Fisheries Research 148 (2013) 1–8

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Effects of location errors on estimates of dredge catchability from depletion based methods

Michael J. Wilberg[a,*], Jason M. Robinson[a], Sarah A.M. Rains[a], Jennifer L. Humphrey[a], Romuald N. Lipcius[b]

[a] Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, P.O. Box 38, Solomons, MD 20688, USA
[b] Virginia Institute of Marine Science, College of William & Mary, P.O. Box 1346, Gloucester Point, VA 23062, USA

ARTICLE INFO

Article history:
Received 2 October 2012
Received in revised form 24 July 2013
Accepted 25 July 2013

Keywords:
Dredge efficiency
Chesapeake Bay
Blue crabs
Callinectes sapidus
Depletion methods
Population estimates

ABSTRACT

Depletion-based methods are used to estimate the catchability of a research dredge survey for blue crabs (*Callinectes sapidus*) in Chesapeake Bay. The experimental design relies on the ability to repeatedly sample the same area, but experiments have not been conducted to determine the effects of sampling location error on catchability estimates. We conducted a simulation study to evaluate the effects of sampling location errors on three catchability estimators (Leslie, Ricker, and Rago). We simulated the distribution of crabs in an area and repeatedly sampled from the area using a range of true values of catchability and four methods to constrain the sampling area: perfect knowledge, buoy deployment, high-accuracy GPS, and consumer-grade GPS. No estimator was best across all scenarios, and in some scenarios no estimator performed particularly well. Error in sampling location generally caused negative bias in the catchability estimates with the amount of bias increasing as location error increased. While the Leslie and Rago methods were relatively accurate when location errors were small, the Ricker method performed poorly because of the constant added to allow zero catches. The Leslie or Rago method performed well when combined with buoys to demarcate the sampling area, and the Rago method performed well with high-accuracy GPS.

1. Introduction

Depletion-based methods are commonly used to estimate catchability (*i.e.*, efficiency) of survey gear, which then allows estimation of absolute density and abundance of organisms in a study area (Leslie and Davis, 1939; DeLury, 1947; Ricker, 1958; Seber, 1982). In traditional depletion experiments the sampling gear is deployed multiple times within the study site, causing the catch per unit effort (CPUE) to decline as a result of decreasing density. Effort and catch are recorded after each sampling event, and the rate of decline in CPUE compared to the amount of removals is used to infer initial abundance or density of the population and catchability. While this approach is particularly appealing because it provides estimates of absolute abundance directly from a survey, it is prone to violations of model assumptions. Most depletion-based methods assume that the population is closed over the timeframe of the depletion experiment, that each animal has an equal probability of capture, and, in some cases, that the location of the sampling gear is known throughout the experiment (Leslie and Davis, 1939; DeLury, 1947; Rago et al., 2006; Hennen et al., 2012). Small violations of these model assumptions can cause bias in estimates of catchability and abundance (Rago et al., 2006).

Annual blue crab (*Callinectes sapidus*) abundance in Chesapeake Bay is estimated by adjusting CPUE of the blue crab winter dredge survey for estimated catchability from depletion experiments (Vølstad et al., 2000; Sharov et al., 2003). Winter dredge survey sampling is conducted from December to March when blue crabs are dormant and buried in the sediment (Sharov et al., 2003). For each depletion experiment, a random sampling station is selected in an area of medium to high crab density. Each station establishes a 100 m by 5.5 m (three dredge widths) sampling area, and a vessel tows a 1.8-m-wide Virginia crab dredge over the area at low speed (Vølstad et al., 2000). Three parallel adjacent dredge tows constitute a sample because it is very difficult to repeat a single tow (G. Davis, Maryland Department of Natural Resources, personal communication). Maryland and Virginia use slightly different methods to demarcate the sampling area. In Maryland, the sampling area is marked by four corner buoys, while in Virginia a Global Positioning System (GPS) is used to mark the corners of the sampling area. Both of these methods have some error in the dredging location, but effects of location errors on depletion estimates of catchability are not well understood.

* Corresponding author. Tel.: +1 410 326 7273; fax: +1 410 326 7318.
E-mail address: wilberg@umces.edu (M.J. Wilberg).

0165-7836/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.fishres.2013.07.016

This study evaluates the performance of three depletion-based catchability estimators under a range of location accuracy, survey design scenarios, and individual variation in catchability scenarios. We conducted a simulation study to approximate catchability experiments for the winter dredge survey of blue crabs in Chesapeake Bay and compared three catchability estimators under a range of scenarios that differed in the true catchability of the gear, the density of crabs in the area, the amount of location error in the sampling, and the amount of inter-individual variation in catchability.

2. Methods

2.1. Simulation design

Our study simulated the distribution of blue crabs in a sampling area (grid) and repeatedly sampled the grid with different true catchabilities and amounts of location error to generate data sets. Three methods for estimating catchability were applied to the data sets, and estimates were compared to the true values to characterize bias and accuracy. We implemented four location accuracy scenarios: perfect accuracy, the buoy method, the Wide Angle Augmentation System (WAAS)-enabled GPS unit method (*i.e.*, high accuracy GPS), and non-WAAS-enabled GPS unit method (*i.e.*, low accuracy or commercial grade GPS; Witte and Wilson, 2005). We also simulated three levels of crab density (high – 0.5 m^{-2}, medium – 0.1 m^{-2}, low – 0.05 m^{-2}) and five levels of true catchability (0.1, 0.3, 0.5, 0.7, 0.9). Additionally, we evaluated the effect of inter-individual vulnerability to the dredge by drawing catchability values for each individual from beta distributions. For each dataset, we applied the Leslie, Ricker, and Rago catchability estimators (Leslie and Davis, 1939; Ricker, 1958; Rago et al., 2006). We simulated 500 data sets for each of the scenarios.

In the perfect location accuracy scenario no errors were introduced into the simulated dredge path. In the buoy method scenario the four corners of the sampling area were marked with buoys to visually guide the dredge paths. The first buoy is placed, and the second is placed relative to the first by measuring 5.5 m along the length of the vessel. Consumer grade GPS is then used to measure 100 m perpendicular to the first two buoys, and the third buoy is placed. The final buoy is placed by measuring 5.5 m along the length of the boat, as for the second buoy. The buoy method, used by the Maryland Department of Natural Resources (MDNR), should result in accurate placement for the width of the sampling area with GPS error potentially occurring for the length of the sampling area.

The low and high accuracy GPS scenarios use GPS waypoints to mark the corners of the sampling area. Non-WAAS enabled and WAAS-enabled GPS units were assumed to have a standard deviation (SD) of 7.1 and 0.54 m for the low and high accuracy scenarios respectively, based on a study of the perpendicular error in GPS locations when conducting a transect (Witte and Wilson, 2005). The low accuracy GPS scenario simulates the current dredge survey method used in Virginia and the high accuracy GPS scenario simulates what might be possible with a survey grade GPS system. Because these methods use GPS units with less than perfect accuracy and no visual signs to keep dredges within the sampling area boundaries there is potential error in both the length and width of the sampling area as well as the dredge location relative to the target sampling area.

2.2. Simulation model

The simulated sampling area was populated by randomly placing crabs in a grid. Grid cells were 0.18 m^2, based on the carapace width of an adult male crab, and only one crab could occupy each

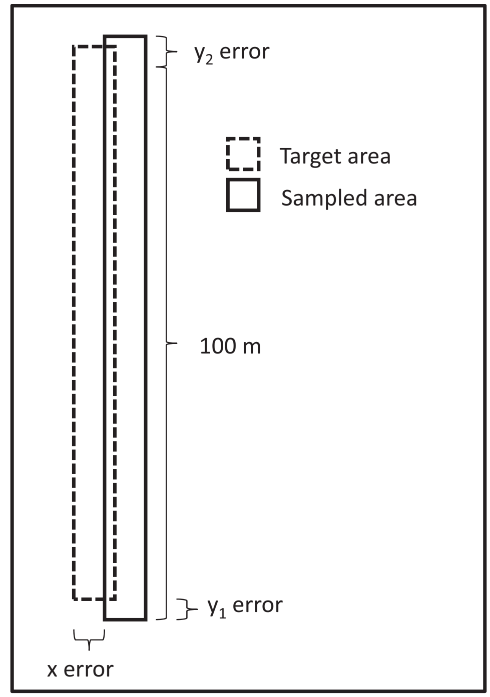

Fig. 1. Example for applying location error in the dredge survey simulation. The initial *x* and *y* coordinates of a tow were randomly drawn depending on the scenario, and the length of the tow was random with a mean of 100 m. Length and width of the dredge tracks are not to scale.

cell. Crabs were placed throughout the grid by randomly selecting grid cells without replacement until the desired number of crabs was placed in the grid, resulting in a random distribution of crabs throughout the grid. The number of crabs placed in each grid was determined by the three crab density levels. The size of the grid over which crabs were distributed was substantially larger than the target sampling area to allow for location error to result in sampling outside of the target area.

2.3. Sampling model

Three potential location errors (starting *x*, starting *y*, ending *y*) were possible for each tow (Fig. 1). We assumed that relatively little error is derived from the side-to-side and diagonal movement of dredge tows. Therefore, all dredge tows followed straight paths, were parallel to one another, and were parallel to the boundaries of the intended sampling area. Three parallel adjacent tows constitute a sample to mimic the approach conducted in Chesapeake Bay for blue crabs (Vølstad et al., 2000).

We included four scenarios of location accuracy for dredge sampling. In the perfect accuracy scenario there was no error in dredge location (Table 1; Fig. 2). For the buoy method, tows were constrained within the sampling area boundaries. Because error could only be toward the inside of the sampling area, half normal distributions were used for the starting *x* location on the two outer tows of a three-tow sample (*i.e.*, all errors were positive for one side, while all errors were negative on the other). A normal distribution was used for the starting *x* location of the middle tow and for the starting and ending *y* locations. We used an SD of 0.75 m for all location errors in the buoy method. This SD was assumed to represent the accuracy of the dredge location because the buoys could be used to judge the location of the vessel relative to the sampling area, and, therefore, dredge tracks should be relatively accurate. We did not include a larger SD for the length of the sampling area because