The Influence of Dominance on Shelter Preference and Eviction Rates in the Crayfish, *Orconectes rusticus*

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**Abstract**

The establishment and reinforcement of dominance status is thought to provide an individual with increased access to preferred resources, such as food, mates, and shelter. Resources within an environment vary based on their availability, abundance, and specific characteristics of the resource. Animals can exhibit preferences for resources by increasing the intensity of competition for access to the resource. We investigated the role that dominance has in acquiring and controlling resources within crayfish populations. Populations of 5 size-matched crayfish were allowed to establish a social hierarchy in the presence of shelters of differing structure in 10 different trials. Crayfish agonistic interactions and the use and control of shelters were quantified from 96 h continuous video recordings. Shelter preference was defined by crayfish use of specific shelter types that were occupied for longer durations. Analysis of the social hierarchy demonstrated that crayfish have a linearity hierarchy in this context. In addition, it is clear that dominance rank had a significant impact on shelter use, shelter acquisition, and shelter eviction. Crayfish with lower average dominance ranks selected specific shelter types (smaller and fewer openings). Dominant crayfish used big shelters and were less likely to be evicted from shelters. These results demonstrate that dominance in crayfish serves a role in the acquisition of resources and is also important for the control of those resources.

**Introduction**

Agonistic interactions occur between conspecifics and are important for both social hierarchies and competition for resources (King 1973; Rahel & Stein 1988; Drews 1993; Lima 1998). In many social systems, agonistic interactions are the underlying mechanism for the establishment of dominance relationships between individuals in a population (e.g. Chase 1982; Drews 1993; Dugatkin 1997; Bergman et al. 2003). Dominance is a pattern of behavior that results in a consistent outcome in favor of an established dyad (Drews 1993). Usually, dyadic relationships within a population can result in the development of dominance hierarchy (e.g. a dominance hierarchy, Drews 1993; Dugatkin & Earley 2004). Theories on the ultimate mechanisms leading to dominance and hierarchies suggest that a higher social status increases an animal’s fitness through increased access to resources, such as food, shelters, or higher quality mates (Ellis 1995; Twiss et al. 1998). In one theory of social behavior, dominance is equated with resource holding potential or the ability to either gain or maintain access to limited resources (Parker 1974; Wilson 1975).

Resources may differ in perceived value within an environment as a result of availability, abundance, spatial distribution, and quality (Ewald & Bransfield 1987; Gabor & Jaeger 1995; Steele et al. 1997; Bart & Earnst 1999; Cutts et al. 1999; Thomas et al. 2001).
The availability and abundance of resources have often been assumed to be correlated with the type and intensity of competition and agonism between conspecifics (Koebele 1985; Candolin & Voigt 2001, 2003; Gherardi & Cioni 2004). Limitation in either resource availability or abundance has been shown to increase the intensity of agonistic interactions (Ewald & Bransfield 1987; Gabor & Jaeger 1995; Gherardi 2006). In cichlids, agonistic interactions increase in frequency when the numbers of individuals competing over a food patch increases. Under these conditions, dominance provides increased access to limited resources (Noel et al. 2005). Limited access to mates has been investigated in a number of different animals and has shown more often that dominant males get either more mates or higher quality matings (Hoi et al. 1994; Gabor & Jaeger 1995; Schuett 1997; Pazol & Cords 2005; Scott & Lockard 2006). Dominance in male elephant seals has been shown to increase copulatory success, where higher ranked males copulate with the most females (Haley et al. 1994). Dominance not only increases access to food and mates, but can also influence access to other important resources.

Shelters are another important resource that can be limited in natural environments. Shelter ownership can influence survivorship, foraging abilities and even mating outcomes (Eggleston et al. 1990; Mintz et al. 1994; Beck 1995; Edsman & Jonsson 1996; Cutts et al. 1999). The distribution and quality of shelters can influence the intensity, duration, and outcome of agonistic interactions (Dingle 1983; Eggleston & Lipcius 1992; Steele et al. 1997). Limited shelter availability and abundance have been shown to decrease survivorship and increase the intensity of agonistic interactions within species such as blennies (Labophyrs pholis and Coryphoblennius galerita), gobies (Gobius cobitis), and crayfish (Procambarus clarkia) (Faria et al. 1998; Figler et al. 2005). Even in habitats with an abundance of shelters, animals often show a preference for specific types of shelters (Eggleston et al. 1990; Eggleston & Lipcius 1992; Hoi et al. 1994; Faria et al. 1998; Pollard & Littlejohn 1999; Rodrigues et al. 2000; Hodgetts et al. 2002; Mariappan & Balasundaram 2003; Figler et al. 2005; Gherardi 2006). If shelters differ in quality and animals exhibit preference for certain shelter types then it is likely that agonistic interactions will impact the acquisition and control of certain shelter types.

Dominance may be important for acquiring and maintaining access to these high quality resources (Caron & Beauprand 1988). Hazlett (1970) has shown that hermit crabs increase the level of agonistic interactions with conspecifics when their own shell is too small or too large. Hermit crabs that won agonistic encounters with conspecifics chose to transfer to the new shell or reject it at the end of the fight (Hazlett 1970). The size of shelters in lobsters has been shown to be important for their ability to brace themselves in the shelter preventing eviction or removal by a predator (Eggleston & Lipcius 1992; Wahle 1992; Mintz et al. 1994). Differential shelter size and darkness have also been shown to impact shelter preference exhibited by crayfish of different species (Blank & Figler 1996; Steele et al. 1997; Antonelli et al. 1999). Crayfish used shelters that were dark (limited light) and small relative to the size of the crayfish providing the animal with thigmotactic (tactile) stimulation (Steele et al. 1997). Crayfish exhibit preference for varying shelter types that may create competition over shelter types within a population.

Crayfish are an excellent model organism for analyzing the impact of dominance relationships on shelter use and preference (Daws et al. 2002; Bergman et al. 2003; Fero et al. 2007). Crayfish have quantifiable ritualized aggressive behaviors and these interactions lead to the development of dominance relationships within populations (Bruski & Dunham 1987; Bergman et al. 2003). In addition, shelter availability influences agonistic interactions in that the intensity of agonistic bouts has been shown to increase in the presence of a shelter (Edsman & Jonsson 1996; Bergman & Moore 2003). Typically, it is the dominant crayfish that obtains use of the shelter. Although, recent work has shown that shelter use by dominant crayfish depends on the social context within the population (Fero et al. 2007). Dominant crayfish used shelters more often when placed in isolation as compared to shelter use within a population. The difference in shelter use may be a result of dominant individuals reinforcing their status through increased agonistic interactions. Occupancy of variable shelter types, as a factor influencing aggression and agonism, has not been analyzed extensively (Alberstadt et al. 1995; Steele et al. 1997). In many of these studies, shelters were either identical or shelter type was not controlled systematically, thus any relationship between use of shelters based on shelter preference and dominance status remains elusive. In this study, the influence of dominance on crayfish shelter acquisition and control was investigated. We hypothesized that if dominance infers increased access to resources then dominant crayfish, in turn, will improve resource control of the preferred shelters in this study.
Methods

Animals

Male crayfish, *Orconectes rusticus*, were collected from the Portage River in Wood County, Ohio. Crayfish used in this study were collected during the spring (April–May) and fall (September–October) of 2005. Intermolt, form I (reproductive) males (N = 50) were used during this study and were housed in an environmentally controlled chamber located at Bowling Green State University (BGSU). The environmental chamber was maintained at a constant temperature (21°C) and light:dark cycle (12:12). Males used in this study had a \( \bar{x} \pm SE \) carapace length of 3.59 ± 0.07 cm and chela length of 3.45 ± 0.07 cm. Crayfish were physically and socially isolated in a re-circulating freshwater holding system for a minimum of 1 wk prior to running the experiment. Only animals that were fully intact (not missing any limbs or sensory appendages) were used in this experiment. Animals were used only once. Consistent with other literature, all animals were provided with one rabbit pellet at a rate of three times per week (Bergman et al. 2003; Bergman et al. 2005; Belanger and Moore 2006).

Experimental Set-Up

All trials were performed in the working section of a 3650 L re-circulating flume (complete dimensions: 568 × 57 × 90 cm\(^3\); working section of flume: 244 × 57 × 61 cm\(^3\)). The working section was modified to contain crayfish populations during the experimental period. A sheet of fluorescent light grating (egg crating) was placed at the downstream end of the working section of the flume to prevent crayfish from escaping. The anterior end of the working section had a translucent mesh screen in place to prevent crayfish from escaping and to allow for video recording of the working section (Fig. 1). In addition, sheets of glass were placed on top of the flume. To control the light:dark cycle of the arena, a black canvas tent was built around the flume and four fluorescent light bulbs (two 25 W cool white and two 25 W red) were set on a 12:12 h light:dark cycle by using a security timer (Intermatic Incorporated). The two white bulbs were used during diurnal hours (0800–2000 h), and the two red lights were used during nocturnal hours (2000–0800 h). A gravel substrate was placed in the working section of the flume.

Resource Type and Distribution

The floor of the flume was divided into 16 quadrants of equal size (28.5 cm × 21.5 cm). A total of 16 shelters made of PVC pipe were distributed randomly among the quadrants (one shelter per quadrant). Two different sizes and four different openings created eight different types of shelter for testing. Sizes consisted of half-pipe PVC with a diameter of 5.08 cm (small) or 7.62 cm (large). The number of openings of the shelters varied between one, two, three, and four openings. Straight PVC pipes 9 cm long were used for the shelters with one and two openings (shelters with one opening were made by closing one end of a straight pipe with plexiglass). Shelters with three openings were constructed from PVC tee’s and cut to 9 cm lengths. Shelters with four openings were constructed from PVC crosses that were cut to a length of 9 cm in length and width. From this point forward, shelters are designated by a number and letter referring to the size/opening combination. Thus, shelter 1s has one opening and is small whereas shelter 4b has four openings and is large.

Behavioral Observations

A stationary underwater camera (Versacam remote zoom lens camera & waterproof housing, Fuhrman Diversified, Seabrook, TX, USA) was set-up at the anterior portion of the flume on the outside portion of the working section. The camera was placed behind a translucent mesh screen and was set at a

Fig. 1: A photograph of the working section of the flume with the mesh screen wall. The camera was located behind the wall to record the experimental trials.
35° angle from horizontal to record the entire behavioral arena. The underwater camera contained an internal infrared light that was used to enhance the visual resolution of the working section during nocturnal hours. Video images were recorded on a time lapse VCR (Exxis ER128TCN) and viewed using a color monitor (Sony Trinitron color video monitor, model #PVM-1315Q). The entire system was powered by two marine batteries that provided uninterrupted power for the entire duration of observations (spare batteries could be replaced without loss of power). Each population of crayfish was continuously recorded for 96 h per trial, at a rate of four frames per second.

**Crayfish Populations**

Five male crayfish were size matched (no more than 10% size difference for carapace and chelae length) for each trial. Crayfish were randomly placed into the working section of the flume at the start of the each trial (N = 10). Animals were marked on the dorsal side of the carapace with white correction fluid to differentiate between individuals for subsequent behavioral analysis. Crayfish were allowed access to food, ad libitum, throughout the trial. During trials crayfish were fed fish gelatin that was placed in metal dishes. Fish gelatin has been used in previous work and crayfish readily identify and consume this food (Kraus-Epley & Moore 2002; Wolf et al. 2004). In this study, crayfish were also observed consuming the fish gelatin throughout a trial. Fish gelatin was prepared by mixing 45 g of homogenized frozen ocean perch (Perca sp.) fillets with 28 g of Knox unflavored gelatin and 0.71 l of boiling water. After mixing, the hot gelatin was poured into several individual circular dishes (diameter = 5.3 cm, height = 1 cm) lined with plastic wrap and refrigerated overnight until solidified. Five dishes were made available during trials at all times. The dishes were spaced out evenly in the center of the flume along the longitudinal plane and were replaced once during a trial on the morning of the third day.

**Agonism and Shelter Use**

Each trial was analyzed for the number and intensity of agonistic encounters, as well as shelter use. The winners and losers of agonistic bouts during each trial were analyzed using a standard ethogram for crayfish agonistic behavior (Table 1: Bergman & Moore 2003). The types of shelters (1–4 openings, large (7.62 cm) or small (5.08 cm)) used and the duration of shelter use by each individual crayfish were recorded throughout trials. A crayfish was defined as a shelter occupant (for eviction analysis) when any part of its tail or thorax was located inside of a shelter for a minimum of 15 s. Shelter use (for temporal analysis) was only recorded if the individual established the minimum requirement (15 s) for occupancy in this study. Pilot evidence suggests that crayfish often maintain prolonged use of a shelter above this time threshold. Agonistic interactions in the presence of a shelter were defined as an eviction if the shelter occupant (as defined previously) was forced out of the shelter by another crayfish.

**Statistical Analysis**

To correlate shelter use with crayfish agonism, the status of each crayfish was determined by calculating the dominance activity index (DAI = log \((p + 0.1)^2/N + 0.1\) + 1; \(p = \) the sum of all dominance interactions exhibited by a crayfish and \(N = \) the sum of all the submissive encounters exhibited by a crayfish; Bartos 1986). DAI was calculated using a matrix of wins and loses between each pair of crayfish. Linearity of hierarchies was tested using Kendall’s and Landau’s statistics, calculated using MatMan with a \(p < 0.05\) (Noldus). Individual crayfish were then assigned ordinal ranks (1–5) based on their DAI within the population with one being the alpha male (most dominant) and five indicating the omega male (least dominant).

The duration of shelter use by all crayfish, regardless of dominance, was calculated based on the definition of shelter use (see paragraph entitled ‘Agonism and Shelter Use’). The types of shelters used in this study were identified by a number and letter designated to indicate the number of openings they contain and their individual size (e.g. 1s = one

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**Table 1: Crayfish ethogram codes**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>–2</td>
<td>Tailflip away from opponent or fast retreat</td>
</tr>
<tr>
<td>–1</td>
<td>Slowly back away from opponent</td>
</tr>
<tr>
<td>0</td>
<td>Ignore opponent with no response or threat display</td>
</tr>
<tr>
<td>1</td>
<td>Approach without a threat display</td>
</tr>
<tr>
<td>2</td>
<td>Approach with threat display using antennal whip, meral spread, raised posture</td>
</tr>
<tr>
<td>3</td>
<td>Initial claw use by boxing, pushing, or touching with closed claws</td>
</tr>
<tr>
<td>4</td>
<td>Active claw use by grabbing or holding opponent with open claws</td>
</tr>
<tr>
<td>5</td>
<td>Unrestrained fighting by grasping and pulling opponent’s claws or appendages</td>
</tr>
</tbody>
</table>

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The influence of dominance on shelter preference in *Orconectes rusticus*  

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opening, small shelter; 1b = one opening, big shelter). Because behavioral observations within a single trial are interdependent, we included trial number as a factor in all ANOVAS or MANOVAS. This method was chosen over repeated measures ANOVA because each individual crayfish only contributed single data points to the analysis rather than repeated data points as in a repeated measures design. The duration of shelter use relative to specific shelter types was analyzed using a three-way ANOVA (shelter size × openings × trial number) with a Fisher-LSD post hoc test. Because of the statistically significant differences in overall shelter use in relation to shelter type (Fig. 1), we have ranked shelters from highest to lowest preference based on the duration of shelter use exhibited by the entire population. Thus, shelter preference was (total duration of use) exhibited by crayfish in each population (explained below). Eviction rates, as influenced by dominance rank of shelter occupants, were analyzed using a two-way ANOVA (dominance rank × trial number). Also, the influence of dominance rank on shelter ownership, the influence of shelter quality on eviction rates, and the influence of dominance rank on shelter use were analyzed using a three-way ANOVA (shelter size × openings × trial number) with Fisher-LSD post hoc tests.

Results

Linearity Index for Dominance Hierarchy

Crayfish dominance hierarchies exhibited a linear relationship. Eight out of ten trials were significantly linear with a Kendall’s coefficient and Landau’s index of greater than 0.95 (p < 0.05, Table 2). The two trials that did not exhibit a significant linear relationship had a Kendall’s coefficient and Landau’s index of 0.85 (0.1 > p > 0.05, Table 2). These two trials showed a strong trend for linearity and were labeled with ordinal ranks and incorporated into the subsequent statistical analysis.

Impact of Trial Number on Behavioral Measures

There were no significant differences between trials for either shelter use, eviction rates, or the influence of status on eviction rates (F(7, 2025) = 1.9, p < 0.05). Thus, trial number did not alter subsequent behavioral measures and is not presented with the other statistical results.

Impact of Shelter Size on Use

Crayfish spent significantly longer periods of time in small shelters (x ± SE) (20.2 ± 0.87 min) as opposed to large shelters (11.6 ± 0.53 min; F(1, 2025) = 72.5, p < 0.05, Fig. 1).

Impact of Shelter Openings on Use

Crayfish spent significantly more time in shelters with fewer openings than shelters with multiple openings. Shelters with one opening (29.0 ± 1.24 min) were used for significantly longer periods of time than shelters with two, three, and four openings (14.6 ± 1.05, 10.6 ± 0.90, 9.5 ± 0.83 min, respectively; F(3, 2025) = 63.4, p < 0.05, Fig. 2).

Table 2: MatMan test for linearity

<table>
<thead>
<tr>
<th>Trial</th>
<th>Kendall’s coefficient of linearity (K)</th>
<th>Landau’s linearity Index (H)</th>
<th>Chi-square test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.95</td>
<td>0.95</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>2</td>
<td>0.85</td>
<td>0.85</td>
<td>p &gt; 0.05</td>
</tr>
<tr>
<td>3</td>
<td>0.85</td>
<td>0.85</td>
<td>p &gt; 0.05</td>
</tr>
<tr>
<td>4</td>
<td>0.85</td>
<td>0.85</td>
<td>p &gt; 0.05</td>
</tr>
<tr>
<td>5</td>
<td>0.85</td>
<td>0.85</td>
<td>p &gt; 0.05</td>
</tr>
</tbody>
</table>

Fig. 2: A correlation between shelter type and duration of shelter use. On the X-axis the numbers 1, 2, 3, and 4 refer to the number of openings and (s) represents a small shelter and (b) a large shelter. Different letters (a), (b), (c), (d), and (e), located above the bars, indicate a significant difference between treatments using a three-way ANOVA with a Fisher-LSD post hoc test (N = 2033; p < 0.05).
Determining Shelter Preference

In addition to the influence of size and openings on shelter use, there was a statistically significant correlation between shelter size and the number of openings. Crayfish used small shelters with one opening for a significantly longer duration than all other shelters (34.6 ± 2.18 min; F(3, 2025) = 5.4, p < 0.05, Fig. 1). Shelters 1b (23.5 ± 1.21 min) and 2s (21.0 ± 1.73 min) were used for significantly longer periods of time than shelter 2b and all shelters with 3 or 4 openings (p < 0.05, Fig. 2). These results clearly showed a preference for shelter type (size and openings) by crayfish in our test arena. Based on these choice preferences, we chose to rank shelters by duration of use. We used this preference as a proxy measure of overall shelter preference by crayfish (high preference = shelters with longest duration of use, low preference = shelters with shortest duration of use; Figs 3 and 5a).

Influence of Social Status on Shelter Selection

Individuals that used shelters 1s and 2s were significantly more subordinate than individuals using other shelters. Individuals in these shelters had a significantly lower average dominance rank (3.2 ± 0.15, 3.2 ± 0.11) than individuals using all other shelter types except individuals using shelter 4s (3.0 ± 0.10; F(3, 2037) = 3.1, p < 0.05, Fig. 3). Crayfish that used shelter 1b were significantly more dominant (2.5 ± 0.08) than the crayfish using all other shelters except 3b (2.6 ± 0.07; F(3, 2037) = 3.1, p < 0.05, Fig. 3). Overall, crayfish that used small shelters had a significantly lower average dominance rank (3.1 ± 0.06) than crayfish using large shelters (2.7 ± 0.04; F(1, 2037) = 31.6, p < 0.05, Fig. 3).

Effects of Social Status and Shelter Use on Eviction

Dominant crayfish were evicted from shelters in only 0.04 proportion of encounters, while more subordinate crayfish were evicted significantly more often (rank: 2, 3, 4, and 5; eviction proportion: 0.55 ± 0.06, 0.75 ± 0.05, 0.86 ± 0.07, and 0.95 ± 0.05, respectively; F(4, 192) = 27.9, p < 0.05, Fig. 4). Since dominance is significantly correlated with shelter use, it is important to note that the two independent variables in Fig. 5a and 5b (Shelter preference [5a] and average dominance rank [5b]) are interrelated. The proportion of crayfish evicted from shelter 1b (0.26 ± 0.094) was significantly less than crayfish evicted from all other shelters (F(7, 189) = 4.9, p < 0.05, Fig. 5a). In a similar fashion, higher ranking shelter occupants (average rank = 2.5) were significantly less likely to be evicted than all other occupants (F(7, 189) = 4.9, p < 0.05, Fig. 5b). In summary, both shelter type and dominance rank significantly impacted eviction rates.
Duration of Shelter Use

Crayfish with the lowest ranking (5) used shelters for longer durations ($14.9 \pm 1.18$ min) than crayfish with rankings of 1 and 2 ($11.4 \pm 0.98$ min, $10.0 \pm 0.75$ min; $F_{(4, \ 2028)} = 3.9$, $p < 0.05$, Fig. 6). Dominant ranking crayfish (ranks 1 and 2) used shelters significantly less than the most subordinate crayfish ($F_{(4, \ 2028)} = 3.9$, $p < 0.05$, Fig. 6). Interestingly, crayfish with a dominance rank of 2 also used shelters for shorter periods of time ($10.0 \pm 0.75$ min) than did crayfish with lower dominance ranks 3, 4, and 5 ($13.5 \pm 1.11$, $13.1 \pm 1.40$, and $14.9 \pm 1.18$ min, respectively; $F_{(4, \ 2028)} = 3.9$, $p < 0.05$, Fig. 6).

Discussion

In this study, crayfish exhibited specific preferences for certain types of shelters. In particular, smaller shelters with fewer openings were used more often than other types of shelters (Fig. 2). Based on these findings, we conclude that crayfish exhibit a specific shelter preference within the context of this study. Shelter preference may be an indication of how crayfish perceive the value of this resource. Research has shown how crayfish may exhibit shelter preference, consequently modifying their aggressiveness during agonistic interactions to compete for these resources (Hazlett 1970; Gherardi 2006). Our results are comparable to results from sand gobies that demonstrate agonistic interactions that are longer in duration in the presence of high quality nests (Lindström & Pampoulie 2005). By engaging in prolonged agonistic encounters within populations, crayfish behavior can provide evidence for shelter preference (possibly an indication of quality).

In addition to the finding of differential shelter use, crayfish in our study developed a linear social hierarchy (Table 2) and were labeled by dominance rank on an ordinal scale. Taken together, these two findings (linear hierarchy and differential shelter use) allow us to conclude that dominance status
impacted the use of shelters as a resource, such as increased dominance, increased shelter ownership (Fig. 3), shelter access (Fig. 5a, 6), and eviction rates (Fig. 4, 5a). Crayfish with the highest dominance ranks were found to use bigger shelters than subordinates and evicted lower ranking individuals during the majority of encounters. Finally, our results showed that dominant crayfish acquired the most preferred shelters, but they did not use these shelters as often as subordinate individuals.

In this study, we determined shelter quality based on the duration of occupancy and then used this definition to rank shelters for preference. The analysis and determination of dominance was performed using the outcomes of aggression interactions. Even though evictions per se were not used to calculate crayfish status (although wins and loses were used), we recognize that dominance, shelter quality, evictions, and wins and loses are interrelated. It is possible that the statistically significant results presented here are, in part, due to the connected nature of these data. We are confident that the experimental design (an abundance of shelters) and previous work on dominance in our lab (Daws et al. 2002; Bergman et al. 2003) allows the data to support our conclusions. We recognize the circular relationship between these aspects of agonism, but this study along with other studies on dominance illustrates the importance of dominance relationships and resources (shelters) have on agonism.

Dominance, in many animals systems, confers increased access to resources (Francis 1988). Within natural environments, resources can vary in availability, abundance, and quality (Dempster & Pollard 1981; Dingle 1983; Michiels & Traunspurger 2005). Patchiness or spatially disparate resources can increase the perceived value of the resource because of the limited abundance. As the availability and abundance of a resource decline, the intensity of interactions can increase in aggressiveness because of increased motivation to gain or maintain access to the limited resource (Enquist & Leimar 1987; Guerra & Mason 2005). Competition over a resource can also lead to an increased aggressive motivation if the quality of the resource is high, as seen in crustacean aggression (Hazlett 1970; Gherardi & Cioni 2004). Specific shelter types allow animals to efficiently protect themselves from predators and conspecifics (Eggleston & Lipcius 1992; Wahle 1992; Mintz et al. 1994). Shelter preference may provide an insight into the concept of quality of shelters. The selection and benefit of using high quality shelters, by crayfish, may be indicated by the correlation between dominance rank, shelter preference, and eviction rates.

In this study, crayfish with a higher dominance rank preferred to use large shelters with only one opening (Fig. 3). Dominant individuals were less likely to be evicted from a shelter than subordinate crayfish (Fig. 4). The highest ranked crayfish exhibited shelter preference and a decreased chance of being evicted from these shelters indicating the importance of becoming dominant. Moreover, increased shelter preference was shown to increase fight success by decreasing the chance of being evicted from a shelter (Fig. 5a). Shelter occupancy increased fight success, but the distinction between dominance and high shelter preference on fight success was indistinguishable in this study (Fig. 5a and 5b). Possession and use of resources often leads to increased levels of fitness (Wilson 1975; Haley et al. 1994; Schuett 1997; Watson 1998; Scott & Lockard 2006). Since dominance status is correlated with resource holding potential and use in crayfish, we can infer that increased dominance status leads to increased fitness as a result of resource holding potential. Thus, it appears as if crayfish engage in agonistic interactions as a mechanism to ultimately increase their overall fitness by out competing conspecifics in their environment.

Agnostic encounters among a population of crayfish causes reinforced dominance relationships. In this study, the dominant crayfish acquired the highest quality shelters; this result supports the dominance theory that increased dominance confers increased access to quality resources (Wilson 1975). The fact that crayfish prefer shelters with a limited number of openings illustrates their ability to recognize shelter variability and exhibit selection. Recognition and preference of shelters may influence the outcome of agonistic interactions. Further analysis of crayfish dominance relationships and the benefits it affords an individual is essential for better understanding how environmental factors influence aggression.

Acknowledgments

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