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A simplified, economical, and robust light trap for capturing benthic and pelagic zooplankton

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ABSTRACT

Most of the commonly used light traps for plankton studies are often large, heavy and expensive, and cannot be easily used for pelagic sampling. Although many small, and simple light traps have been designed, most of them are fragile and have weak light sources, allowing only limited collection. In the present study, a new simplified light trap design was described, which is small, lightweight, robust, inexpensive ($70 USD) and easy to construct. The main body of the trap is constructed from a 6 L commercial mineral water PET bottle, and the lighting component consists of four 3 W white LED bulbs. Pelagic deployment of the new simplified trap and the commonly-used modified Doherty trap was conducted in the same location and compared the composition of the catches including larval fishes and invertebrates. The taxonomic composition of larval fishes collected between the two traps was similar, but it appears that the Doherty trap can collect larger sized larval fishes. Catch composition, wet weights and total number of marine invertebrates collected between the two types of traps are comparable. Ten taxa (copepods, amphipods, crab larvae and juveniles, Cumacea, Euphausiacea, molluscan larvae, isopods, mysids, ostracods and Polychaetes) accounted for over 98% of the total catch of individuals by both trap models. Copepods and crabs larvae were the two most abundant taxa, accounting for more than 55% of the catch. The new and simplified traps therefore represent a robust and comparable design that can be manufactured in large quantities (even in developing countries) and easier in transportation for spatial and temporal studies of plankton dynamics.

1. Introduction

Zooplanktons (including larvae of invertebrates and fishes) are often positively phototactic, moving towards light sources (Floyd et al., 1984). Aquatic light traps are designed to attract and collect phototactic zooplankton at night. Since the 1950s, various types of light traps have been designed. Some of them are partly-immersed or deployed near the water surface (Baylor and Smith, 1953; Husbands, 1967) while others are deployed underwater for sampling (Faber, 1981; Hungerford et al., 1955). Doherty (1987) designed a light trap composed of a single entrance chamber leading to two collection chambers, each with a separate light source. The lighting of the trap is controlled by a mechanical timer which alternates the lighting of the top and middle collection chambers to attract the zooplankton to the deeper portion of the trap. The Doherty trap became the foundational design of most of the commonly-used light traps, particularly for capturing fish larvae. The Doherty trap, however, is expensive, and difficult to construct and deploy (see Jones, 2006). This is especially difficult for colleagues in developing countries where there are limited supplies of materials.

After the development of the Doherty trap, many light traps have been designed by modifying Doherty's design, attempting to produce a more economical and simplified version. These improved traps include the Thorrold trap (Thorrold, 1992), Brogan trap (Brogan, 1994), Munday trap (Munday et al., 1998), Stobutzki trap (Stobutzki and Bellwood, 1998), and Bucket trap (Watson et al., 2002). Light traps are important research tools for studying temporal and spatial patterns of larval fishes in different regions (Sponaugle and Cowen, 1996a, 1996b). In addition, there are many light traps designed for special purposes including the Fisher trap (Fisher and Bellwood, 2002) to sample fish larvae at different depths, the Hovda trap (Hovda and Fosshagen, 2003) to sample hyperbenthic calanoids by a chemical light stick (Cyalume® Lightstick) with green light (510 nm wavelength), the Kehayias trap (Kehayias, 2006) to sample lake zooplankton by light sticks and the Porter trap (Porter et al., 2008) to collect crab larvae. All these traps, however, are either large in size (up to 240 L volume (Hickford and Schiel, 1999), or to use light sticks as the light source which produce weaker light, which limits collection efficiency. Some of these traps are also constructed from acrylic plates which can be

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easily damaged during deployment in rough sea conditions and in shallow waters where surge waves are strong.

In the present study, a design for a small, simplified, economical, and robust light trap for sampling zooplankton including larval fishes and invertebrate larvae was described. The trap body is constructed from a 6 L cylindrical commercially-available mineral water PET bottle. The new trap only costs $70 USD per trap in materials (see Table 1) and weighs 778 g. This trap can therefore be produced in large replicate numbers with easy deployment even in shallow water environments. The catches collected from this new simplified trap and the modified Doherty trap at the same location were also compared.

2. Materials and methods

2.1. The new simplified light trap

A video of the trap construction was included in the supplementary material.

The main body of the light trap (Fig. 1A–B) is modified from a 6 L commercial mineral water PET bottle (35 cm high and 16 cm in bottom diameter, bottles of similar size and volume are available globally and can also be used for the body of the light trap). In the body of the bottle, a total of eight circular entrances (each entrance diameter is 2.6 cm) are made in two rows, with each row having four entrances (Fig. 1A). The lower and upper rows are 6.5 and 16 cm above the bottom of the bottle, respectively. A polypropylene skirted specimen tube (Greiner Cellstar product no. 210270) with its top removed (tube length of 3.6 cm) is inserted in each circular entrance. The bottom of the skirted tip is also cut, so that the diameter of the opening of the tube bottom is 0.6 cm. The junction of the skirted tube and the water bottle is sealed using commercial hot melt adhesives or hot glues and then covered by Epoxy resins.

The electrical circuit (Fig. 1C, D) of the lighting component includes four 3 W, 2 A white LED bulbs, supported by two AAA-sized batteries in a parallel circuit. The switch of the circuit is controlled by a reed relay (the switch is controlled by a magnet). LED bulbs are glued back-to-back, forming two pairs. The two LED pairs are separated 8 cm apart *via* the conducting wire circuit. The body of the lighting component is made from a 30 cm long cylindrical transparent acrylic tube (internal diameter 2.96 cm, tube thickness 0.32 cm), produced by a local acrylic workshop. Polypropylene skirted specimen tubes (4 cm long, Greiner Cellstar product no. 210270), with the skirted end cut-off, were inserted into the top and bottom of the acrylic tube. One end of the cap from the specimen tube was unscrewed and the lighting circuit was placed into the acrylic tube (Fig. 1C). The bottom pair of the LED bulbs was attached 6.5 cm above the bottom. After the lighting component was inserted into the trap body, the positions of the two pairs of the LED bulbs were located at the same vertical level as the two rows of entrances. The acrylic tubes with the LED circuit installed were filled with liquid transparent polyester resin (FuShing Chemical Co. Ltd., resin hardens in 30 min), without filling the battery compartment, allowing the batteries to be changed. The light intensity of the lighting compartment was measured using a light meter (TENMARS TM-201L) in a darkroom. The light intensity of the lighting compartment was 735 ± 113.25 lx (mean ± SD, N = 3) at 0 cm away from the light trap and dropped to 18.67 ± 1.53 lx (N = 3) at a horizontal distance of 50 cm away from the light trap. The LEDs illuminance measurement was analyzed by CL-500A spectrometer (Konica Minolta), which was calibrated during manufacture (Tamura et al., 2014), the illuminance of the light sources output beam was measured in air. In the illuminance measurements of LED light sources, the sensor was attached on the wall of the plastic bottle and it was aiming at one of the LED unit horizontally and precisely. Before the measurement, the light sources were turned on for 10 min to ensure that the outputs were stable, and all works were done in dark room at 25 °C. Three replications were applied in each measurement. The spectrum of each measurement was smoothed by a factor of 5 using a simple moving average (McLean et al., 2007). The spectrum analysis of the LED light revealed that there is a single peak at 450 nm (blue light; Fig. 2D). During deployment, the top cap of the lighting component was covered using Parafilm to further waterproof the battery compartment.

Table 1
Components and estimated costs of simplified light trap.

Component	Cost ($USD)
Four 3 W LED bulbs	32
30 cm long cylindrical transparent acrylic tube	10
6 L cylindrical PET bottles	2
Lead	6
Specimen tubes	6
Two AAA sized alkaline batteries	2
Other components: polyester resin, reed relay, magnet	12
Total	70

During deployment, a small magnet (diameter 2 cm) was attached, using adhesive tape, to the surface of the acrylic tube at the same position as the reed relay to power the LEDs. The lighting rod was then inserted into the water bottle. The light trap can be deployed in benthic environments by tying two 1 kg weights on the bottom edge of the trap body. For pelagic collections, a 1 m rope was tied to the top of trap, which was then tied to a buoy. Placing a 0.5 kg lead weight inside the trap body causes the trap to remain 1 m below the water surface for pelagic sampling (Fig. 1E). The light trap functions by attracting zooplankton into entering the large 6 L bottle *via* the eight skirted tube entrances, then trapping them inside the 6 L bottle. Because the trap does not have a collection chamber, the trap should be placed inside a large water bucket (12 L) once it is out of water to avoid sample loss from the entrance. Samples can then be collected from the larger bucket, as well as from the inside of the trap after screwing off the trap cap and removing the light rod.

2.2. The modified Doherty light trap

Catches from a modified Doherty light trap were compared to the catch of the new trap described in this study (Fig. 2A, B). This modified Doherty trap has effectively collected fish larvae in Taiwanese waters (Ko, 2007; Ko et al., 2013; Shao and Chen, 2011). The modified Doherty light trap is 11 kg in weight and is 30.7 × 30.7 × 61 cm (length × width × height) in dimensions. This trap consists of a single chamber made from acrylic plates attached to a stainless steel frame. The light source (14 W white fluorescent tube) is housed in the center of the chamber. A waterproof cylinder made of an aluminum alloy containing a rechargeable lithium-ion battery (10.8 V, 10,800 mAh) is positioned in the lower section of chamber. Light intensity of the lighting component was measured at 0 and 50 cm along the upper entrance of trap in a dark room at 1766.67 ± 152.75 lx and 77.33 ± 3.79 lx (mean ± SD, N = 3), respectively (TENMARS TM-201L light meter). The fluorescent tube illuminance measurement was analyzed by CL-500A spectrometer (Konica Minolta), with the same measurement condition described in the new simplified light trap part. For the fluorescent tube which was used in the modified Doherty light trap, the horizontal illuminance was measured in 1 m distance from the middle of the task area (Viitanen et al., 2013) through the outer case of the light trap. The spectrum analysis of the fluorescent light revealed several peaks at 436 nm (blue light), 547 nm (green light) and 580 nm (yellow-orange light) in Fig. 2D. Outside the middle and upper chambers are two 15 cm horizontal, tapered entrance slots (outer: 4.5 cm, inner: 1 cm in width) in each side. During deployment, the top of the trap was tied to a 1 m rope, and the other end of the rope was tied to a buoy (Fig. 2A, C), to position the trap vertically 1 m below the sea surface. Positively phototactic organisms enter through the eight entrance slots in the chamber. While retrieving the light trap, a plankton net with very long handle (approx. 1.5 m) is used to haul the trap immediately