

Estimates of Larval Mortality Based on One Cohort Present During Two Consecutive Surveys in the Sea

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한 해역에서 두 번 연속 채집된 동일연급 자치어군의 사망을 추정

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Estimates of larval mortality for many marine fishes are based on field collections from several consecutive ichthyoplankton surveys, assuming that the surveys have covered the entire areas of larval habitats. The oceanic environment, however, is so dynamic and complicated that planktonic forms cannot stay within a confined area for a prolonged period. This note is prepared as a more detailed explanation of the estimates of fish larval mortality in the oceanic dispersing system, as a supplement of Kim and Bang (1990).

일정한 기간동안 한 해역에서 연속적으로 어류플랑크톤 재료를 수집하여 분석함으로써, 그 시기에 존재하는 어류플랑크톤의 사망을 추정할 수 있다. 이 때 대상 어종의 자치어군은 조사 해역내에 모두 존재하며, 다른 곳으로 이동되지 않았음을 전제로 한다. 그러나 해양환경은 대단히 역동적이기 때문에 플랑크톤들은 한 해역에만 계속해서 머물러 있지 못하고, 시간이 지남에 따라 그 분포범위가 넓어진다. 본 연구는 Kim and Bang(1990)에서 제시된 해양확산계내 자치어의 사망을 추정에 대한 내용을 보충 설명하기 위해서 준비되었다.

INTRODUCTION

The abundance and distribution of fish larvae in oceanic environments is effected by mortality as well as dispersion. Larval fish populations obviously decrease in number with time due to several sources of mortality, and the areas of larval occurrence tend to expand with time due to current and diffusion phenomena during their planktonic life stages (Talbot, 1977; Reed *et al.*, 1989). For these reasons, it has seen from the ichthyoplankton surveys, that the concentration of larvae of a certain cohort present in a local area decreases with time.

If surveys cover the entire area of larval occurrence, it would be easy to estimate larval mortality. However, if older larvae have drifted out of the former survey area so that the later survey did not cover the entire area of larval occurrence, the estimation of mortality would become comparatively complicated. Kim and Bang (1990) used biological samples to derive some physical parameters (i.e., advection and diffusion coefficients), and applied them to an oceanic advection-diffusion model to revise estimates of larval mortality. This note demonstrates details of the analytical methods shown in Kim and Bang (1990).

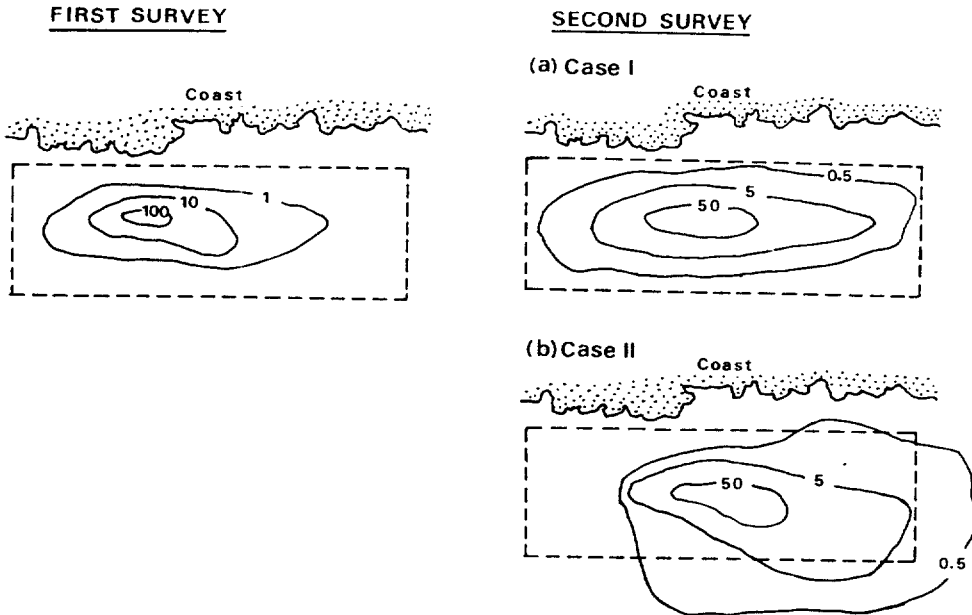


Fig. 1. Schematic maps of the sampling area (dashed line) and larval distributions and concentrations (contour line) from two consecutive surveys.

SITUATION

The situations treated in this note are:

- 1) Two consecutive surveys for one species of fish larvae conducted in the same area with time interval T.
- 2) During the first survey, the survey covered the entire area of larval occurrence. During the second survey, however, two cases can be considered (Fig. 1):

Case I: Cohorts of larvae that we are interested in have stayed in the survey area.

Case II: Some larvae have drifted out of the survey area, and it is assumed that we can identify the proportions of total larvae dispersed out of the survey area using other methods such as an advection-diffusion model.

ANALYTIC METHODS

Case I:

The abundance of the larval population

is,

$$N_1 = d_1 \times A_1 \tag{1}$$

$$N_2 = d_2 \times A_2 \tag{2}$$

where N_1 , N_2 , d_1 , d_2 , A_1 , and A_2 are the total larval populations (N_i), mean larval concentrations (d_i) in the areas (A_i) of larval occurrence during the first ($i = 1$) and second ($i = 2$) surveys, respectively. If this population decreased in number exponentially between the two surveys, the changes in abundance with time is

$$N_2 = N_1 e^{-mT} \tag{3}$$

where m is the instantaneous daily mortality of larvae, and T is the time interval between the two surveys. By substituting (1) and (2) into (3)

$$d_2 \times A_2 = d_1 \times A_1 \times e^{-mT} \tag{4}$$

Because $A_1 = A_2$ in this case, m becomes

$$m = (T)^{-1} \times \log_e (d_1/d_2) \tag{5}$$

Case II:

When the larvae have dispersed out of the survey area, Eq. (3) or (5) cannot be used to estimate mortality, because the total number of larvae present during the second survey is underestimated, and consequently larval mortality based on field collection is overestimated. Due to dispersion since the first survey, the area of larval occurrence (A_2) during the second survey is larger than the area surveyed (A_1). Even though the mortality estimate (m_e) based on field collection data is not identical to the real mortality rate (m_r), m_e can be considered as the first approximation of larval mortality, i.e.,

$$m_e = (T)^{-1} \times \log_e (d_1/d_2) \quad (6)$$

and the real mortality rate (m_r) can be expressed by

$$m_r = m_e - m_d \quad (7)$$

where d_2 is the mean number of larvae observed in the second survey, and m_d is the amount that the mortality estimate deviates from m_r .

The fraction of the total number of larvae that have drifted out of the survey area (f : called out-fraction in this note) can be defined

$$f = 1 - (N_2 / N_1) \quad (8)$$

where N_2 is the number of larvae found in the second survey. No general methods for computing out-fraction have been developed in the oceanic dispersing system. Kim and Bang (1990), however, suggested the use of the two-dimensional diffusion-advection model which requires some physical parameters (i.e., diffusion coefficient and advection rate) extracted from plankton data sets. With daily larval production and daily larval mortality (Kim and Gunderson, 1989), they could simulate eventually the changes in the expected larval distribution and abundance, and estimate the portion of population found in and/or out of the survey area at a specific time. Therefore, f and N_2 in Eq. (8) can be derived independently from the advection-diffusion model, and Eq. (8) becomes

$$N_2 = N_1 / (1-f) \quad (9)$$

Insert Eq. (9) into Eq. (3), and m is replaced m_r , i.e.,

$$\begin{aligned} N_2 &= N_1 \times e^{(-m_r T)} \quad \text{becomes} \\ N_2 / (1-f) &= N_1 \times e^{(-m_r T)} \end{aligned} \quad (10)$$

From Eq. (10), the real instantaneous daily mortality (m_r) of larvae is

$$\begin{aligned} m_r &= - (T)^{-1} \times \log_e ((N_2 / N_1) \times (1-f)^{-1}) \\ &= - (T)^{-1} \times \log_e ((d_2 \times A_1) / (d_1 \times A_2)) \\ &\quad - (T)^{-1} \times \log_e (1-f)^{-1} \end{aligned}$$

$$\begin{aligned} \text{Since } A_1 &= A_2, \quad m_r = (T)^{-1} \times \log_e (d_1/d_2) \\ &\quad - (T)^{-1} \times \log_e (1-f)^{-1} \end{aligned} \quad (11)$$

The first term in the right side is the first approximation of the larval mortality (m_e) based on the field samples and the second term is the correction factor (m_d) due to larval dispersion out of the survey area.

DISCUSSION

Although the concept of the coincidence of mortality and dispersion in larval population has been introduced by several investigators (Hirano, 1965; Smith, 1973; Okubo, 1980), the coupling of those factors with ichthyoplankton survey data was rarely successful due to the difficulties in sampling as well as the limitations of models. For a better understanding of this matter, both physical and biological characteristics should be considered concurrently through several consecutive surveys. Without the consideration of oceanic dispersion, some independent approaches to estimate larval mortality have been proposed (Saila and Lough (1981); Zweifel and Smith (1981); Lo (1986)), but uncertainty in larval aging and growth prevents us evaluating larval mortality. Recently the use of daily growth rings in larval otoliths has been used widely for

determining larval age (Campana and Neilson, 1982), and improved techniques of otolith reading will reduce bias in mortality estimates in the future.

The major limitation of the model in this manuscript is to get the known values of out-fraction (f), because this field has not been deeply considered in fishery science. The use of the diffusion-advection in Kim and Bang (1990) is one way to estimate out-fraction, but should be more elaborated in the future. If there are ways to estimate the out-fraction in various situations, the application of this model could be helpful for the explaining of dynamics of an open-populatin system.

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