# SIZE AND PIGMENTATION AS FACTORS DETERMINING MYSID SCHOOLING BEHAVIOR

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*Abstract:* Schooling behavior of aquatic organisms is thought to be a mechanism which increases individual fitness. The mysid *Mysidium gracile* occurs in schools which may maximize its individual fitness. This study examines size and pigmentation as factors determining segregation of these mysids into schools. I examined the size, pigment and developmental stage of individuals within 13 schools in the back reef of Discovery Bay. Schools were found to be segregated by size and pigmentation. Schools of large individuals had more pigmentation and a greater proportion of females than schools of small individuals. Darkly pigmented schools were located above dark algae/crevice substrates while non-pigmented schools were located above sand. Individual mysids appear to have changing schooling requirements as they develop in size and pigmentation, suggesting that some level of site relocation occurs within the lifetime of an individual mysid.

*Key Words: Mysidacea, mysid schooling, size sgregation, Discovery Bay, Jamaica*

## INTRODUCTION

Schools of the mysid *Mysidium gracile* are commonly found in the backreef of Discovery Bay, schooling during the day within damselfish territories and dispersing at night to feed (Butler, 1989). The schooling behavior of mysids has been proposed as a mechanism that increases individual reproductive and feeding efficiency, and protection from predators (Clutter, 1969; Wittmann, 1976; O'Brien, 1988 in Modlin, 1990). Mysid schools have been noted to be composed of individuals of the same size or life stage (Emery, 1968; O'Brien, 1988; Modlin, 1990). This may decrease individual predation risk by decreasing the conspicuousness of each individual within a school. Mysids are also known to change color through development, from light pigmentation to dark pigmentation (O'Brien, 1988). Thus, mysids may also school in similarly pigmented schools to decrease predation risk. This study examines more closely the segregation of mysid schools by size and pigmentation in Discovery Bay.

I hypothesized that pigmentation and size are important organizing factors in the schooling behavior of mysids, and therefore that schools would be segregated by size and pigmentation. I predicted a higher variance in size in schools of large individuals than schools of small individuals, since small individuals may be able to hide effectively amongst large individuals, whereas large individuals may be more conspicuous to predators amongst small individuals. For similar reasons I predicted that more darkly pigmented mysids would school together and would not be found amongst non-pigmented schools. Furthermore, schools should locate where their pigmentation matched their surrounding substrate, with non-pigmented schools located above white sand, and pigmented schools above dark algae or shadowed crevices.

## METHODS

The mysids examined in this study were collected in the back reef of Discovery Bay, Jamaica, W.I. on 4-6 March, 1998. I collected mysids from 13 schools, apparently varying in size and pigmentation, with a hand net. All schools were separated by at least 5 m, and were located within 15 m of the reef crest. All schools were located within a damselfish territory. The type of substrate the school was over was recorded as sand, algae or crevice. The mysids were preserved in 10% formalin and examined with a dissecting microscope.

31 to 50 individual mysids were examined from each school. Size was measured to the nearest 0.5 mm (from eyes to statocysts). I classified pigmentation as none (transparent), medium (light red and/or green), or dark (darker red and/or green). The presence of a brood sac was used to identify adult females. Adult males can be identified by a thin appendage extending from the mid-ventral section of the abdomen (Fig. 1), however this method of identification was developed after examination of some of my samples. Thus, I calculated % females as the





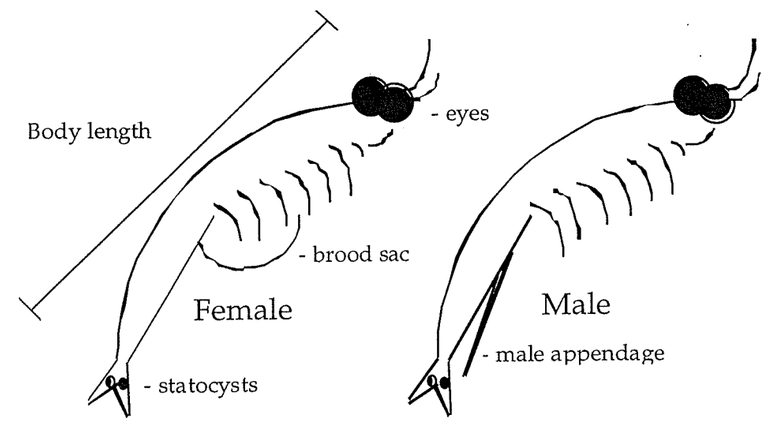


FIG. 1. Female and male adult mysids.

proportion of individuals 3 mm and larger with brood sacs (x100). No individuals 2.5 mm and smaller had brood sacs or male appendages and were considered to be juveniles. Adult females with eggs or embryos inside the brood sac were recorded as gravid, and females that had embryos with eyespots were also noted as a measure of embryonic development.

I used an ANOVA with a Tukey test for multiple comparisons to compare the size of mysids among schools. Individuals from all schools were pooled to compare sizes between pigment classes using an ANOVA with a Tukey test. I correlated the proportion of females, the proportion of gravid females, and the proportion of gravid females with embryos having eyespots within each school to the mean size of each school. I used a Chi-square to test whether the proportion of dark, medium and light pigmented schools was similar between schools with large, medium and small individuals. I also used a Chi-square to test whether the distribution of dark, medium and light pigmented schools was similar over sand, algae and crevice substrates.

## RESULTS

The mean size of individuals differed significantly between the 13 mysid schools ($F_{12,605} = 125.37$, $P < 0.0001$; Table 1). There were significant differences in size between schools above and below 4 mm, and between groups above and below 3 mm, which I used to categorize groups into large, medium and small sized schools (Table 1). Schools differed in variance of size distributions, with large and small schools bounded at the ends by upper and lower size limits (Figure 2). Medium sized schools showed the greatest variance in size (Figure 3).

Schools also varied in pigmentation, with each school having at least 60% of examined individuals within one pigment category (Table 1). Only one darkly pigmented mysid was found within a school categorized as non-pigmented. Darkly pigmented individuals were significantly larger than medium and non-pigmented individuals, and all dark schools were within the large size class (Table 2). Dark schools were located more often over dark crevices, whereas medium- and non-pigmented schools were located more often above sand substrate (Table 2).

The proportion of adult females, the proportion of gravid females, and the proportion of females with embryos having eyespots within each school increased with the size of individuals in the school ($R = 0.90, 0.63, 0.80$; $P < 0.0001$, $P = 0.05, 0.01$, respectively).

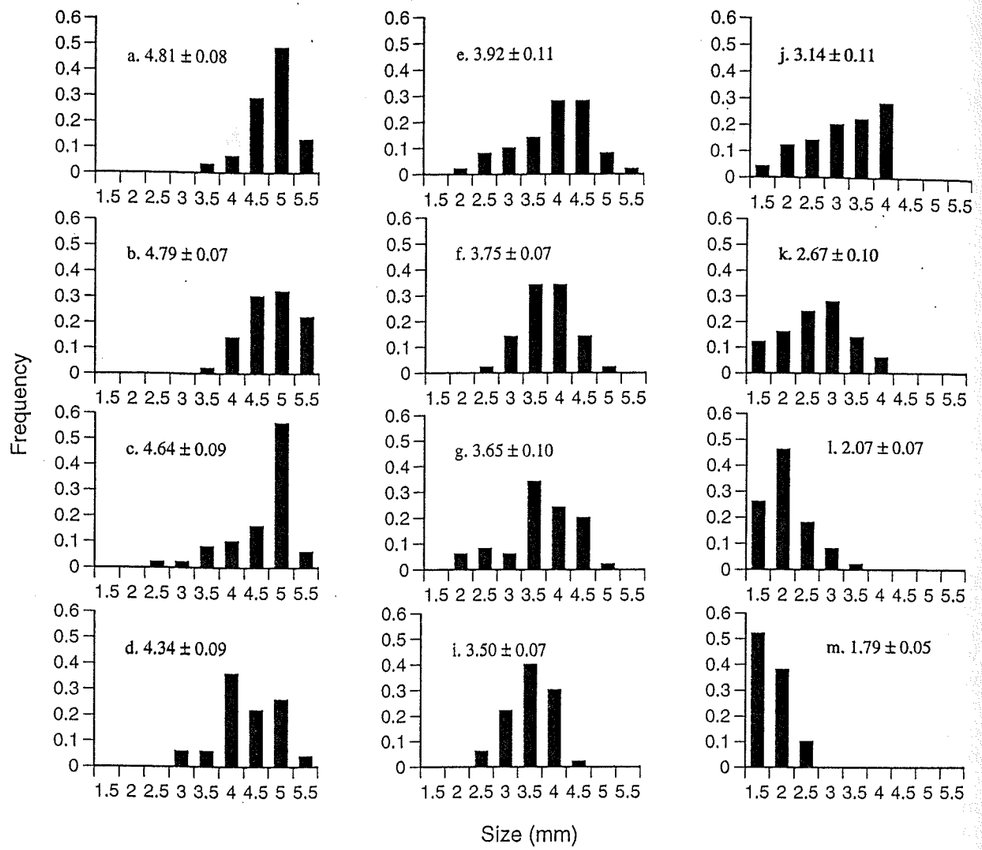


FIG. 2. Frequency distribution of mysid individuals within measured size classes for 12 of 13 sampled mysid schools, with mean size ± 1 SE. School h was not included because of its similarity to school I in distribution and mean size.





TABLE 1. Composition of mysid schools by size, pigment, sex and development. Lines connecting schools indicate that they are not significantly different in size using a Tukey test. This pairwise test was used to differentiate schools into size groups, with a-d as large groups, e-j as medium-sized groups, and k-m as small groups.

| School | N | Mean size ± 1SE (mm) | Size group | Pigment* | % female** | % females gravid | % gravids with eyespots |
|---|---|---|---|---|---|---|---|
| a | 31 | 4.81 ± 0.08 | Large | Med | 87 | 89 | 50 |
| b | 50 | 4.79 ± 0.07 | Large | Dark | 94 | 89 | 43 |
| c | 50 | 4.64 ± 0.09 | Large | Dark | 78 | 97 | 41 |
| d | 50 | 4.34 ± 0.09 | Large | Dark | 52 | 92 | 33 |
| e | 50 | 3.92 ± 0.11 | Med | None | 53 | 83 | 25 |
| f | 50 | 3.75 ± 0.07 | Med | None | 49 | 67 | 38 |
| g | 50 | 3.65 ± 0.10 | Med | None | 51 | 59 | 38 |
| h | 37 | 3.54 ± 0.09 | Med | None | 39 | 71 | 10 |
| i | 50 | 3.50 ± 0.07 | Med | None | 49 | 52 | 8 |
| j | 50 | 3.14 ± 0.11 | Med | None | 43 | 87 | 15 |
| k | 50 | 2.67 ± 0.10 | Small | Med | juveniles | | |
| l | 50 | 2.07 ± 0.07 | Small | None | juveniles | | |
| m | 50 | 1.79 ± 0.05 | Small | None | juveniles | | |

* ≥ 60% of individuals were within the pigment category
** See methods for calculation of % female

TABLE 2. Pigment distribution in mysids and mysid schools. a) Mean size of all dark, medium and no pigment individual mysids, with an ANOVA test for differences in size. b) Distribution of dark, medium and no pigment mysid schools by size and substrate, with Chi-square tests for differences in distribution.

| Pigment | Mean Size ± 1 SE (mm) | Size group: Large | Size group: Medium | Size group: Small | Substrate: Crevice | Substrate: Algae | Substrate: Sand |
|---|---|---|---|---|---|---|---|
| Dark | 4.71 ± 0.08* | 3 | 0 | 0 | 3 | 1 | 0 |
| Medium | 3.89 ± 0.09* | 1 | 0 | 1 | 0 | 0 | 2 |
| None | 3.13 ± 0.05* | 0 | 6 | 2 | 0 | 1 | 6 |
| | F = 142.22 P < 0.0001 | $X^2_4$ = 12.46, P < 0.025 | | | $X^2_4$ = 10.91, P < 0.05 | | |

- all sizes are significantly different from each other using Tukey test of multiple comparisons

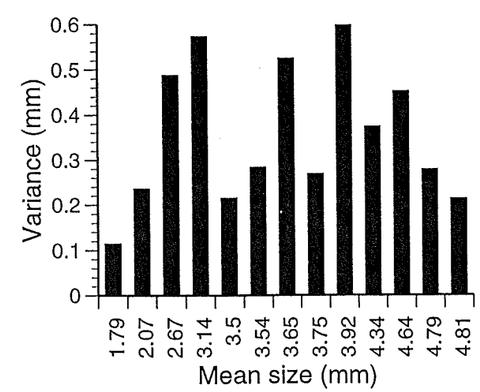


FIGURE 3. Variance in individual mysid size within each school, in order of increasing mean size.

## DISCUSSION

Mysid swarms were segregated by size and color in the backreef of Discovery Bay. Mysids were organized generally into schools of non-pigmented juveniles, schools of non-pigmented adults, and schools of pigmented adults. This segregation may serve to lower the risk of predation for each individual by making each mysid less conspicuous, thereby increasing the cohesiveness of each school. Also, since adults are predaceous (Siegfried and Kopache, 1980 in Modlin, 1991), it is possible that juveniles avoid adult swarms where they may be at some risk of being eaten.

Though schools may be most effective at decreasing predation risk when individuals are of the same size, a higher variance in size occured

within schools of intermediate individuals than in schools of large and small individuals. This may simply be because there is less potential for variation in small and large mysids which are limited by minimum and maximum species size. Considering that mysids have the ability to segregate, this change in variance may indicate that there are differing costs and benefits associated with segregation for different sized mysids. For intermediate individuals, the cost of finding a school of more similarly sized individuals may be greater than the benefits of a more homogeneous school. Larger individuals may avoid swarms of juveniles where they may be more recognized by a predator. Smaller mysids may form more homogeneous schools if they are inherently more susceptible to predation and caniballism. Population densities of mysids and the frequency of proper schooling locations may also be factors which limit the degree to which mysids segregate.

Pigmentation appears to be a strong organizing factor of mysid schools in Discovery Bay. I found only one darkly pigmented mysid within a non-pigmented school. Furthermore, dark schools were associated with dark substrates (algae/crevice) while non-pigmented schools were associated with light substrates (sand). This suggests that mysids preferentially school above substrates which make them most cryptic. Future studies could experimentally test this hypothesis by giving dark or light mysids a choice of substrates of differing darkness and observing their distributions.

Pigmentation increased as mysids became larger, indicating that an individual mysid experiences changing schooling requirements throughout its lifetime. It is likely that as a juvenile, a mysid will school with other juveniles above a sandy substrate. If mysids exhibit homing behavior , this mysid may remain with this school as it develops into a school of non-pigmented adults. However, as this mysid develops pigmentation, it may relocate to a school of pigmented adults above a darker substrate. Observing mysids in schools over the time period of several life cycles would show if mysid schools are dynamic or static in composition, and to what degree recruitment and emigration occurs within a school.

Sex ratios in adult schools varied with size. Three of the four large schools had skewed sex ratios, with high proportions of females. The embryos in these larger schools were also more developed than embryos from medium sized schools. This suggests that as females bear embryos in later stages of development and become more darkly pigmented, they benefit from selectively schooling together. Males may selectively avoid these schools in preference of schools with a greater proportion of non-gravid females to increase their reproductive efficiency. Or perhaps males do not live as long as females, possibly dying after a bout of fertilization.

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