PHOTOTACTIC RESPONSES OF LARVAL *MACROBRACHIUM ROSENBERGII* (de Man)

D.E. Coleman

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SEA GRANT COLLEGE PROGRAM

University of Hawaii
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TABLE OF CONTENTS

LIST OF FIGURES

Figure

LIST OF TABLES

Table

ABSTRACT

Larvae of Macrobrachium rosenbergii *were exposed to green light (500 nm to 580 nm) and blue light (430 nm to 480 nm). Tests show that green light has a greater attractive effect than blue light of equal intensity.*

Within each wavelength range the intensity was increased from 2.5×10^{-3} *watts/m*^{2} *to* 19.9×10^{-3} *watts/m*^{2} *Results show that there is a positive relationship between the intensity of light and its attractive effect.*

INTRODUCTION

A technique for the successful rearing of *Macrobrachium rosenbergii* larvae was developed between 1966 and 1969 (Fujimura, 1966; Ling, 1969a, 1969b; Fujimura and Okamoto, 1972). Since that time the aquaculture of *M. rosenbergii* has become a viable economic industry in Hawaii and interest is growing rapidly in Asia and other areas of the world.

In order to keep pace with other aquaculture products more efficient pond and hatchery techniques will have to be developed for *M. rosenbergii*.

One way to increase hatchery efficiency would be to develop a simple method of separating larvae and postlarvae.

If analysis of the light reactions of larvae and postlarval prawns show that they are attracted to different wavelengths of light, or that one group is not attracted to light at all, a method may be devised to separate the two populations in the rearing tank. This would facilitate culling of postlarvae without having to sort out larvae by hand.

Being able to do this efficiently and with a minimum of labor may have a significant effect on the mortality rate experienced during the hatchery grow-out phase.

Since postlarvae remain at or near the bottom of the tank, larvae that settle first are in an ideal position to feed on their siblings as they sink to the bottom for their final larval molt.

As Table 1 shows, cannibalism can have a significant effect on hatchery efficiency. In small-scale operations where the postlarvae are culled by hand, survival as high as 95% has been reported (A. Muraoka, 1975: personal communication).

TABLE 1. PRODUCTION SURVIVAL RATE*

Total larval estimate	= 4,941,000
Total postlarval estimate	= 2,637,591
Survival	= 53.38%
Total percentage of larvae lost probably due to cannibalism	= 46.62%

Source: Anuenue Fisheries Research Center

*Based on (1) the original number of larvae estimated just after hatching (prior to dropping into the rearing tanks and (2) the original five tanks prior to dividing larvae into other tanks.

The papers of Ling (1969a) and Peebles (1974) comprise the bulk of information dealing with the ethology of the animals. Through these papers, a better understanding of the behavior of *Macrobrachium rosenbergii* can be gained and, in turn, that knowledge can be applied to increasing the efficiency of hatchery and pond operations.

This paper addresses itself to three questions:

1. Is there a difference in the ability of green and blue lights to stimulate photopositive reactions in larval prawns?

2. What is the relationship between the numbers of animals responding positively to green or blue light and the intensity of that light?

3. What is the possible role of light in the behavior of *Macrobrachium rosenbergii*?

MATERIALS AND METHODS

The test chamber consisted of a 21-liter all-glass aquarium. The outside and bottom of the aquarium were painted black with the exception of a 32 cm^2 window at one end. This window was fitted with Kodak Wratten Gelatin filters which were used to control the wavelength of the test light. The top of the aquarium was fitted with a light proof lid that was lowered before turning on the light source.

Wavelength was determined by narrow band Kodak Wratten Gelatin filters no. 50 and no. 74 (Figure 1). The filters were attached directly to the aquarium window so that all light entering passed through the filters.

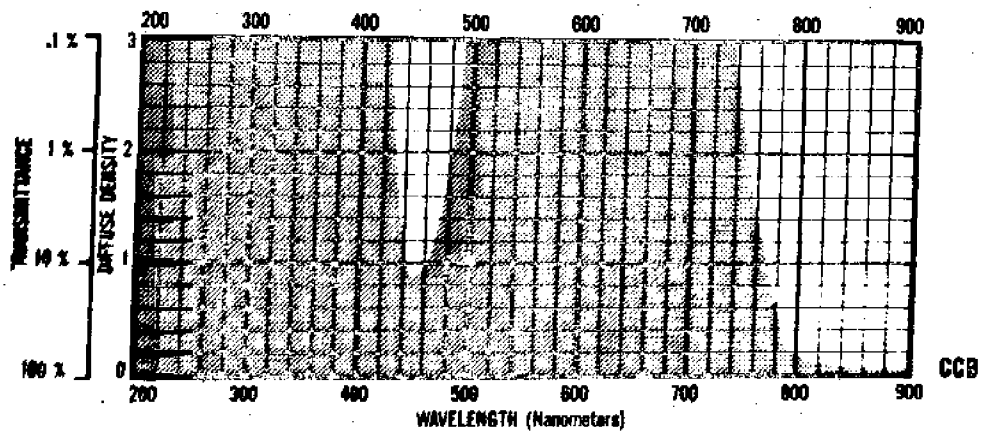
Illumination was provided by a Kodak carousel slide projector equipped with a 500-watt tungsten bulb. Light intensity was adjusted by changing the distance between the projector and aquarium.

Intensity was measured with a G.E. PR3 photometer. It was necessary to convert the E.V. reading to Lux and apply a correction factor to obtain the correct amount of watts/m^2 (Sears and Zemansley, 1955).

All larvae were raised outdoors in fiberglass tanks by Takuji Fujimura and the staff of the Anuenue Fisheries Research Center, Honolulu, Hawaii.

No effort was made to group animals according to age.

During the experiment, water temperature was at 26°C ± 1°C and salinity was at 15 °/₀₀ ± 1 °/₀₀. Ling (1969b) determined that these are acceptable conditions for maintaining *M. rosenbergii*.



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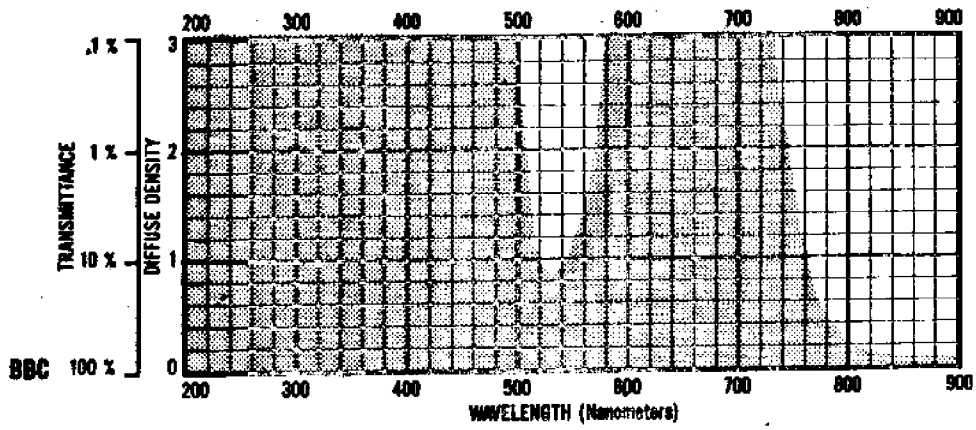
Deep Blue Monochromat. Transmits mercury line at 436 nm, and, to a lesser extent, lines at 398, 405, and 408 nm.

Dominant λ = 457.7 nm



74

Dark Green Monochromat. Transmits 10 percent of green radiation and virtually no yellow radiation from mercury-vapor illumination.

Dominant λ = 538.0 nm

FIGURE 1. TRANSMITTANCE CURVES OF KODAK WRATTEN FILTERS 50 AND 74 (Shaded area = transmittance)

Source: *Kodak Filters for Scientific and Technical Uses.* Kodak Publication No. B-3 (CAT 152-8108). Professional and Finishing Markets Div., Eastman Kodak Co., Rochester, New York.

All animals were kept in darkness for 1.5 hours before being tested. Preliminary tests showed that relatively high intensities of light were required at test wavelengths to evoke any sort of response in the animals which had been exposed to white light for any period of time. Foward and Costlow (1974) found the same to be true for brachyuran (crab) larvae.

Each of the four test groups consisted of ten animals, dark adapted by the method previously mentioned. Four repetitions were made at each intensity and each wavelength. A new group of animals were used in each repetition to eliminate any effects of pre-exposure. A total of 320 animals were used in all.

The experiment consisted of two series of tests. The first used blue light with a dominant wavelength of 457.7 nm and a band width of from 430 to 480 nm. The second series used green light with 538.8 nm as the dominant wavelength and a band width of from 500 to 580 nm. Both wavelengths were projected at intensities of 2.5×10^{-3} watts/m^2, 5.0×10^{-3} watts/m^2, 10×10^{-3} watts/m^2, and 19.9×10^{-3} watts/m^2, respectively.

Each group was exposed to the light for 30 minutes. At the end of that period, a divider was lowered into the tank to seal it off laterally into two sections. The room lights were then turned on and the number of animals in the half nearer the window were counted. These animals were considered to have responded positively to the test light intensities.

Some observations were made of animals that were light adapted but no attempt will be made to present the information in a quantitative manner in this paper. Light-adapted animals were exposed to room light plus a 60-watt bulb.

RESULTS

The data and pooled Chi X^2 values are shown in Table 2. Using the standard analysis for unpaired samples (Snedecor and Cochran, 1967), there does appear to be a significant difference in the number of animals responding to green and blue lights. Green light seems to elicit greater photopositive responses than blue light at equal intensities.

A regression analysis of the relationship between the number of positive responses and the increasing light intensities was performed (Snedecor and Cochran, 1967). The results show a highly significant relationship between the number of positive responses and an increase in light intensity (Figure 2).

Several observations were made on the general behavior of light and dark-adapted larvae under various conditions. For light-adapted animals, an upper limit to the photopositive reaction could not be found with the equipment available (1000-watt tungsten flood lamp). The intensity

TABLE 2. NUMBER OF LARVAE RESPONDING POSITIVELY TO VARIOUS INTENSITIES AND WAVELENGTHS OF LIGHT.

510 to 580 nm Intensity (watts/m^2)	Repetitions (Trials)					Pooled Chi X^2 Values
2.5×10^{-3}	I	6	9	9	8	7.20
5.0×10^{-3}	II	9	10	10	10	18.05
10.0×10^{-3}	III	9	10	9	9	14.45
19.9×10^{-3}	IV	10	10	10	10	20.00

430 to 480 nm Intensity (watts/m^2)	Repetitions (Trials)					Pooled Chi X^2 Values
2.5×10^{-3}	I	5	10	8	6	4.05
5.0×10^{-3}	II	5	7	9	8	4.05
10.0×10^{-3}	III	9	--	9	9	9.60
19.9×10^{-3}	IV	--	9	10	9	13.06

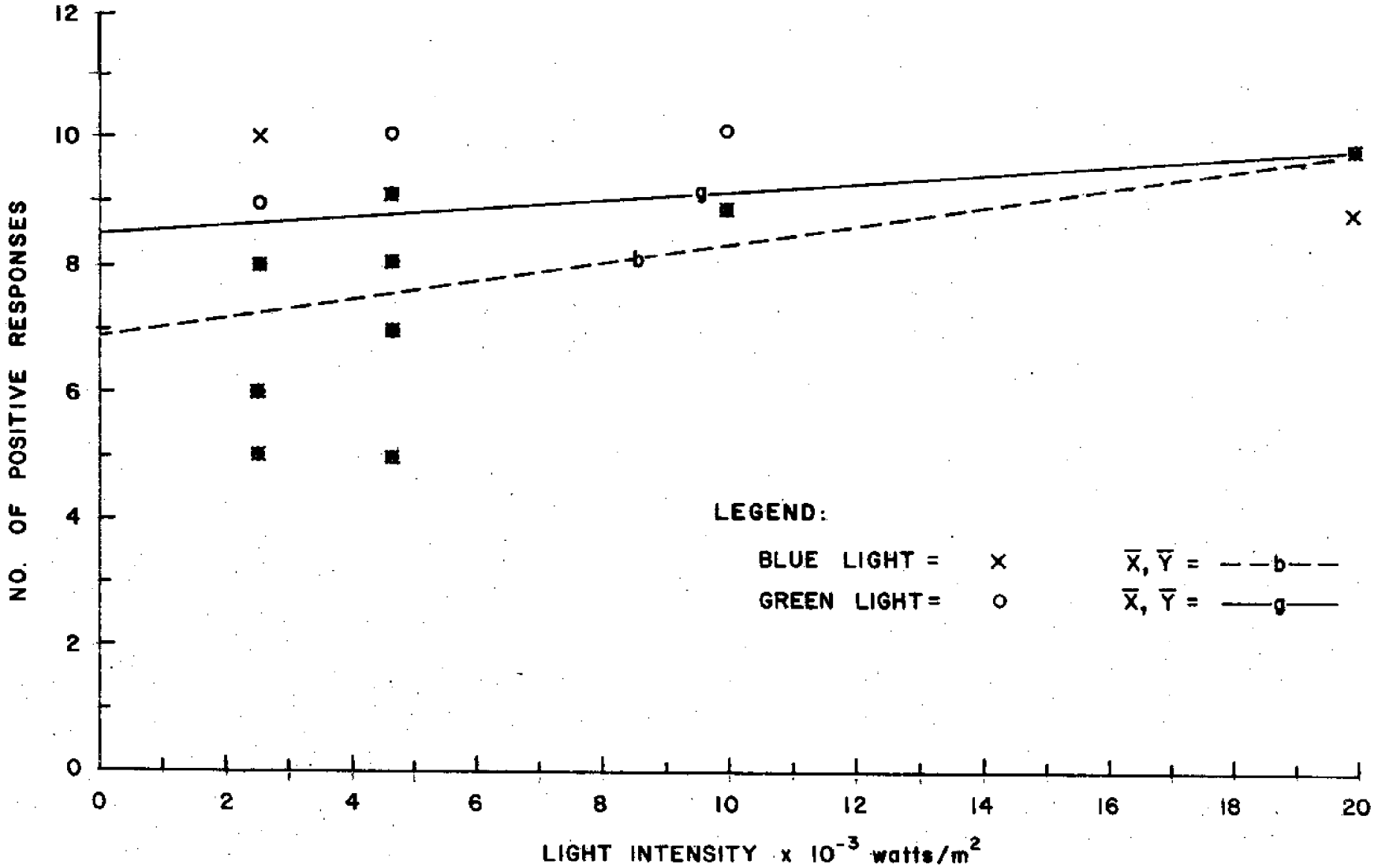


FIGURE 2. CORRELATION COEFFICIENT OF RESPONSES TO BLUE AND GREEN LIGHTS DETERMINED BY REGRESSION ANALYSIS

required to elicit a photopositive response from these animals was considerably higher than that for dark-adapted animals.

Apparently, the intensity range that brings about a photopositive reaction is higher in light-adapted animals. Also, there does not appear to be a lessening of the behavior with time. An indoor larval rearing operation on Maui, Hawaii, where the lights were kept burning 24 hours a day, developed a problem because of this. Apparently, the larvae constantly tried to swim toward the light and the energy expended had a negative effect on growth rate.

In dark-adapted animals, sudden exposure to bright light from above caused the larvae to immediately swim or sink to the bottom of the aquarium. However, after a few minutes, the larvae became photopositive and swam upwards toward the light source or to bright spots in the tank where light reflections were present. The movement toward bright spots in the tank regardless of the position of the light source could explain the photonegative reactions observed in *Uca pugilator* (fiddler crab) by Herrnkind (1968).

DISCUSSION

From these data, it appears that, of the two frequency ranges tested, the green 500 to 580 nm range is more effective in stimulating photopositive responses in *Macrobrachium rosenbergii*. However, it would not be surprising to find other "peaks" or frequencies in the spectrum that would elicit similar responses. Foward and Costlow (1974) have found such "peaks" at 280, 480, and 500 nm in brachyuran larvae. They also found the 500 nm frequency to be the most effective at stimulating photopositive reactions.

This same frequency range within the spectral band has been found to evoke phototactic responses in many aquatic and marine crustaceans. Numerous species of barnacle larvae were found to respond to wavelengths of 520 nm (Barnes and Kepel, 1972) and from 520 to 545 nm (Visscher and Luce, 1928). White (1924) found that the larvae of *Palaemonetes vulgaris* respond to the 450 to 550 nm range. This sensitivity of many aquatic and marine animals to the 450 to 550 nm range is compatible with several ecological and physical principles.

Blue-green light (450 to 550 nm) has excellent penetration qualities in salt and fresh water (Clapham, 1973) so it makes up a good portion of the photic environment. Light has been shown to be a major force in the vertical migration of plankton (Harris, 1953). Any animal feeding on plankton would be at a definite advantage if its phototactic responses kept it in close proximity to its food source. The classic example is *Daphnia magna*. "Blue light induces horizontal orientation and red light vertical orientation or 'dancing'." The density of phytoplankton changes the color of light that the *Daphnia* exposed to from blue to red. Under these conditions, they orient along a vertical axis and remain in the same general area in what may be called their "red dance."

If they move out of the dense area of plankton, more blue light becomes more available and they orient horizontally. In this position, they swim in widening circles until, theoretically, they end up in a plankton-rich area (Green, 1961).

The responses of other aquatic crustaceans and the data from these experiments suggest a hypothesis for the role of light in the behavior of *Macrobrachium rosenbergii* larvae.

During the day when the larvae (light adapted) are photopositive to higher intensities of light, they remain at or near the surface of the water column. This would place them in close proximity to other zooplankton which serve as a food source at the larval stage of development. At sunset as the rest of the zooplankton community begins its evening descent, the larvae, still being light adapted to high intensities of light, are now free to descend as the "attractive" effect of the setting sun decreases. As night progresses, the larvae become increasingly dark adapted (sensitive to lower light intensities) and by sunrise they are sensitive enough to begin the vertical migration to the surface with the rest of the zooplankton community.

On several occasions it was necessary to collect larvae from the covered outdoor rearing tanks (approximate depth of 75 cm) at night. On these occasions, it was noted that the greatest concentration of larvae was at or near the bottom of the tank. However, during the day when the tanks were uncovered, the larvae were usually seen at or near the surface.

CONCLUSIONS

The experiment was designed in such a way that light would be the only significant variable. Given this situation, it is concluded that:

1. Green light, with a wavelength of from 500 to 580 nm, elicits greater photopositive responses than blue light at a wavelength of from 430 to 480 nm when both colors are projected at the same intensity.

2. With each color tested, higher intensities proved more attractive than lower intensities.

3. In the natural environment the reactions of larval *M. rosenbergii* to changing light intensity and color could help them remain near their food source.

It is further concluded that a larval prawn separator may be feasible. Using the principles presented in this paper, the device was constructed and successfully demonstrated by the Agricultural Engineering Department of the University of Hawaii at the Anuenue Fisheries Research Center.

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