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The importance of color in mate choice of the blue crab *Callinectes sapidus*

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SUMMARY

Visual displays often play a large role in animal communication, particularly in sexual interactions. The blue crab *Callinectes sapidus* is both colorful and highly visually responsive, yet almost all studies of their courtship have focused on chemical cues. In the blue crab's underwater environment, however, visual cues may function more rapidly and over a longer distance than chemical cues. Given that blue crabs are aggressive and cannibalistic, visual cues may therefore allow blue crabs to quickly evaluate potential mates from safer distances. In the present study we show that courtship and mate choice behavior in *C. sapidus* can be stimulated by visual cues alone. Further, we show that males have a preference for females with red claw dactyls. In binary choice experiments, males displayed more often to photographs of females with red claws than to those with white claws or to those with black claws that were isoluminant to the red ones. This strongly suggests that male blue crabs made their choices based on the hue of the red claws, further suggesting that blue crabs are capable of color vision and use color in mate choice.

Key words: *Callinectes sapidus*, color vision, sexual selection.

INTRODUCTION

In many breeding systems, animals perform a series of courtship rituals to attract a mate, arouse the breeding state in both genders and finally achieve copulation (Frings and Frings, 1977; Alcock, 2005). These rituals involve a variety of signal modalities, including visual, tactile, chemical and mechanical channels (Johnstone, 1996; Candolin, 2003). Often, signalers will employ more than one modality, using multiple channels to enhance and/or modulate the message of the signal (Candolin, 2003; Alcock, 2005). Whether sexual signals are simple or complex, the signals exchanged should allow each animal to identify both species and gender (Sherman et al., 1997).

Further, in aggressive and competitive species like certain crustaceans, there is a need for sexual signals to clearly communicate signaler intentions (Dingle and Caldwell, 1972; Uetz, 2000). Many species of crustaceans have well developed visual systems paired with colorful displays, and in these species visual cues may play a large role in communication. Moreover, visual signals may function more rapidly and over a further distance than other signal modalities, allowing individuals to communicate instantaneously from safer ranges. In many brachyuran crabs, visual cues play a large role in sexual and agonistic behaviors (Schöne, 1968), and have been most studied in fiddler crabs (genus *Uca*). Visual cues involving both color and movement play a large role in the social interactions of this genus (Detto et al., 2006). *Uca mjoebergi* and *Uca capricornis* identify gender and recognize neighboring individuals based on learned color patterns, and mate choice in *U. mjoebergi* is influenced by claw color (Detto et al., 2006; Detto, 2007). Aside from fiddler crabs, visual cues have been well documented in other malacostracan crustaceans, including several species of stomatopods [*Odontodactylus scyllarus* (Marshall et al., 1996); *Gonodactylis* sp., *Haptosquilla* sp. and *Oratosquilla* sp. (reviewed by Christy and Salmon, 1991)]; in shrimp [*Alpheus heterochaelis* (Hughes, 1996); *Rhynchocinetes typus* (Diaz and Thiel, 2004)]; and in crayfish [*Austropotamobius pallipes* (Acquistapace et al., 2002)].

The blue crab, *Callinectes sapidus*, is of particular interest given the species' exceedingly agonistic nature, wide geographical spread, economic value and ecological importance. Blue crabs spend up to 40% of their time in agonistic behaviors (Clark et al., 1999). This is among the highest values reported in arthropods and 'underlines the bellicose nature of the species' (Clark et al., 1999). Blue crabs are endemic to western Atlantic coastal waters from Nova Scotia to Uruguay, and have been introduced in locations all over the world, including Hawaii, Europe, Japan and Africa (Williams, 2007). They support one of the top-grossing fisheries of the US coastal Atlantic, earning \$130–160 million per year (Bullock et al., 2007). Additionally, the blue crab is a keystone species in the coastal benthic, pelagic and estuarine ecosystems, functioning as predator, prey and scavenger (Hines, 2007). While a large body of literature on the biology of *C. sapidus* exists (reviewed by Kennedy and Cronin, 2007), their sensory physiology and behavior are poorly understood (Jivoff et al., 2007; Hines, 2007). Specifically, the role of vision in the mating behavior of these colorful and highly visual animals has been overlooked.

Previous work on blue crab visual behavior is limited, although the species is known to be an excellent visual predator – catching fish, stalking fiddler crabs and even burying itself up to its eyes to ambush a prey item (Abbott, 1967; Hines, 2007). Behavioral experiments testing visual responses to variously shaped and colored objects suggested that *C. sapidus* was able to discern blue, yellow and red (Bursey, 1984). However, the perceived brightness of the different hues was not controlled for during these experiments, so it is unclear whether the crabs were using color discrimination or brightness cues to differentiate between the targets. Behavioral studies in the 1970s described a number of visual cues used in agonistic and sexual behaviors of *C. sapidus* (Jachowski, 1974; Teytaud, 1971). A more recent study investigating the use of visual and chemical cues during courtship reported mixed results for both components of the experiment, with the author reporting that visual signals were not used but also that chemical cues were not mandatory for mating interactions (Bushman, 1999). These experiments involved antennule ablation and blindfolding, which may have affected courtship and mating behaviors.

During courtship, blue crabs may use chemical cues for mate attraction. Chemical cues in *C. sapidus* have been studied extensively, although the identity of the chemical(s) used remains elusive (Jivoff et al., 2007). By contrast, visual cues in blue crabs have been less studied and the use of vision during mating has often been considered unimportant (e.g. Jivoff et al., 2007). It is well known, however, that blue crabs wave their claws in both agonistic and sexual interactions (Teytaud, 1971; Jachowski, 1974). During courtship, males will rise up on the tips of their walking legs, extend their claws and sometimes raise their swimming paddles and laterally fan them towards the potential mate (Teytaud, 1971). The higher posture and paddling help send chemical cues towards a potential mate but may serve a visual purpose as well (Kamio et al., 2008).

In addition to postures and movements, male and female *C. sapidus* have visible sexual dimorphism of their abdomens and claws (Jivoff et al., 2007) (Fig. 1). Males have a narrow white abdomen that matches the ventral carapace. Mature females have a rounded abdomen with orange, blue and black bands that contrast with the ventral carapace, and immature females have triangular abdomens with pale orange or blue bands. More apparent than the abdominal dimorphism is the striking sex-related difference in claw color. Males have white and blue claws and dactyls (i.e. fingers of the claws) whereas females have blue and white claws with red dactyls. Both males and females exhibit variations in claw color and pattern. The color of males' claws ranges from pale to dark blue. Females' dactyls range from light orange to a deep red (Fig. 2). Anecdotal evidence indicates that the red color of female claws becomes more saturated with maturity. The extent to which color varies is not documented in either gender, nor has it been explored in regards to reproductive status or individual quality.

In this study, we investigated the use of non-postural visual cues in blue crab courtship using photographs of female crabs. We conducted binary choice experiments to investigate whether male blue crabs respond to female visual cues and whether they demonstrate a preference for claw dactyl coloration. Our results show that color cues are potentially important during courtship behavior and also show that male blue crabs perceive and prefer red dactyls to those of other colors.

MATERIALS AND METHODS

Specimen collection and care

Male *Callinectes sapidus* Rathbun were captured from Jarrett Bay near Smyrna, NC, USA (34°45′31.4″N, 76°30′44.4″W) in July and August of 2008. Crabs were immediately placed into individual water-filled buckets and transported to Duke University's central campus in Durham, NC, USA. There, crabs were kept in individual compartments within a 700-liter re-circulating artificial seawater system (salinity 31–35‰, temperature 25–26°C, ambient light). Compartment walls were opaque to minimize stress and agonistic behavior. Crabs were fed pieces of fish or scallop every two days, and kept for at least 48 h before being used in experiments.

Behavioral experiments

Binary choice experiments were conducted in a 130-liter glass aquarium (32 cm×91 cm×46 cm) with a gravel bottom. During acclimation periods, water was filtered and at all times maintained at the same salinity and temperature as the holding tank. The experimental tank was kept in a separate room and visually isolated on three sides by blue cloth and on the fourth side by a light colored wall. The tank was observed *via* a video camera whose monitor and recorder were on the other side of the cloth barriers. The tank was lit using overhead fluorescent and incandescent lamps, resulting in a downwelling irradiance of 8×10^{14} photons cm^{-2} s^{-1} (integrated from 400 to 700 nm).

To limit confounding variables, such as chemical or tactile cues, a photograph of a sexually mature female in a receptive sexual posture was used in place of live females. Preliminary tests showed

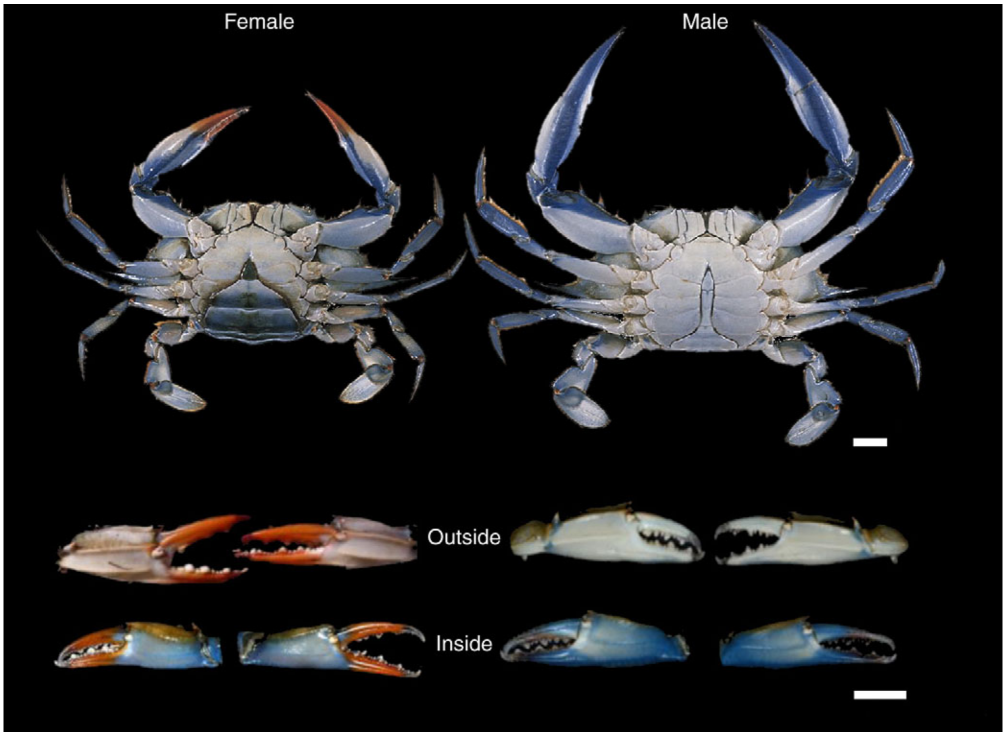

Fig. 1. Ventral views of male and female *Callinectes sapidus* and exterior and interior views of the claws. Scale bars equal 2 cm.

that males preferred females with their claws out and dactyls closed. Three versions of the photograph were used: (1) an original image, (2) an image altered so that the claws were white, and (3) an image altered so that the claws were black (Fig. 3). Images were altered using the 'selective color' feature of Photoshop CS (Adobe Inc., San Jose, CA, USA). The diffuse spectral reflectances of the claws in the printed images were measured using a fiber optic-based spectroradiometer in reflectance mode (USB2000, Ocean Optics Inc., Dunedin, FL, USA) (Fig. 4). The gray value of the black claws was chosen so that its brightness (as perceived by the crabs) matched that of the red claws as closely as possible (Table 1). Perceived brightness L was calculated using:

$$L = C\int_{400}^{700} R(\lambda)I(\lambda)S(\lambda)d\lambda \ , \tag{1}$$

where $R(\lambda)$ is the spectral reflectance of the claw dactyl, $I(\lambda)$ is the downwelling irradiance in the tank, and $S(\lambda)$ is the spectral sensitivity of the crab eye (C is a constant that includes factors such as eye size, etc. that are independent of wavelength and factor out when comparing different colors). The spectral sensitivity of *C. sapidus* was calculated in two ways: (1) using electroretinography (ERG) data from Martin and Mote (Martin and Mote, 1982), and (2) using microspectrophotometry (MSP)-determined visual pigment curves from Cronin and Forward (Cronin and Forward, 1988) (λ_{max}=504 nm) combined with measurements of rhabdom length and absorption coefficient. Using the same methods, the perceived brightness of the white claws was determined to be approximately seven times that of the black and red claws (Table 1). The images were printed on standard paper and mounted to white foam boards for stability.

All trials were conducted between 07:00 h and 19:00 h Eastern Daylight Time from June through to September 2008. At the start of each experiment, one male was placed in the experimental tank. After three hours of acclimation, two photographs were presented to the crab – one at each end of the tank. Photograph positions were assigned randomly. Over the next hour, the male's behavior was monitored. Most crabs made multiple stereotypic sexual displays that were unambiguously directed towards (and occurred within 5 cm of) one of the two images. During these 5–30 s displays, the crabs rose up on their walking legs, extended their claws and waved their paddles while facing the photograph. In between displays, the crabs generally walked around the tank. The total number of sexual displays made towards each image over one hour was counted. Choice was assigned to the image that received the greatest number of displays. Sixteen successful trials were run for the red *vs* white

Fig. 2. Claws of female *Callinectes sapidus*. The coloration of dactyls varies in both the area of the red coloration and also the hue and saturation of the color. Scale bar equals 2 cm.

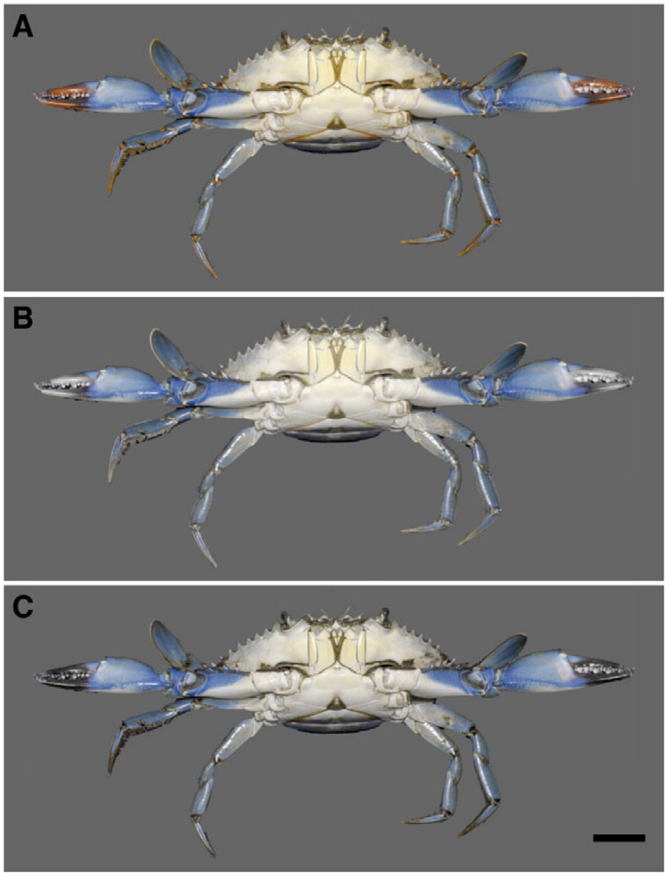

Fig. 3. The three photographs of female *Callinectes sapidus* used in the binary choice experiments. The crab was photographed with her claws out and dactyls closed, a known sexually receptive posture. (A) Original image. (B) Original image altered to make claws white. (C) Original image altered to make claws black. Scale bar equals 2 cm.

Table 1. Estimation of perceived brightness of images of claw dactyls used in this study

	Relative intensity (based on MSP data)	Relative intensity (based on ERG data)
Black claw image (20)	1.0±0.39	1.0±0.39
Red claw image (19)	1.3±0.72	1.4±0.74
White claw image (19)	6.9±1.2	6.8±1.2

Measurements are normalized such that the perceived brightness of the black dactyls is one. Values given are means ± s.d. *N* values are in parentheses. MSP, microspectrophotometry; ERG, electroretinography.

experiment and 15 for the red *vs* black experiment. Each experiment was analyzed using the two-tailed exact binomial test.

Because these males are wild caught, it was not known how recently they had molted or mated. Both of these factors may affect their sexual receptivity. Therefore, if a male made no displays during the one-hour trial, he was tested again 5–7 days later. Eleven of the 31 males were used in both experiments, although no males were used more than once in a five-day period. After testing, the males were returned to the re-circulating system and later to their original capture area.

RESULTS

Males responded to photographs of females with stereotypic courtship behaviors in 65% of the first trials (26 out of 40 combined white and black trials). Of the 14 males that did not respond in their first trial, five were re-tested in the same experiment after 5–7 days and four of these five displayed a behavioral response and preference. Another five of the initial 14 unresponsive males were later used in the other color trial; these five males displayed courtship behaviors and preference in the subsequent experiment. Four of the initially unresponsive males were not retested or reused. Of the 10 that were either retested or later used, nine displayed courtship behaviors giving a total response rate of 87% over two rounds of trials (35 out of 40 trials). Only one male, of those retested, was unresponsive during the course of the trials.

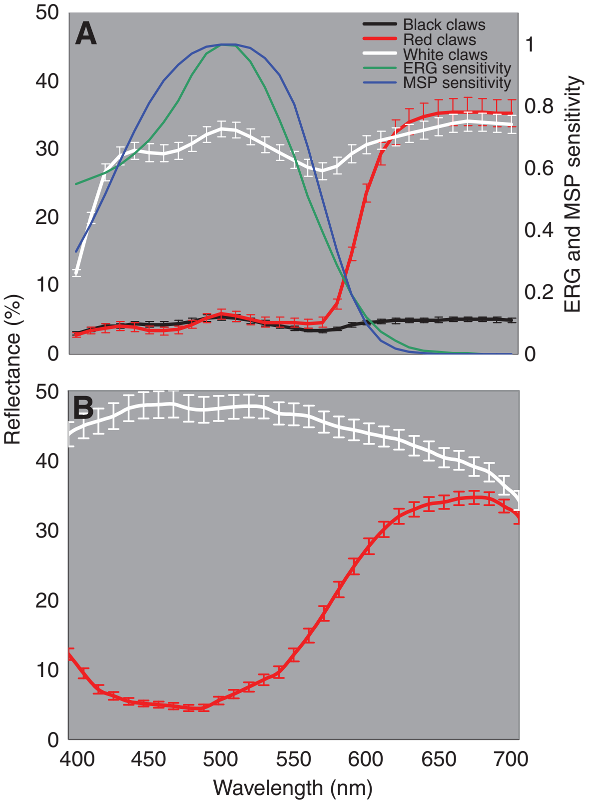

Fig. 4. (A) Spectral sensitivity of *Callinectes sapidus* based on electroretinography (ERG) data from Martin and Mote (Martin and Mote, 1982) plotted with the spectral reflectances of the photographs of the red, white and black claw dactyls used in the experiments (*N*=20 per image). Based on the ERG and microspectrophotometry (MSP) data, the red and black dactyls are nearly isoluminant. (B) Spectral reflectances of actual *C. sapidus* females' red and males' white claws (*N*=36 females, *N*=36 males).

Males chose photographs of females with red claws over those with white claws in 14 out of 16 trials (*P*<0.005; two tailed exact binomial test; Fig. 5A, Table 2). Males also chose females with red claws over those with black claws in 13 out of 15 trials (*P*<0.01, Fig. 5B, Table 3). In all trials except one, the first photograph to receive a sexual display from the male was the photograph that received the most displays. The exception, male 16 in the red *vs* white experiment displayed at the white-clawed photograph first but ultimately (although narrowly) displayed more often to the red-clawed photograph. If this male was assigned a preference of white rather than red, the overall male preference for females with red claws in this experiment is still statistically significant (*P*<0.025). During four of the 16 red *vs* white claw trials, agonistic responses, including open-dactyl claw waving and striking against the aquarium glass, were seen towards the white-clawed photograph. There was no significant bias for the left or right side of the tank in either experiment. Left was chosen nine out of 16 times in the red *vs* white claw trials and nine out of 15 times in the red *vs* black claw trials (*P*>0.5 in both cases).

The total number of displays over the one-hour trials was quite variable, ranging from two to 34 in the red *vs* white trials (11±9.8, mean ±s.d.) and from two to 19 in the red *vs* black trials (8±5.5). The mean percentages of displays towards the photograph with red claws were 85±28 (red *vs* white) and 78±32 (red *vs* black). Ten of the 16 crabs in the red *vs* white trials and eight out of the 15 in the red *vs* black trials only displayed to the photograph with the red claws. Interestingly, the four trials showing a choice of black or white claws over red claws suggested unambiguous preferences, with the test crab performing substantially more displays toward a black-clawed female (two *vs* zero and 10 *vs* two displays) and to a white-clawed female (four *vs* one and 11 *vs* four displays).

DISCUSSION

Color vision is known to play a role in the sexual behavior of certain crabs and crustaceans, although this is the first time it has been documented in blue crabs. The results given here show for

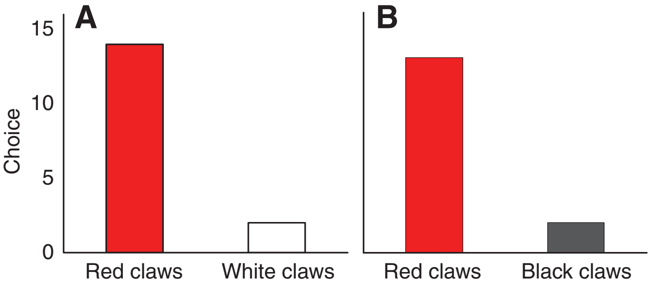

Fig. 5. Results of the choice experiments. (A) Male *Callinectes sapidus* chose the red claws over white ones in 14 out of 16 trials (*P*<0.005, two-tailed exact binomial test). (B) Male *C. sapidus* also chose red claws over black ones in 13 out of 15 trials (*P*<0.01).

Table 2. Individual results of red–white binary choice experiment

Male ID#	Displays to red	Displays to white	Total displays	Color preference	First display	Side of preference
11	3	1	4	Red	Red	Right
12*	7	–	7	Red	Red	Left
13	15	–	15	Red	Red	Right
14	30	4	34	Red	Red	Left
15	4	–	4	Red	Red	Right
16	17	15	32	Red	White	Left
17	10	–	10	Red	Red	Left
18	12	–	12	Red	Red	Right
20	1	4	5	White	White	Left
21	9	2	11	Red	Red	Left
22	4	11	15	White	White	Left
23	7	–	7	Red	Red	Right
25	4	–	4	Red	Red	Left
27	3	–	3	Red	Red	Left
29	2	–	2	Red	Red	Right
31	6	–	6	Red	Red	Right
				Red 14: white 2 $P<0.005$	Red 13: white 3 $P<0.025$	Right 7: left 9 $P>0.5$

*Male did not respond during first trial, so data presented is from retrial.

the first time that visual cues alone can stimulate courtship behavior in male *C. sapidus*. At no time during the trials were males exposed to female chemical cues, which have been routinely used in previous behavioral experiments, including those testing visual cues. Our results also show that male *C. sapidus* are able to express mate preferences based only on the color of a female's claws.

Unexpectedly, the males' choices suggest that blue crabs are able to perceive red as a color, not simply a difference in brightness. While the results of the red *vs* white trials could indicate a male preference for females with red claws or simply a preference for darker claws, the fact that the males could also choose red claws over isoluminant black claws suggests that they were able to discriminate the hue of the claws. It is possible that the spectral sensitivities based on the ERG and MSP data do not accurately represent the achromatic channel in *C. sapidus*, implying that the red and black claws are not isoluminant. This will be further examined in future studies that will also test whether blue crabs can discriminate red from more orange and other long-wavelength dominated hues. However, the males' choice of red claws over claws of two quite different gray values strongly suggests that hue discrimination is taking place.

The physiological mechanism for this hue discrimination is unclear. Previous studies using MSP have found only a single medium-wavelength pigment in the eye of *C. sapidus* that absorbs light maximally at 504 nm (Cronin and Forward, 1988). However, because MSP only looks at one cell at a time, regional variation in pigment expression or the presence of rare pigments can lead to false negatives. ERG by Martin and Mote (Martin and Mote, 1982) suggested the presence of an additional short-wavelength channel in the ventral portion of the eye (λ_{max}=480 nm), and it is possible that opponency between this and the medium-wavelength pigment allows for hue discrimination at longer wavelengths. The ERG data suggesting the presence of this short-wavelength pigment is not robust, however. Only six samples showed evidence of this receptor, and the methods used to collect data from these six were different from the methods used during the rest of the study (Martin and Mote, 1982). Thus, further research is necessary to determine the

Table 3. Individual results of red–black binary choice experiments

Male ID#	Displays to red	Displays to black	Total displays	Color preference	First display	Side of preference
3	3	1	4	Red	Red	Right
4	–	2	2	Black	Black	Left
5	11	–	11	Red	Red	Right
6*	3	–	3	Red	Red	Left
7	11	8	19	Red	Red	Left
9*	8	2	10	Red	Red	Left
10	11	4	15	Red	Red	Left
11	2	–	2	Red	Red	Right
12	2	–	2	Red	Red	Left
15	9	–	9	Red	Red	Left
16	14	–	14	Red	Red	Right
18*	7	–	7	Red	Red	Left
19	2	10	12	Black	Black	Right
21	5	2	7	Red	Red	Left
22	2	–	2	Red	Red	Right
				Red 13: black 2 $P<0.01$	Red 13: black 2 $P<0.01$	Right 6: left 9 $P>0.5$

*Males did not respond during first trial, so data presented is from retrial.

physiological basis for red perception and also to determine over what wavelengths hue can be discerned.

However, if one assumes that there is an opponency mechanism between a 480 nm and a 504 nm pigment in the blue crab eye, it appears that the red claws can be discriminated from the white and black claws. One simple model assumes that the two channels are balanced (ie. have equal influence) and that the hue is the normalized difference between their perceived brightnesses, i.e.:

$$\mathrm{Hue} = \frac{L_{504} - L_{480}}{L_{504} + L_{480}} \;, \tag{2}$$

where L_λ is the perceived brightness calculated in Eqn 1 for a pigment with a peak wavelength of λ. Using this, the 'hues' of the white and black claws are 0.10 and 0.09, respectively, and that of the red claws is 0.20. While admittedly arbitrary, this suggests that the two pigments are different enough to reliably separate greys from red, at least in daylight. For example, horses (dichromats with pigments peaking at 428 nm and 539 nm) can distinguish colors with these hue values (Roth et al., 2007).

The significance of claw color in blue crabs has not been investigated, and it is unknown if color simply indicates sex or if it may also reflect upon the quality of the individual. In blue crabs, color is contained in the hypodermis portion of the cuticle (Smith and Chang, 2007). The colors are pigmentary and derived from carotenoids, which are not synthesized by animals. Carotenoid-based pigments are obtained from diet; therefore, animal colors may be limited in part by an animal's foraging ability (Bagnara and Hadley, 1973; Brush and Power, 1976). In certain species that utilize carotenoid pigments in color displays, coloration is reflective of an individual's foraging ability and may indicate overall fitness (e.g. Endler, 1980; Hill and Montgomerie, 1994). Typically, better foragers have brighter, more attractive coloration and may be perceived as better quality mates and receive mate preference (Burley and Coopersmith, 1987; Kodric-Brown, 1989; Hill, 1990). For example, diet is directly linked to color in guppies (*Poecilia reticulata*). Male guppies fed a carotenoid-enriched diet produced more saturated red and orange patches, which increased their attractiveness to females (Kodric-Brown, 1989). Similar studies have linked diet, color and mate attractiveness in three-spine sticklebacks [*Gasterosteus aculeatus* (Frischknecht, 1993; Bakker and Mundwiler, 1994)], firemouth cichlids [*Cichlasoma meeki* (Evans and Norris, 1996)], and in several species of birds such as house finches [*Carpoducus mexicanus* (Hill and Montgomerie, 1994)] and greenfinches [*Carduelis chloris* (Saks et al., 2003)]. The results of these studies suggest that the blue and red colors of both male and female blue crabs could be indicative of foraging ability and thereby quality if carotenoids are a limited resource.

Additionally, the claw color in blue crabs may enhance the visibility of sexual cues through the blue crab's environment. Blue crabs utilize various habitat types depending on age, molt stage, gender, salinity and season and are typically found in coastal and estuarine waters between 0 m and 15 m deep (Hines, 2007). The drab olive coloration of *C. sapidus*' carapace apparently functions as camouflage, while the bright claw colors may be advertisements, particularly the red claws of females. In some aquatic environments, red colored cues and the ability to distinguish red may be particularly useful. Red is conspicuous against blue or green-dominated underwater light environments, especially in shallow water where red solar illumination is still present (Lythgoe, 1979). Red is used in courtship displays in several relatively shallow water species including: three-spine sticklebacks [*G. aculeatus* (McLennan and McPhail, 1990)], guppies [*P. reticulata* (Endler, 1980)], cichlids [*Haplochromis nyererei* (Seehausen and van Alphen, 1998)], California market squid [*Loligo opalescens* (Zeidberg, 2009)], and the fiddler crab [*U. pugilator* (Hyatt, 1975)], among others. Red coloration may also be visible at longer distances than other hues in the blue crabs' habitat. Displaying red color is common in freshwater systems where short-wavelength light can be heavily attenuated and longer wavelength light pervades the underwater habitat (Kodric-Brown, 1989; Lythgoe, 1979). Similarly, dissolved organic matter in coastal and estuarine environments can shift the underwater light environment to longer wavelengths. For example, underwater irradiance measurements from the Rhode River area of the Chesapeake Bay (38.71–38.89°N latitude; 76.34–76.54°W longitude) show that the underwater light environment is predominately yellow (Tzortziou et al., 2007). The visibility of blue crab claws will depend on habitat conditions and the interaction of light and color.

The red coloration of female *C. sapidus* may play a role in male mate choice by indicating gender, reproductive status and/or individual quality. While investigations of color cues and ornaments have historically focused on males, more recent studies have found that female coloration and ornaments are used in both male mate choice and female–female competition, even in systems where sex roles are not reversed (Amundsen and Forsgren, 2001; Jones and Hunter, 1993). In a marine fish, the two-spotted goby (*Gobiusculus flavescens*), males preferred females with bright yellow–orange colored bellies to those with drab bellies (Amundsen and Forsgren, 2001). Males of the crested auklet (*Aethela christatella*), a seabird, prefer females with lengthier crest ornaments (Jones and Hunter, 1993). Female striped plateau lizards (*Sceloporus virgatus*) develop orange throat coloration during the breeding season that indicates both higher individual quality and fecundity and may function as an ornament to attract mates (Weiss, 2006). Only a few other studies in birds and fish have shown male preference for female ornaments and colors but male mate choice is probably occurring in other groups (Amundsen and Forsgren, 2001). Investigations of female coloration or ornaments as cues or signals during female–female competition are fewer but studies in dotterels [*Charadrius morinellus* (Owens et al., 1994)], capuchinbirds [*Perissocephalus tricolor* (Trail, 1990)], and hummingbirds [*Amazill* spp. (Wolf, 1969)] indicate that showy female traits or colors may be selected through female-female competition over sexual or non-sexual resources. Given the use of female color and ornaments in other systems, it is plausible that the red color of the female blue crab sends a message of reproductive status or mate quality.

Determining the role of claw coloration in *C. sapidus* will require further investigation, both behavioral and physiological. Such investigations are needed to determine the importance of vision and to understand the visual ecology of this economically and ecologically important species that often finds itself inhabiting anthropogenically turbid waters.

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