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Sensitivity of maximum sustainable harvest rates to intra-specific life history variability of lake trout (*Salvelinus namaycush*) and walleye (*Sander vitreus*)

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Abstract

Using lake trout (*Salvelinus namaycush*) and walleye (*Sander vitreus*) we examined the extent of error that is created when non-population-specific or non-sex-specific data are used to develop fishery sustainability models. To put biases in perspective we first compared relative differences in sustainable harvest rate estimates of fast and slow growing populations to the mean difference between species. Few estimates of early mortality exist for either species, and a sensitivity analysis indicated that sustainable harvest rate estimates varied by more than 90% with those available. To evaluate biases created by predicting life history traits we estimated maturation age from asymptotic length in populations whose life history parameters had been measured directly. Incorporating species-specific information produced maturation ages that were closer to those measured (mean difference 22%) than did the estimates from inter-specific relationships (mean difference 42%). This resulted in sustainability estimates from species-specific predictions being closer to those estimated using actual maturation data. In evaluating problems associated with using non-sex-specific data we found that estimates of maximum sustainable harvest rates increased when female-specific life history data were used (could only be done for walleye) instead of combined-sex data (mean change in the two populations was 7%). Analyses indicate that it is desirable to collect life history data on specific populations of lake trout and walleye. If this is not possible, estimates of maximum sustainable harvest rates are most influenced by variation in estimates of early mortality, followed by the taxonomic resolution used to estimate co-variation among life history traits, and finally the use of combined-sex versus female-specific data.

Keywords: Maximum sustainable harvest rate; Lake trout; Walleye; Intra-specific variation

1. Introduction

Life history traits are characteristics of organisms that influence an individual's expected fitness (relative per capita growth rate) via effects on survival,

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reproduction, or transitions between different developmental stages. Such traits include birth rate, growth rate, maturation age, mortality rate, and lifespan (Stearns, 1992). Life history traits do not vary independently of each other (Roff, 1992; Charnov, 1993). Many life history studies have focused on defining and interpreting inter-specific patterns of variation among life history parameters. The degree to which patterns of intra-specific variation differ from those of inter-specific variation among fishes has received relatively little attention (but see Pauly (1980); Beverton (1992)).

General patterns in the co-variation of life history traits (e.g., Beverton and Holt, 1959; Pauly, 1980; Frisk et al., 2001) have become useful tools for determining life history parameters in un-sampled populations of fishes. Not all species however follow these general patterns. For example, the Clupeidae and polar fishes do not follow Pauly's predictive equation for natural mortality (Pauly, 1980). Life history parameters can be used in estimating maximum sustainable harvest rates (Shuter et al., 1998; Cass and Riddell, 1999; Brodziak, 2002). When these data have to be predicted, incorporating appropriate species-specific relationships among life history traits may provide important differences from general patterns in the sustainability estimates obtained. Examples of species where such relationships are available include lake trout (*Salvelinus namaycush*, Shuter et al., 1998), brown trout (*Salmo trutta*, Vøllestad et al., 1993; Mangel, 1996), and Arctic char (*Salvelinus alpinus*, Vøllestad and L'Abee-lund, 1994).

Another generality sometimes made in fisheries models is the disregard for potential sex differences in growth rate, maturation age, and mortality rate (e.g., Boisclair and Leggett, 1989; Shuter et al., 1998). In order to determine egg production, population estimates are generally converted to number of females by assuming a 1:1 sex ratio. Usually egg production is then calculated as a function of the age-specific number of females, average weight, proportion mature, and relative fecundity. Although reproductive rates produced in this way are based entirely on female life history information, sometimes only relative fecundity is based solely on female data (i.e., growth, survival, and maturation based on combined sex data), e.g., Shuter et al. (1998). The differential effects of sexual and/or natural selection on the two sexes can lead to differences between male and female life histories (Quinn et al., 2001). The absence of sex-specific data in models estimating maximum sustainable harvest rates of fishes from life history traits can be a means of convenience and simplification, but may bias resulting calculations.

These problems are relevant to lake trout (alternatively lake charr), and walleye (*Sander vitreus*), which comprise some of the most important recreational and commercial freshwater fisheries in North America. Due to the vast numbers of lakes, management on a per population basis is impossible for either species. An alternative approach of regional management, based on relationships between life history traits and easily measured lake characteristics has been explored (Shuter et al., 1998; Lester et al., 2000). Although this approach is promising, explained variation is not high and life history data will still need to be obtained for some valuable populations. Data are often available to calculate some life history traits (e.g., growth rate) but not others (e.g., maturation age) for a given population. In such cases, it may be desirable to predict unknown life history traits from other traits or data.

These two species vary substantially in their life histories. Lake trout is a salmonid that is confined to cool hypolimnetic water; it grows slowly, spawns in the fall, produces large eggs, and shows little sexual dimorphism. Walleye is a percid that grows quickly, prefers warm water, spawns in the spring, produces many small eggs, and exhibits substantial sex differences in growth and maturation. Walleye thus have a greater potential population growth rate as they can replace themselves at a faster rate, and should be able to withstand higher fishing pressures than lake trout. For each species, we specifically examined the degree to which maximum sustainable harvest rates were affected by intra-specific plasticity, different estimates of early mortality, species-specific versus non-specific equations for estimating values of life history traits, and the incorporation of female-specific life history data (walleye only).

2. Methods

2.1. The general model

To determine how life history variation affects fitness we calculated the Malthusian parameter (*r*, per