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# The effects of mate size and intruder size on the parental division of labor in the convict cichlid, *Cichlasoma nigrofasciatum*

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L.**

**The Effects of  
Mate Size and  
Intruder Size on  
the Parental  
Division of Labor  
in the Convict...**

**January 11, 1998**

**The effects of mate size and intruder size on the parental division of  
labor in the convict cichlid, *Cichlasoma nigrofasciatum***

**By**

**Jennifer L. Barnes**

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## Abstract

This study tested the hypothesis that the gender-specific parental role divisions observed in the convict cichlid, *Cichlasoma nigrofasciatum*, was based on the relative sizes of the parents. By forcing large females to pair with smaller males, I was able to reverse the gender-typical size relationship. As predicted, females larger than males exhibited more defensive activities while smaller males spent more time with the offspring when confronted with larger intruders. I also found that larger intruders seemed to reinforce the parental role division while the presence of small intruders correlated with both parents spending more time together. This evidence suggests that proximate cues (relative sizes of the parents) are important in influence the division of parental roles. At the same time, these cues do not seem to override the ultimate basis for the behaviors usually seen. The male continues to engage in more defensive behaviors and less offspring care. The female performs more offspring care, but will increase her defensive behaviors to the levels of the male. The female seems to be more behaviorally flexible; unlike the male, she will assume more of his defensive roles.



## Introduction

In many biparental species, there is evidence that one parent will change his or her parental behavior based on the behavior of the other parent (birds: Wright and Cuthill 1989, Hatchwell and Davies 1990; fish: Itzkowitz 1984, Keenleyside et al. 1990; humans: Lamb et al. 1985). Winkler (1987) predicted that changes in the level of effort by one parent are based on the age and number of offspring, and the effort and condition of the other parent. He developed the assumptions of his model with birds in mind, and traditionally much of the research emphasis on parental behavior has been placed on birds. The impact of various factors such as brood size (Leffelaar and Robertson 1986, Wright and Cuthill 1990), age of young (With and Balda 1990, Rosa and Murphy 1994), reduced effort by one parent (Wright and Cuthill 1989), loss of one parent (Alatalo et al. 1988, Whittingham et al. 1994), and certainty of paternity (Hartley et al. 1995, Wagner et al. 1996) on provisioning rates and nest defense has been studied. Typical for birds is that both parents usually share the same duties, with little evidence of task specialization.

However, for many other types of species, such as some biparental fish, a distinct division of roles exist where the female performs more direct care of the young and the male performs more territorial defense. Similiar to birds, much work has concentrated on what affects the parental effort. For example, studies have looked at cues such as brood size (Lavery and Keenleyside 1990, Lavery 1995b), brood age or stage of development (Sargent and Gross 1986, Lavery and Colgan 1991, Lavery 1995a), prior reproductive experience (Lavery 1995b), time of day (Reebbs and Colgan 1991), and density of predators (McKaye 1977, FitzGerald and Keenleyside 1978). Interestingly, few studies

have examined role specializations. However, Itzkowitz (1984, 1985) and Lavery and Reeb (1994) found in the absence of the female, the male did reduce his typical role of territorial defense and became more female-like by spending more time near the offspring.

The above mate removal studies on biparental cichlids also revealed that both genders were capable of raising their offspring alone, at least in laboratory conditions (e.g. without a high density of predators). Thus, it is unclear why role specializations exist in these fish and does not resemble the division of labor seen in most biparental birds. One possibility is that unlike monogamous birds, biparental fish exhibit a size dimorphism in which the male is typically larger than his mate. As size is directly correlated to winning fights in fish, it makes intuitive sense for the larger male to specialize in territorial defense, allowing the smaller female to emphasize offspring care. As the male does assume the "female role" in her absence (see above), the performance of his typical role is not gender specific but rather depends on an assessment of the other mate (at least for the male). Here we consider whether choice of the male and/or the female to accept their roles is based on their assessment of their relative ability to perform the role. That is, we consider the possibility that the male assumed the territorial defender role because he has assessed himself as being larger than the female. Similarly, the small female may make a similar assessment before accepting her offspring care role.

There is evidence that a parental fish will revise behavior based on mate size. In a study that concentrated on female mate choice in the convict cichlid, Keenleyside et al. (1985) found that females helped more with brood defense when their mates were large. Perrone (1978) looked at the impact of mate size on breeding success, but not on the

division of labor. He concluded that larger fish can perform some parental duties better than smaller fish, and that cichlid pair size is correlated with the effectiveness of parental care.

In this paper, I examine how the size of the mate and the size of an intruder influence the parental behavior of both the male and the female in a pair of convict cichlids. Convict cichlids display task specialization, where the female spends more time in direct care of the young, and the male spends more time in defense of the brood. In this species, the male is usually larger than the female; thus, we presume he is better able to chase off intruders due to his larger size. We hypothesize that the male's relatively larger size is driving his increased defensive behavior. If size alone is the stimulus for the division of roles, we predicted that the largest member of the pair, irrespective of gender, will assume the role of territorial defender and the smaller individual will emphasize offspring care.

Along with differences in mate size, I also examined the influence of intruder size on the role division. Previous studies on cichlids have revealed that individuals based their defensive behavior based on the size of the intruders (e.g., Beeching 1992; Enquist et al., 1987; Keeley and Grant 1993; Macias-Ordonez and Itzkowitz, in prep.). That is, within increasing intruding size, defenders became increasingly more aggressive. When the intruder becomes much larger than the defender, the defender reduced its defense (Turner 1994). In keeping with these previous studies, I predicted that the larger member of the pair would increase its aggression as the intruder size increased. For the smaller parent, I predicted that it would be most aggressive towards intruders that were similarly small but

as the intruders increased in size, the smaller parent would reduce its aggression. Parents that were the same size should show no differences in their response to changes in intruder size.

## **Methods**

### **Study Animal**

The convict cichlid is a monogamous, biparental, substrate-brooder that engages in extended care of the young (Keenleyside 1991). The young mature through three distinct stages termed the egg, wriggler, and free-swimming fry. The eggs hatch into wrigglers and remain at this stage for 4-6 days, until the yolk sacs have been absorbed. The young then become free-swimming fry. At the egg and wriggler stage, the female spends more time in direct care, but as the young become free-swimming fry parental activities are shared more equally by both parents (Smith-Grayton and Keenleyside 1978), which is similar to the behavior found in other types of cichlids (Barlow 1974, Itzkowitz and Nyby 1982, Itzkowitz 1984). In convict cichlids, however, that the female sometimes engages in defensive behaviors equally to the male (Krischik and Weber 1974, FitzGerald and Keenleyside 1978).

The fish used were raised in our lab, and were descended from stocks purchased at local suppliers. Intruder fish were male convict cichlids.

## Experimental Groups

Fish were taken from uni-sex groups housed in large stock tanks (473 l). The fish were of unknown breeding experience, as some of the fish had been used in other reproduction and courtship experiments. All fish were at least eight months old.

Three experimental groups of mated pairs were established: (1) the male was larger than the female (referred to as large male pairs for the rest of the paper); (2) the male and female were of similar size (similar size pairs); and (3) the male was smaller than the female (large female pairs). Fish were considered to be of similar size when their lengths were within 1 cm of each other. Thus, a male was larger than a female if he was more than 1 cm longer than her. The mean length of all males was  $6.1 \pm 0.18$  cm and the average length of all females was  $6.2 \pm 0.10$  cm. The average lengths of the males and females comprising each of the experimental groups can be found in Table 1. Note that by using the 1 cm rule, the average size of the males in the different groups ranged from 5.0 to 7.1 cm, whereas the average size of the females in these groups did not change (range from 5.7 to 6.7 cm). Thus, the relative size of the females was changed by changing the size of the males.

Pairs of convict cichlids in Costa Rican streams will breed when the male and female are about 3-4 cm long (personal observation). Since the fish in this study were at least eight months old and at least 4 cm long, sexual maturity was not considered to be a factor. In any case, all pairs bred and successfully raised broods.

## **Experiment**

Experimental tanks (284 l) were arranged up with a flower pot placed on its side at one end (to provide a spawning surface), and a clear plexiglass barrier placed at the other (to divide the larger main compartment from the smaller intruder compartment). Tape placed on the front bottom of the tank (out of sight of the inhabitants) divided the tank into three areas: (1) the offspring area was within 10 cm of the flower pot; (2) the intruder area was in the main compartment within 10 cm of the plexiglass barrier; and (3) the "elsewhere" area was all of the area in between the offspring and intruder areas. Total tank length was 120 cm; the intruder compartment was 15 cm wide.

Each experimental group consisted of 11 mated pairs. Pairs of specific relative sizes (large male, similar size, or large female) were formed by placing three males of similar size and three females of similar size into an experimental tank. Once a pair formed the remaining four remaining unpaired fish were then removed. The pair was left undisturbed (except for a daily feeding) through spawning and raising of the brood to the wriggler stage. Data was taken for the during the 5 or 6 day wriggler stage.

On the first day of the wriggler stage, the experiment began. An intruder fish was placed in the intruder compartment. When either the male or the female of the pair noticed the intruder (generally within seconds), a 15-minute trial began. The following data were taken: (a) amount of time the female spent in each of the three areas of the tank, (b) amount of time the male spent in each of the three areas of the tank, (c) number of bites directed at the intruder partition by the female and by the male, (d) the amount of time both members of the pair spent together either in the pot with the offspring, or somewhere

in the tank away from the offspring, and (e) the number of role exchanges (this occurs when the member of the pair patrolling the territory swims up to the member of the pair in the flower pot with the offspring, the parent in the pot swims out, and the parent that offered goes into the pot). Data was taken directly onto a laptop computer at the time of the trial; however, all trials were also videotaped for later review if necessary. At the end of the trial, the intruder fish was removed.

Intruder presentations occurred once per day for the duration of the wriggler stage. On a given day, one of three possible intruders was presented to the pair. An intruder was either smaller than, larger than, or of similar size ("medium" size) to the largest member of the pair. The 1 cm rule was used to determine intruder sizes. Presentation of intruders was "randomized" so the same number of pairs was exposed to a small, medium, or large intruder on the first and subsequent days (since there were 11 pairs, this wasn't exact). Since the wriggler stage usually lasted for six days, a given intruder was presented twice. The order of intruder presentations was kept constant for a given pair, so that a particular intruder was presented either on the 1st and 4th, 2nd and 5th, or 3rd and 6th day (except when the wrigglers lasted only five days). Intruder fish were used for more than one replicate; there were a total of 33 intruders.

### **Data Analysis**

When the same intruder was presented to a given pair on different days, the data for those trials were averaged. Since the pair data were not independent (one pair was presented with three intruders), a Friedman two-way analysis of variance by ranks was

performed to determine differences in the behavior of a given type of pair towards different intruders. If an overall difference was detected, a multiple comparison test of average ranks was performed (Siegel and Castellan 1988, Section 7.2.3). A Kruskal-Wallis one-way analysis of variance for independent samples was used to determine differences in behavior by the three types of pairs toward a given sized intruder. To determine differences in behavior between a male or female and his or her mate, Wilcoxon signed ranks tests were performed. Means  $\pm$  SE are reported.

The statistical package Statgraphics v7.0 was used to perform most statistical analyses. Multiple comparison tests were from Siegel and Castellan (1988).

## **Results**

### **Time spent by each parent with the offspring**

In the large male pairs, the amount of time that the male spent with the offspring was significantly different when intruder size changed (Fig. 1a) (Friedman:  $F = 14.36$ ,  $p < 0.001$ ). The male spent more time with the offspring when the intruder was small (multiple comparison test,  $p < 0.05$ ). In contrast, the amount of time that the female spent with the offspring was not different as intruder size changed ( $F = 3.45$ ,  $p = 0.18$ ).

In similar size pairs, the amount of time the male spent with the offspring did not differ significantly when intruder size changed (Fig. 1b) ( $F = 5.64$ ,  $p = 0.06$ ). However, the female did differ significantly ( $F = 7.09$ ,  $p < 0.05$ ). The difference was the time she spent with the large and small intruder ( $p < 0.05$ ).

In the large female pairs, the time the male spent with the offspring did not differ



(Fig. 1c) ( $F = 0.14$ ,  $p = 0.93$ ). However, the amount of time the female spent was significantly different ( $F = 13.82$ ,  $p < 0.001$ ). Like the male in the large male pairs, she spent the most time with the offspring when the intruder was small ( $p < 0.05$ ).

The female always spent significantly more time with the offspring than did the male (Wilcoxon signed ranks test;  $p < 0.01$ ). Overall, in each 15-minute trial, the female spent an average of 9.9 minutes ( $596 \pm 22$  seconds) with the offspring, whereas the male spent only 2.7 minutes ( $164 \pm 17$  s).

#### **Time spent by each parent at the intruder partition**

In the large male pairs, the time the male spent at the intruder partition was different when intruder size changed (Fig. 2a) ( $F = 8.73$ ,  $p < 0.05$ ). He spent significantly more time with the intruder when the intruder was the same size ( $p < 0.05$ ). The amount of time the female spent at the intruder partition did not differ as intruder size changed ( $F = 2.54$ ,  $p = 0.28$ ).

In similar size pairs, the amount of time that both the male and the female spent at the intruder partition was not different as intruder size changed (Fig. 2b) (female:  $F = 2.65$ ,  $p = 0.26$ ; male:  $F = 3.45$ ,  $p = 0.18$ ).

In large female pairs, the amount of time the male spent with the intruder was not different as intruder size changed (Fig. 2c) ( $F = 0.18$ ,  $p = 0.91$ ). The amount of time the female spent, however, was different, again similar to the male in the large male pairs ( $F = 11.09$ ,  $p < 0.01$ ). She spent the least amount of time with the intruder when he was small ( $p < 0.05$ ).

In the large male and similar size pairs, the female always spent significantly less time at the intruder partition than the male ( $p < 0.01$ ). In these two types of pairs, she spent an average of 1.6 minutes ( $93 \pm 12$  seconds) with the intruder, whereas the male spent an average of 6.9 minutes ( $414 \pm 25$  seconds). In contrast, in the large female pairs, the male and female spent equal amounts of time with the intruder when the intruder was medium or large ( $p = 0.14$  and  $0.23$  respectively). When the intruder was small, the female spent significantly less time with him than did the male ( $p < 0.05$ ).

### **Bites directed at intruder by each parent**

The number of bites directed at different-sized intruders by the male was not different in any of the three types of pairs (Fig. 3) (large male:  $F = 3.82$ ,  $p = 0.15$ ; similar size:  $F = 5.64$ ,  $p = 0.06$ ; large female:  $F = 0.73$ ,  $p = 0.70$ ). In addition, male aggression levels toward a given-sized intruder (small, medium, or large) were not different (Kruskal-Wallis one-way ANOVA; small intruder:  $KW = 4.79$ ,  $p = 0.09$ ; medium intruder:  $KW = 2.59$ ,  $p = 0.27$ ; large intruder:  $KW = 0.40$ ,  $p = 0.82$ ). Thus, the bites performed by the male were always similar in number, regardless of the male's relative size in the pair or the size of the intruder.

The number of bites the female directed at different sized intruders was different in similar sized pairs ( $F = 10.33$ ,  $p < 0.01$ ) and in large female pairs ( $F = 7.09$ ,  $p < 0.05$ ) (Figs. 3b & c). In similar sized pairs, there was a significant difference in the number of bites directed at small and large intruders ( $p < 0.05$ ), and in large female pairs, there was a significant difference in the number of bites directed at small and medium intruders ( $p <$

0.05). In addition, female aggression levels toward a given sized intruder were significantly different. The aggression levels were different against small intruders, based on whether she was the small member of the pair or the large member of the pair (KW = 8.40,  $p < 0.05$ ). The aggression levels were also different when the intruder was of medium size, again based on whether she was the small or large member of the pair (KW = 16.30,  $p < 0.001$ ).

In large male and similar sized pairs, the male always directed significantly more bites at the intruder than did the female ( $p < 0.05$ ). However, in the large female pairs, the male only directed significantly more bites when the intruder was small ( $p < 0.05$ ). The difference in number of bites was insignificant when the intruder was large ( $p = 0.62$ ) and when the intruder was medium in size ( $p = 0.96$ ).

A comparison of the bite-rates of males and females yielded interesting results (Fig. 4). Rates were determined as the number of bites directed at the intruder per second spent in the intruder area. There was no differences between males and females in the large male pairs (Wilcoxon signed ranks test;  $z = 0.18$ ,  $p = 0.86$ ). However, the female bit at a greater rate in the similar sized pairs ( $z = 3.73$ ,  $p < 0.001$ ) and in the large female pairs ( $z = 3.00$ ,  $p < 0.01$ ). Thus, although the absolute number of bites directed at the intruder was greater for the male, the female bit at the same or at a greater rate. The male spent more time just being near the intruder partition. The female, in contrast, spent little time near the partition. She generally spent more time swimming back and forth between the offspring and the intruder. When she was near the intruder, she spent her time biting.

### **Time the pair spent together**

In the large male pairs, the time spent together with the offspring differed significantly with different sized intruders ( $F = 15.12$ ,  $p < 0.001$ ) (Fig. 5); the parents spent the most time together with the young when the intruder was small ( $p < 0.05$ ). The time spent together away from the offspring was not significantly different when intruder size changed ( $F = 5.64$ ,  $p = 0.06$ ).

In similar sized pairs, time together with the offspring differed with different sized intruders ( $F = 7.09$ ,  $p < 0.05$ ); the pair spent significantly more time together with the offspring when the intruder was small than when it was large ( $p < 0.05$ ). In addition, time together away from the offspring differed ( $F = 14.36$ ,  $p < 0.001$ ); they spent more time together away from the young when the intruder was large ( $p < 0.05$ ).

In the large female pairs, the time spent together with the offspring with different sized intruders was not significantly different ( $F = 1.44$ ,  $p = 0.49$ ). However, time spent together away from the young differed ( $F = 11.09$ ,  $p < 0.01$ ); less time was spent away when the intruder was small ( $p < 0.05$ ).

### **Role Exchanges**

Although there was a significant difference in number of role exchanges performed by the parents in the large male pairs with different sized intruders ( $F = 6.64$ ,  $p < 0.05$ ), and in all types of pairs against a medium sized intruder ( $KW = 7.0$ ,  $p < 0.05$ ), none of the multiple comparison tests was significant.

## **Discussion**

While I predicted that task specialization would be driven by proximate cues, this experiment provides evidence that there may be both ultimate and proximate bases for the parental behaviors displayed by the male and the female.

### **Large parent, more defensive activities; small parent, more direct care**

This prediction was supported when the male was the large parent and the female was the small parent. For the large female pairs, she spent the same amount of time with the intruder and directed the same number of bites as her mate (except when the intruder was small - see prediction 2). In addition, her rate of biting was greater than that of her smaller mate. The female always spent more time with the offspring whether she was smaller or not.

Therefore, while it was true that the large parent generally expended more effort in defensive activities, it was not true that the small parent spent more time in direct care of the offspring. When the female was larger, she increased her defensive activities. Her smaller mate, however, did not decrease his defensive activities, nor did he increase his direct care. Thus, this prediction was true for the female, and not for the male.

### **Defenders base their defensive behavior on the relative size of the intruder**

As predicted, the large member of the pair reduced defensive activities and increased time with the offspring when small intruders were present. I presume that a small intruder is not a great enough threat to warrant much defensive activity, at least by the large

parent. This is in agreement with fight theory, which would predict a shorter contest when resource holding power (RHP) is asymmetric (Parker 1974). Also as predicted, the small member of the pair did not lessen defensive activities toward small intruders. In fact, when the male was the small parent, the trend was that he spent more time with the intruder when the intruder was small (not significant), which is different than what was observed for any other size parent (i.e. all other parents spent less time or the same amount of time with small intruders as they did for other size intruders). This again is what fight theory would predict: that extended contests occur primarily when opponents have equal RHP (Parker 1974). The same situation occurred when the male was the large parent: he spent the most time with the intruder when it was the same size as he was. When it was larger, he reduced the time spent at the intruder partition. The female's behavior did not follow the same pattern. She increased her aggressive behavior (both bites and time spent at intruder partition) against both medium and large sized intruders when she was the large member of the pair. Perhaps she is willing to expend more fitness units (sensu Parker 1974) on the current brood than the male is.

Similar size parents did not share both activities equally: the male spent more time at the intruder and directed more bites at the intruder, while the female spent more time with the offspring. However, the female changed her behavior based on the size of the intruder (similar to the large parent in the other two types of pairs). She changed the amount of time she spent with the offspring, and she changed the number of bites directed at the intruder. In addition, her rate of biting was greater than that of the male. Thus, while both the male and female spent more time and effort where ultimate cues would dictate,

the female changed her behavior based on a proximate cue, the size of the intruder.

Only the female increased defense significantly against large intruders, both when she was the large member of the pair and when she was similar in size to her mate. The male, on the other hand, usually treated medium and large intruders similarly. When he was the large member of the pair, he actually spent less time with the intruder when it was large compared to when it was the same size as he was. Here again, the female is willing to expend more fitness units on the current brood than the male is.

### **General discussion**

There seems to be a combination of both proximate and ultimate cues impacting the behavior of both parents. The male's behavior is less flexible. He continues to engage primarily in defensive behavior with little direct offspring care, regardless of the size of his mate or of an intruder. The female's behavior is more flexible; there is evidence that she changed her behavior based on both proximate cues. It is particularly obvious that she takes into account the size of the intruder when her behavior changes with changing intruder size and her mate is the same size as she is. She also takes into account the size of her mate, because she doesn't change defense activities as intruder size changes when she is the small member of the pair, but does change when she is larger or similar in size to her mate. Although the female always spent significantly more time with the offspring than the male, she did increase defensive behavior to the male's levels when she was the large parent. Since he did not decrease his defensive behavior, even when she was the more capable (i.e. larger) defender, she fulfilled both roles of maintaining offspring while

attacking the intruder.

A more flexible female and a less flexible male are in contrast to what Lavery and Reeb (1994) found when they removed the mate (removals were of either the male or the female) in convict cichlids. They found that the male increased direct care in the absence of the female, while there were no differences for either parent in defensive activities (Itzkowitz [1984] also found this for Texas cichlids). Lavery and Reeb concluded that the male's behavior was more flexible than the female's. In their case, it may have been that in the absence of the female, the male had to increase direct care, while in the current experiment, he could rely on the female to keep up her levels of offspring care. This would be similar to what Whittingham et al. (1994) found for tree swallows: there was more compensation by widowed birds than there was for birds whose mates were handicapped (thus reducing parental care). Perhaps in the convict cichlid fish, neither the male nor the female is more or less flexible in the roles that they will assume, but each parent takes into account the behavior of his or her mate before changing the level of defense or care that he or she will give. Wright and Cuthill (1990) point out in a study of starlings that "more complex still is the response of partners in a cooperating team to these factors [e.g. brood size, age, foraging profitability] and *to each other*" (italics added). Preliminary observations of convict cichlids in our lab provide evidence of one parent reacting to the actions of the other (such as the large male chasing the small female away from the intruder and back to the offspring). Other studies have observed an influence of one parent on the other's behavior (Smith-Grayton and Keenleyside 1978, Itzkowitz 1984), but these were limited to the female impacting the behavior of the male.



There is further evidence in the current study that the female updates her behavior based on the size of her mate, while the male may not. The female's absolute size only marginally changed for the three different types of pairs: it ranged from 5.7 cm to 6.7 cm. The male's absolute size ranged from 5.0 cm to 7.1 cm. If we continue to adopt the 1 cm rule established earlier, we can say that the female's absolute size did not change. The only changes in her size were in relation to the size of her mate. Therefore, although the female's absolute size did not change, her behavior did change; conversely, although the male's absolute size did change, his behavior did not.

A possible explanation for the more rigid male behavior is that the male's flexibility is limited only in terms of offspring care. There is evidence in this species that with a female-biased sex ratio or low predation rates, there is a tendency toward polygyny or bigamy (Keenleyside 1985, Keenleyside et al. 1990). The male then might be lowering his possible reproductive success by increasing direct offspring care.

The time the pair spent together provides evidence that the division of labor is breaking down when the female is the larger parent (see Fig. 5). In the large male and similar sized pairs, the pair spends a decreasing amount of time together with the offspring as intruder size increases, and an increasing time together away from the offspring as intruder size increases. In the large female pairs, the pair spend the same amount of time together with the offspring regardless of intruder size. The male is not coming back to the offspring when the intruder is small; he stays at the intruder partition.

In conclusion, there is evidence that convict cichlid parents do consider proximate cues in determining the parental division of labor. At the same time, these cues do not

seem to override the ultimate basis for the behaviors usually seen. The male continues to engage in more defensive behaviors and less offspring care. The female performs more offspring care, but will increase her defensive behaviors to the levels of the male. The female seems to be more behaviorally flexible; unlike the male, she will assume more of his defensive roles.

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Table 1. Average total length of males and females (mean  $\pm$  standard error)

	Male	Female
Large male - Small female	7.1 $\pm$ .11	5.7 $\pm$ .14
Similar Size	6.3 $\pm$ .21	6.1 $\pm$ .12
Small male - Large female	5.0 $\pm$ .10	6.7 $\pm$ .13



## Figure Legends

Figure 1. Time spent ( $\bar{x} + SE$ ) by female and male parents with the offspring (total possible time = 900 seconds). Each panel represents one of the three types of pairs. X-axis is intruder size (small, medium, large). Hatched bar = female. Solid bar = male. Within panels, a is significantly different from b (differences within a gender), and \* is significantly different from \*\* (differences between the male and female).

Figure 2. Time spent ( $\bar{x} + SE$ ) by female and male parents at the intruder partition (total possible time = 900 seconds). Each panel represents one of the three types of pairs. X-axis is intruder size (small, medium, large). Hatched bar = female. Solid bar = male. Within panels, a is significantly different from b (differences within a gender), and \* is significantly different from \*\* (differences between the male and female).

Figure 3. Mean number of bites ( $\bar{x} + SE$ ) directed by female and male parents at the intruder partition. Each panel represents one of the three types of pairs. X-axis is intruder size (small, medium, large). Hatched bar = female. Solid bar = male. Within panels, a is significantly different from b (differences within a gender), and \* is significantly different from \*\* (differences between the male and female).

Figure 4. The number of bites directed at intruder per time spent at the intruder partition. Each panel represents one of the three types of pairs. X-axis is trial number (there were 66

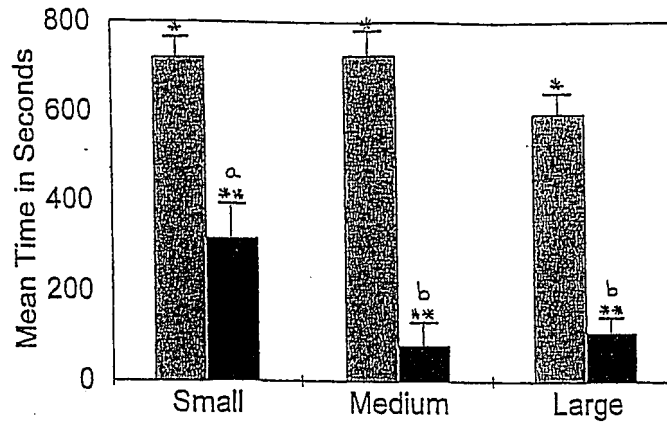
trials per type of pair, averaged by size of intruder into 33 trials). Open circle = female.

Solid square = male. See text for statistical results.

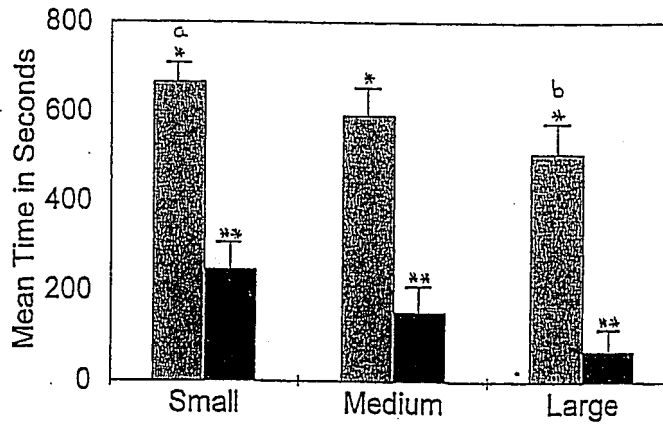
Figure 5. Time spent together ( $\bar{x} + SE$ ) by female and male parents (total possible time = 900 seconds). Top panel is time spent together with the offspring. Bottom panel is time spent together away from the offspring. X-axis is type of pair. Diagonal hatched bar = small intruder. Solid bar = medium intruder. Vertical hatched bar = large intruder. Within panels, a is significantly different from b.

# Time at Offspring

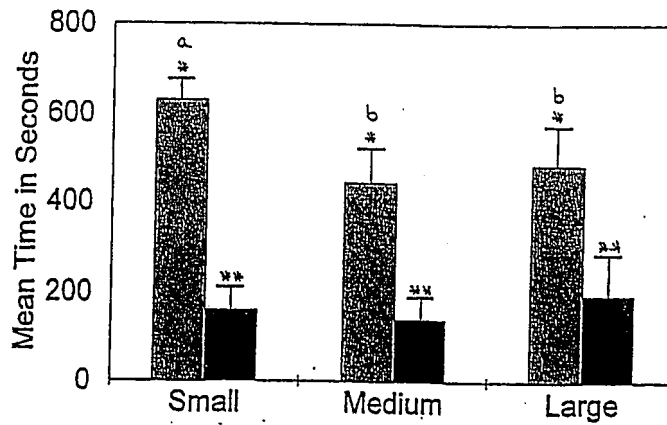
Large Male - Small Female



Similar Size Pair

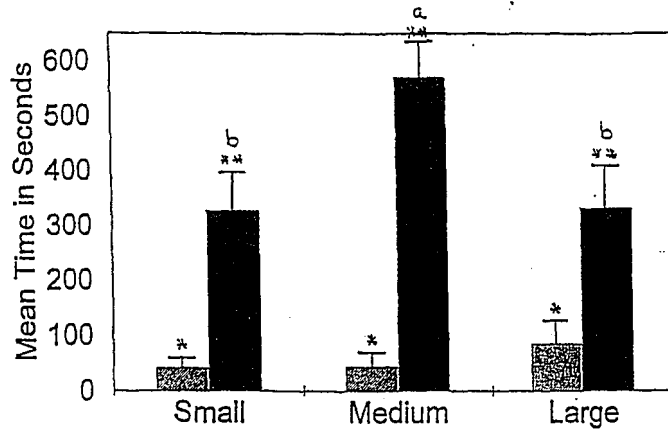


Large Female - Small Male

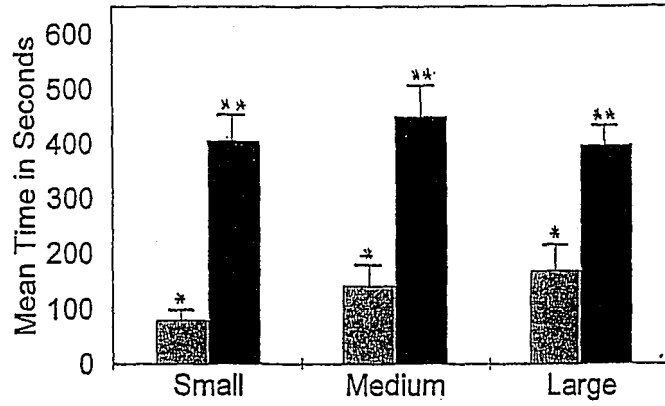


# Time at Intruder

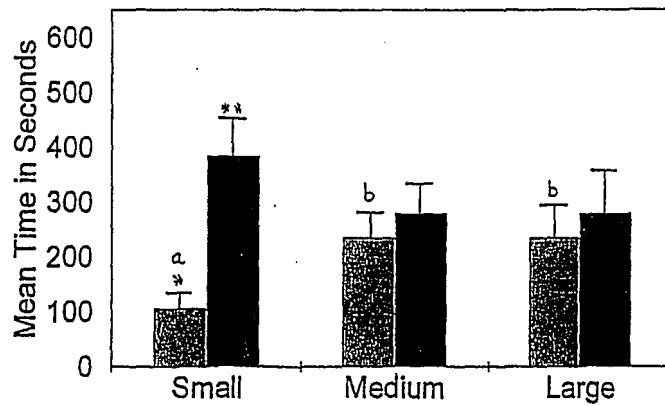
Large Male - Small Female



Similar Size Pair

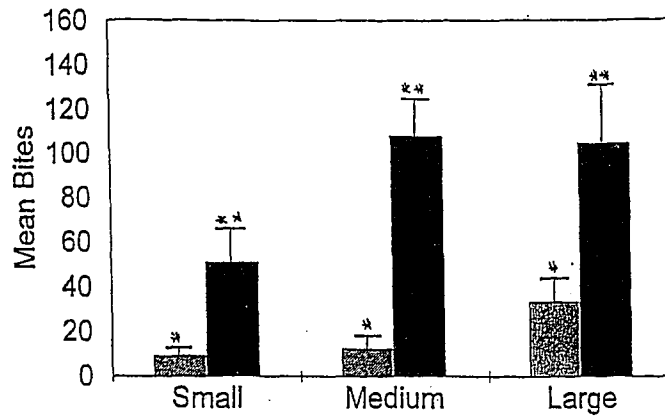


Large Female - Small Male

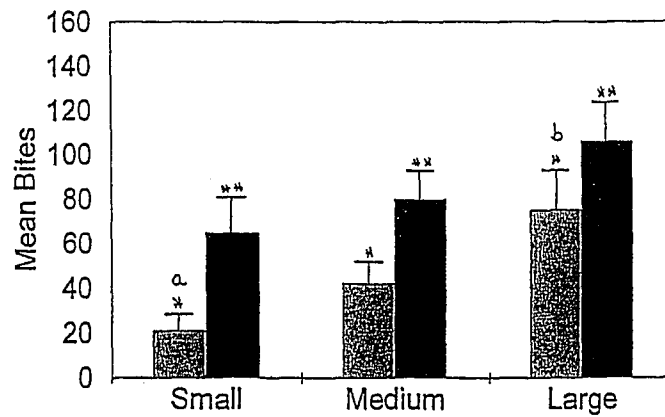


# Bites at Intruder

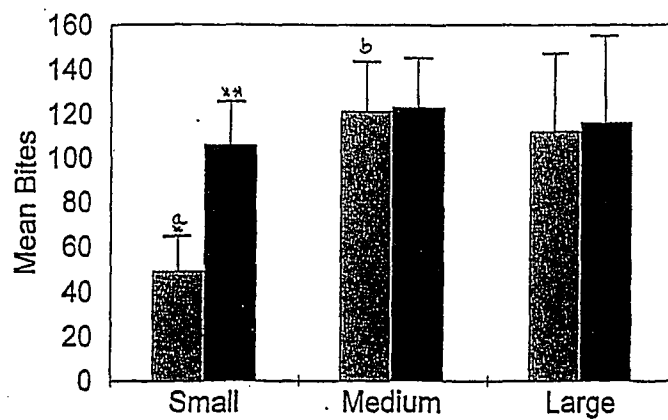
Large Male - Small Female



Similar Size Pair

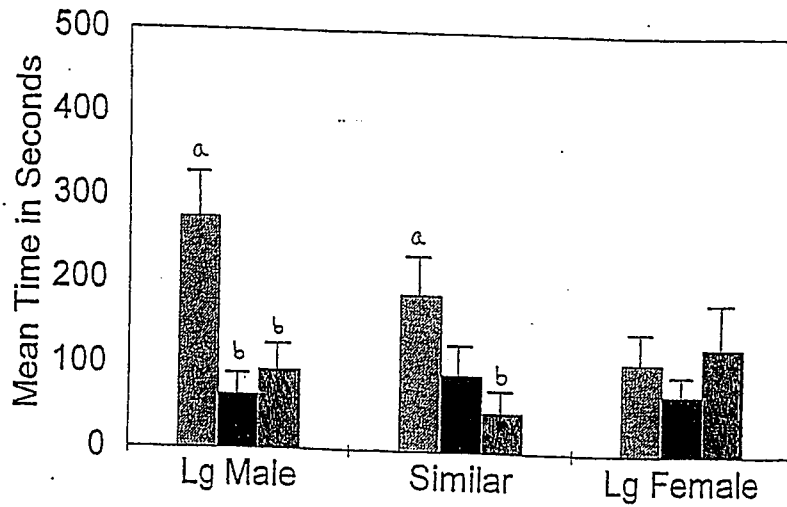


Large Female - Small Male

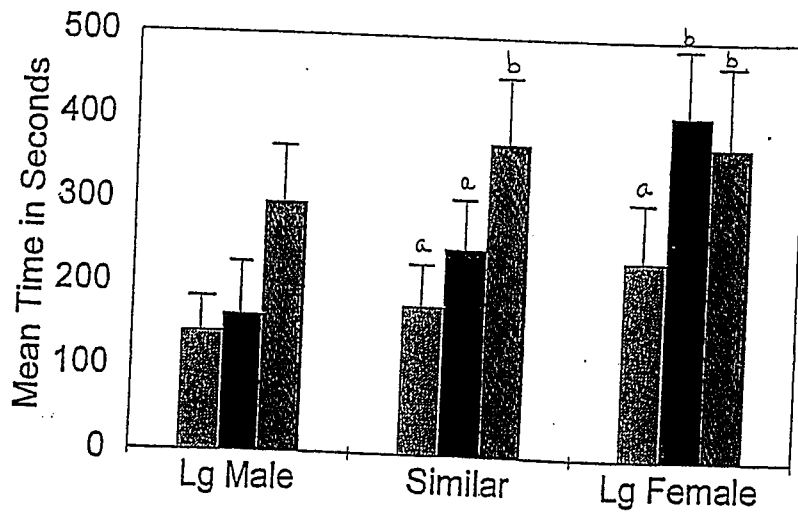


# Time Spent Together

## With Offspring

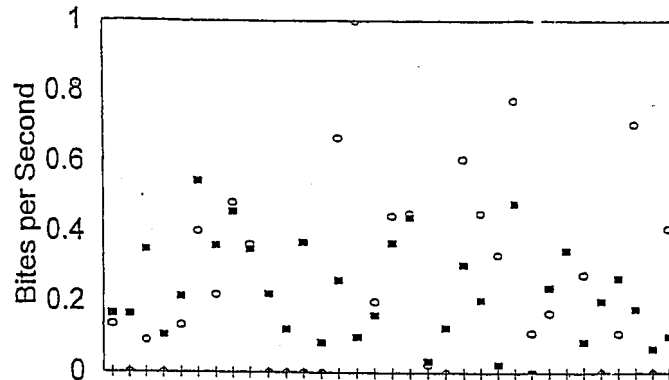


## Away from Offspring

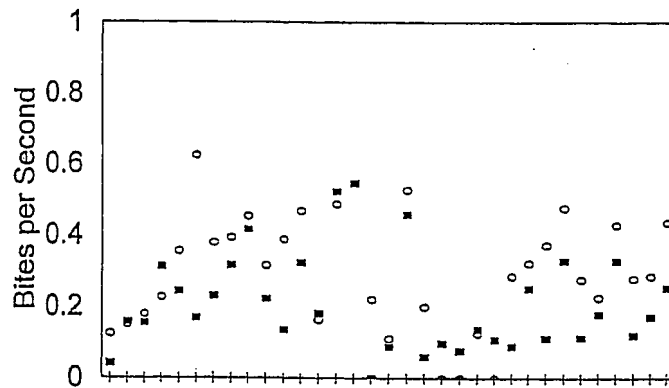


# Rate of Biting

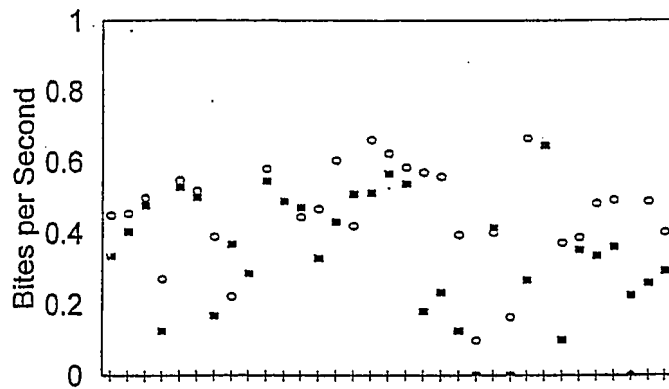
Large Male - Small Female



Similar Size Pair



Large Female - Small Male



## **Vita**

### **Education:**

B.S. Information Systems  
Robert Morris College, 1985  
Summa cum laude

M.B.A.  
University of Poittsvurge, 1989

B.S. Biology  
Chatham College, 1994  
Magna cum laude

### **Achievements and Awards:**

Phi Betqa Kappa, 1994  
NSF REU Fellowship, 1992  
UPMC (U. Of Pittsburg Medical Center) Summer Fellowship in genetics, 1993

### **Work History:**

USX Corporation 1984-1992  
Team Leader, Information  
CNG Corporation 1994, 1995, 12/96 to present  
Consultant and Senior Systems Analyst, Systems Services



**END  
OF  
TITLE**