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Annotated Bibliography II of the Hard Clam *Mercenaria mercenaria*

J. L. McHugh
Marjorie W. Sumner

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA TECHNICAL REPORT NMFS

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34. Additions to a revision of the shark genus *Carcharhinus*: Synonymy of *Aprionodon* and *Hypoprion*, and description of a new species of *Carcharhinus* (Carcharhinidae), by J. A. F. Garrick. November 1985, 26 p.

35. Synoptic review of the literature on the Southern oyster drill *Thais haemastoma floridana*, by Philip A. Butler. November 1985, 9 p.

36. An egg production method for estimating spawning biomass of pelagic fish: Application to the northern anchovy, *Engraulis mordax*, by Reuben Lasker (editor). December 1985, 99 p.

37. A histopathologic evaluation of gross lesions excised from commercially important North Atlantic marine fishes, by Robert A. Murchelano, Linda Despres-Patanjo, and John Ziskowski. March 1986, 14 p.

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40. Potential impact of ocean thermal energy conversion (OTEC) on fisheries, by Edward P. Myers, Donald E. Hoss, Walter M. Matsumoto, David S. Peters, Michael P. Seki, Richard N. Uchida, John D. Ditmars, and Robert A. Paddock. June 1986, 33 p.

41. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes, by James A. Bohnsack and Scott P. Bannerot. July 1986, 15 p.

42. Effects of temperature on the biology of the northern shrimp, *Pandalus borealis*, in the Gulf of Maine, by Spencer Apollonio, David K. Stevenson, and Earl E. Dunton, Jr. September 1986, 22 p.

43. Environment and resources of seamounts in the North Pacific, by Richard N. Uchida, Sigeiti Hayasi, and George W. Boehlert (editors). September 1986, 105 p.

44. Synopsis of biological data on the porgies, *Calamus arctifrons* and *C. proridens* (Pisces: Sparidae), by George H. Darcy. September 1986, 19 p.

45. Meristic variation in *Sebastes* (Scorpaenidae), with an analysis of character association and bilateral pattern and their significance in species separation, by Lochai Chen. September 1986, 17 p.

46. Distribution and relative abundance of pelagic nonsalmonid nekton off Oregon and Washington 1979-84, by Richard D. Brodeur and William G. Pearcy. December 1986, 85 p.

47. Reproduction, maturation, and seed production of cultured species: Proceedings of the twelfth U.S.-Japan meeting on aquaculture, Baton Rouge, Louisiana, October 25-29, 1983, by Carl J. Sindermann (editor). February 1987, 73 p.

48. Widow rockfish: Proceedings of a workshop, Tiburon, California, December 11-12, 1980, by William H. Lenarz and Donald R. Gunderson (editors). January 1987, 57 p.

49. Reproduction, movements, and population dynamics of the southern kingfish, *Menticirrhus americanus*, in the northwestern Gulf of Mexico, by Stephen M. Harding and Mark E. Chittenden, Jr. March 1987, 21 p.

50. Preparation of acetate peels of valves from the ocean quahog, *Arctica islandica*, for age determinations, by John W. Ropes. March 1987, 5 p.

51. Status, biology, and ecology of fur seals: Proceedings of an international workshop, Cambridge, England, 23-27 April 1984, by John P. Croxall and Roger L. Gentry (editors). June 1987, 212 p.

52. Limited access alternatives for the Pacific groundfish fishery, by Daniel D. Huppert (editor). May 1987, 45 p.

53. Ecology of east Florida sea turtles: Proceedings of the Cape Canaveral, Florida, sea turtle workshop, Miami, Florida, February 26-27, 1985, by Wayne N. Witzell (convener and editor). May 1987, 80 p.

54. Proximate and fatty acid composition of 40 southeastern U.S. finfish species, by Janet A. Gooch, Malcolm B. Hale, Thomas Brown, Jr., James C. Bonnet, Cheryl G. Brand, and Lloyd W. Reiger. June 1987, 23 p.

55. Proximate composition, energy, fatty acid, sodium, and cholesterol content of finfish, shellfish, and their products, by Judith Krzynowek and Jenny Murphy. July 1987, 53 p.

56. Some aspects of the ecology of the leatherback turtle *Dermochelys coriacea* at Laguna Jolova, Costa Rica, by Harold F. Hirth and Larry H. Ogren. July 1987, 14 p.

57. Food habits and dietary variability of pelagic nekton off Oregon and Washington, 1979-1984, by Richard D. Brodeur, Harriet V. Lorz, and William G. Pearcy. July 1987, 32 p.

58. Stock assessment of the Gulf menhaden, *Brevoortia patronus*, fishery, by Douglas S. Vaughan. September 1987, 18 p.

59. Atlantic menhaden, *Brevoortia tyrannus*, purse seine fishery, 1972-84, with a brief discussion of age and size composition of the landings, by Joseph W. Smith, William R. Nicholson, Douglas S. Vaughan, Donnie L. Dudley, and Ethel A. Hall. September 1987, 23 p.

60. Gulf menhaden, *Brevoortia patronus*, purse seine fishery, 1974-85, with a brief discussion of age and size composition of the landings, by Joseph W. Smith, Eldon J. Levi, Douglas S. Vaughan, and Ethen A. Hall. December 1987, 8 p.

61. Manual for starch gel electrophoresis: A method for the detection of genetic variation, by Paul B. Aebersold, Gary A. Winans, David J. Teel, George B. Milner, and Fred M. Utter. December 1987, 19 p.

62. Fishery publication index, 1980-85; Technical memoradum index, 1972-85, by Cynthia S. Martin, Shelley E. Arenas, Jacki A. Guffey, and Joni M. Packard. December 1987, 149 p.

63. Stock assessment of the Atlantic menhaden, *Brevoortia tyrannus*, fishery, by Douglas S. Vaughan and Joseph W. Smith. January 1988, 18 p.

64. Illustrated key to penaeoid shrimps of commerce in the Americas, by Isabel Pérez Farfante. April 1988, 32 p.

65. History of whaling in and near North Carolina, by Randall R. Reeves and Edward Mitchell. March 1988, 28 p.

66. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific, by M. James Allen and Gary B. Smith. April 1988, 151 p.

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U.S. DEPARTMENT OF COMMERCE
C. William Verity, Jr., Secretary
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National Marine Fisheries Service
James W. Brennan, Assistant Administrator for Fisheries

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Contribution no. 584 of the Marine Sciences Research Center of the State University of New York, Stony Brook.

Introduction

In this era of proliferating scientific information it is difficult to keep up with the literature, even in one's own field. Review articles are helpful in summarizing the status of knowledge. In oyster biology, several such published reviews have been of great help to working scientists. The outstanding contributions that come to mind are those by Baughman (1948), Korringa (1952), Joyce (1972), Breisch and Kennedy (1980), and Kennedy and Breisch (1981). If done well, such compilations serve as checkpoints, eliminating or vastly reducing the need to consult the literature in detail.

On Long Island, New York, where the hard clam *Mercenaria mercenaria* is the major commercial resource, we have felt the need for some time for a compendium of knowledge on this important mollusk. Several years ago my secretary, students, and I began to gather materials for an annotated bibliography. We have already published a collection of 2233 titles (McHugh et al. 1982), nearly all accompanied by abstracts, and in this publication we have added another 460.

The experience has been rewarding. We have been surprised at the extent of the literature, much of it only remotely related to the shellfish industry itself, but nevertheless throwing light on the biology, physiology, and many other aspects of the scientific knowledge of hard clams.

The following bibliography is divided into three parts. Part 1 comprises the bulk of the bibliography, while Parts 2 and 3 contain additional titles that we decided to include during editing, submission, and approval of the manuscript for publication. All three parts are indexed together, however.

We also reexamined those titles in the previous bibliography (McHugh et al. 1982) which did not include abstracts. These are included in Parts 2 and 3 of this bibliography. Most of these contained no specific reference to *Mercenaria mercenaria*. A few searches were terminated for various reasons.

Acknowledgments

This work was sponsored by the New York Sea Grant Institute under a grant from the Office of Sea Grant, National Oceanographic and Atmospheric Administration, U.S. Department of Commerce. The junior author carried most of the load of searching the literature, and her familiarity with the main library of the State University of New York at Stony Brook and its various branches and their staffs was of inestimable value. Thanks also to the staffs of these libraries for helping to locate elusive papers, including many through interlibrary loan. Preparation of the final copy was done by Carol Case, assisted by John Ellsworth.

Citations

Baughman, J.L.
1948. An annotated bibliography of oysters, with pertinent material on mussels and other shellfish and an appendix on pollution. Texas A&M Research Found., College Station, TX 77843, 749 p.

Breisch, L.L., and V.S. Kennedy.
1980. A selected bibliography of worldwide oyster literature. Md. Sea Grant Publ. UM-SG-TS-80-11, Univ. Md., College Park, MD 20742, 309 p.

Joyce, E.A., Jr.
1972. A partial bibliography of oysters, with annotations. Spec. Sci. Rep. 34, Mar. Res. Lab., Fla. Dep. Nat. Resourc., Tallahassee, FL 32303, 846 p.

Kennedy, V.S. and L.L. Breisch.
1981. Maryland's Oysters: Research and Management. Md. Sea Grant Publ. UM-SG-TS-81-04, Univ. Md., College Park, MD 20742, 286 p.

Korringa, P.
1952. Recent advances in oyster biology. Q. Rev. Biol. 27:266-308, 339-365.

McHugh, J.L., Marjorie W. Sumner, P.J. Flagg, D.W. Lipton, and W.J. Behrens.
1982. Annotated bibliography of the hard clam (*Mercenaria mercenaria*). NOAA Tech. Rep. NMFS SSRF-756. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Seattle, WA 98115, 845 p.

1 Aarset, Arne Vollan. 1982.

Freezing tolerance in intertidal invertebrates (a review). Comp. Biochem. Physiol. 73A(4):571-580.

Freezing tolerance in intertidal invertebrates is restricted to species in the supra- or eulittoral zone of temperate and Arctic regions. Cold resistance of animals appears mainly to be based on tolerance to tissue ice formation. Invertebrates found naturally in seawater of high salinity are more cold-tolerant than those in brackish waters. Improved freezing resistance can be obtained by acclimating animals to low temperature in conjunction with high salinity. Differences in lethal temperatures among bivalves appear to be caused by differences in the freezable fraction of tissue water. The intertidal mussel *Mytilus edulis* possesses less freezable water than the subtidal quahog *Venus mercenaria*. (Modified author's abstract - J.L.M.)

2 Ackman, R.G. 1982.

Fatty acid metabolism of bivalves. *In* Pruder, G.D., C.J. Langdon, and D.E. Conklin (eds.), Biochemical and physiological approaches to shellfish nutrition. Proc. 2d Int. Conf. on Aquacultural Nutrition, p. 358-376. La. State Univ., Baton Rouge, LA 70803.

Reviews papers by Klingensmith and Klingensmith, and Stillway abstracted elsewhere in this volume. (J.L.M.)

3 Adamkewicz, Laura, Stephan R. Taub, and J.R. Wall. 1982.

Genetics of the clam *Mercenaria mercenaria*. II. Size and genotype. Am. Malacol. Union, Genetics Symp.:107.

Clams of known genotype, from a wild population of known composition, were individually induced to spawn. All gametes were mixed at one time to produce a randomly bred cohort of clams. After one year the sample of 1081 was measured and their enzyme phenotypes determined by a starch gel electrophoresis for Pgd, Lap, Pgi, Pgm-2 and Pgm-3. The genotype frequencies differed significantly from Hardy-Weinberg expectation for all genes except Pgd, but only for Lap was the deviation associated with heterozygosity, for which there was a striking deficiency. The explanation must be differential survival. (J.L.M.)

4 Adamkewicz, Laura, Stephan R. Taub, and J.R. Wall. 1984.

Genetics of the clam *Mercenaria mercenaria*. I. Mendelian inheritance of allozyme variation. Biochem. Genetics 22(3-4): 215-219.

Hard clams (*Mercenaria mercenaria*) were spawned individually and mated to produce two sibships. Progeny showed complete conformity with Mendelian expectations in segregation and assortment of ratios for five allozyme loci: Lap, Pgi, Pgm-2, Pgm-3 and 6-Pgd. (J.L.M.)

5 Adamkewicz, Laura, Stephan R. Taub, and J.R. Wall. 1984.

Genetics of the clam *Mercenaria mercenaria*. II. Size and genotype. Malacologia 25(2):525-533.

Clams (*Mercenaria mercenaria*) of known genotype, from a wild population of known composition, were individually induced to spawn. All gametes were mixed at one time to produce a randomly bred cohort of clams. After one year, 1081 of these clams were measured and their phenotypes determined by starch gel electrophoresis for the enzymes Pgd, Lap, Pgi, Pgm-2, and Pgm-3. Genotype frequencies differed from Hardy-Weinberg expectation for all genes except Pgd and Pgm-2, but only for Lap was the deviation associated with heterozygosity, for which there was a striking deficiency. Since the cohort was randomly bred, the Wahlund effect cannot explain this observation but differential survival can. Two genes, Lap and Pgm-3, showed highly significant associations of genotype with shell size. (Modified authors' abstract - J.L.M.)

6 Adams, Chuck. 1986.

Economics of clams. *In* Busby, D. (ed)., An overview of the Indian River clamming industry and the Indian River Lagoon. Tech. Pap. 44, p. 18-22. Fla. Sea Grant Ext. Prog., Univ. Fla., Gainesville, FL 32611, Proj. IR-85-7, Grant NA85AA-D-SG059.

Florida has only recently become a significant producer of hard clams (*Mercenaria mercenaria*). In 1984 the dockside value of hard clam landings representec 43% of total dockside value of all species of clam landed in the U.S. Landings in Florida were 1.8 million pounds of meats with a dockside value of $6.6 million in 1984. Most production in Florida comes from the Indian River Lagoon system. The growth of the hard clam fishery is obviously of importance to the local economy. Tables give total U.S. clam landings, reported Florida landings and value 1970-84, landings of the most important species of fish and shellfish in Florida, hard clam landings and value by county in Florida, and hard clam landings and value for Brevard County 1975-84. (J.L.M.)

7 Akberali, H.B., and E.R. Trueman. 1985.

Effects of environmental stress on marine bivalve molluscs. Adv. Mar. Biol. 22:101-198.

Cites work of several authors abstracted elsewhere in this bibliography. Bivalves can distinguish between favorable and unfavorable environmental conditions and make appropriate behavioral responses. Many utilize valve closure as a protective mechanism. Sensory receptors on the marginal lobes of mantle and siphons can detect changes in the medium even when valves are apparently closed. Valve closure allows the organism to overcome short-term changes in environmental conditions. It has no survival value when changes are long-term. (J.L.M.)

8 Alatalo, Philip. 1980.

Yeast utilization in oysters and clams. Masters thesis, Univ. Del., Newark, DE 19716, 44 p.

Juvenile clams, *Mercenaria mercenaria* were fed one of three diets consisting of the flagellate *Isochrysis galbana*, the torulan yeast *Candida utilis*, or a 50% dry weight mixture of each. Increases in most growth parameters were higher for clams fed algae or the mixture than yeast alone. Clams fed yeast grew at approximately half the maximum rate, while oysters fed yeast showed zero or negative growth. Nutritive quality appears to be important, although amino acid composition among the three diets was similar. Growth of clams was directly related to the amount of protein, lipid, and ash. Growth of oysters was related only to the amount of lipid. Respiration rates appeared normal for all groups, yet respiration frequently accounted for a large percentage of assimilated calories. Growth efficiency for clams fed yeast was very low. The quantity and quality of the ingested yeast ration probably are suboptimal, and differences in diet quantity and quality are reflected by differential partitioning of energy within the energy budget of the animal. It is likely that yeast lacks a vital micronutrient or fatty acid is required. (Modified author's abstract - J.L.M.)

9 Amouroux, J.M. 1984.

Preliminary study on the consumption of dissolved organic matter (exudates) of bacteria and phytoplankton by the marine bivalve (*Venus verrucosa*). Mar. Biol. 82(2):109-112.

Of bacterial exudates (*Lactobacillus* sp.) 61.7% were consumed by *Venus verrucosa*, but only 19.9% of algal (*Pavlova lutheri*) exudates. The clam seems to assimilate bacterial products more easily. (J.L.M.)

10 Amouroux, J.M. 1986.

Comparative study of the carbon cycle in *Venus verrucosa* fed on bacteria and phytoplankton. I. Consumption of bacteria (*Lactobacillus* sp.). Mar. Biol. 90(2): 237-241.

Utilization of a viable bacterial suspension (*Lactobacillus* sp.) by the clam *Venus verrucosa* was investigated as a function of time. Data on the functioning of the different tissues suggest an important recycling of the metabolic products of the bivalves by bacteria of the suspension, demonstrating the role of bacteria as food for bivalves. *Mercenaria mercenaria* is not mentioned. (J.L.M.)

11 Andrews, Jay D. 1961.

Measurement of shell growth in oysters by weighing in water. Proc. Natl. Shellfish. Assoc. 52:1-11.

The technique of weighing in water has been tried with hard clams, *Mercenaria mercenaria*, without much success. Calcification is apparently much slower than in oysters. Hard clams held in trays without substratum become infested with *Polydora websteri* and are incapable of covering the resulting mud blisters satisfactorily. (J.L.M.)

12 Anonymous. 1979.

Shellfish doctor helps N.Y. hatcheries combat diseases in clams and oysters. Aquaculture 6(1):13-15.

Dr. Louis Leibovitz is a shellfish doctor, formerly involved with bird diseases. He says shellfish have several unparalleled assets as a food supply: 1) a very high reproductive rate, and 2) free food. He finds great similarities between raising birds and raising shellfish. The principal difference is that shellfish live in water. The article discusses some of the problems of growing shellfish, including hard clams *Mercenaria mercenaria*. (J.L.M. and M.W.S.)

13 Anonymous. 1981.

The back page. Univ. NC Sea Grant Coll. Prog., Raleigh, NC 27695. Coastwatch, Oct. 1981:7.

Each clam (*Mercenaria mercenaria*) was marked with paint and returned to one of 30 one-meter plots. Half were covered in Cuban shoal grass, the others stripped of their grass and clams left in bare, sandy bottoms. Hard clams with cover of sea grass fared well but clams left in sandy bottom had lost 32% to whelks after 6 months. Repeating the experiment in warm weather for 4 months he found that 70% of clams in sandy areas had been destroyed by whelks. Conclusion: grass beds denuded by raking and clam kicking increase predation by whelks. (J.L.M.)

14 Anonymous. 1982.

Getting a clam out of bed. Univ. NC Sea Grant Coll. Prog., Raleigh, NC 27695. Coastwatch, March 1982:1-2.

Traditionally, most clammers have used rakes or tongs to unearth hard clams from the bottom. Most hand clamming is done in the warmer months. One method is called "swimming for clams" which is done on hands and knees in shallow water. Others clam "by the sign" which involves looking for the small hole made in the sand when they are feeding. Kicking, by which clams are brought out of the bottom by the propeller wash, and dredging, are winter fisheries, limited by the NC Division of Marine Fisheries. In 1981, 1,458,000 pounds of clams were harvested in the State, 30% by kicking, 64% by hand methods, and 4% by dredging. Pollution and overharvesting are the greatest threats. Researchers are looking at harvesting methods and contamination, hoping to manage wisely. (J.L.M.)

15 Anonymous. 1982.

To hatch a million eggs. Univ. NC Sea Grant Coll. Prog., Raleigh, NC 27695. Coastwatch, March 1982:5-6.

Describes the operation of a hatchery in North Carolina Clams are held until January or February before planting, and are protected from predation by nets. They showed good growth and little predation. Others hold them until May. Clam hatcheries face a lot of unknowns, but may produce more clams. (J.L.M.)

16 Anonymous. 1982.

Quahog. Sea Grant Coll. Prog., Texas A&M Univ., College Station, TX 77843, The University and the Sea 15(4), Winter 1982:6-7.

There has never been a commercial hard clam fishery for *Mercenaria campechiensis* in Texas, yet clams are abundant and Indian shell mounds are loaded with clam shells. Researchers are investigating the possibility of establishing a clam fishery. (J.L.M.)

17 Anonymous. 1985.

Aging clams still active in bed. Univ. NC Sea Grant Coll. Prog., Raleigh, NC 27695. Coastwatch Nov/Dec 1985:5.

Despite rumors, big, old clams (*Mercenaria mercenaria*) are not sexually inactive. In fact, they produce many more eggs per clam than smaller clams. (J.L.M.)

18 Anonymous. 1986.

Buying hard clams. NY Sea Grant Ext. Prog., Oswego, NY 13126. Coastlines 17(3):6.

The major nutritional constituents of hard clams (*Mercenaria mercenaria*) are listed. Some shellfish related illnesses are described, and the NY State Dept. of Health has issued an advisory against consumption of all raw shellfish. (J.L.M.)

19 Anonymous 1986.

Clam fishing and farming on the Indian River. Unpubl. manuscr., Div. Applied Biol., Harbor Branch Found., Inc., Fort Pierce, FL 33450, 2 p.

In 1977 a clammer from New Jersey began shipping Florida clams to the Fulton Market in New York. He also opened Florida's first depuration plant to increase the supply of clams. In 1982 an unusually heavy set of clams (*Mercenaria mercenaria*) occurred in the Indian River, FL. Local clammers soon were outnumbered by migrants from the northeast, with high powered boats and sophisticated rakes and tongs. Clams became the second most important fishery in Florida (next to shrimp), valued at some $15 million per year. Cries of "Yankee go home" and rumors of vandalism alarmed officials. The fabulous set of 1982 was quickly decimated over the next few years and only remnants remain. The price of clams has escalated steeply. It is believed that a dependable, long-term supply depends on mariculture. The most serious constraint is the supply of seed, and an experimental hatchery started in 1983 is presently the only hatchery in Florida. The current goal is production of at least 10 million seed in 1986 and more later. (J.L.M.)

20 Ansell, A. D. 1960.

Observations on predation of *Venus striatula* (da Costa) by *Natica alderi* (Forbes). Proc. Malacol. Soc. Lond. 34(3):156-165.

Approximately 15% of the population of *Venus striatula* was bored by *Natica alderi* in the first year of life, 5% in the second, and 1-2% in the third. The holes were near the ventral margins of the shell. The observed distribution of holes over the shell appears to be the result of a stereotyped behavior pattern involving recognition of the prey and adoption of a particular attitude while boring. The possibility that the appearance of *Natica alderi* in Kames Bay was connected with the great increase in density of *Venus striatula* from a high spatfall in 1955 is discussed. (J.L.M.)

21 Arnold, William S. 1983.

The effect of prey size, predator size, and sediment composition on the rate of predation of the blue crab (*Callinectes sapidus* Rathbun) on the hard clam (*Mercenaria mercenaria* Linne). Masters thesis, Univ. Ga., Athens, GA 30602, 46 p.

Hard clams were more vulnerable to predation by crabs in the laboratory in soft sediments (sand, sand/mud) than in crushed oyster shell or granite gravel aggregates. When crabs were given a choice of clam sizes, small crabs (<75 mm carapace width - CW) consumed 5 and 10 mm size-class clams. Medium crabs (75-125 mm CW) preferentially consumed 10 mm size class clams. Large crabs (>125 mm CW) consumed 10 and 25 mm size-class clams equally. All blue crab size-classes showed a preference for soft substrates rather than aggregates. The following sediment types are ranked in increasing order of their potential to protect clams from blue crab predation: bare substrate <san<sand/mud<crushed oyster shell=fine gravel. Shell and fine gravel provide a refuge from blue crab predation for all sizes of clams. (Modified author's abstract - J.L.M.)

22 Arnold, William S. 1984.

The effects of prey size, predator size, and sediment composition on the rate of predation of the blue crab, *Callinectes sapidus* Rathbun, on the hard clam, *Mercenaria mercenaria* (Linne). J. Exp. Mar. Biol. Ecol. 80(3):207-219.

In the laboratory blue crabs of all size classes exhibited a preference for sand, mud, and sand/mud rather than crushed oyster shell or granite gravel. Clams were more vulnerable to predation by crabs in sand and sand/mud than in crushed oyster shell or granite gravel. Small crabs (<75 mm carapace width - CW) consumed clams of 5 and 10 mm shell length. Medium crabs (75-125 mm CW) preferentially consumed 10 mm clams. Large crabs (>125 mm CW) consumed 10 and 25 mm clams equally. Blue crabs did not eat clams >40 mm. (J.L.M.)

23 Austin, H.M. 1981.

Drought has varied effects on Virginia-North Carolina fisheries. Cent. Ocean Manage. Stud., Univ. R.I., Kingston, RI 02881, Coastal Oceanogr. Climatol. News 3(2):17-18.

Salinity intrusions upriver have produced favorable conditions for hard clam (*Mercenaria mercenaria*) larval survival. The hard clam needs a salinity of at least 18‰ for successful reproduction and larval survival. Migration of the 18‰ isohaline north into Pocomoke and Tangier Sounds and the York River may result in the first good clam strike there in many years. (J.L.M.)

24 Ballantyne, J.S., and K.B. Storey. 1983.

Mitochondria from the ventricle of the marine clam, *Mercenaria mercenaria*: substrate preferences and effects of pH and salt concentration on proline oxidation. Comp. Biochem. Physiol. 76B(1):133-138.

Mitochondria with high respiratory control ratios (RCR) have been isolated from the ventricle of the marine clam *Mercenaria mercenaria*. Proline is the preferred substrate of the mitochondria of the ventricle based on state 3 rates. Pyruvate, ornithine, and succinate are oxidized at rates 3/4 that of proline. α-Glycerophosphate was oxidized at rates one-half that of proline. The pH optimum for proline oxidation lies between 6.5 and 7.5 based on RCR and ADP/O, and between 7.0 and 7.4 based on state-3 rates. KCl concentrations between 250 and 450 mM gave optimum values for the oxidation of proline based on RCR and state-3 rates. KCl concentration had little effect on ADP/O between 100 and 850 mM. (Modified authors' abstract - J.L.M.)

25 Ballantyne, J.S., and K.B. Storey. 1985.

Solute effects on mitochondrial respiration: the kinetics of proline oxidation by mitochondria from the ventricle of the marine clam *Mercenaria mercenaria*. Comp. Biochem. Physiol. 81B(3):777-780.

Compared with the isoosmotic state, the rate of oxidation at any concentration of proline by intact mitochondria is greater in the hypoosmotic state and lower in the hyperosmotic state. It is suggested that volume changes in mitochondria during the early stages of osmotic stress may be responsible for adjustments in intracellular concentration of certain amino acids observed during volume regulation in marine bivalves. (Modified authors' abstract - J.L.M.)

26 Barile, Diane. 1986.

The setting - History of the Indian River Lagoon. *In* Busby, D. (ed.), An overview of the Indian River clamming industry and the Indian River Lagoon. Tech. Pap. 44:7-8. Fla. Sea Grant Ext. Prog. Univ. Fla., Gainesville, FL 32611, Proj. IR-85-7, Grant NA85AA-D-SG059.

The Lagoon produced 80% of Florida's clam harvest. Clammers from New York, Rhode Island, and North Carolina have introduced basket rakes, and sophisticated depuration plants and relay techniques purify clams from polluted waters. Today the Indian River is home to a population of about 600,000 people and it is still growing. (J.L.M.)

27 Bass, Ann Elisabeth. 1983.

Growth of hard clams, *Mercenaria mercenaria*, feeding on chlorophyte and cyanobacterial picoplankton. Masters thesis, State Univ. N.Y. at Stony Brook, NY 11794, 66 p.

The purpose was to determine if these small algae and indirectly nitrogenous wastes from Long Island duck farms are responsible for poor growth of *Mercenaria mercenaria* in New York. Preliminary experiments showed that hard clams were capable of clearing "small form" cells from suspension. In a 6-week growth experiment, clams fed *Nannochloris atomus*, a common "small form" species, showed no growth, while clams fed on algal species *Pseudoisochrysis paradoxa*, known to support growth in bivalves, grew well. In subsequent experiments, absorption efficiencies of "small forms" by clams ranged from 17.6% to 31.1% compared with 80.3% and 86.5% for algae normally used in clam culture. (Modified author's abstract - J.L.M.)

28 Bayes, J.C. 1981.

Forced upwelling nurseries for oysters and clams using impounded water systems. *In* Claus, C., N. DePauw, and E. Jaspers (eds.), Nursery culturing of bivalve molluscs, p. 73-83. Spec. Publ. 7, Eur. Maricult. Soc., Bredene, Belgium.

Nurseries are designed for the convenience of the operator, not the stock. The obvious variables such as salinity, turbidity, food type, and concentration have been attended to but losses continue to occur. Frequently mortality occurs apparently due to decay products and associated organisms. To overcome this problem the stock has to be evacuated before mortality sets in. Theoretically decay processes could be kept apart from the healthy animals but this is impossible to do in practice. There is also the possibility of an epizootic. Presently no cures from molluscan diseases have been developed, and in the event of an outbreak, one must assume that it would spread rapidly through the entire stock causing heavy losses. The necessity of pond and stock hygiene should be emphasized. When washing the bivalve stock the washings should not run back into the culture pond, which is a routine practice in many nurseries. (J.L.M.)

29 Bayne, B. 1973.

The responses of three species of bivalve mollusc to declining oxygen tension at reduced salinity. Comp. Biochem. Physiol. 45A:793-806.

Geloina ceylonica and *Anadara granosa* experience hypoxic conditions and can regulate their oxygen consumption at reduced oxygen tension in water of full salinity. These two species and *Mytilus edulis* can also regulate oxygen consumption at reduced oxygen tension in diluted seawater. Their capacity to regulate is reduced under these conditions, although only in *Anadara* is this reduction very marked. At reduced-salinity oxygen consumption *Mytilus* is inhibited at first, but recovers within 48 hours. The ability to regulate oxygen uptake at reduced oxygen tension is not lost during the acclimation period. At 23.5‰ salinity perfusion index increases with reduced PO_2, but at 16.3‰ perfusion index does not change as PO_2 is reduced to 60 mm Hg. *Mercenaria mercenaria* is not mentioned. (J.L.M.)

30 Bayne, B.L., and R.C. Newell. 1983.

Physiological energetics of marine molluscs. Chap. 9 *In* Saleuddin, A.S.M., and K.M. Wilbur (eds.), The Mollusca. Vol. 4. Physiology Pt. 1. p. 407-515. Acad. Press, NY.

Reference is occasionally made to *Mercenaria mercenaria* studied by other authors abstracted elsewhere in this bibliography. (J.L.M.)

31 Beal, B.F. 1983.

Predation of juveniles of the hard clam *Mercenaria mercenaria* (Linne) by the snapping shrimp *Alpheus heterochaelis* Say and *Alpheus normanni* Kingsley. J. Shellfish. Res. 3(1):1-9.

Snapping shrimp *Alpheus heterochaelis* and *A. normanni* in laboratory tanks used their major chelae to crush and consume juvenile hard clams *Mercenaria mercenaria*. Shrimp of 19.1-39.4 mm total body length ate clams in the largest size-class 15.1-20.0 mm shell length. But they preferred smaller clams when offered equal numbers in this large size-class and in each of three smaller size-classes. Female shrimp had a higher predation rate than males. Major chelae of female *A. heterochaelis* >32 mm total length were smaller than those of males of equal size. *A. heterochaelis* 19.1-27.2 mm total length had larger major chelae for a given body length than did specimens of *A. normanni* but predation rates were not significantly different. The number of clams crushed was related to size of major chelae and total body length for *A. normanni* but not for *A. heterochaelis*. *Alpheus* spp. inflict two types of shell damage which are identical with those of blue crabs. The results imply that previous studies may have overestimated the importance of crab predation and underestimated or ignored the importance of predation by snapping shrimp. (Modified author's abstract - J.L.M.)

32 Beal, Brian Fairfield. 1983.

Effects of environment, intraspecific density, predation by snapping shrimp and other consumers on the population biology of *Mercenaria mercenaria* near Beaufort, North Carolina. Masters thesis, Univ. N.C., Chapel Hill, NC 27559, 177 p.

Predation on *Mercenaria mercenaria* by rasping predators occurred only at unvegetated sand flats and accounted for 87% of all clams recovered at one site. This high mortality rate was unique among all sites and rasping rate was significantly lower at other sand sites. *Mercenaria mercenaria* at unvegetated sand sites do not reach an escape in size from rasping predators. Hard clams in muddy areas appear to reach a size refuge from predation by crushing or chipping predators and a spatial refuge from rasping predators, which are less effective in more fluid substrates. Field tests provide little support for the hypothesis that sea grasses provide hard clams the structural habitat heterogeneity as a refuge from predation. Natural shell bottom, on the other hand, served to reduce efficiency of large epibenthic digging or burrowing predators. This is supported by three observations: 1) natural hard clam densities were higher at a shell site than at any other unvegetated site, and higher than natural densities at two nearby sea-grass meadows; 2) survivorship of experimental clams was independent of initial clam size; and 3) recruitment was highest at a shell site. Growth of small clams (<29.9 mm long) was probably exponential, but growth rates differed little between sites perhaps because few small clams survived the full year. Small clams (<29.9 mm long) in the high-density treatment were found to have higher survival rates than their low-density counterparts. It was hypothesized that the dense assemblage of neighboring large clams in the 8x density treatment provided a structural barrier which protects smaller clams from predation. Growth rates were affected positively by increasing intraspecific density at two of the nine sites, suggesting, over the range of densities tested, that no food limitation on growth existed. However, at four sites growth rate of shell length relative to shell width was faster in the high-density treatment, implying that competition for space may have occurred. There was no relationship between recruitment rate and adult density at any site, which suggests that adult-larval interactions were relatively unimportant within the range of densities tested in regulating hard clam populations. Hard clams from Back Sound were transplanted to sites in the North River, Bogue Sound, and Core Sound. At these transplant sites the fate and growth rate of naturally occurring clams were compared to Back Sound-derived clams. Results suggest that environmental factors operate over and above any possible genetic differences. These experiments can be used by shellfish managers to incorporate basic but essential biological parameters into existing regulatory measures and also into fishery yield models. These will help determine whether the abundance of hard clams is self-sustaining given the current rate of commercial exploitation. A management scheme based in spreading of shell or stone aggregate in unprotected areas is considered. (J.L.M.)

33 Becker, Margaret. 1983.

The 1982 shellfish-related disease outbreak in New York State: Agency response and interaction. Rockefeller Institute Working Papers No. 5, The Nelson A. Rockefeller Institute of Government, State Univ. NY, Albany, NY 12203, 39 p.

In 1982 the NY State Dept. of Health (DOH) investigated over 275 incidents of enteric illness associated with eating of raw or partially cooked hard clams and oysters. As a result DOH issued health advisories warning against consumption of raw clams or oysters. This disease outbreak was one of the largest of recent times. Altogether more than 400 people became ill from eating shellfish, mostly hard clams (*Mercenaria mercenaria*), showing symptoms associated with gastroenteritis, an illness causing nausea, vomiting, diarrhea, chills, weakness, low fever, and headache. Ten also contracted infectious hepatitis, a communicable disease of the liver. Later over 250 incidents of enteric illness, including between 5 and 10 cases of infectious hepatitis, associated with raw clam or oyster consumption were investigated, followed by another DOH health advisory. Principal sources of shellfish implicated in the first outbreak were out-of-state. The later outbreaks were caused by a combination of out-of-state and local Long Island clams. These outbreaks clearly demonstrate the need for improved resource management by industry and government cooperatively. These will entail costs to the industry and to the state, and these costs must be weighed against the high cost of maintaining the status quo. (J.L.M.)

34 Behrens, W.J., and I.W. Duedall. 1981.

Temporal variations of heavy metals in *Mercenaria mercenaria*. Int. Counc. Explor. Sea J. Cons. 39(3):219-222.

Simultaneous analyses of changes in dry body weight, heavy metal concentrations, and total body burden of heavy metals in *M. mercenaria* show that temporal variations in metal levels are associated with biological processes of the organism. Changes in Ni, Pb, and Cu levels are related to the spawning cycle, but Cd, Cr, and Zn levels are not. Interpretation of fluctuations in metal concentrations may be misleading unless considered with respect to seasonal variations in body weight. (Modified authors' abstract - J.L.M.)

35 Behrens, W.J., and I.W. Duedall. 1981.

The behaviour of heavy metals in transplanted hard clams, *Mercenaria mercenaria*. Int. Counc. Explor. Sea J. Cons. 39(3):223-230.

An area in Great South Bay, NY, which has been closed to shellfishing from domestic pollution, was also shown to have elevated levels of heavy metals in hard clams and in sediments. Clams from this area were transplanted to the central portion of the Bay which is open to shellfishing. Behavior of heavy metals in transplanted clams was primarily affected by long-term trends based on seasonal fluctuations. The clams were depurated of bacteria, but no depuration of any heavy metal analyzed (Cd, Cr, Cu, Ni, Pb, and Zn) was noted during the 50-day period of the study. In fact, significant increases in total body content of Cd, Ni, and Pb occurred. Cd and Pb levels were not elevated above natural levels found in the transplantation area, but Ni was approximately 56% higher. (Modified authors' abstract - J.L.M.)

36 Berg, Carl J., Jr., and Philip Alatalo. 1984.

Potential of chemosynthesis in molluscan mariculture. Aquaculture 39:165-179.

The large edible clam *Codakia orbicularis* lives in sulfide-rich environments in subtropical regions. Gill tissues contain intracellular procaryotic cells and yield enzyme activities associated with sulfide oxidation, carbon fixation, and nitrogen reduction. This suggests chemoautotrophic capabilities similar to those of deep-sea hydrothermal vent animals. Reproduction, growth rates, and chemical composition of *C. orbicularis* are similar to other commercially exploited clams like *Mercenaria mercenaria*. The potential for mariculture using industrial sulfur waste products is evident, but needs to be demonstrated. (Modified authors' abstract - J.L.M.)

37 Berrigan, Mark. 1986.

Controlling production - Management of the industry. *In* Busby, D (ed.), An overview of the Indian River clamming industry and the Indian River Lagoon. Tech. Pap. 44:29-34. Fla. Sea Grant Ext. Prog., Univ. Fla., Gainesville, FL 32611, Proj. IR-85-7, Grant NA85AA-D-SG059.

A conservative estimate of the landings and values in 1984 is about 166 million clams of various sizes worth over $7 million. This compares with weights of about 125,000 pounds of meats and $0.4 million in the preceding two years. Harvesting, transport, and relocation are closely monitored and supervised by law enforcement officers and the Fla. Department of Natural Resources. Depuration is accomplished in tanks using recirculated UV-treated water. (J.L.M.)

38 Blundon, Jay A., and Victor S. Kennedy. 1982.

Mechanical and behavioral aspects of blue crab, *Callinectes sapidus* (Rathbun), predation on Chesapeake Bay bivalves. J. Exp. Mar. Biol. Ecol. 65(1):47-65.

Shell strength of *Mercenaria mercenaria* was within or below the range of maximum force generated by blue crabs of the sizes tested. All *Mercenaria* could be crushed by blue crabs, yet they persist in nature. Survival must be associated with reproductive behavior and/or their restricted availability to blue crabs and other predators in refuges of time or space. (J.L.M.)

39 Blundon, J.A., and V.S. Kennedy. 1982.

Refuges for infaunal bivalves from blue crab, *Callinectes sapidus* (Rathbun), predation in Chesapeake Bay. J. Exp. Mar. Biol. Ecol. 65(1):67-81.

No mention of *Mercenaria mercenaria*. Ecological studies of predator-prey interactions have frequently concluded that surviving prey live in refuges from their predators. The effectiveness of various refuges in protecting *Mya arenaria* from predation by *Callinectes sapidus* was tested. (J.L.M.)

40 Bodoy, Alain. 1983.

Growth and seasonal variations of the biochemical composition of *Venus gallina* in the Gulf of Marseille (Western Mediterranean). Tethys 11(1):57-66.

The population of *Venus gallina* consists of several cohorts of varying importance. There are generally two recruitments per year, and the life span in the Gulf of Marseille is about 2 years. Growth in weight occurs in spring when nutritional conditions are good. Spawning occurs in summer. *Mercenaria mercenaria* is not mentioned. (J.L.M. and M.W.S.)

41 Bolton, Ellis T., and Noel D. Dey. 1979.

Process for marking molluscs. U.S. patent no. 4,133,294, 5 p.

Describes a new method to mark large numbers of molluscs permanently. They are placed in a tank containing media, food, and tetracycline at a concentration of 0.5/200 mg. Bivalves so treated daily for 1 to 14 days, or longer as desired, will be permanently marked. The mark is normally weakly visible, but fluoresces a vivid yellow-orange when exposed to ultraviolet light. (Modified authors' abstract - J.L.M.)

42 Botton, Mark L. 1983.

What determines the vulnerability of bivalve prey to horseshoe crab predation? J. Shellfish. Res. 3(1):83 (abstract).

There was a preference for *Mulinia lateralis* over hard-shell clams *Mercenaria mercenaria* of equal size. Shell length and shell thickness appear to influence the preference of horseshoe crabs for bivalve prey. (Modified author's abstract - J.L.M.)

43 Boulding, Elizabeth Grace. 1984.

Crab-resistant features of shells of burrowing bivalves: decreasing vulnerability by increasing handling time. J. Exp. Mar. Biol. Ecol. 76(3):201-223.

Mercenaria mercenaria is not mentioned, but the vulnerability of burrowing bivalves to shell-breaking predation by crabs is influenced strongly by shell features: size, shell thickness, degree of inflation, and the presence or absence of a gape. Thick-shelled clams resisted a greater number of force pulses than did thin-shelled clams of the same body weight. This suggests that the reason for increased resistance to crabs is prolongation of the shell-breaking time. A large thick-shelled, tightly-closing clam may eventually be opened, but it probably would be rejected in favor of prey with shorter handling times. (J.L.M.)

44 Boulding, E.G., and T.K. Hay. 1984.

Crab response to prey density can result in density-dependent mortality of clams. Can. J. Fish. Aquat. Sci. 41(3):521-525.

Field experiments involving recovery of marked clams (*Protothaca staminea*) showed that even adult native littleneck clams could suffer high mortality to cancrid crabs. Mortality rates increased with clam density, suggesting that these crabs preferentially forage in areas of higher prey density. Acoustic telemetry showed that at least one of the crabs, *Cancer productus*, is sufficiently mobile to search large areas while foraging. (J.L.M.)

45 Bricelj, Vera Monica. 1984.

Effects of suspended sediments on the feeding physiology and growth of the hard clam, *Mercenaria mercenaria* L. Ph.D. dissertation, Mar. Sci. Res. Cent., State Univ. N.Y. at Stony Brook, NY 11794, 157 p.

The study showed that clams can sort sediments from algae and selectively reject organic-coated and organic-free sediment particles in pseudofaeces. Clams also appear to selectively reject larger/heavier mineral particles from a sediment suspension containing particles <44 μm in diameter. Phaeophorbide a is the predominant phaeopigment in clam faeces, making up 92-99% of total phaeopigments. Algal ingestion rate declines with increasing sediment load, caused by a reduction in clearance rate. Within the concentration range tested, clams lose a limited amount of the algae cleared (up to 18%) as pseudofaeces. Silt additions to a diet of *Pseudoisochrysis paradoxa* or *Nannochloris atomus* do not enhance algal absorption efficiency through a so-called "grinding" effect. Clams maintain a constant absorption rate of organic materials up to a concentration of 20 mg silt/liter. They are thus able to compensate for the dilution of algae by utilizing a considerable fraction (21%) of sedimentary organic materials. Growth rate of juvenile clams is not affected by silt concentrations up to 25 mg/liter, but it is significantly reduced at 44 mg/liter. Thus, growth enhancement by addition of silt, reported for mussels, surf clams, and oysters, was not found in *Mercenaria mercenaria*. It is suggested that these three species are better suited than hard clams for culturing efforts in turbid waters above muddy bottoms. (Modified author's abstract - J.L.M.)

46 Bricelj, V. Monica. 1984.

Effects of suspended sediments on the feeding physiology of the hard clam *Mercenaria mercenaria* (Linne). J. Shellfish. Res. 4(1):82 (abstract).

Suspended sediments, a major component of seston in estuaries, exert a profound effect on food availability and feeding activities of filter-feeding bivalves. Negative and positive effects on growth have been reported. Clams (*M. mercenaria*) were able to sort sediment from algae, and selectively reject organic-coated and organic-free mineral particles as pseudofaeces. They also selectively rejected the larger/heavier mineral particles from a sediment suspension containing a wide range of particle sizes (up to 44 μm in diameter). Amounts of algae ingested declined with increasing sediment concentration. This decline resulted primarily from a reduction in clearance rate. Clams lost a maximum of about 22% of the algae cleared as pseudofaeces. Presence of silt produced no enhancement in utilization of algae ingested through a so-called "mechanical effect." However, clams appeared to be able to compensate for the dilution of algae by utilizing a small fraction of the organic material in the sediment. (Modified author's abstract - J.L.M.)

47 Bricelj, V. Monica, and Robert E. Malouf. 1980.

Aspects of reproduction of hard clams (*Mercenaria mercenaria*) in Great South Bay, New York. Proc. Natl. Shellfish. Assoc. 70:216-229.

Hard clams were repeatedly induced to spawn in the laboratory. Unfertilized spawned ova ranged from 50 to 97 μm and were characterized by a bimodal size-frequency distribution. In spite of high variability in egg production, correlation between size (length) and egg production was significant. Fifteen to 25% of variation in fecundity was attributable to difference in size of clams. Maximum egg production for a single female over the spawning season was 16.8 million eggs. No significant differences in fecundity, size of eggs, or larval survival were detected between clams from two diverse Bay habitats. It was suggested that laboratory spawning tends to underestimate natural fecundities. Sexes were about equal in abundance. Smallest clam to spawn was a sublegal female 33.1 mm long. Seed clams were capable of producing viable spawn, but had extremely low fecundities. Great South Bay populations are dominated by littlenecks under 4 yr of age. Clams are removed in most areas soon after they reach legal size, and intensive harvesting has caused a sharp downward shift in size-frequency distributions. A continuing shift to smaller sizes could significantly reduce total egg production in the Bay. There is no evidence to support a decline in egg production with increasing age. Large cherrystones or chowders are worth using for parent stock. The current New York minimum size may be ineffective in protecting breeding stocks in the Bay. Maximum egg production of a large cherrystone is about eight times that of a seed clam. The State's minimum legal size should be reexamined, or regulatory efforts be directed at preserving beds of larger clams. (J.L.M.)

48 Bricelj, V.M., and R.E. Malouf. 1981.

Aspects of reproduction of hard clams, *Mercenaria mercenaria*, in Great South Bay, New York. J. Shellfish. Res. 1(1):109 (abstract).

An optimum gamete ratio of approximately 1.8×10^5 sperm/100 eggs was determined. Unfertilized spawned ova ranged from 50 to 97 μm and had a bimodal size frequency. Correlation between length and egg production of clams was significant: 15-25% of the variation in fecundity was due to a difference in size of clams. Maximum egg production by a female over the spawning season was 16.8 million eggs. No significant differences in fecundity, size of eggs, or larval survival were detected between clams from two diverse Bay habitats. Laboratory spawning probably tends to underestimate natural fecundity. Sex ratio was approximately equal. Smallest clam to spawn was a sublegal female 33.1 mm long. Seed clams produce viable spawn but had extremely low fecundities. (J.L.M.)

49 Bricelj, V.M., and R.E. Malouf. 1984.

Influence of algal and suspended sediment concentrations on the feeding physiology of the hard clam *Mercenaria mercenaria*. Mar. Biol. 84(2):155-165.

Feeding experiments were conducted to determine response of hard clam *Mercenaria mercenaria* (32 mm shell length) to increasing sediment concentrations. Clams were fed mixed suspensions of *Pseudoisochrysis paradoxa* (50 and 150 cells/μL) and bottom sediments (0 to 44 mg/L). Algal ingestion rate declined with increasing sediment loads. The reduction was of similar magnitude for juvenile (13 mm) clams. Loss of algae in pseudofaeces increased with increasing sediment loads, but even at highest silt and algal concentrations, clams lost a maximum of only 18% of the algae cleared from suspension. Thus, pseudofaeces production is not expected to cause significant loss of algal food at sediment concentrations normally encountered in the natural environment ($\leqq$40 mg silt/L). Integration of physiological rate measurements suggests that at moderate to high algal concentrations ($\geqq$300 μg C/L), growth improvement by addition of silt, documented in mussels, surf clams, and oysters, is unlikely to occur in *M. mercenaria*. It is suggested that a suspension-feeding bivalve's success in maximizing energy gain in a turbid environment depends on a combination of two features: a high selection efficiency and a high rate of pseudofaeces production. It is proposed that species which regulate ingestion primarily by producing pseudofaeces are better adapted to cope with high suspended sediment loads than species like *M. mercenaria*, which control ingestion mainly by reducing clearance rate. (Modified authors' abstract - J.L.M.)

50 Bricelj, V.M., A.E. Bass, and G.R. Lopez. 1984.

Absorption and gut passage time of microalgae in a suspension feeder: An evaluation of the $^{51}Cr/^{14}C$ twin tracer technique. Mar. Ecol. Prog. Ser. 17:57-63.

ercenaria mercenaria was pulse-fed labeled microalgae. Clams absorbed approximately 14% of the ^{51}Cr ingested. When clams were fed *Pseudoisochrysis paradoxa*, a "good" food source, the gut residence time of ^{14}C was greater than that of ^{51}Cr. Thus, analysis of a single faecal subsample can cause significant error in calculated absorption efficiency. Therefore, pulse-chasing, or recovery of faeces over a fairly extended period of time, is strongly recommended. Examination of the time course of ^{14}C egestion revealed that the gut passage time of *P. paradoxa*, which was absorbed with 82% efficiency, was significantly greater than that of two chlorophytes (*Nannochloris atomus* and *Stichocossus* sp.) and two cyanobacteria of the genus *Synechococcus*, which are inefficiently utilized by *M. mercenaria*. Clams are able to sort different algal species as they pass through the gut. Control of gut clearance rates, through more rapid elimination of those algal species which are also poorly utilized, may contribute to the species adaptive strategy. (Modified authors' abstract - J.L.M.)

51 Bricelj, V.M., R.E. Malouf, and C. de Quillefeldt. 1984.

Growth of juvenile *Mercenaria mercenaria* and the effect of resuspended bottom sediments. Mar. Biol. 84(2):167-173.

Growth rates of clams *Mercenaria mercenaria* were not significantly affected by sediment concentrations up to 25 mg/L. Significant reduction in growth and condition of clams occurred at 44 mg silt/L. Growth enhancement by addition of silt to an algal diet, reported in mussels, surf clams and oysters, was not found in *Mercenaria mercenaria*. It is suggested that these species are better suited than hard clams for culturing efforts in inshore turbid waters above uncompacted, muddy bottoms. (Modified authors' abstract - J.L.M.)

52 Brown, Carolyn. 1981.

A study of two shellfish-pathogenic *Vibrio* strains isolated from a Long Island hatchery during a recent outbreak of disease. J. Shellfish. Res. 1(1):83-87.

Two bacterial strains of *Vibrio* were implicated in a recent outbreak of disease in larvae of *Crassostrea virginica* at a Long Island shellfish hatchery. Juvenile clams (presumably hard clam) held at the hatchery were affected by the disease that occurred during the summer of 1979. (J.L.M.)

53 Brown, John W. 1984.

Hard clam price analysis: The effect of supply and demand at the Fulton fish market. J. Shellfish. Res. 4(1):83 (abstract).

Prices at Fulton fish market for three sizes of hard clams (*Mercenaria mercenaria*) were examined for the period Jan. 1973 to Dec. 1982. Prices for littlenecks were highly seasonal and showed the effect of individual holidays. Prices of cherrystones generally followed prices of littlenecks with a strong seasonality factor. Chowder prices generally trended upward, but did not show the strong seasonal price changes of the two smaller sizes. Other factors which affected supply and demand, such as area openings and closures and shellfish-transmitted disease events were also examined. (Modified author's abstract - J.L.M.)

54 Brown, John W., John J. Manzi, Harry Q. M. Clawson, and Fred S. Stevens. 1983.

Moving out the learning curve: An analysis of nursery operations for the hard clam *Mercenaria mercenaria* (Linne) in South Carolina. J. Shellfish. Res. 3(1):85 (abstract).

From Sept. 1980 to Dec. 1981, a total of 19,733,000 seed clams were imported into the nursery. Of these, 13,008,000 remained in the nursery at the end of the year; 3,402,000 were planted in the field; 14,700 were returned to the nursery. Apparent mortality was 3,337,700 clams during the 15 months. This 16.9% mortality is misleading because the number of clams in the nursery was rapidly increasing over the period. With a correction for mortality, a detailed budget analysis was given and linear programming was employed to determine optimal importation strategies. (Modified authors' abstract - J.L.M.)

55 Brown, John W., John J. Manzi, Harry Q. M. Clawson, and Fred S. Stevens. 1983.

Moving out the learning curve: An analysis of hard clam, *Mercenaria mercenaria*, nursery operations in South Carolina. Mar. Fish. Rev. 45(4-6):10-15.

Trident Seafarms Company has a cooperative venture with the South Carolina Wildlife and Marine Resources Department in which Trident Seafarms provides total capital funding while the Marine Resources Research Institute of the South Carolina Wildlife and Marine Resources Department provides technical direction and scientific expertise. The South Carolina Sea Grant Consortium provides funding for scientific research and staff time for some of the analytical work. Seed stock is purchased from commercial shellfish hatcheries which provide set averaging 1 mm in size. These small animals are placed in trays or upflow silos where estuarine water is continuously pumped over them. No supplemental feeding is used. When they reach a size of 8-10 mm they are placed in vinyl-coated wire trays for field growout, and placed in the intertidal zone of a saltmarsh creek. There they grow to a size of about 25 mm. At this stage the trays are opened and clams are sorted and replanted at about one-quarter the density in less well protected trays. These trays are placed in the intertidal zone again and the clams are allowed to grow to marketable size of about 50 mm. The report analyzes the economics of the nursery during the first 18 months of operation. It is concluded that the nursery system works as it was designed. (J.L.M.)

56 Brown, Robert S. 1977.

Histopathological findings in *Mya arenaria* and *Mercenaria mercenaria*, sampled from Quonset Point/Davisville, Rhode Island. *In* The Redevelopment of Quonset/Davisville: An Environmental Assessment. Tech. App. 4, 9 p.

A high prevalence of several types of lesion was found: neoplasia in *Mya*, and hemocytosis, hyperplasia, and lipofuscinosis in both species. The results are preliminary. The field survey indicates that the environment at Quonset/Davisville may be polluted to the extent of having a detrimental effect on the health of clam populations. It was recommended that fishing of *Mya* and *Mercenaria* not be allowed until the populations have been analyzed for hazardous organic chemicals. (J.L.M.)

57 Browne, Robert A., and W.D. Russell-Hunter. 1978.

Reproductive effort in molluscs. Oecologia (Berl.) 37(1):23-27.

A survey of the available molluscan literature shows that reproductive effort is higher in semelparous species (29.9%) than in iteroparous species (18.21%) to which *Venus (Mercenaria)* belongs, and that in iteroparous species reproductive effort increases with successive breeding seasons. Oviparous species like *Mercenaria* were found to divert considerably more into reproduction than viviparous species (24.24% vs 5.25%, respectively). (J.L.M.)

58 Buckner, Stuart C. 1981.

A status report on hard clam culture in the Town of Islip. Tech. Rep. Ser. 5, Dep. Environ. Control, Town of Islip, NY 11751, 22 p.

Seed clams (*Mercenaria mercenaria*) of mean shell length 3.6-6.9 mm were planted in various culture systems during a 2-yr period. All systems were located in a saltwater basin where clams were held in protected enclosures. Best growth and survival were obtained at the larger sizes of clams. Estimated cost per clam was similar in stacked trays and on prepared bottom. Stacked trays were most productive per area because greater quantities of clams could be grown. Bottom plots have one advantage, however, because their low visibility reduces the possibility of vandalism. To increase cost-effectiveness, the entire process—from protected grow-out of seed to transplantation to public grounds—should be completed as quickly as possible. The applicability of hard clam culture as a resource management tool needs to be thoroughly evaluated. The appropriate scale at which seeding can make a contribution to the resource should be established. Each agency must then determine the extent of the contribution required to meet its needs in light of the goals of its shellfish management effort. (J.L.M.)

59 Buckner, Stuart C. 1983.

A case study on management of the hard clam resource in Great South Bay. *In* Buckner, S.C. (ed.), Proceedings of a Management Perspective on the Hard Clam Resource in Great South Bay, p. 29-43. A seminar sponsored by the Town of Islip (NY 11751), March 10, 1983.

In the 1960s and 1970s production of hard clams *Mercenaria mercenaria* increased appreciably in Great South Bay, the most important hard clam producing area in the world. It reached its peak in 1976. This increase in production has been attributed to a shift in fishing effort following collapse of the Bay's oyster fishery, a series of excellent sets in the 1960s, and steadily increasing clam prices. Signs of stress on the resource appeared in the mid-1970s as greater numbers of baymen entered the fishery at a time when the rate of increased production was slowing down. In 1974 the Town of Islip began a Shellfish Management Program aimed at maintaining production. This included stock assessment programs to develop information on abundance and distribution, growth rates, mortality rates, and recruitment. The harvestable population in certified areas has declined from an average of 65 bushels/acre in 1976 to less than 35 bushels/acre in 1980. From 1974 to 1980 the average daily catch per man declined from about 3.05 to 1.75 bushels, and the greatest reduction in catch was in the littleneck size category. The program also included stock-enhancement programs by transplants, spawner relays, and mariculture. These programs were successful only in localized areas and for short periods of time because harvesting pressure was so intense. Their effects were compounded by inadequate law enforcement. Alternative management strategies need to be developed if production is to be increased. A most important aspect of the plan is to limit access to particular areas of the fishery on a rotating basis, to rebuild stocks to productive levels. More funding will be required to explore the full potential of these programs. (J.L.M.)

60 Buckner, Stuart C. 1983.

Panel discussion summary. *In* Buckner, S.C. (ed.), Proceedings of a Management Perspective on the Hard Clam Resource in Great South Bay, p. 67-68. A seminar sponsored by the Town of Islip (NY 11751), March 10, 1983

Overwhelming agreement was reached on the following points: 1) A multidisciplinary approach is the most effective method to develop viable solutions; 2) local government must continue its management efforts; 3) more stringent management controls must be imposed; 4) more enforcement officers and tougher enforcement procedures are needed; 5) tighter public health regulations and better inspection procedures are necessary; and 6) substantial increases in funding will be required. (J.L.M.)

61 Buckner, Stuart Charles. 1984.

Aspects of the population dynamics of the hard clam, *Mercenaria mercenaria* L., in Great South Bay, New York. Ph.D. diss., Mar. Sci. Res. Cent., State Univ. N.Y., Stony Brook, NY 11794, 217 p.

Abundance, distribution, growth, mortality, and recruitment rates of populations of hard clams (*Mercenaria mercenaria*) were studied in a portion of Great South Bay, NY. Surveys were done in two successive years, and population characteristics were examined separately in certified, uncertified, and leased shellfishing areas to determine the effects of different forms of exploitation on the population. Significant differences in mean density were found in both years among harvestable populations in all areas. Substantial reductions in abundance of harvestable stock occurred throughout the study area. Harvest mortality was the major factor. Predicted levels of recruitment were sufficient to maintain existing population levels only if harvesting were greatly reduced. Such reductions were not expected, and it was predicted that abundance and catch would continue to decline. The intensity of fishing in conjunction with reductions in abundance and catch, as well as the presence of characteristic symptoms associated with the size and age composition of an overharvested population gave strong evidence that the resource has been overfished. It was concluded that management measures are needed to control the rate at which the resource is being exploited. A management strategy is described. (J.L.M.)

62 Buckner, Stuart C., and Barry D. Andres. 1978.

Survey procedures and sampling equipment for the hard clam, (*Mercenaria mercenaria*). Tech. Rep. Ser. 3, Dep. Environ. Control, Town of Islip, NY 11751, 23 p.

A method for quantitative survey of the hard clam population was adapted for use, and applied in a 20,000-acre area managed by the Town of Islip. The clamshell bucket was most suitable. The size of the sample was more closely controlled; an intact section of bottom was removed with all included organisms; and the natural appearance and position of organisms in the bottom could be observed. Also it was found that this method permitted satisfactory sampling to depths at which hard clams were found under all substrate conditions, except in extremely rocky areas. (J.L.M.)

63 Burnett, Jay. 1981.

When business clams up. Va. Polytech. Inst., Blacksburg, VA 24061, Sea Grant Today 11(5):8-9.

Harry Clawson of Trident Seafarms Co. in Charleston, South Carolina, is playing a major role in developing an emerging industry in commercial clam production. Working with South Carolina Sea Grant, his company is studying the feasibility of intensive hard clam (*Mercenaria mercenaria*) culture. The raceway system allows them to purchase seed clams too small for field planting and grow them to field size. The raceway presently maintains 5 million seed clams and plans to double that. When clams are ready for field planting they are held in wire baskets in steel reinforced cages. The entire operation takes 18 months. Clawson is confident the program will prove commercially valid within 5 yrs. (J.L.M.)

64 Busby, Derek S. 1986.

Introduction - Overview of the industry. *In* Busby, D. (ed.), An overview of the Indian River clamming industry and the Indian River Lagoon, Tech. Pap. 44, Fla. Sea Grant Ext. Prog., Univ. Fla., Gainesville, FL 32611, Proj. IR-85-7, Grant NA85AA-D-SG059.

Estuaries are among the most productive ecosystems on earth. One species which has recently experienced a rapid growth in production and value is the hard clam, *Mercenaria mercenaria*. The east coast of Florida is the southernmost extent of the range of the northern quahog, which extends as far north as Nova Scotia and the Gulf of St. Lawrence. They have also been introduced to Florida's west coast near St. Petersburg and a small fishery now exists there. Southern quahogs, *Mercenaria campechiensis*, occur from Chesapeake Bay to as far south as St. Lucie Inlet and are also found in the Gulf of Mexico, Yucatan, and Cuba. The calm, shallow flats of the Indian River Lagoon are ideal for this clam which may be found from just below the surface to depths as great as 50 ft. Growth rates in Florida may be three times that of clams living in northern waters. In Tampa Bay they have reached a size of 2½-3 inches by the end of the second year. Changing climatic conditions in the past few years have contributed to significant increases in clam production. In 1984, 1.7 million pounds of meats worth $6.1 million were landed. Part of this increase has been caused by improvememt in depuration technology. The economic success of the clamming industry in the Lagoon has brought clammers from as far away as Massachusetts. This has placed burdens on the enforcement branch of the Florida Department of Natural Resources. The health of the industry is tied to the health of the Lagoon itself. Mariculture is being considered. (J.L.M.)

65 Calabrese, Anthony, Edith Gould, and Frederick P. Thurberg. 1982.

Effects of toxic metals in marine animals of the New York Bight: Some laboratory observations. *In* Mayer, G.F. (ed.), Ecological stress and the New York Bight: Science and management, p. 281-297. Estuarine Res. Fed., Columbia, SC.

Mercenaria mercenaria embryos exposed for 48 hours to mercury had an LC_{50} of 4.8 ppb, and larvae exposed for 10 days had an LC_{50} of 14.7 ppb. Embryos exposed to silver for 48 hours had an LC_{50} of 20.0 ppb, larvae exposed for 10 days had an LC_{50} of 32.4 ppb, and adults exposed for 96 hours had an elevated oxygen consumption and showed a silver uptake by the gills. *Mercenaria mercenaia* also showed elevated oxygen consumption at lower concentrations of silver. (J.L.M.)

66 Calvin, Natasha I. 1977.

Device for splitting small samples of mud containing clams. Prog. Fish. Cult. 39(2):69.

The device is a cylinder glued to an acrylic base. The bottom of the cylinder is divided into four equal parts by thin plastic vanes. A sample of mud and small clams is split by placing the sample in the splitter, adding enough water to fill it, sealing the cylinder and shaking vigorously. (J.L.M.)

67 Captiva, Francis J. 1960.

Equipment note no. 6 - Chain bridles and accumulators increase effectiveness of "Fall River" clam dredges in deep water. Commer. Fish. Rev. 22(12):20-22.

Hard clams (*Venus* (*Mercenaria*) sp.) have been found in offshore waters of North Carolina Attempts to produce commercial quantities were unsuccessful because seas were often too rough, the water was deep, and the bottom was extremely soft. This was corrected by adding chain bridles, control chain, and accumulator chain. Commercial-size catches averaging 6 bushels of clams per 30-minute tow were taken consistently when other types of gear averaged only 1 to 2 bushels per 30 minutes. (J.L.M.)

68 Carbonara, Patty. 1986.

Controlling production - Management of the industry. *In* Busby, D. (ed.), An overview of the Indian River clamming industry and the Indian River Lagoon, p. 35. Tech. Pap. 44, Fla. Sea Grant Ext. Prog., Univ. Fla., Gainesville, FL 32611, Proj. IR-85-7, Grant NA85AA-D-SG059.

Clam mariculture projects on state-owned submerged lands will require a lease. Mariculture can be a valuable asset to the shellfish industry but not if it is done at the expense of the Lagoon. (J.L.M.)

69 Carter, Joseph Gaylord. 1980.

Environmental and biological controls of bivalve shell mineralogy and microstructure. Chapt. 2. *In* Rhoads, D.C., and R.A. Lutz (eds.), Skeletal growth of aquatic organisms - Biological records of environmental change, p. 69-113. Plenum Press, NY.

Changes in the area of secretion of adjacent aragonitic shell layers have yet to be thoroughly evaluated for their utility as records of environmental change independently of growth band and internal growth increment variations. Such changes are commonly described or illustrated in connection with studies of shell growth in the veneroid *Mercenaria mercenaria*. (J.L.M.)

70 Carter, Joseph Gaylord. 1980.

Bivalve shell mineralogy and microstructure. Part A. Selected mineralogical data for the bivalvia. *In* Rhoads, D.C., and R.A. Lutz (eds.), Skeletal growth of aquatic organisms - Biological records of environmental change, p. 627-643. Plenum Press, NY.

The title is sufficiently descriptive. Consult the original paper for details. (J.L.M.)

71 Carter, Joseph Gaylord. 1980.

Bivalve shell mineralogy and microstructure. Part B. Guide to bivalve shell microstructures. *In* Rhoads, D.C., and R.A. Lutz (eds.), Skeletal growth of aquatic organisms - Biological records of environmental change, p. 643-673. Plenum Press, NY.

Mineralogy and microstructure are described and illustrated. Consult the original paper for details. (J.L.M.)

72 Castagna, Michael. 1984.

Methods of growing *Mercenaria mercenaria* from postlarval- to preferred-size seed for field planting. Aquaculture 39(1-4):355-359.

Research has established that 8-mm hard clams survive better in field planting than smaller sizes. For various reasons commercial hatcheries are often unable to fill the demand for larger seed. Most operators prefer to sell smaller (2-4 mm) clams and structure their price schedules to encourage sale of smaller seed. It may be more economical for the clam planter to operate a nursery of postlarval- to field-size seed. Methods and problems associated with nursery culture are discussed. (Modified author's abstract - J.L.M.)

73 Castagna, Michael. 1986.

Improving production - Clam mariculture. *In* Busby, D. (ed.), An overview of the Indian River clamming industry and the Indian River Lagoon, p. 26. Tech. Pap. 44, Fla. Sea Grant Ext. Prog., Univ. Fla., Gainesville, FL 32611, Proj. IR-85-7, Grant NA85AA-D-SG059.

The hard clam *Mercenaria mercenaria* has a good market demand; is a hardy, relatively fast-growing species with few reported diseases; the technology for growing hard clams is available; and a number of successful clam farms are already in operation. Fourth, and perhaps most important, the maximum price is offered at the smallest size marketable. The field grow-out phase requires the lowest investment and has the best cash flow and profit potential. This phase is recommended for starting clam growers. Proper sized seed can be purchased from commercial hatcheries. (J.L.M.)

74 Castagna, M., and P. Chanley. 1973.

Salinity tolerances of some marine bivalves from inshore and estuarine environments in Virginia waters on the western mid-Atlantic coast. Malacologia 12(1):47-96.

Mercenaria mercenaria is found in nature at salinities above 12.5‰. Experimentally the minimum salinity is also 12.5‰. Larvae appear to require a slightly higher salinity than juveniles or adults. (J.L.M.)

75 Castagna, Michael, and John N. Kraeuter. 1981.

Manual for growing the hard clam *Mercenaria*. Spec. Rep. Appl. Mar. Sci. Ocean Eng. 249, Va. Inst. Mar. Sci., Gloucester Point, VA 23062, 110 p.

A manual developed for nonprofessionals. The methods were developed and tested by the staff of the VIMS Eastern Shore Lab. They are not always as technically advanced as the state of the art allows, but they work, are easy to learn, and relatively inexpensive. They are cost effective. For details the manual will have to be consulted. (J.L.M.)

76 Castagna, Michael A., Lawrence W. Mason, and Fred C. Biggs. 1970.

Hard clam culture method developed at VIMS - Aggregates on bottom protect seed clams from predators. Mar. Resour. Adv. Ser. 4, Va. Inst. Mar. Sci., Gloucester Point, VA 23062, 3 p.

For clammers who wish to start trial plantings with aggregates VIMS offers the following suggestions: 1) select aggregates that are cheap and plentiful in your area; 2) before buying in bulk test to see if particles are heavy enough to sink and remain on bottom, and are small enough to pack well; 3) spread over planting area to a thickness of at least 1 to 3 inches; 4) scatter seed clams evenly over the aggregate at a rate of about 25-50/ft^2; 5) aggregate can be put on bottom any time of year, clams should be planted at 48°F or higher when they are still active, plant at slack tide to avoid excessive clumping or scattering. (J.L.M.)

77 Castagna, Michael, R.S. Bisker, Henry Dymsza, and John N. Kraeuter. 1984.

Assessment of supplemental formulated diets for growing seed of *Mercenaria mercenaria* (Linne). J. Shellfish. Res. 4(1): 84-85 (abstract).

A number of diets formulated from inexpensive agricultural or fishery products were tested for promotion of growth in postset hard clams (*M. mercenaria*). Meal-type diets were mixed in a weak brine solution and pumped into the test containers at preset rates. Increases in shell height and dry weight were used as indicators of growth. Significantly higher growth rates were observed in clams fed certain diets. These diets are being refined and will undergo further testing. (Modified authors' abstract - J.L.M.)

78 Cerrato, Robert M. 1980.

Demographic analysis of bivalve populations. Chapt. 12. *In* Rhoads, D.C., and R.A. Lutz (eds.), Skeletal growth of aquatic organisms - Biological records of environmental change, p. 417-465. Plenum Press, NY.

Molluscan populations are used to illustrate how population attributes can be deduced from an analysis of shell characteristics. Many group attributes can be derived directly or indirectly from an evaluation of the class-frequency histogram. (J.L.M.)

79 Cerrato, Robert M., and Elizabeth J. Turner. 1983.

Effects of a storm-induced breach on the growth of *Mercenaria mercenaria* in Moriches Bay. Estuaries 6(3):308 (abstract).

In January 1980 a storm broke through the barrier island just east of the present inlet. The breach eventually merged with the original inlet, creating a broadened connection with the Atlantic Ocean. The breach was filled by 1981, but throughout most of 1980 Moriches Inlet was substantially widened. Microstructural growth increments in shells of *Mercenaria mercenaria* were examined in 6 to 18 month-old individuals collected at two stations, one in the eastern and one in the western half of the Bay. Average monthly growth at the eastern station was 1.76 mm in 1980 and 1.82 mm in 1981. At the western station average monthly growth was 1.6 mm in 1980 but was substantially higher, 2.3 mm, in 1981. The breach apparently had no effect on the population in the eastern bay but may have caused slower growth rates in individuals from the western Bay. (Modified authors' abstract - J.L.M.)

80 Chanley, P. 1967.

Aids for identification of bivalve larvae of Virginia. M.A. Thesis, College of William and Mary, Williamsburg, VA 23186, 65 p.

Larvae of 23 species, including *Mercenaria mercenaria* were identified and described. Identification aids include: 1) comparative photomicrographs of typical larvae arranged by sizes; 2) graphs of length-height relationships for interspecific comparison of larvae throughout development; 3) tables of dimensions and umbonal shapes; 4) keys to straight-hinge and umbonate larvae; 5) indirect aids (spawning seasons and geographic distribution); and 6) brief descriptions of each species. Combined use of all aids is recommended for identification of larvae. Large larvae are easier to identify than smaller ones, so workers should begin with umbonate larvae and progress to smaller individuals. (Modified author's abstract - J.L.M.)

81 Chantler, P.D. 1983.

Biochemical and structural aspects of molluscan muscle. Chapt. 3 *In* Saleuddin, S.M., and K.M. Wilbur (eds.), The Mollusca, Vol. 4, Physiology Pt. 1A, p. 77-154. Academic Press, NY.

Reference is made to *Mercenaria mercenaria* studied by other authors abstracted elsewhere in this bibliography. (J.L.M.)

82 Clark, George R., II. 1979.

Seasonal growth variations in the shells of recent and prehistoric specimens of *Mercenaria mercenaria* from St. Catherines Island, Ga. Am. Mus. Nat. Hist. Anthropol. Pap. 56:161-179.

The use of seasonal growth lines in bivalve mollusk shells to determine prehistoric human occupation patterns is a relatively new concept. To achieve this potential it is essential to determine the relationships between the seasons and the growth lines unambiguously, and also highly desirable to understand the fundamental causes, i.e., the environmental stimuli, as well. Examination of a limited number of prehistoric shells showed that death had occurred about 2 months after a major stress period, and analogy with recent *Mercenaria mercenaria* shells suggests that they were harvested in December or January. The paper is illustrated with numerous photomicrographs of shell sections. (J.L.M.)

83 Clark, George R., II. 1980.

Preparation and examination of skeletal materials for growth studies. Part A. Molluscs. 2. Study of molluscan shell structure and growth lines using thin sections. *In* Rhoads, D.C., and R.A. Lutz (eds.), Skeletal growth of aquatic organisms - Biological records of environmental change, p. 603-606. Plenum Press, NY.

Acetate peels have largely replaced thin sections in recent research on shell structure and growth lines. They provide much less information than thin sections, but can be prepared in a fraction of the time. The introduction of low-speed diamond saws now makes it possible to prepare high-quality thin sections nearly as easily as acetate peels, and this may reverse the trend. Preparation of thin sections is described. (J.L.M.)

84 Clark, George R., II. 1980.

Preparation and examination of skeletal materials for growth studies. Part A. Molluscs. 3. Techniques for observing the organic matrix of molluscan shells. *In* Rhoads, D.C., and R.A. Lutz (eds.), Skeletal growth of aquatic organisms - Biological records of environmental change, p. 607-612. Plenum Press, NY.

Complex crossed lamellar structure, and prominent growth lines in *Mercenaria mercenaria* formed by concentration of organic matter are illustrated by scanning electron micrographs. (J.L.M.)

85 Clark, G.R., II, and R.A. Lutz. 1982.

Seasonal patterns in shell microstructure of *Mercenaria mercenaria* along the U.S. Atlantic coast. Geol. Soc. Am. Abstr. with Prog. 14(7):464.

Shells from New Jersey, North Carolina, and Georgia exhibited reasonably regular patterns, with reasonably consistent relationships to the time of year. Shells from Maine, near the northern limit of the range, exhibited irregular and nearly continuous patterns of stress beyond the juvenile stage. Differences in timing of events was greatest between North Carolina and New Jersey, where features characteristic of winter in one locality could occur in summer in the other. *Mercenaria* shells have great potential for seasonality studies, but interpretations should be restricted to shells with regular seasonal patterns and should be based upon studies of local living populations. (J.L.M.)

86 Clark, Robert Hugh. 1953.

Observations on the rate of growth of the hard clam *Venus mercenaria mercenaria* (L.) in the lower Pocomoke Sound. M.S. Thesis, Univ. Md., College Park, MD 20742, 38 p.

The most rapid rate of growth and the greatest increment of growth occurs in young specimens in length classes 40-70 mm long with 1-4 "annual rings". Growth rings were much more difficult to determine in older clams with 8 or more "annual rings". Two types of rings were observed: 1) thin "disturbance rings" which were more numerous than "annual rings" probably caused by sudden and short changes in the environment; and 2) thick "annual rings" probably caused by seasonal changes in the environment. Shell weights of specimens from Pocomoke and Tangier Sounds were significantly greater than shell weights of clams from Sinepuxent Bay, MD, and Avon, NC. As length increased, the number of "annual rings" increased also. (J.L.M.)

87 Claus, Christine. 1981.

Trends in nursery rearing of bivalve molluscs. *In* Claus, C., N. De Pauw, and E. Jaspers (eds.), Nursery culturing of bivalve molluscs, p. 1-33. Spec. Publ. 7, Eur. Maricult. Soc., Bredene, Belgium.

In Dennis, MA, *Mercenaria mercenaria* is grown on pure algal strains cultured in large outdoor tanks. Mortality in a controlled onshore nursery installation is expected to be 20-60% for *Mercenaria mercenaria*. Thirty-day values for the instantaneous growth rate of 3-mm spat is optimal at a temperature of 20°C. From an economic viewpoint the artificial heating of large volumes of seawater needed for commercial mollusc production is theoretically prohibitively expensive, but waste heat from a power plant may be a solution. Some advocate use of marine cooling water as a culturing medium, but indirect use of thermal effluents of all kinds might be more interesting. A suitable water current is required to stimulate feeding and carry away faeces. There is a significant correlation between flow rate and filtration rate. The regulation of filtration rate is influenced by cell density and by algal size. Optimum cell concentration of a medium-size algal species of 100 μm^3 (± 6 μm) diameter is ± 25 cells/μL for *M. mercenaria*. Presently it is impossible to draw firm conclusions with regard to the future of mollusc nurseries. All systems presented in this paper have proven to be biologically feasible but the economics should be evaluated. The margin of profit in a nursery operation is very narrow. This is a review paper and only specific references to *M. mercenaria* have been recorded. The entire paper should be read for details. (J.L.M.)

88 Claus, C., N. De Pauw, and E. Jaspers (eds.). 1981.

Nursery Culturing of Bivalve Molluscs. Proc. Int. Workshop on Nursery Culturing of Bivalve Molluscs, Ghent, Belgium, 24-26 Feb. 1981, 394 p.

The entire publication is worth reading, although some papers do not mention *Mercenaria mercenaria* specifically. In addition, the roundtable discussions (p. 319-388) contain useful material. Papers that mention *Mercenaria mercenaria* are abstracted elsewhere in this bibliography. (J.L.M.)

89 Claus, Christine, Henk Maeckelberghe, and Niels De Pauw. 1983.

Onshore nursery rearing of bivalve molluscs in Belgium. Aquacult. Eng. 2(1):13-26.

Mercenaria mercenaria is not mentioned. Species examined were *Ostrea edulis*, *Crassostrea gigas*, and *Venerupis semidecussata*. Even very eutrophic water does not provide enough microalgae to sustain growth in winter, whether the water is heated or not. Cultured live algae must be added. Although nursery rearing of burrowing bivalves such as clams appears to be feasible, attention must be paid to shell deformations of clams in the nursery. (J.L.M.)

90 Claus, C., L. Van Holderbeke, H. Maeckelberghe, and G. Persoone. 1981.

Nursery culturing of bivalve spat in heated seawater. *In* Proc. World Symp. on Aquaculture in Heated Effluents and Recirculation Systems, Stavanger, Norway, 28-30 May 1980, vol. II, p. 465-480.

This paper reports on the first results obtained in Belgium at culturing postlarvae of a few millimeters to a few centimeters in size at densities as high as possible in an indoor experimental nursery with spat of *Ostrea edulis*, *Crassostrea gigas*, and *Venerupis semidecussata*. *Mercenaria mercenaria* is mentioned from a paper by Mann and Ryther (1977) abstracted elsewhere in this bibliography. (J.L.M.)

91 Cohen, Carolyn, and Andrew G. Szent-Gyorgyi. 1971.

Assembly of myosin filaments and the structure of molluscan catch muscles. *In* Podolsky, R.J. (ed.), Contractility of muscle cells and related processes, p. 23-36. Prentice-Hall, Inc., Englewood Cliffs, NJ.

Although myosins from various muscles such as white adductor muscle and translucent adductor muscle of *Mercenaria mercenaria* form similar aggregates *in vitro*, they may form quite different structures in nature. As an example of a specialized myosin assembly, we analyzed the thick filaments of molluscan muscle. In this case the myosin assembly is directed by the underlying core of paramyosin. A possible biological role of the special design of this thick filament may be the regulation of tension maintenance. Study of the in vitro aggregates of the purified proteins provides a powerful way to comprehend the organization of the native systems. The structure and interactions of the fibrous muscle proteins are revealed by their polymorphic forms. (J.L.M.)

92 Cole, Richard W., Ellis T. Bolton, Leon E. Spence, and N. Dean Dey. 1978.

A cooperative clam planting program. Prog. Rep., Delaware Dep. Nat. Resour. Environ. Control and Univ. Del., Coll. Mar. Stud., Newark, DE 19716, 10 p.

Preplanting surveys showed that the mean number of wild clams on the primary site was 4.3 (per square foot?). No clams were found on the secondary plot. These natural densities would not support commercial operations. Clams were planted in Sept. 1977 at a density of 270 clams per square foot. They ranged in size from 2 to 4 mm. Eight live tagged clams and 11 unbroken tagged valves were found in Nov. 1977. Thus, at least some clams survived. (J.L.M.)

93 Colvin, Gordon C. 1986.

1986 Legislation. Cornell Coop. Ext. Suffolk County, Riverhead, NY 11901, On the Water 1(1):3.

Describes a new law which increases criminal penalties for violation of fishery laws. Also describes public hearings soon to be held on major proposed revision of shellfish tagging and record-keeping requirements. (J.L.M.)

94 Connell, L.R., Jr., and R.E. Loveland. 1981.

Growth rates and fouling in sediment-free raft culturing of juvenile hard clams, *Mercenaria mercenaria* (L). J. Shellfish. Res. 1(1):110 (abstract).

Juvenile clams collected from natural beds were placed in plastic trays suspended from plastic flotation collars in the intake canal of a nuclear power plant. Clams ranged in size from 2 mm to 15 mm long and were maintained according to a size-frequency distribution similar to a natural population under study. Mortality over a 5-month period was less than 10%. Juveniles on natural beds had a mortality rate of nearly 90%. Maximum growth rate in trays was 0.4 mm per week in September 1979. Influence on growth rate of 10-mm clams by fouling organisms attaching to trays was examined for screens made of galvanized hardware cloth and two commercially available plastic meshes. Mortality was 5% or less in trays which held sediments in the range of 0.5-1.0 grain size and which were covered by galvanized-wire mesh. (J.L.M.)

95 Conrad, Jon M. 1982.

Management of the hard clam resource in Great South Bay. N.Y. Sea Grant Inst. and Cornell Univ., Stony Brook, NY 11794, Coastlines 13(1):2.

Great South Bay has produced most of the hard clams landed in the State of New York. Within the past 5 yrs, however, landings have dropped from a peak of 700,465 bu in 1976 to 338,839 bu in 1980. The number of commercial permits issued also has declined, but the yield per permit has also gone down, from 146.4 in 1970 to 79.3 in 1980. Littlenecks are the most valuable. Baymen would benefit if a larger number of littlenecks were allowed to grow to cherrystone or chowder sizes. Sustainable net revenues of $26 to $54 million could be generated from adherence to an optimal harvest policy. The current uncontrolled fishery has an opportunity cost in the form of foregone net revenues. The gross revenue in 1980 as reported was only $18.8 million. Institution and enforcement of the necessary quotas will not be popular among baymen. But proper controls, though requiring sacrifices today, could lead to a more profitable fishery tomorrow. (J.L.M.)

96 Conrad, Jon M. 1983.

Economics and the management of the hard clam in Great South Bay. *In* Buckner, S.C. (ed.), Proceedings of a Management Perspective on the Hard Clam Resource in Great South Bay, p. 55-65. A seminar sponsored by the Town of Islip (NY 11751), March 10, 1983.

Landings of clams per official permit have been declining since at least 1970, from over 146 bushels per permit per year in 1970 to about 64 bushels per permit per year in 1982. Overfishing brought about by open access to the fishery is probably reinforced by the high price of littlenecks. The hard clam resource in Great South Bay exhibits all the classic symptoms of overfishing caused by open access to the resource. A management program which includes a system of transferable harvest quotas, a system of certified collection centers, a records system, public auctions, and a modest landings tax per bushel, is proposed. Great South Bay could have produced gross revenues of between $35 and $70 million in 1980, and net revenues between $25 and $55 million, compared with the $18.8 million reported. No one can predict with certainty what a well managed fishery might be worth. But it seems worthwhile to consider new alternatives for management. If that gamble is not taken, the true potential of the fishery may never be known. (J.L.M.)

97 Cook, Dick. (no date, probably 1982).

Bountiful bivalve... The hard clam. Va. Inst. Mar. Sci., Sea Grant Mar. Advis. Serv., and Va. Seafood Council and Coastal Plains Reg. Comm., Va. Inst. Mar. Sci., Gloucester Pt., VA 23062, 8-page folder.

A brief account of the life history of *Mercenaria mercenaria* with uses of clams, fishing areas, recent landings, harvest methods, and instructions on holding and buying. Concludes with recipes. (J.L.M.)

98 Cowman, Charles F. 1984.

Status of commercial shellfisheries in Georgia. J. Shellfish. Res. 4(1):86 (abstract).

The amount of acreage available to oyster and clam harvest is severely limited by lack of an adequate Shellfish Sanitation Program and private ownership of most oyster and clam bottoms. Despite this, many out-of-state oyster and clam producers have recently expressed interest in Georgia's shellfish resources (including *Mercenaria mercenaria*). The summary includes attempts to remedy past causes of the decline of the industry and the current program of the State to encourage shellfisheries development. (Modified author's abstract - J.L.M.)

99 Crenshaw, Miles A. 1980.

Mechanisms of shell formation and dissolution. Chapt. 3 *In* Rhoads, D.C., and R.A. Lutz (eds.), Skeletal growth of aquatic organisms - Biological records of environmental change, p. 115-132. Plenum Press, NY.

Zonation in the shell of *Mercenaria mercenaria* is shown in fig. 2. The soluble matrix from the shell of *M. mercenaria* contains about 20% carbohydrates. The B-carboxyl group of aspartic acid appears to be amidated rather than being a free acidic group in the soluble matrix. When alkali-induced B-elimination of the carbonhydrate was tried, to detect the presence of the O-glycosidic linkage to serine, no evidence of this linkage was found in the soluble matrix of *M. mercenaria*. The soluble matrix from *M. mercenaria* specifically binds calcium. It was suggested that the pores in the nacreous interlamellar membranes of several mollusks are filled with a soluble matrix similar to that isolated from *M. mercenaria*. Some bivalves dissolve previously precipitated shell when they become anaerobic. In *M. mercenaria* shell dissolution is caused by an anaerobically produced acid with a pK similar to that of lactic acid. It was later shown that this was succinic acid, and that only 2% of the total acid was lactic acid. Analysis of body fluids and soft tissues showed that there is a stoichiometric relationship between the increase in succinic acid and calcium concentrations. Analysis of extrapallial fluid showed that succinic acid accounted for only 80% of the calcium change in this compartment. This may be accounted for by the carbonate and bicarbonate derived from the shell and by ionic exchange with the mantle epithelium. Dissolution of the shell during anaerobiosis appears to occur primarily inside the pallial line. The chalky appearance of the inner shell surface that characteristically develops with this dissolution is not found outside the pallial line even after extended periods out of water. Scanning electron micrographs show that crystals inside the pallial line have irregular edges and are poorly organized with large voids on the inner surface. Outside the pallial line the crystals have sharp edges, are well organized, and fill available space. (J.L.M.)

100 Cresswell, LeRoy. 1986.

Improving production - Clam mariculture. *In* Busby, D. (ed.). An overview of the Indian River clamming industry and the Indian River Lagoon, p. 27-28. Tech. Pap. 44, Fla. Sea Grant Ext. Prog., Univ. Fla., Gainesville, FL 32611, Proj. IR-85-7, Grant NA85AA-D SG059.

Preliminary results show that hatchery production of hard clams in the Indian River area is feasible. Several million clam seeds were cultured at the Harbor Branch Foundation facility in 1984. This program can expand production of clam seed should the demand for cultured hard clams for mariculture increase. (J.L.M.)

101 Crossen, J.M., and R.J. Smolowitz. 1981.

Power system requirements of an electrohydraulic clam dredge. *In* Marine Techol. 80. The Decade of the Oceans, p. 165. Proc. 16th Annu. Conf. Mar. Technol. Soc., Wash., D.C. (abstract).

This dredge was used successfully during clam surveys along the northeast coast of the United States in water depths up to 50 fathoms. Advantages of the system compared with conventional surface-supplied hydraulic dredges are ease of handling, consistency of operation, and efficiency in power transmission. The dredge and various controls are described in detail. (J.L.M. and M.W.S).

102 Dalton, Rodney C. 1977.

The reproductive cycles of the northern and southern quahogs, *Mercenaria mercenaria* (Linne) and *Mercenaria campechiensis* (Gmelin), and their hybrids, with a note on their growth. Unpubl. Ph.D. thesis, Fla. State Univ., Tallahassee, FL 32306, 89 p.

Young quahogs of the northern and southern species (*Mercenaria mercenaria* and *M. campechiensis*) and both reciprocal hybrids were collected at approximately monthly intervals from Alligator Harbor, Fla. Gonadal sections were examined histologically from Nov. 1974 to Nov. 1975 to determine reproductive cycles. *Mercenaria mercenaria* had three minor spawning peaks (late Jan., late Apr., and mid-Sept.). *M. campechiensis* had a single spawning period with peak activity in early February. *M. campechiensis* × *M. mercenaria* (the female parent is listed first in all hybrids) had a major spawning period (Dec.-March) and a minor spawning (May-Aug.). Data for the reciprocal hybrid were incomplete but seemed to indicate two spawnings (Dec.-Feb. and June-Aug.). Growth among the 4 groups followed the same general trends, but *M. mercenaria* had the best growth. (Modified author's abstract - J.L.M.)

103 Dalton, Rodney, and Winston Menzel. 1983.

Seasonal gonadal development of young laboratory-spawned southern (*Mercenaria campechiensis*) and northern (*Mercenaria mercenaria*) quahogs and their reciprocal hybrids in northwest Florida. J. Shellfish. Res. 3(1):11-17.

All young clams were males and one or more stages of gametogenic activity were seen each month of the year. Winter spawning was considered abnormal and resulted from the unusually warm winter of 1974-75. Gonadal development of hybrid female *M. campechiensis* × male *M. mercenaria* was similar to its southern parent; the reciprocal hybrid was similar to its northern parent. This may indicate maternal influence. Little or no spawning by *M. campechiensis* in the warmer months was unlike that of the other three pedigrees. Temperature was the overall controlling factor in gonadal development and spawning, but genetic differences existed between the two species. (Modified authors' abstract - J.L.M.)

104 Dauvin, Jean-Claude. 1985.

Dynamique et production d'une population de *Venus ovata* Pennant (mollusque - bivalve) de la Baie de Morlaix (Manche occidentale). J. Exp. Mar. Biol. Ecol. 91(1,2):109-123.

The dynamics of a *Venus ovata* population from a muddy fine sand community at station Pierre Noire from the Bay of Morlaix has been studied with a view to estimating its production. *Mercenaria mercenaria* is mentioned only in relation to a publication abstracted elsewhere in this bibliography. (J.L.M.)

105 Davis, Harry C., and Anthony Calabrese. 1964.

Combined effects of temperature and salinity on development of eggs and growth of larvae of *M. mercenaria* and *C. virginica*. Fish. Bull., U.S. 63:643-655.

Rate of growth of larvae at different temperatures was critically affected by the type of food organisms available. Clam and oyster larvae were able to utilize naked algae such as the chrysophytes *Monochrysis lutheri*, *Isochrysis galbana* and *Dicrateria* sp. and show significant growth at lower temperatures than those at which chlorophytes such as *Chlorella* sp. which have cell walls could be utilized. This implies that the enzyme systems required to digest naked flagellates are active at lower temperatures than are the enzyme systems required to digest cell walls. The cells of *I. galbana* and *M. lutheri* are destroyed by temperatures at 27.5-30.0°C, and growth of larvae receiving these foods at such temperatures was reduced. *Chlorella* sp. continued to increase with each 2.5°C increase in temperature up to 33.0°C. Salinity also affects the temperature tolerance of clam and oyster larvae. At near-optimum salinities the larvae survive and grow over a significantly wider range of temperatures than at salinities near the lower limits of their tolerance. We observed the temperature tolerances of clam and oyster larvae at a series of decreased salinities. (Modified authors' abstract - J.L.M.)

106 Davis, Nancy. 1985.

Estuarine garden: Planting clams. Univ. NC Sea Grant Coll. Prog., Raleigh, NC 27695, Coastwatch, Nov/Dec 1985:6.

Mortality among 3-mm seed clams (*Mercenaria mercenaria*) is about 95%. Blue crab is a major predator, but mud crabs, stone crabs, shrimp, snapping shrimps, bottom-feeding fishes, moon snails, and whelks also take their toll. Growth rate of clams affects rate of predation. The faster the growth, the less time is available for predation, and big clams are less vulnerable than small clams. Seed planted in winter will grow in North Carolina, so that by spring they are less vulnerable. Caging also is helpful, but it may not be cost effective. Seed clams might be held in crab shedding tanks during the off-season, growing until they reach sizes sufficient for planting. (J.L.M.)

107 De Pauw, Niels. 1981.

Use and production of microalgae as food for nursery bivalves. *In* Claus, C., N. De Pauw, and E. Jaspers (eds.), Nursery culturing of bivalve molluscs, p. 35-69. Spec. Publ. 7, Eur. Maricult. Soc., Bredene, Belgium.

Nearly all commercial enterprises involved in nursery rearing of bivalve molluscs in Europe use natural phytoplankton as food. In contrast, small-scale and large-scale experiments carried out in many countries have shown the potential and reliability of culturing microalgal species for nursery bivalves, in analogy to the well established algal culturing for hatchery molluscs. Some hatcheries continue to feed spat with the same species of microalgae used to rear larvae. The increasing quantities of algae needed soon becomes a limiting technological and economical factor. Scaling up of sophisticated systems used to produce monospecific algae seems to be prohibitive. Two trends are evident. The first relies on completely controlled production of specific algal species. The second is based on induction of natural phytoplankton blooms in outdoor systems. This arrives at a certain control of species composition by manipulating different internal and ambient conditions, such as nutrients, pH, detention time, and mixing. The biotechnological aspects of large-scale production of algae are discussed, and the present needs and possibilities of a more controlled way to produce food for nursery bivalves are examined. The original paper should be examined for details. (Modified author's abstract - J.L.M.)

108 Dey, N. Dean. 1978.

Recovery of planted clams from Rehoboth Bay, November 1977. Rep. of Coop. Proj. with State of Del., Del. Dep. Nat. Resour. Environ. Control, Dover, DE 19901, 9 p.

Clams (*Mercenaria mercenaria*) were planted at a density of 270/ft^2 over the 100-ft^2 plots. If they were evenly distributed and all had survived, a total of 48 live clams should have been collected. The pooled samples contained eight live tetracycline-tagged *Mercenaria* for a return of 16.67%. In addition, 11 unbroken tagged valves were found, accounting for another 23% of the planted clams. Finding of marked fragments of shells indicates that predation was occurring. Growth was apparent in only one of the live clams. The results, along with return of tagged material, provided preliminary data on evaluation and success of clam planting. (J.L.M.)

109 Dey, N. Dean. 1978.

Recovery of planted clams from Rehoboth Bay: ten month progress report, June, 1978. Rep. of Coop. Proj. with State of Del., Del. Dep. Nat. Resour. Environ. Control, Dover, DE 19901, 15 p.

Hatchery-spawned hard clams, *Mercenaria mercenaria*, were planted at two sites in Rehoboth Bay in Sept. 1977. They were marked with tetracycline. The average size at planting was 2.70 mm. On recovery in June 1978 the average size at the deepwater station was 8.3 mm, and at the shallowwater station was 12.5 mm. Apparent survival was only 0.37% with a range of 0.19-0.49%. No obvious evidence of severe predation was seen. The low survival rate apparently was caused by several factors. Fifty percent appeared to have been killed by other means than predation, probably by the effects of the very cold winter of 1977-78. The very small clams may have been killed by polychaete predation. In spring and summer some predation was caused by *Polinices*, crabs, *Busycon*, and possibly sea stars. Use of tetracycline was important in that it allowed positive identification of planted clams, and provided a marker so that growth could be estimated more quickly. (J.L.M.)

110 Dey, N. Dean. 1981.

Growth of sibling hard clams, *Mercenaria mercenaria*, in a controlled environment. J. Shellfish Res. 1(1):112-113 (abstract).

Sibling populations of hard clams were raised in a controlled environment with excess algal food. Wide variations were observed in shell length and volume. Populations were divided at an early stage into five successively larger size classes. Clams in the larger size classes always grew much more rapidly than smaller clams at 18°C and 25°C. Early setting clams grow more rapidly than late-setting clams but make up only a small fraction of the population. Late-setting clams never match the growth rate of early-setting clams and remain small relative to their larger siblings. During the first 4 weeks growth of spat continue at the larval rate. The rate of increase then decreases (growth pause) for the next 2 weeks, then rapid growth resumes but at a reduced rate typical of juvenile clams. The growth pause may be associated with growth of siphons. Fast-growing larvae make up fewer than 5% of the population, but with proper selection, fast-growing commercial strains, or uniform groups of clams, can be produced for studies of toxicology or nutrition. (J.L.M.)

111 Diener, Richard A. 1975.

Cooperative Gulf of Mexico estuarine inventory and study - Texas: Area description. NOAA Tech. Rep. NMFS Circ. 393, Natl. Oceanic Atmos. Adm., Natl. Mar. Fish Serv., Seattle, WA 98115, 129 p.

The quahog, *Mercenaria mercenaria*, supported essentially no commercial fishery in Texas since about 1900. Prior to 1900 a small fishery did exist. The species occurs in lower Galveston Bay near Port Bolivar and near Carancahua Reef in central West Bay and occupies a combined area of about 4 acres. A similar species, *M. campechiensis*, occurs in Mesquite Bay and in South Bay. Charts are included showing waters closed to shellfishing. Some commercial fishery landings also are tabulated. (J.L.M.)

112 Dierberg, Forrest. 1986.

Knowing how much is there. *In* Busby, D. (ed.), An overview of the Indian River clamming industry and the Indian River Lagoon, p. 23-25. Tech. Pap. 44, Fla. Sea Grant Ext. Prog., Univ. Fla., Gainesville, FL 32611, Proj. IR-85-7, Grant NA85AA-D-SG059.

The smallest size class for clams, "seeds" (1 inch), were the most abundant group of clams at one of four transects in the Indian River Lagoon. An average of 8 clams per 1/4 m^2 indicated that this area had received a successful set and should continue to yield substantial quantities of harvestable clams as long as no significant die-off occurs. For size groups of clams >1-inch long, there were no obvious differences between sampling locations. At Grant (the location previously described) numbers decreased dramatically from the small "seed" clams. Either harvesting reduced the numbers of larger clams to levels similar to the other areas, or unsuccessful sets or mortality of juveniles reduced the numbers of larger clams. Successful recruitment of juvenile clams should sustain the harvest for the next 2 years at Grant, provided mortality remains low. But low recruitment in the other areas will not provide large numbers of harvestable clams. The sampling methodology used, a SCUBA-assisted suction dredge, provided a quantitative picture of shellfish populations, and should be a valuable tool in future studies. (J.L.M.)

113 Dillaman, R.M., and S.E. Ford. 1982.

Measurement of calcium carbonate deposition in molluscs by controlled etching of radioactively labelled shells. Mar. Biol. 66(2):133-144.

Rates of calcium carbonate removal from shell pieces of *Mercenaria mercenaria* were dependent on the type of etching fluid used and not on shell origin. Etching was uniform over the entire shell surface, but surface morphology differed with etching fluids. Peak radioactivity was in early eluant fractions of shells etched immediately after radioactive labelling, and in later fractions when individuals were placed in isotope-free seawater after labelling. The etching technique can measure growth during the labelling period and subsequently by estimating the amount of calcium in fractions prior to the radioactive peak. Geometry of shell layers influenced the pattern of radioactivity seen in fractions. Peak location varied inside and outside the pallial line of individuals. A significant portion of the inorganic carbon used in shell formation was derived from metabolic CO_2. (Modified authors' abstract - J.L.M.)

114 Dobroski, C.J., Jr., and C.E. Epifanio. 1980.

Accumulation of benzo(a)pyrene in a larval bivalve via trophic transfer. Can. J. Fish. Aquat. Sci. 37(12): 2318-2322.

The diatom *Thalassiosira pseudonana* was cultured in 10 $\mu g/L$ ^{14}C-benzo(a)pyrene (B(a)P) and subsequently fed to larvae of the hard clam *Mercenaria mercenaria*. The rate of direct uptake of B(a)P from seawater by the diatoms was much greater than the rate of trophic transfer of B(a)P from the diatoms to the clam larvae. This was attributed to greater efficiency of direct uptake and to the larger quantity of B(a)P available in the water. A comparison of direct uptake by bivalves (as reported in the literature) with trophic transfer measured in the present investigation indicated that the processes may be equally important in accumulation of B(a)P in natural populations of bivalves. (Authors' abstract - J.L.M.)

115 Doering, Peter H. 1982.

Reduction of attractiveness to the sea star *Asterias forbesi* (Desor) by the clam *Mercenaria mercenaria* (Linnaeus). J. Exp. Mar. Biol. Ecol. 60(1):47-61.

In field and laboratory choice tests the sea star was attracted to distant upstream clams. Clams exposed to upstream sea stars were chosen less frequently by downstream sea stars than clams without sea stars upstream. Sea stars neither attracted nor repelled downstream conspecifics. When clams were exposed to upstream sea stars their oxygen consumption decreased, as did their pumping rate and activity as measured by the number of visible siphons. It was concluded that clams and sea stars sense each other over a distance by chemical cues. The response of the clam is a general lowering of activity which may result in decreased attractiveness to sea star predators. This response may serve as a defensive measure against distance detection by sea stars. (Modified author's abstract - J.L.M.)

116 Dube, Paul Richard. 1985.

The growth rates of bivalves suspended in water of different depths in Long Island Sound: Influence of resuspended sediments. M.S. thesis, State Univ. N.Y. at Stony Brook, NY 11794, 90 p.

Mercenaria mercenaria and several other bivalves were suspended near the surface, at mid-depth, and near bottom at two sites with different water depths in Long Island Sound in 1984. Growth through December was measured to determine if growth near bottom would be improved by upwelling of nutrient-rich bottom materials. Cumulative growth and relative growth rates showed best growth in summer at the nearsurface location at both sites for species deployed in July. Between August and November growth rates were highest near the bottom at both sites. For those species deployed in August, at the 10-m depth site, best growth was near the surface from August to October, but subsequent growth was greater near the bottom. At the 20-m depth site growth was equal at all three depths from August to October Subsequently, growth at upper levels was greater than at the bottom. (Modified author's abstract - J.L.M.)

117 Duncan, Patricia L., Michael Castagna, and William D. DuPaul. 1984.

Preliminary data on the use of crab meal as a supplementary food for juveniles of *Mercenaria mercenaria* (Linne). J. Shellfish. Res. 4(1): 87(abstract).

One group of juvenile hard clams (*M. mercenaria*) received continuous crabmeal supplements while the control group received only maintenance seawater flow. Final dry weights of crabmeal-fed clams were significantly greater than those of control clams. Overall, the increase in wet and dry weights was 2.5 times greater in crabmeal-fed clams than in control clams. Ongoing research is being conducted to determine optimum feeding rates and commercial scale applicability. (Modified authors' abstract - J.L.M.)

118 Easley, J.E., Jr. 1982.

Property rights in shellfish relay: Managing fisheries for higher economic returns. N. Am. J. Fish. Manage. 2(4):343-350.

Some shellfish have the ability to purge themselves of contaminants after they are placed in clean water. A North Carolina management practice is to mechanically move (or relay) shellfish from polluted water to clean water for purging and later harvesting. Significantly higher returns may be earned by fishermen if shellfish moved from polluted water are placed on private or leased bottom as opposed to bottoms in public waters. The magnitude of this higher return is discussed in an example from North Carolina, and issues affecting the size of the gain are explored. Implications for management are discussed. (J.L.M.)

119 Eldridge, Peter J., and Arnold G. Eversole. 1981.

Compensatory growth and mortality of the hard clam, *Mercenaria mercenaria* (Linnaeus 1758). Veliger 24(3):276-278.

Clams raised at the same density were similar in mean shell length between replicates and tidal locations at the start of the experiment. However, mean shell length of clams formerly held at a density of $869/m^2$ was significantly smaller than at $290/m^2$, and clams formerly held at $1159/m^2$ were significantly smaller than both of the lower densities. These differences persisted throughout the experiment. Adjustments to reduced population densities were observed in absolute and relative growth. Shell lengths of clams formerly held at $1159/m^2$ and $869/m^2$ increased approximately 10 mm and 8.5 mm during the experiment compared with only 5 mm for clams maintained at $290/m^2$. According to Ricker's (1975) definition this population of hard clams, 3-5 years of age, exhibited compensatory growth. Results also indicated that growth adjustments were influenced by reductions in population density. (J.L.M.)

120 Elfvin, Myra, Rhea J. C. Levine, and Maynard M. Dewey. 1976.

Paramyosin in invertebrate muscles. I. Identification and localization. J. Cell Biol. 71(1):261-272.

By sodium dodecyl sulfate-polyacrylamide gel electrophoresis and immunodiffusion, they identified paramyosin in two smooth invertebrate "catch" muscles including *Mercenaria mercenaria* opaque adductor. Paramyosin was also identified in five invertebrate striated muscles. Paramyosins of all these muscles had the same chain weights and were immunologically similar. All muscles were stained with specific antibody to Limulus paramyosin using the indirect fluorescent antibody technique. Paramyosin was localized to the A bands of the glycerinated striated muscles, and diffuse fluorescence was seen throughout the glycerinated fibers of the smooth catch muscles. (J.L.M.)

121 Endnoff, Mike. 1986.

Conclusions. *In* Busby, D. (ed.), An overview of the Indian River clamming industry and the Indian River Lagoon, p. 39-45. Tech. Pap. 44, Fla. Sea Grant Ext. Prog., Univ. Fla., Gainesville, FL 32611, Proj. IR-85-7, Grant NA85AA-D-SG059.

A review and summary of the proceedings. (J.L.M.)

122 Epifanio, C.E. 1983.

Phytoplankton and yeast as foods for juvenile bivalves: A review of research at the Univ. of Del. *In* Pruder, G.D., C.J. Langdon, and D.E. Conklin (eds.), Proc. 2nd Int. Conf. on Aquaculture Nutrition, Oct. 1981, Rehoboth Beach, Del. Spec. Publ. 2, Coll. Mar. Stud., Univ. Del., Lewes, DE 19958, p. 292-304.

Efficiency of utilization of a given ration is a function of temperature. Large rations can be utilized only at high temperature. Qualitative differences in diets are best explained by differential digestibility of food particles. There is little correlation between chemical composition (gross proximate, amino acid, and fatty acid) of a diet and its value as a food for bivalves. Synergistic nutritional effects of some dietary components may be due to improved balance of micronutrients or fatty acids. Results of the study applied principally to *Crassostrea virginica*, but some discussion of *Mercenaria mercenaria* also is included. (J.L.M.)

123 Estes, Ernest Lathan, III. 1972.

Diagenetic alteration of *Mercenaria mercenaria* as determined by laser microprobe analysis. Ph.D. diss., Univ. N.C., Chapel Hill, NC 27559, 103 p. [From Diss. Abstr. Int. B Sci. 34 (1973):275B-276B.]

Modern, recent, and Pleistocene representatives of *Mercenaria mercenaria* were analyzed in great detail utilizing laser microprobe spectrographic techniques. The main purpose of the study was to determine if diagenetic chemical alteration exists in apparently unaltered skeletal material. Analysis of precision indicates that a coefficient of variation of 3.5% is possible if care is taken throughout the analytical procedure. The principal conclusions are: 1) A large range of Sr/Ca, Mg/Ca, and Na/Ca ratios is present within different portions of modern, recent, and Pleistocene representatives of hard clam and the range of values obtained decreases with increasing geologic age as internal equilibration proceeds. 2) There is no significant change in the amount of Sr deposited at different times in the hard clam's life cycle; Sr is largely incorporated in crystal lattice sites, although a portion appears to be bound either in the organic fraction or on crystallite surfaces; internal equilibrium with respect to Sr within the shell seems to occur shortly after death, apparently due to equilibration of non-lattice material. 3) There is a decreased discrimination against Mg as hard clam ages; the Mg/Ca ratio does not change from modern to recent specimens, but decreases from recent to Pleistocene samples; the decrease in Mg is due to an external re-equilibration of the organically-bound portion or the absorbed portion with the aqueous environment. 4) There is a decreased discrimination against Na as hard clam matures; Na appears to be present mainly as a contaminant, and is not present in the lattice; Na increases from modern to recent samples due to an external re-equilibration of non-lattice material with seawater, and decreases from recent to Pleistocene specimens due to re-equilibration of non-lattice material with fresh water. 5) The prismatic-lamellar interface is the main pathway by which Na and Mg enter and leave the shell. 6) The order of trace element mobility in hard clam is Na>Mg>Sr, which is mainly dependent upon the site in which each element resides. (J.L.M.)

124 Eversole, Arnold G., Peter J. Eldridge, and William K. Michener. 1981.

Reproductive response to increased density: Some observations from molluscs. J. Shellfish. Res. 1(1):113-114 (abstract).

A significant density-dependent reduction in growth of hard clams (*Mercenaria mercenaria*) is evident. Histological evidence gives no indication that gametogenesis is affected by increased density. The amount of gonadal tissue in clams grown at three population densities was compared. Clams at the lowest density were larger, weighed more, and had more gonadal tissue than clams from higher densities. Gonadal-somatic indices showed that density-dependent reduction of growth did not fully account for reductions in amount of gonadal tissue. Results are discussed in relation to existing literature on density-dependent changes in reproductive biology of molluscs with emphasis on ecological advantages and consequence of some changes. (J.L.M.)

125 Eversole, Arnold G., W.K. Michener, and Peter J. Eldridge. 1984.

Gonadal condition of *Mercenaria mercenaria* (Linne) in a South Carolina estuary. J. Shellfish. Res. 4(1):88 (abstract).

Changes in gonadal condition (GSI) reflected seasonal changes in gonadal development. Similar decreases in GSI were observed in spring (May-June) and fall (Sept.-Oct.) spawning peaks. GSI varied significantly with clam (*M. mercenaria*) size and age. Larger clams of the same age had proportionally more gonad tissue than smaller clams. Older clams have larger GSI than younger clams of the same size. No statistical difference was detected between GSI of female and male clams of the same age and size. Clams grown at the lowest density level or at the subtidal location were larger and had proportionally more gonadal tissue than clams from high densities or the intertidal location. Size differences between treatments explained the variation in GSI between density treatments, but not between tidal locations. (Modified authors' abstract - J.L.M.)

126 Evjen, Arthur John. 1985.

Above bottom bivalve growth in Long Island Sound and the influence of resuspended sediment. M.S. Thesis, State Univ. N.Y. at Stony Brook, NY 11794, 83 p.

Mercenaria mercenaria and some other bivalves were suspended at the surface, mid-depth, and near bottom in Long Island Sound in summer 1983. Growth through November was observed to determine if enhanced growth, as proposed by Rhoads et al (1975), occurred near bottom where resuspended sediment concentrations were highest. Cumulative growth and instantaneous growth rates showed best growth between June and August in clams at the surface. Between August and November growth rates were highest near bottom. Measured concentrations of chlorophyll-(*a*), phaeopigments, POC and PON all decreased with depth until October when distribution became more homogeneous. Seston concentrations increased with depth. The dramatic change in October coincided with the breakdown of stratification. It is suggested that food trapped by stratification was then redistributed. Settling food material became available to nearbottom animals by sediment resuspension. Enhanced growth near bottom was observed after sufficient food combined with resuspended sediment. Food availability was apparently the overriding factor affecting growth. Best growth was at the surface, not the bottom. (Modified author's abstract - J.L.M.)

127 Fang, Lee-Shing, and Pouyan Shen. 1984.

Foreign elements in a clam shell: a clue to the history of marine pollution events. Mar. Ecol. Prog. Ser. 18(1,2):187-189.

Mercenaria mercenaria is not mentioned. In *Meretrix lusoria* foreign elements accumulate on the outer surface of the shell and the amounts of S, Fe, Cu and Zn decrease with age. (J.L.M.)

128 Figley, William, and Thomas McCloy. 1979.

New Jersey's 1978 bay shellfish harvest. NJ Tech. Rep. 43M, NJ Dep. Environ. Prot., Div. Fish, Game, and Shellfish., Nacote Creek Res. Stn., Absecon, NJ 08201. Federal-Aid-to-Fisheries Proj. FW54P, 5 p.

New Jersey's harvest of shellfish consisted primarily of hard clam (*Mercenaria mercenaria*), soft clam, oyster, blue mussel, and bay scallop. A survey was conducted to determine the numbers of shellfishermen in New Jersey, the effort expended, and their harvest. Over 1000 shellfishermen responded to the questionnaire. In 1978 there were 22,728 licensed bay shellfishermen. At least 90% of license holders went shellfishing. Effort expended was 211,473 man-days, 2/3 of which were recreational and 1/3 commercial. Licensed shellfishermen took 58 million hard clams. Although commercial fishermen made up only 5% of total shellfishermen, they accounted for 66% of hard clam landings. Recreational clammers averaged 164 hard clams per day, part-time commercial 418, and full-time commercial 622. Treading was the most popular method for recreational and commercial fishermen, which is restricted to water less than 5 feet deep and primarily from April to October. The tables give considerable detail on fishermen and their activities. (J.L.M.)

129 Figley, Bill, Tom McCloy, and Staff of Nacote Creek Research Laboratory. 1979.

New Jersey's bay shellfisheries. NJ Inf. Bull., NJ Dep. Environ. Prot., Div. Fish, Game, and Shellfish., Nacote Creek Res. Lab., Absecon, NJ 08201, 6 p.

New Jersey's oyster, hard clam, and soft clam stocks and their harvests have been declining since the late 1940s or early 1950s. The causes are pollution, habitat destruction, the tremendous demand for seafood which has led to overfishing, and in some cases environmental factors. In 1978, 58 million hard clams were harvested, which probably is conservative. The primary species sought was the hard clam, *Mercenaria mercenaria*, which is found throughout New Jersey estuaries where salinity is regularly above 15‰, and occurs from the intertidal zone to depths >30 feet. They may live for 20-35 years, and reach a maximum size of 5½ inches. In 1978 full-time commercial fishermen took an average of 622 hard clams per day, part-time commercial fishermen took 418 per day, and recreational fishermen took 164 per day. (J.L.M.)

130 Flagg, Paul J., and Robert E. Malouf. 1983.

Experimental plantings of juveniles of the hard clam *Mercenaria mercenaria* (Linne) in the waters of Long Island, New York. J. Shellfish. Res. 3(1):19-27.

Objectives were to determine how seed survival was influenced by (1) seed size at the time of planting; (2) presence, absence, and type of gravel aggregate; (3) season of planting; and (4) site selection. Site characteristics, particularly the types and abundance of predators present, were found to influence the results so strongly that general recommendations cannot be made. Mud crabs (*Neopanope sayi*) and whelks (*Busycon carica* and *B. canaliculatum*) were the most damaging predators at sites tested. Gravel aggregate did not provide adequate protection for planted clams, and use of large (25 mm) gravel appeared to have a negative impact on seed survival. Survival exceeded 10% only among clams that were at least 20 mm long at planting. Mortalities as high as 100% resulted from plantings of such seed (23 mm) at sites having significant populations of whelks. (Modified authors' abstract - J.L.M.)

131 Flimlin, Gef. 1986.

Agent's odyssey reaps rewards. N.J. Sea Grant Ext. Serv., Rutgers Univ., New Brunswick, NJ 08903. The Jersey Shoreline 9(1):3.

This project will attempt to rejuvenate populations of hard clam, *Mercenaria mercenaria*, in Barnegat and Little Egg Harbor bays. Leased bottom will be cultivated with a hydraulic cultivator, which reoxygenates the substrate, opens up the bottom to receive clam spawn, and raises the pH level by washing away acidic sediments. (J.L.M. and M.W.S.)

132 Foster, John E. 1981.

Clam Gardening. Univ. N.C. Sea Grant Publ. 81-3, Raleigh, NC 27695, 7 p.

Reviews briefly the techniques required for artificial rearing of hard clams, *Mercenaria mercenaria*. Includes obtaining seed clams, leasing and permits, location suitability, and managing the clam garden. Appendix gives additional reading, personal contacts, and material suppliers. (J.L.M.)

133 Foster-Smith, R.L. 1975.

The effect of concentration of suspension and inert material on the assimilation of algae by three bivalves. J. Mar. Biol. Assoc. U.K. 55(2):411-418.

Assimilation efficiency was found to be inversely related to total amounts of *Phaeodactylum* ingested over periods of up to 3 hours rather than related directly to concentration of suspension or rates of ingestion. *Mercenaria mercenaria* was not included in the experiments. (J.L.M.)

134 Foster-Smith, R.L. 1976.

Some mechanisms for the control of pumping activity in bivalves. Mar. Behav. Physiol. 4(1):41-59.

No specific mention of *Mercenaria mercenaria*. (M.W.S.)

135 Franz, David R. 1982.

An historical perspective on molluscs in Lower New York Harbor, with emphasis on oysters. *In* Mayer, G.F. (ed.), Ecological stress and the New York Bight: Science and management, p. 181-197. Estuarine Res. Fed., Columbia, SC.

Mercenaria mercenaria was included in a list of shallow bay and shore molluscan species of Staten Island in Smith (1887). Beds of quahogs were abundant locally over much of the lower harbor, and extensive populations occurred in Gravesend Bay, Jamaica Bay, and Raritan Bay. Hard clams raked in Staten Island and Jamaica Bay were marketed in N.Y. City. Most N.Y. City shellfish beds were closed for public health reasons by 1921. (J.L.M.)

136 Fritz, Lowell W., and Dexter S. Haven. 1983.

Hard clam, *Mercenaria mercenaria*: Shell growth patterns in Chesapeake Bay. Fish. Bull., U.S. 81(4):697-708.

Acetate peels of polished and etched radial shell surfaces of *Mercenaria mercenaria* showed growth cessation marks caused by low winter water temperatures present in some annual increments but were not formed each year by each individual clam. This was caused primarily by differences among age groups in seasonal band formation. Clams younger than 8 years tended to form light bands in fall and spring. Older clams tended to form light bands only in spring, and winter growth cessation marks were masked by dark bands deposited from summer through winter. These differ from clamshell growth patterns found elsewhere along the range, suggesting that time of annulus formation varies with latitude. The percentage agreement between increments and days in annual shell increments decreased with increasing age. Thus, dividing total microgrowth increment counts by 365 could underestimate age in years. (J.L.M.)

137 Gabbott, P.A., D.A. Jones, and D.H. Nichols. 1975.

Studies on the design and acceptability of microencapsulated diets for marine particle feeders. II. Bivalve molluscs, p. 127-141. 10th Eur. Symp. Mar. Biol., Ostend, Belgium, Sept. 17-23, 1975, Vol. 1.

In contrast to many crustacea, marine bivalves swallow their food whole. This means that the wall of the microcapsule must be broken down in the gut, either by digestive enzymes or by a change in pH. The main aim of the paper was to demonstrate the feasibility of using microcapsules as artificial food particles for marine bivalves. In our laboratory, nylon-protein capsules were prepared on a routine basis and have been used in experimental studies on feeding and digestion and in simple growth experiments. As an experimental approach this has already been successful. Experiments were with *Mytilus edulis* and *Crassostrea gigas*, not *Mercenaria mercenaria*. (J.L.M.)

138 Gade, Gerd. 1980.

A comparative study of octopine dehydrogenase isoenzymes in gastropod, bivalve and cephalopod molluscs. Comp. Biochem. Physiol. 67B:575-582.

Mercenaria mercenaria is not mentioned. (M.W.S. and J.L.M.)

139 Gaffney, Patrick M., and Timothy M. Scott. 1984.

Genetic heterozygosity and production traits in natural and hatchery populations of bivalves. Aquaculture 42(3/4): 289-302.

Relationship between allozyme phenotype and physiological traits depends strongly on genetic structure of the population in several bivalve species. *Mercenaria mercenaria* was not studied but some discussion from the literature is included. (J.L.M.)

140 Gallagher, Scott M., and Roger Mann. 1984.

Lipids and the condition of marine bivalve larvae. J. Shellfish. Res. 4(1):90 (abstract).

Neutral lipids, predominantly triacylglycerides, are an important energy reserve in larvae of *Mercenaria mercenaria*, *Crassostrea virginica*, and *Ostrea edulis* and are metabolized under stress. Data from our laboratory and two commercial hatcheries suggest that a threshold relationship exists between egg lipid content and subsequent larval growth and metamorphosis. Under otherwise identical culture conditions eggs with a high lipid content give rise to larvae in better condition which complete metamorphosis with a higher degree of success than eggs with a low lipid content. Lipid levels in 24-hour straight-hinge larvae, visualized with lipid-specific stains, may be used as an index of potential culture success. (Modified authors' abstract - J.L.M.)

141 Galtsoff, Paul S. 1940.

Physiology of reproduction of *Ostrea virginica*. III. Stimulation of spawning in the male oyster. Biol. Bull. (Woods Hole) 78(1):117-135.

The sexual reaction of *Ostrea virginica* is nonspecific. It can be provided by the sperm of *Venus* and others. (J.L.M.)

142 Gibbons, M.C. 1984.

Comparison of energetics of hard clam predation by *Neopanope sayi*, *Ovalipes ocellatus*, and *Pagurus longicarpus*. J. Shellfish. Res. 4(1):90 (abstract).

The bioenergetics of ingestion, absorption, and respiration were used to examine the voracity of hard clam *Mercenaria mercenaria* predation by the mud crab *Neopanope sayi*, the calico crab *Ovalipes ocellatus*, and the hermit crab *Pagurus longicarpus*. Crabs were several orders of magnitude more voracious than sea stars or gastropods in terms of ingestion rate. On the basis of body-weight comparisons of the prey consumed per day, however, adult crabs, sea stars, and snails consumed similar amounts of prey. Predatory gastropods and sea stars have long search and attack procedures to pursue their prey. They have specialized diets and generally prey on relatively large prey. Crabs are searchers, do not extensively pursue individual prey, have more flexible diets, and consume large numbers of small prey daily. Ingestion rates of predators are influenced by their metabolic rates and their ability to convert food into net energy. The mud crab, calico crab, and hermit crab have high absorption efficiencies and metabolic costs compared with predatory gastropods. Crabs lost larger percentages of energy via respiration than predatory gastropods. These data are consistent with the different methods of foraging used by crabs and predatory gastropods. (Modified author's abstract - J.L.M.)

143 Gibbons, M.C. 1984.

Predation of juveniles of the hard clam *Mercenaria mercenaria* (Linne) by fifteen invertebrate species with special reference to crabs. J. Shellfish. Res. 4(1):90 (abstract).

Fifteen of 19 species tested consumed juvenile hard clams. Crabs had higher predation rates than gastropods, shrimp, and sea stars. Predation by crabs was influenced by clam size, crab size, crab species, temperature, and substrate. Crabs preyed upon hard clams with shell lengths up to 30% of their carapace widths. The size of prey affected the method of predation used by crabs. Predation decreased with declining temperature and resumed when water temperature rose in spring. The rock crab *Cancer irroratus* was observed to prey on hard clams at a seawater temperature of 0°C. Substrate type influenced predation. Crushed gravel aggregate and, to a lesser extent, sand provided protection for juvenile hard clams against predation by *Neopanope sayi*, *Ovalipes ocellatus*, and *Pagurus longicarpus*. (Modified author's abstract - J.L.M.)

144 Gibbons, M.C., and M. Castagna. 1984.

Serotonin as an inducer of spawning in six bivalve species. Aquaculture 40(2):189-191.

Injection of serotonin into the anterior adductor muscle of the hard clam *Mercenaria mercenaria* induced spawning. A dosage of 0.4 mL of 2 mM serotonin solution stimulated hard clams to spawn within 15 minutes. (J.L.M.)

145 Gibbons, M.C., and M. Castagna. 1985.

Biological control of predation by crabs in bottom cultures of hard clams using a combination of crushed stone aggregate, toadfish, and cages. Aquaculture 47(2,3):101-104.

Use of toadfish (*Opsanus tau*) to control predation by crabs on juvenile hard clams *Mercenaria mercenaria* was tested in this field study. Hard clams 3 mm long, planted in crushed stone aggregate beds, had significantly higher survival when enclosed in cages with toadfish than in cages without toadfish. Toadfish were effective in reducing predation by crabs (*Callinectes sapidus*, *Neopanope sayi*, and *Panopeus herbstii*). (Modified authors' abstract - J.L.M.)

146 Gibson, Ray. 1968.

Studies on the biology of the entocommensal Rhynchocoelan *Malacobdella grossa*. J. Mar. Biol. Assoc. U.K. 48:637-656.

Mercenaria mercenaria is not mentioned. No measurable effects are produced upon the host and the nemertean is a true commensal. Host and worm sex ratios are about 1:1. (J.L.M.)

147 Gillmor, R.B. 1982.

Assessment of intertidal growth and capacity adaptations in suspension-feeding bivalves. Mar. Biol. 68(3):277-286.

Langton and McKay (1974, 1976) found that growth was best in *Crassostrea gigas* spat fed discontinuously rather than continuously. The same phenomenon has been noted in hatchery-reared spat of *Mercenaria mercenaria*. (J.L.M.)

148 Gold, Kenneth, Gerard Capriulo, and Kevin Keeling. 1982.

Variability in the calcium phosphate concretion load in the kidney of *Mercenaria mercenaria*. Mar. Ecol. Prog. Ser. 10(1):97-99.

Appreciable differences in calcium phosphate concretion loads were found between different size classes of the hard clam *Mercenaria mercenaria*. Largest clams (41.3 mm) had significantly higher amounts of concretions than intermediate (36.5-41.2 mm) or small (25.4-36.4) clams. Comparison of concretion weights in clams of comparable size from two selected sites showed that clams from restricted areas (uncertified) had significantly higher loads than those from approved beds (certified). (Modified authors' abstract - J.L.M.)

149 Goldstein, B.B., and O.A. Roels. 1980.

The effect of feed density on the growth of juvenile *Mercenaria campechiensis*, the southern hard clam. Proc. World Maricult. Soc. 11:192-201.

A Tahitian strain of *Isochrysis* sp. was grown in outdoor continuous culture and fed to juvenile *Mercenaria campechiensis* at five different cell densities: 5×10^5, 1×10^5, 5×10^4, and 1×10^4 cells/mL. A control group received only 1 μ-filtered seawater. An additional control consisted of an identical experimental setup receiving 5×10^4 cells/mL without animals. Each treatment went to duplicate populations of 100 animals of 0.1 g each and each population had a whole wet weight of 10.0 g. Total flow rate to each was 120 mL/min. The control treatment of 1 μ-filtered seawater gave no growth. The most concentrated treatment (56.01 μg-at PPN/L) gave good growth. But better growth was obtained at concentrations of 5.75 and 11.34 μg-at PPN/L. It is not clear if the algal concentration referred to in many studies on bivalves is an inflow, outflow, or some average concentration. The actual algal concentration experienced by the animals is equal to the outflow concentration in a perfectly mixed flowthrough system. The algal concentrations referred to in Winter and Langton (1975) and Winter (1978) are those immediately around the *Mytilus edulis* they used. Other workers are not as specific. The best feeding regime of this study resulted in 38% better growth than in the natural environment. Experience will determine if this improved growth can be attained in a production scale operation. (J.L.M.)

150 Goldstein, B.B., and O.A. Roels. 1981.

Nitrogen balance of juvenile southern quahogs (*Mercenaria campechiensis*) at different feed levels. J. Shellfish. Res. 1(1):75-81.

A Tahitian strain of *Isochrysis* sp. was grown in outdoor continuous culture and fed at four different cell densities to juvenile southern quahogs. Cell densities were: 1×10^4, $5 x 10^4$, 1×10^5, and 5×10^5 cells/mL. Controls were trays without animals receiving an inflow cell density of 5×10^4 cells/mL and trays with animals receiving only filtered seawater. Duplicate populations of 100 animals received each treatment; each population had a whole wet weight of 10 g. Total flow rate to each was 120 mL/min. Incoming filtered seawater, incoming algal culture, and effluent from each shellfish population were collected daily and analyzed for nitrite, nitrate, ammonia, urea, dissolved free amino acids (DFAA), soluble protein, total dissolved nitrogen, and particulate protein nitrogen (PPN). A nitrogen balance for juvenile *M. campechiensis* in a continuous flow system was calculated; 85% to 95% of all total incoming nitrogen was accounted for in the different treatments. Only those populations receiving an inflow algal protein concentration of 5.75 μg at PPN/L showed a significant excretion of ammonia. Any excretion of DFAA or urea was absorbed by microorganisms present in the shellfish culture containers. Nitrite and nitrate were absorbed by algae present in the copious biodeposits of shellfish populations receivng an inflow algal protein concentration of 56.01 μg at PPN/L, and a significant uptake of soluble protein by shellfish populations receiving 5.75 μg at PPN/L was noted. (Modified authors' abstract - J.L.M.)

151 Gracy, Robert C., Willis J. Keith, and Raymond J. Rhodes. 1978.

Management and development of the shellfish industry in South Carolina. Tech. Rep. 28, S.C. Wildl. Mar. Resour. Dep., Mar. Resour. Cent., Off. Conserv. Manage, Columbia, SC 29202, 33 p. + charts.

Commercial clam harvesting was not extensively practiced in South Carolina until recently. Newspaper reports indicated that 1120 bags of clams were shipped from Charleston, SC, to New York in 1900. Hydraulic patent tongs were used to sample clams (*Mercenaria mercenaria*) in the present survey. Data collected during the survey were sufficient to consider the feasibility of mechanically harvesting the clam beds. Greatest concentrations were found in the South Santee estuary (35.81% of samples contained clams), North Santee (33.74%), Little River (15.79%) and Bull Bay (10.12%). Controlled harvesting began in North and South Santee in 1974 under special permits, and the operators determined that harvesting clams with hydraulic escalator harvesters was financially feasible. Each vessel was required to complete daily log forms with total catch per tow and fishing time, as a condition for renewal of permit. (J.L.M.)

152 Guthrie, James F., and Curtis W. Lewis. 1982.

The clam-kicking fishery of North Carolina. Mar. Fish. Rev. 44(1):16-21.

Traces the historical progression of methods and gear used in the clam-kicking *Mercenaria mercenaria* fishery. The anchor method, bedstead method, oyster drag method, and the clam trawl are figured and described. In the present fishery hard clams are blown from the bottom by wash from a boat propeller and are retained in a special 12-20 ft-wide trawl towed behind a 17-45 ft boat. The focus is on Carteret County, NC, where the fishery is believed to have started and which is still the leading clam-producing county. (J.L.M.)

153 Hadley, Nancy H., and John J. Manzi. 1983.

Some relationships affecting growth of seed of the hard clam *Mercenaria mercenaria* in raceways. J. Shellfish. Res. 3(1):92 (abstract).

Seed clams (size 3.9 mm) were held in raceways for 6 months at densities of 740, 2220, 6660, and 19,980 clams/m^2. Each density was replicated eight times in the raceways and the highest and lowest densities were replicated four times in subtidal field controls. Raceway clam populations were stocked in four different positions relative to water flow and in 19 different positions relative to total raceway biomass. Growth was significantly reduced at the highest density in the raceway and the field. The lowest density showed greater growth in the raceway than in the field, while the highest density showed no difference in growth between the two locations. In the raceway, growth rate was inversely proportional to distance from water inflow and to effective density (number of clams/unit water). Although clams at the highest density consistently removed the greatest amount of chlorophyll-*a*, less chlorophyll was removed per clam as density increased. Growth was highly correlated with stripping rate (milligrams of chlorophyll-*a* per clam per day) and with effective water flow rate. (Modified authors' abstract - J.L.M.)

154 Hadley, N.H., and J.J. Manzi. 1984.

Growth of seed clams, *Mercenaria mercenaria*, at various densities in a commercial scale nursery system. Aquaculture 36(4):369-378.

Hatchery-raised *Mercenaria mercenaria*, mean size 3.9 mm, were placed in commercial nursery raceways at densities approximating 740, 2220, 6660, and 19,980 seed/m^2. Each density was replicated eight times in the nursery and the highest and lowest densities were replicated four times in adjacent subtidal field controls. Growth was significantly affected by planting density in raceways and field controls. Total mean growths for the raceway and the field were similar, but different factors influence growth in the two locations. Growth in raceways was inversely proportional to distance from inflows and planting density. Greatest growth was observed in the lowest density nearest the inflow and slowest growth in the highest density nearest the outflow. Growth in the field was less variable throughout the study. Clams in the raceway grew much faster than those in the field in spring, but clams in field controls continued to grow in summer when there was little growth in the raceway. These differences suggest that conditions in the two locations were not as similar as believed. (J.L.M.)

155 Hakim, G., E. Carpene, P. Cortesi, and G. Isani. 1985.

Regulation by phosphorylation-dephosphorylation of pyruvate kinase in *Venus gallina* and *Scapharca inaequivalis*. Comp. Biochem. Physiol. 80B(1):109-112.

Pyruvate kinase plays a pivotal role in regulating anaerobic metabolism and gluconeogenesis in marine invertebrates. Pyruvate kinase from the posterior adductor muscle of *Venus gallina* can be converted into a more active form by treatment with a cyclic AMP-dependent protein kinase. (J.L.M.)

156 Hall, C.E., M.A. Jakus, and F.O. Schmitt. 1945.

The structure of certain muscle fibrils as revealed by the use of electron stains. J. Appl. Physiol. 16:459-465.

Fibrils from adductor muscles of the clam *Venus (Mercenaria) mercenaria*) were examined with the electron microscope and found to possess periodic variations in structure. To make these structural variations visible the fibrils were treated with reagents of high electron scattering power (electron stains). Phosphotungstic acid was found to be particularly suitable. This stain combines with specific regions in the fibrils, forming a remarkably regular geometric pattern. This pattern is described. (J.L.M.)

157 Hammen, C.S. 1980.

Total energy metabolism of marine bivalve mollusks in anaerobic and aerobic states. Comp. Biochem. Physiol. 67A:617-621.

A single large hard clam weighing 110 g had a metabolic rate about 1/4 as great as rates of mussels. Oxygen consumption was very low for the first hour, increased to a maximum at 2.0 hours, then declined to zero at 3.5 hours. Heat production was also very low for the first 40 minutes, increased to a maximum at 1.5 hours, then decreased in a stepwise manner to 0.41 J/hr-gram between 3 and 4 hours. At 2.0 hours Q_o was 0.66, Q_H was 1.02, and the ratio Q_o/Q_H was 0.648. (J.L.M.)

158 Hanks, J.E. 1958.

Shellfish predators. Studies on the reproduction and early life history of the clam drills, *Polinices duplicata* and *P. triseriata*. *In* Rep. on Investigations of the Shellfisheries of Massachusetts for 1957, p. 17-21. Ref. No. 58-40, Woods Hole Oceanogr. Inst., Woods Hole, MA 02543. Prepared for Commonwealth Mass., Dep. Nat. Resour., Div. Mar. Fish.

Newly set *P. duplicata* are probably predators from the time of metamorphosis. Clam larvae and drill larvae settle over the flat over much of the same summer period, thus it is probable that predation at this size range is very high even though not readily observable. Such predation can account for apparent lack of set in some areas. *P. triseriata* larvae complete their development within the collar and are released as juvenile drills. At a water temperature of 68°F, development from ova to collar breakup and release of juvenile drills was 30-35 days. Drills immediately attacked small clams and also fed on small mud snails. (J.L.M.)

159 Hart, Kathy. 1982.

Clams today, none tomorrow, say kickers. Univ. N.C. Sea Grant Coll. Prog., Raleigh, NC 27695, Coastwatch, March 1982:2-3.

Kicking is done with propeller wash, and the clams are picked up by towing a heavy net behind the boat. Kicking is a relatively new method, and it is much more efficient than hand raking, taking 20-25 bags of clams per day as compared with 5-6 bags. Kicking is also profitable because clam prices have risen. In 1978 the Marine Fisheries Commission closed grass beds to kicking, and now clam kicking is restricted to Core Sound. Catch per unit of effort is dropping, and the fishery has reached the point where it is limiting itself. Further restrictions may be necessary. More information is needed about clam biology and harvest methods. (Abstracter's note: It is doubtful that more information will help much. What is needed is a system to allow clams to grow to marketable size. Dividing Core Sound into three parts, closing two of them, and rotating seems to be a good thing to try. Limiting the numbers of vessels also might be good.) (J.L.M.)

160 Hart, Kathy. 1982.

Researcher seeks hard facts about hard clams. Univ. N.C. Sea Grant Coll. Prog., Raleigh, NC 27695, Coastwatch, March 1982:4-5.

To test how grass-cover affects whelk predation, 1-meter plots were denuded of grass, others were left untouched. Rates of predation on naked plots were 54% from October to May and 84% from July to November. Clams on plots with grass suffered little predation. Density of clams in an area did not affect the rate of predation. Whelks tended to choose the larger clams. In late summer or fall the clam growth rate slows by 50% and the clam adds a growth line. They also record daily growth lines and events in the shells. Most hard clams reach legal harvest size in 1½ years. But these clams at best have had only one reproductive season. Average age of clams in Core Sound is 9 years, ranging from less than a year to 32 years. This may mean that today's harvests are cropping several years of reproduction. The pea digger and the bull rake are also being compared. The pea digger dug up more large clams than the bull rake, and covered more area. In seagrass areas, on the other hand, the bull rake took more clams and covered a greater area. The bull rake also removed twice as much sea grass as the pea digger. Kicking neither increases nor decreases production of young clams, despite the claims of kickers that this method is good for the bottom. The more intense the harvest, the greater the damage to eelgrass beds by kicking. Grass returned to the low intensity beds after 10 months, but where kicking had been of medium to high intensity, sea grass had not recovered. (J.L.M.)

161 Hart, Kathy. 1982.

The case of the crushed clams. Va. Polytech. Inst., Blacksburg, VA 24061, Sea Grant Today 12(6):3-4.

The big-clawed snapping shrimp (*Alpheus heterochaelis*) is an important predator of small hard clams (*Mercenaria mercenaria*), according to Brian Beal and Charles Peterson, biologists at Morehead City, NC. Three problems of North Carolina clammers are predation, overexploitation, and pollution. Predation by blue crabs, whelks, and rays takes a heavy toll, and snapping shrimp may be responsible for some of the damage previously attributed to blue crabs. (J.L.M.)

162 Hart, Kathy. 1985.

Clamming. Univ. N.C. Sea Grant Coll. Prog., Raleigh, NC 27695, Coastwatch Nov/Dec 1985:1-3.

When northern clam (*Mercenaria mercenaria*) beds were iced up in the winter of 1976-77 seafood dealers began to look south for a supply and the hard clam in North Carolina supplied more of the harvest. Landings doubled in 1977 from the previous year and reached a peak in 1982 of more than 1.7 million pounds. Since that time landings have dropped, and many believe that hard clams are overfished. There are unresolved arguments between hand rakers and mechanical harvesters, and various restrictions have been placed on the harvest. Included are suggestions that grounds be rotated, and that clams be moved from polluted areas to cleanse themselves. (J.L.M.)

163 Hart, Kathy. 1985.

Kicking up more than clams. Studying the effects of clam kicking on seagrass. Univ. N.C. Sea Grant Prog., Raleigh, NC 27695, Coastwatch Nov/Dec 1985:4-5.

Clam (*Mercenaria mercenaria*) kicking is harmful to seagrass beds. Plots in Back Sound were left untouched and used as controls, others were used for raking, light kicking, and intense kicking. In raking and light kicking plots seagrass biomass dropped approximately 25% after harvest, but recovered within a year. In intensely kicked plots seagrass biomass fell about 65%, and the beds did not begin to recover for two years. Four years later these plots still had 35% less sea grass than controls. Sea grass provides food, refuge, and habitat for small marine organisms, and is important for productivity of clams. Removal of adult hard clams by kicking did not enhance recruitment of small clams, and in intensely kicked plots recruitment was 50% to 15% lower. Are the clams lost to fishermen if areas are closed to kicking? No, the clams can still be taken with rakes. If they are not harvested, the clams can act as brood stock. (J.L.M.)

164 Higgins, William J., David A. Price, and Michael J. Greenberg. 1978.

FMRFamide increases the adenylate cyclase activity and cylic AMP level of molluscan heart. Eur. J. Pharmacol. 48(4):425-430.

FMRFamide is a cardioexcitatory peptide recently isolated and identified in molluscan ganglia. FMRFamide and 5-hydroxytryptamine (5HT), the cardioexcitatory neurotransmitter in molluscs, were tested on the ventricle of the bivalve *Mercenaria mercenaria*. Both agents increased myocardial contractility, the intracellular cyclic AMP concentration of intact hearts and the adenylate cyclase activity of a myocardial membrane fraction. FMRFamide was 5 to 10 times more potent than 5HT. All of the effects of 5HT, and none of those of FMRFamide, were blocked by methysergide, a specific 5HT antagonist. (Modified authors' abstract - J.L.M.)

165 Hillman, Robert J., and Michael J. Kennish. 1984.

Commercial and sport fisheries. Chapter 11 *In* Kennish, M.J., and R.A. Lutz (eds.), Ecology of Barnegat Bay, New Jersey. Lecture notes on coastal and estuarine studies, 6, p. 281-301. Springer-Verlag, NY.

Hard clam (*Mercenaria mercenaria*) supports the major commercial fishery in Barnegat Bay. The most productive clam grounds in New Jersey extend from the southern part of Barnegat Bay to Cape May. Little Egg Harbor and Great Bay are consistently the most productive waters in the State. Lower catches in Barnegat Bay are due in part to higher levels of organic pollution which limit the area available for clamming. Nevertheless, recently it is the most valuable species landed commercially in Barnegat Bay. Maximum reported landings occurred from 1950 through 1957. In the early 1960s an outbreak of hepatitis in New Jersey caused a loss of public confidence in the industry. Landings picked up again in the mid and late 1960s, but declined thereafter. Recently the decline was caused by a failure of recruitment. (J.L.M.)

166 Hochachka, Peter W., Jeremy Fields, and Tariq Mustafa. 1973.

Animal life without oxygen: Basic biochemical mechanisms. Am. Zool. 13(2):543-555.

A variety of animals are known to be facultative anaerobes, capable of utilizing molecular oxygen when it is present and capable of sustained anaerobiosis when it is absent. During anoxia these organisms rely upon the simultaneous catabolism of carbohydrate and amino acids. In probing the mechanisms utilized, the paper accounts for 1) maintenance of redox balance during anoxia; 2) sources of energy in the form of ATP; and 3) formation of a multiplicity of anaerobic end-products. (Modified authors' synopsis - J.L.M.)

167 Holmsen, A., and S. Horsley. 1981.

Characteristics of the labor force in quahog handraking. Mar. Memo. 66, NOAA/Sea Grant, Univ. R.I., Kingston, RI 02881, 7 p.

Over the last two decades the number of license holders in the Rhode Island quahog fishery has varied from less than 800 to approximately 3,000. It is believed that this is related to the state of the economy: the higher the rate of unemployment the more licenses are bought. Between 1962-63 and 1978-79 the total number of licenses has more than doubled, and average of licensees has declined considerably. Over 60% of quahoggers derived less than 20% of their income from raking or tonging in 1962-63. In 1978-79 over 60% derived about half of their income from quahogging. The number of full-time handrakers increased over 100%. About 35% had some college education. About 18% had no alternative skills. About 23% said they could increase their income by doing other work. If income were to drop about 25%, approximately half the handrakers would leave the industry. Most handrakers worked on the west side of the Bay, about halfway down. (J.L.M.)

168 Hughes, Roger N. 1970.

Population dynamics of the bivalve *Scrobicularia plana* (Da Costa) on an intertidal mud-flat in North Wales. J. Anim. Ecol. 39:333-356.

There is no discussion of *Mercenaria mercenaria*. This paper probably would not have been abstracted if the title has been correct in the paper from which it was taken. The full title given in that paper was: Population dynamics of the bivalves. This paper deals with the general distribution of *S. plana* throughout the study area, the dispersion pattern of individuals in relation to one another, and the changes in density and size-frequency structure between Nov. 1966 and Nov. 1977. The results were used to estimate annual growth, recruitment, and mortality. Growth was also estimated by using marked animals and by measuring the distances between winter rings. Records of predation by oyster catchers were also kept. Because the structure and dynamics of bivalve populations do not normally reach a steady state, some conclusions were relevant only to the period of study. (J.L.M.)

169 Humphrey, Celeste Marie. 1981.

Ecological genetics of the hard clams *Mercenaria mercenaria* Linne and *Mercenaria campechiensis* Gmelin: Electrophoretic estimation of enzyme variation and the use of shell morphology as a species indicator. Ph.D. diss., Univ. Ga., Athens, GA 30602. [Diss. Abstr. Int. B. Sci. Eng. 42(10):3939.]

Six samples of *Mercenaria mercenaria* from the Georgia coast were analyzed, using protein electrophoresis. They showed high levels of population heterozygosity, but four loci showed large heterozygote deficiencies. Samples were also taken from Massachussetts, Virginia, and Florida, and samples of *M. campechiensis* from Tampa and Port St. Joe, FL. It was concluded from these samples that heterozygote deficiency is caused by selection against heterozygotes. Shells were measured to see if shell shape could be used to differentiate *M. mercenaria* and *M. campechiensis*, but it was concluded that shell morphology was not a species indicator. The *notata* form of *M. mercenaria* was also examined. Phenotypic frequencies ranged from 0.76% to 2.25%. Gene frequencies calculated from Maxima Likelihood Estimation were 0.04% to 0.11%. There were no significant differences between samples. (J.L.M.)

170 Hyland, Jeffrey L., Eva J. Hoffman, and Donald K. Phelps. 1985.

Differential responses of two nearshore infaunal assemblages to experimental petroleum additions. J. Mar. Res. 43(2):365-394.

There is no mention of *Mercenaria mercenaria* in this study. (M.W.S. and J.L.M.)

171 Ingalls, R.A., and A.W.H. Needler. 1942.

Survey of the shore mollusc resources of the Northumberland Strait, coast of Nova Scotia. Prog. Reps., Atl. Biol. Stn. 32:8-10, St. Andrews, N.B., Canada E0G 2X0.

Unexploited stocks of quahaugs (*Venus mercenaria*) were found. (J.L.M.)

172 Jones, Douglas S. 1980.

Annual cycle of shell growth increment formation in two continental shelf bivalves and its paleoecologic significance. Paleobiology 6(3):331-340.

By analyzing annual shell growth increments in *Spisula solidissima* and *Arctica islandica* two main items were determined: 1) age and growth rate; and 2) season of death. Such information can be important for several reasons. *Mercenaria mercenaria* was not mentioned. (J.L.M.)

173 Jones, Douglas S. 1981.

Repeating layers in the molluscan shell are not always periodic. J. Paleontol. 55(5):1076-1082.

No daily, subdaily tidal, or fortnightly tidal cycles were found in shells of *Spisula solidissima* in samples from off the coast of New Jersey. Annual layers were the only ones found and confirmed. The five orders of periodic layers identified by Barker

(1964) were not found to be valid. Other species need to be studied carefully before their fossil relatives are used in paleobiology or geophysics. (J.L.M.)

174 Jones, Tom. 1986.

Industry's view. *In* Busby, D. (ed.), An Overview of the Indian River clamming industry and the Indian River Lagoon, p. 37-38. Tech. Pap. 44, Fla. Sea Grant Ext. Prog., Univ. Fla., Gainesville, FL 32611, Proj. IR-85-7, Grant NA85AA-D-SG059.

A series of recommendations is given on size limits, intense fishing pressure, opening areas in winter when shelf life is longer, relaying of clams, and use of money from "clam diggers licenses." (J.L.M.)

175 Jory, Darryl E., and Edwin S. Iversen. 1985.

Molluscan mariculture in the Greater Caribbean: An overview. Mar. Fish. Rev. 47(4):1-10.

A study, growing oysters and clams in rafts by the Wallace Groves Aquaculture Foundation of Freeport in the Bahamas, produced discouraging results. Another study, by Worldwide Protein Bahamas, Ltd., using imported spat of American and European oysters and hard clams, *Mercenaria mercenaria*, from Long Island, indicated that fouling by algae and particulate matter hindered production, but growout of hard clams continues. Since May 1972 the St. Croix Artificial Upwelling Project on the north shore of the U.S. Virgin Islands produced phytoplankton by pumping nutrient-rich seawater from 870 m depth into 100-m^2 ponds. This was used to feed oysters, clams, and scallops, which grew adequately. Molluscan mariculture in the Caribbean has a long way to go to augment catches from traditional fisheries. It is doubtful that it can soon achieve the production per unit area obtained in other parts of the world, because it is still in its infancy and many problems remain unsolved. (J.L.M.)

176 Jory, Darryl E., Melbourne R. Carriker, and Edwin S. Iversen. 1984.

Preventing predation in molluscan mariculture: An overview. J. World Maricult. Soc. 15:421-432.

Predation remains one of the major hurdles to successful field mariculture of molluscs in many areas of the world. Traditional predator control methods include physical barriers such as trays and enclosures, off-bottom culture, chemical poisons, removal and trapping, dredges, mops, X-ray sterilization, and biological means. Most of these methods have produced only limited success, although two or more methods in combination, such as enclosures and active predator removal, are effective but expensive. Examples of recent attempts at predator control include substrate modifications for hard clams (*Mercenaria mercenaria*) and other methods for other molluscs. The ecological concepts of "size selective predation," "optimum patch use," "prey switching', "ingestive conditioning," and "search image formation" and their relevance to effective predator control in molluscan field culture are discussed. Several guidelines based on these ecological concepts emerge. Juvenile molluscs should not be planted until they reach a size at which they are less vulnerable to predators. Releasing large numbers of molluscs in some areas allows predators to concentrate their efforts, and can result in some predators narrowing their diets and concentration on the most common prey, or in a density-dependent switch in prey choice in predators whose diets only occasionally include these animals. Ingestive conditioning may reinforce these dietary adjustments. (J.L.M.)

177 Kaplan, Milton. 1984.

State and local restrictions on siting coastal aquaculture facilities in New York. Coastal Law Ser. 84-2, Sea Grant Law Prog., Jaeckle Center for State and Local Government Law, State Univ. N.Y. at Buffalo, NY 14260, 160 p.

Covers in great detail all State and local restrictions. (J.L.M. and M.W.S.)

178 Karney, Richard C. 1981.

Shellfish propagation on Martha's Vineyard. J. Shellfish. Res. 1(1):117 (abstract).

Of various raft designs tested, economical, sand-filled wooden trays suspended from floats gave best growth and survival of hard clams (*Mercenaria mercenaria*). Seed quahogs raft-cultured in 1979 had over 80% survival of 480,000 clams. Seeds as small as 2 mm have been successfully cultured. (J.L.M.)

179 Kassner, Jeffrey. 1982.

The gametogenic cycle of the hard clam, *Mercenaria mercenaria* from different locations in the Great South Bay, New York. Masters thesis, State Univ. N.Y. at Stony Brook, NY 11794, 72 p.

The reproductive cycle of the hard clam, *Mercenaria mercenaria*, was determined over a 2-year period at five locations in the eastern third of Great South Bay. At one location, sampling was designed to include three sizes of clams, corresponding to clams marketed as sublegals, littlenecks, and cherrystones. The gametogenic cycle of spawner transplant clams also was compared. Differences between years were greater than among the five locations. In 1978 spawning went rapidly to completion, as evidenced by a high percentage of "spent" females. In 1979 the percentage of "spawning" females was much greater. No differences were apparent among the three size classes of clams or between the size classes and the other four stations. Two critical assumptions were found not to be valid, however: It was not true that the spawning period of native clams is defined and predictable, nor that transplant clams spawn later than native clams. This suggests that introduction of spawner transplants is of questionable value. (J.L.M.)

180 Kassner, Jeffrey. 1983.

Trace metals in shellfish and growing area designation. J. Shellfish. Res. 3(1):94-95 (abstract).

Hard clams (*Mercenaria mercenaria*) were sampled over five locations in Port Jefferson Harbor and five locations in Setauket Harbor, Long Island, N.Y., and analyzed for copper, lead, zinc, and cadmium. In both harbors, hard clams from the station with fewest coliform bacteria did not have the lowest metal concentrations. In Setauket variability of metal concentrations among sampling locations was much less than in Port Jefferson, and in Port Jefferson overall metal concentrations were higher than in Setauket. Concentrations of metals in hard clams does not appear to be reliably related to coliform levels. (Modified author's abstract - J.L.M.)

181 Kassner, Jeffrey. 1985.

Early hard clam mariculture on Great South Bay. Suffolk Mar. Mus., W. Sayville, NY 11782, The Dolphin, Sept. 1985:5.

Mariculture is not a recent development. In 1909 a New York shellfish dealer purchased 5,000 bu of naturally produced seed clams (*Mercenaria mercenaria*) from Massachusetts at $3 per thousand. He realized 4 bu of littlenecks for every bu of seed. Early hard clam mariculture in New York has not been well documented, but information available suggests that it may have been substantial, and Great South Bay was one area in which it was pursued. It was begun in Great South Bay some time prior to 1931 as an adjunct of the oyster industry. Conflicts developed and by 1931 many baymen believed that a minimum size limit should be established. As a compromise a ¾-inch minimum size was adopted. From 1933 to 1939 the number of bu sold in New York increased from about 30,000 to over 128,000 bu and the value of clams sold increased from slightly under $52,000 in 1933 to over $420,000 in 1942. Production of hard clams by mariculture was not recorded after 1942. Glancy was successful in spawning hard clams in the early 1930s and rearing them to over 1 inch in size, but large-scale production of hard clams was never tried. Somewhat later Shellfish Inc. became the first Long Island hatchery to sell hard clams commercially. Since that time the Town of Islip has planted seed clams on public bottom, and a few years later Babylon and Brookhaven began planting seed clams, and today these three towns and the Bluepoints Company are still planting. But mariculture accounts for only a small part of production from the Bay, and probably will not play a significant role in hard clam production from the Bay because private mariculture is vehemently opposed by baymen. (J.L.M.)

182 Kassner, Jeffrey, and Thomas W. Cramer. 1984.

Evolution of the Great South Bay shellfish industry. J. Shellfish. Res. 4(1):91-92 (abstract).

During the past 180 years the shellfish resource and its fishery in Great South Bay have undergone dramatic change, shifting from the American oyster *Crassostrea virginica* to the northern hard clam *Mercenaria mercenaria*. This came about from changes in management of shellfish and hydrography of the Bay. In the early 1800s the Bay supported a sizeable oyster fishery, but overfishing and oyster dredging depleted the natural beds by 1840. Beginning in 1880, oyster production increased, as large areas of the Bay were leased for oyster planting. Between 1910 and 1940 salinities in the Bay increased markedly caused by changes in flow through Fire Island Inlet and opening of Moriches Inlet in 1931. Oyster drills *Eupleura caudata* and *Urosalpinx cinerea* increased in abundance and few oysters survived past setting. In the 1940s dense blooms of a small flagellate that interfered with oyster feeding caused a further decline in oyster abundance and no significant oyster fishery existed after 1948. Conditions detrimental to oysters proved beneficial to hard clams, and hard clam production increased rapidly, peaking at 24,668 m^3 (700,000 bu.) in 1976. Landings have since declined by more than half from overfishing and further changes in the Bay. A variety of management measures are now being tried to stabilize landings. (Modified authors' abstract - J.L.M.)

183 Kennish, Michael J. 1977.

Growth increment analysis of *Mercenaria mercenaria* from artificially heated coastal marine waters: A practical monitoring method. Proc. 12th Int. Soc. Chronobiol. Conf., Wash., D.C., p. 663-669.

Microscopic analysis of 85 *Mercenaria mercenaria* from natural populations within a 1.6-km radius of the Oyster Creek Nuclear Generating Station showed that the thickness of daily growth increments in summer was reduced by 10 to 30% in comparison with those of clams outside the effect of thermal discharges. The accretionary shell-growth pattern was occasionally interrupted by rapidly fluctuating temperaures, which caused physiological shocks to clams. Transplanted bivalves also showed similar reductions in microgrowth patterns. Also the normal prismatic shell structure was replaced by crossed-lamellar shell structure, immediately following transplanting. In addition, growth breaks appeared frequently in shell microstructure after transplantation. (J.L.M.)

184 Kennish, Michael Joseph. 1977.

Effects of thermal discharges on mortality of *Mercenaria mercenaria* in Barnegat Bay, New Jersey. Ph.D. thesis, Rutgers Univ., New Brunswick, NJ 08903, 161 p. [From Diss. Abstr. Int. B Sci. Eng. 38:2086B.]

Mortality of *Mercenaria mercenaria* in Barnegat Bay is normal and is not caused by thermal discharges. Mortality is high during the planktonic larval stages, low subsequent to spat settlement, and high again in the gerontic stage. Maximum frequency of death is between 50 mm and 65 mm in height and 5 to 6 years of age. Peak frequency of death is in summer. Mortality rates rise significantly after sexual maturity is attained. (J.L.M.)

185 Kennish, Michael J. 1978.

Effects of thermal discharges on mortality of *Mercenaria mercenaria* in Barnegat Bay, New Jersey. Environ. Geol. 2:223-254.

Thermal discharges from the Oyster Creek Nuclear Generating Station do not affect mortality in natural populations of *Mercenaria mercenaria* in Barnegat Bay, NJ. Hard clams collected at the mouth of Oyster Creek (strongly affected by thermal discharges) and at three control sites in the Bay showed that mortality rate curves, survivorship curves, and life tables were nearly identical for each assemblage. Mortality data recorded on life assemblages of hard clams transplanted to the substrate for 1 year at the mouth of Oyster Creek and at a single control site in the Bay showed that mortality was significantly greater in the assemblage transplanted to the control site. It was concluded that mortality of hard clams in Barnegat Bay was caused by the normal population dynamics of the species. Mortality was high during the planktonic larval stages, low subsequent to spat settlement, and high again in the gerontic stage. Mortality rates rise significantly after sexual maturity is attained. (Modified author's abstract (J.L.M.)

186 Kennish, Michael J. 1980.

Shell microgrowth analysis - *Mercenaria mercenaria* as a type example for research in population dynamics. Chapt. 7 *In* Rhoads, D.C., and R.A. Lutz (eds.), Skeletal growth of aquatic organisms - Biological records of environmental change, p. 255-294. Plenum Press, NY.

The shell of *M. mercenaria* is composed primarily of calcium carbonate (aragonite) and conchiolin. A vertical section through a valve reveals four shell layers: 1) inner homogeneous layer, 2) pallial myostracum (muscle scar layer), 3) middle layer, and 4) outer layer. These are illustrated in a diagram. In youth (approximately 2 yr) the outer shell layer terminates in concentric ridges at the outer surface, with growth increments intersecting the outer shell surface nearly at right angles. When mature growth is attained, concentric ridges disappear and growth increments become recurved in shape. This stage corresponds with onset of sexual maturity and lasts 3-8 yr. The final stage is old age, and crossed lamellar structure replaces prismatic shell structure in the outer layer, growth increments become thin and perpendicular to outer shell surface and numerous growth breaks develop. Using acetate peels and thin sections shell microgrowth patterns were studied. Cyclical growth patterns include subdaily, daily, bidaily, fortnightly, lunar monthly, and annual types. These patterns come from variable rates of calcium carbonate deposition or dissolution or both. Environmental conditions and a biological-clock mechanism appear to control the formation of these growth patterns. Growth breaks reflect periods of environmental and physiological stress. Seven types have been documented, which develop from random or periodic events. They consist of growth breaks caused by freeze shock (winter), heat shock (summer), thermal shock, shell-margin abrasion, spawning, neap tides, and storms. These are described and figured in great detail. These can be applied to analysis of population dynamics of hard clam by using size and age distributions, growth rates, and recruitment patterns, and mortality, and inferences can be made on a variety of subjects, including varying rates of mortality, and the reason for higher mortality as the animals age. Young are added to the population only sporadically, but the population can be maintained by a single year of good recruitment. By using shells of death assemblages in stressed environments temporal and spatial changes in populations can be related to anthropogenic factors. It is possible that analysis of growth patterns could be used to reconstruct paleolatitudes, paleoclimates, and paleobathymetry through the Tertiary period. The entire chapter needs to be studied to recover all the fascinating facts contained in this paper. (J.L.M.)

187 Kennish, Michael J. 1984.

Summary and conclusions. Chap. 14 *In* Kennish, M.J., and R.A. Lutz (eds.), Ecology of Barnegat Bay, New Jersey. Lecture notes on coastal and estuarine studies, 6, p. 339-353. Springer-Verlag, NY.

Mercenaria mercenaria is the only bivalve of commercial importance in Barnegat Bay. The standing crop has declined since the mid-1960s, and commercial landings are at their lowest level since the early 1960s. Recruitment has not been successful since the early 1970s and recruitment failure, closure of shellfish beds due to poor water quality, and reduced fishing effort from adverse winter weather conditions have been largely responsible for lower commercial production. Hard clams are distributed in patches, and densities increase toward the southern margin of the estuary. Hard clam is currently the most valuable species landed commercially. (J.L.M.)

188 Kennish, Michael J., and Robert E. Loveland. 1980.

Growth models of the northern quahog, *Mercenaria mercenaria* (Linne). Proc. Natl. Shellfish. Assoc. 70: 230-239.

The Gompertz growth equation provides an accurate model of ontogenetic growth in hard clams from New Jersey waters. It yields a correlation coefficient of -0.982 when fitted to yearly height data collected from sectioned valves of 277 specimens from death assemblages from Barnegat Bay. It also predicts asymptotic height values and growth curves that are realistic in comparison with those derived from the logistic and monomolecular growth equations. Selection of the best fitting growth model for *M. mercenaria* depends on estimation of growth parameters in the Gompertz, logistic, and monomolecular functions. A new mathematical procedure is presented which allows for rapid calculation. It requires two steps: 1) linearization of growth functions, and 2) linear regression analysis of transformed data. Most bivalves exhibit a growth rate that decreases according to a nonlinear function with increasing age. The Gompertz, logistic, and monomolecular equations accurately describe this type of growth. (J.L.M.)

189 Kennish, Michael J., and Robert E. Loveland. 1984.

Trophic relationships. Chapt. 12 *In* Kennish, M.J., and R.A. Lutz (eds.), Ecology of Barnegat Bay, New Jersey. Lecture notes on coastal and estuarine studies, 6, p. 302-317. Springer-Verlag, NY.

Commercially important and recreationally important bivalves, such as *Mercenaria mercenaria,* are particularly susceptible prey to such species as *Limulus polyphemus*, *Callinectes sapidus*, *Polinices duplicatus*, *Busycon* spp., *Eupleura caudata*, *Urosalpinx cinerea*, and *Asterias forbesi*. Some fishes feed on young hard clams. Hard clams also sometimes feed on phytoplankton that fall to the estuarine substratum as water temperature rises in spring. (J.L.M.)

190 Kennish, Michael J., and Richard K. Olsson. 1975.

Effects of thermal discharges on the microstructural growth of *Mercenaria mercenaria*. Environ. Geol. 1:41-64.

Mercenaria mercenaria in Barnegat Bay, NJ, were affected mainly by temperature extremes, temperature variations, tides, type of substratum, and age. Growth patterns in hard clams within approximately a 1.6-km radius of Oyster Creek showed a lower summer growth rate (10% to 25% lower) and a greater number of growth breaks (2 to 6 more per clam) than from away from the Creek. The lower summer growth rates in bivalves subjected to effluent occur because added heat in summer caused water temperatures to exceed a critical threshold for optimum growth of the species. Effluent also may upset natural spawning events in clams when abrupt changes in power station operations overlap breeding periods. Spawning may be precluded by sharp temperature changes which result in physiological shocks to the animal. (Modified authors' abstract - J.L.M.)

191 Kennish, Michael J., Richard A. Lutz, and Donald C. Rhoads. 1980.

Preparation and examination of skeletal materials for growth studies. Part A: Molluscs. 1. Preparation of acetate peels and fractured sections for observation of growth patterns within the bivalve shell. *In* Rhoads, D.C., and R.A. Lutz (eds.), Skeletal growth of aquatic organisms - Biological records of environmental change, p. 597-601. Plenum Press, NY.

Details are given for embedding, sectioning, grinding, polishing, acid-etching, washing and drying, and application of acetone and acetate to acetate peels, and preparation of fractured sections of bivalve shells. (J.L.M.)

192 Kennish, Michael J., James J. Vouglitois, Donald J. Danila, and Richard A. Lutz. 1984.

Shellfish. Chapt. 7 *In* Kennish, M.J., and R.A. Lutz (eds.), Ecology of Barnegat

Bay, New Jersey. Lecture notes on coastal and estuarine studies, 6, p. 171-200. Springer-Verlag, NY.

Hard clam (*Mercenaria mercenaria*) and blue crab (*Callinectes sapidus*) are the only shellfish currently important in the fisheries of Barnegat Bay. The life history of the hard clam, its growth, recruitment, and mortality, and its distribution and density are described, and the status of the resource is reviewed. The hard clam has a mean longevity of less than 10 years and usually grows to less than 80 mm in shell height and length. Mortality peaks during the planktonic stages. Lowest mortality is between the ages of 1 and 5 years. It increases to a maximum in summer and winter and decreases to a minimum in spring and fall. The standing crop has declined since the mid 1960s. Poor recruitment of juveniles caused either by lack of successful larval settlement or heavy losses to predators after setting appears to be largely responsible. There is a paucity of juveniles in the population caused by year-class failure since the early 1970s. (J.L.M.)

193 Klingensmith, J. Scott. 1982.

Distribution of methylene and nonmethylene-interrupted dienoic fatty acids in polar lipids and triacylglycerols of selected tissues of the hardshell clam (*Mercenaria mercenaria*). Lipids 17(12):976-981.

Fatty acid profiles of polar lipids and triacylglycerols were determined for six tissues of the hard clam (*Mercenaria mercenaria*): mantle, gill, mouth, foot, digestive tract/gonadal tissue, and adductor muscle. Largest concentrations of nonmethylene-interrupted dienoic (NMID) fatty acids were found in gill, mantle, and foot. Structural analyses were undertaken to determine the double-bond configurations of the various NMID isomers. The major 22C NMID species were Δ7,13- and Δ7,15-docosadienoic acid. The major 20C NMID species were Δ7,11- and Δ7,13-eicosadienoic acid and Δ5,11-eicosadienoic acid. (Modified author's abstract - J.L.M.)

194 Klingensmith, J. Scott, and Lewis W. Stillway. 1982.

Lipid composition of selected tissues of the hardshell clam, *Mercenaria mercenaria*. Comp. Biochem. Physiol. 71B(1):111-112.

Total lipids and lipid classes from six tissues of *Mercenaria mercenaria* were determined. Polar lipids accounted for the largest fraction of lipids. The highest concentration was found in the gill. Free sterols were found only in trace amounts in the gill, but were found in much higher quantities (up to 22.6%) in other tissues. The largest stores of triacylglycerols were in the digestive tract, gonads, and the adductor muscle. Relative tissue weights and lipid contents of six tissues from the hard clam were:

Tissue	*Wet wt.*	*Dry wt.*	*Lipids*
Digestive tract-Gonads	48	33	5.35
Adductor muscle	18	34	0.44
Mantle	12	10	2.63
Gill	8	7	1.86
Foot	7	12	1.25
Mouth	7	3	0.43

(J.L.M.)

195 Knutson, Amy Beth. 1984.

Sediment as a source of trace metals to the hard clam, *Mercenaria mercenaria*. Masters thesis, State Univ. N.Y. at Stony Brook, NY 11794, 111 p.

Metal concentrations of clams varied primarily with physiological state as determined by seasonal and genetic factors. Seasonal patterns of uptake of all metals were similar to seasonal changes in dry flesh weight. Maximum increases in body burden corresponded to periods of rapid growth in fall and spring. However, metal body burdens increased 1 or 2 months prior to dry flesh weight in spring, and with the exception of lead, metal content remained constant over winter. Possible differences in feeding activity, arising from small differences in grain size of experimental plots, may have contributed to observed differences in clam copper concentration. Of the six metals studied (Cd, Cu, Fe, Ni, Pb and Zn) only copper showed clear differences in concentration among clams from different plots. Exposure to more readily available dissolved and suspended copper sources was more critical in determining copper concentration than exposure to copper associated with sediment. However, in muddy environments, where clam filtering activity is reduced, exposure to dissolved and particulate copper sources is lower, and uptake from sediment may become more important (Modified author's abstract - J.L.M.)

196 Koppelman, Lee E., DeWitt Davies, Lauretta Fischer-Key, Mark Reigner, and Ronald Verbarg. 1984.

Feasibility of establishing a large scale, publicly supported hard clam seed hatchery/nursery system for rehabilitating bay resources after an oil spill disaster. Long Island Regional Planning Board, N.Y.S. Comptroller's Contract D000369, CEIP Grant-In-Aid Award NA-83-AA-D-CZ035, Hauppauge, NY 11788, 103 p.

Objectives of the study were to: 1) estimate the potential impact of spilled oil on the hard clam (*Mercenaria mercenaria*) and its associated habitats; 2) identify the full range of techniques and methods to remove spilled oil and hasten recovery of habitats and hard clam populations; 3) discuss the shellfish hatchery, land-based nursery, and field-nursery facilities required to produce seed clams for planting; and 4) prepare and apply site selection criteria and identify potential sites for land-based facilities. If a decision were made to implement a massive hard clam seed-planting program to mitigate oil spill impacts, this report could be used to address the following questions: a) should a publicly-financed shellfish hatchery be constructed, and where? and b) should land-based and field-based nursery facilities be constructed, and where? The appendix to the report contains capsule summaries of hard clam seed-planting programs being conducted by Long Island towns, and descriptions of the facilities and capabilities of the five operating shellfish hatcheries located on Long Island. (J.L.M.)

197 Kosko, Kim. 1986.

Carter and Cantelmo's quest for cleaner clams. The Jersey Shoreline 8(4):2.

Carter and Cantelmo have studied the efficiency of commercial depuration. Clams (*Mercenaria mercenaria*) taken from marginally contaminated waters could be effectively depurated and thus release 26,000 acres of condemned waters in New Jersey for harvesting hard clams. Also clam siphoning activity seems to increase under certain conditions, as if some clams are spurring others on to more active states. (J.L.M.)

198 Kraeuter, John N., Michael Castagna, and Rosa van Dessel. 1981.

Egg size and larval survival of *Mercenaria mercenaria* (L.) and *Argopecten irradians* (Lamarck). J. Exp. Mar. Biol. Ecol. 56(1):3-8.

Eggs were graded into three size categories, split into replicates, and these were replicate-sampled. A chi-square analysis compared the proportion of larvae (48-hr survival) with the proportions of eggs in each initial replicate experiment. Statistically significant differences attributed to egg size were found. Large eggs survived better than small eggs, while those of intermediate size showed no difference between expected and observed survival. (Modified authors' abstract - J.L.M.)

199 Kremer, J.N., and S.W. Nixon. 1978.

A coastal marine ecosystem. Simulation and analysis. Ecological studies 24, Springer-Verlag, NY, 217 p.

The community of larger benthic animals is not dominated by finfishes but by dense populations of hard clam *Mercenaria mercenaria*. In the West Passage near the Jamestown Bridge an estimate of 35-40 bu. (80 pounds) per acre was determined by survey prior to the commercial dredging season. Although the subsequent harvest lowered the population to 14 bu/acre, it can be assumed that some replacement of the loss occurred, and 35 bu/acre was chosen as a reasonable stock estimate. Prorated population estimates ranging from $3.23/m^2$ near the mouth of the Providence River to $0.65/m^2$ near Newport were used ($clams/m^2$). (J.L.M.)

200 Kvaternik, Andre C., and William D. DuPaul. 1983.

Estimation of standing crop of *Mercenaria mercenaria* (Linne) in the James River, Virginia, using commercial records. J. Shellfish. Res. 3(1):96 (abstract).

Commercial catch-and-effort records for boats using patent tongs to harvest hard clams from the James River were obtained for 1978-81. Catch-per-unit-effort of the sample fleet was regressed against accumulated catch to give estimates of initial abundance. Estimates for 1978, 1979, 1980, and 1981 were 280,650 bu, 406,250 bu, 557,250 bu, 344,364 bu, and 397,142 bu, respectively. The mean for the period, 397,142 bu, was 30% below that estimated by Haven et al. (1981). Commercial catch records can be used in this application but limitations in the data must be understood. (Modified authors' abstract - J.L.M.)

201 La Bombardi, Ellen Levine, and Stephen D. Young. 1982.

Collagens of the mollusca. Separation by exclusion and hydrophobic interaction chromatography. Comp. Biochem. Physiol. 72B(3):465-468.

Mercenaria mercenaria was not mentioned. The collagen of *Cryptochiton stelleri* isolated from the visceral area had a different biochemical property from the mantle girdle, which was in direct contact with the ocean. The visceral area was protected from the environment by the eight plates. The collagen of *Loligo peali* eluted as a single homogeneous hydrophilic peak. Collagen from *Octopus bimaculoides* was also hydrophilic but exhibited great diversity within this region. (Modified authors' abstract - J.L.M.)

202 Larkin, Edward P., and Daniel A. Hunt. 1982.

Bivalve mollusks: Control of microbiological contaminants. BioScience 32(3):193-197.

Voluntary cooperation between the shellfish industry and government agencies has reduced the incidence of shellfish-borne disease. Contamination of bivalve mollusks including hard clams (*Mercenaria mercenaria*) by bacterial pathogens, viruses, and toxin-containing phytoplankton is controlled by harvesting shellfish only from approved waters and by use of sanitary food-handling practices. Although market shellfish in the United States are usually of high quality, control agencies and the shellfish industry cannot guarantee that raw shellfish will be free of disease producing organisms or toxic substances. (J.L.M.)

203 Larsen, Peter F. 1985.

The benthic macrofauna associated with the oyster reefs of the James River estuary, Virginia, U.S.A. Int. Rev. Hydrobiol. Gesamten. 70(6):797-814.

Mercenaria mercenaria was found only in the lower end of the James River off Newport News. (J.L.M.)

204 Laughlin, Roger A. 1982.

Feeding habits of the blue crab, *Callinectes sapidus* Rathbun, in the Apalachicola estuary, Florida. Bull. Mar. Sci. 32(4):807-822.

Blue crabs (*Callinectes sapidus*) consumed *Rangia, Brachidontes, Crassostrea, Macoma, Mactra*, and *Tellina* in the Apalachicola estuary but no *Mercenaria mercenaria*. (J.L.M. and M.W.S.)

205 Le Borgne, Yves. 1981.

Nursery culturing of postlarvae: Key to further development for bivalve molluscs hatcheries. *In* Claus, C., N. De Pauw, and E. Jaspers (eds.), Nursery Culturing of Bivalve Molluscs, p. 141-149. Spec. Publ. 7, Eur. Maricult. Soc., Bredene, Belgium.

Mercenaria mercenaria is among the species discussed. If the goal of the nursery is to provide customers with a product meeting their demands at a price competitive with natural spatfall, nurseries play an essential role. Hatcheries can produce very large numbers of very small spat at low cost, but they are of no use to most professional growers. Only after an additional growth period in a nursery can the product reach a wide market. Success of the nursery stage is a condition for development of controlled reproduction. Nurseries' technical problems seem to be easier to solve than those of hatcheries that have received less attention in research. Yet here one may expect the most spectacular improvement in productivity, with survival rates increasing from 50% to 80%. The additional number of spat has indeed a much higher commercial value than an equivalent number of larvae. (J.L.M.)

206 Lehman, William, and Andrew G. Szent-Gyorgyi. 1975.

Regulation of muscular contraction - Distribution of actin control and myosin control in the animal kingdom. J. Gen. Physiol. 66(1):1-30.

Control systems regulating muscle contraction in approximately 100 organisms including *Mercenaria mercenaria* have been categorized. Myosin and actin-control operate simultaneously in most invertebrates, but single myosin control is present in muscles of molluscs and some other groups. (J.L.M. and M.W.S.)

207 Leslie, Mark D., and Robert S. Wilson. 1983.

Effects of light and gravity upon the motile behavior of trochophore larvae of *Mercenaria mercenaria* (Linne). J. Shellfish. Res. 3(1):96 (abstract).

Results showed a random distribution of larvae in horizontal dark and horizontal light experiments, a substantial surface aggregation in the vertical dark chamber, and a decrease in surface accumulation with the light source shining from above and below the vertical chamber. Illumination from below caused a significant drop in vertical velocity and swimming speed and a small decline in rate of change of direction. Phototaxis was not observed. Photostimulation caused trochophores to exhibit a negative orthokinesis with a weakening in their negative geotactic behavior. (Modified authors' abstract - J.L.M.)

208 Levine, Rhea J. C., Myra Elfvin, Maynard M. Dewey, and Benjamin Walcott. 1976.

Paramyosin in invertebrate muscles. II. Content in relation to structure and function. J. Cell Biol. 71(1):273-279.

By quantitative sodium dodecyl sulfate-polyacrylamide gel electrophoresis, paramyosin:myosin heavy chain molecular ratios were calculated for three molluscan muscles including *Mercenaria mercenaria* opaque adductor, and four arthropodan muscles. These ratios correlated positively with thick filament dimensions and maximum active tension development in these tissues. The role of paramyosin in these muscles was discussed with respect to the following characteristics: force development, "catch," and extreme reversible changes in length. (J.L.M.)

209 LoGrande, Michael A. 1983.

Introduction. *In* Buckner, S.C. (ed.), Proceedings of a Management Perspective on the Hard Clam Resource in Great South Bay, p. 1. A seminar sponsored by the Town of Islip (NY 11751), March 10, 1983.

The hard clam resource has produced tremendous reductions in harvest during the last few years, and recent outbreaks of shellfish-related disease have compounded the problems. This meeting was convened to discuss the situation and suggest solutions. (J.L.M.)

210 Longwell, A.C. 1976.

Review of genetic and related studies on commercial oysters and other pelecypod mollusks. J. Fish. Res. Board Can. 33:1100-1107.

Mercenaria mercenaria and *M. campechiensis* were crossed and the hybrids reared. Haven and Andrews (1957) found that the relative yield of hybrid clams grown in Virginia was superior to that of the original species. Menzel (1968) also reported the superiority of the hybrid in certain environments and questioned the species rank of these two clams. (J.L.M.)

211 Loosanoff, Victor L. 1962.

Effects of turbidity on some larval and adult bivalves. Proc. Gulf Caribb. Fish. Inst., 14th Annu. Sess., p. 80-95.

Silt is much more harmful to oyster (*Crassostrea virginica*) eggs than to those of clams (*Venus* (*Mercenaria*) *mercenaria*). The percentage of eggs developing to straight-hinge larvae in different concentrations of turbidity-creating substances were:

Concentration	*Silt*		*Kaolin*		*Fuller's earth*	
G/L	*Oyster*	*Clam*	*Oyster*	*Clam*	*Oyster*	*Clam*
0.125	95	95	99	82	100	75
0.250	73	96	100	82	100	61
0.500	31	99	100	52	100	41
1.000	3	79	100	37	98	57
2.000	0	39	94	49	79	50
3.000	0	0	—	—	—	—
4.000	0	0	76	42	26	45

(J.L.M.)

212 Losee, Brian. 1983.

Shellfishing in Islip Town: A bayman's viewpoint. *In* Buckner, S.C. (ed.), Proc. of a Management Perspective on the Hard Clam Resource in Great South Bay, p. 49-53. A seminar sponsored by the Town of Islip (NY 11751), March 10, 1983.

Illegal harvesting of seed clams, overharvesting of legal-size clams, poaching of clams from uncertified waters, and a general disregard for clam conservation laws are genuine threats to the industry. The initial group of baymen who operated from 1960 and before usually took legal-size clams only and returned smaller clams (seed) to the water. As clamming increased through good sets, a new group of clammers came in, and they did not have the same respect for the law. Illegal harvesting became common, and when law officers did summon and arrest violators, their efforts were negated by ridiculously low fines. The Southwest sewer construction further exacerbated the problem, and created a "get it while you can" attitude. Attempts by the Town of Islip Shellfish Commission to manage the industry were negated by poachers. The State had some success in transplanting clams from uncertified areas, and also opening uncertified areas at times when clamming was safe, thus reducing the numbers of clams in uncertified areas and reducing the temptation to poach. But this led some baymen to take clams with dredges, illegally reducing abundance still further. This led many clammers to leave the industry for other jobs. Other environmental mistakes also have played a part: unrestricted residential development, no attempts at human population control, removal of sand bars in Fire Island Inlet, and the negative effects of the Southwest Sewer District. Even the law-abiding clammers eventually were forced to break laws to make a living from the greatly reduced clam stocks. Yet all is not yet lost. The Town must assume a role of leadership, and do the things necessary to manage the resource successfully. (J.L.M.)

213 Lozada, Eliana, and Hector Bustos. 1984.

Madurez sexual y fecundidad de *Venus antiqua antiqua* King & Broderip 1835 en la bahia de Ancud (Mollusca: Bivalvia: Veneridae). Rev. Biol. Mar. 20(2):91-112.

Sexual maturity cycle was continuous, with a long period of maximal sexual activity, having intense spawnings during August, December-January, and April. Minimum sexual activity was during May and June. Sexual rate was 1:1. First male spawning size was at 46.6 mm, for females 48.3 mm, and for both sexes at 2 years of age. Fecundity was a direct function of gonad volume, and varied from $3,092 \times 10^6$ to $14,484 \times 10^6$ oocytes. Since this species has a continuous sexual cycle and a long spawning period, population renewal may be favored, thus overcoming fishing mortality. (Amended authors' abstract - J.L.M.)

214 Lunz, Robert G. 1949.

The clam situation in S.C. Contrib. Bears Bluff Lab. 6, 6 p.

The clam industry in South Carolina is small. Incomplete production figures show a high of slightly over 5,000 bu to a low of 40 bu. In general, production has declined over the years. No culture has been recorded, and management of the fishery has been confined to an occasional closed season. No estimate is available of the quantity of clams (presumably *Mercenaria mercenaria*) in South Carolina. (J.L.M.)

215 Lunz, G. Robert, Jr., J.T. Penney, and T.P. Lesesne. 1944.

Special study of the marine fishery resources of South Carolina. Bull. 14, S.C. State Planning Board, Columbia, SC, 61 p.

Most clams harvested in South Carolina are consumed locally, and the harvesting is done by children and farmers. Production of hard clams (*Mercenaria mercenaria*) from 1929 to 1940 ranged from 47 thousand pounds to 0. Statistics are given for North Carolina, Georgia, and Florida also. About the turn of the century the clam industry was apparently more productive. It is centered in Georgetown County, but clams are plentiful in other places although seldom harvested. The reason is lack of demand. Demand was increased during the middle 1940s because a food shortage caused by the war had stimulated sales, but this demand was not being met by local fishermen. Wholesale dealers still obtain clams from northern markets. (J.L.M.)

216 Lutz, Richard A., and Donald C. Rhoads. 1980.

Growth patterns within the molluscan shell - An overview. Chap. 6 *In* Rhoads, D.C., and R.A. Lutz (eds.), Skeletal growth of aquatic organisms - Biological records of environmental change, p. 203-254. Plenum Press, NY.

Microgrowth increments within the molluscan shell were first described in detail by Barker (1964) in thin-section observations of four genera of bivalve including *Mercenaria*. Valve-movement rhythmicity is usually most pronounced in intertidal specimens, but subtidal specimens of *M. mercenaria* exhibit rhythms in relative synchrony with the tidal cycle. Dissolution during anaerobiosis is now believed to be the cause. It has been demonstrated that *M. mercenaria* becomes anaerobic when the valves are closed. The concentrations of succinate and calcium in extrapallial fluids increase rapidly at first, then more slowly, as the clam is held out of water. The width of the residual matrix provides a record of the length of time that the shell was exposed to metabolic acids, according to Gordon and Carriker (1978). Microscopic growth increments are formed with solar periodicity. These are largely reflections of complex interactions between lunar and solar cycles. Also fortnightly patterns appear, sometimes in pairs, with one fortnightly cluster more pronounced than the other. There are also annual patterns. *M. mercenaria* grows faster in sandy sediments than in mud, and growth rate and shell structural changes occur when specimens are transplanted to a laboratory tank without substratum. Hard clams within the vicinity of a thermal discharge from a nuclear power plant also showed the effects of raised temperature. Crossed lamellar structure replaced prismatic structure in the outer shell layer of *M. mercenaria* during high-temperature stress periods. The annual nature of pigmented growth bands within the inner "homogeneous" of hard clam has been observed. (J.L.M.)

217 MacDonald, H.J. 1940.

Animal associates of oysters at Beaufort, North Carolina. M.S. Thesis, Duke Univ., Durham, NC 27706, 49 p.

Venus mercenaria mercenaria was found beneath oysters in sandy mud. Common around edges of oyster beds and occasionally found under areas exposed several hours at low tide. (J.L.M.)

218 MacMillan, Robert B. 1983.

Impacts of shellfish-related illness and the importation of out-of-state clams. *In* Buckner, S.C. (ed.), Proc. of a Management Perspective on the Hard Clam Resource in Great South Bay, p. 11-14. A seminar sponsored by the Town of Islip (NY 11751), March 10, 1983.

In 1964 the National Shellfish Sanitation Workshop endorsed a set of principles that would govern safe use of a natural resource and encourage water quality programs that will preserve coastal areas for this beneficial use. New York's shellfish industry has continued with a minimum of health-related problems since the winter of 1924-25, with the notable exception of an outbreak of infectious hepatitis in Raritan Bay in 1961. The result was permanent closure of all waters in Raritan Bay. In 1982 gastrointestinal illnesses were reported in several places in New York from eating raw clams. Advisories were issued not to eat raw clams and oysters. The economic impact was devastating. The Department of Environmental Conservation responded by proposing legislation to increase harvester and dealers' permit fees, to establish a dedicated fund to receive permit revenues and support Department programs, and a general increase in fines and penalties for violations of laws. The Division of Marine Resources is also considering changes to improve recordkeeping. (J.L.M.)

219 MacPhail, J.S. 1961.

A hydraulic escalator shellfish harvester. Fish. Res. Board Can., Bull. 128, 24 p.

The escalator harvester is described in considerable detail, but this should be considered as a guide only. Many changes could be made, depending on the specific use. It is, however, extremely versatile, and takes quahaugs (*Mercenaria mercenaria*) and other mollusks with high efficiency. Depths of 10-12 feet appear to be near maximum for best operation. (J.L.M.)

220 Malinowski, Steve M., and R.B. Whitlatch. 1984.

Natural survivorship of young hard clams, *Mercenaria mercenaria* (Linne) in eastern Long Island Sound. J. Shellfish. Res. 4(1):94 (abstract).

Experimental field manipulations were used to determine the natural survivorship of *Mercenaria mercenaria* during the first 3 years of life in a small protected inland estuary (Poquonock River, Groton, CT) and an exposed outer harbor (West Harbor, Fishers Island, NY). Clams were planted and recovered at monthly and full-season intervals from May 1982 to Nov. 1982. Three densities (25, 150, and 300 clams/0.25 m^2) and six sizes (1, 5, 10, 15, 18, and 21 mm) were tested. More than 99% of mortality at both sites was the result of crustacean predators. Green crabs (*Carcinus maenas*) were the dominant predators of clams up to 10 mm, while lobsters (*Homarus americanus*) readily consumed 15-21 mm clams. Full season survival of all size classes was consistently higher in the estuary than at the outer harbor site. The dramatic difference between survival of 3rd-year clams was attributed to the absence of lobsters in the Poquonock River. Survival was strongly density-dependent, particularly in West Harbor, where the mean monthly survival of 5- and 10-mm clams planted at the lowest density was more than four times higher than survival of clams planted at the highest density. (Modified authors' abstract - J.L.M.)

221 Malouf, Robert E. 1981.

Use of heated effluents for the nursery culture of bivalve molluscs: Its problems and potential. *In* Claus, C., N. De Pauw, and E. Jaspers (eds.), Nursery culturing of bivalve molluscs, p. 171-188. Spec. Publ., 7, Eur. Maricult. Soc., Bredene, Belgium.

Despite active research programs, little commercial use of heated effluents has been made for culturing bivalve molluscs. Some problems associated with nursery culture in heated effluents include: contamination from radionuclides discharged from nuclear power plants; contamination from heavy metals; toxicity problems from chlorine used to control fouling in power plants; temperature shock resulting from shutdowns; and lack of temperature control. Other problems, more closely related to the biology of the animals than to operation of the plant, include fouling and disease, and inability to provide supplemental food to offset increased energy demands. This last is the most important barrier to realizing the advantages of heated culture. High temperatures should be avoided when possible when food is scarce. This requires that the system include some type of temperature control or that animals be removed from the heated effluent when necessary. *Mercenaria mercenaria* is not mentioned, but the general principles apply. (Modified author's abstract - J.L.M.)

222 Malouf, Robert. 1983.

The potential of hard clam culture for resource management. *In* Buckner, S.C. (ed.), Proc. of a Management Perspective on the Hard Clam Resource in Great South Bay, p. 45-48. A seminar sponsored by the Town of Islip (NY 11751), March 10, 1983.

Mariculture must be defined before it can be intelligently discussed. Intensive culture may involve complete control of every aspect of the life cycle. It is highly productive, but expensive and technically sophisticated. Extensive culture may involve only minimal control over the organism. It is less productive per unit area, but also less expensive and tends to be less technologically demanding. There is also a distinction between private and public mariculture. The methodology may be identical, but private mariculture produces a crop on ground that is privately controlled, whereas public mariculture supplements natural reproduction and increases the public harvest. Either method may be costly, and it is necessary to ask whether the costs can be justified. Mariculture has certain advantages over other options, like restrictions on harvest, because they are unpopular and hard to enforce. But high-percentage survival must be obtained from seed planting, if cost is to be justified, and this requires consideration of predators and site selection. The problem of scale is also important, and present attempts are simply too small to have significant effects. Mariculture is only a part of the total effort that must be exerted, and it must be combined with enhanced enforcement, selected closures, stock assessment, and efforts to enhance natural reproduction by spawner relays and spawner sanctuaries. Solving the shellfish industry's problems cannot come without cost, and present expenditures are very small in comparison with the value of the industry. (J.L.M.)

223 Manzi, John J. 1985.

Clam aquaculture. Chapt. 7 *In* Huner, J.V., and E.E. Brown (eds.), Crustacean and mollusk aquaculture in the United States, p. 275-310. AVI Publ. Co., Inc., Westport, CT.

The prognosis for clam aquaculture in the U.S. is encouraging. Commercial quantities of hatchery-reared seed are available from a number of private hatcheries. Pilot projects indicate the feasibility of nursery and field growout methods developed over recent years, and new materials make these methods more cost-efficient. Diseases and parasites, although not studied extensively, are under control in hatchery and nursery culture and have not been a common problem in field growout systems. The hard clam (*Mercenaria mercenaria*) seems particularly appropriate for aquaculture. They are in strong demand, are highly valued, consumer demand and acceptance are high, extensive transportation and marketing networks exist, and the biology is well known. The chapter includes sections on basic biology, culture techniques, parasites and diseases, constraints, and status and economic overview. The entire chapter should be read. (J.L.M.)

224 Manzi, John J. 1986.

The South Carolina commercial clam fishery. S.C. Sea Grant Consort., S.C. Wildl. Mar. Resour. Dep., Columbia, SC 29202. Hook, Line & Sinker, 4 p.

Although the hard clam, *Mercenaria mercenaria*, makes up only about 15% of the national total annual clam landings, it accounts for nearly 50% of total value. Historically, the major hard clam fisheries have been to the north, but these traditional fishing grounds have not had sufficient production to meet the growing demand for this species. This has stimulated interest in the southeast. In South Carolina this has stimulated appreciable growth over the last 10 years, and in addition has started a commercial hard clam mariculture facility. The life history of the hard clam, the fishery and mariculture, the market, and local constraints to development are described. Future development of the industry depends upon events in the Santee delta, where rediversion of the Santee River will decrease landings in that area. Increased harvests in other parts of the State, and increased aquaculture activities will compensate. Depuration also will increase production. (J.L.M.)

225 Manzi, John J., and Jack M. Whetstone. 1981.

Intensive hard clam mariculture: A primer for South Carolina watermen. Mar. Advis. Publ. 81-01, S.C. Sea Grant Consort., Charleston, SC 29412, 21 p.

Clam farming is feasible if people start small, make sure they have the legal right to use the site, be certain that they have the permits and licenses necessary, have notified state and federal agencies about the activity, construct culture units with predator control and maintenance as primary considerations, and are prepared to dedicate sufficient time for regular and complete inspection of the site. The outlook is promising but is still a "high-risk" venture. (J.L.M.)

226 Manzi, John J., M. Yvonne Bobo, and Victor G. Burrell, Jr. 1985.

Gametogenesis in a population of the hard clam, *Mercenaria mercenaria* (Linnaeus), in North Santee Bay, South Carolina. Veliger 28(2):186-194.

Adult hard clams were sampled monthly between Dec. 1977 and Feb. 1979 and semimonthly from March to June 1981, from subtidal populations in North Santee Bay, South Carolina. Gonad development was monitored using standard histological methods and resulting slides were examined with light microscopy at 100 and 400×. Observed gametogenic progression was best categorized by five states or phases of development: inactive, ripe, spawning, partially spent, and spent. Males and females displayed a complex progression of gametogenesis. Gonadal tissue was not uniformly dominated by clearly defined, distinct stages. Instead, gonads routinely exhibited several stages simultaneously and progressed through slow shifts in domination of stages in gonad tissue. Spawning in the population occurred continuously for 6 months (May to October) with at least two apparent peaks of spawning activity in summer. (Modified authors' abstract - J.L.M.)

227 Manzi, John J., Victor G. Burrell, Jr., and W.Z. Carson. 1980.

A mariculture demonstration project for an alternative hard clam fishery in South Carolina: Preliminary results. Proc. World Maricult. Soc. 11:79-89.

Abstracted elsewhere in this bibliography. (J.L.M.)

228 Manzi, John J., Victor G. Burrell, Jr., and Harry Q.M. Clawson. 1981.

Commercialization of hard clam (*Mercenaria mercenaria*) mariculture in South Carolina: Preliminary report. World Maricult. Soc. 12(1):181-195.

The State of South Carolina has established a demonstration-scale hard clam (*Mercenaria mercenaria*) culture project. The project operates on a two-stage growout protocol. Raceways provide initial growout (to 10 mm). Final growout is done in field units with protection from predators and substrate for support and orientation. Over 2.7 million imported seed are being planted in South Carolina estuaries over a 13-month period. Field units are stocked at three densities, 2150, 4300, and 6450/m^2, using intertidal and floating (raft) formats and a variety of substrates. Units are sampled monthly to determine growth and survival and coincidental monitoring of various environmental data. Small field units have shown that densities as high as 2156 seed clams/m^2 do not show density-limited growth, at least to a mean population size of 39 mm, but smaller seed at lower densities sometimes have shown density-limited growth. Thus, this needs to be repeated on a larger scale. Economic analysis is also necessary. The State also has a legislative committee to study existing shellfish lease policies and make recommendations for modifications (J.L.M.)

229 Manzi, John J., Nancy H. Hadley, and Mark B. Maddox. 1986.

Seed clam, *Mercenaria mercenaria*, culture in an experimental-scale upflow nursery system. Aquaculture 54:301-311.

The study was conducted to evaluate growth of seed clams in an upflow nursery culture system in South Carolina relying on natural productivity as the only food source. Experimental-scale passive upflow cylinders were stocked with small seed clams (initial mean size ~4 mm) at various densities (2.3, 5.0, 10.0, 20.0, 30.0, and 40.0 kg/m^2) in trials begun quarterly. Cultures received a continuous uniform water flow rate of 2.5 L/minute from an adjacent estuary, at ambient phytoplankton concentration, temperature, and salinity. Most rapid growth was obtained with seed stocked in April and October, when water temperatures were between 18 and 22°C. Monthly biomass increases as high as 267 g/100 g were achieved. Growth was positively correlated with flow rate in all seasons except winter. A flow:biomass ratio of 15:1 resulted in a doubling of biomass in 30 days, while a ratio of 30:1 resulted in a tripling over the same period. Under favorable environmental conditions, a biomass doubling could be achieved at stocking densities as high as 20 kg/m^2. Maximum production over a 3-month period was 495 g (309 g/100 g) of 7-mm seed, corresponding to 62 kg/m^2. Although water requirements were similar to those previously reported for raceway culture in South Carolina, results indicated much greater biomass carrying-capacities per unit area with upflow culture systems. (Modified authors' abstract - J.L.M.)

230 Manzi, John J., M.B. Maddox, F.S. Stevens, and H.Q.M. Clawson. 1984.

Commercial-scale, upflow nursery culture of the northern hard clam *Mercenaria mercenaria* (Linne) in South Carolina. J. Shellfish. Res. 4(1):94 (abstract).

The nursery consists of 60 forced upflow silos used for initial growth of imported 1-mm seed, and 120 passive upflow silos used for seed growth from ~3 mm to field planting size (~8 mm). At full operation the nursery requires a minimum total flow rate of ~5000 L/minute, has a holding capacity of 24×10^6 seed, and an optimum annual production capacity of $18\text{-}36 \times 10^6$ planting-size seed. Data generated from experimental-scale upflow systems operating in coincidence with a commercial nursery compared favorably with raceway data based on water use per unit biomass supported and biomass support capacities per unit area. (Modified authors' abstract - J L.M.)

231 Manzi, John J., F.S. Stevens, Y.M. Bobo, V.G. Burrell, Jr., and Nancy H. Hadley. 1983.

Size and volume relationships in juveniles of *Mercenaria mercenaria* (Linne): A revision of Belding's tables. J. Shellfish. Res. 3(1):97 (abstract).

The model assumed that the volume of a hard clam is proportional to the cube of a linear dimension. Iterations allowed model refinements which produced positive correlations between predicted and observed data. Collected data were summarized on size/volume relationships in seed clams and a model was presented, based on truncated spheres, which attempts to relate size and volume characteristics in seed clams within the size range 1-15 mm. (Modified authors' abstract - J.L.M.)

232 Manzi, John J., N.H. Hadley, C. Battey, R. Haggerty, R. Hamilton, and M. Carter. 1984.

Culture of the northern hard clam *Mercenaria mercenaria* (Linne) in a commercial-scale, upflow, nursery system. J. Shellfish. Res. 4(2):119-124.

Upflow nursery systems for culture of bivalve mollusc seed are attractive alternatives to traditional raceway systems. The potential benefits include maximizing space utilization, low construction cost, ease of maintenance, and operational longevity. A commercial nursery facility for raising *Mercenaria mercenaria* in South Carolina employs forced and passive upflow culture instead of traditional raceway systems. Biomass increases as high as 1400% per month were achieved in forced-flow systems at stocking densities of 0.3-0.5 g/cm^3 and flow rates of 80-120 L/min/kg. In passive-flow systems, biomass increases of as high as 800% per month were achieved at stocking densities of 0.2-0.6 g/cm^3 and flow rates of 23-117 L/min/kg. Results were compared with those from raceways and from an experimental-scale, passive upflow system. (Modified authors' abstract - J.L.M.)

233 Margulis, B.A., K.I. Galaktionov, O.I. Podgornaya, and G.P. Pinaev. 1982.

Major contractile proteins of mollusc: tissue polymorphism of actin, tropomyosin and myosin light chains is absent. Comp. Biochem. Physiol. 72B(3):473-476.

Neither *Mercenaria mercenaria* nor any other mollusk is mentioned. Mollusks were collected on the shore of the Japan Sea. Isoforms of the proteins had identical molecular masses, mass-charge ratios, and isoelectric points. (J.L.M.)

234 Marinucci, Andrew Carmen. 1975.

Interrelationships among growth, growth physiology, and external algal metabolites in the larvae of the quohog clam, *Mercenaria mercenaria* L. Masters thesis, Univ. Del., Newark, DE 19716, 92 p.

Six different algae: *Isochrysis galbana*, *Monochrysis lutheri*, *Phaeodactylum tricornutum*, *Nannochloris oculata*, *Dunaliella tertiolecta*, and a *Cryptomonas* sp. were fed to *Mercenaria mercenaria* larvae. *M. lutheri* produced the fastest growth rate. The second highest growth rate was produced by *P. tricornutum*, *I. galbana*, and *Cryptomonas* sp., followed by *N. oculata*. *D. tertiolecta* was unable to sustain growth to metamorphosis of hard clams. Weight specific respiration was determined by a modified Gilson respirometry technique and showed $b = 0.942$ and $k = -0.310$. The b value was thought to be a result of structural tissue development; the k value was found to vary with the larval brood. Extracellular metabolites of the algal species affect larval respiration. Mean overall effect of *P. tricornutum* and *M. lutheri* metabolites appeared to be negligible. *I. galbana*, *D. tertiolecta*, and *Cryptomonas* sp. metabolites showed an overall stimulation of larval respiration. *N. oculata* metabolite inhibited respiration. Metabolites also affected clearing of inert starch particles by clam larvae. Only the response of clearance to *D. tertiolecta* metabolite was concentration dependent. Results of clearance experiments showed that *I. galbana* and *M. lutheri* stimulated clearing by larvae. *D. tertiolecta* inhibited clearing. Comparison of growth rate, respiration, and clearing results showed that the external metabolites of *I. galbana*, *M. lutheri*, and *D. tertiolecta* may influence the food value of these algae to *Mercenaria mercenaria* larvae. (Modified author's summary -J.L.M.)

235 Marshall, Nelson. 1970.

Food transfer through the lower trophic levels of the benthic environment. *In* Steele, J.H. (ed.), Marine food chains, p. 52-66. Univ. Calif. Press, Berkeley.

Mercenaria mercenaria is mentioned with reference to positive correlation between phytoplankton concentration and growth in a paper by Pratt and Campbell (1956) abstracted elsewhere in this bibliography. (J.L.M.)

236 Maurer, Don. 1983.

The effect of an infaunal suspension feeding bivalve *Mercenaria mercenaria* (L.) on benthic recruitment. Mar. Ecol. 4(3):263-274.

The hypothesis tested was that benthic recruitment is more successful in low densities of infaunal suspension feeders than in high densities. Densities of young hard clams *Mercenaria mercenaria* ranging from 82.5-330/m^2 were placed in defaunated boxes of sand. Mean number of species, mean number of individuals, mean wet weight biomass, mean species richness, and mean dominance index per sample were calculated per density of hard clams from May to October. The experiment did not support the hypothesis. It was concluded that feeding behavior of dense populations of *M. mercenaria* did not preclude successful recruitment of other benthic species. (J.L.M.)

237 McCay, Bonnie J. 1981.

Optimal foragers or political actors? Ecological analyses of a New Jersey fishery. Am. Ethnol. 8(2):356-382.

Harvesting of hard clams (*Mercenaria mercenaria*) replaced oystering as the major shellfishery in the "Shoal Harbor" area (Raritan and Sandy Hook bays) about the turn of this century. Specific clam beds were often "condemned" in response to hepatitis and typhoid fever epidemics. In 1961-63 all were condemned, and this provided some resilience to the system because they continue to thrive and provide valuable sources of juvenile clams, which can be transplanted to unpolluted beds elsewhere. The law sharply constrained the flexibility of local fishermen, and they responded to it by breaking the law whenever possible. They also were successful in gaining exemption from the State's relay program, so that they could not be transplanted elsewhere. The baymen's association has recently agreed to allow relay of clams to southern bays, but only if a depuration plant is provided to them. Depuration introduces technical and biological problems and has been resisted by the State. (J.L.M.)

238 McCay, Bonnie J. 1984.

The pirates of piscary: Ethnohistory of illegal fishing in New Jersey. Ethnohistory 31(1):17-37.

Clamming is one of the lynchpins of the bayman system. Hard clams (*Mercenaria mercenaria*) are easily available and abundant in the bays, and can be taken literally all year-round. "Shoal Harbor" baymen still consider themselves "clammers" despite the fact that pollution has resulted in "condemnation" of the shellfish beds of Raritan Bay since 1962. Piracy is their remaining alternative, and has become a custom in Shoal Harbor. This has been partly caused by conflicts between common-property clammers and the oyster corporations. Baymen in the area have been able to keep the State from engaging in a program of transplanting clams from the polluted waters of Raritan and Sandy Hook bays to purer waters elsewhere in New Jersey. This led in 1981 to a decision to license a pilot plant for depuration of clams, stimulated by this attitude on the part of baymen and by the costs to the State of trying to cope with piracy. (J.L.M.)

239 McCay, Bonnie J. 1982.

The shore fisheries of New Jersey: Centennial reflections. Paper prepared for Conference on Natural Resources in New Jersey History: Three Centuries of Change, sponsored by Cent. Coastal Environ. Stud., Rutgers Univ., and N.J. Hist. Comm., Nov. 6-7, 1982, North Brunswick, NJ. Rutgers Univ., New Brunswick, NJ 08903, 25 p. (xerox).

The very important shellfish resources of the State's bays and estuaries, including hard clams (*Mercenaria mercenaria*), stay inshore all the time. Almost every man living near the water catches a few fish and gathers clams for his own table. The more important settlements where clamming is carried on extensively are Fair Haven, on the Shrewsbury River, and Mannasquan, on the Squan River. The clammers whom Ingersoll praised were men of private property "the stout-armed native oystermen and farmers who live adjacent to the water and make hard-clamming a regular summer occupation" (Ingersoll 1887:597). (J.L.M.)

240 McDermott, John J. 1964.

Food habits of the toadfish, *Opsanus tau* (L.), in New Jersey waters. Proc. Pa. Acad. Sci. 38:64-71.

Of 115 digestive tracts of *Opsanus tau* examined from Delaware Bay in 1952, 1953, and 1955, *Mercenaria mercenaria* was found only in one. Crustacea were the major food. (J.L.M.)

241 McDonald, Jack. 1982.

Divergent life history patterns in the co-occurring intertidal crabs *Panopeus herbstii* and *Eurypanopeus depressus* (Crustacea: Brachyura: Xanthidae). Mar. Ecol. Prog. Ser. 8:173-180.

Panopeus herbstii, which consumes primarily oysters, hard clams, mussels, and barnacles, is prevented by its larger size from entering most of the narrow spaces between living oysters while the narrow spaces are the primary refuge for *Eurypanopeus depressus*, which has a less restricted, more omnivorous diet. *P. herbstii* is larger, faster growing, longer lived, and more fecund, while *E. depressus* matures earlier, produces more broods per lifetime, and has a shorter generation time. (M.W.S. and J.L.M.)

242 McHugh, J.L. 1983.

An overview of the hard clam resource. *In* Buckner, S.C. (ed.), Proc. of a Management Perspective on the Hard Clam Resource in Great South Bay, p. 3-9. A seminar sponsored by the Town of Islip (NY 11751), March 10, 1983.

The hard clam, *Mercenaria mercenaria*, has long been the leading marine resource in New York State. In the 1960s it produced over 50% of the value of New York landings of all seafoods, and continued to produce at least 50% or more until 1978. In 1947 landings reached a peak of over 10 million pounds of meats, and in 1976 produced a secondary peak of over 9 million pounds. In 1982, however, landings had dropped to less than 4 million pounds of meats. The cause almost certainly was overfishing. Even more ominous have been serious outbreaks of human disease, not definitely traced to Great South Bay, which caused demand and prices to drop substantially. Poaching in closed areas and poaching of undersized clams in open areas have reduced egg production considerably. One way to improve the situation might be to divide the area under control of the Town into three to five parts, each containing approximately an equal number of harvestable clams. Only one part would be open to clamming at any one time, and these parts would be rotated annually, so that each would be open every third to fifth year. Adequate enforcement would be absolutely necessary, and this is not now possible. In addition to sufficient inspectors to watch for violations, adequate support in the courts is a must. It is possible also that licenses should be restricted so that baymen can make a decent living. These actions will not stabilize hard clam production, but they will maximize natural production, and preserve a great natural resource. The Marine Sciences Research Center is hoping to establish a Living Marine Resources Institute with primary mission to improve hard clam production. (J.L.M.)

243 McLaughlin, J.J.A., G.S. Kleppel, M.P. Brown, R.J. Ingram, and W.B. Samuels. 1982.

The importance of nutrients to phytoplankton production in New York Harbor. *In* Mayer, G.F. (ed.), Ecological stress and the New York Bight: Science and management, p. 469-479. Estuarine Res. Fed., Columbia, SC.

Some enrichment from nutrients and other bioactive materials resulting from domestic and industrial wastes may enhance biological productivity, but further enrichment may begin to alter certain food webs, as was the case in Moriches Bay, Long Island, NY, where nutrients from duck farm wastes altered the food stock of the hard clam, *Mercenaria mercenaria*, by replacing diatoms with less suitable food organisms. This caused deterioration of the fishery. Diatoms form the basis for some food webs that are commercially important to man, such as the hard clam. (J.L.M.)

244 Meyers, Theodore R. 1981.

Endemic diseases of cultured shellfish of Long Island, New York: adult and juvenile American oysters (*Crassostrea virginica*) and hard clams (*Mercenaria mercenaria*). Aquaculture 22(4):305-330.

At monthly intervals between Feb. 1975 and Oct. 1976, hard clams were collected from two hatcheries on Great South Bay, NY. A large unidentified ciliated protozoan was observed within the water tubules of the gills in 4 our of 190 adult clams. A probable sporozoan parasite resembling a gregarine spore stage was found in four. Four types of intracytoplasmic inclusion bodies were observed in several adult hard clams. Rickettsia-like organisms and a chlamydial agent were observed. Single and multiple small papillomatous growths were found on the mantle surfaces of two clams. In juvenile clams two types of intracytoplasmic inclusion bodies reported in adults were observed. Hard clams had a lower diversity of parasitisms and histologic abnormalities, none of which provoked any host response or had any pathological significance. No parasites were found with known significance to public health. (J.L.M.)

245 Meyers, Theodore R. 1984.

Marine bivalve mollusks as reservoirs of viral finfish pathogens: Significance to marine and anadromous finfish aquaculture. Mar. Fish. Rev. 46(3):14-17.

Hard clams, *Mercenaria mercenaria*, can depurate human polio virus type I within 96 hours if placed in clean seawater at 13-15°C. If certification procedures are exercised for shellfish pathogens, some additional effort made in screening mollusk tissues for incidental viral finfish pathogens would provide significant protection against introduction of these agents by movement of shellfish stocks. Shellfish may be seasonal reservoirs for some endemic finfish pathogens originating from finfish epizootics or from subclinically diseased "carrier fish." Shellfish could introduce exotic finfish diseases when transported to other waters for commercial or experimental purposes from areas where such agents may be endemic. (J.L.M.)

246 Miller, W.L., N.J. Blake, and R.H. Byrne. 1985.

Uptake of Zn^{65} and Mn^{54} into body tissues and renal concretions by the southern quahog, *Mercenaria campechiensis* (Gmelin): Effects of elevated phosphate and metal concentrations. Mar. Environ. Res. 17(2-4):167-171.

M. campechiensis was examined for uptake and tissue distribution of Zn^{65} and Mn^{54} accumulated from seawater containing varied concentrations of inorganic phosphate, total zinc and manganese. Highest 10-day tissue concentrations for both metals were found in the kidney with results showing different uptake patterns for zinc and manganese. Total metal and inorganic phosphate concentrations showed marginal effects on manganese distribution but produced significant variation in zinc distribution between kidneys and gills. (J.L.M.)

247 Mohlenberg, Flemming, and Hans Ulrik Riisgard. 1978.

Efficiency of particle retention in 13 species of suspension feeding bivalves. Ophelia 17(2):239-246.

Mercenaria mercenaria was not included. Species which possessed eu-latero-frontal cirri, as the hard clam does, completely retain particles above 4 μmm. Particles down to 1 μmm in most cases were efficiently retained. (J.L.M.)

248 Moore, Carol A. 1981.

Phagocytosis and degradation of a unicellular algae by hemocytes of the hard clam *Mercenaria mercenaria*. J. Shellfish. Res. 1(1):119 (abstract).

Hemocytes of the hard clam were observed to phagocytize *Isochrysis galbana* and several other species of unicellular algae and congo red-stained yeast. "Blunt" cytoplasmic granules received degraded materials from the phagosomes containing the algae but not those containing a yeast cell. Blunt granules were further observed to participate in intracellular processing of the hemocyte of vital dyes and endotoxin. It is suggested that blunt granules represent a mechanism whereby hemocytes can contain or further degrade foreign material. (J.L.M.)

249 Moore, Carol A. 1972.

The cytology and cytochemistry of the amebocytes of the hard clam *Mercenaria mercenaria*. Masters thesis, Montclair State College, Montclair, NJ 07043, 57 p.

Amebocytes of the hard clam were of three types: a small granulocyte, a large granulocyte, and a lymphocyte-like cell. The similarity of the nucleus in all three cell types might suggest that these cells represent different stages of maturity. This was also suggested by the gradation of cytochemical reactions. Blunt granules were identified as mitochondria. They also exhibited unidentified material which was PAS-positive-diastase resistant and metachromatic. Dot-like granules were identified as lysosome. These probably serve as centers of digestion for phagocytized materials. Refractile granules were demonstrated to be membrane bound, lipid-filled structures. These may act as storage centers. (J.L.M.)

250 Morse, M.P., E. Meyhofer, and W.E. Robinson. 1985.

Accumulation of ^{109}Cadmium in extracellular granules in the kidney of the bivalve mollusc *Mercenaria mercenaria* (L.). Mar. Environ. Res. 17(2-4):172-175.

Preliminary results show that cadmium is associated with large extracellular granules in the lumina of the kidneys. The presence of radioactive cadmium was determined morphometrically by counting developed silver grains on sections coated with a photographic emulsion. The results were highly significant to show that more radioactive cadmium was associated with large granules than with the background tissue. (J.L.M.)

251 Multer, H. Gray, Dennis M. Stainken, and J. Michael McCormick. 1981.

Spatial/temporal patterns of macrobenthos, sediments and pollutants in Raritan Bay-Lower N.Y. Bay. Abstracts, Sixth Biennial Int. Estuarine Res. Conf., Nov. 1-5, 1981, Gleneden Beach, OR. Estuaries 4(3):302.

Seasonal sediment sampling at 82 stations (1-mile spacing) throughout Raritan Estuary was analyzed for macrobenthos, size-grade, metals and HC (22 stations). Distinct allopatric communities of clams *Tellina agilia* and *Mercenaria mercenaria* showed seasonal spatial distribution. *Mercenaria* density was lower than in earlier studies. No major change in quality of the environment was indicated for the last 6 yrs. (from authors' abstract). (J.L.M.)

252 Muneoka, Yojiro, and Betty M. Twarog. 1983.

Neuromuscular transmission and excitation - Contraction coupling in molluscan muscle. Chapt. 2 *In* Saleuddin, A.S.M., and K.M. Wilbur (eds.), The mollusca, Vol. 4, Physiology Pt. 1, p. 35-76. Academic Press, NY.

Reference is made to *Mercenaria mercenaria* studied by other authors abstracted elsewhere in this bibliography. (J.L.M.)

253 Murphy, Richard C. 1985.

Factors affecting the distribution of the introduced bivalve, *Mercenaria mercenaria*, in a California lagoon - The importance of bioturbation. J. Mar. Res. 43(3):673-692.

In Colorado Lagoon the mean total bivalve density was $143/m^2$. Of this the density of *Mercenaria mercenaria* was $78/m^2$. In the Marine Stadium mean total clam density was $57/m^2$ and *M. mercenaria* was absent. Bivalve populations were dominated by suspension-feeders in the Lagoon. In the Stadium deposit-feeders were most abundant. Burrows of ghost shrimp, *Callianassa californiensis* appeared to be more abundant in the Stadium than in the Lagoon. There was a strong negative correlation between growth and survival of *M. mercenaria* and suspended particulate matter. *Callianassa* can create levels of turbidity and sediment destabilization sufficient to reduce the growth and survival of *M. mercenaria*. Absence of *C. californiensis* from the Lagoon came from stressful conditions such as elevated summer temperatures, low winter salinity, periods of anoxia, and possibly pollutants. Hardiness of *M. mercenaria* and its need for elevated temperatures for spawning probably contribute to its success in the Lagoon. (Modified author's abstract - J.L.M.)

254 Nassau-Suffolk Regional Marine Resources Council. 1983.

Long Island hard clam resource management: Research needs. Regional Marine Resources Council, A committee of the Long Island Regional Planning Board, Hauppauge, NY 11787, 18 p.

This brings up-to-date the report: *Guidelines for the management of Long Island hard clam resources*, published in 1974. The hard clam industry is presently in a state of crisis brought about by a precipitous decline in landings and a lack of consumer confidence caused by a series of disease outbreaks linked to ingestion of raw shellfish taken from polluted waters in New York and other states. The history of the industry is reviewed, public health issues discussed, and recommendations made for future research. (J.L.M.)

255 National Marine Fisheries Service. 1980.

National Aquaculture Plan (draft for review purposes only). U.S. Dep. Commer., Natl. Oceanic Atmos. Adm., Wash., D.C., 532 p.

The hard clam, *Mercenaria mercenaria*, species plan is covered in Appendix D, pages 168-196. A critical review and in-depth summary of the literature should be completed. A series of pilot-growout demonstrations, and hatchery and nursery demonstrations, should be established. Feeding and nutritional studies should receive high priority. Development of a prepared food or diet should be started. Existing hatcheries should be funded to increase production. To develop better seed-production methods, to furnish seed for experimentation, and to encourage aquacultural development, two regional research hatcheries should be constructed. Training courses and demonstrations should be established for commercial culturists and marine-extension personnel involved in clam aquaculture. Annual or biennial workshops should be held to review recent developments. Several other lesser recommendations are made. (J.L.M.)

256 Nelson, Julius. 1892.

Cause of the viridity of New Jersey clams. Tuckerton (NJ) Beacon, 3 November 1892.

The green color in clams (*Venus mercenaria*) was caused by a microscopic plant which the dryness of last summer caused to multiply. Clams ate it in large quantities. There was no disease or parasite present, and no copper. The color was confined mostly to the gills, but in some clams in the liver also. Fatness and flavor were excellent. There was no harm to people and no need for alarm. (From Baughman's bibliography - J.L.M.)

257 Nelson, Thurlow C. 1941.

Stimulation of the sperm. Anat. Rec. 81, suppl.:88.

The sperm of *Venus mercenaria* has no effect on the pumping of the oyster. (J.L.M.)

258 New Jersey State Department of Environmental Protection. 1981.

Approved area charts 4 and 5. Bur. Shellfish. Control, CN-029, Trenton, NJ 08625.

Shows areas approved and dates, from Island Beach to Long Beach. (J.L.M.)

259 Newkirk, Gary F. 1980.

A review of the genetics and the potential for selective breeding of commercially important bivalves. Aquaculture 19(3):209-228.

We are at present far from having control over genetics and other aspects of biology of mollusks. Significant advances have been made recently toward understanding many aspects of genetics, however, and these are briefly reviewed in this paper. Included is some mention of genetics of hard clams (*Mercenaria mercenaria*). Chanley's work on the notata shell markings in hard clams, Menzel's hybridization experiments, and Chanley's study of selection for growth rate are mentioned. Most of the paper, however, is concerned with oysters. (J.L.M.)

260 Newkirk, Gary F. 1983.

Applied breeding of commercially important molluscs: A summary of discussion. Aquaculture 33:415-422.

There are exciting possibilities for new approaches to the genetic improvement of molluscs for commercial culture. What is needed now is a refinement of techniques and a clear demonstration of gains that can be made, not general statements. The time is ripe to incorporate genetic improvement programs in development of this industry. No specific mention of *Mercenaria mercenaria* but the paper applies to all commercial molluscs. (J.L.M.)

261 Nimmo, D.R., T.L. Hamaker, E. Matthews, and W.T. Young. 1982.

The long-term effects of suspended particulates on survival and reproduction of the mysid shrimp, *Mysidopsis bahia*, in the laboratory. *In* Mayer, G.F. (ed.), Ecological stress and the New York Bight: Science and management, p. 413-422. Estuarine Res. Fed., Columbia, SC.

Deleterious effects of turbidity on eggs of the hard clam, *Mercenaria* (=*Venus*) *mercenaria*, were documented by Davis (1960) and Loosanoff (1961). (J.L.M.)

262 Nyland, Steve. 1986.

Hard clams: A quality-assured product. Cornell Coop. Ext. Suffolk County, Riverhead, NY 11901, On the Water 1(1):8,19.

Describes the Long Island Green Seal program, a new voluntary tagging procedure, which attempts to assure quality of clams (*Mercenaria mercenaria*) by placing a tamper-proof Green Seal on bushel bags of clams so that the origin can be traced if desired. (J.L.M.)

263 O'Connor, Joseph M., and Joseph W. Rachlin. 1982.

Perspectives on metals in New York Bight organisms: Factors controlling accumulation and body burdens. *In* Mayer, G.F. (ed.), Ecological stress and the New York Bight: Science and management, p. 655-673. Estuarine Res. Fed., Columbia, SC.

Bioconcentration factors (BCFs) for hard clams (*Mercenaria mercenaria*) were 109 for cadmium. (J.L.M.)

264 O'Connor, J.M., J.B. Klotz, and Theo. J. Kneip. 1982.

Sources, sinks, and distribution of organic contaminants in the New York Bight ecosystem. *In* Mayer, G.F. (ed.), Ecological stress and the New York Bight: Science and management, p. 631-653. Estuarine Res. Fed., Columbia, SC.

Polychlorinated biphenyls (PCBs) in the flesh of hard clams (*Mercenaria mercenaria*) from the Hudson River and New York Bight region were no greater than 0.2 μg/g wet weight. (J.L.M.)

265 Olla, Bori L., Allen J. Bejda, and Walter H. Pearson. 1983.

Effects of oiled sediment on the burrowing behaviour of the hard clam, *Mercenaria mercenaria*. Mar. Environ. Res. 9(3):183-193.

Burrowing behaviour of juvenile hard clams in oil-contaminated sediment was examined in a series of laboratory experiments. At oil concentrations within the range that might occur after an oil spill, depth and rate of burrowing were altered. The depth to which clams in oiled sediment burrowed after 96 hours was significantly shallower than the depth in controls, while the time taken to burrow beneath the surface was longer in oil-contaminated sediment. Alterations in burrowing were indicative of avoidance behaviour rather than oil-induced debilitation. Results suggest that such alterations may increase vulnerability of this species to predation. (Modified authors' abstract - J.L.M.)

266 Osorio, Cecilia, Daniel Frassinetti, and Eduardo Bustos. 1983.

Taxonomy and morphometry of *Venus antiqua antiqua* King and Broderip, 1835 (Mollusca, Bivalvia, Veneridae). Tethys 11(1):49-56.

Results suggest that the valid name is *Venus antiqua antiqua*. Increasing harvests of clams in Chile caused state institutions to carry out biological and fishery studies of one of the most important species. *Mercenaria mercenaria* is not mentioned. (J.L.M. and M.W.S.)

267 Otwell, W. Steven, John A. Koburger, and Scott W. Andree. 1986.

Survival of southern hard clams in refrigerated storage. Rep. 83, Sea Grant Proj. IR-83-6, Grant NA80AA-D-00038, Fla. Sea Grant Coll., Univ. Fla., Gainesville, FL 32611, 17 p.

Two species of hard clam are harvested in Florida, the northern hard clam, *Mercenaria mercenaria*, and the southern hard clam, *M. campechiensis*. *M. campechiensis* is more dominant in commercial harvests from the west coast. A subspecies, *M. mercenaria texana*, occurs along the northern coast of the Gulf of Mexico and extends westward beyond Apalachicola Bay. Marketability has been hampered by limited survival when placed in common refrigeration. *M. mercenaria* survived better in refrigeration than *M. campechiensis*, as did the hybrid. Clams from two places were tested. Those from Indian River survived better than those from St. Joe Bay in refrigerated storage at 40o F. Indian River is on the east coast of Florida near Cape Canaveral, St. Joseph

Bay is on the west coast near Panama City. Most clams from Indian River were *M. mercenaria* whereas those from St. Joseph Bay were mostly *M. campechiensis* with some possible *M. m. texana*. There was no discernible pattern in mortality in relation to clam size. Clams taken from warmer waters, e.g., in summer rather than in winter, had shorter storage life. (J.L.M.)

268 Pannella, Giorgio. 1980.

Growth patterns in fish sagittae. Chapt. 15 *In* Rhoads, D.C., and R.A. Lutz (eds.), Skeletal growth of aquatic organisms - Biological records of environmental change, p. 519-560. Plenum Press, NY.

Infrared spectra obtained from powdered sagitta of *Merluccius bilinearis* (silver hake) and homogeneous shell layer of *Mercenaria mercenaria* are virtually identical, as shown by a graph. (J.L.M.)

269 Parulekar, A.H. 1984.

Review of: Ecology of Barnegat Bay, New Jersey. Indian J. Mar. Sci. 13(4):207-208.

A general review of the book, without reference to species. (J.L.M.)

270 Patterson, Captain R.A. 1986.

Controlling production - Management of the industry. *In* Busby, D. (ed.), An overview of the Indian River clamming industry and the Indian River Lagoon, p. 36. Tech. Pap. 44, Fla. Sea Grant Ext. Prog., Univ. Fla., Gainesville, FL 32611, Proj. IR-85-7, Grant NA85AA-D-SG059.

Present regulations and enforcement problems are described. (J.L.M.)

271 Paul, R.K.G. 1981.

Natural diet, feeding, and predatory activity of the crabs *Callinectes arcuatus* and *C. toxotes* (Decapoda, Brachyura, Portunidae). Mar. Ecol. Prog. Ser. 6(1):91-99.

No specific mention of *Mercenaria mercenaria*, which does not occur that far south. (J.L.M. and M.W.S.)

272 Paynter, Kennedy T., George A. Karam, Lehman L. Ellis, and Stephen H. Bishop. 1985.

Subcellular distribution of aminotransferases, and pyruvate branch point enzymes in gill tissue from four bivalves. Comp. Biochem. Physiol. 82B(1):129-132.

Aspartate aminotransferase (AAT), alanine aminotransferase (ALAT), malic enzyme (ME), malate dehydrogenase (MDH), pyruvate kinase (PK), and phosphoenolpyruvate carboxykinase (PEPCK) activities in cytosolic and mitochondrial fractions of gill tissue from ribbed mussel, sea mussel, oyster, and *Mercenaria mercenaria* were determined. AAT showed distinct mitochondrial and cytosolic isozymes in gills of all animals. ALAT showed the same in gills of oysters, sea mussels, and quahogs, but only mitochondrial ALAT was found in ribbed mussel gill tissue. PK and PEPCK were cytosolic in all. ME was found only in the mitochondrial fraction of ribbed mussel and quahog gill tissue whereas sea mussel gills showed distinct cytosolic and mitochondrial ME isozymes. MDH showed distinct cytosolic and mitochondrial isozymes in all gills. (Modified authors' abstract - J.L.M.)

273 Peterson, C.H. 1982.

Clam predation by whelks (*Busycon* spp.): Experimental tests of the importance of prey size, prey density, and seagrass cover. Mar. Biol. 66(2):159-170.

Density of clams (*Mercenaria mercenaria*) was positively associated with seagrass cover in a meadow of *Halodule wrightii*. Seagrass provides these clams with a refuge from whelks (*Busycon* spp.). In the unaltered (control) seagrass meadow hard clam density remained constant over 13 months. Where seagrass was experimentally removed, marked individuals showed high rates of mortality in two successive experiments spanning 13 months. Whelk predation fell preferentially on larger size classes, while factors which contribute to clam disappearance usually acted more intensely on smaller sizes. Experimental exclusion of large predators by caging demonstrated that even in unvegetated areas survivorship of clams was high in the absence of whelks and other predators. (Amended author's abstract - J.L.M.)

274 Peterson, Charles H. 1983.

A concept of quantitative reproductive senility: Application to the hard clam *Mercenaria mercenaria* (L) ? Oecologia (Berl.) 58(2):164-168.

Quantitative reproductive senility occurs when older age classes achieve less reproductive effort than expected from the allometric (power) curve relating body size to reproductive effort among younger adults. Among *Mercenaria mercenaria* from North Carolina up to age 19, there is no evidence of either absolute or quantitative reproductive senility. (Modified author's abstract - J.L.M.)

275 Peterson, C.H. 1986.

Quantitative allometry of gamete production by *Mercenaria mercenaria* into old age. Mar. Ecol. Prog. Ser. 29(1):93-97.

Among 67 hard clams collected during spawning from Core Sound, NC, gonadal masses increased significantly with body size. Clam age did not explain a significant amount of the residual variance in linear regression of log gonadal mass on log shell length. Because this collection contained 11 individuals over 24 yrs of age, including the oldest *Mercenaria mercenaria* ever reported, at 41 and 46 yrs, these results imply that gamete production in hard clams continues into old age at a quantitative level predicted simply by the power curve relating gonadal mass to body size. There was no suggestion of even partial reproductive senility in gamete production at old age. (Modified author's abstract - J.L.M. and M.W.S.)

276 Peterson, Charles H. 1986.

Enhancement of *Mercenaria mercenaria* densities in seagrass beds: Is pattern fixed during settlement season or altered by subsequent differential survival? Limnol. Oceanogr. 31(1):200-205.

The hypothesis that passive hydrodynamic influence of projecting sea grasses on larval and postlarval settlement is sufficient to explain higher *Mercenaria mercenaria* densities inside a seagrass habitat was tested. This was done by comparing the between-habitat ratio of 0-year-class recruits after each of two settlement seasons with the between-habitat ratio of densities of all older age classes. Differential survival after settlement must be invoked to explain at least half the seagrass enhancement in *Mercenaria* population density. (J.L.M.)

277 Peterson, Charles H., and Stephen R. Fegley. 1986.

Seasonal allocation of resources to growth of shell, soma, and gonads in *Mercenaria mercenaria*. Biol. Bull. (Woods Hole) 171(3):597-610.

Thirteen monthly measurements of individually marked juvenile and adult specimens of *Mercenaria mercenaria* from field plots in North Carolina demonstrated similar seasonal patterns in size-adjusted monthly growth rates in shell volume. A large absolute maximum occurred in spring (April or May) and smaller relative maxima in midsummer and late autumn. The ratio of juvenile to adult size-adjusted growth rates in shell volume was nearly constant for 10 months but then increased eightfold in December and January. This growth anomaly between size classes could not be explained by examining dry weights of soma and gonads from additional marked juvenile and adult clams that were sacrificed monthly. Juveniles differed from adults by possessing negligible gonadal mass on all dates. However, knowledge of monthly changes in adult gonadal mass did not explain a significant amount of the residual variation in the regression of monthly juvenile volumetric growth on monthly adult volumetric growth. Seasonal changes in growth of adult gonadal mass and quarterly examinations of gonad histology suggested a winter period of negligible gametogenesis followed by a spring burst of intense reproductive activity. The best explanations for the anomalously high volumetric growth of juveniles relative to adults in December and January are: 1) winter availability of a food source accessible only to juveniles, or 2) biochemical storage of energy during winter by adults in preparation for the process of rapid gametogenesis in spring. If the second explanation is correct, adult clams exhibit a large seasonal change in allocation of resources between somatic growth and reproduction, with maximal allocation to reproduction in winter before gonad histology and growth of gonadal mass indicate reproductive effort. (Modified authors' abstract - J.L.M.)

278 Peterson, Charles H., and Millicent L. Quammen. 1982?

Siphon nipping: its importance to small fishes and its impact on growth of the bivalve *Protocatha staminea* (Conrad). J. Exp. Mar. Biol. Ecol. 63:249-268.

Mercenaria mercenaria is not mentioned. Siphon nipping by *Leptocottus armatus*, *Hypsopsetta guttulata*, and *Paralichthys californicus* reduced growth of *Protothaca staminea* in nature as compared with the same bivalve in cages that excluded large predators and croppers. (J.L.M.)

279 Peterson, C.H., H.C. Summerson, and P.B. Duncan. 1984.

The influence of seagrass cover on population structure and individual growth rate of a suspension-feeding bivalve, *Mercenaria mercenaria*. J. Mar. Res. 42(1):123-138.

Average density of *Mercenaria mercenaria* in samples taken from an eelgrass (*Zostera marina*) bed in Back Sound, NC was 9/m^2, more than five times average density (1.6/m^2) in samples from a nearby sand flat. Size-frequency distributions differed between environments, the sandflat contained a larger fraction of *Mercenaria* in the smallest group (0-1 cm). Age-frequency distributions also differed between environments but average *Mercenaria* age was identical. Average sizes of 0-, 1-, and 2-year-class *Mercenaria* were significantly greater in the seagrass collection. There was also an implication of higher growth rates inside the seagrass environment. Seagrass baffles currents near the bottom, where *Mercenaria* feeds, to levels 50% lower than those measured simultaneously on the sandflat. The paradoxically higher growth rate of *Mercenaria* in the lower current regime inside the seagrass bed may be a consequence of higher particulate food concentrations produced by the hydrodynamic baffling of the emergent vegetation. (J.L.M.)

280 Peterson, Charles H., Henry C. Summerson, and Stephen R. Fegley. 1983.

Relative efficiency of two clam rakes and their contrasting impacts on seagrass biomass. Fish. Bull., U.S. 81(2):429-434.

Habitat strongly influences the relative effectiveness of these clam rakes. In unvegetated sandy sediments the pea digger took significantly more legal-sized hard clams *Mercenaria mercenaria* per unit time than the bull rake. In a seagrass bed the relative effectiveness was reversed. The difference between rake effectiveness was not a consequence of greatly differing efficiencies of clam capture within raked areas, but rather of differing rates of areal coverage. Any habitat-specific regulation of a fishery requires more intense enforcement to be effective than an outright prohibition of certain gear. But the deeper water and unvegetated mudbottom usages of bull rakes suggest that this gear deserves a place among legal clamming gear, despite its threat to seagrass. (J.L.M.)

281 Peterson, Charles H., P. Bruce Duncan, Henry C. Summerson, and Brian F. Beal. 1985.

Annual band deposition within shells of the hard clam, *Mercenaria mercenaria*: consistency across habitat near Cape Lookout, North Carolina. Fish. Bull., U.S. 83(4):671-677.

Banding data from marked *Mercenaria mercenaria* after 24 months provided a compelling case for using major growth bands to age hard clams in the Cape Lookout region. Growth bands were recognized in sectioned shells. Of 89 individuals 17 showed insufficient growth or lacked a disturbance check to mark the precise size at the beginning of the experiment. Of the remaining 72, all but 2 deposited exactly 2 additional dark growth bands. Ages ranged from 0 to 17 years at the beginning of the experiment. (J.L.M.)

282 Peterson, C.H., P.B. Duncan, H.C. Summerson, and G.W. Safrit, Jr. 1983.

A mark-recapture test of annual periodicity of internal growth band deposition in shells of hard clams, *Mercenaria mercenaria*, from a population along the southeastern United States. Fish. Bull., U.S. 81(4):765-779.

Individually marked and measured *Mercenaria mercenaria* were placed in field enclosures of three types near Cape Lookout, NC, in June 1978. Subsets were collected and sacrificed in Oct. 1979, May 1980, Oct. 1980, and Oct. 1981. Growth bands were deposited annually during the summer-early fall season. Enclosure type did not alter the regular annual band pattern. Only about 7% of recruits in spring samples failed to show an identifiable growth band from their first summer-fall period. Thus, southeastern *M. mercenaria* near Cape Lookout can be aged by counting internal growth bands, but, unlike northern populations, show slow growth and annual band deposition during summer-early fall rather than in winter. Aging of a Core Sound collection gave a high proportion of older clams (up to 32 years old) and a mean age of over 9 years. Growth rates gave an average legally harvestable size reached in 1½ years. A lower recruitment success was shown from the 1977, 1978, and 1979 year classes than for previous years. This corresponds with a fourfold increase in commercial harvest, and suggests that the spawner-recruit relationship should be examined. (Modified authors' abstract - J.L.M.)

283 Phelps, H.L., J.T. Hardy, W.H. Pearson, and C.W. Apts. 1983.

Clam burrowing behaviour: Inhibition by copper-enriched sediment. Mar. Pollut. Bull. 14(12):452-455.

Burrowing rates of small clams (not *Mercenaria mercenaria*) were significantly faster than those of larger clams. Above a threshold of 5.8 μg Cu/g added to dry sediment, the time for 50% of the clams (*Protothaca staminea*) to burrow (ET_{50}) increased logarithmically with increasing sediment copper concentration. Previously exposed clams had a lower threshold to Cu and a longer reburrowing time. Clams exposed to sediment mixed with Chelex-100-sorbed Cu showed no significant change in burrowing time. Bioassays based on clam burrowing behavior can measure bioeffectiveness of sediment-sorbed metals and a sublethal effect with ecological meaning. (J.L.M.)

284 Phelps, Harriette L., Walter H. Pearson, and John T. Hardy. 1985.

Clam burrowing behaviour and mortality related to sediment copper. Mar. Pollut. Bull. 16(8):309-313.

Gravel sediment freshly enriched with over 4.4 μg Cu/g significantly increased the burrowing and reburrowing times of littleneck marine clams (*Protothaca staminea*). *Mercenaria mercenaria* is not mentioned. (J.L.M.)

285 Potts, W.T.W. 1967.

Excretion in the molluscs. Biol. Rev. 42(1):1-41.

No specific mention of *Mercenaria mercenaria*. The general morphology of the molluscan kidney is outlined. The excretion of nitrogenous waste by aquatic molluscs is described. (J.L.M. and M.W.S.)

286 Price, David A., and Michael J. Greenberg. 1980.

Pharmacology of the molluscan cardioexcitatory neuropeptide FMRFamide. Gen. Pharmacol. 11(2):237-241.

FMRFamide has positive inotropic and chronotropic actions on the isolated heart of *Mercenaria mercenaria*. In addition, it causes a sustained contraction of the radula protractor muscle of *Busycon contrarium*. The action of 5-hydroxytryptamine (5-HT) is similar to that of FMRFamide on *Mercenaria* heart, and the 2 dose-response curves are parallel, but 5-HT cardioexcitation is blocked by methysergide; that of FMRFamide is not. Acetylcholine (ACh) also contracts the radula protractor; but the effect is qualitatively different from that of FMRFamide and the dose-response curves are not parallel. Benzoquinonium blocks ACh contractures, but not those of FMRFamide. A number of amino acid derivatives and peptides were screened for biological activity on these two muscles, but most were inactive. (Modified authors' abstract - J.L.M.)

287 Price, Thomas J. 1962.

Accumulation of radionuclides and the effects of radiation on molluscs. 3d Seminar on Biol. Problems in Water Pollution, p. 202-210. U.S. Dep. Health, Educ., Welfare, 200 Independence Ave., SW, Wash., D.C. 20201.

Accumulation and retention of cesium-137, cerium-144, zinc-65, and gold-199 and the effects of radiation were followed on hard clams, *Mercenaria mercenaria*, oysters, *Crassostrea virginica*, and bay scallops, *Aequipecten irradians*. LD_{50} for clams in the various dose groups was: 186,656 roentgens (r), 5.5 days; 163,324 r, 4.5 days; 139,992 r, 6.5 days; 116,600 r, 25.5 days; 93,328 r, 38.5 days. The remaining groups of irradiated clams (46,664; 23,332; 11,666; and 5,833 r) had not attained a 50% mortality after 60 days. (J.L.M.)

288 Pruder, G.D. 1975.

Engineering aspects of bivalve molluscan mariculture: Culture system configurations. *In* Avault, J.W., and R. Milter (eds.), Proc. 6th Annu. Meet. World Maricult. Soc., p. 203-212. La. State Univ., Baton Rouge, LA 70803.

Abstracted elsewhere in this bibliography under College Marine Stud., Univ. Delaware, Newark, DE 19716, NOAA Sea Grant 04-3-158-30, 13 p. (J.L.M.)

289 Pruder, Gary D. 1976.

Engineering aspects of bivalve molluscan mariculture: Culture system configurations. Coll. Mar. Stud., Univ. Del., Newark, DE 19716, NOAA Sea Grant 04-3-158-30, 13 p.

The information was presented at the 6th Annual Meeting of the World Mariculture Society, Seattle, WA, in January 1975. Three principal controlled-environment system configurations have been designed and utilized. Each has served a specific purpose. The technical feasibility of raising bivalve molluscs, including *Mercenaria mercenaria*, from egg to market size in a recirculating system with a diet of cultured algae has been demonstrated. Currently system optimization and cost reduction efforts are working toward achievement of an economically feasible system. System I was discontinued because algal cells could not be harvested efficiently from the media and because it had a limited capacity to produce massive quantities of algae. System II worked well but it was too small for scale-up to commercial operation. System III demonstrated the success of growing bivalve molluscs on cultured algal cells, productivity of algal cultures was increased, and the recycle potential to make the alga-mollusc route a reasonable one was demonstrated. A 50-bushel system including a solar-powered mass algal culture facility is currently under design. (J.L.M.)

290 Pruder, G.D., E.T. Bolton, and S.R. Faunce. 1979.

System configuration and performance: Bivalve molluscan mariculture. *In* Avault, J.W., Jr. (ed.), Proc. 9th Annu. Meet. World Maricult. Soc., p. 747-759. La. State Univ., Baton Rouge, LA 70803.

After several years effort the technical feasibility of raising bivalve molluscs from egg to market size in a recirculating system on a diet of cultured algae has been demonstrated. This system was developed for oysters, *Crassostrea virginica*, but the general features of the system apply also to the hard clam, *Mercenaria mercenaria*. (J.L.M.)

291 Pruder, Gary D., Ellis T. Bolton, Earl F. Greenhaugh, and Robert E. Baggaley. 1976.

Engineering aspects of bivalve molluscan mariculture - Progress at Delaware 1975. *In* Avault, J.W. Jr. (ed.), Proc. 7th Annu. Meet. World Maricult. Soc., p. 607-622. La. State Univ., Baton Rouge, LA 70803.

The University of Delaware Project is working toward development of commercial, closed-cycle, controlled-environment shellfish mariculture suitable for rapid growth of *Mercenaria mercenaria* and other bivalves. The paper reviews improvements in growth rate of oysters. (J.L.M.)

292 Pruell, Richard J., Eva J. Hoffman, and James G. Quinn. 1984.

Total hydrocarbons, polycyclic aromatic hydrocarbons and synthetic organic compounds in the hard shell clam, *Mercenaria mercenaria*, purchased at commercial seafood stores. Mar. Environ. Res. 11(3):163-181.

Total hydrocarbons in store samples were generally higher than in samples collected from a control location in lower Narragansett Bay. Polycyclic aromatic hydrocarbons concentrations were similar to levels reported for other shellfish species. Two substituted benzotriazoles also were detected in clam extracts. Levels of polycyclic aromatic hydrocarbons and substituted benzotriazoles were also generally higher than in samples from the control location in the lower Bay. The significance of these findings to human health was unknown at this time because human health standards for these compounds in seafoods have not been established. (J.L.M.)

293 Purchon, R.D. 1971.

Digestion in filter feeding bivalves - a new concept. Proc. Malacol. Soc. Lond. 39, Pt. 4:253-262.

In certain genera the digestive processes are now known to comprise a chronological sequence of events associated with some exogenous or endogenous rhythm. Thus, it will be essential to make adequate provision for this possibility in all future investigations. With respect to investigations on the Bivalvia, a tidal simulator and/or kymograph have become essential pieces of equipment to any biochemist. *Mercenaria mercenaria* is not mentioned. (J.L.M.)

294 Rask, Hauke K. 1983.

Growth enhancement of *Mya arenaria* Linne and *Mercenaria mercenaria* (Linne) by marine macroalgae. J. Shellfish. Res. 3(1):99-100 (abstract).

Juveniles of *Mya* and *Mercenaria* were alizarin-stained and cultured for 12 weeks in flowthrough tanks containing one of three different species of macroalgae. Clams grown with *Ascophyllum nodosum* Linnaeus and *Laminaria longicruris* De la Pylaic were significantly larger in shell dimensions than controls and those grown with *Ulva lactuca* Linnaeus. Treatments with *Ascophyllum* and *Laminaria* were 12.6% and 9.6% larger than controls, respectively. (Modified author's abstract - J.L.M.)

295 Rathjen, Warren F. 1986.

Economics of clams. *In* Busby, D. (ed.), An overview of the Indian River clamming industry and the Indian River Lagoon, p. 15-17. Tech. Pap. 44, Fla. Sea Grant Ext. Prog., Univ. Fla., Gainesville, FL 32611, Proj. IR-85-7, Grant NA85AA-D-SG059.

Despite management and environmental problems the U.S. clam fisheries are operating at record levels. The hard clam is the most valuable of the four primary east coast species. Production has been under stress in New England and in the middle Atlantic coast, but this has been offset by increased production in the south, particularly in Fla. (J.L.M.)

296 Rhoads, Donald C., and Richard A. Lutz (eds.). 1980.

Skeletal growth of aquatic organisms - Biological records of environmental change. Plenum Press, NY, 750 p.

This volume is a valuable literature review of skeletal growth which should be consulted by all workers on hard parts of aquatic organisms. The papers review *Mercenaria mercenaria* extensively, and many other mollusks, but other organisms also are covered, for example, corals, fishes, polychaetes, and barnacles, and others. (J.L.M.)

297 Rhoads, D.C., and R.A. Lutz. 1981.

The molluscan shell: Biological record of environmental change, p. 1-4. EPA-600/S-3-81-019, EPA Research and Development, Environ. Res. Lab., Narragansett, RI 02882.

Species such as *Mercenaria mercenaria* are ideal candidates for study because their long life-span allows analysis of skeletal records that encompass predisturbnce growth conditions and postdisturbance growth recovery. Ontogenetic growth records, demographic parameters, after-the-fact pollution studies, identification of adaptive strategies, and fishery management are some of the factors that can benefit from growth studies. (J.L.M.)

298 Rhoads, Donald C., and Giorgio Pannella. 1970.

The use of molluscan shell growth patterns in ecology and paleoecology. Lethaia 3(2):143-161.

The relationship of growth patterns to specific environmental factors was studied by transplanting trays of bivalves from one environment to another. Juvenile *Mercenaria mercenaria* were transplanted from holding tanks to the intertidal zone and finally to a subtidal environment. The sequence of events was recorded accurately in the microgrowth patterns of all specimens. Growth over the period of study could be followed on a day-by-day level of resolution. Growth rate decreased after the transplant from holding tanks to the intertidal zone and from the intertidal to the surface of a turbid subtidal mud bottom. Growth increased, however, from the intertidal to subtidal environment in specimens elevated above the turbid mud bottom. Growth rate was higher in specimens living in sand than in those living in mud in all stages of the experiment. *M. mercenaria* deprived of its natural substratum exhibited marked changes in its microgrowth patterns. Large varices, periostracal extensions, and sharply delimited daily growth bandings marked the period of growth without a granular substratum. Changes in shell structure were also observed during the period of growth without sediment. The molluscan shell may be considered as a long term continuous environmental recorder. Additional research is required to be able to identify particular recorded patterns with specific environmental conditions. (J.L.M.)

299 Rhoads, Donald C., Larry F. Boyer, Barbara L. Welsh, and George R. Hampson. 1984.

Seasonal dynamics of detritus in the benthic turbidity zone (BTZ): Implications for bottom-rock molluscan mariculture. Bull. Mar. Sci. 35(3):536-549.

The benthic turbidity zone (BTZ) is an open adaptive zone for commercially important eulamellibranchs. It is possible that bioturbating activity might decrease if molluscs were grown in the BTZ. This negative feedback might have to be allowed for. (J.L.M.)

300 Rhodes, Edwin W., James C. Widman, and Elizabeth L. Grinbergs. 1984.

Optimum algal concentrations and algal consumption rates for bivalve larvae in culture, and some implications for feeding protocols. J. Shellfish. Res. 4(1):99 (abstract).

In two separate types of experiments with larvae of the northern quahog *Mercenaria mercenaria* and northern bay scallop *Argopecten irradians irradians* optimum concentrations of *Isochrysis* aff. *galbana* for growth were determined, and estimates made of algal consumption rates. This presented a clear picture of larvae-food interactions in culture systems, and suggested some new feeding strategies. (Modified authors' abstract - J.L.M.)

301 Robinson, W.E. 1981.

Statistical analysis of digestive gland tubule variability in *Mercenaria mercenaria* (L.), *Ostrea edulis* L., and *Mytilus edulis* L. J. Shelfish. Res. 1(1):121-122 (abstract).

Four main tubule types, signifying various stages of intracellular digestion, can be recognized: I, holding; II, absorptive; III, fragmenting; and IV, reconstituting. Digestive tubules and similar tubule types are not distributed randomly within the digestive gland, but are grouped together around common secondary ducts. In *Mercenaria mercenaria* variability of tubule types is high within individual digestive glands, as well as between individuals sampled at the same time. Based on calculations to minimize total variance, it is better to sample a small area from numerous individuals rather than a large area from a few animals. Problems imposed by variability and tubule clustering have not been considered adequately in previous investigations of digestion. (J.L.M.)

302 Robinson, William E., Michael R. Pennington, and Richard W. Langton. 1981.

Variability of tubule types within the digestive glands of *Mercenaria mercenaria* (L.), *Ostrea edulis* L., and *Mytilus edulis* L. J. Exp. Mar. Biol. Ecol. 54(3):265-276.

The variability of the four tubule types previously recognized in the digestive glands of bivalve mollusks (e.g., holding, absorptive, fragmenting, and reconstituting) was investigated using photomicrographs. The clustering of similar tubule types around common secondary ducts was observed histologically and by statistical analysis. Intra-animal variances were approximately the same for each species. Inter-animal variances were also similar but only 10% to 25% of the intra-animal values. Sampling schemes involving large numbers of animals but few photomicrographs of each digestive gland would minimize overall variance. The necessity of taking numerical data and using proper statistical analysis is stressed. (J.L.M.)

303 Rodhouse, P.G. 1973.

Factors affecting spatfall of the clam *Mercenaria mercenaria* L. in Southampton water. Masters Diss., Univ. Southampton, U.K., pages not known.

Thesis not available at University of Southampton. (J.L.M.)

304 Rodhouse, P.G., B. Ottway, and G.M. Burnell. 1981.

Bivalve production and food chain efficiency in an experimental nursery system. J. Mar. Biol. Assoc. U.K. 61(1):243-256.

Four bivalve species were grown in the system, *Ostrea edulis*, *Crassostrea gigas*, *Tapes decussatus* (= *Venerupis decussata*), and *Chlamys varia*. The system was less productive, per unit area, than some natural populations of bivalve, but probably approached the maximum attainable in a semi-closed system relying on in situ primary productivity. *Mercenaria mercenaria* is mentioned only with reference to papers abstracted elsewhere in this bibliography. (J.L.M.)

305 Romeril, M.G. 1979.

The occurrence of copper, iron and zinc in the hard shell clam, *Mercenaria mercenaria*, and sediments of Southampton Water. Estuarine Coastal Mar. Sci. 9(4):423-434.

A change of metal concentration with age was the most easily recognized relationship. All metal concentrations were lower at the seaward end of the estuary, and sediment metal levels generally followed a similar trend. But tissue and sediment values appeared to correlate with each other only for iron. Effects attributable to the Marchwood Power Station were insignificant in relation to natural variability. (J.L.M.)

306 Rosenberg, Gary D. 1980.

An ontogenetic approach to the environmental significance of bivalve shell chemistry. Chapt. 4 *In* Rhoads, D.C., and R.A. Lutz (eds.), Skeletal growth of aquatic organisms - Biological records of environmental change, p. 133-168. Plenum Press, NY.

The extent to which shell chemistry of bivalves can be used to make environmental and evolutionary interpretations is, at present, unclear. Shell composition is complex, varying with position in the shell and with ontogenetic age. The distribution of elements in a shell must be fully described before interpretaion can be made. The description of chemical ontogeny and its allometric variations promised to be a long and difficult task with present analytical methods. (J.L.M.)

307 Ryther, John H. 1973.

The use of flowing biological systems in aquaculture, sewage treatment, pollution assay, and food-chain studies. Unpubl. prog. rep. WHOI-73-2, Woods Hole Oceanogr. Inst., Woods Hole, MA 02543, prepared for N.S.F. under grant NSF-RANN GI-32140 [U.S. Dep. Commer., Natl. Tech. Inf. Serv., PB-299 036] p. 1-131.

A combined tertiary sewage treatment-marine aquacultural system has been designed and successfully tested on a small, experimental scale. Effluent from secondary sewage treatment, diluted with seawater, is used as a source of nutrients for growth of unicellular marine algae, and the algae, in turn, are fed to oysters or other shellfish (e.g., *Mercenaria mercenaria*). The algae remove the objectionable constituents from the secondary sewage effluent (ammonia, nitrate, phosphate, etc.) and the algae are removed by the oysters or other shellfish. The products are purified waste effluent, which will not support further algal growth (undesirable "algae blooms") in nature, and a commercially-valuable crop of seafood. Using a continuous flow mode of operation the process was capable of removing 95-100% of the inorganic nitrogen content of the sewage effluent, the discharge from the system being unable to support further algal growth and often containing less nitrogen than the receiving seawater. Dissolved wastes, produced as excretory products of the oysters, are removed by a final "mop-up" step consisting of macroscopic algae (seaweeds), of which several species have been tested. It is projected that this basic system should be capable of providing advanced (tertiary) sewage treatment for a population of 50,000 people with the ancillary annual production of 900 tons of oyster meats or 250,000 bushels of whole oysters worth $1-5 million. Space required for an operation of that scale would be some 144 acres as compared with about 110 acres for a conventional filterbed, land disposal system. (Modified author's abstract - J.L.M.)

308 Ryther, John H. 1977.

Preliminary results with a pilot-plant waste recycling-marine aquaculture system. Chapt. 4 *In* D'Itri, F.M. (ed.), Wastewater renovation and reuse, p. 89-132. Marcel Dekker, Inc., NY.

During the first year the pilot plant operated, shellfish culture was largely unsuccessful. Seed clams (*Mercenaria mercenaria*) showed poor growth and high mortality. This was believed to be due to unresolved problems such as unfavorable culture conditions in the raceway system, unfavorable algal food of *Phaeodactylum tricornutum*, reported in the literature as poor to indifferent food for bivalves, or an inferior stock of shellfish whose growth was stunted prior to or after acquisition. Data from small-scale experiments and from the literature indicate that enough algae were produced from a million gallons per day of sewage effluent to grow 11 million market-sized oysters per year. This possibility must remain speculative until a successful method of shellfish production is demonstrated and evaluated. (J.L.M.)

309 Ryther, John H. 1986.

The resource - Biological and environmental factors affecting the clamming industry. *In* Busby, D. (ed.), An overview of the Indian River clamming industry and the Indian River Lagoon, p. 14. Tech. Pap. 44, Fla. Sea Grant Ext. Prog., Univ. Fla., Gainesville, FL 32611, Proj. IR-85-7, Grant NA85AA-D-SG059.

It is suggested that the recent success of the Indian River clam fishery may have resulted from unusually heavy rainfall during 1982, and above-normal rainfall during 1983 and 1984. This is only theory, however, and must be confirmed by monitoring and meteorological data. (J.L.M.)

310 Ryther, John H. 1986.

Division of Applied Biology. Harbor Branch Found., Inc., Fort Pierce, FL 33450, 4 p.

Describes activities in algae culture, mollusc cultivation, fish culture, aquatic biomass research, and environmental research. An unusually successful natural set of hard clams (*Mercenaria mercenaria*) in the Indian River led to rapid growth of the clam fishery, aided by decline of Long Island's clam fishery and migration of diggers from the northeast. The Division has developed a hatchery, which presently is doing exploratory production of hard clam seed. (J.L.M.)

311 Ryther, John H., and Joel C. Goldman. 1975.

Microbes as food in mariculture. *In* Starr, M., J.L. Ingraham, and S. Raffel (eds.), Annu. Rev. Microbiol. 29, p. 429-443. Annual Reviews, Inc., Palo Alto, CA.

The best food organisms were the small flagellates *Isochrysis galbana* and *Monochrysis lutheri*. For *Mercenaria mercenaria* best growth occurred at cell concentrations of about $2\text{-}2.5 \times 10^5$ cells/mL of either species. Most of the algae tested produced growth of *M. mercenaria* ranging in size from about 0.5 to 10.0 mm. Exceptions were the dinoflagellate *Amphidinium klebsi* and several species of *Chlorella*, *Stichococcus*, and other coccoid algae, which usually gave less growth than unfed controls. Good growth was obtained with diatoms (*S. costatum*, *P. tricornutum*) and with several small flagellates, but the best results were obtained with mixtures of three or four diatoms and flagellates. Walne (1970) also published an extensive survey of the relative food value of 25 species of 19 genera for juvenile (0.5-5.0 mm) clams (*M. mercenaria*) and got similar results. Large-scale sea farming operations involving use of cultivated microorganisms is not a reality at present. (J.L.M.)

312 Ryther, John H., Joel C. Goldman, Cameron E. Gifford, John E. Huguenin, Asa S. Wing, J. Philip Clarner, Lavergne D. Williams, and Brian E. LaPointe. 1975.

Physical models of integrated waste recycling - marine polyculture systems. Aquaculture 5:163-177.

A combined tertiary sewage treatment-marine aquaculture system was developed, tested, and evaluated at Woods Hole, MA, and Fort Pierce, FL. Domestic wastewater effluent from secondary sewage treatment mixed with seawater was used as a source of nutrients for growing unicellular marine algae, and the algae, in turn, were fed to oysters, hard clams (*Mercenaria mercenaria*), and other bivalve molluscs. The output from each algal pond was fed into cement raceways which contained, among other molluscs, 150,000 seed clams ~1.25 cm long. The raceway containing hard clams was stocked with 1,400 "bait worms" (*Nereis virens*) ~2 cm long. It was expected that these worms would grow on clam biodeposits. To provide worms with shelter and reduce cannibalism the bottom of the raceway was lined with beach stones because fine sand tends to become anoxic. (J.L.M.)

313 Sager, Gunther. 1984.

Prolonged seasonal growth stagnation demonstrated for the bivalve *Mercenaria mercenaria*. Beitr. Meereskunde, Heft 51:57-66. (Akad. Wiss. DDR Inst. Meereskunde, Akademie-Verlag, Berlin).

From original: Verlangerte saisonale Wachstumsstagnation am Beispiel der Venusmuschel (*Mercenaria mercenaria*). Beitr. Meereskunde 51:57-66.

Environmental factors have a more or less gravitating influence upon organic life, and can lead to a reduction of growth development. For a temporary slowing down and a momentary stagnation growth functions can be modified as was recently shown by the author (Sager 1982). This method does not apply to stagnation over weeks or even months, however, as is the case for different species including fishes and clams. Therefore a second revision is necessary for such a special behavior. A new formula is presented and tested for the bivalve *Mercenaria mercenaria* of Southampton Water, English Channel. (Author's abstract - J.L.M.)

314 Saleuddin, A.S.M., and Henri P. Petit. 1983.

The mode of formation and the structure of the periostracum. Chapt. 5 *In* Saleuddin, A.S.M., and K.M. Wilbur (eds.), The Mollusca. Vol. 4. Physiology, Pt. 1, p. 199-234. Academic Press, NY.

Reference to *Mercenaria mercenaria* studied by other authors is included under references. (J.L.M.)

315 Saleuddin, A.S.M., and Karl M. Wilbur. 1983.

The Mollusca. Vol. 4, Physiology, Pt. 1. Academic Press, NY, 523 p.

Contains numerous references to *Mercenaria mercenaria*, most of which are by other authors abstracted elsewhere in this bibliography, but some of which are previously unpublished observations. (J.L.M.)

316 Saleuddin, A.S.M., and Karl M. Wilbur. 1983.

The Mollusca. Vol. 5, Physiology, Pt. 2. Academic Press, NY, 500 p.

This book continues the series begun with Wilbur and Yonge (1964). Chapters by Morton (65-147), Jones (189-238), Burton (291-352), Martin (353-405), and Bayne (407-486) are pertinent to *Mercenaria mercenaria* even in places where *M. mercenaria* is not mentioned specifically. The book should be read for information on feeding and digestion, circulatory system, ionic regulation and water balance, excretion, and immunobiology. (J.L.M.)

317 Sandine, Phillip H. 1984.

Zooplankton. Chapt. 5 *In* Kennish, M.J., and R.A. Lutz (eds.), Ecology of Barnegat Bay, New Jersey. Lecture notes on coastal and estuarine studies, 6, p. 95-134. Springer-Verlag, NY.

Mercenaria mercenaria larvae were sampled in Barnegat Bay, and densities up to $67{,}000/m^3$ were reported in Little Egg Harbor. (J.L.M.)

318 Santoro, Peter F., and Joel A. Dain. 1981.

A comparative study of B-N-acetylglucosaminidase from *Mercenaria mercenaria*, *Mya arenaria* and *Spisula solidissima*. Comp. Biochem. Physiol. 69B(3):337-344.

B-N-acetylglucosaminidase was partially purified from the digestive gland of hard clam, soft clam, and surf clam and their properties compared. Heat inactivation studies on the B-N-acetylglucosaminidases preincubated at 45°C showed that the preparation from surf clam was stable up to 60 minutes, while that from soft clam and hard clam lost 47% and 91% of their original activities under the same conditions, respectively. D-glucuronolactone is more inhibitory towards the soft clam enzyme, while $HgCl_2$ is less inhibitory towards the surf clam enzyme. The V_{max} value for B-N-acetylglucosaminidase from hard clam was about 2.5-fold "greater" than that from the other two bivalves. The pH optimum, K_m, molecular weight, energy of activation, and effect of ionic strength on enzyme activity were similar for all three species. The digestive gland of all three species also contained several other activities. (J.L.M.)

319 Schwartz, Frank J. 1974.

Movements of the oyster toadfish (Pisces: Batrachoididae) about Solomons, Maryland. Chesapeake Sci. 15:155-159.

Toadfish are much less sedentary than formerly thought. No mention of food. (J.L.M.)

320 Scott, Roy F. 1981.

Shell planted on public bottom in Chincoteague Bay to aid hard clam set. MD Dep. Nat. Resour., Annapolis, MD 21401, Tidewater Fish. News, 14(5):2-3.

Present commercial fishery consists of a few individuals raking clams in summer, and 5 to 10 hydraulic dredges working in winter. Harvesters are restricted to 8,000 clams/day. The dredge fishery is expanding because prices are higher and the population is increasing, allowing a harvest of 4,000 to 5,000 clams per boat per day. Shell areas increase recruitment by providing a better opportunity for setting and reducing crab and fish predation. Hard clam is relatively long-lived and more susceptible to overfishing than short-lived soft clams or blue crabs. It is believed that Maryland's hard clam fishery can best be served by: 1) a shell planting program to improve the habitat; 2) encouraging private clam culture; and 3) careful monitoring of the harvest and status of the clam population. The Tidewater Administration barged 43,000 bu of oyster shells from Chincoteague and planted on a 17-acre site east of Mills Island. The area will be cultivated and opened to clam harvesting in 3 yrs. Planting efforts will be continued. Hard clam culture has excellent potential. (J.L.M.)

321 Seed, Raymond. 1980.

Shell growth and form in the bivalvia. Chapt. 1 *In* Rhoads, D.C., and R.A. Lutz (eds.), Skeletal growth of aquatic organisms - Biological records of environmental change, p. 23-67. Plenum Press, NY.

On page 54 is a figure showing burrowing habit of *Mercenaria*. (J.L.M.)

322 Shaw, William N. 1984.

Research in molluscan culture under the National Sea Grant Program. Part 3. Woods Hole Oceanographic Institution waste recycling-aquaculture system. Aquaculture Mag. 10(6A):37-38.

Mercenaria mercenaria grown in raceways did not grow significantly in 18 months. A good food organism, *Skeletonema costatum* grew best only in winter, at temperatures between 0o and 9°C. During the remainder of the year the diatom *Phaeodactylum tricornutum* was dominant, but this species is known to be a poor food for most bivalves. In the author's opinion using wastewater for aquaculture is limited. Yet one cannot overlook the role these wastes could play at the hatchery level, when shellfish are small and food demand is not great. (J.L.M.)

323 Shumway, Sandra E., Terry L. Cucci, Richard C. Newell, and Clarice M. Yentsch. 1985.

Particle selection, ingestion, and absorption in filter-feeding bivalves. J. Exp. Mar. Biol. Ecol. 91(1,2):77-92.

Mercenaria mercenaria was not included among the six bivalve species experimented with. (J.L.M.)

324 Sick, Lowell V., and Carole A. Siegfried. 1972.

Effects of the ambient environment on metabolic regulation of shell biosynthesis in marine bivalve mollusks. *In* Pruder, G.D., C.J. Langdon, and D.E. Conklin (eds.), Proc. 2nd Int. Conf. on Aquacultural Nutrition: Biochemical and Physiological Approaches to Shellfish Nutrition, p. 377-399. La. State Univ., Baton Rouge, LA 70803.

Reviews papers by Weiner and Hood, Crenshaw, Gordon, and Carriker and Young, Crenshaw and King abstracted elsewhere in this volume. (J.L.M.)

325 Sindermann, C.J., S.C. Esser, E. Gould, B.B. McCain, J.L. McHugh, R.P. Morgan II, R.A. Murchelano, M.J. Sherwood, and P.R. Spitzer. 1982.

Effects of pollutants on fishes. *In* Mayer, G.F. (ed.), Ecological stress and the New York Bight: Science and management, p. 23-38. Estuarine Res. Fed., Columbia, SC.

Data on commercial landings of most species caught in New York Bight show no signs of adverse effects on abundance. *Mercenaria mercenaria* landings are somewhat lower, but there is no evidence that pollution in New York Bight has been a cause. (J.L.M.)

326 Squires, Donald F. 1983.

Aquaculture development in New York State (draft plan). N.Y. Sea Grant Inst., State Univ. N.Y. and Cornell Univ, Stony Brook, NY 11794, 54 p.

A rather complete review of the potential for aquaculture in New York State including hard clams (*Mercenaria mercenaria*). Includes discussion of present status of aquaculture, aquaculture and the law, social and political attitudes toward aquaculture, economic constraints, marketing constraints, and biotechnical constraints. (J.L.M.)

327 Stanley, Steven M. 1969.

Bivalve mollusk burrowing aided by discordant shell ornamentation. Science (Wash. D.C.) 166(3905):634-635.

Oblique and chevron-like ridges on the shell surfaces of certain burrowing bivalve mollusks grip the sediment during shell-rocking movements to aid in sediment penetration. These ridges, characterized by steep dorsal slopes and gentle ventral slopes, have evolved through convergence in several families in association with particular behavioral and ecological traits. No specific mention of *Mercenaria mercenaria*. (Modified author's abstract - J.L.M. and M.W.S.)

328 Stanley, Steven M. 1975.

Why clams have the shape they have: An experimental analysis of burrowing. Paleobiology 1(1):48-58.

The prosogyrous shape and flattened lunule of a typical clam shell such as *Mercenaria mercenaria* form a blunt anterior, the function of which is related to the forward-and-back rocking motion of the shell in burrowing. Analysis of movies revealed that each rocking motion of a morphologically typical clam involves purely rotational movement, with no translational component. The clam is able to burrow by "walking" its way downward only because the axis of backward rotation lies to the anterior of the axis of forward rotation. Experiments with burrowing robots show that the blunt anterior serves to shift the axis of backward rotation anteriorly, thus aiding in downward progress. The prosogyrous condition and the rotational mechanism of burrowing are fundamental adaptations of burrowing clams and were apparently present in the ancestral bivalves of the Cambrian. (Modified author's abstract - J.L.M.)

329 Steimle, Frank W., Jr. 1982.

The benthic macroinvertebrates of the Block Island Sound. Estuarine Coastal Shelf Sci. 15(1):1-16.

No mention of *Mercenaria mercenaria*. (M.W.S.)

330 Steimle, Frank W., Jr. 1985.

Biomass and estimated productivity of the benthic macrofauna in the New York Bight: A stressed coastal area. Estuarine Coastal Shelf Sci. 21(4):539-554.

Waste disposal in the apex of New York Bight has resulted in contamination of sediments by toxic chemicals and some alteration to the community composition of the benthic macrofauna. This paper presents data on an extensive survey of the macrofauna biomass. *Mercenaria mercenaria* is not mentioned. (J.L.M.)

331 Stephens, G.C., and R.A. Schinske. 1957.

Uptake of amino acids from sea water by ciliary-mucoid filter feeding animals. Biol. Bull. (Woods Hole) 113:356-357 (abstract).

Crepidula fornicata, *Mytilus edulis*, and *Astrangia danae* all removed gylcine from sea water, and *Astrangia* also removed glutamic acid, methionine, alanine and arginine. *Mercenaria mercenaria* was not tested. (J.L.M.)

332 Stephens, Grover C. 1982.

Dissolved organic material and the nutrition of marine bivalves. *In* Pruder, G.D., C.J. Langdon, and D.E. Conklin (eds.), Proc. 2nd Int. Conf. on Aquacult. Nutrition: Biochem. and Physiolog. Approaches to Shellfish Nutrition, p. 338-357. La. State Univ., Baton Rouge, LA 70803.

Reviews a paper by Stephens and Schinske abstracted elsewhere in this volume. (J.L.M.)

333 Stevens, Fred S., J.J. Manzi, and H.Q.M. Clawson. 1984.

Development of field growout techniques for the northern hard-shell clam *Mercenaria mercenaria* (Linne) in South Carolina. J. Shellfish. Res. 4(1):101 (abstract).

Field planting of nursery-reared seed through the cooperative project has increased from 600,000 seed in 1980 to 2.4 and 2.9 million seed in 1981 and 1982. Field plants for 1983 are projected to exceed 12 million seed. Harvest size (45-50 mm) clams were retrieved from initial plants in Nov. 1982, exactly 24 months from first primary unit deployment. Mean recovery from secondary field units harvested to date was 79% and overall field survival was over 50%. This paper summarizes results to date. (Modified authors' abstract - J.L.M.)

334 Stone, Richard Byron. 1963.

A quantitative study of benthic fauna in lower Chesapeake Bay with emphasis on animal-sediment relationships. Masters thesis, College of William and Mary, Williamsburg, VA 23186, 40 p.

Mercenaria mercenaria is mentioned only in connection with the work of others, abstracted elsewhere in this bibliography. (J.L.M.)

335 Sunderlin, Judith Baab. 1975.

Growth of shellfish in an artificial upwelling mariculture system. Proc. Int. Symp. Coastal Upwelling, Nov. 18-19, 1975, p. 25-42. La Universidad, Coquimbo, Chile.

Ten species of shellfish were screened for growth and survival in the St. Croix mariculture system. Eight species, all except *Crassostrea virginica* and *Mercenaria mercenaria*, grew well and reached market size quickly. *M. mercenaria* grew poorly and sustained high mortalities at all locations. (J.L.M.)

336 Sutherland, John P., and Ronald H. Karlson. 1977.

Development and stability of the fouling community at Beaufort, N.C. Ecol. Monogr. 47:425-446.

Initial community development was relatively unpredictable. Larval recruitment patterns varied markedly from year to year. Instead of preparing the way for subsequent arrivals, most resident adults strongly inhibited recruitment and growth of other species. *Mercenaria mercenaria* was not included in fouling communities. (J.L.M.)

337 Tebble, Norman. 1966.

British bivalve seashells: A handbook for identification. Trustees of the British Museum (Nat. Hist.), Alden Press, Oxford, 212 p.

Lists *Venus verrucosa* from the English channel, the southwest of Ireland, Irish Sea, and west coast of Scotland, south to the Iberian Peninsula, into the Mediterranean, Canary Islands, Cape Verde Islands, Madeira, and down the west coast of Africa to Mossamedes (Angola) and from the Cape of Good Hope around to Durban and Delagoa Bay. *Venus casina*, common around the British Isles, south of Norway to the Iberian Peninsula, the Mediterranean, the Atlantic coast of Morocco, Canary Islands, Senegal, and Dahomey. *Venus (Timoclea) ovata*, widely distributed around the British Isles, northern Norway and Iceland to the Iberian Peninsula, Mediterranean, Black Sea to the Atlantic coast of Morocco, Canary Islands, and Cape Verde Islands. *Venus (Clausinella) fasciata*, widely distributed around the British Isles, and from the Lofoten Islands south to the Iberian Peninsula, Mediterranean, Atlantic coast of Morocco, Canary Islands. *Venus (Chamelea) striatula*, very common around the British Isles, Lophoten Islands south to the Iberian Peninsula, Mediterranean, Black Sea, Atlantic coast of Morocco, to Madeira and the Canary Islands. And *Venus (Mercenaria) mercenaria*, the first living specimens of which in the United Kingdom were found in the Humber River in 1860 (a dead shell, probably originating in a ship's ballast, was found in the Mersey River in 1859). Since that time it has been reported from the Menai Straits. Unsuccessful attempts have been made to introduce it into the Dee (Cheshire) and Mersey estuaries. Large colonies have become permanently established in the Solent, Southampton Water, and Portsmouth Harbor, possibly introduced from the kitchens of Transatlantic liners. Recently, experimental colonies have been introduced into the River Yealm, Devon, Poole Harbor, Dorset, the Rivers Crouch, Roach, and Blackwater, and at Walton, Essex. It was introduced into various places in France, but none of these was successful until 1910 when a population deposited in the basin of the River Seudre became properly acclimatized. This was the basis for a now flourishing clam fishery. It has also been reported from various places in Brittany, where colonies still survive, in Zeeland, the Netherlands, and in Ostend Harbor, Belgium. Shell solid, equivalve; inequilateral, beaks in the front half of the shell; rarely more than 5" (12.7 cms) long; broadly oval in outline; dirty white, light varnish-brown, dull grey or grey-brown, occasionally with red-brown zig-zag markings near the margins. Periostracum grey-brown. Ligament a deeply inset, dark brown elliptical band, behind the beaks reaching half-way to the posterior margin. Lunule well defined, broad, heart shaped. Escutcheon indistinct. Sculpture of concentric lines, raised here and there into ridges, and fine radiating lines. In young specimens ridges are present all over the shell, but in the adult they persist, after wear and tear, only near the anterior and posterior margins. Growth stages prominent. Both valves with three cardinal teeth; in addition there is present in each valve a rough tooth-like area behind the beaks and immediately below the ligament; this area has the appearance of a supplementary posterior cardinal tooth which has been broken off. No laterals. Inside of shell white, sometimes deep violet about the adductor muscle scars. Pallial sinus not deep, triangular. Margin crenulate. *Venus mercenaria* lives in mud, with stones and shells, from between tidemarks to depths of a few fathoms, being most abundant a short distance above low-water mark. It is native to the coast of North America from Nova Scotia to Yucatan where it is harvested in some places as a wild crop for sea food. (J.L.M.)

338 Terry, Orville W. 1974.

The New York aquaculture program - Past, present, and future. N.Y. Sea Grant Inst. Rep. NYSSGP-RS-74-018, State Univ. N.Y., Stony Brook, NY 11794, 16 p.

A general discussion of aquaculture in New York without reference to species. (J.L.M.)

339 Thorson, G. 1950.

Reproductive and larval ecology of marine bottom invertebrates. Biol. Rev. Camb. Philos. Soc. 25(1):1-45.

Larvae of *Venus mercenaria* are easily nourished by a quantity of different ultraplankton organisms, most of which are disregarded by the much more particular larvae of *Crassostrea virginica*. No other mention of *Mercenaria (Venus) mercenaria*. (J.L.M.)

340 Tourtellotte, Gary H., and Daniel M. Dauer. 1983.

Macrobenthic communities of the lower Chesapeake Bay. II. Lynnhaven Roads, Lynnhaven Bay, Broad Bay, and Linkhorn Bay. Benthic studies of the lower Chesapeake Bay 5. Int. Rev. Gesamten. Hydrobiol. 68(1):59-72.

Mercenaria mercenaria is not mentioned. (M.W.S.)

341 Trueman, E.R. 1968.

The burrowing activities of bivalves. *In* Fretter, V. (ed.), Symp. Zool. Soc. Lond. 22. Studies in the structure, physiology and ecology of molluscs, p. 167-186. Academic Press, London.

The study includes *Mercenaria mercenaria*. They dig into the sand by a series of steps, which continue until the animal is beneath the surface. Digging cycles consist of six different phases of activity, and involve integration of pedal protraction and retraction with opening and closing of valves, much of the musculature of the body playing a part in each cycle. The hinged shell acts as the basis of a fluid-muscle system which allows the strength of adduction to be used in digging. The fluid-muscle system consists of two separate fluid-filled chambers, the haemocoele and the mantle cavity, adduction generating high pressures in each equally and simultaneously. In the haemocoele this pressure gives rise to the characteristic dilated form of the foot which ensures a secure pedal anchorage so that at retraction the shell is drawn down. From the mantle cavity the pressure produces powerful jets of water which assist movement of the shell by loosening the adjacent sand. Subsequently the foot is protracted with probing movements by means of the intrinsic pedal musculature at relatively low hydrostatic pressures, while the shell is held still by the elastic ligament pressing the valves open against the substrate. The hinge teeth function to maintain contact between the valves dorsally during digging, when the valves are gaping ventrally. The possibility that the tissues adjacent to and between the teeth contain tactile receptors is considered and the nervous coordination of digging is discussed. (Modified author's synopsis) (J.L.M.)

342 Trueman, E.R. 1976.

Locomotion and the origins of mollusca. *In* Davis, P.S., and N. Sunderland (eds.), Perspectives in experimental biology. Vol. 1, p. 455-465. Zoology. Pergamon Press, Oxford and New York.

While a largely muscular tissue suffices to supply the necessary forces for movement over hard surfaces, burrowing requires greater forces and has resulted in the convergent but separate development of a large pedal haemocoelic cavity in Bivalvia and Gastropoda. There is no evidence for the development of a large coelomic cavity for locomotory purposes in the Mollusca, as occurs in the Annelida, and the origin of the molluscs from a pre-annelidan acoelomate worm is likely. *Mercenaria mercenaria* is not mentioned. (J.L.M.)

343 Trueman, E.R. 1983.

Locomotion in molluscs. Chapt. 4 *In* Saleuddin, A.S.M., and K.M. Wilbur (eds.), The mollusca. Vol. 4. Physiology Pt. 1, p. 155-198. Academic Press, NY.

Reference is made to *Mercenaria mercenaria* studied by other authors abstracted elsewhere in this bibliography. (J.L.M.)

344 Turgeon, Donna DeMoranville. 1968.

Guide to estuarine and inshore bivalves of Virginia. Masters thesis, College of William and Mary, Williamsburg, VA 23186, 126 p.

Mercenaria mercenaria, *M. M. notata*, and *M. campechiensis* are assigned to the Superfamily Veneracea. The northern hard clam has a shell subtriangular to roundly ovate, posterior half narrower and slightly drawn out; heavy, inflated; equivalve; inequilateral, umbones prominent in anterior third of shell, beaked anteriorly and directed toward each other, nearly touching; rarely more than 127 mm (5 inches) in length; color white, dull gray or straw-yellow to flesh tones. Lunule conspicuous, heart-shaped. Escutcheon indistinct. Periostracum often worn and inconspicuous, fawn to chocolate-brown. Ligament dark brown, posterior to beaks and reaching halfway to posterior margin. Sculpture of strong concentric ridges and radiating ribs, center of valves often worn smooth; growth increments prominent. Interior of shell flat white or blue-violet in color; sculpture lacking. Three teeth in each valve, left with anterior tooth large and posterior bifid; right with large posterior tooth and two oblique contiguous teeth; rough irregular points below hinge interlocking with those of opposite valve; laterals lacking. Muscle scars subcircular and impressed, often having colored sculpture. Sinus triangular, shallow, apex directed toward ventral portion of anterior muscle scar. Margin crenulate. Siphons short and united. Found abundantly in a wide variety of substrates intertidally to channel depths. In Virginia it is found where salinities are above 15‰; under laboratory conditions Chanley (1958) states 12.5‰ is the lower survival limit. The form *M. m. notata* is rarely found in Virginia. It coexists with *M. mercenaria* in the same habitat. The shell is shiny, white, tinged with sand-brown and with red-brown zig-zag marks; the surface is almost smooth. Range: Nova Scotia to the Gulf of Mexico; introduced to California, United Kingdom, Netherlands, Belgium, and France (Tebble 1966). The southern hard clam has the following distinguishing features from the northern: shell thicker, heavier and more obese; up to 168 mm (8½ inches) in length (Sims 1965); growth ridges deeper and retained longer in young specimens; color white, rarely with blue or violet stain on escutcheon and brown zig-zag lines on the side. Lunule usually as wide as long. Internal color usually white. It is uncommon in Virginia and exists only in the lower reaches of the Bay and offshore. Range: New Jersey (offshore) to Cape Canaveral and the Gulf of Mexico (Abbott 1954). (References abstracted elsewhere in this bibliography - J.L.M.)

345 Turner, Elizabeth J. 1983.

Effects of a storm-induced breach on *Mercenaria mercenaria* in Moriches Bay. Masters thesis, State Univ. N.Y. at Stony Brook, NY 11794, 77 p.

Samples of *Mercenaria mercenaria* were obtained from Moriches Bay, Long Island, NY, a shallow lagoon which in 1980 had a breach in the barrier island separating the Bay from the Atlantic Ocean. The breach was closed artificially by 1981. Shell growth rates in eastern Moriches Bay averaged 1.7 mm per 30 days in 1980, and 1.8 mm per 30 days in 1981. No significant differences were seen between years at any station except Narrow Bay in western Moriches Bay, where growth rates in 1980 averaged 1.6 mm per 30 days and those in 1981 averaged 2.3 mm per 30 days. Results can be related to salinity conditions within the Bay, and how those conditions may have changed in response to the breach. (Modified author's abstract - J.L.M.)

346 Turner, Harry J., Jr. 1958.

Abnormal development of quahaug larvae resulting from multiple fertilization. *In* Report on Investigations of the Shellfisheries of Massachusetts for 1957, p. 7-8. Woods Hole Oceanogr. Inst. Ref. 58-40, prepared for Commonwealth of Mass., Dep. Nat. Resourc., Div. Mar. Fish., Woods Hole, MA 02543.

In a previous report an experiment was described which demonstrated that quahaug (*Mercenaria mercenaria*) eggs exposed to dense suspensions of sperm usually develop into abnormal larvae which fail to survive to the setting stage. When sperm first penetrates the egg, a change in the surface occurs which prevents any other sperm from entering. However, when sperm suspensions are thick, two or more sperms may enter the egg before the barrier is developed, and the resulting chromosome number may be 54 or 72 rather than 36. Cells receiving more or less than 36 chromosomes develop abnormally, and even cells receiving exactly 36 sometimes develop in peculiar fashion. They seldom lived more than a few days. (J.L.M.)

347 U.S. Environmental Protection Agency. 1982.

Impact assessment on shellfish resources of Great South Bay, South Oyster Bay, and Hempstead Bay, N.Y. Exec. Summ., Nov. 1982. U.S. EPA, 401 M St. SW, Wash. D.C. 20460, 10 p.

The major finding of the impact assessment is that as a result of salinity increases projected for Great South Bay from complete sewering in contiguous areas of Nassau and Suffolk Counties, there could be an 8% decrease in standing crop of hard clams *Mercenaria mercenaria* in the study area of Great South Bay. The most probable reason for the present decline in hard clam production is overharvesting. Clam resources in South Oyster Bay and in Nassau County bays will not be affected as much, and the projected decline in Brookhaven town will also be lower. Increased predation on clam resources will result in economic losses to the local economy amounting to $9.8 million. (J.L.M.)

348 Van Winkle, W., S.Y. Feng, and H.H. Haskin. 1976.

Effect of temperature and salinity on extension of siphons by *Mercenaria mercenaria*. J. Fish. Res. Board Can. 33(7):1540-1546.

Extension of siphons was used as a criterion of activity to examine the response of the hard clam *Mercenaria mercenaria* to various combinations of test and acclimation temperatures and salinities. A quadratic regression model for the percentage of clams active as a function of the test temperature and salinity was assumed, and response surface contours for various percentages of activity were calculated and plotted. The regression model accounted for 72 to 88% of the observed variability in the 13 experiments considered. Contours are hyperbolic instead of elliptical for five of the experiments. No biologically meaningful estimates of lower and upper temperature and salinity limits can be obtained in such cases. Low levels of activity, even at optimal T-S combinations, occurred in summer. Some observed shifts in position and shape of T-S response surfaces were expected in light of shifts in acclimation temperature or salinity. Other shifts in response surface could not be accounted for. The results suggest T-S limits necessary for purification of hard clams. *M. mercenaria* is only moderately euryhaline. Purification of hard clams should not be considered at salinities below 20‰ and is likely to be most successful at salinities above 22 to 23‰. The two March experiments suggest that purification of hard clams should not be considered at temperatures below 10°C. Results of spring and fall experiments suggest that purification should not be considered at temperatures above 30°C and are likely to be most successful at temperatures of 25°C and below. Results of summer experiments suggest that it may be difficult to purify hard clams from June to August, regardless of temperature and salinity conditions. Other studies at Rutgers have led to conclusions that depuration of hard clams should not be attempted when activity levels drop below 50%. (J.L.M.)

349 Walka, Richard. 1983.

Potential effects of changed salinity on clam harvest. *In* Buckner, S.C. (ed.), Proc. of a Management Perspective on the Hard Clam Resource in Great South Bay, p. 15-28. A Seminar sponsored by the Town of Islip (NY 11751), March 10, 1983.

Increased predation is the most important effect that the projected salinity increase caused by construction of sewers could have on the clam resources of Great South Bay. Predators that probably will increase in distribution and abundance are whelks, moon snails, calico crabs, oyster drills, and hermit crabs. The average hard clam loss from increased predation will be 8% of the 1978 standing stock. The projected salinity increase is not likely to have a substantial effect on hard clam reproduction and survival. The increased predation could bring economic losses - the Towns of Babylon, Islip, and Brookhaven could have a combined loss of about $2.8 million at current prices, per year. (J.L.M.)

350 Walker, Randal L. 1983.

Feasibility of mariculture of the hard clam *Mercenaria mercenaria* (Linne) in coastal Georgia. J. Shellfish. Res. 3(2):169-174.

Feeder creeks (generally less than 4.5 m wide and several hundred m long) appear to be the best habitat for clam mariculture in Georgia. Many clam predators do not occur there. Seed clams (6 mm) planted in densities up to $3027/m^2$ can be grown to shell lengths greater than 20 mm within 7 months with greater than 80% survival if planted in spring or summer and if crabs are removed from their cages at least once a month. Once clams reach a shell length of 25 mm they can be transplanted into plots with baffles or into creeks using shell cover and/or tent structures as protective cover, or left in cages after densities have been reduced. Baffles, cages, and pens placed in major creeks or open areas in Georgia sounds do not protect clams. Beds in small feeder creeks are nominally protected from boats, vandals, and wave action. (J.L.M.)

351 Walker, Randal Leonard. 1983.

Population dynamics of the hard clam, *Mercenaria mercenaria* (Linne), and its relation to the Georgia hard clam fishery. Masters thesis, Ga. Inst. Technol., Atlanta, GA 30332, 121 p.

Growth of stocks of *Mercenaria mercenaria* planted in the coastal waters of Georgia were as follows: Virginia>Georgia>Massachusetts. No significant difference in survivorship was determined. Annual production, standing crop, and turnover ratios also decreased as follows: Virginia>Georgia>Massachusetts. Growth, production, and the effects of fishing pressures were observed for three natural clam populations in Wassaw Sound, GA. Growth rates between stations did not vary significantly. Annual production, mean standing stock, and average clam density decreased from commercial fishing for Cabbage and Wassaw Island clam populations, but remained about the same for the Little Tybee Island clam population, which had no substantial fishing pressure. A minimum legal size limit of 44.4 mm shell length or 25.4 mm shell height is recommended for the commercial harvest of Georgia hard clams. At this size clams are approximately 3 years old and have passed through at least one reproductive cycle. If a clam fishery is to exist in Georgia several events must occur: 1) a thorough survey for clam populations; 2) establishment of a water quality monitoring program; 3) enforcement of current shellfishing laws; 4) reevaluation of the shellfish leasing system(s); and 5) development of local markets. (Modified author's abstract - J.L.M.)

352 Walker, Randal L. 1984.

Effects of density and sampling time on the growth of the hard clam, *Mercenaria mercenaria*, planted in predator-free cages in coastal Georgia. Nautilus 98(3):114-119.

Hard clams, *Mercenaria mercenaria*, were planted in predator-free cages on an intertidal sandflat at Cabbage Island at densities of 509, 1009, 2018, and 3027 clams/m^2. Replicate plots per density were sampled monthly and seasonally. Clams at all four densities sampled seasonally grew significantly more in shell length than those sampled monthly and within the same time period. The seasonally sampled cage was lost after 6 months. Clams planted at the lowest density and sampled monthly reached commercial size (44 mm) in 16 months, and 52% of the clams were of legal size. After 19 months 83% of clams at $509/m^2$ had obtained legal size as compared with 57, 13, and 3% for clams grown at 1009, 2018, and $3027/m^2$. Overall clam survival increased from 77% after the first month to 99% or better 3 months later, and remained greater than 99% throughout the remainder of the experiment. Survival of clams less than 18 mm shell length depends on monthly removal of newly-metamorphosed crabs from the cages. (Modified author's abstract - J.L.M.)

353 Walker, Randal L., and Celeste M. Humphrey. 1984.

Growth and survival of the northern hard clam *Mercenaria mercenaria* (Linne) from Georgia, Virginia, and Massachusetts in coastal waters of Georgia. J. Shellfish. Res. 4(2):125-129.

Clams were planted in predator-exclusion cages at 1000 clams/m^2 at a mean initial shell length of 10.4, 11.0, and 12.8 mm for Georgia, Virginia, and Massachusetts stocks, respectively. Georgia clams grew from 10.4 to 28.7 mm in the first year and 45.2 mm in the second year. Virginia clams grew from 11.0 to 36.9 mm in the first year to 51.6 mm after 2 years. The Virginia and Georgia stocks reached commercial size (44.4 mm) in 24 and 33 months, respectively. Massachusetts clams grew from 12.8 to 23.9 mm in the first year. First year survival for Georgia, Virginia, and Massachusetts stocks was 29%, 31%, and 14%, respectively. No significant difference in survival between stocks was observed. Survival in the second year for Georgia, Virginia, and Massachusetts stocks was 64%, 8%, and 0%, respectively. Mortalities in the first year were caused by blue crab and common mud crab predation. In the second year mortalities were caused by storm activity. (Modified authors' abstract - J.L.M.)

354 Walker, Randal, and Mac V. Rawson. 1985.

Subtidal hard clam, *Mercenaria mercenaria* (Linne), resources in coastal Georgia. Tech. Rep. 85-1, Univ. Ga., Mar. Ext. Serv., Savannah, GA 31414, 164 p.

Sampled 2227 stations representing 1385 m^2 of bottom for hard clams. Clams occurred at 11.6% of stations and most (61.5%) occurred intertidally. Of subtidal clams 65% were in water less than 1 m deep. Highest densities were in shell ($3.1/m^2$) and decreasing amounts in sandy-mud, mud, and sand. They occurred most frequently in feeder creeks, with lesser amounts in headwaters of creeks, in creeks and rivers, and were absent from sounds and nearshore areas. Of 1575 clams collected 46% were chowders, 27% cherrystones, 21% legal littlenecks, 2% prelegal littlenecks, and 4% juveniles. Large subtidal populations do not occur in coastal Georgia, and mechanical clam harvesters do not appear to be feasible. (Modified authors' abstract - J.L.M.)

355 Walker, Randal L., and Kenneth R. Tenore. 1984.

The distribution and production of the hard clam, *Mercenaria mercenaria*, in Wassaw Sound, Georgia. Estuaries 7(1):19-27.

Hard clams, *Mercenaria mercenaria*, occurred in four intertidal habitats in the outer, high salinity (18‰) region of Wassaw Sound, Ga.: small feeder creeks ($x = 36/m^2$); oyster shell bar deposits ($x = 31/m^2$); headwaters of shelly, sandy-mud, sand, and mud bottom creeks (x = 26, 19, 13, and $3/m^2$, respectively; and among live oysters ($x = 1/m^2$). Clams from creek bottoms were larger (x = 7.3 cm) than those from intertidal flats (x = 4.7 cm) from differences in predation or harvesting pressures, not from differing rates of recruitment. Juveniles were absent from most areas, possibly because of increased juvenile mortality, natural sporadic setting, or restricted gonadal development from abnormally low spring salinity from 1977 through 1979. Clams from Little Tybee Island, where sediments are sandy-mud, had faster growth rates than those from North Cabbage and Wassaw Islands, where clam beds were in shell deposits. Clams older than 7 years dominated at Wassaw and Little Tybee Islands (64 and 71%, respectively) and younger clams dominated at North Cabbage Island (82%). These differences in age-class structures were attributed to different harvesting or predation pressures. Clams from Little Tybee and Wassaw Islands occurred in creek bottoms, whereas clams from North Cabbage Island occurred on an intertidal flat in the open Sound. A greater variety of clam predators and greater densities of *Urosalpinx cinerea* and *Busycon* spp. occur on intertidal flats of the open Sound than on creek bottoms. Net reproduction of hard clams was 7.7 g ash-free dry weight (AFDW)/m^2/yr at Little Tybee Island, 6 g AFDW/m^2/yr at Wassaw Island, and 2.7 g AFDW/m^2/yr at North Cabbage Island. Differences were attributed to differences in standing stocks, age class structure, and growth rate. Standing stocks were low (11 g AFDW/m^2) at North Cabbage, moderate at Little Tybee (50 g AFDW/m^2), and high (120 g AFDW/m^2) at Wassaw Island. Turnover ratios of Wassaw, Little Tybee, and North Cabbage Island populations were low (0.05, 0.14, and 0.23, respectively) because a high percentage of clams older than 7 yrs made up the populations. (Modified authors' abstract - J.L.M.)

356 Walker, Randal L., Michael A. Fleetwood, and Kenneth R. Tenore. 1980.

The distribution of the hard clam *Mercenaria mercenaria* (Linne) and clam predators in Wassaw Sound, Georgia. Tech. Rep. Ser. 80-8, Ga. Mar. Sci. Cent., Univ. System Ga., Skidaway Inst. Oceanogr., Savannah, GA 31414, 59 p.

Hard clam occurred in four habitats at different densities: live oyster bars ($X < 1$ clam/m^2; shell deposits associated with oyster bars ($X = 23$ clams/m^2); headwaters of sandy-mud, sand, and mud bottom creeks ($X = 16$, 12, and 3 clams/m^2, respectively); and small feeder creeks ($X = 36$ clams/m^2). Clams were most abundant in intertidal areas. Clam beds were small and patchy. One of the larger and denser beds (50/m^2) in Wassaw Sound measured approximately 90 m, but this size was rare. Clams from creeks were larger (7.3 ± 1.6 cm long) than clams from intertidal flats (4.7 ± 1.8 cm). Juveniles (<3.7 cm) were absent from all locations. This recruitment failure may have been caused by recent high predation or from low salinity or spawning stress from heavy runoff. Predation was exerted by whelks, drills, rays, and crabs, especially blue crab, *Callinectes sapidus*. Density of whelks peaked in fall and spring and was low in winter and summer. Drills were primarily *Urosalpinx cinerea*. Greatest density of clams occurred in substrates containing shell. (J.L.M.)

357 Watabe, Norimitsu. 1983.

Shell repair. Chapt. 7 *In* Saleuddin, A.S.M., and K.M. Wilbur (eds.), The mollusca. Vol. 4. Physiology Pt. 1, p. 289-316. Academic Press, NY.

Reference is made to *Mercenaria mercenaria* studied by other authors abstracted elsewhere in this bibliography. (J.L.M.)

358 Webber, Harold H. 1968.

Mariculture. BioScience 18(10):940-945.

American oyster (*Crassostrea virginica*) and northern hard shell clam (*Mercenaria mercenaria*) are the primary forms being reared for market, based on technology developed in the 1920s by Wells and Glancy of the New York State Fish and Game Commission and at the Bureau of Commercial Fisheries Biological Laboratory at Milford, CT. Selected parents are cultured in the laboratory as a source of egg and sperm. Selection for growth rate, size, meat quality, and certain shell characteristics is being made. Because both species have very high fecundity, very few breeding parents are required. When spawning is desired, selected parents are transferred to trays through which water precisely controlled for temperature is flowing. They are then subjected to a temperature with a controlled rate of change which will induce gonadal development and result in spawning. Since spawning is a completely predictable event and can be achieved on command, a set is assured. For the first 24-36 hrs after fertilization no feeding is required. The larvae are then transferred to large tanks and fed known quantities of known species of algae. After 10 days the veliger larvae reach the umbo stage and are ready to set, and are transferred to settling tanks with cultch distributed over the bottom, maintained at a temperature of 28°C. Cultch bearing attached larvae is placed in polyethylene net bags suspended in large concrete nursery tanks. The water is supplemented with a rich culture of small phytoplankton. Light and heat energy is provided through the walls and roof of polyester/glass fiber panels. Water temperature is controlled. Spat reach about 1/2 inch in diameter after 3 or 4 weeks. They are then transferred to rafts, still in the plastic bags, where they are readily accessible to be monitored and tended. They remain for about a month, when they have grown to 1¼ inches and can be put out in the bay on selected bottom and reared to market size. They may be lifted off the bottom and transplanted to other beds before they are finally harvested for sale. The success of this economically sound venture is based on fundamental biological research and empirical evidence. (J.L.M.)

359 Wenner, E.L., D.M. Knott, R.F. Van Dolah, and V.G. Burrell, Jr. 1983.

Invertebrate communities associated with hard bottom habitats in the South Atlantic Bight. Estuarine Coastal Shelf Sci. 17(2):143-158.

No mention of *Mercenaria mercenaria*. (M.W.S.)

360 Weyl, Peter K. 1979.

An analysis of shellfish sanitation data. Spec. Rep. 30, Ref. 79-13, Mar. Sci. Res. Cent., State Univ. N.Y., Stony Brook, NY 11794, 26 p.

The study examines the statistical aspects of shellfish sanitation data for the period 1973-77 for Great South Bay, Moriches Bay, Flanders Bay, and the Huntington Bay complex. The nature of the multitube fermentation tests greatly limits the information content of the data. The statistical fluctuations make it difficult to untangle the relative importance of storm runoff and tides and to compare fecal and total coliform results. The problem arises when one wants to use the data for purposes for which they were not intended. Nevertheless, the study shows that it is possible to obtain some answers by analyzing many years of data. (J.L.M.)

361 Whetstone, Jack M., and Arnold G. Eversole. 1981.

Effects of size and temperature on mud crab, *Panopeus herbstii*, predation on hard clams, *Mercenaria mercenaria*. Estuaries 4(2):153-156.

Predation was affected significantly by temperature and by the size of predators and prey. Larger *P. herbstii* opened more clams and preyed more successfully on larger clams than did smaller crabs. Increase in seed clam size and decrease in water temperature significantly reduced predation. Clam size appeared to be more important than crab satiation in reducing predation rate. Planting larger seed clams in cooler waters should help to improve clam survival by reducing the impact of *P. herbstii* in culture operations. No crabs less than 20.1 mm carapace width were successful in opening clams. Clams greater than 35 mm were not opened by any size of crab tested. Tests in pilot clam culture conditions are required before these methods can be recommended to clam culturists. (J.L.M.)

362 White, Conrad. 1986.

The resource - Biological and environmental factors affecting the clamming industry. *In* Busby, D. (ed.), An overview of the Indian River clamming industry and the Indian River Lagoon, p. 9-13. Tech. Pap. 44, Fla. Sea Grant Ext. Prog., Univ. Fla., Gainesville, FL 32611, Proj. IR-85-7, Grant NA85AA-D-SG059.

Temperature and salinity are the major factors that determine the type of aquatic system that develops in the Lagoon, together with the shallow waters. The temperature range over the past five years varied from 46o to 90°F, salinity ranges in the northern portion were 14-44 ppt with a mean value of about 22-24 ppt, and depth range varied from 0 to 13 ft with an average depth of 5 ft. The major biological communities in the Lagoon are described. Some areas have "good" water quality, some have "fair," some conditions are *enriched* and some are *degraded*. (J.L.M.)

363 Whitman, Barbara Carr. 1978.

Shellfish Survey and Biological Evaluation of Greenwich Cove, Town of Greenwich, Connecticut. Oceanic Soc., Stamford, CT 06902, 76 p.

Benthic studies in Greenwich Cove showed that the Cove was an excellent environment for culture of hard clams (*Mercenaria mercenaria*), although commercial shellfishing could not be considered an appropriate course of action at this time. Soft clams also abound in the cove. Some zinc readings appear to be rather high and may relate to heavy use of galvanized pipe in the area. Few, if any, of the remaining metals are naturally found in clams at the levels indicated here, but none (except zinc) appear to be exceptionally high. (J.L.M.)

364 Wilbur, Karl M., and A.S.M. Saleuddin. 1983.

Shell formation. Chapt. 6 *In* Saleuddin, A.S.M., and K.M. Wilbur (eds.), The mollusca. Vol. 4. Physiology Pt. 1, p. 235-287. Academic Press, NY.

Reference is made to *Mercenaria mercenaria* studied by other authors abstracted elsewhere in this bibliography. (J.L.M.)

365 Wilkins, N.P. 1973.

Genetic variation in marine bivalvia (Mollusca). Science (Wash. D.C.) 182, 30 Nov. 73:946.

A letter taking issue with Levinton (abstracted elsewhere in this bibliography) with respect to the number of allelles with depth of burial. Levinton disagrees in part. (J.L.M.)

366 Wilkins, N.P. 1976.

Genic variability in marine bivalvia: Implications and applications in molluscan mariculture. *In* Persoone, G., and E. Jaspers (eds.), Proc. 10th Eur. Symp. Mar. Biol., Ostend, Belgium, 17-23 Sept. 1975, Vol. 1, p. 549-563. Universa Press, Wetteren.

The extent of genetic variability at enzyme gene loci is assessed in 12 species of marine bivalve molluscs including *Mercenaria mercenaria*. The data presented, although they are probably the most comprehensive yet available, are only the beginning of the application of biochemical genetics to molluscan mariculture. For the immediate future, the study of variability in wild populations is likely to remain the most pressing aspect of this work. (J.L.M.)

367 Wilson, Charles A., John Mark Dean, and Richard Radtke. 1982.

Age, growth rate and feeding habits of the oyster toadfish, *Opsanus tau* (Linnaeus) in South Carolina. J. Exp. Mar. Biol. Ecol. 62:251-259.

No remains of *Mercenaria mercenaria* were found in digestive tracts of 312 fish taken in 1978 and 1979. Mud crabs (*Panopeus herbstii* and *Eurypanopeus depressus*) dominated in 65% of digestive tracts in 1978 and in 32% in 1979. (J.L.M.)

368 Winter, Jurgen. 1970.

Filter feeding and food utilization in *Arctica islandica* L. and *Modiolus modiolus* L. at different food concentrations. *In* Steele, J.H. (ed.), Marine food chains, p. 196-206. Univ. Calif. Press, Berkeley.

Mercenaria mercenaria is mentioned with reference to a paper by Rice and Smith (1958) abstracted elsewhere in this bibliography. It is noted that the filtration rate with different particle concentrations of *Nannochloris* did not show significant results. (J.L.M.)

369 Yount, James Locke. 1950.

A study of the blood cells of some marine lamellibranchs. Masters thesis, Univ. N.C., Chapel Hill, NC 27559, 34 p.

Observations on the morphology and physiology of the blood cells of *Venus mercenaria* are included. There are three major types of blood cells: lymphocytes (or hyaline leucocytes), finely granular leucocytes, and coarsely granular leucocytes. Coarse granules are probably composed of nutritive material. Other materials in the blood are bacteria, cellular debris, and hyaline cell-like bodies. Blood cells probably play a prominent role in defense of the animal from microorganisms. Blood cells are important in nutrition, serving the functions of ingestion, distribution, and digestion. They have been shown to contain enzymes that digest margarine and gelatin. The plasma has been shown to contain enzymes that digest starch, margarine, and gelatin. (J.L.M.)

370 Zouros, E., and David W. Foltz. 1984.

Possible explanations of heterozygote deficiency in bivalve molluscs. Malacologia 25(2):583-591.

In *Crassostrea virginica* heterozygotes attain larger size, thus producing more gametes than homozygotes, and may also have lower post-settlement mortality rates. The plausibility of models is judged by comparing predicted heterozygote deficiences to values commonly reported in the literature for *C. virginica* and other species of bivalve. No specific mention of *Mercenaria mercenaria*. (J.L.M.)

BIBLIOGRAPHY: Part 2

373 Arnold, William S. 1985.

The effects of prey size, predator size, and sediment composition on the rate of predation of the blue crab *Callinectes sapidus* Rathbun on the hard clam *Mercenaria mercenaria* (Linne). J. Shellfish. Res. 5(1)31 (abstract).

All blue crab size classes showed a preference for sand, mud, and sand/mud sediments rather than crushed oyster shell or granite gravel. Sediment feeding tests showed that clams were significantly more vulnerable to predation by crabs in sand and sand/mud than in crushed oyster shell or granite gravel, although the outcome of such predatory encounters depends on the interaction between clam and crab size. When crabs were given a choice of clam sizes, with no sediment present, small crabs (<75 mm carapace width (CW)) consumed 5- and 10-mm size-class clams equally. Medium crabs (75-125 mm CW) preferentially consumed 10-mm size-class clams. Large crabs (>125 mm CW) consumed 10- and 25-mm size class clams equally. Clams larger than 40 mm CW were not consumed by even the largest blue crabs, suggesting that hard clams may achieve a size refuge from blue crab predation. (Modified author's abstract - J.L.M.)

374 Austin, Herbert M., and Dexter S. Haven. 1981.

A report on the operation of a hydraulic escalator dredge on private ground on Hampton Flats, James River, during October 1980. Mar. Resour. Rep. 81-3, Va. Inst. Mar. Sci., Gloucester Pt., VA 23062, 41 p.

Only littlenecks (mean length 60.9 mm) and cherrystones (mean length 77.9 mm) were retained, chowder clams were discarded. Highest average daily catch of retained clams (*Mercenaria mercenaria*) was 4330 clams/hr (72 clams/min). Average catch was 2888 clams/hr (48 clams/min). Catch rates varied considerably during the day. High was 105.6 clams/min during a 33-min period to a low of 0 clams/min many times for short periods. Three dives were conducted after the experimental plots had been worked. Four days after operation of the hydraulic dredge, troughs left by the gear were about 4 ft wide and 5¾ in. deep in the center. During subsequent dives, the troughs became less distinct and shallower, filling in about 2 in., 21 days after being formed. Much of the oyster shell that was on the surface after the first dive was covered by a layer of silt and mud by the third dive. The area worked by patent tongs was also observed 4 days later, and holes left by the gear were about 4×3 ft and 6-8 in. deep. The holes collected large amounts of drifting sponge. The holes did not fill with sediment to the same degree as did the troughs. The holes were about 6 in. deep 21 days later. The catch rate of the hydraulic dredge was 7.5 times greater for littlenecks and cherrystones than patent tongs. About 1 in 2000 clams was damaged by the dredge. (Modified authors' summary - J.L.M.)

375 Bearden, C.M. 1976.

Report on the hard clam (*Mercenaria mercenaria*) industry in South Carolina. S.C. Mar. Resour. Div., Off. Conserv. Manage., Charleston, SC 29403, 41 p. Unpubl. manuscr. submitted to T.P. Ritchie for preparation of *A comprehensive review of the commercial clam industries in the United States*.

See Ritchie (1977) in McHugh et al. (1982), citation 1552. (J.L.M.)

376 Bockstael, G. 1976.

Comprehensive report on the hard clam (*Mercenaria mercenaria*) industry in Rhode Island. R.I. Dep. Mar. Resour., Providence, RI 02908, 9 p. Unpubl. manuscr. submitted to T.P. Ritchie for preparation of *A comprehensive review of the commercial clam industries in the United States*.

See Ritchie (1977) in McHugh et al. (1982), citation 1552. (J.L.M.)

377 Bright, Thomas J., and M.A. Craig. 1985.

Populations of *Mercenaria mercenaria texana* (Gmelin) in Texas bays and their commercial potential. J. Shellfish. Res. 5(1)32 (abstract).

Moderate to low, contagious populations of Texas quahog clams occupy high-salinity portions of Texas bays intertidally to over 3-m depths (rarely over 4 clams/m^2, usually much less). Small clams, less than 3 yrs old, predominate directly adjacent to major passes, suggesting more favorable conditions for recruitment and early survival. With increasing distance from passes, population size-frequency composition shifts toward larger and older clams (upper Christmas Bay contains mostly clams of 4 yrs and older). Growth rates are comparable to those of the northern quahog clam *Mercenaria mercenaria* (Linne) in Florida (30-40 mm high in first year). Within Texas, growth appears somewhat more rapid in southern bays (Corpus Christi) than in northern (Galveston). Natural populations will not support a clam fishery in Texas, but hatchery development and a bay seeding program may support such a fishery. (Modified authors' abstract - J.L.M.)

378 Butler, Philip A. 1965.

Reaction of some estuarine mollusks to some environmental factors. *In* Biological problems in water pollution, third seminar, 1962, p. 92-104. U.S. Pub. Health Serv. Publ. 999-WP-25. (Avail. P.A. Butler, 106 Matamoros Dr., Gulf Breeze, FL 32561.)

Over a broad range of environmental conditions, survival of molluscan populations is a result of highly complex and interrelated attitudes toward individual factors. Apparently simple responses, such as growth rates, may be greatly influenced by age, heredity, or nutrient salts and vitamins naturally present in the environment in only trace amounts. The effect of temperature on growth rates of hard clams (*Mercenaria mercenaria*) was shown by clams from Rhode Island replanted in Florida. These clams added about 75% of new shell in December-January, but would have been hibernating had they remained in their native habitat. Another group of clams from Milford, Connecticut, also replanted in Florida, were sorted into two lots of approximately equal length. These were planted in protected boxes on two sides of the laboratory island where conditions were believed to be similar. After 2 years, although mortality was negligible, there were very significant differences in size range and average size. The larger-size group had 24% more meats than the smaller. A supply of seed hard clams derived from reciprocal crosses of pairs of the northern (*M. mercenaria*) and southern (*M. campechiensis*) quahog was held for over 4 years in protected boxes hung from the laboratory pier. At the end of that time the stock of pure *M. mercenaria* was on the average 50% longer, and the meat yield of shucked clams was nearly double that of the hybrid stock. Knowing these different growth responses, we need the complete background of test animals before guessing the observed growth rates in any particular situation. We must know the age of the animal, its genetic background, and the similarity of test sites before we can suggest responses to environmental factors. Only by understanding the role of beneficial and harmful factors will we be able to reach maximum utilization of our estuaries. (J.L.M.)

379 Castagna, Michael. 1985.

Farming of the northern hard clam *Mercenaria mercenaria* (Linne) in Virginia. J. Shellfish. Res. 5(1)33 (abstract).

Clam farming has been practiced in Virginia since the 1920s. Historically, clam shippers would relay harvested clams onto intertidal flats so they could be reharvested when market demand and price were more favorable. On the Eastern Shore of Virginia from the 1930s to early 1950s, several leaseholders purchased "buttons" (larger sized natural seed about 10-20 mm in length) which were planted on intertidal or shallow subtidal areas and later harvested when they had grown to market size. Clam farming that uses hatchery-reared seed is a relatively new industry in Virginia. Currently about 12 individuals or companies are farming clams, of which three have been in operation for more than 5 yrs. Most of this seed was purchased from commercial hatcheries in New York and Massachusetts. Four of the Virginia companies have their own hatcheries and nurseries with the potential of producing excess seed to sell. Clam seed are grown to littleneck size using a variety of field growout methods. Clams are grown in trays, under nets, under nets with gravel or shell aggregate, or by a combination of these methods. Market size of approximately 25 mm width is reached in 2-3 yrs. (Modified author's abstract - J.L.M.)

380 Castagna, M., and D.S. Haven. 1972.

The hard clam industry. *In* Burrell, V.G., M. Castagna, and R.K. Dias (eds.), A study of the commercial and recreational fisheries of the eastern shore of Virginia, Accomack and Northampton Counties, p. 64-82. Spec. Rep. Appl. Mar. Sci. Ocean Eng. 20, Va. Inst. Mar. Sci., Gloucester Point, VA 23062.

Not seen.

381 Cole, R.W. 1976.

Comprehensive report on the hard clam (*Mercenaria mercenaria*) industry in Delaware. Dep. Nat. Resour. Environ. Control, Div. Fish. Wildl., Dover, DE 19903, 9 p. Unpubl. manuscr. submitted to T.P. Ritchie for preparation of *A comprehensive review of the commercial clam industries in the United States*.

See Ritchie (1977) in McHugh (1982), citation 1552. (J.L.M.)

382 Conrad, Jon M. 1980.

Price of hard clams in Fulton Market. Working paper, Dep. Agric. Econ., Cornell Univ., Ithaca, NY 14850, 14 p.

Hard clam (*Mercenaria mercenaria*) prices for all market sizes were very noisy, and did not conform well to received theories of supply and demand. (J.L.M.)

383 Conrad, Jon M. 1982.

Management of a multiple cohort fishery: The hard clam in Great South Bay. Am. J. Agric. Econ. 64(3):463-474.

The paper develops a reasonably general multiple cohort model and derives conditions for optimal harvest and age structure based on a discrete time control problem which maximizes the present value of net revenues subject to recruitment and spawning constraints. The model is applied to the hard clam (*Mercenaria mercenaria*) resource in Great South Bay, NY. The steady-state optimum calls for exclusive harvesting of the younger, and more valuable, littleneck cohorts, leaving the older, and less valuable, cherrystone and chowder cohorts to specialize in regeneration. (Modified author's abstract - J.L.M.)

This was followed later by Hsiao, Yu-Mong. 1985. Management of a multiple cohort fishery: Comment. and Conrad, Jon M. 1985. Management of a multiple cohort fishery: Reply. Am. J. Agric. Econ. 67.

The problem was that Conrad measured cohort stocks and yields in bushels. while the spawning constraint was measured in numbers of clams. Thus, the right-hand side of the spawning constraint must be divided by 500 to be consistent with the unit of measurement defined on the lefthand side, and thus a steady-state solution does not exist. (J.L.M.)

385 Cummins, Joseph M., and Alan A. Stevens. 1970.

Investigations on *Gymnodinium breve* toxins in shellfish. U.S. Pub. Health Serv., Environ. Health Serv., Gulf Coast Water Hygiene Lab., Dauphin I., AL 36528, 76 p. (Avail. J.M. Cummins, EPA Region 10 Lab., P.O. Box 549, Manchester, WA 98353.)

Evidence supporting the relationship between *Gymnodinium breve* and human illness became available in December 1962, when several persons became ill after eating oysters *Crassostrea virginica* and clams *Mercenaria campechiensis* taken in Sarasota Bay, Florida, during a "red tide" outbreak. A crude toxic substance was extracted from these shellfish, similar to ciguatera fish poison. Consideration of potential health-related aspects of *G. breve* "red tides" prompted this investigation. Hard clams taken from the head of Venice Inlet, 550 meters from the Gulf of Mexico, contained 270 mouse units per 100 grams of meats. Long-range goals of the project were: 1) identify and isolate the causative microorganism(s); 2) develop methods to maintain laboratory cultures; 3) isolate and purify samples containing the active material; 4) determine the chemical nature and structure of the poison; 5) investigate the conditions and mechanisms by which shellfish accumulate, retain, and eliminate the toxin(s); and 6) assist in developing analytical techniques for rapid determination of the poison. These objectives were satisfied. (J.L.M.)

386 Doering, Peter H., and Candace A. Oviatt. 1986

Application of filtration rate models to field populations of bivalves: an assessment using experimental mesocosms. Mar. Ecol. Prog. Ser. 31(3):276-275.

Gross sedimentation of ^{14}C labelled carbon was 58% greater in mesocosms (13 m^3) containing the bivalve *Mercenaria mercenaria* (16 indiv./m^2) relative to controls without this filter feeder. The difference was attributable to the activities of *M. mercenaria* and presumably due to filtration of particles from the water column. Of this increase, 32% and 47% respectively were attributable to assimilation into clam tissue, and respiration by the benthic community. Permanent biodeposition by clams contributed the least (21%). The ability of eight filtration rate models to predict the increase in gross sedimentation was examined. Those models (four) which were based on data for bivalves filtering natural suspensions of particulate matter gave estimates which agreed well with observed differences. Those models (four) which yielded poor predictions used dyes or algal monocultures to generate data and overestimated gross sedimentation due to bivalves by up to an order of magnitude. Such overestimation may exaggerate the role of bivalves in enhancing sedimentation and controlling phytoplankton biomass in shallow waters. (Modified authors' abstract - J.L.M.)

387 Dow, R.L. 1976.

Comprehensive report on the hard clam (*Mercenaria mercenaria*) industry in Maine. Maine Dep. Mar. Resour., Augusta, ME 04333, 15 p. Unpubl. manuscr. submitted to T.P. Ritchie for preparation of *A comprehensive review of the commercial clam industries in the United States*.

See Ritchie (1977) in McHugh (1982), citation 1552. (J.L.M.)

388 Duncan, Patricia L., W.D. DuPaul, and M. Castagna. 1985.

Successful use of crab meal as a supplemental food for juveniles of the hard clam *Mercenaria mercenaria* (Linne). J. Shellfish. Res. 5(1)34-35 (abstract).

Nursery culture of the hard clam, a necessary step in the production of seed for field growout, is not considered economically feasible by many workers. This is because costs to supply large quantities of food for juveniles are too high. Commercially available crabmeal, a byproduct of crab-picking houses, was tested as supplemental food with various sizes of juveniles. Six 30-day feeding experiments were conducted from July to December 1983. Control and crabmeal fed groups received filtered seawater at flow rates which contained enough natural food to support clam maintenance activities. Test groups also received crabmeal supplements at different rations proportional to total live weight of clams. Growth was considered as the increase in shell height, and total live, dry, and ash weights. Greater increases in shell height and weight were seen in supplemented clams compared with controls when crabmeal was fed in proper amounts. Optimum feeding rates for smaller clams (4-6 mm) were crabmeal rations of 20-25% of total clam live weight per day, and for larger clams (7-10 mm) rations were 10 to 12% of clam live weight per day. Overall, crabmeal fed clams showed increases in weight and shell height from 10 to 100% greater than in controls. (Modified authors' abstract - J.L.M.)

389 Eble, Albert F., S. Georgiew, and A. Stubin. 1985.

The cortical renal epithelia of the hard clam *Mercenaria mercenaria* (Linne). J. Shellfish. Res. 5(1)35 (abstract).

The kidney of the hard clam has two different types of cortical epithelia: the shellside epithelium is in juxtaposition to the shell and closely resembles the shellside mantle epithelium with which it is contiguous; the mantle-cavity epithelium faces the pallial cavity and is partially covered with a portion of the gills. The shellside cortical epithelium is simple columnar with basally situated nuclei; the cytoplasm is faintly eosinophilic and contains many bundles of microfilament of microtubule-like structures oriented in the long axis of the cells. The mantle-cavity epithelium is also simple columnar in construction and is supported by a dense collagenous connective tissue. Some details have been excluded from this abstract. (Considerably modified authors' abstract - J.L.M.)

391 Gibbons, M.C., and M. Castagna. 1985.

The use of the toadfish *Opsanus tau* (Linnaeus) as biological control of crabs preying on juveniles of the hard clam *Mercenaria mercenaria* (Linne) in field cultures. J. Shellfish. Res. 5(1)36 (abstract).

The oyster toadfish, a hardy and abundant fish that feeds primarily on crustaceans, was tested as a biological control against crabs. Hard clams (3-mm shell length), planted in cages under gravel aggregate, were protected against crab predation by toadfish. Crabs found in the experimental area were blue crab *Callinectes sapidus* Rathbun and mud crabs *Neopanope texana sayi* (Smith) and *Panopeus herbstii* Milne-Edwards. After 6 weeks, 49.2% of hard clams in cages with toadfish had survived, while only 1.6% survived in cages without toadfish. Predation by crabs in bottom cultures of hard clams protected by a combination of gravel aggregate and plastic nets may be reduced by placing toadfish under the nets. (Modified authors' abstract - J.L.M.)

392 Godwin, Walter F. 1975.

Exploratory suvey of hard clam stocks in the Intracoastal Waterway, Brunswick County, North Carolina. Unpubl. Rep., N.C. Div. Mar. Fish., Morehead City, NC 28557, 12 p.

Hard clams (presumably *Mercenaria mercenaria*) were very abundant in the Intracoastal Waterway of Brunswick County. Of a total of 79 random samples, 32% produced catches in commercial abundance (10 clams/min) and an additional 6% produced catches in near-commercial abundance (7 clams/min). Almost all high density areas were located outside the 90-ft authorized channel in water depths of -2 to -8 feet MLW and were consistently associated with heavy bottom shell deposits. Most clams were chowder and cherrystone sizes, with one notable exception which produced 62% littlenecks. Size data indicated that most clam areas had good recruitment, adequate growth, and a uniformly low harvest rate. Survey results show that the best utilization of these resources would be achieved by allowing mechanical harvesting. (J.L.M.)

393 Godwin, Walter F., Michael W. Street, and Thomas R. Rickman. 1971.

History and status of North Carolina's marine fisheries. Inf. Ser. 2, N.C. Dep. Conserv. Dev., Div. Commer. Sports Fish., Raleigh, NC 27611, 77 p.

Two species of clam are currently harvested in North Carolina: hard clam (*Mercenaria mercenaria*) and brackish water clam (*Rangia cuneata*). Exploratory fishing has revealed undeveloped stocks of surf clams (*Spisula solidissima*) and southern quahogs (*Mercenaria campechiensis*). Reported landings of clams have declined in recent years, although value has increased to the highest level since 1951. Clams are harvested year-round. Greatest landings occur in winter and spring. Harvesting is done with rakes or by hand. In some areas hydraulic dredges are coming into extensive use. No definite reasons can be given for the general decline in clam landings. An important factor is probably pollution, which has resulted in closing of many areas. Little scientific effort has been expended on clam research. A tremendous increase of clams occurred in Core Sound following the opening of Drum Inlet by a hurricane in 1933. A similar situation occurred in the southern part of the State when Hurricane Hazel opened an inlet across Long Beach in 1954. (J.L.M.)

394 Greenberg, Michael J. 1985.

The heart of the northern hard clam: Its enduring role in neuropharmacological research. J. Shellfish. Res. 5(1)37 (abstract).

Except for FMRFamide and its analogs, most of the known neuropeptides are inactive on the isolated clam heart (*Mercenaria mercenaria*). However, and unexpectedly, the red-pigment concentrating hormone of prawns, and the chemically related adipokinetic hormone of locusts, are potent excitors of this preparation. The effect is especially intriguing in that only half of the hearts tested responded to these peptides. The mechanism of this unusual action is not known, but it is not related to sex or subspecies. Clam ganglia contain a red-pigment concentrating factor active in crustaceans, but its physiological significance in the clam is unknown. Much of this abstract was deleted because the mechanisms described have been described before, but it probably should be read by those not familiar with the earlier literature. (Modified author's abstract - J.L.M.)

395 Gussman, David. S. 1985.

Growth of juvenile oysters and clams on heterotrophic microflagellates. J. Shellfish. Res. 5(1)37 (abstract).

Heterotrophic microflagellates are potential bivalve foods that may be more easily cultured in shellfish hatcheries than conventional algal strains. Microflagellates, which ranged in length from 2.6 to 7.8 μ included *Paraphysomonas vestita*, a colorless chrysophyte, two bodonids, and a choanoflagellate. Microflagellates were raised on estuarine bacteria cultured on brewerXs condensed solubles (BCS), a syrupy byproduct of the brewing industry. Groups of 10 clams (*Mercenaria mercenaria*), with initial weights ranging from 5.3 to 6.8 g, were raised in 1-L beakers. Clams grew on diets of *P. vestita* and the unidentified colorless chrysophyte but not with the bodonids or the choanoflagellate. Clams fed comparable quantities of the alga *Tetraselmis suecica* showed greater growth than those fed microflagellates. Microflagellates, however, produce significantly greater growth rates than phytoflagellates and can be raised in the dark at high cell densities. The sections that dealt with oysters (*Crassostrea virginica*) were not included in this abstract. (Modified author's abstract - J.L.M.)

396 Haskin, H.H., and S.E. Ford. 1985.

The status of the hard-clam fishery in New Jersey. J. Shellfish. Res. 5(1)37-38 (abstract).

The hard-clam fishery (*Mercenaria mercenaria*) in New Jersey operates in coastal bays from Raritan Bay to Cape May. Production has fluctuated from 453,600 to 2,268,000 kg (1 to 5 million pounds) per year since records began in 1889. Peak harvests in the late 1940s and early 1950s were followed by a sharp downward trend, coincident with closing of clam beds in contaminated areas. Since 1960 the reported harvest has been between 453,600 and 1,360,800 kg (1 to 3 million lbs). Because the price of clams increased from about $1.10 to $5.50 per kg ($0.50 to $2.50 per lb) between 1967 and 1983, however, the total value of the harvest has increased. The 1983 harvest of 590,000 kg (1.3 million lbs) was valued at $3.3 million. Since 1970 clammers have relaid stocks from restricted (70-700 MPN/mL) and condemned (700 or more MPN/mL) areas to privately leased grounds in approved waters. Clams are marketed after 30 days at temperatures above 10°C. Relaid clams account for 5 to 18% of each year's total production. In July 1983, a depuration plant opened which can process clams from restricted water only. Between July and Dec. 1983, the depuration plant handled approximately 3 million clams (about 10% of annual production and equal to the number of relaid clams). Two individuals have operated hatcheries to provide seed for their own growout grounds for about 10 yrs. However, they produce less than 1% of the total New Jersey harvest. A third hatchery/growout operation started this spring. (Modified authors' abstract - J.L.M.)

398 Howard, Dorothy W., and Cecelia S. Smith. 1983.

Histological techniques for marine bivalve mollusks. NOAA Tech. Memo. NMFS-F/NEC-25, Northeast Fish. Cent., Natl. Mar. Fish. Serv., Woods Hole, MA 02543, 97 p.

Mercenaria mercenaria is covered on pages 20-26. (J.L.M.)

399 Hsiao, Yu-Mong, Thomas Johnson, and J.E. Easley, Jr. 1986.

An economic analysis of a potential overfishing problem: The N.C. hard clam fishery. Sea Grant Tech. Rep. UNC-SG-86-11, Univ. N.C. Sea Grant Coll. Prog., N.C. State Univ., Raleigh, NC 27695, 86 p.

The recent increase in landings in the North Carolina hard clam fishery has triggered concern about potential overfishing. This is investigated by contrasting historical data and the empirical supply curve with the long-run steady-state supply curve. The steady-state supply curve is derived from intertemporal maximization of social welfare subject to population dynamics. The empirical supply curve is estimated using a simultaneous equation model. The model components of the steady-state supply curve are estimated. The results show that the North Carolina hard clam fishery shows decreasing returns to scale with respect to resource stock. The maximum sustainable yield is not significantly different from 2 million pounds of meats per annum. Historical records show that the suspected biological overfishing has not been serious yet. But economic overfishing has occurred in the past and has reached serious levels recently. Since these results are based on the mean value estimated from the past 20 years' catch-effort data, the maximum sustainable yield may be underestimated, and the economic overfishing statement may be too conservative. (Modified authors' abstract - J.L.M.)

400 Kellogg, Robert L. 1985.

A bioeconomic model for determining the optimum timing of harvest with application to two North Carolina fisheries. Ph.D. diss., N.C. State Univ., Raleigh, NC 27607. [Diss. Abstr. B. Sci. Eng. 1986.]

The study examines how dynamic bioeconomic models and optimal control theory can be used to help fishery managers promulgate regulations consistent with economic efficiency and gains in social welfare. The model was estimated and applied to two North Carolina fisheries: bay scallop and New River shrimp. *Mercenaria mercenaria* was not used, but the general principles might apply. (J.L.M.)

401 Kvaternik, A.C.

Analysis of population and price aspects of the Virginia hard clam (*Mercenaria mercenaria*) fishery. Master's thesis, College of William and Mary, Williamsburg, VA 22386.

Not seen. (J.L.M.)

402 Kvaternik, Andre C., and William D. DuPaul. 1982.

The hard clam fishery: Problems and approaches. A paper presented at the Workshop on Chesapeake Bay fisheries data, Fredericksburg, VA. Va. Inst. Mar. Sci., School Mar. Sci., Coll. of William and Mary, Gloucester Point, VA 23062, 8 p.

The hard clam (*Mercenaria mercenaria*) is found along the eastern and Gulf of Mexico coasts of North America from the Gulf of St. Lawrence to the Yucatan Peninsula. It is the focus of an important commercial fishery. Larger clams (>80 mm) are used in chowder; littlenecks (<60 mm) and cherrystones (61 to 80 mm) are steamed or eaten raw. The fishery in Chesapeake Bay is understood only on a broad scale. Landings in Virginia have decreased from a high of 2.4 million pounds of meats in 1965 to a low of 0.4 million pounds in 1978. Maryland landings peaked at about 0.8 million pounds of meats in 1969 and reached a low of about 0.02 million pounds in 1979. Total landings and number of permits are the only catch and effort data collected, so catch-per-unit-of-effort as a measure of abundance is not possible. Accurate determination of catch and catch-per-unit-of-effort is not possible now either in the commercial or the recreational fishery. Varying price according to size of clam is not possible from published statistics. Also published statistics are less than actual landings by a considerable amount. Acquisition of accurate landings data can be obtained only through increased dealer participation. (J.L.M.)

403 Kvaternik, Andre C., William D. DuPaul, and Thomas J. Murray. 1983.

Price flexibility analysis of Virginia hard clams: Economic considerations for management of the fishery. Spec. Rep. Appl. Mar. Sci. Ocean Eng. 266, Va. Inst. Mar. Sci., Gloucester Point, VA 23062, 53 p.

Price flexibility coefficients estimated for exvessel prices of Virginia hard clams (*Mercenaria mercenaria*) show that a very small (4.292×10^{-6} to 6.994×10^{-6}%) decrease in price would occur given a 1% increase in the quantity supplied by Virginia harvesters. Data used were monthly landings of Virginia, New Jersey, Rhode Island, Maryland, and North Carolina over the period 1960-79. Fifty-eight percent of the exvessel price changes are not explained by the supply response model used, suggesting other market and consumer demand factors play a large role in determining exvessel price. Possible legislative changes to aid the fishery are: 1) use efficient harvesting technologies on private leased bottom; 2) seasonal use of efficient harvesting technologies to take advantage of seasonal peaks in exvessel prices; 3) a new statistical reporting system that reports the catch/day of each harvester and the proportion of each market grade caught; 4) establishment of subaqueous bottom areas specifically for field culture of hard clams; and 5) set and enforce a minimum legal cull size. (J.L.M.)

404 Langdon, Christopher J. 1985.

Development of artificial diets for marine bivalves. J. Shellfish. Res. 5(1)39 (abstract).

The culture of clams (*Mercenaria mercenaria*) is mainly dependent on algae as a source of nutrients. But algae are expensive and undependable. One way of overcoming these difficulties is to use artificial diets as a food source, but problems in presenting microparticulate foods and in determining their optimum dietary composition have hindered development of satisfactory artificial diets. Recent advances are reviewed. Application of microencapsulation technology and use of dispersants and antibiotics to control food particle clumping and bacterial growth are discussed. (Modified author's abstract - J.L.M.)

405 Lutz, Richard A., and Harold H. Haskin. 1985.

Some observations on the longevity of the hard clam *Mercenaria mercenaria* (Linne). J. Shellfish. Res. 5(1)39 (abstract).

In the late 1940s and early 1950s a series of mark-recapture experiments was conducted. Two specimens were recovered alive in 1980. Interpretation of surface and internal growth patterns of the prenotch shell regions suggested that each was approximately 3 yrs old at the time of notching. The age estimates of 36 and 33 yrs for these specimens are, to the best of the authors' knowledge, the oldest reported to date for this species from long-term monitoring studies. (Modified authors' abstract - J.L.M.)

406 MacKenzie, C.L. 1977.

Predation on hard clam, *Mercenaria mercenaria*, populations. Trans. Am. Fish. Soc. 106(6):530-537.

407 Malouf, Robert E., and Scott E. Siddall. 1985.

The status and potential of public and private culture of the hard clam *Mercenaria mercenaria* (Linne) in New York. J. Shellfish. Res. 5(1)40 (abstract).

Juvenile "seed" hard clams are being produced by four commercial hatcheries on Long Island. Seed from those hatcheries and from hatcheries in Maine and Massachusetts have been planted on public grounds by seven Long Island towns. Ranging in scale from 0.1 to 3.0 million clams, these plantings are being carried out in an effort to supplement natural recruitment. Most town programs include some type of nursery system designed to grow clams from their 0.5-6.0 mm size at purchase to 15-20 mm at planting. The programs have been carried out for several years, but their contribution to the fishery has not been rigorously determined. Our preliminary evaluation of those programs and experimental plantings on Long Island suggest that they are much too small to make a significant quantitative contribution to the public harvest. The plantings might be useful to establish self-sustaining populations at specific sites. Private hard clam culture involving rafts, floating stacks of trays, bottom boxes, etc. has been carried out on Long Island by Blue Points Co., F.M. Flower Co., and Shellfish Inc., among others. Nursery costs, lack of suitable underwater land, and opposition from baymen continue to inhibit the expansion of private clam culture on Long Island. (Modified authors' abstract - J.L.M.)

408 Manzi, John J. 1985.

Mercenaria in South Carolina: Wildstock fishery and commercial mariculture. J. Shellfish. Res. 5(1)41 (abstract).

The fishery in South Carolina began at the turn of the century but remained small and localized until recently. Mechanical harvesting began in 1973 and greatly increased annual yields. Latest available statistics (Sept. 1982-May 1983) show that the wildstock industry now accounts for 3-5% of the national harvest and for the first time exceeds the value of the state's oyster (*Crassostrea virginica*) landings. A summary of fishery techniques and historical statistics is given for the state's wildstock hard clam fishery. Mariculture began in South Carolina with tray growout experiments in the mid-1970s. These led to a commercial-scale project involving public and private resources. The cooperative project used a 3-step culture protocol: nursery culture to field planting size; high-density primary field growout; and lower-density secondary field growout to minimum market size. A discussion of the progress enjoyed by the project, its production to date, and a summary of the potential of, and constraints to, hard-clam mariculture in South Carolina is given. (Modified author's abstract - J.L.M.)

409 Manzi, John J., M.Y. Bobo, and V.G. Burrell, Jr. 1985.

Gametogenesis in a population of the hard clam *Mercenaria mercenaria* (Linne) in North Santee Bay, South Carolina. J. Shellfish. Res. 5(1)41 (abstract).

Adult hard clams were sampled monthly between Dec. 1977 and Feb. 1979 and semimonthly from March to June 1981 in North Santee Bay. Observed gametogenic progression was best categorized by five stages of development: inactive, ripe, spawning, partially-spent, and spent. Both sexes showed a complex progression of gametogenesis. Gonadal tissue was not uniformly dominated by clearly defined, distinct stages. Instead gonads routinely exhibited several stages simultaneously and progression was documented through slow shifts in domination of stages in gonad tissue. Spawning occurred continuously over a 6-month period (May-October) with at least two apparent peaks of spawning activity in summer. Stages of gametogenesis encountered are described for both sexes and seasonal progression of gonad development is discussed. (Modified authors' abstract - J.L.M.)

410 Manzi, John J., N.H. Hadley, C. Battey, R. Haggerty, R. Hamilton, and M. Carter. 1985.

Culture of the hard clam *Mercenaria mercenaria* (Linne) in commercial-scale, upflow nursery system. J. Shellfish. Res. 5(1)41 (abstract).

The potential benefits of upflow nursery systems compared with traditional raceway systems include maximization of space utilization, low construction cost, ease of maintenance, and operational longevity. A commercial nursery facility for raising hard clam seed in South Carolina uses upflow culture. The first year of operation of this system shows how seed growth is analyzed in relation to seed density, water flow, and environmental factors. Growth rates of seed from three different broodstocks is reported. Performance of passive and active upflow systems are compared. Results are compared with those from raceways and from an experimental-scale, passive upflow system. (Modified authors' abstract - J.L.M.)

411 Marine Research, Inc. 1976.

A summary of the clam industry in Massachusetts. Mar. Res. Inc., Falmouth, MA 02541, 38 p. Unpubl. manuscr. submitted to T.P. Ritchie for preparation of *A comprehensive review of the commercial clam industries in the United States.*

See Ritchie (1977) in McHugh et al. (1982), citation 1552. (J.L.M.)

412 McHugh, J.L. 1984.

Fishery management. Lecture notes on coastal and estuarine studies, No. 10. Springer-Verlag New York, Inc., 207 p.

The hard clam (*Mercenaria mercenaria*) has a remarkable capacity to remain closed under adverse conditions, which helps it to survive. North of Cape Cod in New England they exist only in certain bays where oceanographic conditions favor spawning. Abrupt and spectacular changes in abundance and distribution occur as water temperatures rise and fall in relatively long-term environmental change. The nucleus for resurgence is provided by the relatively few that survive cold periods. (J.L.M.)

413 McHugh, J.L. 1985.

An overview of some aspects of hard clam biology. J. Shellfish. Res. 5(1)41-42 (abstract).

Among subjects covered are the detrimental effects of oil on clams, and the responses of clams to other pollutants. Shell uniformity and the ability of clams to remain closed for weeks out of water are discussed. The production of antitumor agents by clams, the effects of certain neurosecretions on clam hearts, the effects of environmental factors on shell growth increments, and the functioning of the catch-muscle mechanism are described. General fishery topics covered include techniques for preventing predation, and certain aspects of a new hard-clam fishery in the Santee River delta in South Carolina following the diversion of Santee River water to the Cooper River. (Modified author's abstract - J.L.M.)

414 McHugh, J.L., and R.B. MacMillan. 1976.

Comprehensive report on the hard clam (*Mercenaria mercenaria*) industry in New York State. State Univ. NY, Stony Brook, NY 11794, 57 p. Unpubl. manuscr. submitted to T.P. Ritchie for preparation of *A comprehensive review of the commercial clam industries in the United States.*

See Ritchie (1977) in McHugh et al. (1982), citation 1552. (J.L.M.)

415 Menzel, W. 1976.

Comprehensive report on the quahog clam (*Mercenaria* spp.) industry in Florida. Dep. Oceanogr., Fla. State Univ., Tallahassee, FL 32306, 20 p. Unpubl. manuscr. submitted to T.P. Ritchie for preparation of *A comprehensive review of the commercial clam industries in the United States.*

See Ritchie (1977) in McHugh et al. (1982), citation 1552. (J.L.M.)

416 Otwell, W.S., J.A. Koburger, S. Andree, and L.T. Johnson. 1985.

Survival of three species of quahog clams (*Mercenaria* spp.) in refrigerated storage. J. Shellfish. Res. 5(1)42 (abstract).

Northern quahog *Mercenaria mercenaria* has a significantly longer shelf-life than southern quahog *M. campechiensis* and the Texas quahog *M. mercenaria texana*. Survival response across all storage temperatures was significantly longer for all species harvested during January through April compared with harvest from June through August. All species in 4°C refrigeration experience stress which would be interpreted as death by commercial standards. Survival was longer in 10° and 15°C, but potential adverse microbial consequences and objectionable odors resulting from single deaths would preclude use of this storage temperature. Fecal coliform and aerobic plate counts (35°C) of live clams remained relatively constant during storage. However, aerobic plate counts conducted at 25°C showed a marked increase for clams stored at all temperatures. Further considerations with use of initial, temporary wet storage in ambient and refrigerated water for acclimation offered advantages, but do not appreciably extend subsequent shelf-life. (Modified authors' abstract - J.L.M.)

417 Parker, Kenneth M. 1975.

A study of natural recruitment of *Mercenaria mercenaria*. Unpubl. rep., N.C. Div. Mar. Fish., Wrightsville Beach, NC 28480, 29 p.

An experiment was conducted to determine if protection of *Mercenaria mercenaria* using *Argopecten gibbus*, calico scallop shells, as a covering is feasible. A total of 150 L/5 m^2 samples were gathered, 75 from control areas and 75 from experimental areas. Comparisons were made of overall numbers of clams, natural recruitment of clams, substrate analysis, and size frequency. Results show that there was a substantial increase in numbers of clams in experimental areas, apparently caused by protection provided by *Argopecten gibbus* shells. (Modified author's abstract - J.L.M.)

418 Peterson, Charles H. 1985.

Application of experimental hypothesis-testing to hard-clam management problems in North Carolina. J. Shellfish. Res. 5(1)42 (abstract).

Seagrass beds provide some natural refuge for hard clams *Mercenaria mercenaria* from predatory whelks. If mechanical clam harvesting is prohibited in seagrass beds, these habitats can shelter older, economically less valuable clams to serve as a "spawning pump" for heavily harvested areas. Mechanical harvesting in seagrass beds causes long-term damage to the seagrass and does not enhance settlement success of hard clams. Consequently, the benefits of habitat-specific clam management that prohibits mechanical harvesting in seagrass beds outweigh the costs, as judged from field experiments in North Carolina. (Modified author's abstract - J.L.M.)

419 Petrovits, Eugene J. 1985.

Commercial mariculture of *Mercenaria mercenaria* (Linne) at Aquacultural Research Corporation, Dennis, Massachusetts. J. Shellfish. Res. 5(1)42 (abstract).

In May and June, 5- to 8-mm hatchery-produced quahog seed is planted in a field nursery. Two types of nursery are used: surface-suspended and bottom-suspended trays. In September and October nurseries are harvested. Seed-size ranges between 15 and 25 mm, and recovery is between 90 and 95%. Within 48 h of harvest, seed is bottom planted in an intertidal area and covered with 0.5-in. Conwed mesh. Field growout including nursery time requires 2.5 to 3 growing seasons, and a recovery of 65% is expected. (Modified author's abstract - J.L.M.)

420 Rinaldo, R., and R. Scott. 1976.

Comprehensive report on the hard clam (*Mercenaria mercenaria*) industry in Maryland. MD Dep. Nat. Resour., Annapolis, MD 21401, 10 p. Unpubl. manuscr. submitted to T.P. Ritchie for preparation of *A comprehensive review of the commercial clam industries in the United States*.

See Ritchie (1977) in McHugh et al. (1982), citation 1552. (J.L.M.)

421 Strand, Ivar. 1976.

Comprehensive report on the hard clam (*Mercenaria mercenaria*) industry in Maryland. Univ. Md., College Park, MD 20742, 14 p. Unpubl. manuscr. submitted to T.P. Ritchie for preparation of *A comprehensive Review of the Commercial Clam Industries in the United States*.

See Ritchie (1977) in McHugh et al. (1982), citation 1552. J.L.M.

422 Street, Michael W. 1976.

Comprehensive report on the hard clam (*Mercenaria mercenaria*) industry in North Carolina. N.C. Div. Mar. Fish., Morehead City, NC 28557, 26 p. Unpubl. rep. prepared for T.P. Ritchie for preparation of *A comprehensive review of the commercial clam industries in the United States*.

See McHugh et al. (1982), citation 1552. (J.L.M.)

423 Street, Michael. 1986.

Annual look at the N.C. commercial catch. N.C. Nat. Resour. Commun. Dev., Morehead City, NC 28557, Tar Heel Coast 21(2):1-5 (and previous issues in this series).

The hard clam fishery was of relatively minor importance until the mid-1970s when harvests increased through use of hydraulic escalator dredges. Landings increased dramatically and set new records during 1977-82. Much of the increased catch came from Carteret County where kicking is the harvest method. Landings have been relatively level since 1983. The fishery may be at its maximum level despite increasing effort. (J.L.M.)

424 Sugihara, T. 1976.

Comprehensive report on the hard clam (*Mercenaria mercenaria*) industry in New Jersey. Cent. Coastal Environ. Stud., Rutgers Univ., Piscataway, NJ 08854, 19 p. Unpubl. manuscr. submitted to T.P. Ritchie for preparation of *A comprehensive review of the commercial clam industries in the United States*.

See Ritchie (1977) in McHugh et al. (1982), citation 1552. (J.L.M.)

425 Wass, M.L. 1972.

Phylum mollusca. *In* A check list of biota of lower Chesapeake Bay. Spec. Sci. Rep. 65, Va. Inst. Mar. Sci., Gloucester Point, VA 23062, p. 122-129.

See original. (J.L.M.)

BIBLIOGRAPHY: Part 3

426 Adamkewicz, Laura. 1987.

Geographical effects on growth rate in the hard clam *Mercenaria mercenaria*. J. Shellfish. Res. 7(1):5 (abstract).

To investigate the extent to which populations of *Mercenaria mercenaria* might be genetically adapted to local conditions, adult clams were collected from three natural populations in Massachusetts, Virginia, and South Carolina. Three sets of females from each location were mated with males from all three locations to produce the nine possible combinations of a factorial cross. When ready for growing out, each cross was divided into three portions and shipped to nurseries in each of the three localities. Shell length was measured in a sample of clams, 100 clams from each of the nine crosses. After six months shell length was measured in a sample of 100 individuals from each subset of each cross. Data from the first samples, all bred in one location, showed a strong effect of parental origin on shell length. The second set of samples, from each of the nine crosses raised in each of the three locations, continued to show a significant effect of parental origin. However, in the second samples, location of the rearing nursery explains an even larger portion of the variation than does the geographical origin of parental stocks. The more northerly the rearing hatchery, the larger the mean shell length achieved. Each cross performed better in northern waters, but within any one nursery clams with higher proportions of southerly parental contribution tended to grow larger. This was interpreted to mean that stocks from southern areas were able to take greater advantage of preferred growing conditions. (Modified author's abstract - J.L.M.)

427 Amouroux, J.M. 1986.

Comparative study of the carbon cycle in *Venus verrucosa* fed on bacteria and phytoplankton. II. Consumption of phytoplankton (*Pavlova lutheri*). Mar. Biol. 92(3):349-354.

The aim of this study was to compare the consumption of two kinds of food: bacteria and phytoplankton. (J.L.M.)

428 Arnold, W.S., D.C. Marelli, and P.A. Gill. 1987.

Population distribution of hard clams in the Indian River Lagoon, Florida. J. Shellfish. Res. 7(1):67 (abstract).

Hard clams (*Mercenaria* spp.) were sampled in the Indian River Lagoon in summer 1986. Clams were abundant throughout the central region of the sampling area, but were scarce at the northern and southern extremes. Patterns of environmental variability are invoked to explain the macrodistribution of the animal in the Lagoon, whereas water depth and sediment composition influence small-scale distribution patterns. A study of internal growth lines is utilized to explain the recent history of hard clams in the Lagoon. Information on age distribution of the population elucidates the pattern of annual recruitment in the population. This is considered in light of macroscale disturbances which impact on the Lagoon. (Modified authors' abstract - J.L.M.)

429 Auster, P.J., and B.D. Haskell. 1987.

Predator-hard clam (*Mercenaria mercenaria* interactions: Spatial scale effects. J. Shellfish. Res. 7(1):59 (abstract).

A manipulative field experiment was conducted to determine the covarying effects of juvenile clam patch size and density on survivorship ($\bar{x}$ SL = 3.45 mm, SD = 0.38 mm). A complete 3×4 factorial design was used with three densities (25, 150, and 300 clams/0.25 m^2). Patch size had a very significant effect ($p<0.005$) on survivorship; the larger the patch, the greater the mortality. The density effect was only slightly significant ($p<0.10$). The interaction of both variables was not significant. Clams show an escape response caused by foraging activities of predators. A laboratory experiment demonstrated a significant decrease in growth of juvenile hard clams ($\bar{x}$ SL = 1.2 mm, SD = 0.275, at start) subjected to foraging by hermit crabs (*Pagurus longicarpus*, 12.8/0.25 m^2) when compared with a treatment with no predators (t-test, $p = 0.05$). This effect caused individuals to grow at a slower rate and be available longer to a more diverse predatory milieu. The shelter related behavior of some crustacean species restricts the area searched during part of each 24 hour period. The densities of shelter sites and predators, and apparent diel patterning of search area by predators may affect the spatial mortality patterns of prey species. (Modified authors' abstract - J.L.M.)

430 Bisker, Robert, and Michael Castagna. 1985.

The effect of various levels of air-supersaturated seawater on *Mercenaria mercenaria* (Linne), *Mulinia lateralis* (Say), and *Mya arenaria* (Linne), with reference to gas-bubble disease. J. Shellfish. Res. 5 (2):97-102.

Supersaturated seawater was produced in a flowthrough system by injecting air into a pressurized seawater line. *Mercenaria mercenaria*, *Mulinia lateralis*, and *Mya arenaria* were exposed to several different levels of supersaturated seawater at temperatures ranging from 5 to 17°C. Gas-bubble disease occurred at total gas saturation levels of 108% in juveniles of *M. lateralis* and 114% in juveniles of *M. arenaria*. Air blisters in the tissue, flotation, and mortality were observed at these levels. Reduced growth in juveniles of *M. mercenaria* was found at a total gas saturation level of 115%. (Authors' abstract - J.L.M.)

431 Bisker, Robert, and Michael Castagna. 1987.

Predation of mud crabs and blue crabs by toadfish *Opsanus tau*, with a discussion of biological control of crabs in molluscan aquaculture. J. Shellfish. Res. 7(1):59 (abstract).

Blue crabs *Callinectes sapidus* of 77.8-105.3 mm carapace width (CW) were exposed to toadfish of 196-322 mm total length (TL) in the presence of hard clams *Mercenaria mercenaria* of 4.3-6.5 mm shell height with sand, gravel or hardbottom substrate for 24-96 hrs. in the laboratory. Toadfish could injure or kill blue crabs of almost one-third their size. Crab predation on clams was reduced with the presence of toadfish or gravel. The use of toadfish as a biological control of crab predation in molluscan aquaculture is discussed. (Modified authors' abstract - J.L.M.)

432 Buzzi, Bill and J.J. Manzi. 1987.

Growth and survival of larval and juvenile polyploid clams, *Mercenaria mercenaria*. J. Shellfish. Res. 7(1):3 (abstract).

Five families of *Mercenaria mercenaria* were produced by spawning adults of known genotypes. Following fertilization, ploidy-altering treatments of 1 mg/L cytochalasin B in 0.1% dimethylsulfoxide were applied at two times. Polar body production, growth, survival and ploidy alteration were analyzed with respect to treatments and families. (Modified authors' abstract - J.L.M.)

433 Crenshaw, John W., Jr., Peter B. Heffernan, and Randal L. Walker. 1987.

Quantitative genetic selection in the future of shellfish culture. J. Shellfish. Res. 7(1):4 (abstract).

Reference to *Mercenaria mercenaria* is made in a paper by Chanley (1961), abstracted in McHugh et al. (1982) (J.L.M.)

434 Day, Elizabeth A., and P. Lawton. 1987.

Substrate type and predatory risk: Effects on mud crab interaction with juvenile hard clams. J. Shellfish. Res. 7(1):59 (abstract).

Mud crabs such as *Neopanope sayi* are significant predators of juvenile hard clams *Mercenaria mercenaria* in Long Island waters. Abundance and survival of mud crabs and hard clams are affected by substrate type and predatory risk. In binary substrate-choice experiments, mud crabs preferred broken oyster shell most, followed in order by large gravel (>30 mm diam), small gravel (<17 mm diam), mud, and sand. Mud crab preference for substrates such as gravel or broken oyster shell may result in decreased susceptibility to predation. When substrate combinations contained juvenile hard clams (250 8.8-11.0 mm clams/substrate; 1000 clams/m^2), crab predation was lower in sand than in small gravel (82.2% less), large gravel (64.8% less), or small gravel overlaid with sand (64.8% less). Crab behavior and activity patterns in these substrate combinations were determined from video time-lapse recordings and visual observation. Addition of a predator on mud crabs, the toadfish, *Opsanus tau*, caused a reduction in crab-induced mortality of clams in individual substrate trials (97.6% less in sand, 91.3% less in small gravel). This effect is primarily a result of depressed crab activity, rather than direct crab mortality. In areas where mud crab predation is of primary concern to mariculturists, clam survival may be increased by planting in sand substrates, for which crabs have a low preference. Mud crabs also may be more vulnerable to their natural predators in such substrates. (Slightly modified authors' abstract - J.L.M.)

435 Dennison, William C. 1987.

"Brown tide" algal blooms shade out eelgrass. J. Shellfish. Res. 7(1):16 (abstract).

Eelglass meadows serve as nursery and habitat for many shellfish species including the bay scallop (*Argopecten irradians*) and hard clam (*Mercenaria mercenaria*). Previous studies have demonstrated the importance of eelgrass (*Zostera marina*) in providing optimal hydrodynamic regimes for bay scallop and hard clam feeding, and providing protection from predators. Recolonization rates of eelgrass are relatively slow (years to decades) even without a recurrence of algal blooms (*Aureococcus anorex-*

efferens) which dramatically reduce light penetration into the water column. The impact of blooms on shellfish in Long Island waters will last well beyond the impact observed during blooms. Recurrence of blooms and slow rates of eelgrass recolonization may promote a shift from a benthic dominated ecosystem to a pelagic dominated ecosysten. (Modified author's abstract - J.L.M.)

436 Dillon, Robert T., Jr., and John J. Manzi. 1987.

Heterozygosity, growth, and linkage disequilibrium in hybrid populations of *Mercenaria mercenaria*. J. Shellfish. Res. 7(1):9 (abstract).

Lines of the hard clam, *M. mercenaria,* have been selected for fast growth by Aquaculture Research Corporation and Virginia Institute of Marine Science. These lines do not seem to be inbred, judging from allele frequencies at seven enzyme loci, although there is evidence of genetic drift and loss of rare alleles. Very little relationship between heterozygosity and growth was detected in the offspring of individual crosses between these two lines, nor does variance at any particular enzyme locus seem to affect growth. We do, however, report evidence of loose linkage disequilibrium between alleles at a variety of enzyme loci and alleles at loci affecting growth in the nursery. (Authors' abstract - J.L.M.)

437 Duncan, Patricia L. 1986.

The use of crab meal as a supplemental food for juvenile hard clams (*Mercenaria mercenaria*). Masters diss., College of William and Mary, Williamsburg, VA 23186.

In all experiments significantly greater increases in clam shell height and weight were observed in supplemented clams compared with controls when crab meal was fed in proper amounts. There appeared to be a direct relationship between percentage increase in shell height and crab meal ration at optimum feeding rates. Optimum feeding rates for smaller clams (4-6 mm) were crab meal rations 20-24% of total clam live weight per day. Crab meal sieved through 100 or 134 micron mesh, autoclaved, and mixed with 25-micron filtered seawater produced the greatest increases in clam weight and shell weight. This indicates the potential for use of crabmeal in commercial nurseries as partial replacement for cultured algae. (J.L.M.)

438 Gainey, Louis F., Jr., and Sandra E. Shumway. 1987.

Physiological effects of *Protogonyaulax tamarensis* on bivalve molluscs. J. Shellfish. Res. 7(1):15 (abstract).

After exposure to *Protogonyaulax tamarensis* (clone GT429), shell valve and/or siphon closure was unchanged in *Mytilus edulis, Spisula solidissima, Arctica islandica*, and *Modiolus modiolus*; increased in *Mercenaria mercenaria*, *Ostrea edulis*, *Placopecten magellanicus*, *Geukensia demissa*, *Mya arenaria*, and *Mytilus edulis*. Clearance rates were increased in *Mytilus* from Maine, and *Ostrea*; were unchanged in *Mytilus* from Rhode Island, and *Spisula*; were decreased in *Mercenaria*, *Geukensia*, and *Mya*; and were unchanged in *Mytilus* from Maine, and decreased in *Placopecten*. Cardiac activity was unchanged in *Spisula*, *Mercenaria*, *Arctica*, and *Placopecten*. There was a transient decrease in heart rate in *Mya* after exposure to GT429 which was correlated with increased siphon closure. There were significant changes in cardiac activity in *Ostrea* (22% of individuals tested), *Geukensia* (60%), and *Mytilus* (57%). These changes were increased heart rates in *Geukensia* and *Mytilus*, periods of cardiac arrhythmia and decreased heart rates. (Modified authors' abstract - J.L.M.)

439 Gibbons, M.C. and M. Castagna. 1985.

Responses of the hard clam *Mercenaria mercenaria* (Linne) to induction of spawning by serotonin. J. Shellfish. Res. 5(2):65-67.

Clam size, sex of clam, concentration of serotonin, and site of administration of serotonin were found to influence the induction of spawning in the hard clam *Mercenaria mercenaria*. Overall male clams greater than 36.4 mm thickness were more likely to spawn in response to serotonin injection at concentrations of 0.2 or 2.0 mM. Administration of serotonin by injection in the anterior adductor muscle resulted in significantly more spawnings than intragonadal injection or dispersal in water surrounding the incurrent siphon. (Modified authors' abstract - J.L.M.)

440 Gill, Paige A., and Donald M. Hesselman. 1987.

Preliminary results of a study of the relationship between reproductive development of the quahog (*Mercenaria* spp.) and influential physical factors in the Indian River Lagoon, Florida. J. Shellfish. Res. 7(1):67 (abstract).

The northern quahog (*Mercenaria mercenaria*) shows a distinctly cyclical pattern of gonadal development throughout most of its range along the eastern seaboard of the United States, but little information is available for the species at the southern limit of its range. Discerning the reproductive cycle in Florida is complicated by the occurrence of *Mercenaria campechiensis* and hybrids in this region. Hard clams were collected monthly from September 1986 to June 1987 in two geographically distinct areas of the Indian River Lagoon. Temperature, salinity, dissolved oxygen and chlorophyll concentration were monitored biweekly during this same time period. Hard clams of a variety of size classes were collected from three stations in each area, sectioned for histological examination, and classified according to developmental stage based on visual appearance of the gonads and average monthly oocyte diameters. The relationship between reproductive development and potentially influential physical factors is discussed. (Modified authors' abstract - J.L.M.)

441 Goodsell, Joy G. 1987.

A comparative analysis of larval and early postlarval shell morphology of the hard clams *Mercenaria mercenaria*, *Mercenaria mercenaria texana*, and *Mercenaria campechiensis*. J. Shellfish. Res. 7(1):43 (abstract).

Prodissocohch I and II length and height and larval hinge structure did not appear significantly different among offspring of the three parental types. *Mercenaria campechiensis* larvae appeared to exhibit increased external shell sculpturing and increased shell depth at late larval and early juvenile stages. (Modified author's abstract - J.L.M.)

442 Grizzle, Raymond E. 1987.

The relative effects of seston flux and sediments on individual growth rates of *Mercenaria mercenaria*: Results of a factorial field experiment. J. Shellfish. Res. 7(1):67-68 (abstract).

Preliminary descriptive/correlative field studies on wild *Mercenaria mercenaria* in a coastal lagoon in southern New Jersey suggested that individual growth rates are affected by "food provision rate" (equivalent to the horizontal flux of seston; flux units: mg seston/cm^2/s) and deposited sediments. Ten clams (30-45 mm shell length) were placed in each of 36 experimental plots (12 per site), each a round excavation of 0.3 m^2 area and 10-15 cm deep in the ambient sediment filled with either mud, sandy mud, or sand. Clams were also put in undisturbed sediment at each site as controls for the sediment transplant procedure. An ANOVA, with change in shell length as the dependent variable, showed significant differences between sites ($P<0.001$) and sediment type ($P<0.05$). Combining all data by site and sediment type showed a 13% difference in growth rates between the slowest and fastest sites, and a 6% difference between sediment types, with slowest growth in mud and fastest in sand. Tidal current velocities and four seston parameters (chlorophyll *a*, particulate inorganic and organic matter (PIM and POM), and energy content) were measured 20 times in near-bottom waters at each site. Flux of POM was well-correlated with growth rates. Neither seston concentrations nor current velocities alone were correlated with growth rates. Hence the significant "site" differences are attributed to differences in seston flux. This experiment provides further support for the importance of seston flux in controlling growth rates of suspension-feeding bivalves. It also provides the first estimate of the relative importance of seston flux and sediment type. (Modified author's abstract - J.L.M.)

433 Gussman, David S. 1987.

The use of brewers condensed solubles in bivalve mariculture. Ph.D. diss., College of William and Mary, Williamsburg, VA 23186.

Brewers condensed solubles (BCS) was used to culture bacteria which were fed to colorless flagellates which were in turn fed to juvenile oysters (*Crassostrea virginica*) and clams (*Mercenaria mercenaria*). Growth of clams fed colorless flagellates, BCS enrichment cultures, and bacteria was compared with growth of starved controls and animals fed *Tetraselmis suecica. Paraphysomonas vestita* was the only species of colorless flagellate to consistently give growth greater than the starved control. BCS enrichment culture varied greatly in its nutritional value. Average oyster growth on *P. vestita* was 55% of growth obtained with *T. suecica*. Oysters fed combinations of *T. suecica* and *P. vestita* did not grow as rapidly as on a pure diet of *T. suecica*. No growth occurred when oysters and clams were fed on a purely bacterial diet. (J.L.M.)

444 Heffernan, Peter B., Randal L. Walker, and John W. Crenshaw, Jr. 1987.

Growth of Georgia *Mercenaria mercenaria* (L.) juveniles in an experimental downweller system. J. Shellfish. Res. 7(1):68.

Five cohorts of *Mercenaria mercenaria* seed were stocked at various densities (0.3-3.3 kg/m^2) on experimental scale downweller systems and growth was analysed for the period Oct. 15 to Dec. 1, 1986. To ensure maintenance of each cohort's inherent genetic variance, seed were never graded or separated according to size. Mean flowrate to downwellers was 1.2 L/min with ambient water supply (sand filtered) replaced daily for about 6 hrs by cultured seawater (Wells Glancy method) at the same mean flowrate. Mean biomass increases varied among downwellers from 130.6-954% in the 47-day period. Flowrate to biomass ratios are shown to have a great effect on growth rates. Flowrate to biomass ratios varied from 11.6-72.8 L/min/kg. A doubling to trebling of biomass was achieved within the flowrate/biomass range of 14.1 to 17.2 L/min/kg after 47 days. These figures are very similar to the results reported by Manzi et al.

(1986) for experimental scale upweller systems in South Carolina. Cohorts can be divided into groups which grew faster in the first (Oct. 15-Nov. 11) or second half (Nov. 11-Dec. 1) of the study period. Growth rates achieved by these groups were shown to be significantly different during the second half, and are thought to be dependent on the flow rate to biomass ratio. (Modified authors' abstract - J.L.M.)

445 Hilbish, Thomas J. 1987.

Quantitative and single-locus genetic analysis of production in bivalves. J. Shellfish. Res. 7(1):10-11 (abstract).

Variation in phenotypic traits such as production characteristics may be studied using either quantitative or single locus genetics. An analysis of juvenile growth rate in the hard clam *Mercenaria mercenaria* is underway and will be discussed later. (Modified author's abstract - J.L.M.)

446 Humphrey, Celeste M., and Randal L. Walker. 1982.

The occurrence of *Mercenaria mercenaria* form *notata* in Georgia and South Carolina: Calculation of phenotypic and genotypic frequencies. Malacologia 23(1):75-79.

Genotypic and phenotypic frequencies of the *notata* form of *Mercenaria mercenaria* were calculated from data provided by four studies: two natural populations from Georgia, one from South Carolina, and one hatchery brood. Phenotypic frequencies calculated for each study ranged from 0.76% to 2.25%. Gene frequencies calculated by Maximum Likelihood Estimation were 0.04 to 0.11%. There were no significant differences between samples of natural populations. The natural populations and the hatchery brood were not comparable. The *notata* variant is the only morphological character inherited as if controlled by a single gene that has been found in *M. mercenaria*. The uses of such a marker are numerous. One application would be the marking of offspring from controlled matings to determine their subsequent success. (J.L.M.)

447 Hurley, Geoffrey V., K. Henderson, M. Percy, and D. Roscoe. 1987.

Small scale shellfish hatchery: Design manual. J. Shellfish. Res. 7(1):39-40 (abstract).

The manual outlines the processes and equipment required to culture four shellfish species, including the hard clam, *Mercenaria mercenaria*. Methods of producing food for shellfish are also included. (Modified authors' abstract - J.L.M.)

448 Kassner, Jeffrey. 1987.

Hard clam (*Mercenaria mercenaria*) abundance in eastern Great South Bay, Long Island, New York: Population distribution and structure. J. Shellfish. Res. 7(1):67 (abstract).

In 1986, the Town of Brookhaven undertook a hard clam population survey in eastern Great South Bay, an area of 3238 hectares, that in 1985 produced 40,000 bushels of hard clams. Replicate 1.20 m^2 grabs were taken at 140 stations according to a block random design with 1.7×105 m^2 quadrants. Length and thickness of all clams greater than 20 mm in length were measured. A hard clam distribution map was prepared using a 5 clam/m^2 (apparent minimum density for harvesting) cutoff. Five distinct areas (beds) having densities greater than the cutoff, and three areas with densities below the cutoff (non-beds) were identified. Size (age) frequency distributions were calculated baywide and for each bed and non-bed. Bottom type in beds was sand or muddy sand with shell fragments, while non-beds had muddy sand or mud without shell fragments. The population structure was similar for beds and non-beds even though the mean density of all beds and all non-beds was 10.6 and 2.4 clams/m^2, respectively, and both had annual recruitment. However, individual bed stations had a greater range of sizes than did non-bed stations. This suggests that population dynamics in beds and non-beds are different. Field, laboratory and literature data provide some insight as to causes. Management implications are considered. (Modified author's abstract - J.L.M.)

449 Kassner, Jeffrey, and Robert E. Malouf. 1982.

An evaluation of "spawner transplants" as a management tool in Long Island's hard clam fishery. J. Shellfish. Res. 2(2):165-172.

A traditional management practice in New York's hard clam (*Mercenaria mercenaria*) fishery has been to transplant adult clams from cooler northern waters to the relatively warmer waters of Great South Bay. It is believed that such spawner transplants increase the length of time that clam larvae are present in the bay and, thereby, enhance the probability that at least some of the larvae will encounter favorable conditions for survival and settlement. Histological analysis of the gametogenic cycle of native and transplanted clams showed that two critical assumptions were unsound: 1) that spawning by the native clams is defined and predictable, and 2) that the transplanted clams spawn after the native clams have ceased spawning. Other considerations, including the scale of the transplant projects relative to the natural stocks suggest that these programs are unlikely to significantly increase recruitment in Great South Bay. (Authors' abstract - J.L.M.)

450 Koppelman, Lee E., DeWitt S. Davies, and staff. 1987.

Strategies and recommendations for revitalizing the hard clam fisheries in Suffolk County. Suffolk County Planning Dep., Hauppauge, NY 11788, 58 p.

Suffolk County is the center of the marine fishing industry in New York State. The industry has been dominated by landings of hard clams (*Mercenaria mercenaria*) but the hard clam fishery has fallen on hard times recently. By 1985 hard clam landings in the County had declined 76% from the last peak production year of 1976. In response to this decline a report was funded by the County and completed by the Marine Sciences Research Center of SUNY entitled "Suffolk County's hard clam industry: An overview and an analysis of management alternatives." With funding from the National Marine Fisheries Service a Suffolk County hard clam advisory group was formed to screen these management alternatives and suggest others. The charge made to the Advisory Group was to assist the County's Planning Department in preparing a plan for management of the hard clam resources. The goals of the plan were to: 1) identify actions that should be taken to assure the survival of a viable commercial hard clam industry capable of supporting a significant number of baymen harvesting clams on a full-time basis; 2) identify actions that should be taken to preserve a hard clam industry that provides baymen with a source of income, and others with the opportunity to enjoy clam harvesting on a recreational basis; 3) identify actions that should be taken to: a) maintain environmental conditions in local marine waters that are conducive to the reproduction, growth, and survival of hard clams; and b) maintain the certification of these waters for the harvest of shellfish resources. The rest of the report summarizes these goals in some detail, under the headings: 1) hard clam stock enhancement strategies and recommendations; 2) fishery management information, enforcement strategies, and recommendations; 3) marine water quality monitoring, fishery habitat protection strategies, and recommendations. (J.L.M.)

451 Kraeuter, John N., and Michael Castagna. 1985.

The effects of seed size, shell bags, crab traps, and netting on the survival of the northern hard clam *Mercenaria mercenaria* (Linne). J. Shellfish. Res. 5(2):69-72.

Seed size at planting is the dominant factor affecting hard clam survival to marketable size when field growout techniques are used. The use of plastic mesh nets, crab traps, and wire mesh bags (filled with oyster shells) alone or in combination can be used to increase survival of hard clams of $\geqslant$6 to 8-mm shell height. These techniques do not provide sufficient protection for 2-mm seed. The combination of net + crab trap + shell bag was nearly twice as effective as the net alone when 10-14 mm seed was used and over five times as effective as the net alone when 6-8 mm seed were planted. Survival in excess of 50% slows the growth rate and yields higher percentages of submarketable <25-mm thick (New York legal limit) clams. Local markets and dealers would accept all clams > 22 mm. (Authors' abstract - J.L.M.)

452 MacKenzie, Clyde L., Jr. 1987.

Historical trends in the shellfisheries of Raritan Bay (New York, New Jersey). J. Shellfish. Res. 7(1):40 (abstract).

In the 1800s and early 1900s Raritan Bay had commercial fisheries for five shellfishes, including hard clam *Mercenaria mercenaria*. Oyster and soft clam fisheries have ceased to exist, and hard clam, blue crab, and lobster fisheries have had periods of substantial decline. The hard clam fishery was limited by pollution and increasingly smaller areas of the bay were open for marketing clams. The entire bay was closed in 1961. The eastern end has been reopened for clamming since 1983 when a depuration plant was constructed to process hard clams. These clams can be and have been relayed to clean beds in Barnegat Bay. (Modified author's abstract - J.L.M.)

453 Malinowski, Steve. 1986.

Small-scale farming of the hard clam on Long Island, New York. New York State Urban Dev. Corp., 1515 Broadway, New York, NY 10036, 60 p.

The purpose of this manual is to acquaint the reader with farming techniques to raise hard clams (*Mercenaria mercenaria*). Site selection is the most important decision that must be made. The upwelling system is used to grow very small seed clams to field planting size (5-8 mm). Field growout must provide protection from predators, be inexpensive and easy to maintain. Legal requirements are complex, and a minimum of 3 months is needed to obtain all required permits. Expenses depend on site, culture methods, clam growth, and survival, among other things. Guidelines are: 1) prepare to confront new problems each day, and devise cheap solutions; 2) write everything down; 3) never expect something to work until it actually has; and 4) when things get tough, never lose sight of why you are doing this. The appendix contains criteria for selection of sites. (J.L.M.)

454 Malinowski, Steve. 1987.

Variable growth rates of seed clams, *Mercenaria mercenaria*, in an upflow nursery system: Can production costs be decreased by removing slow-growers. J. Shellfish. Res. 7(1):68-69 (abstract).

The results of the cost-analysis model indicated that removing slow growing animals from the production system would not result in a net reduction in production costs, since the value of the animals discarded exceeded the savings realized by confining production to fast growing individuals. (Modified author's abstract - J.L.M.)

455 Manzi, John J., Nancy H. Hadley, and R.T. Dillon. 1987.

Applied breeding of the hard clam *Mercenaria*: Growth of outbred lines from crosses of selected commercial hatchery stocks. J. Shellfish. Res. 7(1):9 (abstract).

Selected broodstocks from Aquaculture Research Corporation and Virginia Institute of Marine Science were spawned on three occasions at different times of year for production of inbred and reciprocal outbred lines. Growth and survival were monitored at regular intervals for two years and the populations were sampled at one year of age to determine allozyme frequencies. In each trial one of the outcrossed lines demonstrated more rapid growth than the parental lines, but not the same line in each case. Early growth was not a good predictor of subsequent growth. Early growth was strongly affected by the time of spawning, resulting in great disparities between trials. But this difference disappeared by the time the lines reached 18 months of age. There was some indication that the fastest growing lines were more heterozygous than other lines, but no relationship between heterozygosity and rapid growth could be demonstrated within lines. Some of the population reached market size in 18 months and a large portion were market size in two years from spawning, an increase of at least 6 months over growout expectations of South Carolina wildstock. (Modified authors' abstract - J.L.M.)

456 Pline, Marc J. 1984.

Reproductive cycle and low salinity stress in adult *Mercenaria mercenaria* L. of Wassaw Sound, Georgia. Masters thesis, Georgia Inst. Technol., Atlanta, GA 30332, 74 p.

457 Rhodes, Edwin W., Ronald Goldberg, James C. Widman, and Kathryn T. Chiba. 1987.

Hard clam recruitment in Long Island Sound: A life-history approach. J. Shellfish. Res. 7(1):68 (abstract).

Experiments in 1986 were designed to determine whether larval settlement of *Mercenaria mercenaria* occurred at specific sites around the perimeter of Long Island Sound, and the relative growth rate of clams at those sites. Stations were located at the 5-m depth contour, were out of the influence of major riverine inputs or polluted harbors, and were chosen to be relatively uniform in substrate type. Settlement was monitored in 21×21×5 cm plastic boxes, filled with either natural substrate from the site or with a standard sand, and covered with 8-mm plastic mesh. Growth of 10-mm hatchery-reared clams was determined by measuring groups held at a density of $500/m^2$ in 0.4 m^2 plastic-coated wire mesh cages with 8-mm openings. The cages were buried approximately 10 cm into the substrate. Divers were used for all gear deployment and subsequent sampling. *Mercenaria* settlement occurred at all stations, and site differences are discussed. Seasonal growth of planted clams was statistically different at the four Connecticut stations for which complete growth data were obtained. Growth of the clams did not simply reflect known east-west gradients of salinity, temperature, phytoplankton abundance or pollution levels. Based on 1986 results, three sites that produced very different growth results were chosen for further study in 1987. (Modified authors' abstract - J.L.M.)

458 Schubel, J.R., staff, and advisers. 1985.

Suffolk County's hard clam industry: An overview and an analysis of management alternatives. Spec. Rep. 63, Ref. 85-19, by the COSMA prog. of the Mar. Sci. Res. Cent., State Univ. N.Y., Stony Brook, NY 11794, 343 p.

This report was prepared with support provided by Suffolk County through the Suffolk County Planning Commission and by the William H. Donner Foundation. It includes: History and current status of the hard clam (*Mercenaria mercenaria*) fisheries in Suffolk County; A selection of management alternatives for individual water bodies; Information priorities; The hard clam fishery; Histories of Suffolk County's hard clam fisheries; The history of the hard clam fishery of Moriches Bay and Shinnecock Bay; History of the Peconics and North Shore hard clam fisheries. The recreational hard clam fishery in Suffolk County; Hard clam management in New York - a historical overview; Suffolk County's changing coastal environment; Salinity and Great South Bay; Effects of dredging activities on hard clams; Management alternatives; Seed planting; Spawner sanctuaries; Predator control as a means of inmproving hard clam production; Selected closure of harvest grounds; Limited entry and harvest quotas as tools for managing Suffolk County's hard clam fishery; The economics of management alternatives for the hard clam in Great South Bay, New York - Executive summary; Private mariculture; Law enforcement aspects of hard clam management; The hard clam relay ; New Jersey's program and the outlook for Suffolk County; The economics of management alternatives for the hard clam in Great South Bay, New York; and Glossary. (J.L.M.)

459 Walker, Randal L. 1987.

Intertidal populations of four species of whelks (*Busycon*) in Wassaw Sound, Georgia. J. Shellfish. Res. 7(1):22 (abstract).

Hard clams, *Mercenaria mercenaria*, and oysters, *Crassostrea virginica*, occur intertidally in Georgia, and intertidal whelks prey upon these commercially important shellfish, the abundance, migrational and feeding habits of intertidal whelks were studied. A small percentage (8%) of whelks was found actively feeding on these two species, 54% on Mercenaria and 48% on Crassostrea. (Modified author's abstract - J.L.M.)

460 Wikfors, Gary H. 1987.

Algal species ranked as nutritional sources for hard clams. Monthly Highlights, Northeast Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Woods Hole, MA 02543, p. 3.

The Northeast Fisheries Center has compared and ranked, under laboratory conditions, five algal species as nutritional sources for juvenile hard clams (*Mercenaria mercenaria*). A pennate diatom, *Nitzschia* sp., common to eastern Long Island Sound's phytoplankton, promotes rapid growth. But a chain-forming centric diatom does not support growth. - J.L.M.

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Errata

Following are two corrected references from the earlier hard clam bibliography by McHugh et al. (1982) published as NOAA Technical Report NMFS SSRF-756.

22 Allen, E.J., and R.A. Todd. 1900.

The fauna of the Salcombe estuary. J. Mar. Biol. Assoc. U.K. 6(new ser.): 151-217. (Corrected journal title)

405 Croker, R.A., and A.J. Wilson. 1965.

Kinetics and effects of DDT in a tidal marsh ditch. Trans. Am. Fish. Soc. 94(2):152-159. (Corrected page numbers)