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An estimator of episodic mortality in bivalves with an application to sea scallops (*Placopecten magellanicus*)

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Abstract

In marine invertebrate populations natural mortality events tend to be episodic in nature. The impact of these episodic mortality events can be estimated from the decline in catch rate of live animals over time obtained through successive population sampling. However, the high variability of catch rates makes them relatively insensitive indicators of mortality. For bivalve mollusks another means to estimate mortality is to assess the change in abundance of recently dead animals, called clappers, which are gaping shells still hinged together. We present a change in ratio estimator and its associated variance of the proportion of animals dying due to an episodic mortality event. This estimator is more sensitive to mortality events and may be preferable to a traditional estimator based upon changes in catch rates of live animals. When applied to a scallop population in Narragansett Bay, RI, the change in ratio estimator indicated that a 72% reduction in the population occurred after an intense mortality event associated with an epizootic of a rickettsia-like organism.

Keywords: Episodic mortality; Epizootic; Ratio estimator; Bivalves; Scallops

1. Introduction

The frequency and intensity of episodic natural mortality events attributed to epizootics, algal blooms, declines in water quality and other sources of mass mortality has increased dramatically since the mid-1970s (Hayes et al., 2001). Particularly in marine invertebrates the frequency of epizootic events has increased (Fisher, 1988; Ritchie et al., 2001), resulting in massive mortalities (Bower, 1989; Le Gall et al., 1991; Moyer et al., 1993). Due to the limited mobility of many marine invertebrates, mortality events tend to be episodic, brief and intense, which presents a challenge for monitoring populations and estimating mortality rates.

In bivalves, evidence of many forms of recent natural mortality is left behind for some time after death in the form of clappers or gaping, still hinged, paired shells. Assuming the pool of clappers is in equilibrium, i.e., the number entering the pool must equal the number exiting (through ligament decomposition), and if the degradation rate of the ligament is known, the natural mortality rate can be estimated by treating the population of recently dead animals as a dynamic pool (Dickie, 1955). Merrill and Posgay (1964) found that clapper degradation rates of the sea scallop (*Placopecten magellanicus*) on Georges Bank vary by scallop size and environmental conditions. Nonetheless, they concluded that degradation rates can be estimated and current estimates of sea scallop natural mortality rate (0.10 year^{-1}) are based on Dickie's (1955) method (NEFSC, 2004).

The brief and intense nature of episodic mortality events violates the equilibrium assumption needed to estimate mortality rate using Dickie's (1955) method. Provided a population is otherwise closed, the impact of this increased mortality can be estimated from the decline in catch rate of live animals sampled over time. However, the high variability of catch rates makes them a relatively insensitive measure of mortality. A ratio index can be constructed from the ratio of sample counts of clappers and live animals that is more sensitive to changes in natural mortality rate. Such a ratio index benefits from the high correlation between clappers and live animals. Intuitively, and independent

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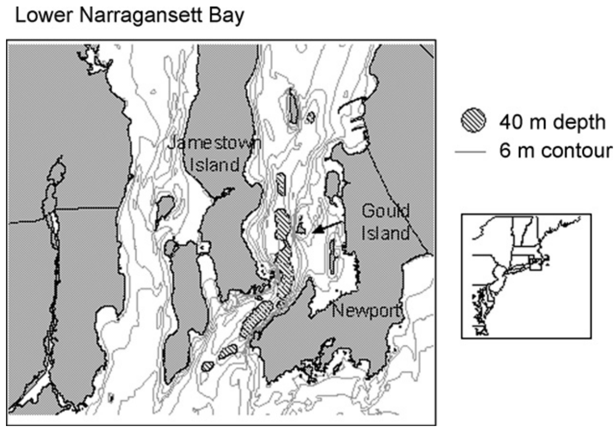

Fig. 1. Map of Narragansett Bay showing the 40 m depth contour. Scallops were sampled in these depths directly south of Gould Island (Map coverage obtained from Rhode Island Geographic Information System©http://www.edc.uri.edu/rigis/).

of the mortality rate, a sample with a high number of live animals will have high numbers of clappers and vice versa. The same information can be used to construct a change-in-ratio estimator of mortality and its associated variance using the ratio of clappers to live animals before and after a severe mortality event. These methods were used to estimate the proportion of scallops that died when struck by an epizootic in Narragansett Bay, Rhode Island (Gulka et al., 1983; Gulka and Chang, 1985).

2. Methods

2.1. Population monitoring

Some time between October 1979 and January 1980 an unfished and isolated population of adult sea scallops (*P. magellanicus*) living in 40 m of water, just south of Gould Island in the East Passage of Narranganset Bay, RI (Fig. 1) experienced severe mortality originally attributed directly to an epizootic (Gulka et al., 1983). Later this mortality was attributed to a combination of infection and adverse environmental conditions (Gulka and Chang, 1985).

Samples (Table 1) were collected in relatively the same location over 13 months using 20 min, constant-speed tows of a 2 m wide dredge with a ring mesh size of 57.2 mm. The status of the population was monitored by observing four indices: (1) the catch of clapper shells (per standard tow), (2) the catch of live animals per tow, (3) the ratio of clappers to live animals, and (4) the ratio of clappers to clappers plus live animals, i.e., proportion of clappers (Fig. 2a–d). It appears that up to 16 October 1979, the ratio of clappers to live animals and the proportion of clappers were both stable. On the last planned sampling date (25 January 1980), catch rates of live animals were low while clappers were abundant (Fig. 2a–d). The ratio of clappers to live (Fig. 2c) and clappers to clappers plus live (Fig. 2d) suggested that a major increase in mortality had occurred.

Following Dickie's (1955) method, we can treat the clappers as a dynamic pool. Assuming that over the short term this is a population closed to recruitment, emigration and immigration, and that the disintegration rate of the clappers remains constant, the obvious change in the ratio and proportion indices implies an abrupt increase in the natural mortality rate between 16 October 1979 and 25 January 1980 (Figs. 2c and 2d). This was later confirmed through the additional set of tows on 6 August 1981, in which no live scallops were found.

3. Derivation of a mortality estimator

A model can be developed for estimating the proportion of bivalves that dies as a result of an episodic mortality event. This increase in natural mortality simultaneously decreases the number of live bivalves and increases the clapper pool by an equal number. Let C and L be the number of clappers and live animals present, and let the subscripts 1 and 2 represent times prior to and following the episode, respectively. Also, let X be the number

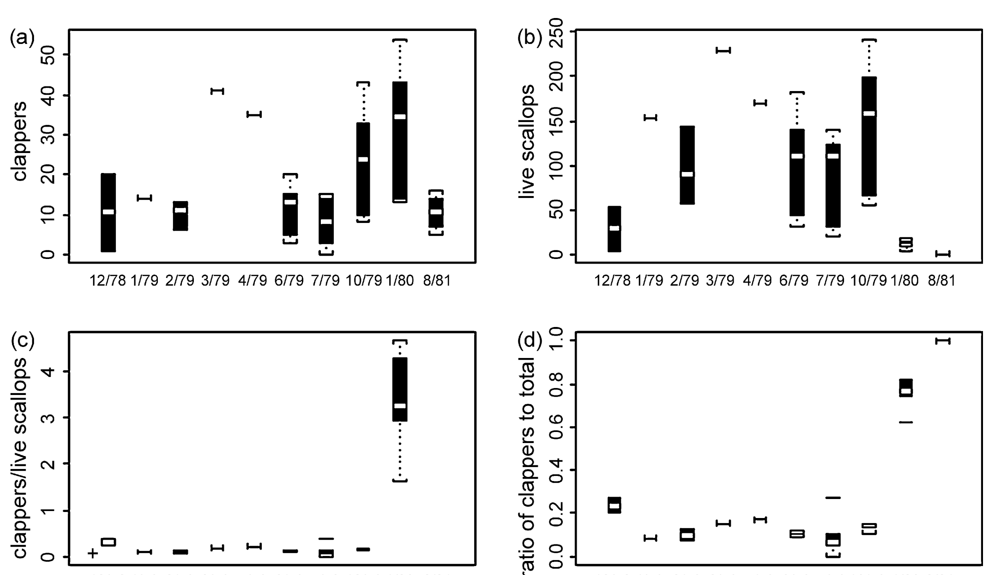

Fig. 2. Box and whisker plots of survey catches per standard tow for (a) clappers, (b) live scallops, (c) clappers/live scallops and (d) ratio of clappers to total scallops.