ScienceDirect

Fisheries Research

Volume 251, July 2022, 106304

Length-based approaches to estimating natural mortality using tagging and fisheries data: The example of the eastern Aleutian Islands, Alaska golden king crab (*Lithodes aequispinus*)

M.S.M. Siddeek [a], B. Daly [b], V. Vanek [b], J. Zheng [a], C. Siddon [a]

Show more

Share Cite

https://doi.org/10.1016/j.fishres.2022.106304

Get rights and content

Highlights

- Tagging data can be used to estimate plausible natural mortality (*M*) provided it is supported by independent methods.
- Length-based tag-recapture model has similar structures as the integrated length-based assessment model.
- For tagging data, restricted time-at-large, insignificant initial tagging mortality, and complete reporting assumptions produce *M* estimate closer to *M* of integrated length-based assessment model.

- Large number of tagged crab releases with precautions taken to minimize initial tagging mortality and to maximize tag-recapture reporting is paramount for successful estimation of *M*.

Abstract

We evaluated natural mortality (M yr^{-1}) estimation reliability for eastern Aleutian Islands male golden king crab (*Lithodes aequispinus*), an exploited stock, by comparing an integrated length-based assessment model approach and a likelihood method using tag release-recapture data. We used 1997, 2003, and 2006 tag release-recapture data to estimate the size transition matrix, *M*, fishing mortality, total selectivity, and retained selectivity and compared *M* likelihood profiles between both methods. Furthermore, we conducted simulations with varying initial survival and tag reporting rates to show that *M* estimation reliability declines as these rates decline. Restricted time-at-large, full initial survival, and complete reporting assumptions produce an *M* estimate closer to that of the integrated length-based assessment method. Because the reliability of the *M* estimate is sensitive to changes in these assumptions, future efforts should focus on maximizing the number of tagged crab (and hence recaptures), evaluating initial tag-induced mortality, and optimizing tagged crab recapture reporting rates. The reliance of fishery-dependent data and high tag reporting rates highlights the importance for maintaining a positive cooperation with fishers for efforts towards sustainable management.

Introduction

Instantaneous natural mortality (*M*) is a vital parameter in stock assessment and management of fish and crustacean stocks for reference point calculations, population abundance estimation, and is often used as a surrogate in the absence of a known maximum sustainable yield level of fishing mortality (F_{MSY}) (Restrepo et al., 1998). *M* likely varies by size (Balsiger, 1974), sex, maturity state (Stockhausen, 2021, Zheng and Siddeek, 2020), age (Reeves and Marasco, 1980), or year (Zheng et al., 1995) for Bering Sea and Aleutian Islands (BSAI) crab stocks. However, the estimation of variable *M* is difficult for heavily exploited stocks because of several confounding parameters, such as catchability, growth, maturity, and fishing mortality. For these reasons, the use of an average *M* is practical for stock assessment and management especially for species with relatively long lifespans including Aleutian Islands golden king crab (*Lithodes aequispinus*) which has significant commercial importance but is a data poor stock that lacks a reliable estimate of *M*.

Tag-recapture data have been used to estimate various population parameters, such as abundance, mortality, and movement (Seber, 1982) and provide a promising avenue for *M* estimation. Multinomial likelihood is widely used in tag-recapture data analysis (e.g., Seber, 1982; Pollock et al., 2002) and some variants, such as Poisson distribution (e.g., Hilborn, 1990) and negative binomial distribution (e.g., Whitlock et al., 2012), are used to estimate mortality when movement is an integral part of the analysis. Methods such as simple linear regression (Balsiger, 1974), least squares (Siddeek et al., 2002), likelihoods (Pollock et al., 2002), and Bayesian mark-recapture models (Whitlock et al., 2012) have been used with tag-recapture data to estimate various population dynamics parameters (including *M*) in various fish and crustacean populations. Although simple linear regression fit is easier for *M*, catchability, and fishing mortality estimation, the data often do not adhere to underlying normal error assumption and estimates can be unrealistic, and this problem can also arise with least square methods. Conversely, likelihood methods provide opportunities to use non-normal error model structures. While we prefer likelihood methods for tag-recapture-based *M* estimation, any estimation method is not guaranteed to provide realistic results for a given dataset.

The reliability of *M* estimation is affected by several factors such as the effective number of tagged crab at-large (i.e., the actual released number of tagged crab x initial survival rate) and actual recaptured numbers. Initial survival can be influenced by short-term tag-related death, nonsystematic tag loss, or emigration from the fishing area (Ricker, 1975). Related to this, a reliable reporting rate is needed to estimate the actual number of tagged crab recaptures; however, these rates can vary depending on fishery. For example, for Irish Sea plaice (*Pleuronectes platessa*), the product of initial survival and reporting rates can be as low as 37% (Siddeek, 1989). Ignoring the effective number of tagged crabs is likely to affect absolute abundance not total mortality (Z) estimate.

Earlier work on *M* estimation for Aleutian Islands golden king crab using a virtual population analysis (VPA) method on annual tagged crab recaptures (irrespective of size) estimated *M* values higher (0.375–0.573 yr^{-1}) than expected given our understanding of the species lifespan (Siddeek et al., 2002). Because of uncertainties related to the fact that the *M* estimates were not compared to any other independent method of estimation (Siddeek et al., 2002), we seek to develop a novel length-based tag-recapture model which uses a likelihood function on log recaptures and to validate those results with an independent estimate from an integrated length-based assessment model likelihood approach. As part of this, we include simulated tagged crab recaptures with variable but plausible errors to test the reliability of the length-based tag-recapture *M* estimator. Because initial survival of released tagged crab and reporting rate by fishers in an open population have adverse effects on *M* estimation (Ricker, 1975; Siddeek, 1989), our simulation analysis evaluated effects of variable initial survival and reporting rates.

Section snippets

Tagging data

We used eastern Aleutian Islands male golden king crab tagging release-recapture data from 1997, 2003, and 2006. Tagging occurred during summer (July-September) each year, which was before the fishery season started. Crab were captured by rectangular, king crab pots; location, date, and fishing depth were recorded for each pot retrieved. Upon pot retrieval, crab carapace lengths (CL) were measured to the nearest millimeter and shell condition (old or new) was recorded. Crabs were tagged with…

M estimate from the integrated length-based assessment (EAG21.1a) model

The EAG21.1a model produced an *M* of 0.2189 (± 0.0243) yr^{-1} for initial optimization of the log likelihood of *M* using integrated data. An arbitrarily (rounding down) fixed *M* of 0.21 yr^{-1} was used to estimate several stock assessment parameters (Table 4, Table 5, and 6). A profile likelihood plot for *M* was also created to visually compare the *M* estimate at the lowest negative log likelihood with that from the length-based tag-recapture model (Fig. 1).…

M estimate from length-based tag-recapture model

The length-based tag-recapture model produced…

Discussion

Our length-based tag-recapture model developed in this paper provided a plausible estimate of *M* for eastern Aleutian Islands golden king crab that was verified with an independent estimate from the EAG21.1a model and simulation analysis. The longevity of eastern Bering Sea golden king crab is unknown; however, we inferred that the maximum age for male Bristol Bay red king crab (*Paralithodes camtschaticus*) is a reasonable approximation as the maximum size is consistent with our samples (~220 mm…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

Acknowledgements

We thank CAPAM for organizing manuscripts under the natural mortality topic for this special publication. We thank Andre Punt of University of Washington, Seattle for useful suggestions that strengthened our analytical approach. We also thank Lee Cronin-Fine of University of Washington, Seattle, and two anonymous reviewers for useful suggestions, which improved the earlier draft of this manuscript. This manuscript is contribution CFPP.293 of the Commercial Fisheries Division of the Alaska…

Special issue articles Recommended articles

References (24)

R.M. Hillary *et al.*
Length-based Brownie mark-recapture models: derivation and application to Indian Ocean skipjack tuna
Fish. Res. (2015)

A.E. Punt *et al.*
Data weighting for tagging data in integrated size-structured models
Fish. Res. (2017)

M.S.M. Siddeek
Estimation of natural mortality of Kuwait's grooved tiger prawn *Penaeus semisulcatus* (de Haan) using tag-recapture and commercial fisheries data

Fish. Res. (1991)

M.S.M. Siddeek *et al.*

Estimation of size–transition matrices with and without molt probability for Alaska golden king crab using tag–recapture data

Fish. Res. (2016)

R.E. Whitlock *et al.*

Estimating fishing and natural mortality rates for bluefin tuna (*Thunnus orientalis*) using electronic tagging data

Fish. Res. (2012)

J.W. Balsiger

A Computer Simulation Model for the Southeastern Bering Sea King Crab Population (Ph.D. thesis)

(1974)

D.A. Fournier *et al.*

AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models

Optim. Methods Softw. (2012)

G.W. Gray

Tags for marking king crabs

Prog. Fish Cult. (1965)

J. Hampton

Natural mortality rates in tropical tunas: size really does matter

Can. J. Fish. Aquat. Sci. (2000)

R. Hilborn

Determination of fish movement patterns from tag recoveries using maximum likelihood estimators

Can. J. Fish. Aquat. Sci. (1990)

Matsuura, S., Takeshita, K., 1989. Longevity of red kingcrab, Paralithodes camtschatica, revealed by long-term rearing...

K.H. Pollock *et al.*

A general model for tagging on multiple component fisheries: an integration of age-dependent reporting rates and mortality estimation

Environ. Ecol. Stat. (2002)

There are more references available in the full text version of this article.

Cited by (1)

Natural mortality: Theory, estimation and application in fishery stock assessment models

2023, Fisheries Research

View full text