Population Risk-Based Criteria – The Piscivorous Bird Demonstration (WQ MYP): Incorporating Demography Into Ecological Risk Assessments

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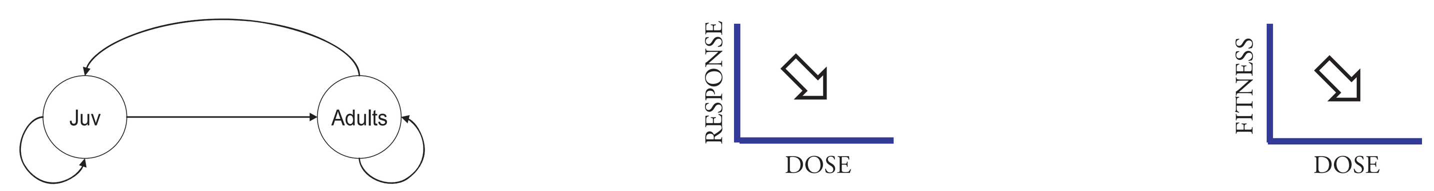
AED Peer Review '07

AGENCY PROBLEM



DEMOGRAPHY + TOXICOLOGY = RISK

The Office of Water's actions are mandated to be protective of whole populations. However, there is increasing recognition that commonly measured toxicity effects on vital demographic rates such as survival or reproduction are not necessarily representative of effects at the population level. Moreover, a given vital rate may seem insensitive to a given chemical but may be so important to population fitness that even small chemically-induced changes can increase risk. This is because population-level risk results from both toxicological and demographic sensitivity and their interactions against a background of other stressors. The Office of Water needs methods to integrate these components of sensitivity in wildlife risk assessment and criteria development.

APPROACH

NHEERL's Wildlife Research Strategy (US EPA 2005) lays out a conceptual approach for integrating toxicology and population demography in wildlife risk assessment (Figure 1).

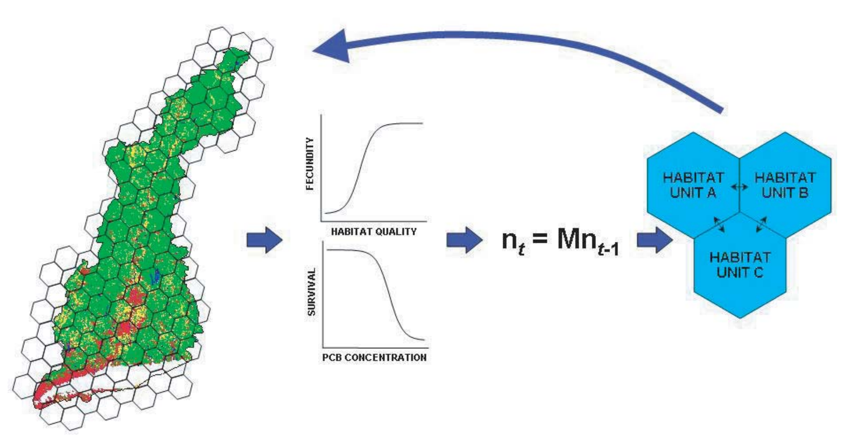


Figure 1. Conceptual approach to wildlife risk assessment.

For wild populations, this strategy requires integration of sometimes disparate sources of data from toxicologists and field ecologists. Life history theory and demographic population modeling can help us to achieve this integration. This poster demonstrates such an approach using disparate but rich data sources to evaluate potential effects of mercury exposure on common loon populations (*Gavia immer*).

WHY LOONS?

- Loons and the mercury to which they are exposed via aquatic food webs occur against a background of other stressors, providing a useful opportunity to develop and demonstrate integration of toxicological and demographic sensitivity for wild populations (Nacci et al. 2005).
- Common loons are top piscivores in the northern U.S. and Canada lakes where they breed. Certain aspects of their exposure to bioaccumulating toxicants are therefore typical of many aquatic-dependent wildlife species.
- Mercury is regulated by the US EPA and has been found to occur in wild loons at levels consistent with biological effects on embryonic survival.
- Loons are also affected by other stressors, including habitat degradation, and therefore provide an opportunity to develop general methods for assessing risk in the context of multiple stressors
- The strong citizen science component of current knowledge about loons provides an opportunity to collaborate with non-government organizations.

LITERATURE CITED

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BASELINE MODEL

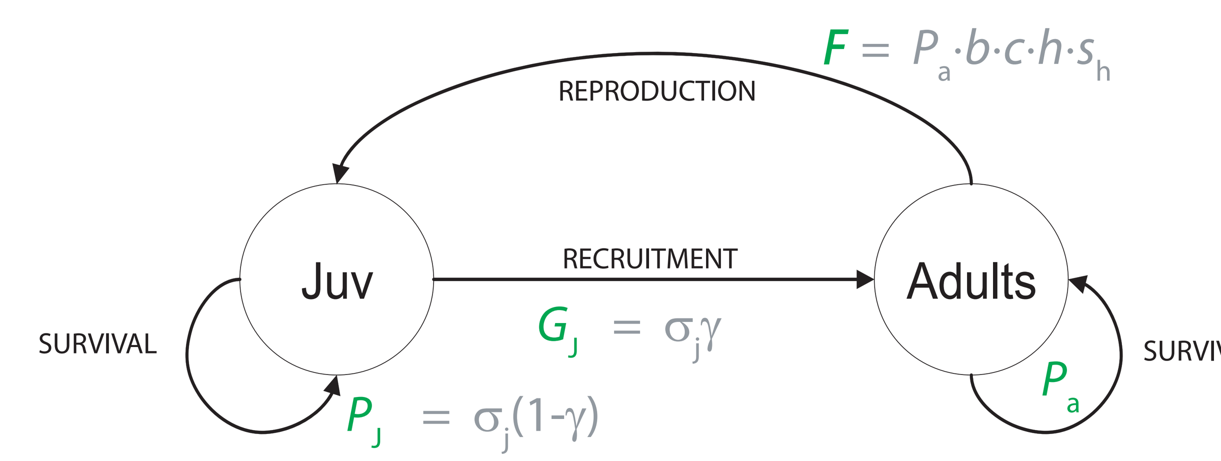
VITAL RATES

Vital rates provide a common currency for linking demography and toxicology.

VITAL RATES (annual)	
b	breeding propensity
c	brood size (♀)
h	embryonic survival
s_h	hatchling survival
σ_j	total juvenile survival
γ	conditional recruitment
P_a	adult survival

DEMOGRAPHY

These vital rates are based on existing knowledge about species life history, often from disparate sources. Population models combine the vital rates in specific ways to represent pathways in the life cycle.



VITAL RATES (annual)		ESTIMATED REFERENCE	DATA SOURCES CURRENTLY INCLUDED
b	breeding propensity	0.54	NH Loon Preservation Committee
c	brood size (♀)	0.84	NH Loon Preservation Committee
h	embryonic survival	0.63	NH Loon Preservation Committee
s_h	hatchling survival	0.85	NH Loon Preservation Coittee
σ_j	total juvenile survival	0.74	M. Meyer; Mitro et al. in press
γ	conditionall recruitment	0.24	Maturity assumed in 4th year
P_a	adult survival	0.91	Mitro et al. in press

MATRIX MODEL

Matrix models provide a formal and exact mathematical represenation of the life cycle diagram, with each matrix parameter representing a pathway.

$$\mathbf{A} = \begin{bmatrix} P_j & F \\ G_j & P_a \end{bmatrix}$$

$$= \begin{bmatrix} 0.5640 & 0.2124 \\ 0.1784 & 0.9088 \end{bmatrix}$$

$\lambda_1 = 1.0$ = Density-independent population growth rate based on matrix **A**

DENSITY DEPENDENCE: Current versions of the loon population model are density-independent, ignoring the potentially important limitation placed on growth rates by breeding habitat availability. Ongoing work such as that mentioned in Box 5 will allow more direct treatment of this limitation, but qualititative insights such as those presented here appear insensitive to such improvements.

RESULTS: PROJECTING STRESSOR EFFECTS

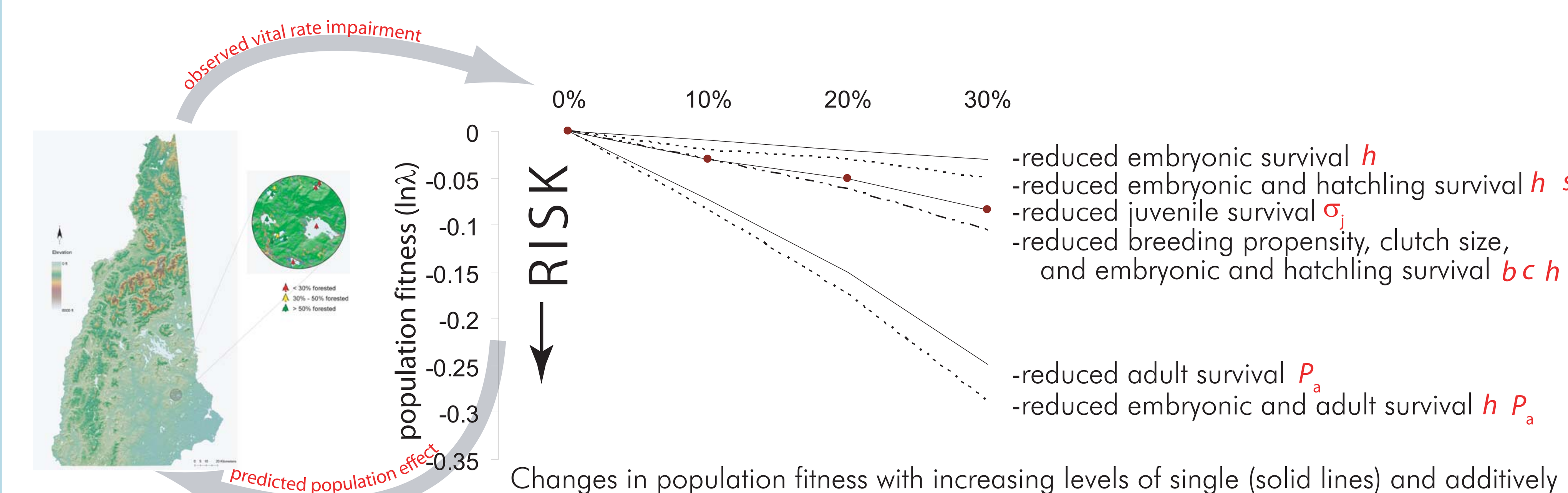
TOXICOLOGY

Stressor effects that are expressed in terms of this same vital rate currency can then be used in the model to generate risk projections.

VITAL RATES (annual)		MERCURY EFFECTS ON LOONS
b	breeding propensity	Unknown
c	brood size (♀)	Unknown, but under study in kestrels by R. Bennett (MED) and others
h	embryonic survival	Probable effects (Kenow et al. 2003); under further study by Kenow and others
s_h	hatchling survival	Lab and field studies by Kenow et al. (2003), M. Meyer and others
σ_j	total juvenile survival	None or not detectable from available mark-recapture data (Mitro et al. in press)
γ	conditional recruitment	Unknown
P_a	adult survival	None detected, but Mitro et al. (in press) concluded that potentially important effect sizes are not detectable with current mark-recapture data.

RISK ASSESSMENT

Risk projections can be expressed in terms of effects of stress-induced vital rate impairments on population fitness (i.e., population growth rate). The poster by Kuhn et al describes research allowing these projections to incorporate spatial variation across the landscape.



Changes in population fitness with increasing levels of single (solid lines) and additively combined (dotted lines) vital rates.

IMPACTS AND OUTCOMES

It is unlikely that single-rate impairments occur in nature, or that multiple impairments lack covariance, but the above projections provide useful insight for risk assessment. One such insight is that, although adult survival of many species tends to be less chemically sensitive than reproduction, very small --perhaps even undectable-- changes in adult survival could significantly affect populaton fitness in the common loon. This expectation is well-founded in the theoretical literature and is critical for risk assessment specific to common loons and other wildlife species with similar life histories. We demonstrate how the predicted population impact of seemingly small stressor effects can be assessed through integration of toxicology and demography. Application of this approach will allow development of criteria by the Office of Water to minimize potential impacts on wildlife populations. State partners report that the demographic models described here have affected regulatory policy.

FUTURE DIRECTIONS

- Integrate demographic model with habitat modeling by Anne Kuhn and others (see poster by Kuhn et al.)
- Incorporate variance components into stochastic models to inform the uncertainty component of risk estimation (see SP2 poster by Grear et al., this session)
- Evaluate potential effects of ignoring density-dependence in this strongly territorial species (discussed in m.s. in prep. by Grear et al.)
- Compare model endpoints with independent data (Grear et al. 2006 and m.s. in prep. by Grear et al.; also see poster by Kuhn et al.)
- Implement spatial matrix modeling approach (Grear and Burns 2007) at state and regional scales (see SP2 poster by Grear et al., this session) and compare with RAMAS (c) application by Walters et al. (in press)
- Continue to provide techical interaction to project collaborators
- Provide an integrated report and guidelines to the Office of Water for incorporating population models into wildlife criteria development

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The Loon Preservation Committee

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