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Linking temperature and salinity tolerance to winter mortality of Chesapeake Bay blue crabs (*Callinectes sapidus*)

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Abstract

Blue crabs (*Callinectes sapidus*) form one of the most important and largest commercial fisheries in Chesapeake Bay. Blue crabs have evolutionary origins in the tropics, although they currently inhabit temperature estuaries that exhibit major fluctuations in diurnal, monthly, and seasonal environmental conditions. Therefore, harsh winter conditions in Chesapeake Bay are a potentially important source of blue crab stock loss. However, this variable has been largely unexamined. To assess the effects of variation in winter environmental conditions on blue crab survival, we measured winter morality of crabs in the field and conducted laboratory experiments to test the interactive effects of low temperature, salinity, and blue crab life stage. Field studies indicated that blue crabs suffered relatively low winter morality rates (≤3%) during five out of eight winters, when bottom water temperature in February was at or above the 8-year average (3.4 °C). However, in years when bottom water temperature fell below the February average, annual mortality rates rose to 6.0–14.5%. Mortality rates were highest in the coldest regions of Chesapeake Bay, and larger crabs and female crabs were most vulnerable to these stressful conditions. Similarly, in the laboratory, mortality was highest in the lowest temperature (1 °C) and salinity (8 ppt) treatments. Mature females were more sensitive to winter conditions than juvenile crabs. Of the juvenile life stages, recruits (<15 mm carapace width) were least tolerant to winter conditions. These results indicate that temperature, salinity, and blue crab life stage are important variables in predicting survivorship over winter months. Because winter mortality may be a significant source of stock loss for blue crabs, especially during severe winters and in low salinity areas of Chesapeake Bay, these predictions can be used to improve management estimates of stock size prior to each summer fishing season.

Keywords: Blue crab; *Callinectes sapidus*; Salinity tolerance; Temperature tolerance; Winter mortality

1. Introduction

Blue crabs (*Callinectes sapidus*) comprise the largest and most important commercial fishery in Chesapeake Bay (Rugolo et al., 1998). Recent studies

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suggest that the Chesapeake Bay blue crab population is at a depressed level after an 85% decline in spawning stock biomass during 1990–2001 (Lipcius and Stockhausen, 2002). To better understand these trends, it is important to identify all sources of natural and anthropogenic mortality.

Past efforts to identify sources of mortality and estimate annual changes in stock size have been elusive. The majority of studies have focused on fishing data, thereby excluding sources of mortality that occurred during the non-fishing season, such as winter-induced mortality (Dudley and Judy, 1973; Cole, 1998). Recent estimates of stock size have been based on several approaches, including fall recruitment estimates (Lipcius and Van Engel, 1990), spatially explicit and multiple life stage models (Miller, 2001, in press), and winter dredge surveys (Schaffner and Diaz, 1988; Volstad et al., 2000). However, these stock predictions have varied in accuracy, in part due to demographic responses to large fluctuations in environmental conditions during the period between when the data are collected and the time when the estimate of stock size is applied. For example, recruitment and stock assessment data collected in the fall and early winter do not include probabilities of winter-induced mortality into stock size estimates for the following spring.

Winter-induced mortality is a potentially important source of mortality for blue crabs due to large fluctuations in winter conditions; however, this variable has been largely unexamined (Van Engel, 1987, 1999). As a species with evolutionary and biogeographic origins in the tropics, and a historical geographic range of Nova Scotia to northern Argentina (Rathbun, 1930), the Chesapeake Bay population is approaching the northern limits of the species' distribution. Crabs in this region may not be well adapted for the most extreme winters, impairing the Chesapeake population. For example, watermen and scientists conducting winter dredge surveys have noted higher rates of mortality during extreme cold winters (Pearson, 1948; Dudley and Judy, 1973; Kennish et al., 1982; Kahn et al., 1998; Davis, 1999).

Within estuarine environments, species distributions are often limited by temperature and salinity tolerance, as estuaries are exposed to large diurnal, seasonal, and yearly fluctuations in salinity, temperature, and dissolved oxygen (Leffler, 1972; Mangum and Towle, 1977). While blue crabs can tolerate a wide range of salinities (Tan and Van Engel, 1966; Ballard and Abbott, 1969; Tagatz, 1971; Guerin and Stickle, 1992), osmoregulation efficiency is lowest and energy demands are highest at low salinities and temperatures, especially for mature females (Tagatz, 1971). In a laboratory study, Tagatz (1969) found that temperature tolerance levels decreased in lower salinity waters. Thus, the physiological stress of low salinities and extreme low temperatures may have a synergistic effect in lowering blue crab tolerance to winter conditions.

To assess the relative importance of severe and moderate winter environmental conditions on blue crab mortality, we examined the combined effects of low temperature and salinity on adult and juvenile survivorship through field sampling of Chesapeake Bay blue crabs and controlled laboratory experiments. The goals of this study were: 1) to assess annual and spatial variation of blue crab winter mortality within the northern, lower-salinity half of the Chesapeake Bay over a period with wide fluctuations in winter severity; 2) to test the interactive effects of temperature, salinity, and crab life stage on blue crab mortality; and 3) to compare levels of stress, as defined by number of autotomized (dropped) limbs, among low salinity–temperature regimes.

2. Methods

2.1. Winter dredge survey

The Maryland Department of Natural Resources (MDNR), Chesapeake Biological Laboratory (CBL), and Virginia Institute of Marine Science (VIMS) have conducted an annual winter dredge survey throughout Chesapeake Bay since 1989 (Volstad et al., 2000; Sharov et al., in press). The survey sampled blue crab populations using a standard 1.83-m-wide Virginia sampling dredge to determine the geographic location, bathymetric distribution, size, and sex of over-wintering blue crabs. The dredge was lined with a 12.7-mm nylon mesh to select for crabs of at least 15 mm carapace width (CW; Sulkin and Miller, 1975). From 1989 to 1995, annual stratified random sampling occurred throughout Chesapeake Bay between mid-December and March, as described in Sharov et al. (in