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Collection of Soft-shell Clam (*Mya arenaria* L.) Spat with Artificial Substrates

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ABSTRACT

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A 2-yr study was initiated in 1996 at a beach near St. Andrews, New Brunswick, Canada, to optimise collection of early juveniles ("spat") of the soft-shell clam, *Mya arenaria*. Six different collector types were tried in 1996 in the mid-intertidal zone. The results indicated that artificial turf (a plastic door-mat type of material) collected most spat, with a mean of 14,325 spat/m^2. Those collectors that accumulated sediment within their structure also collected many more juveniles than collectors without sediment. In 1997, the artificial turf collectors were placed at the high, mid and low intertidal levels to test the effect of tidal level on spat collection. The results showed that the mid-intertidal location maximised spat collection. Further analysis of the results indicated there was a negative correlation between the degree of fouling from the intertidal green alga, *Enteromorpha intestinalis*, and the amount of settlement by soft-shell clam juveniles.

RÉSUMÉ

Chandler, R.A., Robinson, S.M.C., and Martin, J.D. 2001. Collection of soft-shell clam (*Mya arenaria* L.) spat with artificial substrates. Can. Tech. Rep. Fish. Aquat. Sci. 2390: iii + 8 pp.

En 1996, une étude de deux ans a été entreprise sur une plage près de St. Andrews, au Nouveau-Brunswick, Canada; celle-ci avait pour but de déterminer la méthode optimale de collecte de naissain (début du stade juvénile) de la mye *Mya arenaria*. En 1996, on a fait l'essai de six modèles différents de collecteur de naissain dans la partie intermédiaire de la zone intertidale. Les résultats ont démontré que la pelouse artificielle (une matière plastique genre tapis d'entrée) était le substrat qui favorisait la capture de la plus grande quantité de naissain : une moyenne de 14 325 juvéniles/m^2. Les collecteurs à l'intérieur desquels les sédiments pouvaient s'accumuler ont également capturé davantage de juvéniles que les collecteurs dépourvus de sédiments. En 1997, les collecteurs faits de pelouse artificielle ont été placés aux niveaux supérieur, intermédiaire et inférieur de la zone intertidale afin d'évaluer l'effet des niveaux de marée sur la collecte du naissain. Les résultats démontrent que la collecte optimale de naissain a lieu au niveau intermédiaire de la zone intertidale. Une analyse plus poussée des résultats révèle une corrélation négative entre le degré de salissure par l'algue verte, entéromorphe intestinal, et le succès de la fixation par les myes juvéniles.

INTRODUCTION

Soft-shell clams, *Mya arenaria* Linneus, are a commercially important bivalve with an extensive range in the northern hemisphere, occurring on both sides of the Atlantic Ocean and along the Pacific coast of North America (Miner 1950; Abbott 1974). In the northwest Atlantic, harvest fisheries exist in all New England states and in all east coast provinces (Newell 1983; Jenkins et al. 1997). The Charlotte County area of the Bay of Fundy has historically been a major clam producer as it has an extensive intertidal region. Formal catch records from the Canada Dept. of Fisheries and Oceans on this species date to the late 1800s. Clams are found in sediment ranging from soft mud to sandy-gravel, although not all beaches support clam populations (pers. obs.).

Spawning of the soft-shell clam occurs in the early summer, after which the larvae remain planktonic for 2-3 weeks, depending on the temperature, before settling to the bottom (Newell 1983). At settlement, the clam changes from a pelagic larva to a benthic juvenile stage and attaches itself to objects on the bottom using byssal threads. Settlement appears to occur primarily in the lower intertidal/shallow subtidal region (Gunther 1992), after which the juveniles tend to move up the beach over time (Smith 1955, Matthiesson 1960; Scapati 1984). This up-shore movement is similar to a conspecific bivalve, *Macoma balthica*, which uses byssal drifting to migrate up the beach (Beukema and de Vlas 1989; Armonies 1992; Armonies and Hellwig-Armonies 1992). Up-beach movement of juveniles appears to be a behavioural response related to predation pressure in the lower intertidal zone that involves bio-physical coupling to local hydrodynamic forces (such as current and turbulence) on the beach (Matthiessen 1960; Emmerson and Grant 1991; Roegner et al. 1995). Predators such as *Euspira (=Lunatia) heros* (Commito 1982), *Crangon crangon* (Moller and Rosenberg 1983), *Carcinus maenas* (i.e. Moller and Rosenberg 1983, Newell 1983) and *Cancer productus* (Zaklan and Ydenberg 1997) can have major impacts on population numbers of *M. arenaria.* Moller and Rosenberg (1983) report that juvenile densities of 132,000/m^2 in a shallow bay in Sweden were severly reduced by predators within 2 mo.

Landings of soft-shell clams from the commercial fishery in the Bay of Fundy have decreased over the last century to historically low levels (Fig. 1). The same general declining trend has also been observed in eastern Maine (Beal 1991; Beal et al. 1995). The causes of the population decline are likely both biological (i.e. green crab, *C. maenus*, predation (Jenkins et al. 1997)) and anthropogenic (over-harvesting, pers. obs.). The low levels of clam production have resulted in an interest by the fishing industry and culturists in returning the industry to its earlier productivity so that enhanced economic benefits can be realised by the coastal communities.

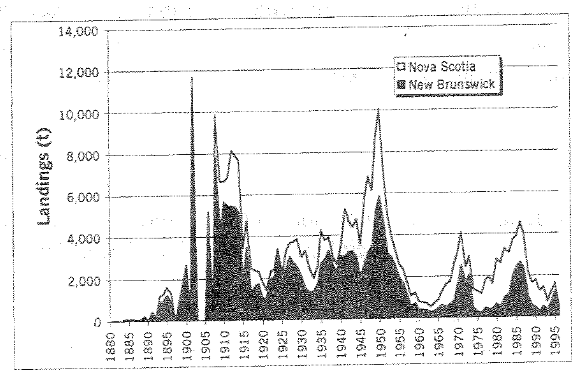

Fig. 1. Landing records of soft-shell clams in the Bay of Fundy from Nova Scotia and New Brunswick. The data are cumulative (i.e. Nova Scotia is added to New Brunswick). Data are from the Statistics Branch, Dept. Fisheries and Oceans.

Previously, the general approach taken by coastal communities to enhance the clam industry has been to increase the recruitment rate to the population by adding juveniles. Such juveniles have often been produced in a hatchery and then planted on beaches for subsequent harvest after they have grown to full size. Recent advances in the production of hatchery-reared, soft-shell clam juveniles by the Beal's Island Shellfish Hatchery in Maine and the Centre Marin Hatchery in Shippagan, New Brunswick, have brought the cost of juvenile clams (also known as "seed") down to about $10.00-12.00/1000 ($Can.). Clams are now available for seeding in the spring, approximately 6 mo ahead of the natural populations.

While making observations on the spread of the filamentous alga, *Enteromorpha intestinalis*, over clam flats in Passamaquoddy Bay in an unrelated study on clam growth, the authors noticed that large numbers of soft-shell clam spat were attached to, and entangled in, this alga. This observation corroborated previous studies showing a movement stage of early juveniles across the beach. It also suggested that if a suitable artificial collector could be designed that could be set out, retrieved, and transported with relative ease, it would enable farmers to collect spat naturally in one area and plant them in another. Therefore, in 1996, six types of material were tested at mid-tide levels on a clam flat near the Blockhouse beach in St. Andrews Harbour to determine spat collection efficiency. In 1997, the most promising one of these collectors was placed on the same beach at low, mid and high tide locations to examine spatial patterns of collection efficiency.

MATERIALS AND METHODS

STUDY SITE

The research was conducted on the Blockhouse beach in St. Andrews, New Brunswick (Fig. 2). This is a good commercial, clam-producing beach, with a mixture of sand-mud forming a firm surface, ideal for commercial digging. The 5-m^2 plot, where we placed our collectors, was situated in a low clam density area to avoid possible interference with commercial clam diggers. *E. intestinalis* was relatively widespread on this beach, and we attempted to place our plot in an area of lower incidence in order to avoid confounding effects from the alga.

REPRODUCTIVE SURVEY (1989-90)

Timing of collector deployment was based on earlier sampling to determine the reproductive cycle of the clams at the Blockhouse beach. From January to December in 1989 and 1990, samples of clams (n=30) of a wide size range (20–60 mm) were collected monthly from the mid-intertidal zone of the beach and measured to the nearest 0.1 mm and weighed whole to the nearest 0.01 g. The clams were then dissected into two components: 1) the combined reproductive and visceral mass (RVM) and 2) the remaining soft tissue (RST) including mantle, gills, foot and siphon. Each of the two components was weighed to the nearest 0.01 g after being blotted on absorbent paper, and a gonadosomatic index (GSI) was calculated as:

$$\mathbf{GSI} = RVM/(RVM + RST) * 100 \qquad (1)$$

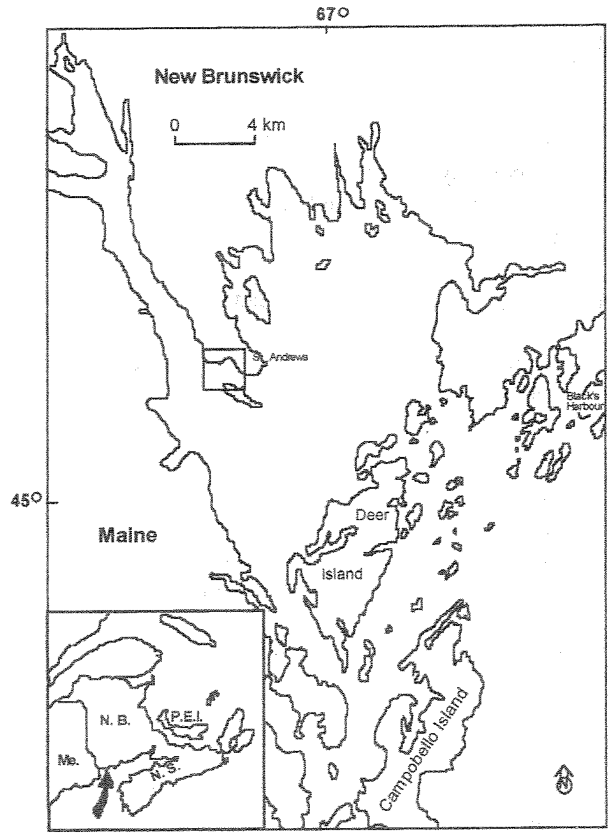

Fig. 2. Location of study site for soft-shell clam spat collectors.

This was then compared as means on a monthly basis for all size classes combined.

1996 TRIALS

Six types of clam spat collectors were assessed in 1996:

1. "Artificial turf" pad - four turf pads (similar to common doormats with rosettes of plastic bristles), each 12 x 39 cm with 18-mm deep fibres, were attached to a base made of plastic-coated lobster cage mesh. This created a mat 48 x 39 cm. Two adjacent corners were tied to wooden stakes anchored in the beach to hold it in place.

2. Monofilament "sandwich" - 250 g of gillnetting were spread evenly and sandwiched between two 58 x 38 cm sheets of plastic-coated lobster cage mesh; the meshes were 30 mm^2. Two adjacent corners were tied to wooden stakes to hold it in place.

3. Plastic mesh "sandwich" - A modification of #2 collector by substituting monofilament gillnetting for ¼ inch plastic mesh (Internet™, 2730 Nevada Ave. N, Minneapolis, Minnesota, 55427). Twelve layers of clear plastic mesh were sandwiched in a 38 x 62 cm frame and staked to the substrate.

4. Scallop spat collector - a Japanese onion bag (1.5-mm mesh opening) with 250 g of gillnetting stuffed inside. The bag was staked at both ends in the sediment to hold it in place.

5. Black Biocord™ - a 140-cm long piece of black Biocord™ (Fukui North America, P.O. Box 119, Island View Dr., Golden Lake, Ontario, K0J 1X0) was twisted and tied at each end to stakes. This cord had a rope core with 12-cm long filaments woven in to increase the surface area. It is commonly used in bio-filters and for mussel spat collection.

6. White Biocord™ - a 140-cm long piece of white Biocord™ was twisted and tied at each end to stakes. This collector was similar to #5 except the filaments were 10-cm long monofilament fibres.

These collectors were put out June 11, 1996 and left undisturbed until they were retrieved on October 16, 1996, at which time they were detached from their stakes, carefully placed in plastic bags and returned to the lab for examination.

LAB PROCEDURE

The collectors were hosed down with a saltwater spray into a series of three screens with mesh sizes of 4 mm, 2 mm and 0.25 mm. Clams from the 4-mm and 2-mm screens were sorted by hand, while the clams from the 0.25-mm screen were sorted by the procedure described in Robinson and Chandler (1992) using a floatation technique. Briefly, sediment samples were washed using an elutriation technique to float off the light organics; the remaining sediment was then put into a high specific gravity solution (sodium polytungstate) to separate the clams from the sediment. All clams were counted, with a subsample being videotaped and subsequently measured for shell heights using an image analysis system (Optimas™). The associated species were noted and recorded as being present, common or abundant.

1997 TRIALS

In 1997 we used the artificial turf pads (Fig. 3) to examine inter-annual variability of settlement and to assess spat settlement at the low, middle and high tide levels. Three 30 x 20 cm collecting pads were staked in place at each of the tidal levels on the Blockhouse beach. The three sites had different characteristics apart from duration of tidal exposure:

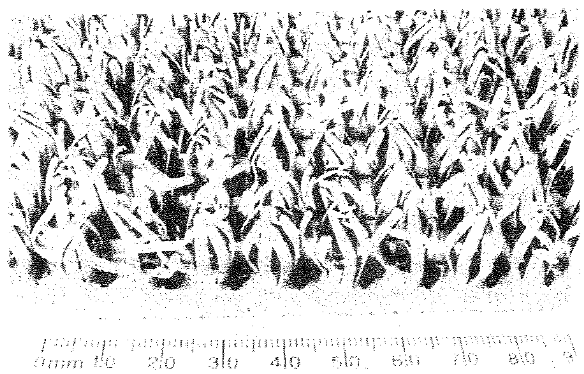

Fig. 3. Photograph of "artificial turf" showing the rosettes of plastic bristles.

1. The lower site was roughly 1.5 h from the low water mark and had a fine, soft mud sediment. There were only a very few, exceptionally large clams in the vicinity.

2. The middle site was near the plot used in the 1996 study, at approximately half tide, roughly 2.5 h from the low water mark. It had good populations of various sized clams. The sediment was a firm mud-sand that made it ideal for commercial harvesting, although during the summer months some of the area was heavily covered with algae, mainly *E. intestinalis*.

3. The upper site was about 4 h from the low water mark. The sediment was very firm with a coarse sand-mud mixture laying thinly over outcroppings of red sandstone ledges. The site was on the fringe of a dense population of small clams (*M. arenaria* and *M. balthica*) which was present annually based on past observations by the authors.

The collectors were put out June 13, 1997 and retrieved on October 23, 1997. As in the 1996 study, upon retrieval, the collectors were carefully placed into separate plastic bags and returned to the lab where the sediment was processed as described above.

A post-hoc analysis was done to examine the effect of *E. intestinalis* on soft-shell clam spat densities. Clam densities were compared between subsamples taken from the low water collection site where *E. intestinalis* was present in varying degrees. The number of spat in *E. intestinalis* was recorded as well. The biomass of *E. intestinalis* in a sample was measured by wet weight after being blotted on absorbent paper until excess water was removed.

RESULTS

REPRODUCTIVE SURVEY (1989-1990)

Monthly sampling in 1989-90 showed the mean gonadosomatic index in this population peaked at approximately 18-20 during June in both years (Fig. 4). It subsequently declined until December. There was either a slight decrease or no change in the index after December until April when the index climbed quickly from 10-12 to the peak in June.

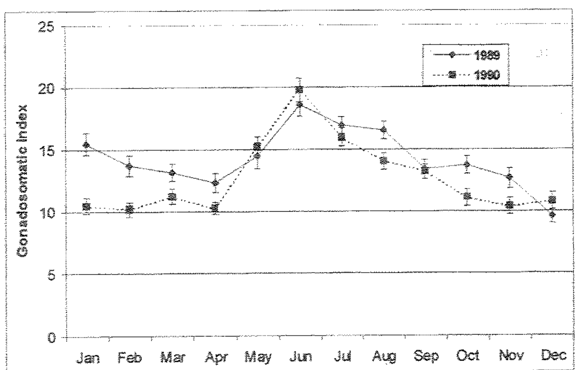

Fig. 4. Mean monthly gonadosomatic indices from soft-shell clams harvested from the Blockhouse, St. Andrews in 1989-90 (n=30 for all samples). Error bars represent 1 standard error.

1996 TRIALS

Observations on retrieval showed that the Biocord™ collectors were most fouled and the spat bag was least fouled. Most collectors were partially fouled with algae, the most common species being *E. intestinalis*. The mesh of the sandwiched monofilament and plastic mesh collectors, as well as the artificial turf collector, were heavily impacted with sediment as well as being partially covered with algae.

Of the six types of collectors put out, the artificial turf pad collected the most spat: 15,070 spat/m^2 (Fig. 5a). The "plastic sandwich" and the "monofilament sandwich" also had high numbers: 10,000 and 6,038/m^2, respectively. The two Biocord™ collectors had some settlement while the spat bag with the monofilament mesh inside had the least. There was a significant difference between those collectors with sediment trapped inside (artificial turf, plastic mesh, monfilament mesh) and those without (black and white Biocord™ and the spat bag) ($p < 0.05$, Students t-test). Mean clam spat shell lengths were largest in the spat bag (average 2.78 mm), with the black Biocord™ having the smallest (1.78 mm) (Fig. 5b).

The Biocord™ had the most fouling from *E. intestinalis* and the spat bag had the least. The most common fouling organism was the blue mussel, *Mytilus edulis*, with 5,656 individuals attached to the black Biocord™.

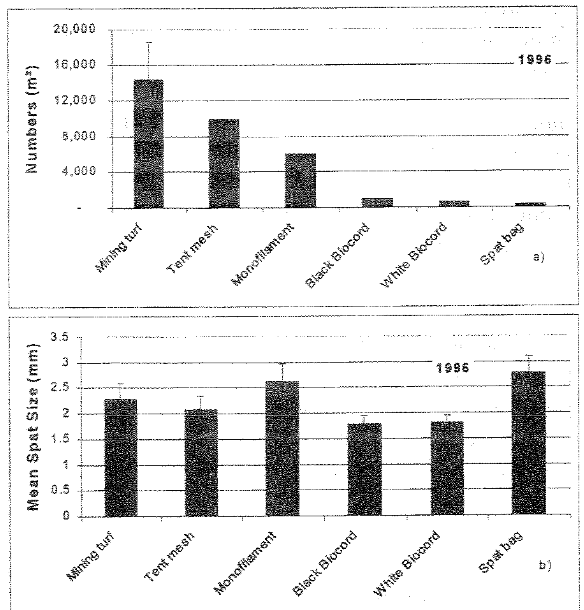

Fig. 5 a.) Spat settlement densities on experimental substrates deployed at the mid-intertidal region of the Blockhouse beach, St. Andrews. b.) Mean clam spat size from the experimental collectors. Error bars represent 1 standard error.

1997 TRIALS

Soft-shell clam spat densities on the artificial turf were highest in the mid-intertidal zone (12,158/m^2) and lowest in the upper zone (1,360/m^2) (Fig. 6a). Intermediate numbers were found on the low water collector (9,088/m^2). Mean sizes were larger in the upper and mid levels of the beach (Fig. 6b). The mean size of spat from the mid-intertidal

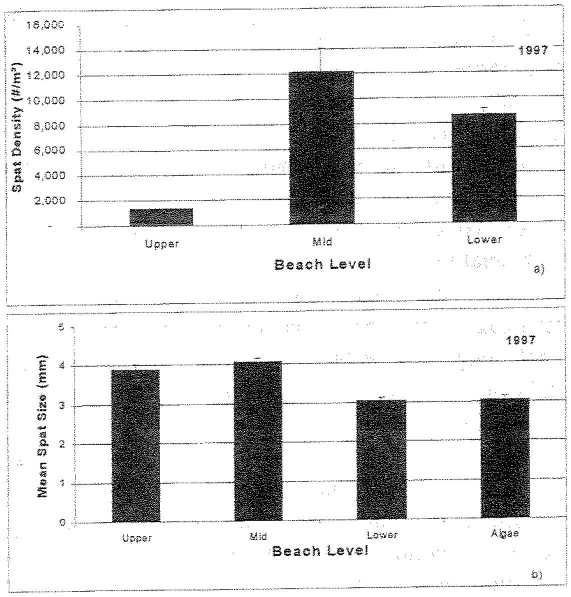

Fig. 6 a.) Spat settlement densities on artificial turf deployed at various intertidal regions of the Blockhouse beach, St. Andrews. b.) Mean clam spat size from the experimental collectors. Error bars represent 1 standard error.also larger in 1997 (4.1 mm) than the size found in 1996 (2.3 mm) on the artificial turf.

zone was also larger in 1997 (4.1 mm) than the size found in 1996 (2.3 mm) on the artificial turf.

The size distributions of the spat differed among the intertidal levels. The upper and mid beach had the largest animals, the widest distribution of size classes and were the most similar (Fig. 7). The lower beach and the sample of clams from the *E. intestinalis* were smaller and had a more limited distribution of size classes.

There was a weak inverse relationship between clam spat densities found in panels at all three tidal heights and the degree of algal cover (Fig. 8). The highest spat densities were only found in mats with algal densities of 200 g/m^2 or less. Two observations were made on numbers of spat found in the algae as opposed to the numbers in the soil of the same sample: 7 in algae versus 198 in the sediment and 17 in algae versus 217 in the sediment.

There were several other species associated with the soft-shell clam spat found in the collectors. Mussels and periwinkles were the most abundant, with *M. balthica* abundant in the upper intertidal area (Table 1). Other species present were several types of polychaetes, amphipods and small gastro-

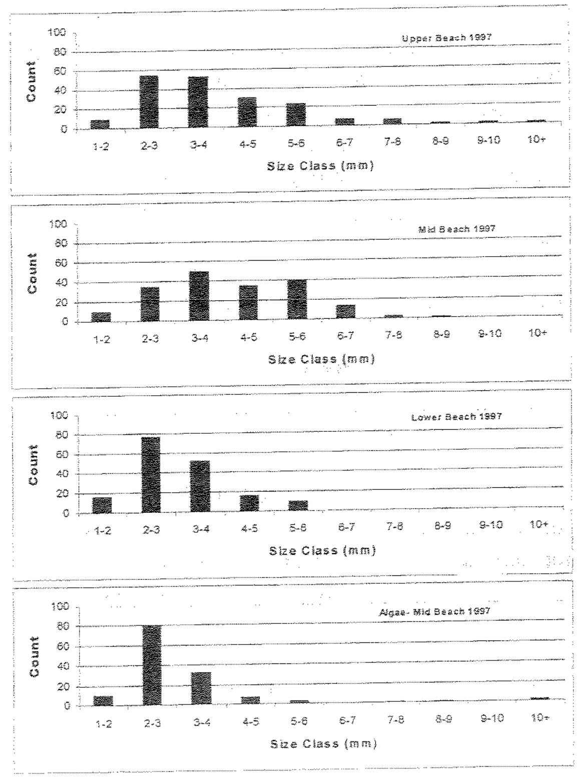

Fig. 7. Size frequency distributions of clam spat harvested at different intertidal levels in 1997 with the artificial turf collectors.

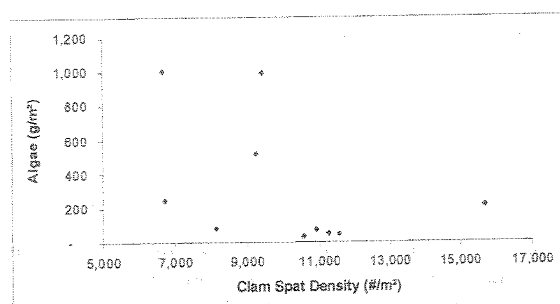

Fig. 8. Relationship between the biomass of algae on the collectors and the density of clam spat recovered from the panels.

Table 1. List of other associated species found in settlement substrates.

Species	Common Name	Abundance
Littorina littorea	Common periwinkle	Abundant
Mytilus edulis	Blue mussel	Abundant
Macoma balthica	Little Macoma	Abundant-present
Hydrobia minuta	Salt marsh spire shell	Common
Polychaete spp.	Marine worm	Present
Gammarus spp.	Amphipod	Present
Carcinus maenas	Green crab	Rare

pods. One small green crab was found on one of the panels.

DISCUSSION

This study demonstrated that it was feasible to collect early juveniles of soft-shell clams using an artificial settlement medium. The best material was the artificial turf, as it readily collected silt and provided a suitable environment for the early juveniles as they were transported up the beach.

The early life history dynamics observed in this study are similar to other published studies of the soft-shell clam. Based on the decrease in the mean values for the gonadosomatic index, the clams at the Blockhouse begin to spawn in June to early July. This is a little later than the same species in Germany, where spawning occurs in late May and mid-June (Gunther 1992) and in late May in Sweden (Moller and Rosenberg 1983). The sampling frequency was not enough to determine spawning patterns of less than a monthly period. Once settlement occurred, there appeared to be movement up the beach. Based on the distribution of sizes at the three tidal levels sampled (i.e. smallest sizes at the lower site and also in the algae in the mid tidal area), it would appear that the settlement may be taking place in the lower intertidal or shallow subtidal zone. The early juveniles may then be moving up the beach, either passively with the current or with byssal drifting, until they encounter suitable habitat, in this case the experimental substrates we deployed. This redistribution process is consistent with patterns found by other researchers. Gunther (1992) found that settlement in *M. arenaria* in Sweden was limited to the lower part of the beach. Smith (1955), using a series of trays, demonstrated the movement of small juvenile soft-shell clams over clam beaches in Massachusetts and suggested that movement can continue until the animals reach a shell length of 12-13 mm. This is in agreement with Matthiessen (1960) who also reported that appreciable movement of juvenile soft-shell clams occurred between 2 and 15 mm shell length in Massachusetts. Scapati (1984) showed that juvenile soft-shell clams in New Jersey had different distributions than adult animals.

The actual mechanism for early juvenile clam movement is probably a combination of both physical and biological processes. The maximum tidal range in this area is 8.3 m (Trites and Garrett 1983) and there are times when the wind can create 1-m waves in the water overlying the beaches during a flood tide (Robinson, pers. obs.). Matthiessen (1960) suggested hydrodynamic forces caused the distribution patterns of the soft-shell clam population size classes and Roegner et al. (1995) demonstrated in a flume that transport of soft-shell clam juveniles occurred at velocities greater than 20 cm/s. The latter study estimated that transport distances could range from 10 to 100 m; however, the animal itself may play an active role. The intertidal bivalve, *M. balthica*, has been observed to secrete a byssal thread and use it in conjunction with a tidal flow or wind-induced currents to move up the beach (Armonies and Hellwig-Armonies 1992). A study in the Wadden Sea showed that *M. arenaria* was occasionally found in nets designed to sample for byssal drifting, although in much lower number than *M. balthica* (Armonies 1992). This would support the notion that soft-shell clams are capable of at least limited active transport.

The collection densities of spat in the collectors were the highest in the mid-intertidal area. The reasons for this are likely related both to habitat and the predation pressure. In the upper intertidal area, the grain size of the sediment was much coarser than further down the beach and as a result, the collection mats were only filled approximately 30%. This was probably one of the reasons for the lower settlement. The collectors on the mid and lower sections on the beach were estimated to be filled to about 90% of their capacity. Although spat probably initially attached to the fibers by a byssal thread (or were captured by the fibers), it would appear that there is value in the collector's ability to hold sediment, thus providing a more suitable environment in which spat may settle and grow. It may also provide some refuge from predation. Commito (1982) and Moller and Rosenberg (1983) showed that *Euspira (=Lunatia) heros*, *C. crangon*, and *C. maenas* can have major impacts on the survival of juvenile *M. arenaria*. All of these species are present at the Blockhouse beach, which may partly explain why such movement takes place. Zaklan and Ydenberg (1997), in a model of why clams burrow, demonstrated that *M. arenaria* were more at risk to predation from crabs in the lower intertidal areas than in the upper intertidal areas.

There was a negative impact by the alga, *E. intestinalis*, on the collection ability of the settlement substrates for juvenile soft-shell clams. The available data were not adequate to determine whether this was due to the *E. intestinalis* partially sealing off the collector to the settling juveniles or trapping them and holding them. Work by Vadas and Beal (1987) in Maine showed that *E. intestinalis* could trap juvenile soft-shell clams. The algae and clams were then wound up into long "algal ropes" due to local hydrographic conditions. More work is required to determine the fate of juveniles trapped in the *E. intestinalis* mats and the impact these may have on recruitment. This phenomenon is especially important as these *E. intestinalis* beds seem to be increasing in size and abundance with increasing coastal zone nutrient enrichment (Robinson, pers. obs.).

The practical implication of this study is that it would appear feasible on some beaches to collect natural spat of soft-shell clams from collectors in the mid-intertidal region. Based on 2 yr sampling data, there was relatively little variability in the density of juveniles collected with the artificial turf. Therefore, if an operation wished to collect 1 million seed for culture, this would amount to approximately 67 m^2 of artificial turf, an area that could easily be accommodated on most shellfish leases. Once the juveniles were sorted from the sediment, a procedure essential in areas that are subject to ice coverage in the winter, they could be overwintered in mesh bags subtidally according to the protocols of Beal et al. (1995) and then either seeded on the beach (Beal 1991), or grown in suspended intermediate culture for 1 yr prior to seeding, in order to reduce predation mortality (C. Gray and S. Robinson, unpub. data). Another feature of this collection method is that it could also fit into supplementing hatchery production. Because the amount of spat collected from the natural populations would be known by late fall, a hatchery could predict what levels of seed would be required for the spring and then start the spawning process in December-January. This, of course, assumes a predictable mortality rate over the winter.

The final stage of development for this technique would be the design of an automated sorter to remove and grade the juvenile clams from the sediment. This phase will be attempted when the local clam industry is ready to enhance and grow clams on the beaches.

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