2000), which easily applies to the highly agile *O. brevispinum*. In this case, higher benthic diversity has been observed in algal mats than in eelgrass habitats. Oftentimes high abundance can have a negative effect as the population approaches its carrying capacity. However, dense ophiuroid populations are very common, benefiting from increased feeding efficiency and reproductive success (Broom 1975). Drifting algae mats cause spatial variation and patchy mosaics within the benthic community and transport many juvenile organisms (Bostrom and Bonsdorff 1997). And even though rapid summer growth also creates temporal variation along the estuary bottom, this particular *S. filipendula* bed is a large, fixed component of the ecosystem supporting a unique community of organisms, as evidenced by *O. brevispinum*'s significantly larger size.

Habitat Selection

O. brevispinum showed a strong, consistent preference for structured habitats over barren substrates. Detritus was chosen over intact, live vegetation (Table 1). Habitat selection most likely reveals the aspects of the environment that invoke a feeling of protection such as decreased light penetration or complex structure. While eelgrass meadows are significantly structured, detritus is low lying and possibly provides more effective protection. Significantly less aggregation in dark treatments can explain the tendency to seek out detritus and algal habitats where light penetration is minimal. Algal populations significantly choosing algae mats over eelgrass stands implies an acquired, retained ability to utilize the habitat that the eelgrass population did not exhibit.

Unlike many benthic organisms and other echinoderms, ophiuroids are highly mobile and capable of moving distances great enough to cross habitat boundaries and make the type of choices presented in laboratory selection experiments. Although considered somewhat primitive creatures, ophiuroids have what appears to be a memory created from stimuli produced by contact with solid objects (Cowles 1910). This explains how they can efficiently find structural components of their natural environment. Evidence also suggests that *O. brevispinum* are particularly sensitive to polarized light (Johnsen and Kier 1999; Johnsen 1994). As a diurnal species sensitive to high light levels, it is logical that these animals behaved in the lab as they would in nature by choosing the dense, dark habitats.

Food Choice

O. brevispinum exhibited omnivorous behavior and were skilled in finding and consuming animal matter during laboratory experiments. All individuals quickly devoured one type of animal meat before approaching the detritus or mud. Observations of different physical feeding mechanisms are confirmed by Reimer and Reimer (1974), who noted the different feeding mechanisms as "coil arm, ingest" and "carry down arm." They also observed that the feeding mechanism correlated to the intensity of the response to the chemical compounds released by the food source, suggesting that the genus *Ophioderma* responds more aggressively to specific compounds released by animal meat. Ophiuroids have been confirmed as deposit feeders, carnivores, herbivores, scavengers, detritivores, and opportunistic omnivores (Reimer and Reimer 1974; Warner and Woodley 1971; Aronson and Harms 1985). Although filter feeding is more common

among long-spined brittle stars (Davoult and Gounin 1995; Allen 1998), *O. brevispinum* was observed with small mucus strings trailing behind its arms.

Even though observed behavior is undoubtedly consistent with natural tendencies and potential carnivorous behavior, an animal's diet is not composed of what they can or choose to eat, but rather of what is available to them with minimal exerted energy. Available food sources are most likely small worms and other benthic invertebrates feeding on detritus, bivalve remains and large zooplankton dependent on a phytoplankton derived carbon pathway, vegetation, and plant detritus. Isotopic analysis of *O. brevispinum* and the possible carbon sources revealed brittle stars as omnivorous carnivores in a high trophic position largely dependent on detritus derived carbon sources. The eelgrass *O. brevispinum* population derives its carbon from a mixture of algae (45%) and detritus (55%) based carbon pathways. Live eelgrass is not a potential direct food source because ophiuroids have no mechanism for breaking or tearing things apart, thus everything they consume must fit inside their pliable bodies. This dependence on eelgrass through detritus is strongly supported by Thayer et al (1978), who found deposit feeding ophiuroids to be 60% dependent on eelgrass carbon with the remaining portion as particulate matter. Contrary to their findings, the *O. brevispinum* population living in algae mats is much more heavily dependent on detritus derived carbon, as it is 98% of the brittle star diet while algae based carbon is only 2%.

The variation in isotopic composition of these two *O. brevispinum* populations is the combination of the different resource availability within the two habitats and the size discrepancy between the two populations. In other words, diet may vary because the detritus and benthic communities are different but also because the brittle stars may eat differently depending on age and developmental stage. Eelgrass detritus has a high C:N ratio and is slow to decompose whereas algae have a much lower C:N ratio and a fast turnover, thus decomposing much more quickly. This stimulates the benthic worms, snails, and other invertebrates (Bostrom et al 2002), making for rich, muddy detritus as opposed to the uniform, tough, plant detritus in the eelgrass beds that compel brittle stars to turn towards algae for a food source.

The other explanation for the isotopic variation in the *O. brevispinum* and why eelgrass brittle stars are slightly higher on the food web is decreased predation within the algae mat that is conducive to a larger and possibly older population. After juvenile ophiuroids have undergone metamorphosis from the plankton stage, they are under severe predation pressure for as much as two years until they grow to sexual maturity. Young *O. brevispinum* are scavengers and deposit feeders because they are not large enough to filter feed effectively (Skold et al 2001). Filter feeding is considered the more efficient mechanism because it is enhanced by abundance as opposed to competing for bits of scallop muscle tissue. Because these *O. brevispinum* find protection in vegetation and detritus, they have relatively low predation pressure and most likely grow in regular increments (Gage 1990) with juveniles largely dependent on high quality food sources and adults able to sustain themselves mainly on detritus or particulate matter.

In conclusion, ophiuroid food sources and feeding behavior are so controversial and ambiguous because not only do species differ in their feeding methods but many species are capable of utilizing multiple mechanisms to obtain food. Generalization and specialization both have competitive advantages in being able to exploit a wide variety of resources and outcompete other species (Reimer and Reimer 1974). However, in a

changing environment such as West Falmouth Harbor, such high diet plasticity and range of feeding mechanisms give *O. brevispinum* the ability to survive in alternative habitats and may also play a role in shaping the ecosystem itself.

O. brevispinum and the Future of West Falmouth Harbor

Despite researchers' best efforts to direct policy toward lessening the nutrient enrichment in West Falmouth Harbor, improved sewage effluent treatment may not be enough to offset the effects of increased development within the watershed. Although a very well-flushed system, West Falmouth Harbor has suffered a 40% loss of eelgrass habitat within the last fifty years (MEP). Even though *O. brevispinum* can effectively live in algae mats, this does not mean that the species will remain unaffected as eelgrass meadows become increasingly compromised as an important habitat for the whole community of benthic fauna. Approximately 50% of the brittle star diet is composed of organisms dependent on the eelgrass as a food source. In terms of productivity, low-end estimates predict that brittle stars utilize more than 100% of the total system annual production. *O. brevispinum* eelgrass dependence does not change but the amount of available production does, indicating that unless a higher proportion of *O. brevispinum* settle in the algae, the population will suffer proportionally to the eelgrass habitat loss. However, not all predictions are dismal. Because *O. brevispinum* can successfully exist in algae mats with sufficient protection and food, it is possible that the population will not be heavily affected by algae colonization, and any loss in population density can be reestablished if eelgrass coverage recovers with decreased nutrient enrichment.

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FIGURES AND TABLES



Figure 1. Aerial map of West Falmouth Harbor with Snug Harbor and Outer Basin as noted sampling locations

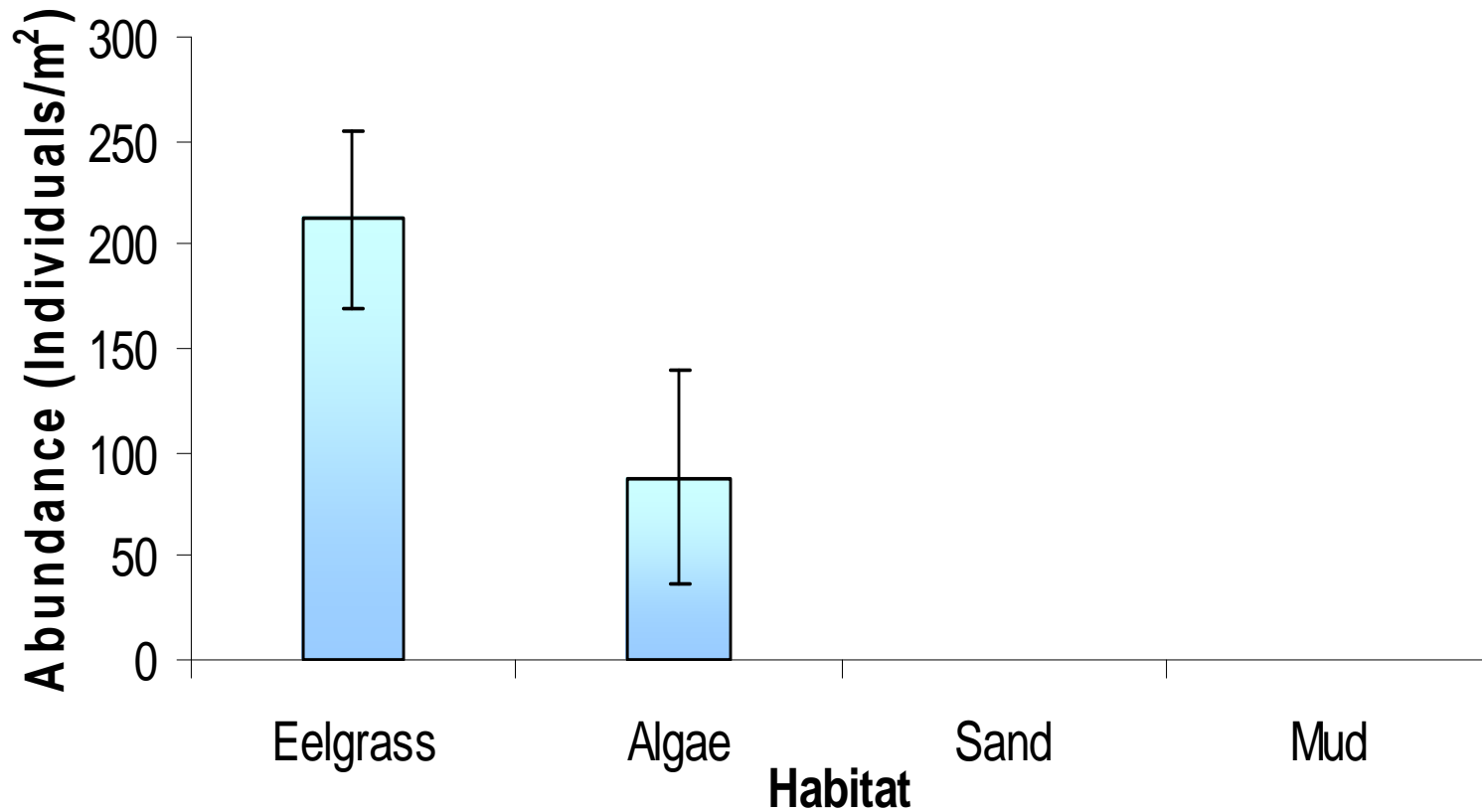


Figure 2. Abundance of *O. brevispinum* highest in eelgrass followed by algae ($p=0.1$) with none in bare habitats in Snug and Outer Harbors. $N=4$. Error bars represent ± 1 S.E. of the mean.

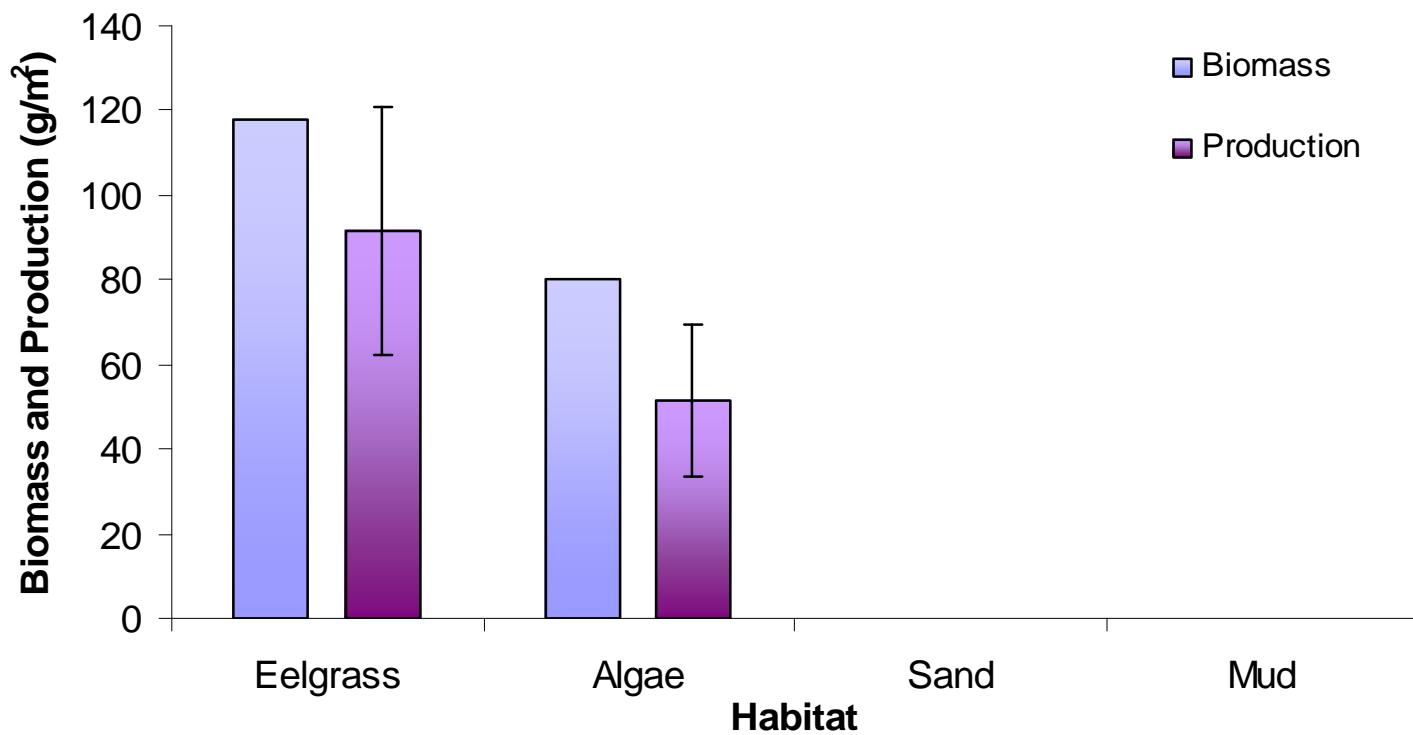


Figure 3. High biomass and production in vegetated habitats but no significant difference between the eelgrass and algae habitats ($p=0.35$). Error bars represent ± 1 S.E. of the mean.

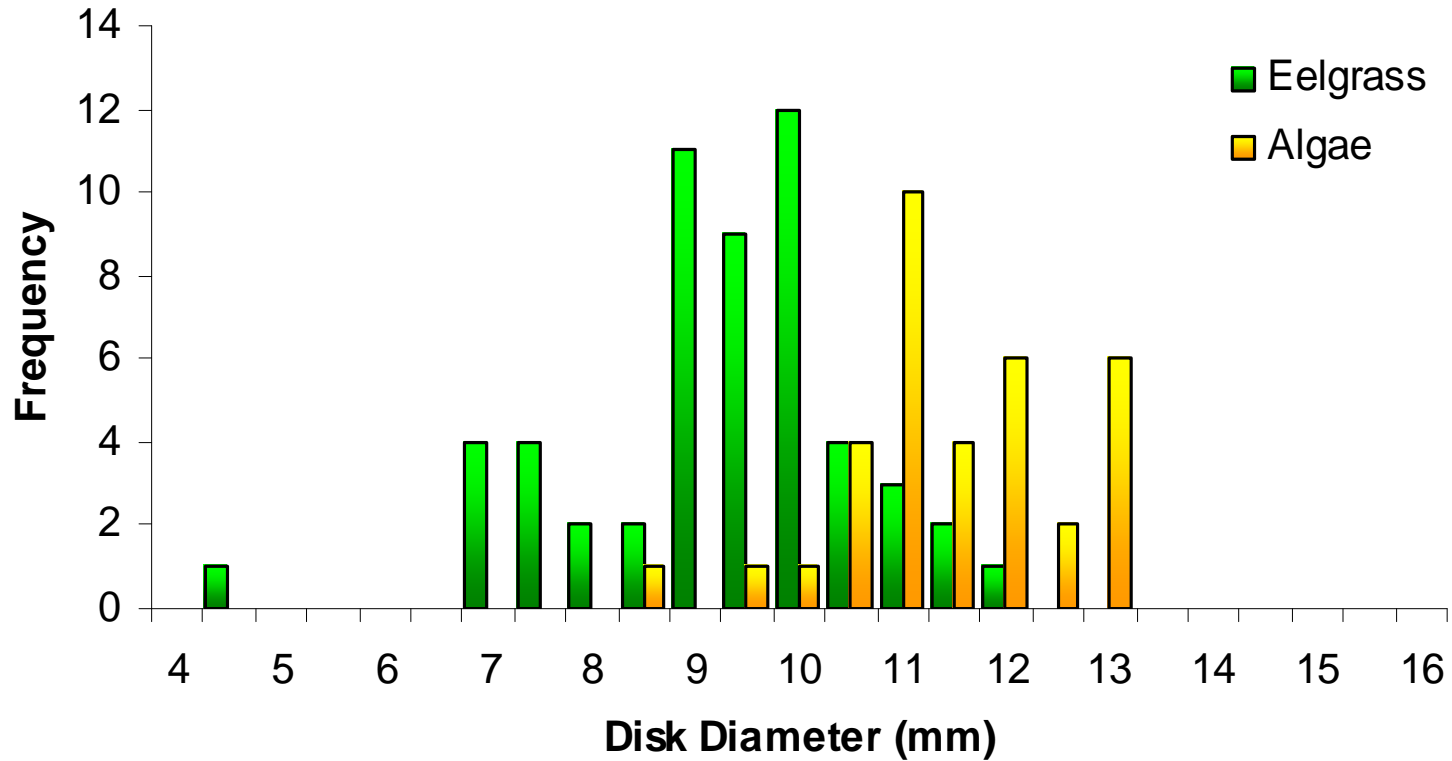


Figure 4. Size frequency of *O. brevispinum* shows larger maximum mean disk size in the algae habitat with a normal distribution in both populations.

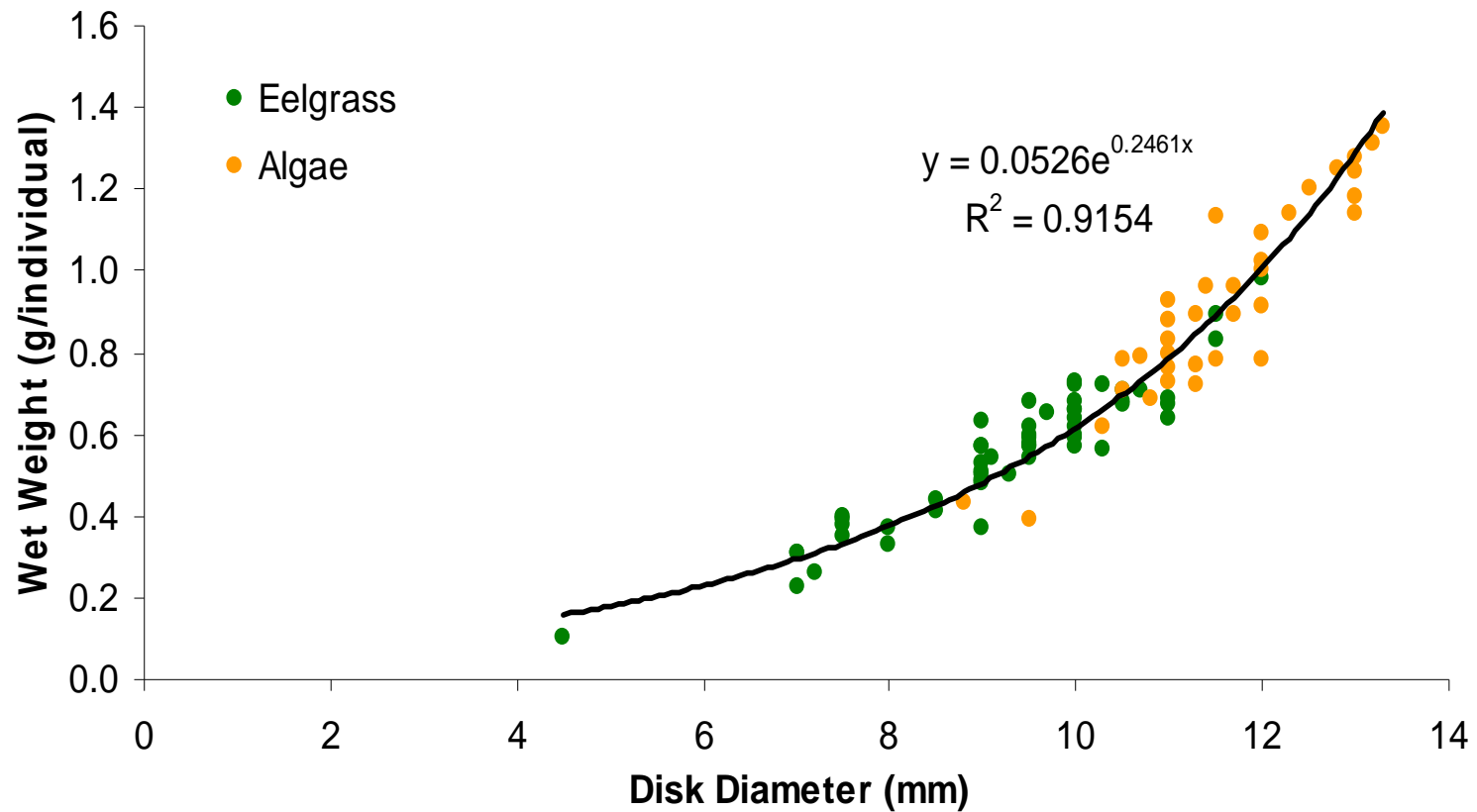


Figure 5. *O. brevispinum* larger in algae bed (n=35) than in eelgrass (n=55) and population size is allometrically scaled, following an exponential curve ($R^2 = 0.92$). $P < 0.0001$.

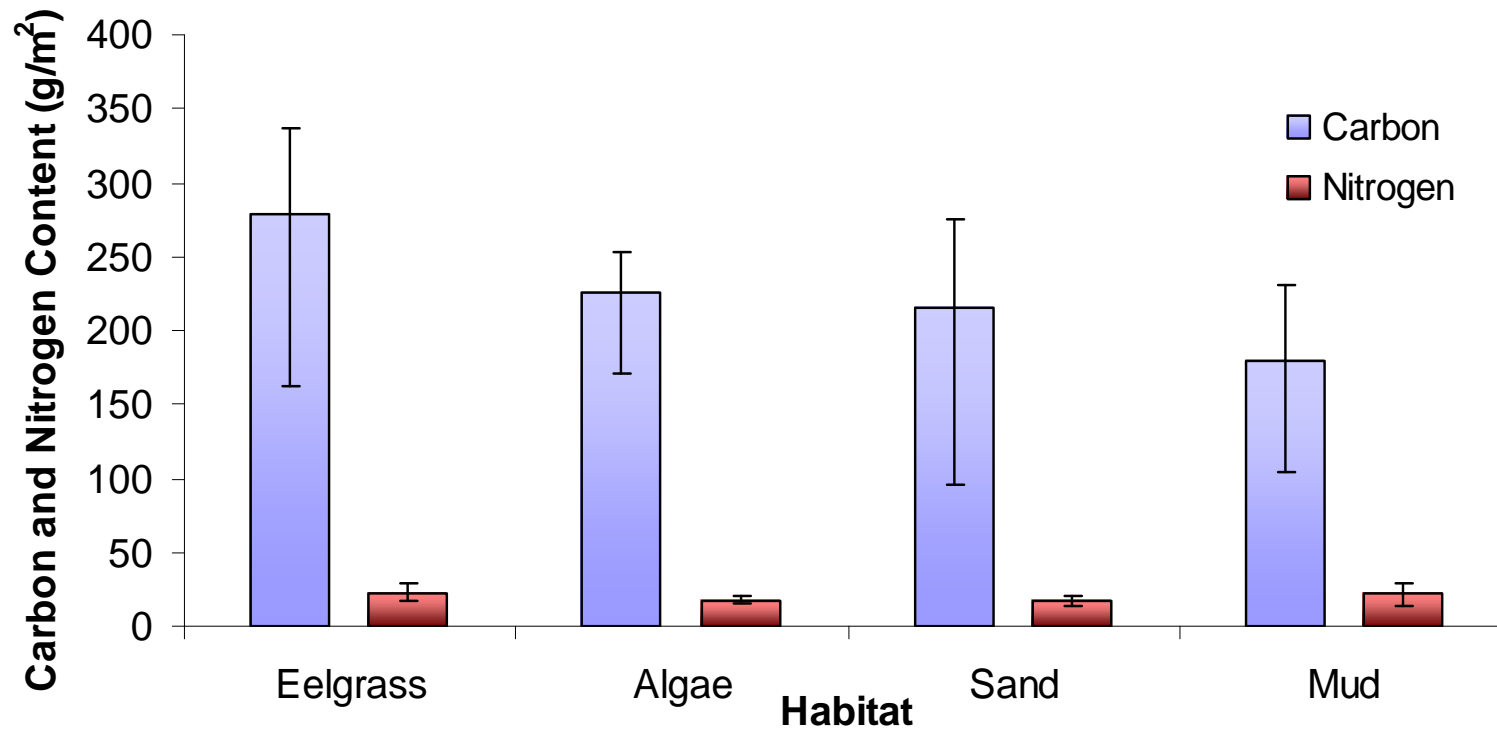


Figure 6. Carbon and nitrogen content similar in all sediment types with highest N content in muddy bottom habitat. N=4. Error bars represent ± 1 S.E. of the mean.

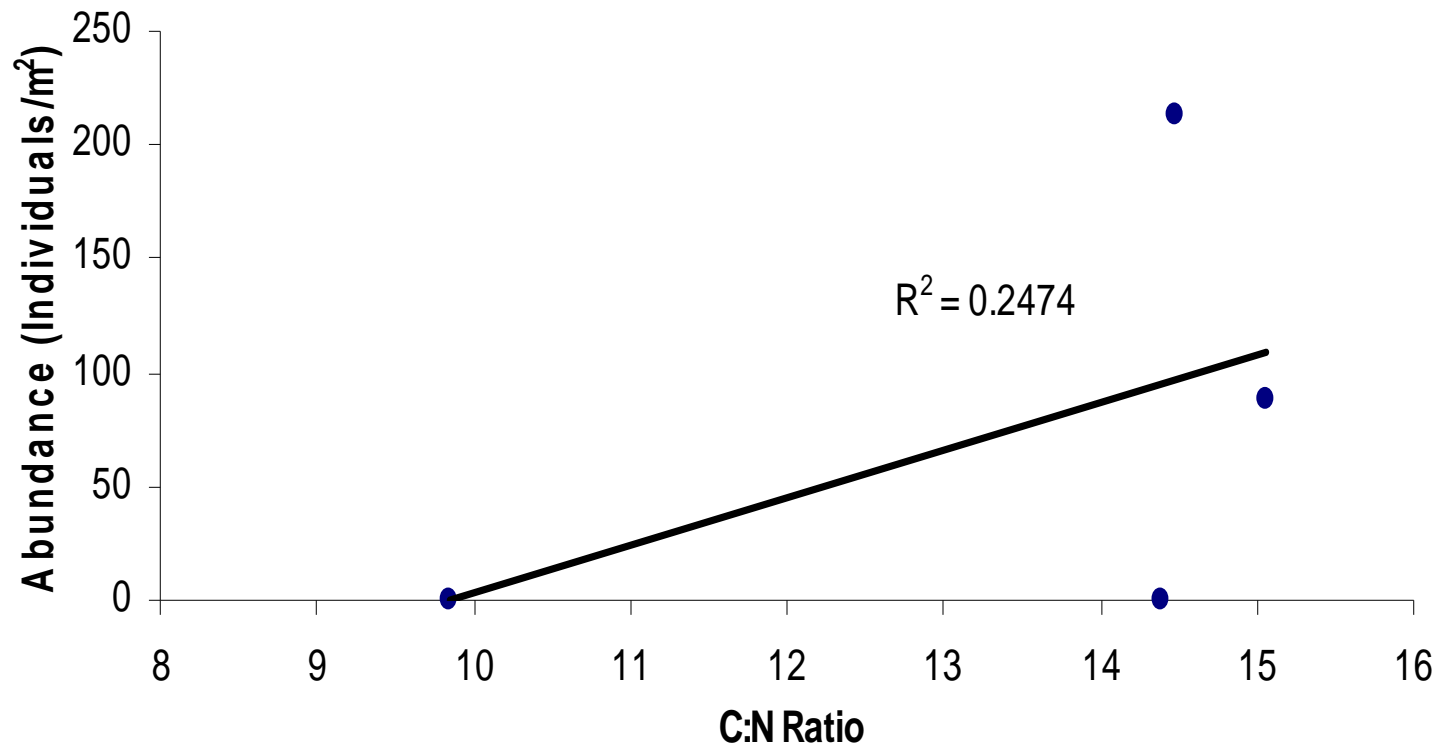


Figure 7. *O. brevispinum* abundance not correlated to molar C:N ratio.

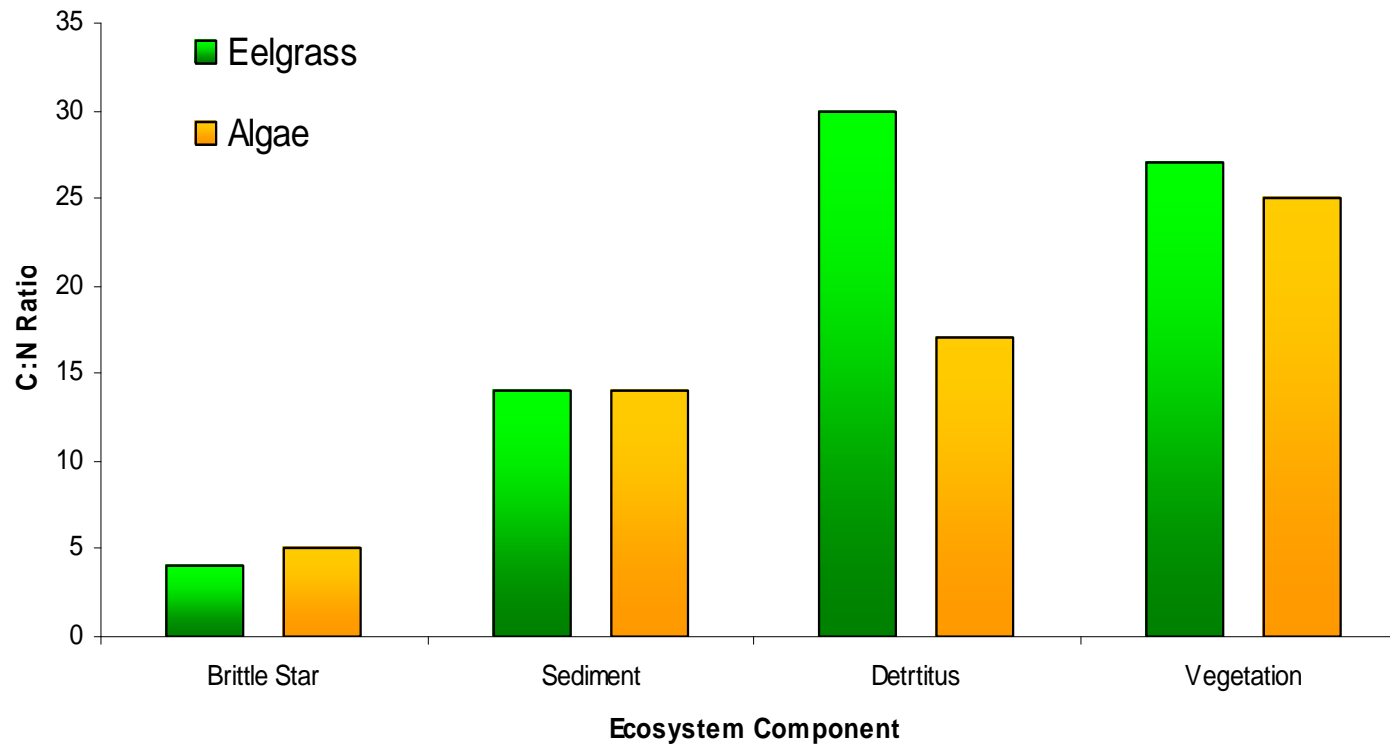


Figure 8. The molar C:N ratio of the components of each habitat shows low ratio in brittle stars with highest in live and dead eelgrass. Eelgrass detritus is rich in structural tissues with a high C:N ratio.

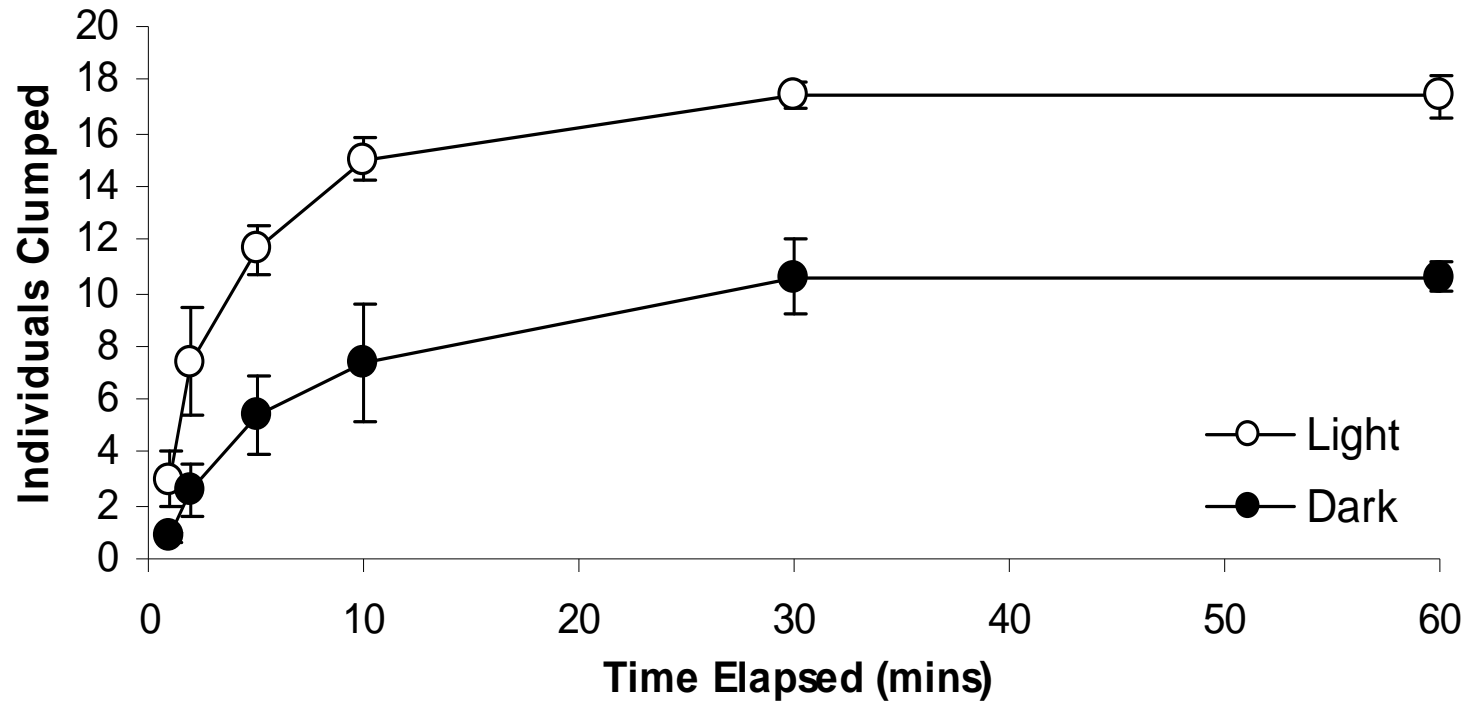


Figure 9. More individuals clump in corners of lighted aquaria than dark controls showing negative reaction to light. $P=0.001$. $N=5$. Error bars represent ± 1 S.E. of the mean.

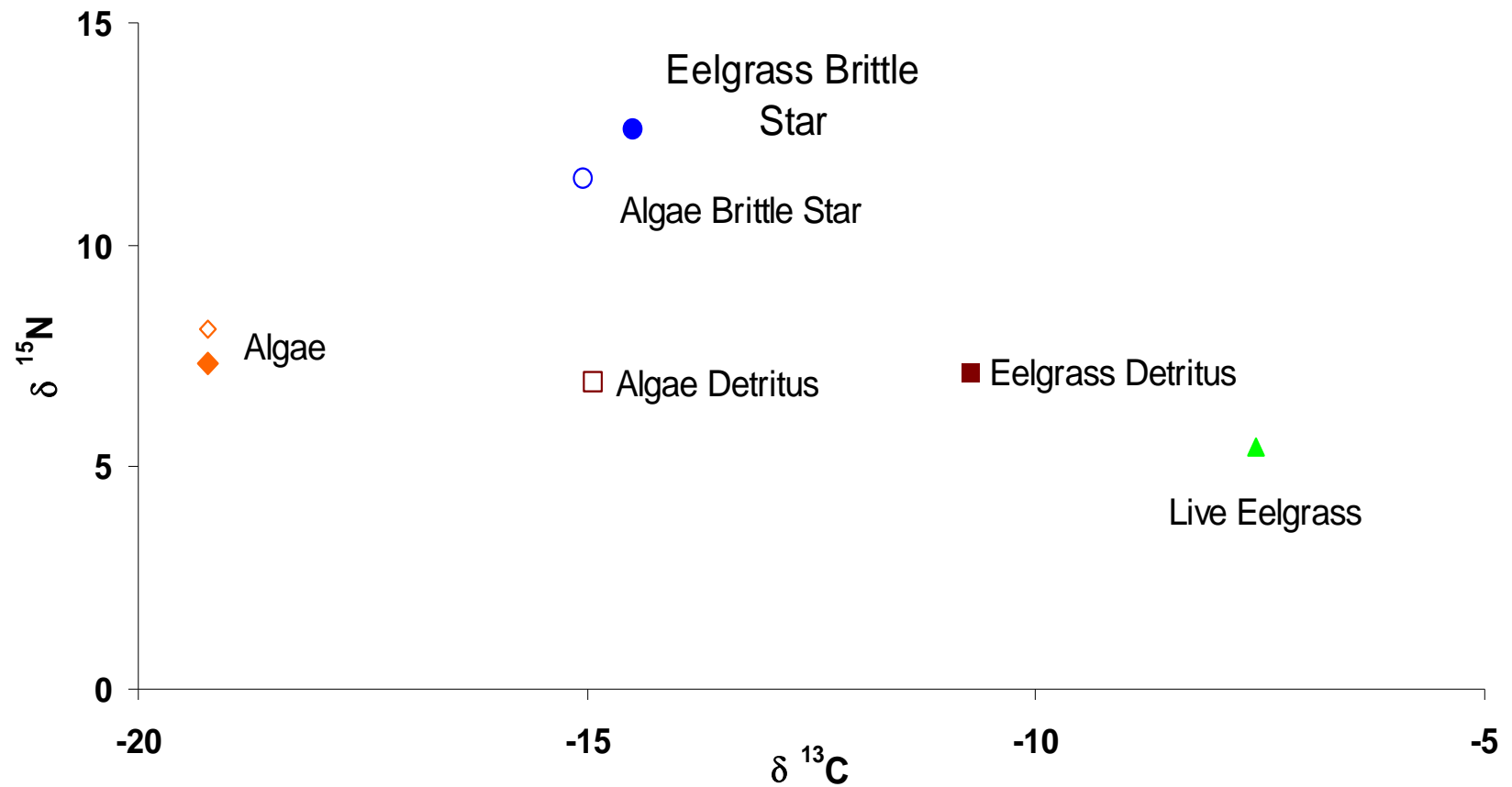


Figure 10. Closed symbols pertain to the eelgrass habitat, open symbols pertain to the algal habitat. Brittle stars from both habitats at a high trophic level and with algae brittle star having detritus as a significant carbon source while that from the eelgrass has a mixed carbon source.

Table 1. Sand was least preferred as lacking three dimensional structure, while detritus was chosen above eelgrass. Differences in eelgrass and algae preference dependent on original habitat. N=5. * indicates significance at $\alpha=0.05$, ** indicates individuals taken from algae bed as opposed to eelgrass.

Habitat 1		Habitat 2
Mud	>	Sand*
Detritus	>	Sand*
Eelgrass	>	Sand*
Detritus	>	Eelgrass*
Algae	=	Eelgrass*
Algae	>	Eelgrass* **
Sand	>	Algae*
Mud	>	Algae*

Table 2. *O. brevispinum* from eelgrass show no preference for either habitat whereas those from the algae bed show strong preference for algae, suggesting better capacity for maximizing algae as protection. N=5. *indicates significance at $\alpha = 0.05$.

Original Habitat	Habitat Selection	
	<u>Eelgrass</u>	<u>Algae</u>
<u>Eelgrass</u>	10	10
<u>Algae*</u>	7	13