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Agreement of net and acoustical methods for surveying euphausiids using a net based LED strobe light system.

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Abstract

Euphausiids are well known for their ability to avoid capture by standard oceanographic plankton nets. During a study of euphausiid/herring interactions in Franklin Basin (Gulf of Maine), MOCNESS tows were made at night and during daylight to provide ground truth for acoustic surveying of the euphausiids and fish. A 1 m^2 MOCNESS was equipped with an LED based strobe light with peak output between 490 and 520 nm that filled a region in front of the net with light several orders higher than normal. Concurrent acoustic data were collected at 43, 120, 200, and 420 kHz. To evaluate its efficacy in increasing euphausiid capture, two horizontal tows were done at a site where euphausiids (mostly *Meganyctiphanes norvegica*) were present. During each tow (60– 75 m at night; 160–190 m during daylight), four of the eight nets sampled with the strobe flashing and four sampled with the strobe off, in a random sequence. There was a the night (factor of 4.5) and during the day (factor of 11.0). Euphausiids caught with the strobe light on accounted for most of the observed volume backscattering at 43 and 120 kHz, whereas those caught with the strobe light off did not. In addition, with the strobe light on the abundance of euphausiids collected by the nets matched the acoustically estimated abundances.

Introduction

Euphausiids are well known for their ability to avoid capture by standard oceanographic plankton nets (Cochrane et al., 1991; Sameoto et al., 1993; Wiebe et al., 1982, 2004). Traditional methods to reduce avoidance of nets have been to increase the towing speed or to increase the cross-sectional area of the net opening (Clutter and Anraku, 1968). Both methods have serious shortcomings: high tow speeds causes significant extrusion of animals through the net mesh

(Vannucci, 1968) and large nets that may reduce avoidance are difficult to handle on most oceanographic research vessels. Since most strong net avoiders have good visual acuity (e.g. fish, squid, euphausiids) and can use this to detect the approach of the net, recent efforts to reduce avoidance have been to use bright continuous or flashing lights to create a blinding effect so that individuals cannot see the net (Sameoto et al., 1993; Herman et al., 1993; Wiebe et al., 2004). The objective of this study was to test the efficacy of a LED based strobe light system specifically designed for use on the Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS - Wiebe et al., 1985) to reduce the net avoidance of euphausiids in the Gulf of Maine.

Methods

During a study of euphausiid/herring interactions in Franklin Basin (Gulf of Maine - 42° 12'N; 67° 44'W) aboard the R/V Endeavor, MOCNESS tows were performed at night and during daylight to provide ground truth for acoustic surveying. A 1-m^2 MOCNESS was equipped with an newly designed LED (LUXEON Rebel LED) based strobe light with peak output between 490-520 nm that filled a region in front of the net with light several orders higher than ambient. The LEDs are powered by the MOCNESS battery and their pulse width, amplitude, flash rate period, and on/off are controlled by the MOCNESS software. For this experiment the pulse width was 2 ms, the relative amplitude was 99%, and the flash interval was 100 ms. The output of the LEDs is in a Lambertian pattern and at 2 m range the intensity is about 50 $\mu W/cm^2$.

To evaluate its efficacy in reducing euphausiid avoidance of the net, two horizontal tows were taken at a site where euphausiids (mostly *Meganyctiphanes norvegica*) were present. Each tow consisted of a sequential series of down and up oblique casts through a set depth interval (60 to 75 m at night; 160 to 190 m during daylight). The strobe light was set to either "on" or 'off' with four of the eight nets (335 µm mesh) sampling with the strobe flashing and four sampling with the strobe off, in a random sequence. For both tows, volumes filtered by each net ranged from 463 to 741 m^3.

Concurrent acoustic data were collected with the "Greene Bomber" towed v-fin equipped with a four frequency acoustic system (43, 120, 200, and 420 kHz) manufactured by Hydroacoustic Technologies Inc. HTI, Seattle, WA. The transducers were split-beam and had full beam widths (−3 dB to −3 dB) of 7° for the 43 kHz and 3° for the 120–420 kHz. A 10 kHz bandwidth, linear frequency modulated (chirp) signal was used at a repetition rate of 0.5 pings/ s. Echo integration was performed every 6 s to obtain volume backscattering strength, S_v. Measurements of S_v, (S_v =10 $\log_{10}(s_v)$ in units of decibels relative to $1m^{-1}$, and s_v is the volume-scattering coefficient), and target strength (TS = 10 $\log_{10}(\sigma_{bs})$ in units of decibels relative to $1m^2$, where σ_{bs} is the differential backscattering cross-section) were collected from sequential transmissions from all four transducers in 1 m depth intervals to a range of 300 m at 43 and 120 kHz, 150 m at 200 kHz, and 100 m at 420 kHz. Only the 43 and 120 kHz are considered.

Sample processing

Samples were preserved in a 4% formalin solution buffered above pH 8.0 with sodium tetraborate decahydrate. Two sets of data were developed from the samples: (1) total zooplankton displacement volume was measured using the techniques of Alhstrom and Thrailkill (1963) and Wiebe et al. (1975) and (2) a silhouette technique modified from those of Davis and Wiebe (1985) and Foote (2000) was used to determine the abundance and size frequencies of zooplankton taxa in the samples. Generally, a sample was split using a Folsom splitter modified to gently blow air into the main compartment for better mixing (Longhurst and Seibert, 1967) to reduce the sample so as to allow all the krill to lie in a photo tray without overlap. A silhouette photo was taken of the animals in the tray and then the photo was scanned with Epson Expression 1600 scanner in black and white (8 bit) at 1200 DPI.

The photos were analyzed using the a MATLAB-based digitizing program, the WHOI Silhouette DIGITIZER (v 1.12 - Little and Copley, 2003). Organisms were identified to taxonomic and/or size category and lengths were measured on either a random sample of very abundant taxa or in the case of the euphausiids, all individuals in the image using standard length 3 (i.e. base of the eye-stalk to posterior margin of the 6^{th} abdominal segment - Mauchline, 1980). Wet weights were estimated from euphausiid lengths using WW=0.0055*(Length)^3.2059. Counts of the taxa were standardized to numbers per m^3 taking into account sample aliquot size and volume filtered by a net.

Data analysis

Comparisons were made of the biovolumes and the quantitative abundance and size distribution estimates of the catches of euphausiids in each net relative to whether the strobe light was off or on. In addition, the silhouette data were used in a procedure referred to as the "Forward Problem" that enabled comparison of observed versus volume backscattering levels predicted on the basis of net catches. Specifically, the backscattering cross section σ_{bs} was calculated for each individual organism measured in the silhouette images using models of acoustic scattering appropriate to the individual's taxonomic group (Stanton et al., 1994, 1998; Stanton and Chu, 2000). Estimates of expected backscattering cross-sections for each individual were summed over all individuals in each taxon and then over all taxa to yield an estimate of the total expected volume backscattering strength (S_v, in dB) in the volume (V) defined by the depth range sampled by each net. For comparison to these predictions, the observed median volume backscattering was determined from the collocated acoustics data for the same time intervals and range of depths as were sampled by each of the MOCNESS nets in a tow.

Inversions of volume backscattering measurements at 120 kHz were performed to estimate the numerical density of euphausiids in each net using the equation $s_v = N * \langle\sigma_{bs}\rangle$, where N is the number of individuals per m^3, $\langle\sigma_{bs}\rangle$ is the average individual backscattering cross section, and s_v is the observed volume backscattering for each net. The mean length of individuals caught in each net and the target strength model in relation to length of Lawson et al. (2006), re-parameterized with parameter values suitable for *M. norvegica*, was used to estimate the average backscattering cross-section $\langle\sigma_{bs}\rangle$ as a weighted average over the observed length distribution. These acoustic estimates of euphausiid numbers were compared to their abundance in the net samples.

Results

Both sets of samples were dominated by *Meganyctiphanes norvegica*, and *Calanus finmarchicus*. The euphausiids were between 10 to 35 mm length in both sets of samples. The distribution on both tows was bimodal, although at night the large mode was dominant whereas during the day the small mode was dominant. Biovolumes in the night tow ranged from 74 to 223 cc/1000 m^3 and in the deeper daytime tow from 129 to 1664 cc/1000 m^3. There was a significant ($P < 0.05$) increase in biovolume catch of zooplankton when the strobe light was activated with total displacement volume increased by a factor of 2.2 at night (mean of 173 versus 80 cc/1000 m^3) and by a factor of 5.5 during the day (1180 versus 224 cc/1000 m^3) (Figures 1 and 2). The change in biovolume was due largely to a higher abundance of euphausiids.

The abundance of euphausiids in the night tow ranged from 66 to 591 ind/1000 m^3 and during the day tow ranged from 168 to 10,267 ind/1000m^3. The mean catch with the strobe off during the night was 85 ind/1000 m^3 and with it on it was significantly higher ($P<0.01$) at 381 ind./1000m^3. There was no difference ($P = 0.76$) in the mean size of individuals caught with strobe off (27.1 mm) versus strobe on (27.4 mm). Thus at night the nets with strobe-on caught significantly more euphausiid individuals than nets with the strobe-off by a factor of 4.5. The mean catch with the strobe off during the day was 870 ind/1000 m^3 and with it on it was significantly higher ($P< 0.01$) at 9,610 ind/1000m^3. In this case, there was a significant difference ($P < 0.01$) in the euphausiids mean size with strobe off (16.1 mm) versus strobe on (20.3 mm). Many more small individuals were present in the day tow. Thus the nets with strobe-on during the day caught significantly more euphausiids than nets with the strobe-off by a factor of 11.0.

There was very good correspondence between the observed volume backscattering and the predicted backscattering just for the euphausiids when the strobe light was on for both tows. The average deviation between predicted Sv and median observed Sv was 0.7 dB for 43 kHz and -0.6 dB for 120 kHz. When the strobe was off the average deviation was -11.2 dB for 43 kHz and -10.2 dB for 120 kHz. The euphausiids caught with the strobe light on accounted for most of the observed volume backscattering at 43 and 120 kHz, while those caught with the strobe light off did not. The contributions of all the other taxa to the predicted volume backscattering did not change this result.

Using the mean size of the euphausiids for each net to estimate $<\sigma_{bs}>$, the acoustically estimated numbers of individuals ranged from 323 to 13,106 ind./1000 m^3 with the strobe on and 324 to 35,316 ind./1000 m^3 with the strobe off. For the strobe on the estimated numbers were on average 0.9 times as high as observed in the nets and for the strobe off they were 18 time higher than the observed. The agreement between the net and acoustic measurements and the fact that the nets did not measure higher abundances than estimated acoustically strongly suggests that the euphausiids were caught in higher numbers not because they were attracted by the light to the net, but because were blinded by the bright light and thus could not see the net and avoid capture.

Summary

The results of this experiment lead us to conclude that the use of an LED based strobe light causes a significant increase in biovolume of zooplankton caught both day and night when large krill dominate the biovolumes. Total displacement volume was significantly increased when the strobe light was being used and this due largely to the enhanced catch of euphausiids between 10 and 35 mm. The enhancement in catch of krill was substantially higher during the daytime. Both the forward problem and the inverse acoustic computations showed that with the strobe light the abundance of euphausiids caught by the net system matched estimates based on the acoustic data. The results suggest that the new MOCNESS strobe light system significantly reduces the effects of krill net avoidance and reaffirms the results of earlier studies. Studies of krill distribution that use standard nets without a strobe light system risk seriously under estimating the adult krill standing stock.

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Figures

Figure 1. Top: The path of the nighttime MOCNESS tow taken on 27 Sept 2010 displayed on 43 and 120 kHz echograms. Color change marks change of nets. Each net was cycled twice between 60 and 75 m. Nets were randomly selected for strobe-on or off with four on and four off. Bottom: The samples collected on the tow with labels to indicate the net number and whether the strobe was on or off.

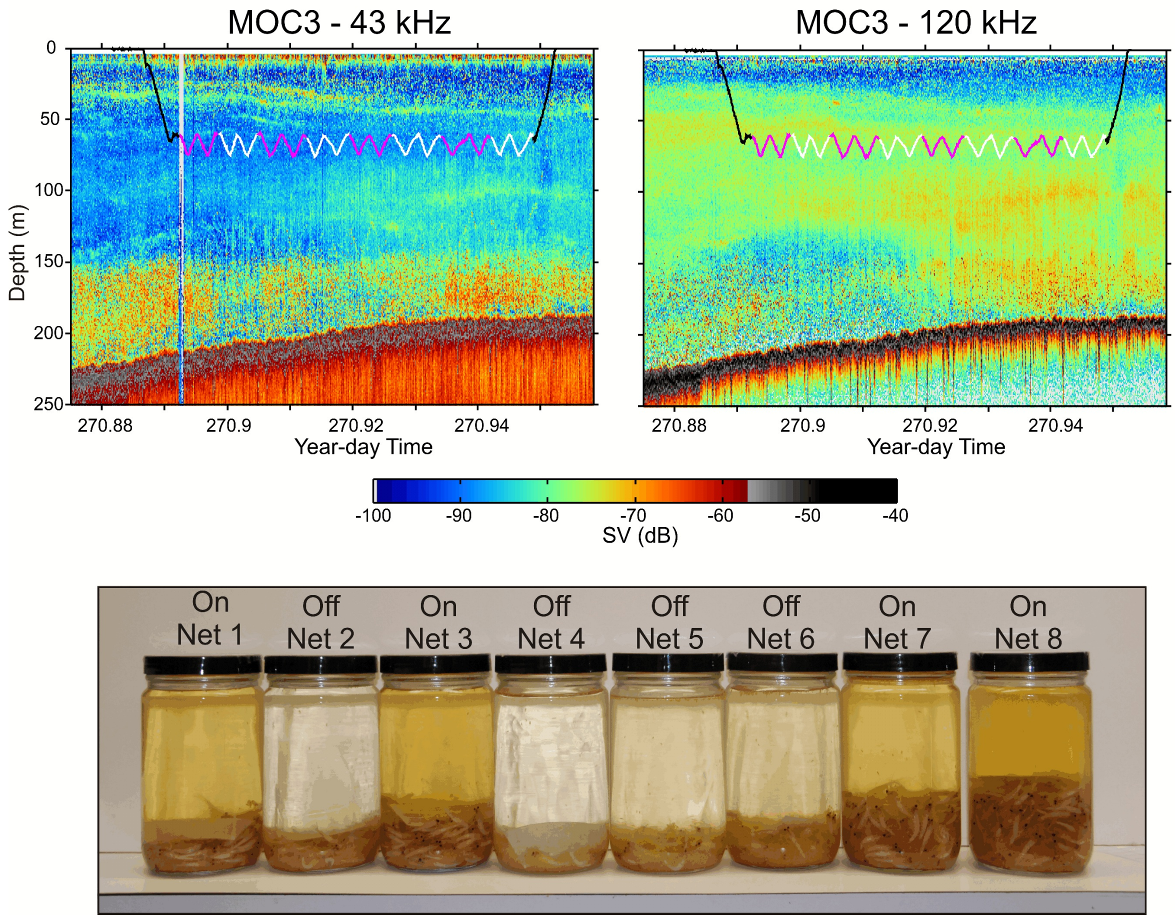

Figure 2. Top: The path of the daytime MOCNESS tow taken on 29 Sept 2010 displayed on 43 and 120 kHz echograms. Color change marks change of nets. Each net was cycled once between 160 and 190 m. Nets were randomly selected for strobe-on or off with four on and four off. Bottom: The samples collected on the tow with labels to indicate the net number and whether the strobe was on or off.