# The effects of population density on the reproduction and survival of daphnia mag...

Abstract The population dynamics of Daphnia magna are observed under three different conditions; low, medium, and high density. The effects of different population densities on the survivorship and reproduction of Daphnia are observed over a two-week period within a lab environment. Over the two week period, the numbers of parent Daphnia alive and dead are recorded daily, along with the amount of offspring produced each day. From the main parameter investigated, the net reproductive rate, the results of the experiment support that higher densities result in less successful reproduction and decreased fecundity.

Values for the instantaneous growth rate of the populations also suggests that low and medium density populations allow for greater growth rates than high density populations. The results indicate that greater resource availability is directly related to higher fecundity, but that medium density populations can have similar growth rates despite a much smaller birth rate.
Introduction In any population, birth rates, mortality rates, immigration, and emigration determine whether the population's numbers will increase, decrease, or remain the same.

Factors that can have great effects on both fecundity and mortality rates can include density-dependent mechanisms (those that have a greater influence on population dynamics as population densities remain high) and intraspecific competition (occurs when members of the same species compete for resources). The objective of our experiment is to determine the effect that population density has on both the survival and reproduction of lab-grown Daphnia magna. Because the experiment was done in a controlled lab environment, immigration and emigration of individuals can be ignored.

This study will address how certain variables, such as net reproductive rate and instantaneous rate of growth, change with respect to three different population densities of Daphnia. The ecological hypothesis of this experiment is that higher densities will lead to more competition for food between Daphnia, resulting in lower rates of survival and reproduction. A similar experiment was carried out by Cox et al. (1992), who found that decreased food levels resulted in a smaller cumulative fecundity but larger offspring while relatively high food levels resulted in many offspring of smaller size.

This illustrates how organisms can alter their life history strategies in the face of stressful conditions and limited resources. Yurista and O'Brien (2001) observed the population dynamics of Daphnia in the natural environment and found that both food availability and quality have the greatest effect on the population growth of Daphnia middendorffiana. They also observed that greater resources lead to greater survivorship and fecundity, and that predation (a density-dependent factor excluded from our experimentation) can play a significant role in altering the distribution of the Daphnia and decreasing the population size.

According to Preuss et al. (2009), populations that have to cope with low densities of algae are limited by food availability, whereas populations that have access to a high food supply are limited by crowding effects. They describe " crowding" as a density-dependent mechanism because of a chemical substance that is released upon physical contact of two individuals (which would happen more frequently at higher densities). They also found that daphnia at higher densities produced much less offspring than those at lower population densities.

According to Luerling et al. (2003), Daphnia pulex react to these crowding chemicals in the same way that they react to food limitations. Although growth and survivorship are unaffected by high population densities, reproduction is significantly decreased. As demonstrated in the experimentation of Cox et al. (1992), Luerling et al. (2003) suggest that, in times of low food availability, individuals change their life history strategies in order to produce fewer offspring that will survive, conserving resources essential to their own survival as well.

This can explain why growth and survivorship seem to remain constant within a population regardless of resource availability. Ban et al. (2009) also found that Daphnia pulex grown under crowded conditions grew much more slowly than those that were grown alone, even when the food supply was sufficient. The individuals grown in a high density population were also observed to have a smaller net reproductive rate, due to the essential need for them to conserve resources necessary for their own survival.

These sources, as well as the results obtained from our experiment, support the claim that higher population densities result in reduced rates of reproduction and decreased chances of survival. Methods The experiment took place in a laboratory setting, and the first step was obtaining sixty individual Daphnia magna (that were neither adults nor tiny offspring) from a large tank in the lab. These individuals were equally divided into three groups; low density, medium density, and high density.

The twenty Daphnia assigned to the low density group were split into four groups of five and pipetted into one of four tubes filled with 10mL of Chlamydomonas algae. The twenty Daphnia assigned to the medium density group were split into two groups of ten and placed into one of two tubes also filled up to 10mL with Chlamydomonas. The final twenty Daphnia were all placed into a single tube filled with 10mL of the algae. In order to avoid suffocation-related damage to the Daphnia, all of the caps on the tubes were left loosely screwed and set aside for counting the following day.

Each day, the number of parent Daphnia, alive and dead, were recorded and the tubes were filled with fresh algae according to how many parent individuals were remaining. For example, if four parents remained in the low density tube, the tube would be filled with 8mL of algae to keep the density (2mL/individual) consistent. The number of offspring were also recorded each day and removed from the tubes immediately after so that they would not be counted twice. Because no counts were taken on weekends, the amount of food within the tubes was tripled after Friday sessions and numbers were divided by three on Monday counts.

Four replications of this experiment were carried out, and after the two week counting period the results from each replication were combined and averaged. From the attained means, values for age-specific survivorship (lx) and age-specific birth-rate (mx) were calculated for each density. The sum of the products of these two values for each age gives the net reproductive rate (Ro), a value that reveals whether a populations' numbers are increasing, decreasing, or remaining constant. Results

The results obtained from the experimental design are very similar to the findings of most of the researchers who conducted studies regarding the effects of population density on population growth and reproduction. Graph 1 shows the age-specific fecundity for the three density classes, and it is clear that the lower the population density, the higher the fecundity. The peak of each populations age-specific fecundity is observed to be at 8 days old for all three densities, which suggests that the Daphnia magna exhibit a discrete pattern of population growth.

The graph also shows that each population began producing by the first day. Graph 2 displays the survivorship curves for each population density. A similar curve can be seen between the low and high density populations, both of which seem to be of Type 1 survivorship. Graph 3 shows the relationship between density and net reproductive rate, illustrating an almost perfect negative correlation between the two variables. For the low density population, Ro had a value of 25. 83. The medium density group had an Ro value of 14. 5, and the high density population had an Ro value of 5. 544. Values for r (instantaneous growth rate) were also obtained. The low density group had an r value of 0. 5299, the medium density group had an r value of 0. 5348, and the high density group had an r value of 0. 3716. Discussion The graph showing fecundity versus age for the three densities indicates that higher resource availability results in higher fecundity, as individuals are not as desperate to conserve energy for their own survival.

Yurista and O'Brien (2001) observed that areas with three times the food availability had approximately three times the amount of neonate and diapause eggs for the Daphnia middedndorffiana population. Although their observations came from the natural environment, Cox et al. (1992) obtained similar results within a controlled laboratory setting. Preuss et al. (2009) found that five individuals at a density of 0. 2mg of algea per individual were able to produce (cumulatively) a mean of 120 offspring after 21 days, while the same number of individuals at a density of 0. 5mg of algae per individual only produced a mean of 57 offspring after the same amount of time. Although the low density population of Daphnia had much higher fecundity than the other populations, they exhibit (along with the high density class) a Type 1 survival curve. During the first two days, there was a sudden decrease in parent numbers, as seen in the high density population. The parents of the medium density population, on the other hand, seem to die at a more steady rate throughout the two-week period, exhibiting more of a Type 2 survivorship curve. Luerling et al. 2009) found that in highly crowded populations, up to 83% of non-developing eggs can be observed, possibly due to the presence of crowding chemicals. The rate of population growth was also observed to have decreased by up to twenty-five percent in the high density populations. The chemicals excreted by the daphnia that may be responsible for lower reproductive rates remain unknown, but both urea and ammonia seem to have some effect (Luerling et al, 2009). Ban et al. (2009) claim that neither resource limitation nor chemical secretions/imbalances are the reason for decreased growth and reproductive rates within high density populations.

This negative effect was found to be caused by physical interference between individuals, as food levels were always maintained at sufficient levels. Contrary to the statements made by Luerling et al. (2009), Ban et al.

(2009) show that crowding chemicals secreted by Daphnia pulex are not responsible for any alterations in reproduction, feeding, or behavior, because in their experiment, the water in which the populations grew was always conditioned in addition to the sufficient food supplies.

These findings are contradicted to a degree by the results of our experiment, as the Daphnia in the medium density tubes had a slightly higher instantaneous growth rate than the Daphnia at the lowest density, despite being more physically crowded within their tubes. However, the net reproductive rate for the medium density Daphnia was significantly smaller than that of the low density Daphnia, as Ban et al. (2009) would support. The Ro results obtained for each density support the original hypothesis made.

The reason for the smaller low density r may be that parents in these populations allocated the majority of their resources and energy to reproduction, whereas the medium density populations were more balanced in allocating resources to both offspring and survival. Contrary to what our experimental results show, Nandini et al. (2000) concluded from their results that neither r (instantaneous growth rate) nor peak population density of Daphnia laevis were affected by the amount of food available, but rather the type of food available.

Altering the food type in their experiment had the most significant impact on their populations' net reproductive rates. Although our results, for the most part, seem consistent with other findings, improvements can be made to the experimental design. First of all, doing counts on weekends would have given more accurate results regarding age-specific birth and survival rates. It is possible that the Daphnia were put under stress each day as they were pipetted from tube to petri dish and back. This may have had an effect on their behavior, metabolism, or even reproduction.

The tubes they were kept in could have been wider in diameter, as the individuals of the high density group were especially crowded. If, in future experimentation, one decided to test the effect of physical crowding and interference on population dynamics, this change in tube diameter would be a worthwhile consideration. In our experiment, the Daphnia were released after the second week, although we could have observed their population patterns throughout their entire life spans. Effects of either predation, interspecific competition, or both, could have been tested either in a lab setting or in the wild.

This would involve mixing two different species of Daphnia and then introducing a predatory fish into their environment and observing the population dynamics and life history strategies of the two competing species. In the wild, as opposed to the controlled setting of our experiment, density-independent factors including weather and droughts would also have to be accounted for. Literature Cited Ban, S. , Tenma, H. , Mori, T. , and Nishimura, K. 2009. Effects of physical interference on life history shifts in Daphnia pulex.

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