

Comparing *Metacarcinus magister* settlement preferences among the
seagrasses *Z. marina* and *Z. japonica*

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Introduction:

Metacarcinus magister (Dungeness crab) is a commercially important species on the Pacific Northwest coast (Pauley et al. 1986). This fishery is the most profitable fishery in Oregon (ODFW 2012). Not only is *M. magister* valuable to fisheries but this species also plays ecological roles as important predators and prey (Pauley et al. 1986). *M. magister* populations have many periods of fluctuation (Pauley et al. 1986) and so understanding their distribution at different life history stages is beneficial both ecologically and economically.

M. magister larvae are transported offshore after hatching until they molt into megalopae, the most advanced stage. Megalopae are most abundant in Oregon in April and May (Pauley et al. 1986). Settlement intensity is most highly affected by larval survival to metamorphosis, due to a combination of predation, temperatures, currents, and food availability (Eggleston and Armstrong 1995). Once larvae molt into juveniles, they are found in shallow estuaries, largely among *Zostera* spp. (eelgrass) or other seagrasses, which provide food, protection, and substrate (Pauley et al. 1986). Juveniles will typically molt 11 or 12 times, and each stage between molts is called an instar (Pauley et al. 1986). Most first instar *M. magister* are between 5mm and 8.5mm (Pauley et al. 1986). The Pacific Northwest native *Zostera marina* (common eelgrass) provides important habitats for crabs, especially juveniles, which require protection and easy access to prey (Harrison and Bigley 1982). *Zostera japonica* (dwarf eelgrass) is an established invasive species of seagrass in the Pacific Northwest (Harrison and Bigley 1982) and may also be important habitat for juvenile Dungeness.

Greater *M. magister* prey abundances are found in more complex habitats (Hedvall et al. 1998), showing that seagrass can be a source of both protection and prey. Shoot density can be a measure of habitat complexity. Attrill et al. (2000) found that macro invertebrates, such as crabs, show a higher abundance in seagrasses with greater shoot density. Hedvall et al. (1998) also found that 24-40% of crabs preferred structurally complex habitats versus 0-2% of crabs choosing sand habitats. This preference may be because predation is highest in open habitat (Ramsay 2012). Shoot density can be a measure of above ground structural complexity of a habitat (Webster et al. 1998). Ruesink et al. (2009) reported that *Z. japonica* has a higher shoot density than *Z. marina*

and thus may provide better habitat for juvenile crabs. Plant biomass has also been shown to be significantly correlated with the abundance of invertebrates and thus may be another important measure of juvenile crab habitat preference (Heck and Wetstone 1977; Lewis et al. 1983).

Coastal and bay development can have important implications for juvenile *M. magister* settlement preferences. For example, dredging in Grays Harbor in Washington led to an estimated killing of 161,561 subadult *M. magister* in 1990 (Wainwright et al. 1992). Assessing the relative importance of different habitats can allow for informed decisions on the significance of the ecological effects of habitat removal.

We observed that many organisms prefer structurally complex habitats, especially juveniles escaping predation. We narrowed our focus to *M. magister* and seagrasses because of their abundance in the Yaquina Bay estuary, Oregon. We hypothesized that juvenile *M. magister* will prefer to settle in seagrass habitats over open habitat because of the greater structural complexity. We also hypothesized that juvenile *M. magister* will prefer to settle in *Z. japonica* over *Z. marina* because *Z. japonica* has the most above-ground structural complexity. Our null hypothesis is that there will be no settlement preference of juvenile *M. magister* for *Z. japonica* or *Z. marina* or open habitat.

Materials and Methods:

We collected the data for this study on the north band of the Yaquina Bay estuary in Newport, OR (44.6181° N, 124.0302° W). Yaquina Bay is a drowned river estuary. We chose a study site with a large mud flat that has all three habitats needed for the study: open mud, *Z. japonica*, and *Z. marina*. *Z. japonica* is closer to the shore than *Z. marina*, and the open mud habitat is between the two seagrasses. Using NOAA data, we determined the tidal heights for each habitat by noting when the tide hit each series of bags. The *Z. marina* area is at a tidal height of -0.54ft, the open mud habitat was at a tidal height of 2.99ft, and the *Z. japonica* area is at a tidal height of 3.92ft.

We used mesh bags with oyster shells to attract juvenile *M. magister*. We obtained oyster shells from Oregon Oyster Farms, Inc, in Newport, OR. Megalopae generally settle 8-10 times more frequently on oyster shell substrates than mud (Eggleston and Armstrong 1995). Each bag of oyster shells was about a foot long by half

a foot wide. We staked down three bags using small metal stakes in each of the three habitats, n=9. The bags were about 30ft apart. The bags sat for 19 days, roughly the length of the tidal cycle, to allow for *M. magister* settlement. At the end of 19 days we assessed the nine bags as well as seven extra open plots in each habitat, for *M. magister* abundance and size. We also recorded the abundance and size of *Hemigrapsus oregonensis* due to their unexpected appearance.

We determined abundance by counting the number of *M. magister* and *H. oregonensis* within each oyster bag. To do this, we placed a crab corral around the bag. We placed the bags' contents, as well as the substrate, down to 2cm, into a sieve. We counted the number of crabs and measured the carapace width of each one.

To determine the normal density of *M. magister* in these habitats, we sampled seven representative areas in each of *Z. marina*, mud, and *Z. japonica* habitats, n=21. The areas were in relatively close proximity to the shell bags, and represented the area the bags were placed in. The chosen area was not too close to the bags that the settled crab were frightened away. We enclosed the area with the crab corral and placed all substrate, down to 2cm, into a sieve. We counted the number of crabs present and recorded the carapace width of each. We also collected and bagged all the seagrass present in each area.

After bagging the seagrass from each plot, we brought it back to the lab and, keeping the seagrass from each area separate, washed and weighed the samples.

We determined shoot density of *Z. japonica* and *Z. marina* by placing 0.25m² quadrats within 10ft of each shell bag, in both habitats. We did three replicate quadrats at each shell bag area for a total of 18 shoot density quadrats. We counted the number of shoots within a 0.09m² sub-quadrat.

Our statistical analysis was conducted using the statistical program Minitab. A one-way ANOVA tests to find if habitat was a significant predictor of *M. magister* abundance. We used the Tukey method to find which habitats were significantly different from each other. We used a multiple linear regression to test interactions between crab species as well as to see if the presence of oyster bags affected abundances. To test if biomass and shoot density were significant factors in *M. magister* abundance we performed linear regressions.

Results:

We performed a multiple linear regression to test the interactions of oyster shell bags and *H. oregonensis* on *M. magister*. The test showed that neither oyster shells bags nor *H. oregonensis* presence affected *M. magister* abundances ($F_{3,26}=1.30$, $p=0.296$).

Using a one-way ANOVA test we found that habitat does significantly predict *M. magister* abundance ($F_{2,27}=0.018$, $p=0.001$) (Fig. 1). In this test we used the natural log of *M. magister* abundance so that our data would follow a more normal distribution. The Tukey method showed that the mud habitat has a significantly lower *M. magister* abundance than either of the seagrasses, however the seagrasses did not have a significant difference in abundance between *Z. marina* and *Z. japonica*.

We also looked at the size frequency distribution of *M. magister* and saw that we mainly had first and second instars (Fig. 2). A one-way ANOVA test showed that the average sizes in each habitat were not significantly different ($F_{2,77}=2.22$, $p=0.115$), and the Tukey method grouped the three habitats together.

Z. japonica does have a significantly higher shoot density than *Z. marina* ($p<0.001$). However, after running a linear regression, we found that shoot density does not significantly predict *M. magister* abundance ($p=0.547$, $R^2=0.001$) (Fig. 3). We used the natural log of *M. magister* abundance to allow for a more normal distribution.

There was not a significant difference in biomass between the two seagrasses ($p=0.168$). By running a linear regression we found that seagrass biomass does significantly predict *M. magister* abundance ($p=0.001$, $R^2=.446$) (Fig. 4).

A linear regression also showed that tidal height does significantly predict *M. magister* abundance ($p=0.015$, $R^2=.597$).

Discussion

We found a significantly higher abundance of *M. magister* in seagrasses compared to mud, and so our hypothesis that mud would have a significantly lower abundance than seagrass, is supported. However the data does not support our second hypothesis that *Z. japonica* would have a significantly higher abundance than *Z. marina*. Therefore, our data indicates that *M. magister* show preference for seagrass habitats over mud, but do

not show any preference between seagrass habitats. We may have not been able to see any significant difference in abundances between seagrasses because a study by Lewis and Stoner (1983) showed that random or sparse sampling may not give an adequate estimate of *M. magister* abundance. We suggest that future studies perform more comprehensive sampling of *M. magister* abundance.

Hedvall et al. (1998) showed that there are greater *M. magister* abundances in habitats with greater structural complexity. Seagrass structural complexity is important for settling *M. magister* because it provide increased prey items, increased protection, decreased hydrodynamic forces, and increased living space (Lee 2001). Habitat structural complexity was determined in this study using two different methods: shoot density and biomass. We expected *Z. japonica* to have more structural complexity than *Z. marina*, and while it did have significantly higher shoot density, we found that *Z. marina* had significantly higher biomass. Studies by Ruesink et al. (2009) and Webster et al. (1993) have found similar results. We were able to determine that *M. magister* show a preference for habitats with higher biomass, but not higher shoot density. This is similar to results found from previous studies (Heck and Wetstone 1977; Lewis et al. 1983). Our data supports that biomass is a determining factor for juvenile *M. magister* abundance; however, it is difficult to say if *M. magister* abundance is correlated with structural complexity because *Z. japonica* had greater shoot density.

While there was no significant interaction between the abundance of *H. oregonensis* and the abundance *M. magister*, the presence *H. oregonensis* may influence *M. magister* abundance. A study done by Visser et al. (2004) found that *H. oregonensis* negatively affects *M. magister* abundance. *M. magister* abundance is dependent on the density of *H. oregonensis* because *H. oregonensis* excludes *M. magister*. The exclusion of *H. oregonensis* would be important to look at in future studies.

First and second instars were primarily found in our samples. This size frequency is probably due to the fact that *M. magister* larvae settle most often in April and May (Pauley et al. 1986), which was when we were sampling. Habitat did not predict any size differences, and this is supported by a study done by Gunderson et al. (1990) who found that *M. magister* do not leave their area of settlement during their first year, and so they do not move to different habitats, as they grow bigger. However, our data did show that

there were more second instars among *Z. japonica* than *Z. marina*. An in depth analysis that takes into account the size at instar rather than just the average size would be needed to further research in size distribution between habitats.

We found that tidal height is significantly correlated with *M. magister* abundance. There were higher abundances of *M. magister* in lower tidal elevation areas, and this result is supported by Ramsay (2012) who found similar results indicating that tidal could be an influence on *M. magister* abundance. Lower tidal elevation areas are subject to less desiccation and increased food availability and may be preferable settlement areas (Ramsay 2012). Therefore it is difficult to conclude whether it is habitat type or tidal height that is determining *M. magister* abundance.

Z. japonica is an invasive species in the Pacific Northwest, and its interactions with macrofauna, including *M. magister* is still in question (Gribben et al. 2008). There is very little knowledge on if invasive species of seagrass are harmful or beneficial to the recruitment of *M. magister* (Gribben et al. 2008). This study shows that both *Z. marina* and *Z. japonica* are important and beneficial to *M. magister* settlement, and this should be taken into account for any eradication intentions. *M. magister* are the most profitable fishery in Oregon (ODFW 2012) and if there was to be mass extraction of seagrass or destruction of seagrass habitats in estuaries there would be consequences for stakeholders in the *M. magister* fishery.

In order to have a comprehensive and sustainable fishery there has to be a strong understanding of the life cycle and habitats of the target species. Seagrasses are important for *M. magister* settlement. The more biomass of seagrass available for settlement, the more sustainable *M. magister* populations will be. Estuarine seagrasses should be conserved and protected from damaging activities such as dredging. Sustainable yields of *M. magister* may be achievable if we can increase their settlement success.

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Figures:

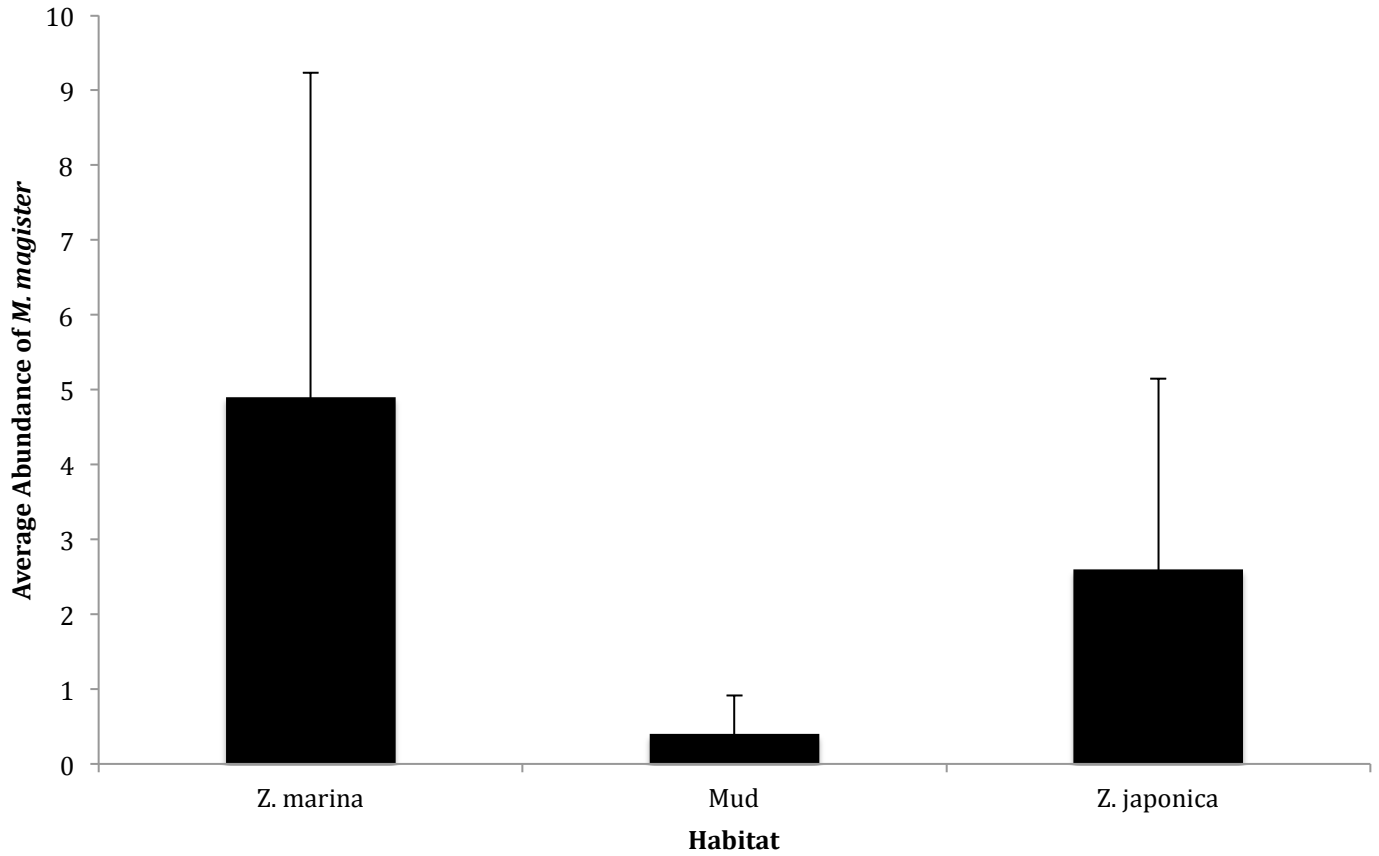


Fig. 1. Average abundances of juvenile *M. magister* were found among three different habitats. The error bars correspond to standard deviation. The Tukey method showed that there was a significant difference between the seagrasses and mud but not between the seagrasses themselves.

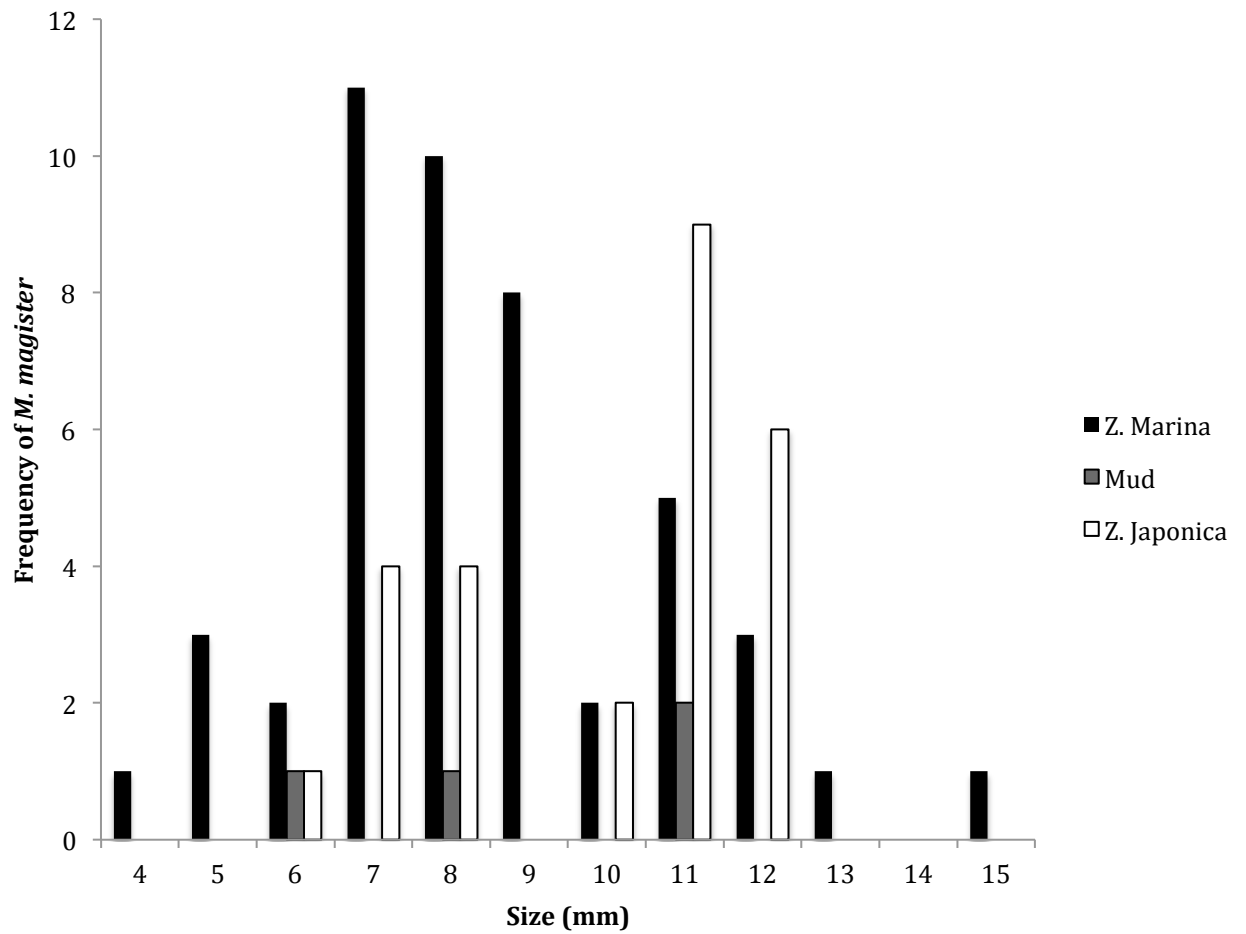


Fig. 2. The size frequency distribution for *M. magister* among the three different habitats was found by measuring the lengths of the crabs' carapaces. The two peaks presumably mark the first and second instar size classes.

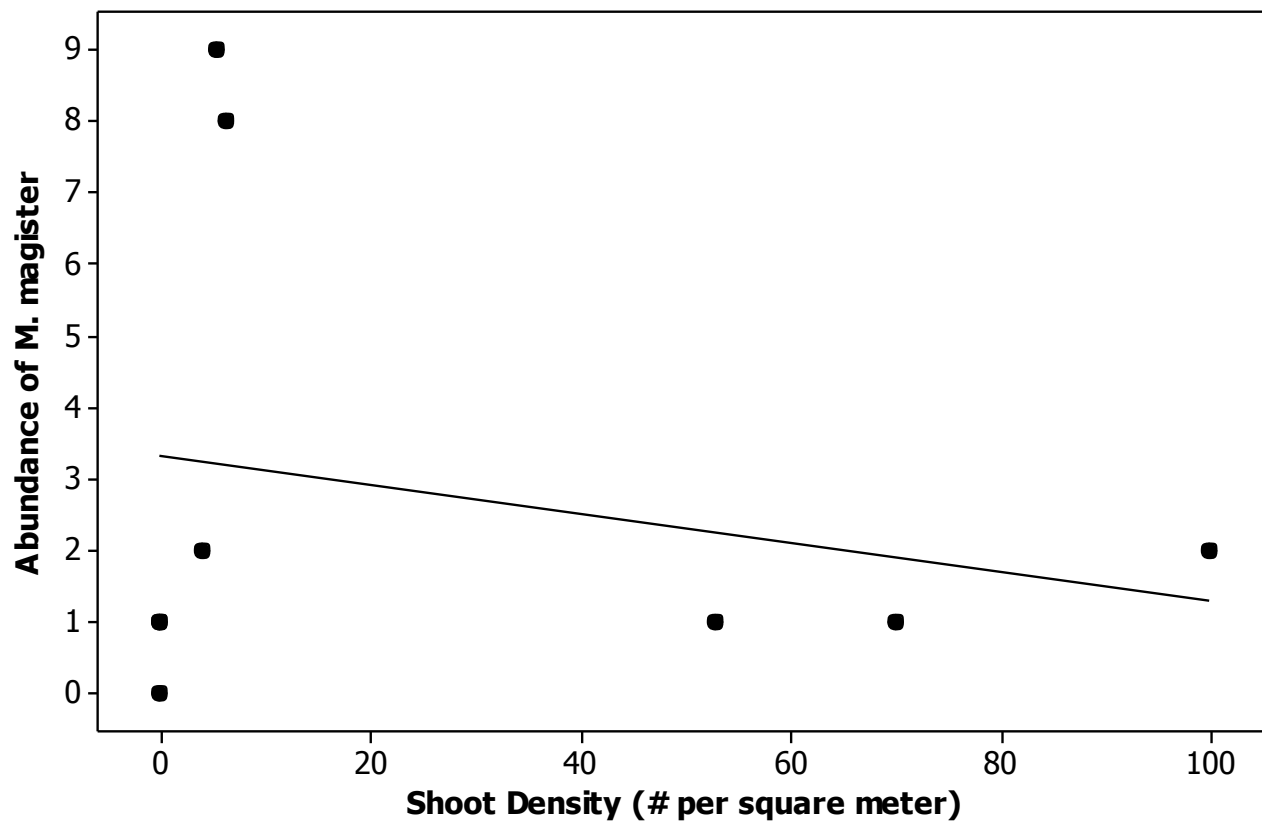


Fig. 3. Shoot density was compared with the abundance of *M. magister*. The linear regression showed that shoot density does not significantly predict *M. magister* abundance ($p=0.015$, $R^2=0.1\%$).

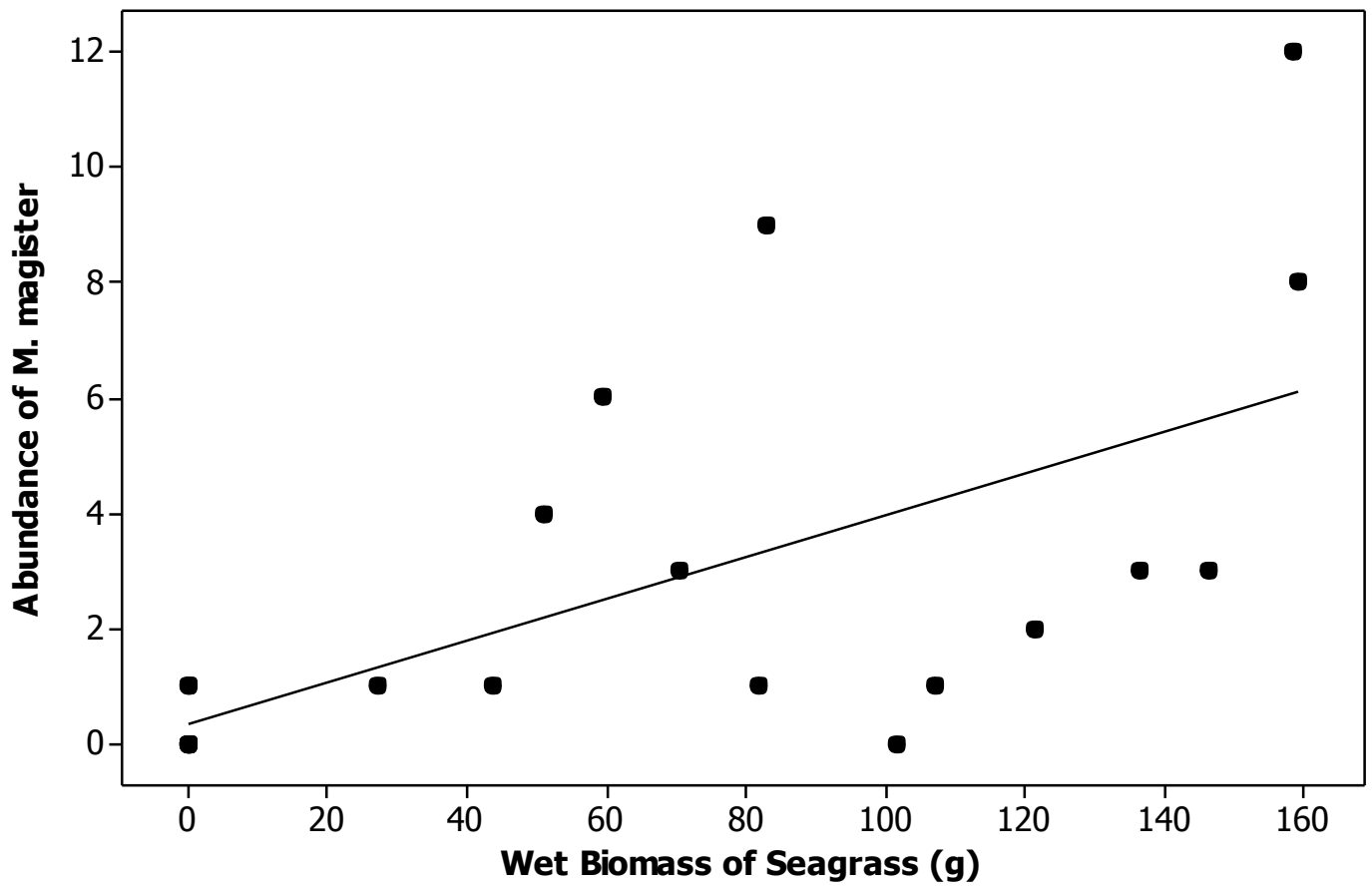


Fig. 4. Biomass was compared with *M. magister* abundance. The linear regression showed that biomass does significantly predict *M. magister* abundance ($p=0.001$, $R^2=44.6\%$).