Available online at www.sciencedirect.com

SCIENCE DIRECT®

Aquaculture

Aquaculture 244 (2005) 263–281

www.elsevier.com/locate/aqua-online

Effect of prepared and macroalgal diets and seed stock source on somatic growth of juvenile green sea urchins (*Strongylocentrotus droebachiensis*)

T.L. Daggett[a,*], C.M. Pearce[a,1], M. Tingley[b], S.M.C. Robinson[c], T. Chopin[d]

[a] *Ross Island Salmon Ltd., P.O. Box 1304, Grand Manan, New Brunswick, Canada E5G 4M9*

[b] *Department of Mathematics and Statistics, University of New Brunswick, P.O. Box 4400, Fredericton, New Brunswick, Canada E3B 5A3*

[c] *Shellfish Aquaculture Division, Fisheries and Oceans Canada, St. Andrews Biological Station, 531 Brandy Cove Rd., St. Andrews, New Brunswick, Canada E5B 2L9*

[d] *Centre for Coastal Studies and Aquaculture, Department of Biology, University of New Brunswick Saint John, P.O. Box 5050, Saint John, New Brunswick, Canada E2L 4L5*

Received 28 May 2004; received in revised form 29 November 2004; accepted 29 November 2004

Abstract

Populations of sea urchins, harvested for their gonads, are in decline worldwide and so scientific research is now focusing on full life cycle grow-out. The objective of this study was to compare the growth rates of juvenile (initial test diameter: 4.5–13.7 mm) green sea urchins that were held in laboratory tanks and fed a variety of diets. Two separate experiments were conducted. The first compared juvenile growth on seven different diets: 1) prepared diet, 2) *Porphyra purpurea*, 3) *Palmaria palmata*, 4) *Ulva linza*, 5) a mixture of *Ulvaria obscura* and *Ulva lactuca*, 6) *Laminaria saccharina* collected from an Atlantic salmon aquaculture site, and 7) *L. saccharina* collected from a site relatively distant from salmon aquaculture operations. The latter two treatments were chosen in order to determine if the nutrient regime in which an alga was grown could affect juvenile growth rate. A second experiment compared the growth rates of wild-caught and hatchery-reared juvenile green sea urchins fed either a prepared diet or fresh kelp (*L. saccharina*) collected from a site relatively distant from salmon aquaculture. Test diameter and whole wet weight measurements were taken monthly for a period of 16 months. In the first experiment, feed type significantly affected somatic growth rate, the overall best growth being supported by *Porphyra purpurea* (mean growth rate $\pm$SE: 0.059 ± 0.001 mm d^{-1}) and the prepared diet (0.056 ± 0.001 mm d^{-1}). *L. saccharina* collected from the site distant from salmon aquaculture operations (0.019 ± 0.001 mm d^{-1}) produced significantly slower growth than any other feeding treatment including *L. saccharina* collected from a salmon aquaculture site (0.047 ± 0.001 mm d^{-1}). In the second experiment, feed type also significantly affected growth with the prepared diet (0.058 ± 0.001 mm d^{-1}) supporting better growth than *L. saccharina*

* Corresponding author. Present address: 1287 Route 776, Grand Manan, New Brunswick, Canada E5G 1G4. Tel.: +1 506 662 9890; fax: +1 506 662 3093.

E-mail address: tdaggett@simcorp.ca (T.L. Daggett).

[1] Present address: Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, British Columbia, Canada V9T 6N7.

doi:10.1016/j.aquaculture.2004.11.030

(0.027 ± 0.001 mm d^{-1}). Seed stock source also affected overall growth with the hatchery-reared individuals displaying significantly greater growth (0.045 ± 0.002 mm d^{-1}) than wild-caught individuals (0.040 ± 0.002 mm d^{-1}). Identifying which diets and sources of juvenile sea urchins optimize growth may help aquaculture operations produce market-size sea urchins in a minimum amount of time, thus maximizing profitability.

Keywords: Sea urchin; Growth; *Strongylocentrotus droebachiensis*; Macroalgal diet; Prepared diet

1. Introduction

Commercial harvesting of sea urchins is a major fishing industry in many countries of the world including Japan, the United States, Canada, Chile, and Russia, with Japan being the world's largest consumer of sea urchin roe (Keesing and Hall, 1998). The development of many of the world sea urchin fisheries has been in response to changing economies and urchin stock declines in other countries (Keesing and Hall, 1998; Andrew et al., 2002). Declining populations of urchins and the ever-present demand for sea urchin gonads have created opportunities for sea urchin aquaculture.

Aquaculture techniques need to be developed that will minimize the time required for small juveniles to reach a marketable size; consequently, an understanding of the nutritional requirements of small individuals is essential. There are two basic food choices for rearing juvenile sea urchins in a commercial-scale grow-out facility: prepared diets or macroalgae. Growth rates of small *Strongylocentrotus droebachiensis* fed *Laminaria saccharina* have been reported by Briscoe and Sebens (1988), Nestler and Harris (1994), Lemire and Himmelman (1996) and Williams and Harris (1998), but only one published study has examined growth rates of juvenile *S. droebachiensis* fed different species of macroalgae. Devin et al. (2004) reported no significant differences in growth rates among juvenile *S. droebachiensis* fed *L. saccharina*, *Palmaria palmata*, or a mixture of macroalgae (*L. saccharina*, *P. palmata*, *Ulva lactuca*). All of these algal treatments, however, induced greater growth than *U. lactuca* alone (Devin et al., 2004). As well as macroalgal species, the location from which algae are collected may be important in determining their suitability as food sources. Algae grown around Atlantic salmon aquaculture cages incorporate nitrogenous wastes from the fish into their thalli (Subandar et al., 1993; Ahn et al., 1998; Chopin et al., 1999, 2001), which may make them more nutritional as feed for juvenile sea urchins.

While the determination of suitable feeds for juvenile *S. droebachiensis* is valuable information, without an alternate source of juveniles, the aquaculture industry remains dependent on wild populations. In order to become truly self-sufficient, aquaculture will require whole life cycle production. Little is known, however, about the growth rate of hatchery-produced juvenile *S. droebachiensis* and how this rate may compare with that of wild-collected juveniles. The present study compares the growth rates of juvenile *S. droebachiensis* fed one of five species of macroalgae and a prepared diet and compares the growth rates of juveniles reared in a hatchery to those collected from the wild.

2. Materials and methods

2.1. Sea urchin collection and maintenance

2.1.1. Experiment 1

Juvenile *S. droebachiensis,* ranging from 4.5 to 10.7 mm test diameter, were collected by Scuba divers at Whale Cove, Grand Manan Island, New Brunswick (44°47′ N, 66°45′ W); Bancroft Point, Grand Manan Island (44°43′ N, 66°44′ W); and Brandy Cove, St. Andrews, New Brunswick (45°06′ N, 67°05′ W) on rocky cobble bottoms at depths of 7 m (St. Andrews site) and 9 m (Grand Manan sites) at high tide on November 10, 14, 22, and 29, 2000. They were placed in plastic boxes with ambient seawater and transported to the laboratory at Woodwards Cove, Grand Manan, New Brunswick. Urchins were measured for test diameter and wet weight and randomly transferred to experimental tanks (L×W×H:50×50×28 cm). Overhead fluorescent lights (Sylvania "Cool White";