中文摘要

本研究主要目的為發展以內部效應濃度(Internal effect concentration, IEC)為基礎之環境品質標準(environmental quality criteria, EQC)，用以保護養殖九孔暴露於含鋅水域之存活與成長模式。本研究流程以美國環保署(U.S. EPA)於 1998 年提出之生態風險評估為主架構，加入不同地區之現地生物累積資料，結合一階雙區塊之生物累積模式(bioaccumulation model)與三參數之希爾方程式模式(hill equation model)，重建九孔體內累積鋅濃度之劑量與反應曲線，並以機率之方法加以求取使九孔死亡不超過 10%之劑量來做為建構風險門檻值模式及急、慢性毒之環境品質標準。風險門檻值模式之推導，係以變動靈敏度分析下最具統計顯著效應之水中鋅濃度與九孔對鋅之排除速率二參數進行多變數非線性之迴歸分析所求得。急性毒之環境品質標準主要以 IEC 及生物累積因子預測而得，而慢性毒之環境品質標準則主要應用急慢性之比值(ACR)加以推導。上述模式內所使用之參數皆隨地域而變。本研究以蒙地卡羅之機率分析方法模擬模式中之參數不確定性與變異性，並提供統計之信賴區間予決策者，以增加其評估特定含鋅養殖生態系之決策彈性與靈活性。由本研究獲知，頭城、口湖、安平三地之九孔養殖池之急性毒環境品質標準中位數範圍為 0.32 - 0.33 μg ml^{-1}；而慢性毒環境品質標準之中位數範圍則為 0.047 - 0.048 μg ml^{-1}。本研究以機率架構為基礎發展風險門檻值模式及急、慢性之環境品質標準，將有助於提供政府相關部門制定隨地域不同養殖池水質管理之依據，以及九孔受鋅污染之體內影響濃度規範參考值。

關鍵詞：九孔；隨地域而變之環境品質標準；機率；風險；毒性門檻值；鋅

Abstract

The purpose of this thesis is to develop mechanistic models to accurately quantify environmental quality criteria (EQC) and to predict a risk threshold for the survival and growth of farmed abalone *Haliotis diversicolor supertexta* exposed to waterborne zinc (Zn) based on a probabilistic internal effect concentration (IEC)-based modeling framework. We couple a first-order two-compartment bioaccumulation model and a reconstructed dose-response profile based on a three-parameter Hill equation model associated with a field bioaccumulation study to form a probabilistic model to determine the risk threshold and the acute and chronic EQC based on a 10% probability of exceeding the abalone 10% IEC (IEC10) for site-specific abalone farms. Sensitivity analysis reveals that waterborne Zn concentration (C_w) and abalone depuration rate (k_2) have a significant effect on Zn levels in abalone. Using a multiple nonlinear regression analysis with C_w and k_2 as parameters, a predictive risk threshold equation that can be used with a variety of site-specific conditions was developed for the survival protection of farmed abalone. The acute EQC (a-EQC) is predicted from IECs and a field-derived bioaccumulation factors, whereas a statistical procedure with an acute-to-chronic value is used to derive chronic EQC (c-EQC) based on bioaccumulation. Field bioaccumulation study demonstrates a linear relationship between water and tissue Zn concentrations in abalone and algae. Our model, designed for simplicity and theoretical insight, yields explicit mathematical results through a probabilistic analysis to capture EQC modeling methodology in a more realistic way by analyzing computationally through Monte Carlo simulation technique that propagates parameter uncertainty/variability throughout the model, providing decision makers with credible range information and increased flexibility in establishing a specific Zn level in aquacultural ecosystems.

Here we show that the median a-EQC range from 0.32 – 0.33 μg ml^{-1}, whereas the median c-EQC are 0.047 – 0.048 μg ml^{-1} for selected abalone farms. We believe that this probabilistic dose-based framework is an effective method for conceptualizing a public policy decision vis-à-vis establishing a mechanistically-based site-specific acceptable acute and chronic EQC and a specific reasonable risk threshold for better management and restoration of the rapidly degrading aquacultural ecosystems.

***Keywords*:** Abalone; Site-specific environmental quality criteria; Probabilistic; Risk; Toxicity threshold; Zinc