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INTRODUCTION

There is worldwide commercial interest in cephalopods, with several fisheries providing significant quantites of octopus and squid for human consumption, animal feed and fishing bait. The great medical scientific interest in cephalopods centers around the squid giant nerve axon. Neurophysiological experiments require the use of live or freshly killed squids; consequently, the availability of these animals for research depends largely upon atraumatic capture and transport techniques. The best methods for capturing live undamaged animals include dipnetting from the surface, fishing artificial lures called squid jigs, and using very large nets (e.g. lampara net or purse seine) to encircle squid schools. To be successful, these methods are usually carried out at night and depend upon the attraction of squids to the immediate vicinity of a night light. The primary aims of this study were to assess the effectiveness of different lights both at the surface and on the bottom by direct underwater observations, and to better understand the attraction of various squid species to a light. The study was conducted during a saturation dive mission from 1-7 September 1978 in NOAA's underwater laboratory system (NULS-1; formerly Hydrolab) in Salt River Submarine Canyon, St. Croix, U.S. Virgin Islands.

It is well known that many cephalopods can be attracted to lights at night but the attraction mechanisms are not understood. Woodhead (1966) and Bearse and Saila (1975) reviewed and summarized most of the current theories of light attraction among marine organisms: 1) positive phototaxis 2) intensity preference (brightness) 3) wavelength preference (color response) 4) conditioned or unconditioned response where light is associated with food 5) curiosity 6) photic disorientation and 7) hypnosis. No one has reliably determined which factors are responsible in any particular species.

Zuev and Nesis (1971) have reviewed many of the light attraction techniques employed in squid fisheries throughout the world. Among these, squids of the genus *Loligo* are important for commercial and scientific purposes. Tardent (1962) reported that *Loligo vulgaris* is attracted to night lights and subsequently captured with lampara nets in the Bay of Naples, Italy. Waller and Wickland (1968) described the attraction of large mating congregations of *Loligo (Doryteuthis) plei* to a lighted underwater submersible at night in the Bahama Islands. Voss (1971 and 1973) has reviewed light attraction of squids in the Caribbean and worldwide. In the U.S., Hochberg and Couch (1971) attracted *Loligo (Doryteuthis) plei* to lights during Tektite II at St. John, U.S. Virgin Islands. Allen and Taber (1974) conducted exploratory squid fishing along the northeast coast of the U.S. They tested different light attraction methods and were consistently able to attract moderate numbers of adult *Loligo pealei*. Bearse and Saila (1975) also attempted to evaluate various light attraction methods for *Loligo pealei* off Rhode Island, but their attempts were seriously hampered by inability to see how squids reacted to the lights and poor weather conditions experienced during their experiments. Kato and Hardwick (1975) have reviewed light attraction techniques for the commercial harvest of *Loligo opalescens* in southern California. In the Gulf of Mexico, we have briefly reported our results in capturing *Loligo pealei, Loligo (Doryteuthis) plei* and *Lolliguncula brevis* (Rathjen, et al., 1979).

Many commercially and scientifically important oceanic squids (Suborder Oegopsida) are also attracted to night lights. Noteworthy among these are *Todarodes pacificus* (Okutani, 1977) and *Dosidicus gigas* (Nesis, 1970; Sato, 1976) in the Pacific Ocean, and *Ommastrephes pteropus* (Baker, 1960; Voss, 1973; Vovk and Nigmatullin, 1972) and *Onychoteuthis banksi* (Voss, 1971 and 1973) in the Atlantic Ocean. In addition to the above mentioned references there are many other anecdotal reports scattered throughout the literature of squid attraction by night lights.

MATERIALS AND METHODS

NULS-1 is a cylindrical four-person underwater habitat, 4.9 m long and 2.4 m in diameter, situated 15 m deep at the base of Salt River Submarine Canyon. The continental margin is narrow and the canyon is in close proximity to deep water. The details of the canyon and the positions of the night light stations are illustrated in Figure 1. The character of the east and west canyon walls is very dissimilar. The West Wall is nearly vertical rock with caves and overhangs. The East Wall is characterized by alternating zones of near vertical rock wall and gently sloping side tributaries of coral rubble. Farther seaward, a more vertical wall predominates on both sides and is populated with a very well developed West Indian coral reef community. The flat canyon floor dips seaward and is composed of medium sand and silt with isolated seagrass beds (mainly *Halophila baillonis*).

Three types of lights were used: non-submersible 500 watt quartz-iodide lights and 250 watt incandescent lights or a submersible 1000 watt mercury vapor light. Figure 2A shows the equipment and general set up for various types of night light stations. The quartz-iodide bulbs were General Electric quartzline lamp, model #Q500T3/CL, with a primary color temperature of 3000°K and brightness of 10,950 lumens. They were equipped with rheostats for dimming. The mercury vapor light was Hydro

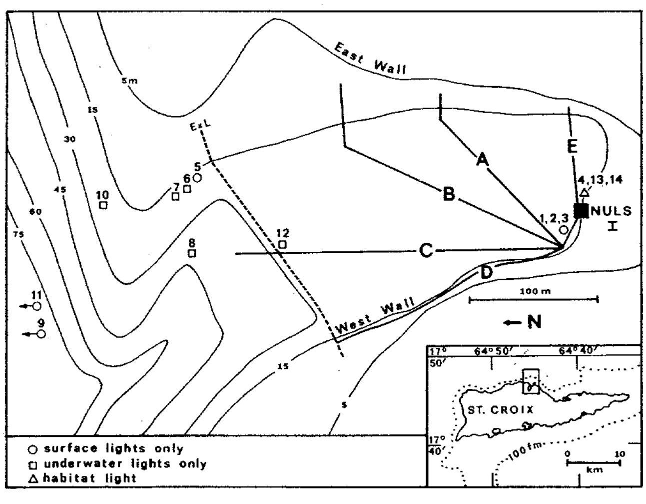

Figure 1. Map of Salt River Submarine Canyon showing its geographic location and the positions of three different types of night light stations. Superscripts indicate station numbers given in Table 1; Stations 9 and 11 were conducted farther offshore. A through E and ExL (standard excursion limit line) are the primary string highways used by divers for bottom orientation.

TABLE 1
CEPHALOPOD NIGHT LIGHTING STATION RESULTS

Sta. #	Date	Time	Depth (m)	Light Type	Light Position U/W	Light Position Surface	Observations
1	1 Sept 78	1930-2000	15	Incandescent Quartz-iodide		X	No cephalopods seen. Moderate zooplankton concentration.
2	1 Sept 78	2000-2045	15	Quartz-iodide		X	No cephalopods seen. Moderate zooplankton concentration.
3	1 Sept 78	2100-2140	15	Incandescent		X	No cephalopods seen. Moderate zooplankton concentration.
4	1 Sept 78	2200-2230	13	Quartz-iodide Mercury vapor	X		No cephalopods seen. Quartz-iodide lights operated through habitat viewing port. Moderate zooplankton concentration.
5	2 Sept 78	1940-2045	16	Quartz-iodide		X	Small school of 5 *Sepioteuthis sepioidea* observed in mid-water by support diver. Heavy zooplankton concentration.
6	2 Sept 78	2045-2155	16	Mercury vapor	X		Observed many individual *Abralia veranyi* and several individual Macrotritopus. Heavy zooplankton concentration.
7	3 Sept 78	2020-2120	16	Mercury vapor	X		Observed several individual *Abralia veranyi* and a few individual *Sepioteuthis sepioidea, Loligo* sp. and Macrotritopus. Collected 3 *Abralia veranyi* (ML 23-39 mm), 2 *Loligo* sp. (ML 19 and 20 mm) and 2 Macrotritopus (ML 7 and 9 mm). Heavy zooplankton concentration.
8	4 Sept 78	2100-2130	40	Mercury vapor	X		Observed many schooling and individual *Ommastrephes* sp. and a few Macrotritopus. Collected 6 *Abralia veranyi* (ML 20-38 mm). Heavy zooplankton concentration.

9	4 Sept 78	2225-2325	*	Quartz-iodide		X	Observed many schooling and individual *Ommastrephes* sp. and a few *Loligo* sp. Collected 14 *Ommastrephes* sp. (ML 57-86 mm). Station located approximately 1.5 kms offshore. Heavy zooplankton concentration, particularly crab megalopa.
10	5 Sept 78	2200-2330	21	Mercury vapor	X		Observed a few individual *Abralia veranyi, Loligo* sp., Macrotritopus and *Octopus burryi.* Collected 1 *Loligo* sp. (ML 45 mm), 3 Macrotritopus (ML 12-15 mm) and 2 *Octopus burryi* (ML 13 and 15 mm). Heavy zooplankton concentration.
11	5 Sept 78	2350-0020	*	Quartz-iodide		X	Observed several individual *Ommastrephes* sp. near the surface and small schools deeper. Collected 3 *Ommastrephes* sp. (ML 71-80 mm). Station located approximately 1 km offshore. Heavy zooplankton concentration.
12	7 Sept 78	0030-0115	30	Mercury vapor	X		Observed a few individual *Abralia veranyi, Ommastrephes* sp., *Sepioteuthis sepioidea* and Macrotritopus. Moderate zooplankton concentration.
13	7 Sept 78	0215-0245	13	Quartz-iodide	X		Observed a few *Sepioteuthis sepioidea* and 1 *Abralia veranyi.* Lights operated through viewing port. Moderate zooplankton concentration.
14	7 Sept 78	2000-2130	13	Quartz-iodide	X		Observed several juvenile and adult *Sepioteuthis sepioidea*. Lights operated through viewing port. Moderate zooplankton concentration.

*Depth unknown but over deep water beyond 100 fm. (183m) line.

Products model L-2, with a non-submersible ballast (transformer) and a 60 m underwater cable. Wavelength equalled 4-6000A and the brightness was 54,000 lumens. Color slide photographs were taken with either a Nikon F camera and 55 mm Nikkor lens or a Canon F-1 with 50 mm Canon lens and a Rollei E27 electronic flash, all in Ikelite underwater housings.

For surface night light stations a 500 watt quartz-iodide light or a 250 watt incandescent lamp were turned on and observations of attracted squids were made by the surface support technician from the boat or skin diving on the surface. Aquanauts positioned below the surface station also made observations except at stations 9 and 11.

For observations from the habitat, the 500 watt quartz-iodide lamp was placed at the inside bottom of the large circular viewing port at the east end of the habitat and observations were made from inside the habitat. At station 4 a diver entered the water to check if other cephalopods were outside the view of aquanauts in the habitat.

At underwater night light stations, the 1000 watt mercury vapor light was lowered from the support boat to the aquanauts below. The aquanauts first positioned the light, then during the station recorded observations from behind the directional beam of light. Occasionally one aquanaut would swim out into or beyond the lighted area for further observations. Several live animals were captured in plastic bags for identification.

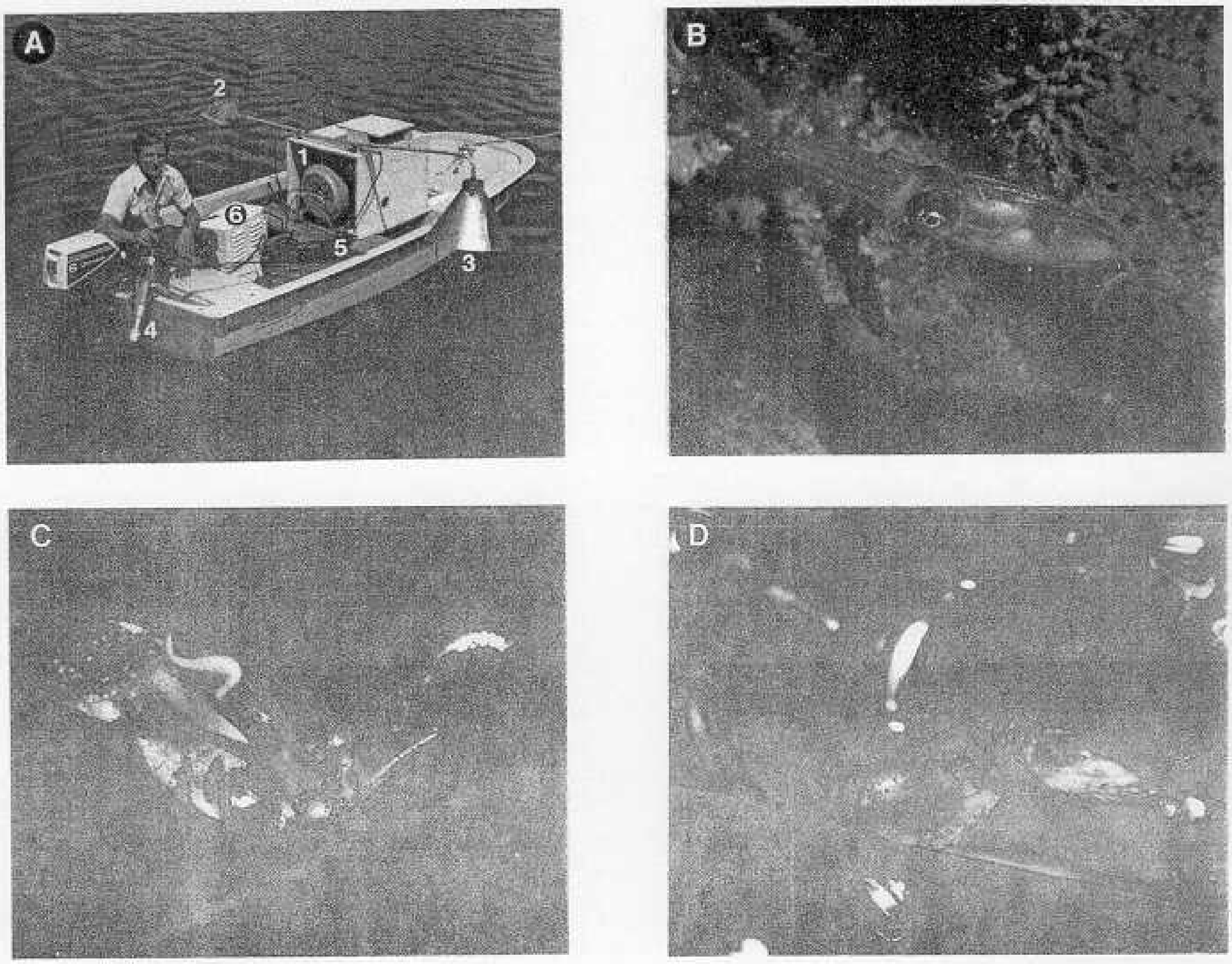

Figure 2A. Small skiff equipped with various night lighting equipment: 1) 1500 watt gasoline-operated generator with wooden cover to protect it from salt spray 2) non-submersible 500 watt quartz-iodide light 3) non-submersible 250 watt incandescent light 4) submersible 1000 watt mercury vapor light with 5) 60 m cable and 6) ballast (transformer).

Figure 2B. *Abralia veranyi* (approximately 40 mm mantle length) swimming erratically near the reef bottom while mesmerized by the bright mercury vapor night light.

Figure 2C. *Sepioteuthis sepioidea* (approximately 60 mm mantle length) swimming in a version of the "upward V curve" posture while in front of the bright mercury vapor night light.

Figure 2D. Small *Octopus burryi* (approximately 10 mm mantle length) sitting on the bulb of a brightly lighted mercury vapor night light.

RESULTS AND DISCUSSION

We conducted 14 separate night light stations during the study at depths ranging from 13 to 40 m. Total observation time was almost 11 hours with a mean duration of 45 minutes per station (range 30 to 90 minutes). A compilation of the results of each station is given in Table 1. Weather conditions were generally favorable for night lighting throughout the mission and the nights were all very dark during a new moon.

We attracted four squid species to our night lights, including the pelagic squids *Abralia veranyi* and *Ommastrephes* sp., the typically continental shelf form *Loligo* sp. and the reef squid *Sepioteuthis sepioidea*. We observed and collected only small juvenile *Ommastrephes* and *Loligo* and were thus not able to identify them to species. Additionally, we attracted to the underwater light two juveniles of the rarely collected *Octopus burryi* and several of the special octopod "Macrotritopus larvae." Unfortunately, we could not accurately quantify any of our observations due to the erratic swimming patterns of individual cephalopods in and out of the lighted area.

Our first three experiments conducted from the surface near the habitat, as well as our first use of the lamp within the habitat, attracted no cephalopods. We carried out most of our subsequent experiments near the mouth of the canyon in close proximity to deep water where we also encountered clearer water and had better underwater visibility. Underwater stations conducted over reefs in this area (Stations 6, 7, 8 and 10) attracted all six cephalopods collected during this study, while surface night lights (Station 5) did not attract any cephalopods to the surface in the same vicinity. Surface night lights did attract large numbers of juvenile *Ommastrephes* sp. over deep water (Stations 9 and 11) north of the reef margin.

We saw no cephalopods feeding although potential food organisms were also attracted to the night lights. Either moderate or heavy zooplankton swarms were attracted to the immediate vicinity of the lights or to the surface under the above-water lights. We noted small fishes and shrimps at all stations, and crab megalopa were especially numerous at the two offshore stations. From previous observations we have made at other night light stations we know that both *Loligo* and *Ommastrephes* will feed on the size range organisms that was available in the lighted area.
indicated that nearly all species were attracted individually and not as a school, and that they did not subsequently group together during the station. Some small schools of five to 20 *Ommastrephes* sp. were observed at Stations 9 and 11 and a school of five *Sepioteuthis sepioidea* was seen at Station 5, but mostly single individuals of both species were seen during the study. Published descriptions and our own previous observations have shown that *Ommastrephes*, *Loligo* and *Sepioteuthis* are usually schooling animals, especially juveniles. The Macrotritopus attracted to the underwater lights also occurred only as individuals.

All species appeared disoriented while in the immediate vicinity of the lights. *Abralia veranyi*, *Sepioteuthis sepioidea* and *Ommastrephes* sp. assumed a type of distinctive "upward V curl" posture (Moynihan, 1975) in which all or most of the arms on both sides of the body were held upward and somewhat backward forming a V (Figure 2C). This posture and its associated color arrangements are thought to be an indication of alarm, possibly allowing the squid to thwart predators by mimicing or hiding in drifting *Sargassum* weed or gorgonians. The *Ommastrephes* sp. attracted over deep water were so agitated that several jetted out of the water, with four of them landing in our night light boat. *Ommastrephes* propel themselves out of the water to avoid predators and are commonly known as the flying squid. At no time during the stations did we observe any predators (except perhaps ourselves) that could elicit such responses.

The very bright underwater lamp (54,000 lumens) appeared to daze or mesmerize the cephalopods. *Loligo* sp., *Abralia veranyi*, *Octopus burryi* and Macrotritopus were drawn to the light and occasionally swam very near to it through the accumulated zooplankton swarm. In fact, the two *Octopus burryi* were collected as they crawled onto the light bulb itself (Figure 2D). It is very possible that the absence of normal schooling or feeding behavior and the defensive posture and escape reactions we observed were due in part to the intensity of our night lights.

Overall, few cephalopods were attracted to our night lights. We conclude that the small area in which we conducted our stations supported few pelagic cephalopods, particularly the shelf form *Loligo*.

Since we attracted few animals, it was not possible to properly compare the effectiveness of our night lighting techniques or clearly establish which factors influenced attraction. Many other workers (Maeda, 1951; Woodhead, 1966; Polutov, 1970; Zuev and Nesis, 1971; Vovk and Nigmatullin, 1972; Bearse and Saila, 1975; Allen and Taber, 1974) have also noted the highly varying results of light attraction of squids and the poor understanding of attraction mechanisms. The results among workers are often so contradictory and inconsistent that presently it is difficult to make sound evaluations of different lighting schemes. It is likely that there is a species-specific response to light and, in addition, that a host of other factors such as hydrographic conditions, moon phase, food availability and sexual condition can influence individual squid behavior in relation to artificial light.

We feel that the method of placing saturation divers underwater with simultaneous surface observations could help establish which factors effect the attraction of squids to light. In the future, very specific experiments that would test individual factors in light attraction should be designed. In addition, special attention must be made to accurately quantify observations made at night.

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A UNIQUE METHOD OF AGING SURF CLAMS

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INTRODUCTION

Within the range of the Atlantic surf clam, *Spisula solidissima* (Dillwyn), from Cape Hatteras, North Carolina, to the Gulf of St. Lawrence, Canada, most of the shells collected for aging by the National Marine Fisheries Service are from the extensive Middle Atlantic continental shelf and areas containing fishery concentrations (Ropes 1979; Serchuk et al 1979). An objective of the collections is to assess population age composition. Such analyses require that accurate ages be determined for all clams in a sample and for the two to three thousand clams taken during a research survey cruise. Thus, rapid, simple processing techniques are needed that result in study specimens showing growth marks in as clear definition as possible.

Problems in the interpretation of all growth marks in some shells were encountered during studies begun in 1975. For large clams, erosion of the external valve surfaces deposited in the earliest years of life and crowding of growth marks during later years made precise age determinations difficult or impossible; some valves exhibited very irregular marks, complicated by an overlapping of shell. Sawing through shells from the umbo to ventral margin, followed by grinding and polishing the cut surfaces, improved detection of growth mark deposition (Chang et al 1976). Later, Jones et al (1978) reported on a study of aging surf clams using the same technique.

The speed of cutting shells was increased by modifying a diamond blade saw machine, but polishing the cut edges to enhance growth mark detection was a laborious, time consuming process. Microscopic examination of the cut shell was tedious, requiring two independent observations per shell for an assurance of accuracy. Even with this precaution, differences in counting growth marks were not easily resolved. Accurate measurements of growth increments also posed technical difficulties.

Chang et al (1976) found correspondence between the number of growth marks in the chondrophore and valve of surf clams and related chondrophore length to shell length and cross-section dimensions. Consequently, techniques were developed to produce thin-sections of the chondrophore. It is a small, easily processed part of the valve. As part of the hinge, it and the umbo are often all that remains of broken clams in a sample. After describing the methodology, examples of thin-sectioned chondrophores are given and an analysis relating measurements of increments at growth marks in the chondrophores and valves of a sample.

METHODS

Preliminary to thin-sectioning, a piece of the chondrophore was excised from the valve hinge. Right-hand valves were routinely chosen, since this simplified positioning successive valves for cutting. A valve was clamped on a hinged table over two 25-cm-diameter by 0.096-cm-thick diamond saw blades separated on the saw arbor by a 0.635-cm-wide flange.[1] The cut of the blade nearest the anterior end of the valve was critical. To insure including the umbo in the excised piece, the blade nearest the anterior end of the valve was oriented to pass through the chondrophore immediately anterior to the umbo and directed to a point at the ventral margin of the valve which, if completed, would separate the posterior quarter from the remainder of the valve (Fig. 1). This is the same plane of section used by Chang et al (1976) and Jones et al (1978). In this new method, however, parallel cuts were made only through the chondrophore just beyond the umbo area. Gravitiy forced the valve into the fast-