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CULTURE OF SURFCLAMS *SPISULA SOLIDISSIMA* SP., IN COASTAL GEORGIA: NURSERY CULTURE

FRANCIS X. O'BEIRN,[1] RANDAL L. WALKER,[2]* DORSET H. HURLEY,[2] AND DEBORAH A. MORONEY[2]

[1]*Virginia Cooperative Fish and Wildlife Research Unit*
Department of Fisheries and Wildlife Sciences
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061-0321
[2]*Shellfish Aquaculture Laboratory*
University of Georgia
Marine Extension Service
20 Ocean Science Circle
Savannah, Georgia 31411-1011

ABSTRACT Growth of the Atlantic surfclam, *Spisula solidissima solidissima,* was compared with that of the southern Atlantic surfclam, *Spisula solidissima similis.* All experimental animals were reared in upweller units at 20°C and fed cultured algae on a daily basis. Over the 14 wk of the study, the Atlantic surfclams grew markedly better (8.9-mm increase in shell length and a 1,103% increase in biomass) than the southern Atlantic surfclams (6.6-mm increase in shell length and 573% increase in biomass). Mortality for both groups was negligible. The mean shell lengths attained for the Atlantic surfclams (15.3 mm) and the southern Atlantic surfclams (13 mm) at the conclusion of the study were large enough to ensure good growth and survival on relocation to a field growout environment. The growth patterns obtained under similar growth conditions further highlight some basic life history differences between these subspecies, which were apparent from other studies.

KEY WORDS: *Spisula solidissima* sp., surfclam, growth, biomass

INTRODUCTION

The Atlantic surfclam, *Spisula solidissima solidissima,* has shown exceptional potential as a candidate for aquaculture in coastal Georgia (Goldberg and Walker 1990, Walker and Heffernan 1990, Walker and Heffernan 1990b). It has demonstrated excellent growth rates, with the ability to achieve commercial size within 1 y postfertilization (Goldberg and Walker 1990), while also achieving sexual maturity in 1 y (Spruck et al. 1995). The southern Atlantic surfclam, *Spisula solidissima similis,* which extends from Massachusetts through the Gulf of Mexico (Abbott 1974), does not occur in sufficient numbers to sustain a natural fishery. Preliminary studies based on growth rates observed in natural populations seem to indicate that the aquacultural potential for this subspecies is good (Walker and Heffernan 1994). Technical difficulties encountered while attempting to rear the southern Atlantic surfclam through larval and juvenile phases has in the past proved prohibitive to their development as an aquacultural candidate (Walker and O'Beirn 1996). Protocols have since been established whereby the successful culture of *S. s. similis* has been achieved through the larval phase and into the nursery phase of culture (Walker et al. 1995, Hurley 1996).

Logically, it would be seem that the next step would be to establish protocols for rearing the juveniles to a size (≈15 mm) large enough to relocate to field growout environments. As an initial step in this process, the growth of the southern Atlantic surfclam was evaluated under protocols established previously for both the Atlantic surfclam and the northern quahog, *Mercenaria mercenaria* (Goldberg 1980, Castagna and Kraeuter 1981). These protocols would require the maintenance of juveniles of either subspecies in a temperature-controlled room (ca. 20°C) throughout the summer months (June to September; Walker and Hurley 1995). Ambient summer water temperatures in Georgia can exceed 30°C for extended periods, which have in the past proved lethal to *S. s. solidissima* (Walker and Heffernan 1994). This reports describes a study whereby the growth of the southern Atlantic surfclam, *S. s. similis,* was compared with that of the Atlantic surfclam, *S. s. solidissima,* under identical culture conditions.

METHODS

On March 11, 1995, Atlantic surfclam, *S. s. solidissima,* individuals were brought into the Shellfish Aquaculture Laboratory (SAL) of the University of Georgia Marine Extension Service on Skidaway Island, GA, from the winter holding cages at House Creek in Wassaw Sound, GA. These animals had all been spawned in the spring of the previous year (1994); thus, they were approximately 1 y old. On return to the laboratory, clams were divided into three separate groups (n = 65, 65, 66) to be used as broodstock.

On March 19, 1995, two groups (n = 65, 66) of the Atlantic surfclam broodstock spawned spontaneously. Larvae from these spawns were reared according to standard hatchery techniques (Castagna and Kraeuter 1981). Initial embryo stocking densities in the rearing tanks were 30 larvae/mL, which were reduced to 7.8 and 6.4 larvae/mL on attainment of the veliger stage of development. Throughout the larval stages, they were fed a ration of 50,000 cells of Tahitian strain *Isochrysis* sp. per milliliter per day, which was increased to 75,000 cells/mL per day when the larvae reached the veliger stage. On April 14, 1995, the first animals set. Most animals were set by April 21. The mean size at set was approximately 300 μm.

*Corresponding author.

On March 11, 1995, southern Atlantic surfclams, *S. s. similis,* were brought into the laboratory and were maintained under conditions similar to those of their Atlantic counterparts. They were approximately the same age as the Atlantic surfclams, having been acquired from the wild (St. Catherines Sound, GA) the previous year (1994) and aged as young-of-the-year (as per Walker and Heffernan 1994). The adults were conditioned until March 31, 1995, when they were induced to spawn with serotonin. The larvae were stocked in the larval tanks at 3.6 larvae/mL and were fed according to the regimen outlined above. Throughout their larval and most of their postset existence, both sets of subspecies were fed cultures of Tahitian strain *Isochrysis* sp. and *Chaetoceros muelleri,* individually and in combination. The southern Atlantic surfclam larvae were set by Day 23 (April 23, 1995), at a mean size of approximately 280 μm.

Both sets of juvenile clams were maintained in raceways (3.6 × 0.6 × 0.3 m) until the commencement of the study. A daily feeding regimen was implemented for both sets of animals. However, because of the constraints imposed by the number of clams being cultured in the hatchery in 1995, food was often in short supply. It was necessary, on occasion, to sacrifice a daily feed for the Atlantic surfclam juveniles. This protocol did appear to retard the growth in the Atlantic surfclams, thus making the sizes of the animals from both species, at the start of the study, comparable.

On June 21, 1995, two tanks (400 L each) were set up in a thermally regulated (ca. 20°C) room at the SAL. Within each tank, 10 upwellers (ca. 40 cm in diameter) were assembled, with 1-mm-pore-size mesh screen bottoms. In each upweller, 40 g wet weight of juvenile surfclams was placed. In each tank, five upwellers contained individuals of *S. s. similis* and five contained *S. s. solidissima.* Each group of animals was assigned randomly to the upwellers. At the commencement of the study, the mean sizes of the Atlantic and southern Atlantic surfclams were 6.40 ± 0.11 (SE) and 6.43 ± 0.16 (SE) mm, respectively.

Each tank was drained on a daily basis, and each upweller and tank were cleaned and rinsed. The tanks were refilled with conditioned (at 20°C) mass algal cultures that had been pumped into the room the previous day. The food consisted of batch cultures of *C. muelleri,* Tahitian strain *Isochrysis* sp., and *Skeletenema* sp. Later in the study, food was supplemented with lyophilized *Isochrysis* and *Chaetoceros.* Every 2 wk, the contents of each upweller were weighed (gram wet weight) and the sizes of 30 animals were measured for maximum posterior-anterior distance (shell length). No sampling was carried out in Week 12. A repeated measures analysis was carried out, comparing the Atlantic surfclam wet weights and shell lengths with those of their southern Atlantic congeners, using analysis of variance and Tukey's Studentized Range Test ($\alpha = 0.05$). The study was terminated on October 10, 1995, 14 wk after its initiation.

RESULTS

Within each subspecies, no significant differences in shell lengths or wet weights were apparent between the two tanks. Consequently, the results of the two tanks were combined for each species. From the onset of this experiment, it was apparent that the Atlantic surfclam juveniles grew more rapidly than their southern counterparts (Figs. 1 and 2). By the first sampling period (Week 2), the proportional increase in wet weight of the Atlantic surfclam was more than double that of the southern surfclams (257 vs. 118%). These differences in proportional increases between the two groups of animals decreased through subsequent samplings. Overall, however, the increases in the Atlantic surfclams (1,103%) were substantially greater than the corresponding increases in wet weight in the southern Atlantic surfclams (513%). The increase in wet weight was linear for both sets of animals throughout the first 6 wk of the study, after which there was a lowering in the rate of increase (Fig. 1).

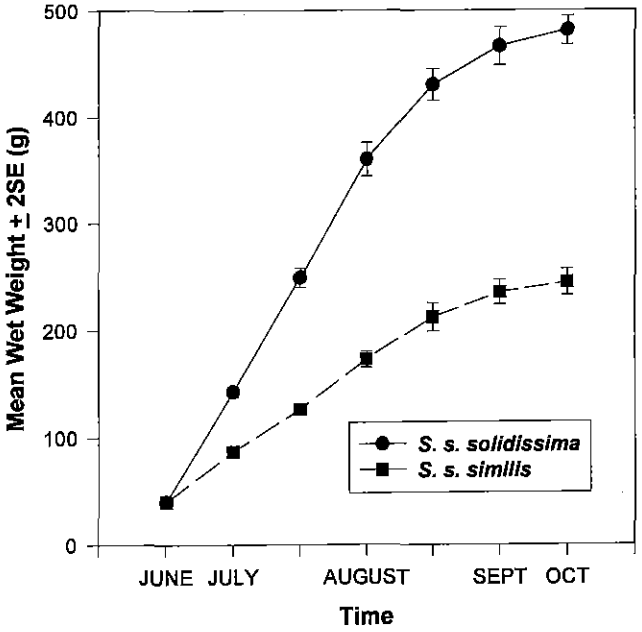

Figure 1. Mean ± 2 SE, wet weights (g) of Atlantic surfclams, *S. s. solidissima,* and southern Atlantic surfclams, *S. s. similis,* obtained throughout the 14-wk grown trial.

No shell length differences existed ($p = 0.8707$) between *S. s. solidissima* and *S. s. similis* on initiation of the study. However, in the subsequent sampling periods, the repeated measures analysis revealed highly significant differences ($p < 0.0001$) between the two groups. The Atlantic surfclams were significantly larger throughout the study than the southern surfclams. Throughout the study, clam numbers in each upweller did not fluctuate drastically,

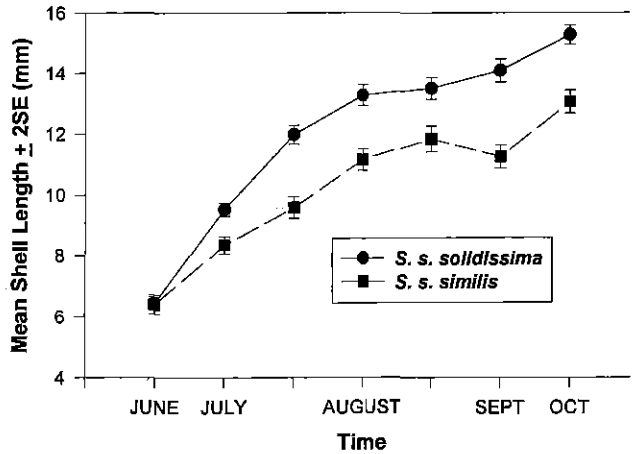

Figure 2. Mean ± 2 SE, shell lengths (mm) of Atlantic surfclams, *S. s. solidissima,* and southern Atlantic surfclams, *S. s. similis,* obtained throughout the 14-wk growth trial.

and values in and around 1,000 clams per upweller were maintained. Consequently, we concluded that there was little or no mortality observed in this study.

DISCUSSION

The Atlantic surfclam, *S. s. solidissima,* performed markedly better that its congener, the southern Atlantic surfclam, *S. s. similis,* in our study. Over the 14 wk of our study, the mean increase in the size of the Atlantic surfclam was 8.9 mm, whereas that of the southern surfclam was 6.6 mm. The percent increase in biomass was 1,103% for *S. s. solidissima,* compared with a 513% increase for *S. s. similis.*

It is appreciated by the authors that the handling of the broodstock, larvae, and postset juveniles was different for the two species. However, on the basis of the literature pertaining to the culture of marine bivalves (Castagna and Kreauter 1981), the southern animals were treated markedly better in terms of larval densities and feeding regimen than their more northerly counterparts, thus seemingly conferring an advantage on them. Inadvertent selection for hardier and more vigorous animals might have occurred with the Atlantic surfclams, given their low food rationing, compared with the more regular feeding regimen used for the southern surfclams before the study. Yet on the basis of the observations throughout the raceway stage of their culture, mortality did not appear to be high in the Atlantic surfclam cohort, suggesting that selection was not occurring. Having acknowledged this, the results are still surprising. The considerable growth exhibited by the Atlantic surfclam over that of the southern Atlantic surfclam was remarkable. The growth increases of *S. s. solidissima* (approx. 9 mm in 14 wk) achieved in this study were modest compared with the 12 mm in 3 wk obtained by Goldberg (1980), who cultured juvenile Atlantic surfclams with unfiltered seawater in a flow-through system. However, given the limitations imposed by low food quantities in this study (as attested by the rapid clearing of the water subsequent to feeding in both tanks), the differences observed between the two studies (Goldberg 1980, this study) were not surprising. The reduction in the growth rate imposed by apparent low food rations is clearly visible in the respective figures relating to both clam biomass and size. After 6 wk, there was a noticeable reduction in the increases in clam biomass values (Fig. 1) and growth rates (Fig. 2). The finding that this reduction was similarly observed in both *S. s. similis* and *S. s. solidissima* suggests that this particular phenomenon was an artifact of suboptimal environmental conditions (i.e., low food). However, the differences in the responses of the congeners to similar environmental conditions throughout the study do suggest that some basic physiological differences exists between the two, under the conditions of this study. Given the differences documented elsewhere between adults of these species, the results of this study might not be as surprising as they seem. The Atlantic surfclam does differ from the southern surfclam in a number of life history characteristics, e.g., maximum size and age, as well as timing of gametogenesis (Abbott 1974, Ropes and Ward 1977, Sephton and Bryan 1990; Kanti et al. 1993, Spruck et al. 1994, Walker and Heffernan 1994).

A costly, yet critical portion of operating a bivalve mollusk hatchery/nursery is the rearing of the animals from the larval stages through juvenile stages, until such a time as they are large enough to plant in the field. A consistent source of quality water, as well as food, is required throughout this phase. This can financially stress even the most efficient of operations. The problem is exacerbated even further if the animals require water temperature other than that of ambient conditions. Given that the optimal temperature for rearing larval *Spisula* sp. has been determined to be in the region of 20°C (Walker and Hurley 1995), that temperature was chosen for the nursery stage in the trials described here. If a facility is constrained by such temperature requirements, the ideal situation would be to grow these animals to planting sizes as soon as possible and, therefore, minimize nursery costs. The sizes achieved for both sets of animals at the end of the study were sufficient to plant in the field such that survival and growth would be maximized (Goldberg and Walker 1990). One apparent advantage the southern Atlantic surfclam has over the Atlantic surfclam is their ability to withstand higher water temperatures, such as those experienced in summer in coastal Georgia. This advantage would enable the culturist to plant the southern animals in the field earlier (September), when the water temperatures are still high enough (approx. 28°C) to induce mortality in the Atlantic surfclam juveniles. Yet, the feasibility of such a protocol would still have to be evaluated, given the relatively small sizes of the southern animals during September (Fig. 2).

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