SYNOPSIS OF ACCOMPLISHMENTS:

Behavior and Swimming Performance of Red Snapper: Its Application to Shrimp Trawl Bycatch Reduction*

Prepared for:

Red Snapper SEDAR Workshop
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Prepared by:

Glenn R. Parsons
Professor of Biology
The Department of Biology
The University of Mississippi
University, MS 38677

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PURPOSE:

The study was initiated to:

1). Determine the influence of season on red snapper swimming ability. *(completed)*

2). Determine the influence of size on red snapper swimming ability. *(completed)*

3). Determine the influence of time of day (day vs. night) on red snapper swimming ability. *(completed)*

4). Describe the flow dynamics of the Fish Box BRD. *(in progress)*

5). Evaluate, in the laboratory, the efficacy of the Fish Box BRD for escape of red snapper. *(in progress)*

6). Examine various aspects of red snapper behavior for its application to bycatch reduction. *(in progress).*

METHODS:

Fish collecting and maintenance: All snapper were supplied by Dan Foster of the National Marine Fisheries Service, Pascagoula Laboratory, Pascagoula, Mississippi. Fish were trawled, as needed, from NMFS maintained trawlable, artificial reefs just south of the barrier islands. All fish were transported to the University of Mississippi Animal Care Facility and were held in 2000 liter, closed system flumes. Fish were fed daily a diet of squid, shrimp, cuttlefish and fish *ad libitum.* All fish were held at the temperature, salinity, and photoperiod from which they were collected. Prior to swim tunnel testing, fish were typically allowed several days to recover from capture and transport stress. Swimming performance trials for a given collection of fish typically required about 1 month for completion.

Swimming ability measurements.- Swimming ability in red snapper was evaluated using a 1000 liter Brett type swim tunnel and the critical swimming speed protocol. Fish were acclimated to the swim tunnel at the test temperature. Fish were swam at an initial speed of 10 cm/s for 0.5 hour. After this time period the speed was increased by 5 cm/s and the fish were forced to swim for another 0.5 hour period. This procedure was repeated until the fish fatigued as evidenced by it impinging upon the screen at the rear of the tunnel. The amount of time swam at the fatigue velocity was used to calculate critical swimming speed. Fish were swam approximately every two months to detect any seasonal effects on performance. We likewise swam the full size range of fish collected to detect size effects on performance. Finally, we swam fish in both daylight and darkness (at night) to detect light level (time of day) effects on performance.

BRD construction and testing.- We constructed a prototype Fish Box bycatch reduction device (BRD, Figure 1) and used it to examine the ability of red snapper to escape during trawling. The device was constructed from plexiglas. In this prototype, the front plate was angled at 45° and the top plate was approximately 40 cm x 40 cm. We evaluated the current speed profile in the BRD using a Marsh-McBirney flow meter. Speed was measured at various positions in the BRD (Figure 1).

BRD evaluation.- We evaluated the response of red snapper to the BRD by introducing fish into the test chamber and recording the number of fish that exited and the time required for fish to exit. The tests were typically conducted at the temperature and salinity at which fish were held in the laboratory. Fish were allowed to acclimate to the test chamber for 1 to several hours prior to subjecting them to current. Fish were tested during both daylight hours and at night.

RESULTS AND DISCUSSION:

Swimming ability measurements.- Critical swimming speed determinations were completed for approximately 300 red snapper. We observed no significant difference in swimming ability between day and night (Table 1, Figure 2). This was an important finding because shrimp trawling is often conducted at night. If snapper were found to be unable or unwilling to swim after dark, the development of a BRD that is effective during all hours of the day, might have been in jeopardy.

Because there was no time of day effect we pooled all Ucrit measurements within each month and used ANOVA to assess any effect of month on swimming ability. The month when fish were collected significantly affected the swimming ability of red snapper with February collected fish showing the lowest Ucrit. Critical swimming speed in February averaged 47.6 cm/sec and in December averaged 59.4 cm/s.

As expected there was a significant size effect on swimming ability (Table 1, Figure 2). Large snapper demonstrated higher critical swimming speeds than small. The smallest fish (6 to 8 cm standard length) had critical swimming speeds around 30 to 35 cm/s and the largest (16 to 18 cm standard length) had critical swimming speeds around 65 to 75 cm/s. We likewise found no significant interaction (no synergistic effect) of time of day and length on swimming ability (Table 1).

BRD evaluation.- We assessed the flow characteristics at various positions in the BRD (Figure 1) and found that free stream velocities in the "throat" of the device can exceed 120 cm/s. We also observed a sudden reversal of flow in and around the escape opening. This was an anticipated result because of the vortex that is generated in that area.

Daylight tests-- This portion of the project is still in progress. The efficiency of the BRD has been assessed for fish swimming during both day and at night using an infra-red video recording system. We first tested the tendency for snapper to exit the BRD during daylight at about 50 cm/s current speed (measured just above and anterior to the BRD exit). Fish exited the device an average of 1.8 minutes after being introduced into the test chamber (Figure 3). Approximately 77% of fish tested exited the chamber and 23% did not. We were curious as to whether the fish were responding to the current reversal present at the escape opening, or perhaps to a need to find refuge. We therefore painted the BRD black and examined the tendency for fish to exit during daylight swimming. With this modification approximately 80% of fish exited and 20% did not. Fish exited an average of 11.3 minutes after being introduced into the device. At this time there appears to be little difference between the response to the unpainted and painted BRD which suggests that, at least during the day, the need for refuge does not appear to drastically change the behavior of the fish. Because there was no difference in the response of snapper when the BRD was painted black, we combined all of the above tests to obtain an average of 8.1 minutes for fish to exit the BRD (Figure 3) and an exit rate of 79% in daylight.

Nighttime tests-- We also examined the efficiency of the BRD when tested at night under darkness. A disappointing 15% of fish were observed to exit the chamber while 85% did not exit (4 fish exited out of 27 tested) (Figure 3). These fish exited the chamber an average of 23.4 minutes after their introduction. In many cases, fish were observed to move to the escape opening and then remain in that position for long periods of time. The appearance was that the fish were reluctant to move out of the BRD but were content to remain in the lower flow area at the opening. Because much shrimp trawling is conducted at night, the inability of snapper to exit the

BRD in darkness was not a promising result.

Dark/light tests-- This set of experiments was designed to test the effect of light on snapper when swimming at night (Figure 3). Snapper were subjected to nighttime swimming in the BRD test chamber from 9 PM to midnight. At midnight, the room lights were set to come on and the response of the fish to this light was recorded. We found that all 23 fish tested failed to exit the chamber when swimming in darkness. However, when the room lights came on at midnight, 100% of fish exited. The average time to exit was 3.98 minutes and in 75% of cases the fish exited in less than five minutes. Many fish were observed to exit within seconds after the room lights came on.

Light as a means of "herding" snapper– Our recent experiments on the response of snapper to light after dark adaptation suggested appropriately placed light may be an effective tool for encouraging snapper to exit from the trawl. To this end we conducted experiments using, first, high intensity Cyalume light sticks and, later, LED lights strategically placed in the BRD. Cyalume light sticks placed under the top plate of the BRD discouraged fish from exiting. When seven fish were tested none of the individuals were observed to exit after 3 hours of swimming.

When light sticks were placed at the rear and front of the BRD the fish held position mid-way between the light sources. With light sticks in these positions 53% (16 of 30) fish were observed to exit in an average of 10.9$\pm$ 0.94 S.E. minutes (Figure 4). The fact that 47% of fish failed to exit was not a satisfactory result in our opinion. In observing the response to light the fish seemed to be "comfortable" to remain in the dimly lit area between the light sources but did not seem to be encouraged, necessarily to escape. We felt that the Cyalume light sources were too diffuse and a more intense, direct light source was needed.

We replaced the Cyalume light sticks with higher intensity LED light sources. Aside from being much brighter, these lights are more directional and thus may be directed onto a specific area. For the next experiments we directed the more focused light beam directly onto the escape opening and observed snapper behavior. Although only six fish were tested with this arrangement, not a single fish would even approach the opening with the light in this position and it was readily apparent that snapper were not going not respond appropriately. All six fish swam for at least four hours with no exit. For this reason these tests were terminated.

In the next tests we placed the LED lights 30 cm downstream of the exit. In addition, we used several Cyalume light sticks to further illuminate the rear of the test chamber. Our reasoning for this arrangement was that current would force fish over the escape opening and the light sources encountered would "herd" them upstream and out of the exit. We tested 28 fish with this arrangement and obtained a very promising 96% escape rate (26 of 27 fish) (Figure 4). Additionally, fish exited on average 7.1$\pm$0.3 S.E. minutes after their introduction into the chamber. Eighty five percent of fish exited in 10 minutes or less and many exited within seconds.

Red snapper response to color/contrast– Although not originally proposed, we conducted experiments on the response of snapper to various colors/contrasts (it is not known whether or not snapper see color). We painted 25 cm x 25 cm, plexiglas panels, red, yellow, green, black and white and placed them on the bottom of a large tank. Snapper were released at the surface and near the center of the tank and the time required for them to associate with a particular color was recorded. In 48 trials, snapper unerringly associated with the black test panel within seconds of their release into the test chamber. In every case, fish were observed to orient in a head-down fashion and swim against the plate. The fish seemed to be trying to swim down into the plate. This suggests that snapper respond to the black plate as if it were an opening for them to swim into, i.e. they seem to be seeking refuge when disturbed. We will investigate further the possibility of exploiting this "refuging" behavior in future BRD designs.

TABLE 1. ANOVA results of the effect of fish standard length (S.L., cm) on snapper critical swimming speeds using time of day (day vs. night) as a covariate. The P-values from the ANOVA are shown in the Table.

	P- VALUES		
	Day/Night	Standard Length	Interaction (Day/Night x S.L.)
February	0.227	<0.0001	0.317
April	0.152	<0.0001	0.267
July	0.304	<0.0001	0.836
October	0.618	<0.0001	0.505
December	0.664	<0.0001	0.627

Figure 1. Current speeds at various positions in the BRD test chamber. Speed 120, 85 and 50 refer to free stream speeds of 120, 85 and 50 cm/s. The inset shows a diagram of the BRD and the numbers on the x-axis refer to the numbered positions in the diagram.

CURRENT SPEED AT VARIOUS POSITIONS IN THE BRD

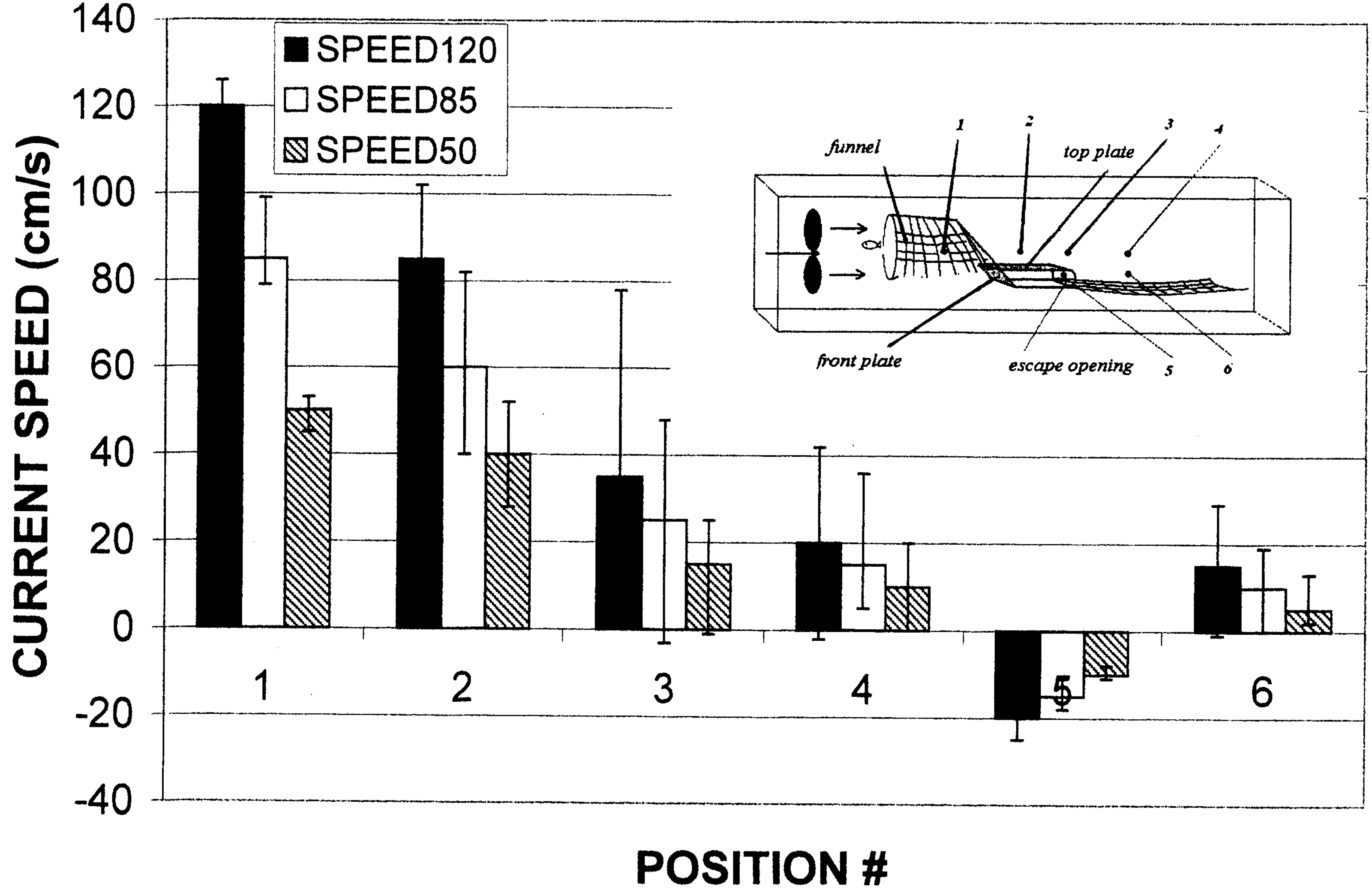
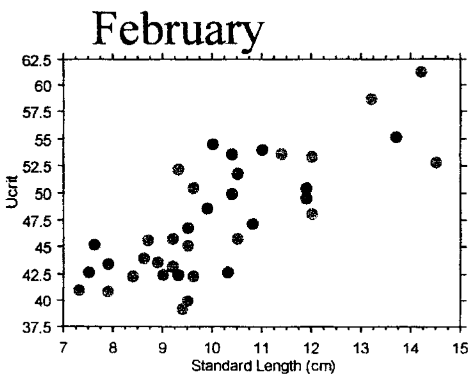
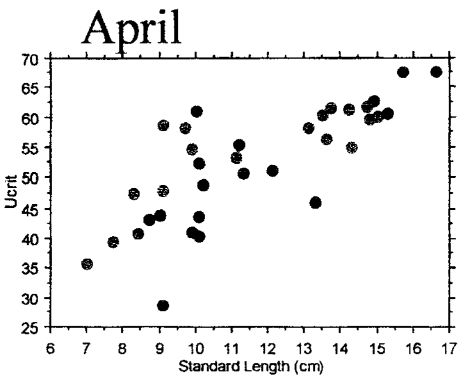
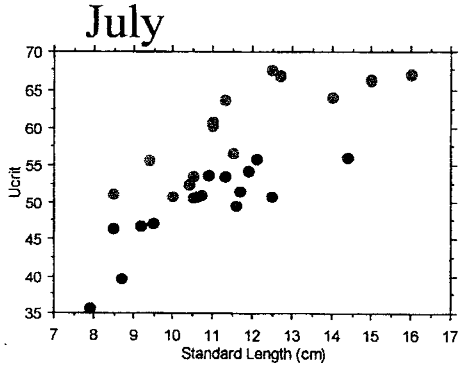
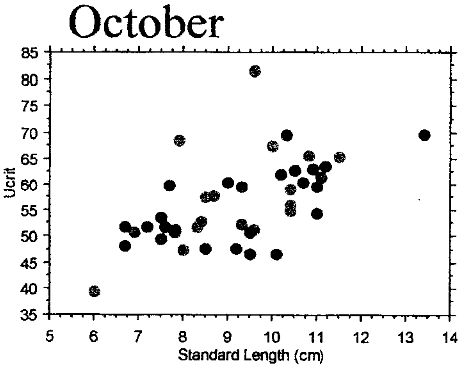


Figure 2. The results of critical swimming speed (Ucrit) experiments on red snapper in which performance was examined over season, size and during day vs. night. The blue points are daylight swims and the red are night-time swims. There was no significant effect of day vs. night on swimming. A size effect is evident in each month.


February
Ucrit
Standard Length (cm)


April
Ucrit
Standard Length (cm)


July
Ucrit
Standard Length (cm)


October
Ucrit
Standard Length (cm)

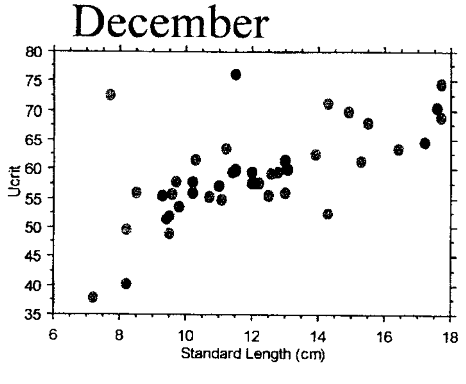

December
Ucrit
Standard Length (cm)

Figure 3. The percentage of fish that exited the BRD test chamber and the time required to exit the chamber under various light conditions. The light-dark data were obtained by setting the room lights to come on at midnight after swimming for 3 hrs under total darkness.

RESPONSE OF SNAPPER TO VARIOUS LIGHT TREATMENTS

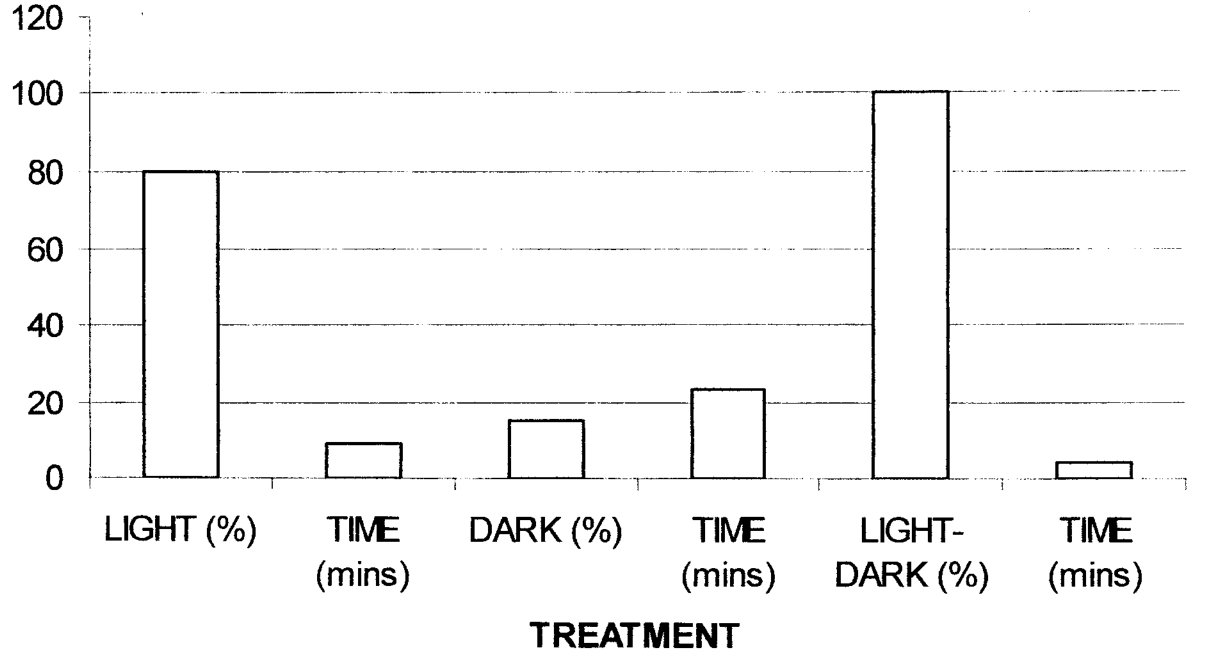
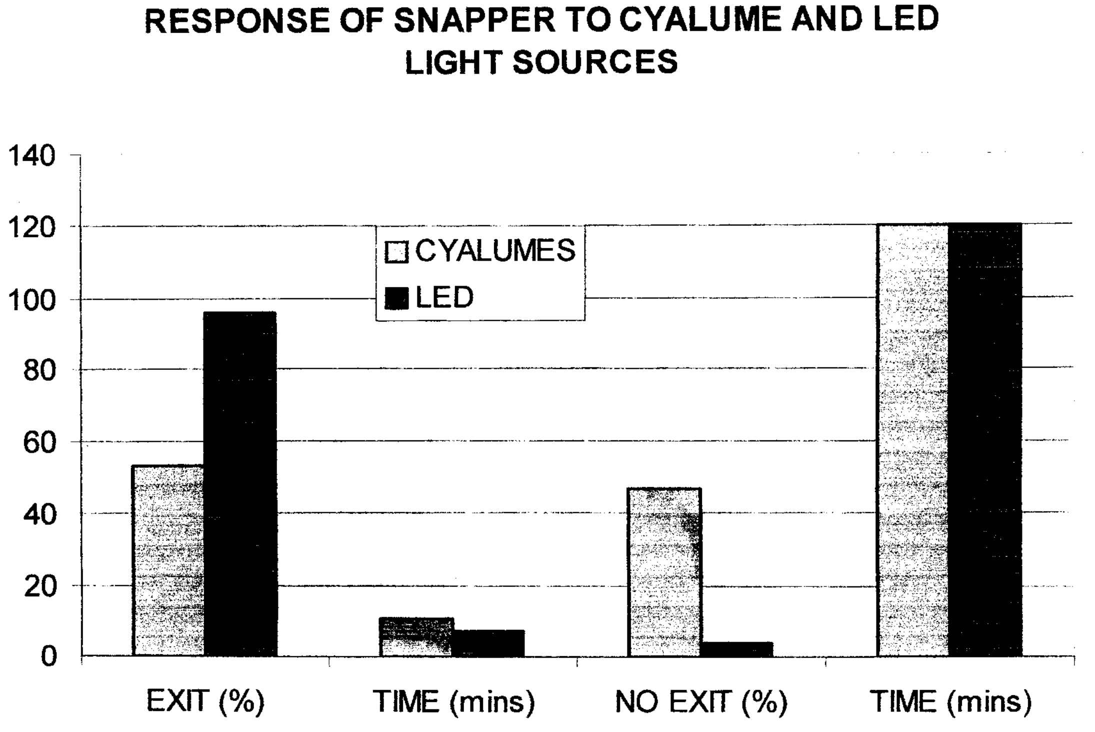


Figure 4. These data were obtained by placing Cyalume light sources in the front and rear of the test chamber. The LED tests were conducted with the light source near immediately down stream of the escape opening.


RESPONSE OF SNAPPER TO CYALUME AND LED
LIGHT SOURCES
140
120
100
80
60
40
20
0
CYALUMES
LED
EXIT (%)
TIME (mins)
NO EXIT (%)
TIME (mins)