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PREDICTING INVASIONS: PROPAGULE PRESSURE AND THE GRAVITY OF ALLEE EFFECTS

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Abstract. Invasions by nonindigenous species impose large environmental and economic costs. In order to prevent invasions and target monitoring efforts most effectively, we need to forecast locations at the greatest risk of new invasions. To accomplish this, we need to estimate propagule pressure (inoculum size) and consider population processes, including possible Allee effects. Here, we develop a method to estimate the probability of population establishment, based on survival analysis and maximum likelihood techniques. We demonstrate theoretically the validity of this approach, considering environmental heterogeneity, estimation error, and nonlinearity. We then apply this method to zebra mussel (*Dreissena polymorpha*) invasions of Michigan inland lakes. We fit our model using presence/absence data for 1589 lakes between 1992 and 1996 and propagule pressure estimates from gravity models of boater traffic. Using our fitted model, we estimated the probabilities of establishment and demonstrated that Allee effects were present in the zebra mussel system. We validated our model using invasion data from 1997–2001 (data not used to parameterize the model). For the validation time period, we correctly predicted up to nine times as many invasions as a null (random) model. Further, the Allee model assigned average probabilities of invasion four times higher for lakes that became invaded than for uninvaded lakes, whereas the non-Allee model predicted probabilities for invaded lakes only two times higher. Thus, our model demonstrates the importance of considering the Allee effect and improves predictions of invasions.

Key words: Dreissena polymorpha; *exotic; extinction; gravity model; incidence model; invasive species; nonindigenous; risk; time series; zebra mussel.*