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A Set of Brightness Categories for Examining Diel Change of Catch Efficiency of Saury Larvae and Juveniles by a Neuston Net*

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Abstract

The survey area for young Pacific saury (*Cololabis saira*) census extends to east from Japan in the northwestern Pacific Ocean. As we use Japan Standard Time (JST) on shipboard, times of the sunrise and the sunset on a given day are quite different among tow sites depending on longitude. Moreover, the the saury census has been conducted almost year-round. We, therefore, cannot use shipboard tow times to examine the association of diel brightness with the number of fish captured by a tow. I defined a new set of brightness categories of the day based upon the angles between the center of the sun and the celestial horizon and made a procedure to retrospectively assign tows to one of the categories using Local Mean Solar Time (LMT) instead of JST. The new method detected drastic change of catch efficiency of young sauries by a surface net tow in crepuscular times more clearly than the clock time divisions by JST did. The method proved useful in correcting catch data biases due to day and night difference in catch efficiency.

1. Introduction

Day and night difference in the catch efficiency of the Pacific saury (*Cololabis saira*) larvae and juveniles by a surface net tow has been reported (FUKATAKI, 1959; ODATE and HAYASHI, 1977). These reports showed that daytime tows were less efficient than nighttime tows for older larvae and juveniles. We need precise information of catch efficiency fluctuations as a function of brightness in order to obtain quantitative estimates of young saury population from net tow surveys.

The survey area of the saury extends from the Japanese Islands to further than 170°E in the northwestern Pacific Ocean and the survey season extends almost year-round. We have had a problem in examining day and night difference of catch efficiency from accumulated routine survey data using tow times recorded in Japan Standard Time (JST), because the brightness at the same JST time is quite different between tow dates and locations, e.g., 0500 at 160°E corresponds to daylight brightness in June but in January at 130°E 0500 corresponds to total darkness. To solve this problem, I have devised a new set of brightness categories and procedures for retrospectively assigning tow samples to these categories. The new method is then applied to routine saury larval and juvenile census data to examine catch efficiency with diel changes in brightness.

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2. Definition of the brightness categories

In order to define a set of brightness categories that correspond with respect to the diel cycle, I used the angle between the center of the sun and the celestial horizon. Times of sunrise, sunset, and the limits of civil twilight and astronomical twilight were used to delimit ten categories (Fig. 1). Time of sunrise or sunset is when the center of the sun is on the celestial horizon in the morning or in the afternoon. The darker limit of civil twilight occurs when the center of the sun is 6° below the celestial horizon. This agrees with the time when stars of the first magnitude are appearing in the evening or disappearing in the morning with naked eyes. The darker limit of astronomical twilight occurs when the center of the sun is 18° below the celestial

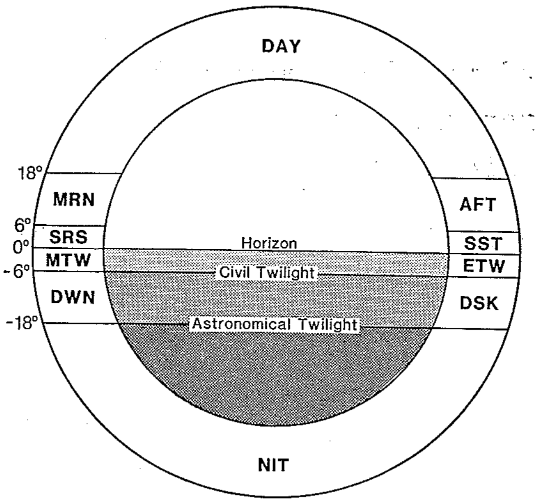

Fig. 1. Ten brightness categories of the day delimited by the angles formed between the center of the sun and the celestial horizon. The limit of civil twilight occurs when the center of the sun is 6° below the celestial horizon, and that of astronomical twilight 18° below the horizon. SRS, sunrise; MRN, morning; DAY, daytime; AFT, afternoon; SST, sunset; ETW, evening twilight; DSK, dusk; NIT, nighttime; DWN, dawn; MTW, morning twilight.

horizon. This agrees with the time when stars of the sixth magnitude are appearing or disappearing with naked eyes (Maritime Safety Agency, Japan, 1982). Four categories defined by times of the darker limits of the two twilights and by time of sunrise or sunset were desig nated DAWN (DWN), MORNING TWILIGHT (MTW), DUSK (DSK), and EVENING TWILIGHT (ETW). Four other categories for the same time durations after the sunrise and before the sunset were designated SUNRISE (SRS), MORNING (MRN), AFTERNOON (AFT) and SUNSET (SST). Time duration between the end of MRN and the beginning of AFT was designated DAYTIME (DAY), and that between the end of DSK and the beginning of DWN was NIGHTTIME (NIT). Average time durations of the categories are 24 min in MTW, SRS, SST, and ETW, 48 min in DWN, MRN, AFT, and DSK, and 9 hr and 36 min in DAY and NIT.

3. Source of saury catch data

To apply the new brightness categories, I used counts of saury larvae and juveniles in 4,508 ichthyoplankton samples collected over 15 years (1972–'86) by towing one type of neuston net in the northwestern Pacific Ocean between 29–45° N and between 129–174°E. The net was conical with a circular mouth ring of 1.3 m diameter. The two thirds of the diameter is underwater when towed. The mesh size of the forward 3.0 m was 2.0 mm and the posterior 1.5 m was 0.33 mm. The net was towed at the surface for 5 min at 2 kt by three bridles in front of the mouth. The area covered by one tow is 401.3 m^2. Samples were washed down after towing and preserved in 10% unbuffered formalin. Knob length (KnL) of sauries, the distance from the tip of the lower jaw to the posterior end of the muscular knob on the caudal base, was measured to the nearest 0.1 mm after preservation. Sauries up to 44.9 mm were grouped into 8 size classes of 5 mm intervals.

4. Assignment of tow samples into one of the categories

Tow samples of saury larvae and juveniles were collected in an extensive area of the northwestern Pacific Ocean over 12 months of the year. Within this spatial and temporal scale, times of sunrise and sunset could differ by 4 or 5 hr in JST and accurate classification of tow samples as a function of brightness could not be expected using shipboard tow time recorded in JST. I converted the tow times to Local Mean Solar Time (LMT) by adding or subtracting 4 min per 1° of longitude east or west of the meridian for JST. Every sample after the time conversion into LMT was assigned to one of the time categories using the tables of "The Sunrise and Duration of Twilight for Northern Latitudes" and "The Sunset and Duration of Twilight for Northern Latitudes" (Maritime Safety Agency, Japan, 1982). Although times of the sunrise and the sunset expressed in LMT and durations of the twilights before the sunrise and after the sunset on given date are different from year to year, the differences are within a few minutes. So I used the table for 1983 (published in 1982) for all 15 years in this paper.

As an index of catch efficiency with the neuston net, I used the number of saury larvae and juveniles captured by a tow (catch/tow). Patterns of diel cycles of the catch/tow in 8 size classes were compared between the conventional method of 12 clock time divisions of 2 hr intervals assigned by JST and the new method of 10 brightness categories assigned by LMT presented in this paper.

5. Results

New brightness categories and assigning procedures

Catch/tow over a diel cycle was high at dark, decreased with the increase of brightness, and increased again toward darkness in all the size classes except the small larva classes (Fig. 2). The sauries were much less catchable by a surface tow in DAY than in NIT. The ratio of DAY to NIT was 1.11 in the 7.5 mm class. It decreased with fish growth to 0.049 in the 42.5 mm class.

Decline and increase in catch/tow during the diel cycle were not linear. Moreover, the precipitous decline and sharp increase in catch/tow during crepuscular intervals (DWN-SRS and SST-ETW) were punctuated with sharp troughs.

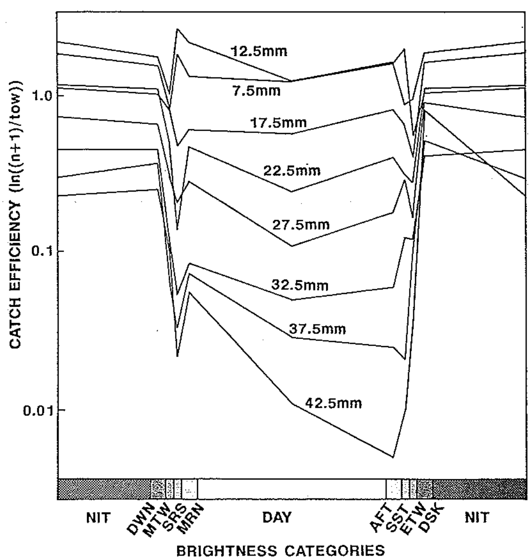

Fig. 2. Diel changes of catch efficiency of larval and juvenile sauries expressed in the brightness categories. Because none was collected in two categories in 42.5 mm class, natural logarithm of the number of fish captured (n) plus 1 divided by tow samples were plotted on the ordinate.

In the main, the pattern of response in catch/tow was similar among all size classes of fish. Lowest values of catch/tow occurred either in the morning or evening, but there was no consistent trend with fish size. Fish in five size classes (42.5, 37.5, 27.5, 17.5, and 12.5 mm) were least catchable at AFT and SST, but in the others (32.5, 22.5, and 7.5 mm) fish were least catchable at SRS.

Twelve clock time divisions of 2 hr intervals

General trend of diel change in catch/tow relative to JST was similar to that relative to brightness categories shown in Fig. 2; i.e., high at nighttime divisions, decreased in the morning, low in daytime and increased in the evening (Fig. 3). This trend was not evident for the 7.5 mm size class, but it became clearer with fish growth. The ratio of catch/tow of a typical bright time division (1200–1400) to a nighttime division (0000–0200) was 1.34 in the 7.5 mm class and decreased down to 0.016 in the 42.5 mm class.

The decrease in the morning or the increase in the afternoon, however, was not as steep as the changes observed in brightness categories.

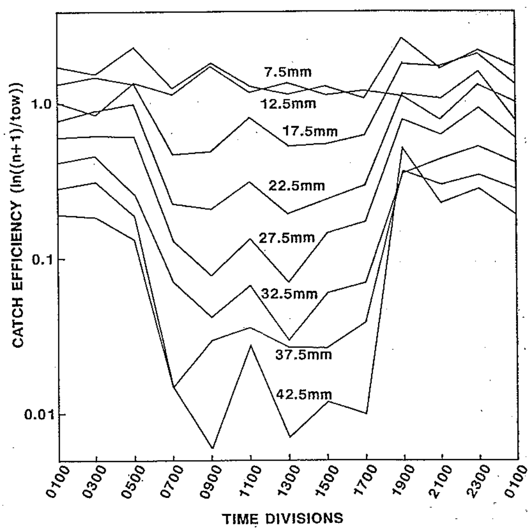

Fig. 3. Diel changes of catch efficiency of larval and juvenile sauries expressed in 12 clock time divisions. n, number of fish captured.

The decrease took 4-6 hr in the morning and the increase took about 2 hr in the evening. The curves of diel cycle for the size classes were smooth with a somewhat rise in 1000-1200.

6. Discussion

Behavioral changes associated with diel cycle are evident in many crustacean plankters (WILLIAMS and FRAGOPOULO, 1985; HARDING *et al.*, 1986) and ichthyoplankters (PEARCY *et. al.*, 1977; ROE and BADCOCK, 1984). Such change can affect estimates of catch efficiency when collection are obtained irrespective of time of day and celestial brightness, and over broad seasonal and longitudinal scales. In a routine larval census as we do in Japan for Japanese sardine (*Sardinops melanostictus*), mackerels (*Scomber japonicus* and *S. australasicus*), Pacific saury (*Cololabis saira*), etc., collections of ichthyoplankton samples have been conducted throughout the day during winter and spring months in the offshore areas of western and eastern Japan. In these cases, we need to assign tow sample into a set of time categories defined by brightness when examining day and night difference in catch efficiency. The brightness categories and the assigning procedures of tow samples presented in this paper will provide us with a new tool for the analyses of this type of tow data assemblage.

The decrease in the morning and increase in the evening of catch/tow occurred during 2-3 time intervals (4-6 hours) under JST divisions, more gradual than the change observed with the new method of brightness categories, where they occurred in about an hour. This is because one time division in the morning or in the afternoon contains samples collected under various brightness. The new method revealed that saury juveniles reacts sensitively to brightness change in the morning and in the evening.

Day and night difference of catch/tow of sauries has been reported in young Atlantic saury, *Scomberesox saurus* (WALB.) (HARTMANN, 1970) and Pacific saury, *C. saira* (ODATE and HAYASHI, 1977). These authors suggested the presence of diel vertical migration insaury juveniles. The causes of day-night difference are not limited, however, to vertical movement. Another possibility is net avoidance by fish. Either of these papers did not have data of saury distribution in layers deeper than 1.0 m, and consequently could not separate vertical migration from net frame avoidance as a factorof day and night difference.

The general trend of the catches as a function of brightness indicates that there are diel changes in vulnerability and availability to the net caused by either improved avoidance of the net or by migration out of upper meter or both in daytime. The relative importance of these two behavioral phenomena is not yet known. A stratified sampling scheme combined with the current surface net tow would be the best method to solve the question. OKIYAMA (1965) and PARIN (1967) conducted net tows of deeper layers, but the results were not sufficient to answer the question about what fraction of the young saury population is in the upper meter, which is available to the net of this study, and what fraction is in the rest of a water column. We need a more elaborated sampling scheme to answer the question. Comparison of catch data by nets with and without bridles in front of the mouth would also help to answer the question by minimizing the net frame avoidance by fish.

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稚魚ネットによるサンマ仔稚魚採集効率の昼夜比較のための時間帯区分

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仔稚魚の現存量評価のためのネット採集では，通常昼夜を問わず曳網を行う。しかし，ネットによる採集効率が昼と夜とで異なることはよく知られており，現存量評価のためには曳網時間帯を考慮した採集尾数の補正を行う必要がある。北西太平洋におけるサンマ仔稚魚調査は東経130°～170°の海域でほぼ周年行われてきたために，日本標準時で記録されている曳網時刻を用いた時間帯区分では，明るさに対応した採集効率の検討を行うことができない。本研究では，曳網時刻を地方平時に変換した後に，太陽の中心と視水平線との角度によって定義した10の明るさ区分に各曳網標本を割り当てる方法を考案した。この方法によって稚魚ネットによる1曳網当りサンマ仔稚魚採集尾数を検討した結果，全体として明るい時間帯に採集尾数が少ないこと，この傾向は体長が大きいほど顕著なことが確認された。また，明け方及び夕方の薄明時間で夜間より採集尾数が少ない傾向も明らかになった。

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