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Effects of Temperature and Density on Consumption of Trout Eggs by *Orconectes propinquus* and *O. rusticus*

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ABSTRACT. *Using laboratory experiments, we assessed the effect of temperature and predator density on consumption of trout eggs by crayfish. We quantified the effect of four temperature ranges (2–3, 4–5, 7–8, and 10–12°C) on consumption of lake trout* (Salvelinus namaycush) *and rainbow trout* (Oncorhynchus mykiss) *eggs by a native* (Orconectes propinquus) *and an exotic (Orconectes rusticus) crayfish found in the Great Lakes. Mean individual consumption ranged from 0.1 to 1.5 lake trout eggs per day and from 1.0 to 5.5 rainbow trout eggs per day, respectively. Temperature influenced consumption for* O. rusticus *feeding on rainbow trout eggs but not* O. propinquus*. The effect of conspecific predator competition on rainbow trout egg consumption was evaluated using three densities of crayfish (1, 5, 10 per tank). For* O. rusticus*, mean individual consumption rate was higher at the lowest crayfish density (1 crayfish/tank) than at medium (5 crayfish/tank) or high (10 crayfish/tank) densities. A similar conspecific effect was not evident in* O. propinquus *and total consumption per unit area increased with crayfish density. The effect of competition among crayfish species on consumption of rainbow trout eggs was examined by comparing feeding rates at high crayfish abundance levels in single and mixed species treatments. Mixed species interactions did not significantly alter crayfish feeding rates. Results from these experiments provide empirical data to aid in modeling how temperature and predator density affect lake trout egg predation rates in the field.*

INDEX WORDS: *Lake trout, rainbow trout, crayfish, egg consumption, temperature.*

INTRODUCTION

Predation on early life stages of lake trout (*Salvelinus namaycush*) has been suggested as an important impediment to lake trout restoration in the Great Lakes (Jones *et al.* 1995, Savino *et al.* 1999). Models of lake trout egg and fry survival developed by Jones *et al.* (1995) and Savino *et al.* (1999) showed that predation by interstitial egg predators such as sculpins and crayfish could be a particularly significant source of lake trout mortality; however, obtaining field estimates of interstitial predation on lake trout eggs in the Great Lakes can be difficult as unfavorable weather conditions during fall and winter when lake trout spawning and embryo incubation occurs may prohibit assessment efforts. Additionally, analysis of crayfish diets is

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problematic because of their "shredding" style of feeding, and stomach contents only represent a relatively short period of foraging history. Interstitial predator consumption rates estimated from laboratory studies with crayfish have ranged up to 3 lake trout eggs per day (Horns and Magnuson 1981, Savino and Miller 1991). These estimates of egg consumption were primarily obtained from single-predator studies conducted using temperatures between 6 and 8°C. Savino and Miller (1991) rationalized their use of this temperature range by stating that 6 to 8°C represented the thermal range when eggs are deposited in fall and fry are hatching in spring in the Great Lakes.

Previous predation models assumed that feeding by interstitial predators was a function of temperature, but that the specific relationships had not yet been determined (Jones *et al.* 1995, Savino *et al.* 1999). Temperature is likely to significantly affect predation, and predators that are more tolerant of low temperatures will forage more effectively later into the incubation period than less tolerant species and thus have a greater impact on egg mortality. Understanding the functional relationship between the consumption of lake trout eggs by crayfish and temperature, including the entire range of temperatures to which eggs and predators are exposed, is key to understanding the potential impact of crayfish on lake trout egg mortality. Estimating this relationship will provide empirically derived predictive models to aid in larger modeling efforts estimating lake trout egg mortality.

Predator density and predator interactions may also be important variables affecting egg predation on lake trout spawning reefs. Mixed species (Werner and Hall 1979) and conspecific (Genner *et al.* 1999, Matsumoto 2001) competitive interactions have been shown to affect food resource utilization within fish species and may affect feeding behavior of other interstitial egg predators. Crayfish often display agonistic behavior during conspecific interactions (Goessmann *et al.* 2000, Stocker and Huber 2001), suggesting that feeding rates of individuals may be altered in the presence of others. Abundance of crayfish can vary dramatically on lake trout spawning reefs both between and within lake systems. Mean crayfish densities (#/m^2) assessed using similar methodologies ranged from 0 to 2 in Lake Champlain, to 3 to 10 in Parry Sound, Lake Huron, and from 4 to 54 in northern Lake Michigan, suggesting that, based strictly on number alone, predation effects may vary by over an order of magnitude (Jonas *et al.* 2005). Moreover, certain species of crayfish may present a more formidable predation effect than other species. The relatively high crayfish density observed in some nearshore areas of northern Lake Michigan can be largely attributed to the recent introduction of *O. rusticus*, which is now the dominant lake trout egg predator at many locations (Claramunt *et al.* 2005, Jonas *et al.* 2005). Lake Michigan crayfish assemblages were once dominated by native crayfish (*O. propinquus* and *O. virilis*); these species are now competing with and being displaced by the more aggressive *O. rusticus* (Capelli 1982, Lodge and Hill 1994). Given their ability to consume eggs, the variation in crayfish species and abundance observed among lake trout spawning reefs may have important consequences for lake trout recruitment. Even the native crayfish *O. virilis*, which occurs in lower densities than *O. rusticus,* has demonstrated negative influences on fish populations in ponds (Dorn and Mittelbach 2004).

The goal of our study was to determine how temperature and predator density affect consumption rates of lake trout and rainbow trout (*Oncorhynchus mykiss*) eggs by native (*Orconectes propinquus*) and exotic (*O. rusticus*) crayfish found in the Great Lakes. For each crayfish species, we estimated the relationship between temperature and daily egg consumption. We then examined the effect of competition on egg consumption both within and among each species of crayfish.

METHODS

Experiments were conducted at the Rubenstein Ecosystem Research Laboratory, University of Vermont. *O. rusticus* were collected from the Connecticut River located on the eastern border of Vermont and *O. propinquus* were obtained from the Winooski River in Richmond, Vermont. Lake trout and rainbow trout eggs were obtained from the Salisbury Fish Hatchery in Salisbury, Vermont. Rainbow trout eggs were also obtained from White Sulfur Springs National Fish Hatchery in White Sulfur Springs, West Virginia.

Crayfish were held at ambient room temperature (15 to 20°C) in 114 L glass aquaria and were fed lake trout and rainbow trout eggs, aquatic vegetation, and goldfish flake food. We used rainbow trout eggs to examine the influence of inter and intraspecific competition on egg consumption. The effect of temperature on egg consumption was estimated with both lake trout and rainbow