Annotated Bibliography

Annotated Bibliography
Of Chesapeake Bay Oyster Literature

Abrahamson, J. D. 1961. Economic aspects of markets for middle Atlantic oysters. Proc. Gulf Carib. Fish. Inst. 13: 128-131.

Examined economic aspects of the oyster industry in post-World War II years. Concluded that oyster production had not met demand, with a consequent decrease in per capita consumption. The supply had set the limit on national consumption. At the same time, prices rose steadily and the industry prospered. However, the market could absorb a greater production. Limits to increased production include loss of oyster grounds, and loss of oysters to disease and predators. Recommended more rental of grounds and increased culture of oysters.

Agnello, R. J. and L. P. Donnelley. 1975a. The interaction of economic, biological, and legal forces in the middle Atlantic oyster industry. Fish. Bull. 73: 256-261.

Discussed the oyster industry along the U.S. East Coast and presented a supply and demand model of the industry. Included consideration of the industry in Chesapeake Bay, concluding that there was evidence of overexploitation in the common property states, with suboptimal use of the natural resource. A footnote indicates that an unpublished study concluded that oystermen's income in 1969 would have increased by about 50% if all coastal states had relied on rental of oyster grounds.

Agnello, R. J. and L. P. Donnelley. 1975b. Prices and property rights in the fisheries. Southern Econ. J. 42: 253-262.

In this general survey of the effects of property right structures on ex-vessel prices and harvest quantities of fisheries, the authors showed that, for or the eastern oyster, common property rights are associated with lower prices and incomes compared with private property right structures. If all oyster resources were declared common property, the harvesters would tend to bring more oysters to market early in the season with unstable prices result-

Watermen unload the day's catch at a seafood processing house
In Cambridge, Maryland.

ing. A combination of common grounds and private holdings should tend to smooth intraseasonal price movements.

Alford, J. J. 1973. The role of management in Chesapeake oyster production. Geogr. Rev. 63: 44-54.

Discussed the role of public misuse of the common property resource of oysters in leading to the persistent and continuing decline of the productivity of the fishery. Described the history of private oyster culture in the Bay. Suggested the imposition of higher oyster taxes on oyster harvesters to overcome the deficits in taxpayer-supported seed and shell planting programs, and tighter controls on harvesting.

Alford, J. J. 1975. The Chesapeake oyster fishery. Ann. Assoc. Amer. Geographers 65: 229-239.

Reviewed both general aspects of oyster ecology in Chesapeake Bay and the effects of pollution. Discussed and compared Maryland and Virginia laws and practices concerning public use versus private rental of oyster bars. Considered the idea that all oyster bottoms be turned over to private culture but concluded that this was not a completely satisfactory answer. Declared that the Chesapeake oyster fishery should be managed as a single unit, with Virginia seed moved to Maryland waters where Virginia production methods (private culture) would be established to supplement production from natural public beds.

Andrews, J. D. 1949. The 1947 oyster strike in the James River. Proc. Natl. Shellfish. Assoc. (1948): 61-66.

Three bars were studied in 1947. Characteristic setting rates prevailed for each bar. No advantage was found for any particular time of shell planting. Settlement was good throughout the river and, although mortalities were high, the set was effective. On the best bar (Wreck Shoal), an average of 314 spat per shell settled during the season, with 14 spat per shell still alive in November 1947.

Andrews, J. D. 1951. Seasonal patterns of oyster setting in the James River and Chesapeake Bay. Ecology 32: 752-758.

In the James River, Virginia, setting was usually continuous for about 90 days, with the period extending from early July to early October. Setting was consistent from year to year with no failures noted during this study. Ninety percent of the set occurred after the first of August, in contrast to other areas of the Bay where setting was generally earlier. Setting peaked in early September. The late set may have been related to the small size of brood oysters or to the scarcity of net plankton.

Andrews, J. D. 1955a. Setting of oysters in Virginia. Proc. Natl. Shellfish. Assoc. 45: 38-46.

Oyster settlement in Virginia waters was generally prolonged from July to early October, depending upon location. Setting was continuous in the James River, nearly so in the York River, but often discontinuous in the Rappahannock River. One peak of setting often occurred in mid-July, with a second in August or September. The later set was more important in the James River and slightly less so in the York River. The early set was most consistent and important in the Rappahannock and perhaps also in Maryland. In any particular season, timing and intensity of setting was similar within any one river system, suggesting that the same broods of larvae provided spatfall for the whole river. Survival rate increased as the strike decreased, or with decreasing salinities up-river, or as the setting season progressed. In Virginia, setting was heaviest near the mouths of rivers, decreasing progressively upriver. It was also heaviest on the left side of the channel (facing downriver); most natural oyster beds were located on this side. Andrews believed that size of brood stock may not be important because the poorly conditioned small oysters of the James produced consistently good sets in contrast to the fat, large Rappahannock oysters which produced generally poorer sets. Andrews stated that there were turns in the rivers ("pockets") which tended to trap larvae.

Andrews, J. D. 1955b. Notes on fungus parasites in bivalve mollusks. Proc. Natl. Shellfish. Assoc. 45: 157-163.

In 1953-54, twelve of sixteen bivalve species were found to be infected with a fungus resembling *Dermocystidium marinum*. These infections disappeared in late winter and early spring. There seemed to be differences among oysters from different areas with regard to their susceptibility to the fungus disease.

Andrews, J. D. 1956. Trapping oyster drills in Virginia. I. The effect of migration and other factors on the catch. Proc. Natl. Shellfish. Assoc. 46. 140-154.

Various attempts to control oyster drills were reviewed briefly. A drill trapping program in the York River revealed some information on behavior, abundances, and lengths of *Eupleura caudata* and *Urosalpinx cinera*. The relative importance of resident and migratory drill populations was not resolved, nor was it demonstrated satisfactorily that trapping was a useful pest control strategy.

Andrews, J. D. 1964. Oyster mortality studies in Virginia. IV. MSX in James River public seed beds. Proc. Natl. Shellfish. Assoc. 53: 65-84.

Between 1959 and 1961, the disease MSX resulted in the death of half of Virginia's privately-planted oyster stock. MSX appeared in the James River seed beds in fall 1960, apparently in relation to saltwater influx along the channel. The disease spread with time, disappearing at the period of lowest salinities. Persistence of the disease in the James River seed area appeared to depend on importation of infective material from saltier waters at the mouth of the River. Thus serious losses result from planting of infected seed in high salinity waters.

Andrews, J. D. 1965. Infection experiments in nature with *Dermocystidium marinum* in Chesapeake Bay. Chesapeake Sci. 6: 60-67.

The effects of proximity of fungus-infected oysters on epizootiology in isolated disease-free oysters was studied in the York River, Virginia. It appeared that proximity to an infected population led to infection of the disease-free specimens. The fungus was active in warm weather and persisted by chance survival through the winter. The fungal pathogen seemed to depend solely on transmission from oyster to oyster for its spread.

Andrews, J. D. 1966. Oyster mortality studies in Virginia. V. Epizootiology of MSX, a protistan pathogen of oysters. Ecology 47: 19-31.

From 1959 to 1963, the pathogen MSX caused high mortalities in oysters in high salinity areas of Chesapeake Bay. Oysters imported from disease-free locations in winter and spring became infected in early summer and died in late summer. Oysters imported in late summer apparently became infected shortly thereafter. However, infections were subclinical until the following spring (May). Mortalities occurred throughout the year but were highest in warmer months. Prevalence of MSX did not decline as the oyster populations died off, resulting in about half of Virginia's oyster beds ceasing production.

Andrews, J. D. 1967. Interaction of two diseases of oysters in natural waters. Proc. Natl. Shellfish. Assoc. 57: 38-49.

In 1965, the author induced and monitored a localized epizootic of the fungal disease *Dermocystidium marinum* in the York River. During the experiments, an epizootic of the sporozoan disease MSX (caused by *Minchinia nelsoni*) persisted, resulting in about 50% mortality in the experimental oyster populations. The author found that imported disease-free oysters in lower York River became infected with *D. marinum* in one to three years. However, during this time, MSX was causing high mortalities and resulting in declines in oyster populations. Thus, *D. marinum* was prevented from becoming epizootic because it depends on direct transmission, and distances of 15 to 100 feet between populations seemed to result in slowed infection rates.

Andrews, J. D. 1968. Oyster mortality studies in Virginia. VII. Review of epizootiology and origin of *Minchinia nelsoni*. Proc. Natl. Shellfish. Assoc. 58: 23-36.

Intensive epizootics of *Minchinia nelsoni* continued in lower Chesapeake Bay, with high mortalities during the initial year of exposure to the disease. Density of oyster population did not seem to be important for disease activity. It appeared that resistance to the disease can be acquired. The author speculated on the origin of the virulent pathogen and implicated seed transplants in the outbreak and spread of the disease.

Andrews, J. D. 1971. Climatic and ecological settings for growing shellfish. In: Price, K. S. Jr., and D. L. Maurer (eds.), Proc. Conf. on Artificial Propagation of Commercially Valuable Shellfish Oysters, pp. 97-107. University of Delaware, Newark, DE.

Reviewed some aspects of hydroclimates and their effects on distribution and biology of commercial bivalves, including Crassostrea *virginica*. Application was made of this information for culture purposes.

Andrews, J. D. 1973. Effects of Tropical Storm Agnes on epifaunal invertebrates in Virginia estuaries. Chesapeake Sci. 14: 223-234.

Passage of Tropical Storm Agnes in June 1972 led to establishment of low-salinity regimes in areas of Chesapeake Bay that did not normally experience such salinities for any extended period of time. Oligohaline species such as oysters were severely stressed and some mortality resulted. However, populations were not exterminated. Oyster drills were largely eliminated from large areas of their habitat, including, apparently, all of the Rappahannock River. Given the lack of a pelagic larval stage for *Urosalpinx cinerea* and *Eupleura caudata*, return of drills to their former habitats was expected to be slow.

Andrews, J. D. 1979. Oyster diseases in Chesapeake Bay. Mar. Fish. Rev. 41(1): 45-53.

The author reviewed three major oyster diseases which affect Virginia oysters: *Dermocystidium* (=*Perkinsus*) *marinum*, *Minchinia nelsoni* and *Minchinia costalis*. The former is a disease of oysters in higher salinity habitats (15 ppt) which is fatal in warm water conditions. It is a “contact” pathogen. *Minchinia nelsoni* (MSX) is also a problem in higher salinities, with oyster mortalities reaching 20-50% annually. Oyster strains resistant to MSX were found to have developed. *Minchinia costalis* affects oysters in salinities above 30 ppt.

Andrews, J. D. and M. Frierman. 1974. Epizootiology of *Minchinia nelsoni* in susceptible wild oysters in Virginia, 1959 - 1971. J. Invert. Pathol. 24: 127-140.

This oyster disease had been studied in Virginia since 1959. It appeared not to be contagious in trays. Mortalities, prevalence and seasonal patterns of disease activity were described. Size, age, source and history of oysters, and timing of exposure all were found to affect disease activity.

Andrews, J. D., D. Haven and D. B. Quayle. 1959. Fresh-water kill of oysters (*Crassostrea virginica*) in James River, Virginia, 1958. Proc. Natl. Shellfish. Assoc. 49: 29-49.

In winter and spring, 1958, fresh water invaded the upper part of the James River seed area, resulting in the deaths of many oysters between May 1 and June 15. Death rates reached 90%. It appeared that oysters could be "conditioned" in nature to such fresh-water inundations if temperatures were low. A "narcotized" condition of no heartbeat or ciliary motion and no mantle sensitivity would result as long as shell closure occurred. Once "broken" at higher temperatures, the "conditioning" appeared to be lost.

Andrews, J. D. and W. G. Hewatt. 1957. Oyster mortality studies in Virginia II. The fungus disease caused by *Dermocystidium marinum* in oysters of Chesapeake Bay. Ecol. Monogr. 27: 1-26.

This is an extensive discussion of research performed on oysters and the seasonally virulent disease caused by the fungus, *Dermocystidium marinum*. The epidemiology of the disease was studied extensively and the results are presented.

Andrews, J. D. and J. L. McHugh. 1957. The survival and growth of South Carolina seed oysters in Virginia waters. Proc. Natl. Shellfish. Assoc. 47: 3-17.

South Carolina oysters were held in Virginia waters and mortality and growth were monitored. These southern oysters were susceptible to winter low temperatures. They grew no better than did native oysters and yields were smaller. They were more resistant to fungal disease (*Dermocystidium* (=*Perkinsus*) *marinum*).

Andrews, J. D. and J. L. Wood. 1967. Oyster mortality studies in Virginia VI. History and distribution of *Minchinia nelsoni*, a pathogen of oysters, in Virginia Chesapeake Sci. 8: 1-13.

In 1959, the sporozoan, *Minchinia nelsoni*, was the cause of an epizootic among York River, Virginia, oysters. By 1960, high mortality had occurred on all lower Chesapeake Bay oyster grounds. A record-breaking drought from 1963-1965 allowed for the extension of the epizootic further up Chesapeake Bay and its tributaries. Oyster grounds in Virginia were classified into four groups according to intensity of MSX activity.

Andrews, J. D., J. L. Wood and H. D. Hoese. 1962. Oyster mortality studies in Virginia III. Epizootiology of a disease caused by *Haplosporidium costale* Wood and Andrews. J. Insect Path. 4: 327-343.

An epizootic disease on the seaward side of the Eastern Shore peninsula of Virginia (Seaside) was associated with *H. costale*. The disease caused oyster mortality in May-June. Oysters transplanted from James River, Virginia to Seaside suffered higher mortalities after a year of acclimation than did native oysters. On the Bay side of the peninsula, *Dermocystidium marinum* caused mortalities in late summer. Neither disease was found where the other occurred.

Bahner, L. H., A. J. Wilson, Jr., J. M. Sheppard, J. M. Patrick, Jr., L. R. Goodman and G. E. Walsh. 1977. Kepone bioconcentration, accumulation, loss and transfer through estuarine food chains. Chesapeake Sci. 18: 299-308.

Experiments in static and flow-through bioassays indicated that oysters would concentrate kepone both from water and from kepone-contaminated *Chlorococcum* algae. Oysters concentrated kepone up to 10,000 times exposure concentrations within 19 days. They cleared the chemical from their bodies rapidly. No kepone was detected within 7-20 days from the end of exposure for oysters that had been held in kepone-dosed water and within 10 days from the end of exposure to kepone-contaminated algae.

Bahr, L. M. and R. E. Hillman. 1967. Effects of repeated shell damage on gametogenesis in the American oyster, Crassostrea *virginica* (Gmelin). Proc. Natl. Shellfish. Assoc. 57: 59-62.

Two groups of oysters held in Patuxent River water were treated by having their growing edges filed repeatedly over time. One of these groups and an untreated control were held in filtered river water (unfed). The other filed group and a control were held in unfiltered river water (fed). After 8 months, histological preparations were made of the gonads of all four groups. Unfed oysters had less developed gonads than did fed oysters. The filed and undamaged groups were generally similar, although it seemed that lack of food depressed gametogenesis in unfed filed oysters to a greater extent than in the unfed controls. Both filed groups (fed and unfed) had a higher proportion of male oysters than did the undamaged groups.

Barrow, J. H., Jr. and A. C. Taylor. 1966. Fluorescent-antibody studies of haplosporidian parasites of oysters in Chesapeake and Delaware Bays. Science 153: 1531-1533.

A fluorescent antibody was produced against the haplosporidian parasite of oysters, *Minchinia nelsoni*. No reaction occurred with *Minchinia costalis*, indicating that the two species were antigenically distinct.

Beaven, G. F. 1945. Maryland's oyster problem. Maryland Board of Natural Resources, Dept. of Research and Education, Solomons Island, Md., Educational Series, No. 8: 1-14.

Discussed the problem of depletion of the oyster resource, which was then less than one-fifth of the production at its peak in the 1880's. Described instances where local politics or pressure from watermen concerning shell plantings led to management action which was a waste of money and oyster shell. Recommended remedial action involving oyster culture and private leasing.

Beaven, G. F. 1947. Effect of Susquehanna River stream flow on Chesapeake Bay salinities and history of past oyster mortalities on upper Bay bars. Proc. Natl. Shellfish. Assoc. (1946): 38-41.

North of Kent Island, quantities of slow-growing small oysters used to be available for canning purposes. Production on the bars was erratic and heavy mortalities often occurred. These mortalities were linked, not to pollution from Baltimore, but to periods of long-term depression of salinity as a result of high run-off from the Susquehanna River.

Beaven, G. F. 1948. Observations on fouling of shells in the Chesapeake area. Proc. Natl. Shellfish. Assoc. (1947): 11-15.

Principal fouling organisms included bryozoans, barnacles, hooked mussels, tunicates, sponges, tube worms, folliculinids, hydroids, algae and bacteria Bryozoans and barnacles appeared to be the major species with the potential of inhibiting settlement of oysters. Boring sponges eroded shell, leading to decrease in "cultch efficiency." An organic film of diatoms, algae and bacteria may also have deterred settlement. Experiments comparing spat settlement on new shell plantings with settlement on the previous year's plantings revealed greater set on the newer shell.

Beaven, G. F. 1950. Growth observations of oysters held on trays at Solomons Island, Maryland. Proc. Natl. Shellfish. Assoc. (1949): 43-49.

Growth rate was found to vary with region in Chesapeake Bay. For example, in some seed areas in Maryland, few oysters reached legal size even by 6 years

of age. In contrast, in Pocomoke Sound, a heavy oyster set led to many individuals being 3” long by the end of the setting year and 6” long by the second fall. Wide variations in growth of seed oysters after transplanting to other bars, or from year to year, were described. This study followed growth of oysters from 9 locations in Maryland, Virginia, New Jersey, Connecticut and North Carolina which were held in trays at Solomons from 1947 to 1949. In general, growth was greater in fall than in spring and very poor in summer 1948. Mortality was greater for oysters transplanted from higher salinity water. There was greater growth variation among individuals within a group than for between-group averages. All groups contained small oysters (“runts”) which made little noticeable growth during the two years of study.

Beaven, G. F. 1951. Recent observations on the season and pattern of oyster setting in the middle Chesapeake area. Proc. Natl. Shellfish. Assoc. (1950): 53-59.

Set in 1949 was somewhat better than average, with setting very poor along the upper western shore and in the major rivers except near their mouths. However, in the productive St. Mary’s River, setting intensity increased upriver. Spat counts on planted shell were generally higher than on old cultch in the same areas. Similarly, newly planted shell usually received heavier set than older, heavily fouled shell. Plankton sampling coupled with use of shell bags for spat enumeration indicated that areas with limited spatfall had few larvae present. Comparisons between the Solomons region and St. Mary’s River revealed an extended period (June-October) of light setting at Solomons versus a peak 2- to 3-week period in St. Mary’s River. At Solomons, many oysters retained their spawn into fall or early winter, whereas in St. Mary’s River, nearly all oysters were spawned out after the July setting peak and remained thin until cold weather. Areas of high setting typically were somewhat landlocked with limited water exchange. Brood stock was generally found in densely populated groups, probably being more abundant in proportion to water volume than in poorer setting areas.

Beaven, G. F. 1952. A preliminary report on some experiments in the production and transplanting of South Carolina seed oysters to certain waters of the Chesapeake area. Proc. Gulf Carib. Fish. Invest. 5: 115-122.

The author described a major problem in Maryland: that of securing a sufficient supply of seed oysters. The resources in the upper Bay and upper Potomac River had been destroyed by recurring freshets. Sale of James River seed was periodically banned to out-of-state buyers. Pamlico Sound stock had been depleted and its sale restricted. Thus, use of newly-set spat as seed oysters had expanded as “shell plants” were scattered in good growing areas by the State. The author studied the survival and growth of South Carolina seed oysters. Survival was negligible at Solomons or Crisfield when transplanted in November, but was better for seed transplanted in July. Survival was also good in parts of Chincoteague Bay. Survival was generally better in higher salinities.

Beaven, G. F. 1953. Some observations on rate of growth of oysters in the Maryland area. Proc. Natl. Shellfish. Assoc. 43: 90-98.

Reiterated the existence of significantly different growth among the State's oyster bars, among groups of seed from different sources, and from year to year on the same bar. Often in winter there was a recession in length Growth was greater in fall than in spring. Growth in seed areas was generally lower than on growing bars. In the Patuxent River, growth in the upper river was greater than in the lower river. In general in Maryland, it took three years for oysters to reach legal size (3" or 76 mm). However, in some areas, some individuals reached 3" in a year and 6" in two. Quick growing oysters were thin-shelled and easily broken. Growth was more rapid in Chincoteague Bay than in Chesapeake Bay (none of these data were compared statistically).

Beaven, G. F. 1955. Various aspects of oyster setting in Maryland. Proc. Natl. Shellfish. Assoc. 45: 29-37.

Grouped Maryland oyster beds into three classifications: (1) bars on which high quality oysters grew but on which recruitment did not replace harvest losses. Many such bars were depleted and needed to be maintained by seed plantings; (2) limited areas of self-sustaining bars where recruitment balanced harvest losses. These produced most of Maryland's natural yield (at the time of writing); (3) a small number of bars which received intensive sets resulting in overcrowded oysters which could be used as seed oysters. Setting rate in Maryland increased from the upper limit of oyster growth down to the Virginia border, and from upper to lower reaches of tributaries with fairly large stream flow. In many small estuaries in the Bay with little or no drainage or salinity gradient, setting typically was heavier in their upper reaches than near their mouth. Setting was greater on the eastern shore compared with western shore. Setting variations were common from bar to bar, or from one part of a bar to another (better along the shallow or inshore margin of a bar than along its deeper edges). Maryland setting extended from late May into October with a marked peak of about two weeks' duration from late June to September (usually in July). In a few places the principal set occurred in fall. Oysters in tributary and shallow waters usually were the first to spawn, with those in deeper or open water spawning later. Many scattered oysters on deep bars of the Bay or large tributaries may not spawn. Barnacle sets inhibited successful oyster set. The limited areas of high oyster set were believed to be comparatively free from heavy growths of bryozoans and barnacles. Presence of larger quantities of brood stock in the more numerous eastern shore tributaries may have increased the setting potential of the area. Periods of high salinity and fertile water seemed to be favorable for production and growth of oyster larvae. Semi-enclosed areas with slow water movement seemed to lead to high setting and abundant brood stock. This could occur behind or between islands or in sluggish tributaries. Presence or absence of suitable larval food may have influenced setting success. Historically, setting intensity seemed to have declined with time.

Bender, M. E., R. J. Huggett and H. D. Slone. 1972. Heavy metals—an inventory of existing conditions. J. Wash. Acad. Sci. 62: 144-153.

Oysters were surveyed from February to May 1971 in Virginia's Chesapeake Bay and were analyzed for presence of zinc, copper and cadmium. Oysters were also collected in fall 1970 and spring and summer 1971 for mercury determinations. Human influences in some of the metal values noted were discussed.

Bockrath, J. and D. Wheeler. 1975. Closed-cycle mariculture in Maryland, Virginia, and Delaware: An examination of the adaptability of existing fishery laws to new technology. William and Mary Law Review 17: 85-107.

Recent rapid advances in closed-cycle mariculture technology may place strains on laws which were promulgated to regulate natural fisheries at a time when such technology was undreamt of. It appears that Delaware has drafted fishery laws which would readily accommodate closed cycle mariculture of molluscs. In Maryland and Virginia, somewhat ambiguous wording and intent of some aspects of the law (i.e., enactments dealing with leasing of subtidal land) make for uncertain application of these statutes to closed-cycle mariculture. This discourages development of any new industry. The adoption of new statutes would be necessary to encourage closed-cycle mariculture in these two states.

Boon, D. D. 1972. The red pigment in discolored oysters and soft-shelled clams from the Chesapeake Bay. Chesapeake Sci. 13: 334-335.

In winter 1970-71, some oysters from Chesapeake Bay had a red discoloration. This was caused by a red pigment which appeared to be a carotenoid, presumably derived from a plant in the oysters' food.

Boon, D. D. and M. C. Tatro. 1971. Blowing oysters for increased salt content. Chesapeake Sci. 12: 51-52.

Washing oysters in fresh water agitated by air ("blowing") resulted in loss of salt content. Blowing oysters in salt solution restored this salt, which added to consumer appeal. However, oysters blown in salt water lost some of their initial weight.

Breisch, L. L. and V. S. Kennedy. 1980. A Selected Bibliography of Worldwide Oyster Literature. Maryland Sea Grant No. UM-SG-TS-80-11. College Park, Md. 309 pp.

This extensive volume of material covers literature on numerous species of oysters from around the world and includes over 3,700 entries.

Brooks, W. K. 1879. Abstract of observations upon artificial fertilization of oyster eggs and embryology of American oysters. Amer. J. Sci. 18: 425-427.

An early report that oyster eggs could be fertilized and developed into the larval stage in the laboratory.

Brooks, W. K. 1891. The Oyster. A Popular Summary of a Scientific Study. The Johns Hopkins Press. 225 pp. (Second edition, 1905).

In this comprehensive, semi-popular account of his research, Brooks described the anatomy, development and artificial cultivation of oysters. He discussed the problem of continued decline in oyster catch in Chesapeake Bay, relating this to overfishing. He encouraged private cultivation of oysters, providing many cogent arguments to show the sensibility of renting oyster beds, the results of which could answer many of the problems facing the fishery. The problems still exist and his recommendations are still valid.

Burrell, V. G., Jr. and W. A. Van Engle. 1976. Predation by and distribution of a ctenophore, *Mnemiopsis leidyi* A. Agassiz, in the York River estuary. Est. Coastal Mar. Sci. 4: 235-242.

The tentaculate ctenophore, *Mnemiopsis leidyi*, occurred in the York River estuary during a 22 month study period (Aug. 1965-May 1967). Numbers of small plankters varied inversely with ctenophore volume, suggesting a negative (predatory) effect of the ctenophores on the plankters. Bivalve larvae (not identified, but presumably including oyster larvae) were found in 13% of the ctenophore stomodaea examined.

Burton, R. W. 1963. Distribution of oyster microparasites in Chesapeake Bay, Maryland, 1959-1960. Proc. Natl. Shellfish. Assoc. 52: 65-74.

The author examined 663 oysters collected from 165 oyster beds in 1959 and 1960. The parasites included *Nematopsis ostrearum* (in 82 oysters), *Bucephalus cuculus* (in 12), *Hexamita* sp. (in 4), *Ancistrocoma* sp. (in 4), *Dermocystidium marinum* (in 13), and “MSX” (in 12). Bacteria in dense concentrations were also found in seven oysters. The author concluded that upper Chesapeake Bay was relatively free of oyster parasites.

Butler, P. A. 1949a. Gametogenesis in the oyster under conditions of depressed salinity. Biol. Bull. 96: 263-269.

Extensive flooding of upper Chesapeake Bay by Susquehanna River water in summer 1945 and spring 1946 led to fresh water covering oyster beds in this area for protracted periods. Histological studies revealed that gametogenesis was inhibited in 90% of the surviving population of oysters until salinities exceeded 6 ppt. Thereafter, oyster condition improved rapidly, but gametogenesis lagged behind that of a control higher-salinity population by 3-4 months. This suppressed gonadal activity was attributed by Butler to variations in food availability, perhaps due to salinity inhibition of feeding activity.

Butler, P. A. 1949b. Effects of flood conditions on the production of spawn in the oyster. Proc. Natl. Shellfish. Assoc. (1948): 78-81

In 1948, floods in upper Chesapeake Bay caused extensive oyster mortality. In May, a bushel of dredged shell contained 50 - 100 oysters, but by October it was necessary to examine 2-3 bushels to obtain 25 live oysters. The shells were clean because of death of fouling organisms. From May-July, gonads (examined microscopically) generally were resting or indifferent for 50% of the samples, in early development phase for 40%, and ripe for 10%. In August, ripening accelerated and larvae were collected in plankton samples. This occurred as salinities started to increase to 6 ppt and then gradually to 13 ppt. Butler suggested that low salinities inhibited feeding and thus gonad development.

Butler, P. A. 1956. Reproductive cycle in native and transplanted oysters. Proc. Natl. Shellfish. Assoc. 46: 75.

Six-month-old Chesapeake oysters were transferred to Pensacola, Florida, and held for one year. Gonad histology and reproductive behavior were observed for the transplanted population and compared with gametogenesis and spawning in native populations in Chesapeake Bay and Pensacola. The transplanted oysters began spawning and mass spawning occurred at a temperature that was 5°C above that for the parent stock. The spawning period was extended from the normal period of 3 1/2 months for native Chesapeake oysters to 5 months for transplanted oysters.

Cabraal, R. A. 1978. Systems analysis of the Maryland oyster fishery: production management and economics. Ph.D. dissertation, Agricultural Engineering, University of Maryland. 318 pp.

Developed a big-economic model of the Maryland oyster fishery. A computerized data bank of economic, production, and management information on the fishery was organized (a computer listing is included in an appendix).

Factors affecting the productivity of the fishery were evaluated. Oyster population sizes of Eastern Bay, Chesapeake Bay mainstem, Potomac River, Patuxent River, Tangier Sound, and other areas were estimated using the Leslie and DeLury equations. Production functions, relating catch to effort, lagged spatfall, and seed and shell plantings were developed for all regions. Quality of available data and the effectiveness of resource management policies within the fishery were evaluated. Fresh shell was judged the most successful planting material. The demand equation indicated that oysters had a unitary demand elasticity.

Cabraal, R. A. and F. W. Wheaton. 1981. Production functions for the Maryland oyster fishery. Trans. Amer. Soc. Agri. Eng. 24: 248-251, 254.

Using seed planting, shell planting, spatfall and fishing effort data, production functions were developed for or Eastern Bay, Chesapeake Bay mainstem, Potomac River, Patuxent River, and Tangier Sound. Results from these functions were then used to analyze the effectiveness of state operated seed and shell planting programs. The repletion program was found to have significantly increased oyster production although with varying degrees of success. The effectiveness of fresh shell versus seed planting in terms of both dollar and harvestable bushels of oysters returned was assessed. Fresh shell plantings were the most successful planting material.

Calder, D. R. and M. L. Brehmer 1967. Seasonal occurrence of epifauna on test panels in Hampton Roads, Virginia. Int. J. Oceanol. Limnol. 1: 149-164.

Asbestos fiber panels were submerged to a depth of 5 m. While oysters settled from August to October, they were a minor fouling species.

Carter, H. H. 1967. A Method for Predicting Brood Stock Requirements for or Oyster (*C. virginica*) Producing Areas with Application to the Manokin River. Chesapeake Bay Institute, The Johns Hopkins University, Spec. Rep. 13. 46pp.

In an effort to determine the optimum relative positions of brood stock and planted cultch in order to establish a seed bed in the Manokin River, the author performed a dye study to follow current patterns over a 14-day period in July-August 1967. Using the results obtained from drogue studies, the tracking of the spread of the fluorescing dye, and examination of river discharge and salinity data, the author determined that the Manokin River could be divided into three different areas with different circulation patterns. Upstream, the river mode was important, with outflow at the surface and salinity-mediated inflow on the bottom. At the mouth of the river, wind effects were important, with surface inflow and bottom outflow. A transition area occurred between the upriver and river-mouth areas. The Manokin system was thus similar to that described for St. Mary's River on the Potomac. The author was able to recommend a site for placement of brood stock and a more upriver site for placement of cultch.

Castagna, M. and P. Chanley. 1973. Salinity tolerance of some marine bivalves from inshore and estuarine environments in Virginia waters on the western mid-Atlantic coast. Malacologia 12: 47-96.

The oyster, C. virginica, was included in this compendium of information. Selected references describing its salinity tolerances were discussed. The authors did not treat C. virginica experimentally as they did other species in this report.

Chesapeake Biological Laboratory. 1953. The Commercial Fisheries of Maryland (A special report to the General Assembly of Maryland). Board of Natural Resources, Dept. of Research and Education, Solomons Island, MD. 45 pp.

This special report was prepared in response to a joint resolution of the Maryland General Assembly (1951) calling for general information on the fisheries of the state. Concerning the oyster, the report declared that the best methods of culture would yield 40 million bushels of oysters. The limiting factors to such production were not biological, but social and political. Depletion of oyster grounds was attributed to overfishing as a major factor, with other factors (siltation, increased fresh-water runoff up-Bay, pollution of some areas) having a lesser influence. The report recommended encouragement of private cultivation, conservation of shell for cultch, expansion of a seed-production program, and continued research to provide knowledge for appropriate management of the resource.

Christensen, D. J. 1973. Prey preference of *Stylochus ellipticus* in Chesapeake Bay. Proc. Natl. Shellfish. Assoc. 63: 35-38.

The hypothesis of "ingestive conditioning" in *S. ellipticus* was investigated in 1969 using oysters and barnacles. When flatworms were segregated on the basis of prey utilized at the time of collection (i.e., worms feeding on oysters vs. worms feeding on barnacles), barnacle eating flatworms did not feed on oysters, even when no other choice was available. Oyster-eating flatworms fed on oysters or barnacles, but to a greater extent on oysters. Only rarely did oyster-eating worms feed on barnacles if oysters were available. The author concluded that barnacles were the preferred prey under most circumstances because some worms became conditioned to the lack of oysters but not to the lack of barnacles.

Christy, F. T. 1964. The exploitation of a common property natural resource: the Maryland oyster industry. Ph.D. Dissertation Univ. of Michigan. 222 pp.

Discussed common property natural resources in general (effects on the resource, economic consequences, associated public costs). Considered Maryland's oyster industry and its characteristics, and discussed the consequences of the public fishery. Considered alternative management strategies and recommended consideration of "exclusive use" rights. This would allow economically proper allocation of capital and labor resources. Innovative technology would be encouraged. The public would not bear the costs of cultivation and management. Suggested gradual restriction on the number of producers through use of direct license limitation and monetary disincentives.

Colwell, R. R., S. G. Berk, G. S. Sayler, J. D. Nelson, Jr., and J. M. Esser. 1975. Mobilization of mercury by aquatic microorganisms. In: T. C. Hutchinson (ed.), Proc. Int. Conf. on Heavy Metals in the Environment. Institute for Environ. Studies, Univ. Toronto, pp. 831-843.

A simplified food chain involving bacteria and C. virginica was established in the laboratory. Concentrations of ^{203}Hg were found to be 200 times greater in tissue from organisms held in an environment containing mercury-metabolizing bacteria than in controls without these bacteria

Colwell, R. R. and G. S. Sayler. 1977. Effects and Interactions of Polychlorinated Biphenyl (PCB) with Estuarine Microorganisms and Shellfish. USEPA. Ecological Research Series. EPA-600/3-77-070. Gulf Breeze, Fl. 45 pp.

PCBs were found to be present in samples of Chesapeake Bay surface water and sediment. Number of bacteria grown in presence of PCB was found to be positively correlated with presence of PCS in the water or sediment. Acute PCB stress led to a decrease in depuration of *E. coli* and *Salmonella typlimurium* by the oyster C. virginica, although net accumulation of these bacteria was not affected.

Commission of Tidewater Fisheries. 1948. Report on the oyster problem in the Chesapeake Bay. Fourth Ann. Rep. Md. Board of Nat. Res., Annapolis, Md. pp. 27-39.

The Commission blamed the long-term decline in oyster production on harvesting oysters at a rate exceeding the rate of replenishment by natural reproduction. The state oyster-farming program involved in development of seed areas was described. The 20¢ bushel tax on harvested oysters was judged to be insufficient to support the seed enhancement program. A long-term, appropriately funded rehabilitation program was considered to be necessary

in order for the oyster fishery to increase in productivity. However, the Commission recognized the political difficulties in such a long-term program. They suggested as an alternative that depleted oyster grounds be opened to private cultivation. They noted that other oyster-producing states had been unsuccessful in sustaining a public fishery and had resorted to private oyster farming. Such private management would allow private moneys to be substituted for state subsidies. Seed production and seed transfer could be enhanced; supply of market oysters could be stabilized. A private oyster farmer could probably devote more care and attention to his holdings compared with the more general attention the state could afford to provide.

Cory, R. L. 1967. Epifauna of the Patuxent River estuary, Maryland, for 1963 and 1964. Chesapeake Sci. 8: 71-89.

Panels of wood and of black asbestos-cement placed 0.1 m above the bottom at 6 stations along the Patuxent River collected very few oysters, despite the presence of beds of oysters in the river.

Crisp, D. J. 1967. Chemical factors inducing settlement in Crassostrea *virginica* (Gmelin). J. Anim. Ecol. 36: 329-335.

Experiments on oysters cultured in York River, Virginia, revealed that the removal of shell periostracum and outer layers of organic matrix rendered oyster shell less favorable for spat settlement. Body extracts made shell somewhat more favorable for settlement. This was related by the author to gregariousness of settlement in this species, with the larvae presumably recognizing both soluble material coming from living oysters and the insoluble organic layer of the shell. Oyster larvae settled preferentially on the underside of shells and on the smooth inner surf ace.

Drifmeyer, J. E. 1974. Zn and Cu levels in the eastern oyster, Crassostrea *virginica*, from the lower James River. J. Wash. Acad. Sci. 64: 292-294.

In 1973, oysters from the Craney Island area of the lower James River contained up to 10,000 ppm zinc and 584 ppm copper, with average levels of 3,915 ppm zinc and 180 ppm copper. This was an increase over data collected in 1971.

Dunnington, E. A., Jr. 1968. Survival time of oysters after burial at various temperatures. Proc. Natl. Shellfish. Assoc. 58: 101-103.

Oysters were buried 3” deep in containers held in running salt water at five temperature ranges. At less than 5°C, oysters lived over 5 weeks while buried. At 10°-15°C, mortality occurred at 3 weeks, increasing thereafter. At 15°-20°C, most oysters survived for 1 week but all had died after 2 weeks.

Over 25°C, mortality occurred after 2 days, becoming almost total within a week. In declining temperatures (24° to 18°C), the pattern resembled that at 25°C.

Dupuy, J. L. and S. Rivkin. 1970. Cultch-free spat present and future. Proc. Ann. Workshop World Mariculture Soc. 1: 157-158.

This paper introduced the vertical use of frosted Mylar sheets for attachment of newly setting spat.

Dupuy, J. L. and S. Rivkin. 1972. The development of laboratory techniques for the production of cultch-free spat of the oyster, Crassostrea *virginica*. Chesapeake Sci. 13: 45-52.

Methods for successful conditioning and spawning of Chesapeake Bay oysters in 4-6 weeks were outlined. In addition, two methods of producing cultch-free spat were described. The first method was of value in relatively clear estuarine areas. It involved periodic use of small underwater jets of Bay water (every 2 hours) to remove spat from setting trays. The second method was employed in regions with high siltation and fouling. Oyster spat settled on Mylar sheets which, after a few weeks, were shaken over and dipped into a container of water to release the spat.

Dupuy, J. L., S. Rivkin and F. D. Ott. 1973. A new type of oyster hatchery. Proc. Ann. Workshop World Mariculture Soc. 4: 353-368.

Hatchery techniques were described for (a) conditioning oysters to spawn when desired all year; (b) raising oyster larvae year round, with setting in 14 days; (c) production of cultch-free spat (20-25 mm long) for field planting. A continuous flow system (20 liters min^{-1}) for production of pasteurized algal medium used to promote growth of three new algal species (oyster larval food) was described.

Dupuy, J. L., N. T. Windsor and C. E. Sutton. 1977. Manual for Design and Operation of an Oyster Seed Hatchery for the American Oyster Crassostrea *virginica*. Virginia Institute for Marine Science, Spec. Rep. No. 142. 111 pp.

This is an extensive manual outlining steps and procedures for rearing oysters from the initial conditioning of adults to holding of spat. Described are culture facilities, algal culture techniques, and personnel and economic matters.

Earle, S. 1932. The fisheries of Chesapeake Bay. Trans. Amer. Fish. Soc. 62: 43-49.

In this brief report, the author recounted some of the history of the oyster fishery, including the earlier confrontations between scoff-law dredgers and the oyster police, and some of the remedies undertaken to halt the production decline of oysters.

Engle, J. B. 1947. Commercial aspects of the upper Chesapeake Bay oyster bars in light of the recent oyster mortalities. Proc. Natl. Shellfish. Assoc. (1946): 42-46.

Considered reproduction, setting and mortality of oysters from beds in the "Head of the Bay" region (north of a line drawn from the Chester River to Sandy Point). Low salinities in 1944 and 1945 retarded gonad development, inhibited spawning, discouraged setting and resulted in extensive mortality. In 1944, as salinities rose in summer and fall, growth was better than usual.

Engle, J. B. 1948. Distribution of setting guides the Maryland oyster program. Proc. Natl. Shellfish. Assoc. (1947): 16-20.

Summarized results of a research program in Chesapeake Bay: (1) there was a wide range of setting intensity from one area to another; (2) setting was more regular in some areas than in others; (3) setting tended to be heavier on the eastern side of the Bay than on the western side; (4) setting seemed to be heavier in lower portions of rivers and the Bay than upstream or in the "Head of the Bay" (above the present Bay bridge) section. Consistently good sets in three areas (St. Mary's River, Holland Straits in Tangier Sound, Eastern Bay) led to their receiving intensive shelling to encourage seed production. This was important because large portions of the oyster area did not receive adequate natural set and overfishing had depleted oyster bars. In addition to the seed production areas, cultch was placed in areas of Fishing Bay, Tangier Sound and the Choptank River and tributaries to allow for spat settlement to restock the beds.

Engle, J. B. 1951. The condition of oysters as measured by the carbohydrate cycle, the condition factor and the percent dry weight. Proc. Natl. Shellfish. Assoc. 41: 20-25.

A wide range of quality of oyster meat could be found from one location to another, and even on different parts of one oyster bar. The glycogen cycle in Chesapeake Bay followed a cyclic or seasonal pattern. The glycogen level dropped in late spring as gametogenesis occurred. As spawning occurred the lowest glycogen level was reached. After spawning ended, glycogen reaccumulation occurred. Engle recommended that oyster harvesting begin after mid-October to allow for glycogen buildup.

Engle, J. B. 1956. Ten years of study on oyster setting in a seed area in upper Chesapeake Bay. Proc. Natl. Shellfish. Assoc. 46: 88-99.

Reviewed an extensive State and Federal research program designed to reverse the decline in Maryland's oyster industry. Current seed areas were Millhill in Eastern Bay, Cinder Hill in Holland Straits, Seminary Bar and Gravelly Run in St. Mary's River, and Punch Island in Chesapeake Bay. Most of these seed areas were in tributaries. Indicated that the minimum spatfall which could be moved economically as seed was 500 spat per bushel or about 1 spat per shell. These counts were determined in the fall after summer mortalities had occurred. Weekly plankton sampling in Eastern Bay revealed a positive correlation of numbers of spat set and average number of late-stage larvae per 100 litres of water pumped. Noted positive correlation of spat set with "cleanliness" (fouling condition) of shell (older shell had fewer spat; however, no statistical treatment was applied and some of the figures seem very similar - ed.)

Engle, J. B. 1958. The seasonal significance of total solids of oysters in commercial exploitation. Proc. Natl. Shellfish. Assoc. 48: 72-78.

Over a ten-year period, percent dry weight and total solids of oyster samples were measured at least monthly. Lowest solids regularly occurred in August; highest solids occurred in November-December. During a period of unusually low salinity (Aug. 1946), solids reached their lowest point. For best harvesting, the times for optimum quality of oysters were late fall and late spring.

Engle, J. B. 1966. The molluscan shellfish industry: Current status and trends. Proc. Natl. Shellfish. Assoc. 56: 13-21

A brief review of the U.S. shellfish industry, focusing on the varieties of oysters, clams and scallops. With regard to the oyster, the decline in production in Chesapeake Bay and the increase in production in the Gulf and Pacific regions were described. As to Chesapeake Bay, Engle mentioned the change from the time when George Washington and other landowners bought or gathered oysters to provide for their slaves' food, through the period when oysters were commonly eaten at home (often at least once a week) or when dining out, to the time of writing when such customs were not being maintained.

Engle, J. B. and C. R. Chapman. 1952. Oyster condition affected by attached mussels. Southern Fisherman (August): 28-30.

On some oyster grounds in Chesapeake Bay, the hooked mussel, *Ischadium* (=*Brachidontes*) *recurvum*, forms dense colonies attached to live oysters. The authors found that oysters with attached mussels were characteristically more elongate than were mussel-free controls. More meat, relative to shell, was produced in mussel-free oysters, with these oysters having a condition factor about 28% better than the condition factor of oysters with attached mussels.

Engle, J. B. and A. Rosenfield. 1962. Progress in oyster mortality studies. Proc. Gulf Carib. Fish. Inst. 15: 116-124.

A short historical and technical review of disease-induced mortality in Chesapeake Bay oysters, including descriptions of the research underway at the NMFS Laboratory at Oxford, Md.

Fairbanks, W. L. 1932. The Fisheries of Maryland. Maryland Development Bureau, Baltimore Association of Commerce, Baltimore, MD. 140 pp.

With regard to the oyster fishery, the report urged the extension of private culture as a sound business practice. A brief overview of the history of oyster grounds rental from 1906 to 1930 includes statistics on numbers of leaseholders, acres of bottom rented, distribution by county, size of holdings, production from the grounds, etc. The problems of seed oyster production was also reviewed. The poor condition of seed beds was attributed to the past practice of exporting large quantities of oysters in the shell, with immature oysters included, leading to the depletion of the seed beds and associated cultch. Some recommendations included providing the Conservation Department full authority to resurvey and reclassify disused oyster grounds in order to allow for greater production through private culture; more money and authority for the Conservation Department to use in development of large areas of seed beds; an increase in maximum area of bottom that could be rented for private culture; repeal of the prohibition on corporations and joint-stock companies with regard to rental of oyster grounds for private culture; amend the leasing laws to require actual planting of shells, oysters or cultch on private bottom within specific time periods and in specific quantities.

Farley, C. A. 1975. Epizootic and enzootic aspects of *Minchinia nelsoni* (Haplosporida) disease in Maryland oysters. J. Protozool. 22: 418-427.

This disease was studied for an 8 year period (1961-1968) using oysters from Marumsco Bar, Pocomoke Sound, Maryland. The author reviewed the life cycle stages, gross pathology and histopathologic aspects of the disease. He discussed mortality, incidence and prevalence and related these to environmental factors such as salinity and temperature. Genetic resistance to the disease appeared to be increasing during the period of study.

Frazier, J. M. 1972. Current status of knowledge of the biological effects of heavy metals in the Chesapeake Bay. Chesapeake Sci. 13 (suppl.): S149-S153.

A brief summary of studies concerning heavy metal uptake, concentrations, and effects on Chesapeake Bay organisms, including Crassostrea *virginica*.

Frazier, J. M. 1975. The dynamics of metals in the American oyster, Crassostrea *virginica*. I. Seasonal effects. Chesapeake Sci. 16: 162-171.

Hatchery reared oysters maintained in the Rhode River estuary were sampled monthly from September 1971 to May 1973 and seasonal dynamics of Mn, Fe, Zn, Cu and Cd were determined. Concentrations of Mn and Fe in soft tissues were found to be correlated with the deposition of shell, whereas concentrations of the other three metals were not. Thus, the aspects of Mn and Fe metabolism in the oyster were closely involved with processes of shell growth. The rapid discharge of Zn, Cu and Cd in summer and fall implicated reproductive activities such as spawning with the seasonal variation of these metals in oyster tissue.

Frazier, J. M. 1976 The dynamics of metals in the American oyster, Crassostrea *virginica*. II. Environmental effects. Chesapeake Sci. 17: 188-197.

Hatchery reared oysters were held in the Rhode River estuary (September 1972-August 1973) at two locations—one with little human impact (controls) and one subject to much human activity with metal contamination resulting. Growth of both populations was similar, but the metal-exposed population had shells which became significantly thinner (16%) than those of controls. Metal uptake by soft tissues was rapid in summer and fall but was slower in spring. Concentrations of Zn and Cu in soft tissues were higher in metal-exposed oysters than in controls.

Frey, D. G. 1945. Oyster Conservation Problems on the Potomac River. Proc. Natl. Shellfish. Assoc. Vol. 35: 3 pp.

The Potomac River oyster fishery was initially regulated and managed as a result of the compact of 1785 between Maryland and Virginia. However, it was not until 1912 that suitable laws were enacted by both states to regulate the fishery (these included a 2 1/2” cull law and establishment of an upriver seed area). In 1928, the U. S. Bureau of Fisheries was requested to survey the river’s oyster bars. These were found to be much depleted, with the result that dredging was prohibited starting in 1931. In November 1942, the U.S. Fish and Wildlife Service began a resurvey of the oyster bars in the Potomac,

finishing in July 1943. The survey found that stocks were still low (about 10 bushels of marketable oysters per acre on average) although large oysters had increased 10-fold and small oysters 20-fold since 1928. Oysters were found to be unevenly distributed over the larger oyster beds, with larger concentrations occurring on small sections of the bed. Setting appeared to be greater towards the mouth of the river. The author recommended that more cultch be applied in the good setting areas of the lower river, and that the clustered oysters in these areas be broken up. Small oysters should be planted to grow in the upper part of the river. The author concluded that the small increase in oyster abundance from 1928 to 1943 demonstrated that, even with decreased fishing pressure, the oyster bars cannot regain their former productivity by themselves, thus the need for remedial management.

Frierman, E. M. and J. D. Andrews. 1976. Occurrence of hematopoietic neoplasms in Virginia oysters (*Crassostrea virginica*). J. Natl. Cancer Inst. 56: 319-324.

Seventy cases of a rare neoplastic disease were noted during an intensive survey of trayed populations of oysters in Virginia waters. The disease occurred in oysters from a wide geographic range. There was a suggestion of seasonality, with most cases appearing from July to November at salinities from 10-22%. The disease may be associated with inbreeding.

Galtsoff, P. S. 1945. Problems of rehabilitation of Chesapeake Bay oyster resources. Proc. Natl. Shellfish. Assoc. Vol. 35: 3 pp.

Briefly described the decline of the oyster industry in Chesapeake Bay. For example, in Baltimore alone, the value of the oysters produced declined from about $4 million in 1880 to about $1 1/2 million in 1936-37. Galtsoff attributed the decline to a disregard of the fundamentals of the basic principles of conservation. He recommended that an effective system of exploitation and management begin. He briefly described the Bay-wide cooperative efforts between Maryland, Virginia and federal governments that had begun. The U.S. Fish and Wildlife Service had established a field headquarters in Annapolis and at Cambridge, and careful studies of the very low salinity conditions in the upper Bay and of spawning and setting patterns in the central Bay were underway.

Galtsoff, P. S., W. A. Chipman, Jr., J. B. Engle and H. M. Caldewood. 1947. Ecological and physiological studies of the effect of sulfate pulp mill wastes on oysters in the York River, Virginia. Fish Wildl. Serv., Fish. Bull. 43: 60-176.

Studies of the effects on oysters of effluent from a pulp-mill were performed from 1935. Results indicated that the upper part of the York River was an

unhealthy environment for oysters. Superficially, ecological conditions appeared suitable. However, presence of pulp-mill waste reduced the number of hours oysters were open and decreased pumping rates. Filtration rates varied in proportion to pulp-mill effluent concentration.

Glude, J. B. 1966. Criteria of success and failure in the management of shellfisheries. Trans. Amer. Fish. Soc. 95: 260-263.

Evaluated characteristics of successfully managed commercial fisheries for shellfish. Concluded that the oyster fishery in Maryland was managed unsuccessfully because of unlimited entry, inefficient harvesting techniques and limitations on private culture of oyster grounds.

Grave, M. 1912. A manual of oyster culture in Maryland. Fourth Report, Board of Shell Fish Commissioners. pp. 279-348.

A general treatment of physical and biological conditions which directly or indirectly affect oysters. A history of Maryland oyster production and an extensive section on oyster food are included.

Green, B. K. 1916 Seventh Report of the Shell Fish Commission of Maryland 1914 and 1915. Kohn and Pollock Inc., Baltimore, MD. 78 pp.

In a very brief review of oyster legislation, the commission considered private culture and rental of ground. At the time, any rented ground was used to “bed” oysters for growth and future sale. Aspects of the struggle to open more and better grounds to private culture were discussed. During the recent extensive survey of oyster grounds (1906-1912), full copies of the survey were filed in the county seat and there was a period available for challenging the survey findings. In 1912 there was a great increase in rental applications. This was followed by mounting protests by watermen that natural (not barren) oyster grounds were being rented. Much of this problem was caused by their having ignored the appeal period. However, other protests were found to be valid but, unfortunately, the watermen’s representatives had earlier insisted that the findings of the 1906-1912 survey be fixed and final. They had believed that natural grounds were shrinking in area and wanted to have a fixed survey to keep as large an area for their own use as possible. They refused to adhere to the agreed-upon rules and brought pressure on the Shell Fish Commission. Other watermen destroyed the property and stole the oysters of certain lessees. One such case was detailed by R. H. Spedden of St. Mary’s County. As a result of the pressure, further legislation (Shepherd Bill) was passed to modify the private culture laws to provide for greater flexibility in designating grounds as natural oyster beds or as private culture grounds.

Gregory, R. H., R. T. Hill and J. A. Hope, Jr. 1958. Bacteriological studies of harvesting and processing of oysters in Virginia. Proc. Natl. Shellfish. Assoc. 48: 30-43.

Oysters were examined from June 1955 to April 1956 using samples from lower Chesapeake Bay, Mobjack Bay and the mouths of the York and Rappahannock Rivers. The oysters were processed in packing plants. Shucking was found to cause an increase in the bacterial content of oysters. The bacterial content decreased during packing.

Hammer, R. C. 1948. Present status of the Chesapeake Bay oyster bars in Maryland. Proc. Natl. Shellfish Assoc. (1947): 8-10.

Blamed the decline of oyster yield in Maryland from 12 1/4 million bushels in the late 1800s to 2 1/2 million bushels (1946) on overfishing, which led to the result that many bars were completely devoid of oysters and cultch. Production was almost entirely due to more consistent spat sets on shallow bars in tributaries. The Say dredging bars once supported 1000 dredge boats and yielded 50 bushels of oysters per acre. By 1946 48 Bay dredgers remained, harvesting one bushel per acre. Provided data on costs of and yields from state shell planting action. Recommended private culture of oyster bars to help restore Bay's productivity.

Harshbarger, J. C., S. C. Chang and S. V. Otto. 1977. Chlamydiae (with phages), mycoplasmas, and rickettsiae in Chesapeake Bay bivalves. Science 196: 666-668.

Electron microscopy studies of Chesapeake Bay oysters revealed the presence of chlamydia-like organisms, rickettsia-like organisms and mycoplasma-like organisms. The former were observed to have phages present.

Haven, D. S. 1959. Effects of pea crab *Pinnotheres ostreum* on oysters Crassostrea *virginica*. Proc. Natl. Shellfish. Assoc. 49: 77-86

Condition indices were determined for tray-held oysters and oysters from the natural bottom. The latter were tested for condition in June 1956 (prior to spawning season); August 1956 (post-spawning); December 1956 (after full fattening); May 1957. The former were tested in December 1957. Measurements included volume, wet and dry mean weight, and shell cavity volume. During the seasons of maximum fatness (late spring, late fall, winter), oysters containing pea crabs had less meat by weight and lower condition index than did crab-free oysters. In August 1956 (post-spawning), condition indices for both groups of oysters were similar. Monthly samples of oysters from 1953 to 1958 revealed incidences of pea crab infestations varying from 6-22% in James River, 12-21% in York River, and 7-16% in Rappahannock River.

Haven, D. S. 1962. Seasonal cycle of condition index of oysters in the York and Rappahannock Rivers. Proc. Natl. Shellfish. Assoc. 51: 42-61.

Oysters collected annually from Wreck Shoals oyster bed in James River were held on the bottom or in trays elevated off the bottom in the York and Rappahannock Rivers. Each month, 25 oysters from stations in both rivers were processed either as a group or individually, and condition indices were determined. Incidence of pea crab and *Dermocystidium marinum* infestation were noted. In winter, York River tray and bottom oysters generally had a lower condition index than did Rappahannock tray or bottom oysters. Bottom oysters in both rivers often had a consistently lower index than did tray oysters. Rappahannock oysters generally had high indices of condition in late spring, followed by a decline in summer and a return to high values in fall. Peak condition was reached in York River in late spring, followed by a decline in summer and no quality increase in fall. The winter of 1960-61 produced a six-year high in quality and yields for oysters from public oyster grounds in both rivers, and for the experimental oysters held in trays and on the bottom in both rivers. Presence of *Dermocystidium marinum* or *Pinnotheres ostreum* was not responsible for condition index differences between tray and bottom oysters.

Haven, D. S. 1965. Supplemental feeding of oysters with starch. Chesapeake Sci. 6: 43-51.

The author added cornstarch or wheat flour to provide supplemental food for James River oysters held in flowing York River water. This influenced meat weight but generally not oyster air weight or shell cavity size. Reducing water volume flow or filtering incoming water inhibited meat development. Added starch tended to compensate for these restrictions. Under estuarine conditions, tissue weights may be influenced by quantities of starch in planktonic algal cells more than by the species or volume of plankters ingested.

Haven, D. S. 1980. Virginia seed sources. In: D. Webster (ed.). Oyster Culture in Maryland ‘79. A Conference Proceedings. Md. Coop. Ext. Service, pp. 25-30.

A brief review of Virginia’s seed resource.

Haven, D. S., W. J. Hargis, Jr., and P. C. Kendall. 1978. The Oyster Industry of Virginia: Its Status, Problems and Promise. Va. Inst. Mar. Sci., Spec. Papers in Mar. Sci. No. 4. 1024 pp.

An extensive survey of the history, economics, fishery, culture, biology and ecology of oysters in Virginia, with recommendations for management and rehabilitation.

Haven, D. S., J. P. Whitcomb, J. M. Zeigler and W. C. Hale. 1979. The use of sonic gear to chart locations of natural oyster bars in lower Chesapeake Bay. Proc. Natl. Shellfish. Assoc. 69: 11-14.

A microphone encased in a PVC tube, suspended from an A-frame, and towed over the bottom of Chesapeake Bay was used as a means of detecting shell material. The information collected was used in conjunction with other data to chart oyster bottoms in Virginia.

Hewatt, W. G. and J. D. Andrews. 1954. Oyster mortality studies in Virginia. I. Mortalities of oysters in trays at Gloucester Point, York River. Texas J. Sci. 6: 121-133.

During the warm months of summer and fall, oysters growing in trays in York River, Virginia, suffered high mortality. Studies of this mortality began June 1950. The fungus, *Dermocystidium marinum*, was implicated. It caused seasonal variations in mortality.

Hewatt, W. G. and J. D. Andrews. 1956. Temperature control experiments on the fungus disease, *Dermocystidium marinum*, of oysters. Proc. Natl. Shellfish. Assoc. 46 129-133.

In summer 1954, oysters from the James River (a fungus-free area) and the Rappahannock River (a diseased area) were collected. They were twice exposed to minced oyster tissues from fungus-infected oysters, then divided into groups held at 15°C, 28°C and in ambient seawater (26°-30°C). Over a 6-week period, there was a 10% mortality at 15°C compared with 99% mortality at 28°C. Mortality was 53% in ambient seawater. Mortalities were greater in oysters from the fungus-free river.

Hidu, H., K. G. Drobeck, E. A. Dunnington, Jr., W. H. Roosenburg and R. L. Beckett. 1969. Oyster Hatcheries for the Chesapeake Bay Region. Univ. of Maryland, Natural Resources Institute, Spec. Rep. No. 2. 18 pp.

The authors performed trials to determine feasibility of hatchery technology for rearing oysters to supplement natural recruitment. They reviewed some history and discussed the general recalcitrance of southern populations of oysters, including those of Chesapeake Bay, to spawn under artificial conditions. Unlike their more northerly counterparts, southern oysters do not respond well to attempts to initiate spawning by chemical or thermal stimulation, or both. However, properly conditioned Chesapeake Bay oysters will spawn eventually, appear to be able to spawn periodically during the summer, and may even be spawned in the fall. The authors provided information on rearing larvae and for handling spat.

Hidu, H., W. H. Roosenburg, K. G. Drobeck, A. J. McErlean and J. A. Mihursky. 1974. Thermal tolerance of oyster larvae, Crassostrea *virginica* Gmelin, as related to power plant operation. Proc. Natl. Shellfish. Assoc. 64: 102-110.

Fertilized eggs, ciliated grastrulae, and two-day-old veliger larvae of Chesapeake Bay oysters were subject to temperature increases for periods ranging from 10 seconds to 16 hours. Percentage mortality increased with increasing temperature and time of exposure. Fertilized eggs were most sensitive to higher temperatures, with veliger larvae most tolerant. The application of these findings to entrainment in power plant cooling water systems was discussed.

Hillman, R. E. 1964. Chromatographic evidence of intraspecific genetic differences in the eastern oyster, Crassostrea *virginica*. Syst. Zool. 13: 12-18.

Paper partition chromatography was used to determine patterns of free amino acids or small peptides in samples of oysters from Long Island Sound and James River, Virginia. Under the experimental conditions, one reproducible difference in these patterns was obtained. The author regarded this as evidence of intraspecific genetic differences between the two populations.

Hillman, R. E. 1965. Chromatographic studies of allopatric populations of the eastern oyster Crassostrea *virginica*. Chesapeake Sci. 6: 115-121.

The author extended his 1964 study of genetic differences among oyster populations by adding material from Delaware Bay, Louisiana, Long Island, Virginia, and parts of Chesapeake Bay. A new chromatographic technique was used and described. No data were given, but the author reported qualitative differences occurring in chromatograms, which he interpreted as indirect evidence for metabolic differences among the oyster populations.

Hoese, H. D. 1964. Studies on oyster scavengers and their relation to the fungus *Dermocystidium marinum*. Proc. Natl. Shellfish. Assoc. 53: 161-174.

Traces of this parasitic fungus were found in the stomach of the snail *Urosalpinx cinerea*, the body and guts of the fishes *Gobiosoma bosci*, *Chasmodes bosquiences* and *Opsanus tau* and the body and setae of the crab *Neopanope texana* and *Rhithropanopeus harrisii.* All had previously fed on infected oysters. In the presence of fishes which had been fed infected oyster tissue, some healthy oysters became lightly infected. In a field study, killed oysters placed on the bottom in a tidal inlet of Chesapeake Bay were eaten by scavengers in less than 24 hours when temperatures exceeded 24°C. Above 18°C, tissue never had a chance to decay because of rapid

scavenging. The author surmised that the parasites in the infected oysters must pass through the guts of scavengers, hastening transmittal of fungal spores to other oysters in the vicinity.

Hopkins, S. H. 1962. Distribution of species of *Cliona* (boring sponge) on the Eastern Shore of Virginia in relation to salinity. Chesapeake Sci. 3: 121-124.

Four species of *Cliona* were found to occur in Chesapeake Bay waters off Virginia's Eastern Shore. The most abundant boring sponge in high salinity waters of Virginia (*C. celata*) was least abundant in the lower salinities of Bayside creeks. *C. truitti* was most abundant in Bayside creeks. Its abundance increased as salinity decreased.

Hussong, D., R. R. Colwell and R. M. Weiner (in press). Seasonal concentration of coliform bacteria by Crassostrea *virginica*, the eastern oyster in Chesapeake Bay. J. Food Protection.

Oysters, water and sediment samples from Tolly Point and Eastern Bay were collected from February 1977 to October 1978. Total coliforms remained at low densities over this time period. However, coliform MPN counts in oysters rose significantly in the fall (October - early November) of each year (approx. 13°C). These increases, and a smaller increase at Tolly Point in late spring/early summer, were not the result of increases in coliforms in the water column. The resultant concentration of coliforms by oysters is unexplained.

Ingersoll, E. 1881. The History and Present Condition of the Fishing Industries. The Oyster Industry. U. S. Census Bureau, Tenth Census, Dept. of the Interior, Washington, D.C. 251 pp.

An extensive treatment of the oyster industry in the U.S. (and Canada's maritime provinces) encompassing fishery statistics, processing and shipping industries, and even aspects of the sociology of oystermen. The Maryland and Virginia industries were described in some detail (pp. 156-187).

Jensen, W. P. 1981. Leased bottom and the Maryland oyster fishery. In: D. Webster (ed.). Oyster Culture in Maryland 1980: A Proceedings. University of Maryland Cooperative Extension Service, College Park, Md. pp. 117-127.

A brief discussion of the status of the Maryland leased bottom program, extent of bottom presently in lease (9,000 acres by 651 leaseholders), extent that could be made available under present law (about 25,000 acres of ground suitable for oyster cultivation), and current state policy towards expansion of private holdings.

Kennedy, V. S. 1980. Comparison of recent and past patterns of oyster settlement and seasonal fouling in Broad Creek and Tred Avon River, Maryland. Proc. Natl. Shellfish. Assoc. 70: 36-46.

Settlement of oyster spat, barnacles, encrusting bryazoans, and some additional invertebrates was studied for three summers (1977-1979) in these lower Choptank River tributaries. Results were compared with a similar study in this area in 1961 to 1966. In contrast to the earlier results, in 1977-1979 oysters settled predominantly on upper surfaces, perhaps as a result of increased turbidity or decreased light penetration in the intervening years. Average numbers of oyster spat were lower than in 1961 to 1966. Barnacles and bryozoan colonies settled predominantly on under surfaces, as before. Numbers of hooked mussels settling were lower than in the past. As before, Broad Creek had a higher incidence of oyster settlement than did Tred Avon River, which continued at its former low level.

Kraeuter, J. and O. S. Haven. 1970. Fecal pellets of common invertebrates of lower York River and lower Chesapeake Bay, Virginia. Chesapeake Sci. 11: 159-173.

The authors describe the fecal pellets of 70 species of Chesapeake Bay invertebrates, including the oyster, Crassostrea *virginica*.

Krantz, G. E. and J. V. Chamberlin. 1978. Blue crab predation on cultchless oyster spat. Proc. Natl. Shellfish. Assoc. 68: 38-41.

Blue crab predation on oyster spat reared on and then removed from Mylar plastic sheets was studied by providing the spat to blue crabs in aquaria. Shell chipping and crushing by the crabs was described.

Krantz, G. E. and D. W. Meritt. 1977. An analysis of trends in oyster spat set in the Maryland portion of the Chesapeake Bay. Proc. Natl. Shellfish. Assoc. 67: 53-59.

From 1939 to 1975, there was a general trend of declining spat settlement in Chesapeake Bay, Maryland, although there had been some short periods of good spat settlement (e.g., 1943, 1945, 1965). Tropical Storm Agnes which flooded the Bay with freshwater in 1972 obviously influenced oyster mortality, reproduction and recruitment. However, the available data showed that this and other natural disasters were not totally to blame for the decline in recruitment. Other possible factors, including overfishing, were considered. A recommendation that shellfish hatchery oysters be used to supplement natural set on selected oyster bars was made.

Lackey, J. B., C;. Vander Borgh, Jr., and J. B. Glancy. 1953. General character of plankton organisms in waters overlying shellfish-producing grounds. Proc. Natl. Shellfish. Assoc. (1952): 152-156.

Study locations included Woods Hole; Milford, Long Island; and, in Chesapeake Bay: Solomons, the Patuxent River and St. Mary's River. Of several hundred plankton samples collected since 1948, the lowest number of organisms was 300,000 liter^{-1} (over Thomas Bar, Solomons, Md.) with the greatest abundance being over 300,000,000 liter^{-1}. In St. Mary's River (an excellent setting ground but a poor fattening area) there was a large plankton assemblage with relatively few diatoms and dinoflagellates compared with other locations. There were large numbers of various small flagellates, including very small green flagellates. The authors felt that the small flagellates are good larval food, with diatoms and dinoflagellates a better food for adults. The other Chesapeake locations were also lower in diatoms but had more dinoflagellates than did St. Mary's River. The authors concluded that inshore waters were able to produce sufficient plankton to maintain large shellfish populations, that kind and not abundance was critical, and that smaller flagellates were best for larvae.

Larsen, P. F. 1974. Structural and functional responses of an oyster reef community to a natural and severe reduction in salinity. In: Proc. First Int. Congress of Ecology, Structure, Functioning and Management of Ecosystems. Cntr. Agric. Publ. Docu. Wageningen (Neth.), pp. 80-85.

In June 1972, Tropical Storm Agnes inundated Chesapeake Bay, with resultant flooding causing sharp drops in salinity. This study involved the James River estuary, Virginia. Samples on 8 oyster reefs before and after the freshet indicated decreases in numbers of species and densities of individuals following the storm. Down-estuary sites lost their less euryhaline species, whereas up-estuary sites showed less change, presumably due to greater adaptabilities and tolerances to salinity stress of the associated organisms.

Larsen, P. F. 1978. *Boccardia hamata* (Polychaeta: Spionidae): A potential pest of the American oyster in the James River, Virginia. Estuaries 1: 183-185.

Boccardia hamata is a boring species of spionid polychaete which was found in large numbers in oyster reefs of the James River, Virginia. It had not been reported in such high numbers before, either in Chesapeake Bay or elsewhere on the Atlantic coast.

Lawler, A. R. 1969. Occurrence of the polyclad *Coronadena mutabilis* (Verrill, 1873) in Virginia. Chesapeake Sci. 10: 65-67.

Coronadena mutabilis, like the polyclad *Stylochus ellipticus*, was found in association with oysters. This report concerns its presence at two new locations, both in lower Chesapeake Bay. It was not observed to feed on C. virginica during the course of the study.

Lewis, T. B. and G. Power. 1979. Chesapeake Bay oysters: Legal theses on exotic species. In: R. Mann (ed.) Exotic Species in Mariculture, pp. 265-305. MIT Press, Cambridge, Mass.

The authors reviewed oyster laws in the Chesapeake Bay area, especially recent court decisions concerning county residency requirements. They recommended that Maryland's oyster management program move to protect its property interest in state oyster grounds, and to encourage widespread cultivation of privately managed oyster beds. The introduction of a new (exotic) species of oyster would need to be preceded by statutory changes in Maryland's law.

Lewis, T. B. and I. E. Strand, Jr. 1978. Douglas v. Seacoast Products, Inc.: The legal and economic consequences for the Maryland oystery. Maryland Law Review 38: 1-36.

The authors reviewed possible consequences of a U.S. Supreme Court decision concerning use of federally licensed vessels by non-residents or aliens in a Virginia fishery. The implication was that a federal vessel license allows non-residents to harvest oysters in Maryland on the same terms as residents, restrictive-entry state laws notwithstanding. The authors compared the Supreme Court decision with a Maryland judgment which struck down county residency requirements for the taking of oysters and crabs. Their conclusion was that public oyster bars may be in danger of even greater fishing pressure without the protection of state residency restrictions. They recommended a restructuring of the state management program and encouragement of private culture of oyster bars.

Lipschultz, F. and G. Krantz. 1978. An analysis of oyster hatchery production of cultched and cultchless oysters utilizing linear programming techniques. Proc. Natl. Shellfish. Assoc. 68: 5-10.

A system of linear equations and a computer optimization program were used to compare manpower and operational requirements in a large-scale hatchery. The model was used to determine the best production schedule and use of equipment, to compare hatchery production of cultched and cultchless spat, and to evaluate the suitability of the design of an oyster hatchery operating in Chesapeake Bay. The model allowed for manipulation of various aspects of hatchery procedure and equipment use to determine the most economic (in terms of labor, energy and dollars) production scheme. Cost of production of cultched spat was estimated to be 44% less than for cultchless spat. Design errors in the hatchery were noted and production bottlenecks were identified.

Loosanoff, V. L. 1932. Observations on Propagation of Oysters in James and Corrotoman Rivers and the Seaside of Virginia. Virginia Commission of Fisheries, Newport News, Va. 46 pp.

This report is a description of the results of extensive studies undertaken from spring to fall, 1931. The author made many observations on temperature and salinity, including the use of recording thermometers at two stations in Chesapeake Bay. Plankton samples were collected (usually at slack tide) nearly every day in the James River, with occasional samples made elsewhere. Spat settlement was monitored on shell in wire bags. In the James River, oyster spawning began in late May-early June and extended until October. General spawning occurred at 26°C (bottom), not at 20°C (a "critical temperature" of early investigators). Straight-hinge larvae were collected from late May to mid-October but umbo larvae were very rare. Setting extended from mid-June to mid-October with peaks in mid-August and mid-September. The heaviest setting occurred near the bottom and decreased towards high water mark. The author recommended that oyster cultivation be encouraged in the Corrotoman River and in Virginia's seaside waters.

Loosanoff, V. L. 1969. Maturation of gonads of oysters, Crassostrea *virginica*, of cliff Brent geographical areas subjected to relatively low temperatures. Veliger 11: 153-163.

The author studied gametogenesis in oysters collected from a number of locations along the U.S. Atlantic coast (including lower York River, Virginia) and held in Long Island Sound waters (Milford Harbor). Over a 2 1/2-month period, beginning January 15, groups of oysters were held at 12°, 15° and 18°C and their gonadal maturation was assessed periodically using histological techniques. At 12°C, the gonads of Virginia oysters had not progressed past winter stages, even after 78 days of conditioning. At 15°C, Virginia gonads were in the early development stage after 72 days, even though most appeared to be feeding. At 18°C, the Virginia oysters continued to be in the early stages of development, even after 71 days of conditioning.

Lovelace, T. F., H. Tubiash and R. R. Colwell. 1968. Quantitative and qualitative commensal bacterial flora of Crassostrea *virginica* in Chesapeake Bay. Proc. Natl. Shellfish. Assoc. 58: 82-87.

Water, mud, oyster mantle fluid, and oyster gill tissue were examined from material collected every 6 weeks from Marumsco Bar in Pocomoke Sound, and from Eastern Bay. Salt-requiring bacteria appeared to be a significant part of the bacterial flora of both areas. On Marumsco Bar, 81% of water, mud and animal samples were composed of *Vibrio*, *Pseudomonas* and *Achromobacter* spp. In Eastern Bay, these bacteria comprised just 46%, with *Cytophaga/Flavobacterium* spp. dominant. Eastern Bay was considered to harbor a "balanced" population.

MacKenzie, C. L., Jr. 1977. Sea anemone predation on larval oysters in Chesapeake Bay (Maryland). Proc. Natl. Shellfish. Assoc. 67: 113-117.

Diadumene leucolena is a sea anemone which is commonly found attached to oyster shell in Chesapeake Bay, Maryland. It was found to feed on oyster larvae in the laboratory and presumably feeds on these larvae in nature.

Mackin, J. G. 1951. Histopathology of infection of Crassostrea *virginica* (Gmelin) by *Dermocystidium marinum* Mackin, Owen, and Collier. Bull. Mar. Sci. Gulf Carib. 1: 72-87.

In late summer, 1949, high mortality occurred among oysters in the Rappahannock River, Virginia. Histological sections of survivors revealed the presence of the fungus *Dermocystidium marinum*.

Manning, J. H. 1953. Setting of oyster larvae and survival of spat in the St. Mary's River, Maryland, in relation to fouling of cultch. Proc. Natl. Shellfish. Assoc. 43: 74-78.

Wire bags of oyster shell which had been held beneath the laboratory pier at Solomons, Maryland, for varying periods of time were moved on July 2 to St. Mary's River in time for the major period of spatfall. Counts of barnacles, bryozoan colonies and oyster spat at varying periods until November were made. Barnacle fouling appeared to inhibit oyster setting. Heavily fouled cultch caught only about 25% as many spat as did cultch which was relatively free of barnacles during the spatfall period. Light to moderate bryozoan fouling had no apparent influence on oyster set.

Manning, J. H. 1957. The Maryland Soft Shell Clam Industry and its Effects on Tidewater Resources. Md. Dept. Res. Educ., Resource Report No. 11. 25 pp.

This report contains the results of an experiment performed in Cox Creek, Queen Anne's County, to determine the effects of hydraulic clam dredging on oysters. An experimental plot was established. It contained oysters unevenly distributed over a generally shelly bottom, An approximately 0.25 acre plot at the north end of the experimental area was dredged thoroughly

on the ebbing tide (0.1-0.9 knots) for 9.5 hours in late August 1956. This was done after all oysters from within 4 randomly-placed 20 ft rectangles on each of 7 parallel transects had been removed by divers. The transects were established at intervals of 25, 50, 75, 100, 200, 300 and 400' from the experimental area. About 1" of sediment was deposited down-current 25' from the dredged area and about 0.6" was deposited 50' away. About 4 months later, the 7 transects and the experimental (dredged) area were resampled as before. Numbers of oysters collected after dredging were not significantly different from those collected before dredging, except in the dredged area and on the transect 25' away, where numbers were higher before dredging. The author concluded that no damage from the results of hydraulic dredging would be expected at a distance 75' down-current from the dredging area, assuming currents up to 1 knot (a high velocity for most parts of the oyster areas of the Bay).

Manning, J. H. and H. H. Whaley. 1955. Distribution of oyster larvae and spat in relation to some environmental factors in a tidal estuary. Proc. Natl. Shellfish. Assoc. 45: 56-65.

The authors sampled plankton and measured spatfall, current velocities, salinity and temperature in St. Mary's River, a tributary of the Potomac River, in June and July 1951. The sluggish circulation of the river seemed to produce three main sub-regions: Area I, the lower river, had wind-induced circulation with surface inflow and bottom outflow; Area II, middle river, had a very weak net upstream water movement; Area III, upper river, had a 2-layer system of upper-level outflow and lower-level inflow. Spat settlement was highest in Area III, decreasing downstream. Contrarily, 88% of the charted oyster bars lay in Area I, 9% in II and 3% in III. Plankton sampling at various depths indicated a tendency of oyster larvae as they mature to be found at progressively greater depth. Thus the authors postulated that Area I would lose early stage larvae to Area II and later stage larvae to the Potomac River. Area II larvae would slowly be carried upstream to Area III, which in turn would act as a "larval trap."

Marasco, R. J. 1973. An appraisal of the alternative earning power of the Maryland oystermen. Proc. Natl. Shellfish. Assoc. 63: 47-52.

Oystermen of the communities of Rock Hall and Crisfield-Smith Island on the Eastern Shore and of Shadyside and Avenue on the Western Shore were studied by personal interview. Oystermen from the Eastern Shore communities would appear to have more difficulty finding employment outside the fishing industry than would the oystermen from the Western Shore.

Marshall, N. 1954. Changes in the physiography of oysters bars in the James River, Virginia. Proc. Natl. Shellfish. Assoc. 44: 113-121.

The author compared data from depth surveys on transects across selected public oyster bars in lower James River. These bars had been surveyed for depths at different times from 1854-1855 onward to the late 1940's. At most points, depth comparisons indicated an increase in depth with an average loss of about a foot in elevation of oyster grounds. Most of the formerly emergent or intertidal oyster shoals which had been noted in the 1871-73 surveys (17,000 yards in area) had disappeared in the late 1940's (100 yards left). The author calculated (roughly) that the oyster fishery would have been responsible for less than about half the depth increase. Thus, presumably both natural and fishery influences resulted in dynamic changes in oyster bar physiography.

Maryland Commission on Conservation of Natural Resources. 1948. Report to the Governor of Maryland. 91 pp.

The Commission recommended oyster farming and presented estimates of the yields in seed or harvestable oysters per bushel of shell or seed that was planted in the proper area. They noted that the 1948-49 increase in the shell tax to 20% of fresh resin shell was insufficient and stressed the need to have all shell returned to the State.

McHugh, J. L. 1956. Trapping oyster drills in Virginia. II, The time factor in relation to the catch per trap. Proc. Natl. Shellfish. Assoc. 46: 155-168.

Experiments on trapping oyster drills using seed oysters as bait were performed at Gloucester Point, Va. in summer 1953 and spring and summer 1954. *Urosalpinx cinerea* was the most common drill trapped, being about 22 times more common at the experimental location than was *Eupleura caudata*. For both species, the rate of being trapped declined with time. This decline was not statistically significant for *U. cinerea* over the first week, thus traps could be lifted weekly rather than daily with little loss of catching efficiency compared with lifting them more frequently. Significantly lower catches occurred for *E. caudata* in traps fished weekly compared with traps fished daily.

McHugh, J. L. and J. D. Andrews. 1955. Computation of oyster yields in Virginia. Proc. Natl. Shellfish. Assoc. 45: 217-239.

Oysters were held in trays suspended from the Virginia Fisheries Laboratory Pier, Gloucester Point, Va., for 4 years. Data on mortality and growth were collected at closely-spaced intervals. Rather than the normal yield of one bushel of market oysters for one bushel of planted seed (typical for Chesapeake Bay), the tray-held oysters yielded three bushels of market oysters for each bushel of seed placed in the trays. The authors calculated Walford growth curves and determined seasonal growth patterns, mortality rates, and the instantaneous rate of mortality. Yields were then computed.

Merrill, A. S. and K. J. Boss. 1966. Benthic ecology and faunal change relating to oysters from a deep basin in the lower Patuxent River, Maryland. Proc. Natl. Shellfish. Assoc. 56: 81-87.

Oysters were found in substantial numbers in 120-130 feet of water in a deep basin near the mouth of the Patuxent River. Their condition was not as good as that of shallow water (10') oysters. In June, oysters from 10', 65' and 130' were ripe. By December, shallow water oysters had spawned, but some oysters from 65' and 130' (30% and 40% respectively) were only partly spawned. Deep-water oysters grew more slowly than their shallow-water counterparts.

Morse, D. C. 1945. Some observations on the food and feeding of oysters in Chesapeake Bay. Proc. Natl. Shellfish. Assoc. 35: 3 pp.

In 1943-44, Patuxent River oysters were collected biweekly during periods of oyster activity and less frequently in winter. Stomach contents were collected from about 10 oysters in the field and preserved immediately. Plankton samples were generally collected at the same time. Stomach contents included diatoms, dinoflagellates, tintinnids, silicoflagellates, ostracods, unidentified eggs and larvae and land pollen. Red pigmentation of the meats on one occasion was due to the dinoflagellate *Exuviella apora*. Seasonal patterns in feeding were evident. In autumn, until the weather turned cold, the diatom *Cyclotella striate* dominated in stomach samples (up to 80% of the food). It was accompanied by other diatoms and by dinoflagellates. After mid-November, feeding declined until it halted in mid-December. No food was noted in stomachs sampled at water temperatures less than 5°C. In mid-March when bottom temperatures passed 5°C, diatoms predominated, with *Erataulina bergonii* and *Nitzchia seriata* comprising up to 90% of the stomach contents. After mid-April, *Cyclotella striata* reappeared. Below 10-12°C, few food organisms were found in the stomachs although some oysters had crystalline styles. Above 20°C, oysters were fat and full of diatoms. Comparison with plankton samples revealed that oysters rejected the large spring diatoms such as *Rhizosolenia* and large *Chaetoceras*, larger dinoflagellates (*Ceratium*), and copepods (however, parts of these organisms were found to be ingested). The nanoplankton appeared to be important, as evidenced by the numbers of *Cyclotella* ingested in fall and spring.

Munson, T. O. and R. J. Huggett. 1972. Current status of research on the biological effects of pesticides in Chesapeake Bay. Chesapeake Sci. (Supplement) 13: S154-S156.

A brief summary of the limited number of studies concerning pesticides and their effects on Chesapeake Bay ecosystems and organisms, including C. virginica. In Virginia, a number of stations had been established for monitoring of pesticides (DDT, dieldrin, PCB, etc.). A few studies had been performed in Maryland. Although EPA was there monitoring fish, no other Bay-wide monitoring was being performed.

Newcombe, C. L. . and R. W. Menzel. 1945. Future of the Virginia oyster industry. Commission of Fisheries of Virginia, Contrib. No. 22: 1-11. Reprinted from The Commonwealth 12(4) 1945.

A general, illustrated essay on the biology of oysters in Virginia, with a summary of research needs.

Nichol, A. J. 1937. The Oyster-Packing Industry of Baltimore. Its History and Current Problems. Chesapeake Biological Laboratory Bulletin, Solomons Island, MD. 32 pp.

An extensive illustrated history of the Maryland oyster industry, especially that which centered around Baltimore, from colonial days when oysters were eaten only because of fear of starvation, through the boom days of the late 1800's, to the depressed market in the mid 1930's. The author saw a solution to the depressed market in the guarding and replenishing of the supply. "This will come in Maryland when the oystermen of Chesapeake Bay realize that their excessive independence has worked against their best interest, economically and socially, while at the same time, it has been dissipating a treasure which belongs not alone to them but to all the people of the State."

Orbach, M. K.. 1980. Fishery cooperatives on the Chesapeake Bay: advantage or anachronism. Anthropol. Quart. 53: 48-55.

Discussed cooperative activity among Bay watermen over time and attempted to explain rise and fall of cooperatives and unions in the Bay area.

Outten, W. 1980. Maryland's state seed problem. In: D. Webster (ed.). Oyster Culture in Maryland '79. A Conference Proceedings. Md. Coop. Ext. Serv., pp. 15-24.

A brief review of the state seed program.

Pfitzenmeyer, H. T. 1972. Molluscs of the Chesapeake Bay. Chesapeake Sci. 13 (Suppl): S107-S115.

This is a brief review of research performed on the ecology and biology of Chesapeake Bay molluscs, including Crassostrea *virginica*.

Power, G. 1970. More about oysters than you wanted to know. Maryland Law Review. 30: 199-225.

An extensive study of legal aspects of the public and private oyster fishery in Maryland. Reviewed history of state regulation of the industry and of the attempts to allow private cultivation of oyster ground. Concluded that discriminators in Maryland law which excluded non-residents and corporations from the fishery were generally unconstitutional, and that a successful judicial attack on these discriminations might stimulate general reform of existing oyster laws. Recommended encouragement of greater private cultivation of oyster grounds and the granting of broad management authority to the Fish and Wildlife Administration (now Tidewater Administration). The latter action would free the Administration from anachronistic laws and would abolish the current hold the legislature has over the industry.

Pritchard, D. W. 1953. Distribution of oyster larvae in relation to hydrographic conditions. Proc. Gulf Carib. Fish. Invest. 5: 123-132.

Oscillatory tidal currents produce a typical coastal plain estuarine circulation pattern in which ebb velocities are relatively large at the surface, decreasing with depth, while flood velocities are relatively small at the surface, increasing with depth, and then decreasing as bottom friction exerts an influence. This leads to a two-layered circulation pattern, with a surface of no net motion at some mid-depth. Salt balance in the James River, Virginia, is maintained primarily by the mean horizontal advection and the vertical mixing term. Mean vertical advection and the horizontal mixing term are of lesser or no importance, respectively. Pritchard proposed that distribution of oyster larvae could be influenced by the described hydrographic conditions. For example, the northeast side of the James River had higher production of oyster seed than did the southwest shore. This could be attributed to slow upwelling of deeper waters over the shallow northeast bars. However, field sampling was difficult because the counting of oyster larvae is onerous. Further, Pritchard calculated that only 1 larva per 100 litres of water was required to achieve the large observed sets. A sampling program involving samples of 100 litres obviously would be inadequate. Examination of the results of a field sampling program indicated that larval distributions were more compact and concentrated than were predicted on the assumption that oyster larvae were passively distributed in the same manner as dissolved material, e.g., dye. Dye studies in estuaries seemed to indicate that dissolved or suspended materials spread more quickly than did oyster larvae.

Quittmeyer, C. L. 1966. A Report on the Chesapeake Bay Fisheries of Maryland. Seafood Advisory Committee of Wye Institute, Centreville, Md. 68 pp.

This privately-commissioned report was prepared by an independent research group of consultants, including an oyster biologist, two business administrators, a sociologist, an economist, and a political scientist. They studied other fisheries in addition to the oyster fishery. However, with regard to the latter, they reiterated the conclusion of "generations of studies and reports," i.e., encourage private cultivation of the resource to complement the public fishery. They felt that if this were done, a doubling of production would occur in five years. Further, oyster grounds should be classified as "seed, self-sustaining, and growing grounds," with appropriate management of the different grounds. They compiled a list of 14 steps or actions based on biological understanding which they regarded as necessary for enhancement of oyster production.

Rawls, C. K. 1977. Field studies of shell regrowth as a bioindicator of eastern oyster (*Crassostrea virginica* Gmelin) response to 2,4-D BEE in Maryland tidewaters. Chesapeake Sci. 18: 266-271.

Eurasian watermilfoil can be controlled by application of the butoxyethanol ester of 2,4dichlorophenoxy-acetic acid (2,4-D BEE). To determine its effect on oysters, new growth was filed from the edges of oysters which were then held in trays in field environments to which three different quantities of the herbicide were applied. There was no evidence that oyster shell regrowth or replacement was adversely affected by the herbicide in the amounts used.

Roosenburg, W. H., J. C. Rhoderick, R. M. Block, V. S. Kennedy, S. R. Gullans, S. M. Vreenegoor, A. Rosenkranz and C. Collette. 1980. Effects of chlorine-produced oxidants on survival of larvae of the oyster Crassostrea *virginica* Mar. Ecol. Prog. Ser. 3: 93-96

Effects of chlorination on straight-hinge veliger larvae and pediveliger larvae were studied over time in flowing estuarine water. Larval mortality was directly related to increased concentrations of chlorine-produced oxidants (CPO) and extended exposure time. Pediveliger larvae were generally more resistant to CPO than were straight-hinge larvae, especially with lower exposure time. Equations for predicting mortality under different conditions of time and CPO concentrations were developed.

Sayler, G. S. J. D. Nelson, Jr. and R. R. Colwell. 1975. Role of bacteria in bioaccumulation of mercury in the oyster Crassostrea *virginica.* Appl. Microbiol. 30: 91-96.

In an experimental system, mercury concentrations in tissue of oysters dosed with mercury metabolizing bacteria were 200 times greater than in tissues of oysters in control conditions. Mercury accumulation was significantly higher in gill and visceral tissues than in other tissues.

Sayler, G. S., J. D. Nelson, Jr., A. Justice and R. R. Colwell. 1976. Incidence of Salmonella spp., *Clostridium botulinum*, and *Vibrio parehaemolyticus* in an estuary. Appl. Envir. Soc. Microbiol. 31: 723-730.

During the sampling period, September 1974 - December 1974, C. virginica was found to be free of pathogens which were found in water or sediment samples. As water temperatures fell from 23.8°C to 6.2°C, bacteriological quality of the oyster generally improved.

Sawyer, T. K., M. W. Newman and S. V. Otto. 1975. A gregarine-like parasite associated with pathology in the digestive tract of the American oyster, Crassostrea *virginica*. Proc. Natl. Shellfish. Assoc. 65: 15-19.

An amoeboid or gregarine-like parasite was found to be associated with seasonal pathology of the digestive tract in oysters from Connecticut and Maryland waters.

Shaw, W. N. 1966. The growth and mortality of seed oysters, Crassostrea *virginica*, from Broad Creek, Chesapeake Bay, Maryland, in high- and low-salinity waters. Proc. Natl. Shellfish. Assoc. 56: 59-63.

Seed oysters from Mulberry Point bar, Broad Creek, were held off-bottom in trays or strung on wires in Tred Avon River (low salinity) and Chincoteague Bay (high salinity). Over a two-year observation period, shell growth was similar in both areas. In the second year, high mortality occurred in Chincoteague Bay, apparently unrelated to high salinity.

Shaw, W. N. 1967. Seasonal fouling and oyster setting on asbestos plates in Broad Creek, Talbot County, Maryland, 1963-65. Chesapeake Sci. 8: 228-236.

Weekly setting frequencies of oysters, bryozoans, barnacles, mussels, and flatworms were observed on asbestos-cement plate collectors. The barnacles, bryozoans and flatworms set predominantly on plate undersurfaces. Oysters and mussels preferred the undersurface when plate collectors were 4” apart, but settled predominantly on upper surfaces when the plates were 1” apart. It was recommended that shells be planted in Broad Creek during the first week of July to serve as cultch for spat that should become available at that time.

Shaw, W. N. 1969. Oyster setting in two adjacent tributaries of Chesapeake Bay. Trans. Amer. Fish. Soc. 98: 309-314.

Over a 5-year period (1962-66), oyster setting in Broad Creek, Choptank River, was consistently greater than in adjacent Tred Avon River, as measured by spat settlement weekly on asbestos plates and seasonally on oyster shell. Setting generally began in June, peaked in July, and ended in September. Broad Creek appeared to be a suitable area for expansion of a seed reserve.

Shaw, W. N. and G. T. Griffith. 1967. Effects of Polystream and Drillex on oyster setting in Chesapeake Bay and Chincoteague Bay. Proc. Natl. Shellfish. Assoc. 57: 17-23.

Significantly more oysters were caught on Polystream-treated and Drillex-treated shells compared with untreated controls when both were suspended either intertidally or on the bottom of Chincoteague Bay. In Tred Avon River, Polystream-treated shells held off-bottom caught more oysters than did controls. On the other hand, no significant differences were found in Tangier Sound and Broad Creek, Chesapeake Bay. Fouling organisms apparently were not affected by treatment of shell with the two chemicals.

Shaw, W. N. and A. S. Merrill. 1966. Setting and growth of the American oyster Crassostrea *virginica* on navigation buoys in the lower Chesapeake Bay. Proc. Natl. Shellfish. Assoc. 56: 67-72.

Oysters were collected from navigation buoys over a 7-year period. Growth of oysters setting on newly placed buoys was very rapid and mortalities were low. These results suggest that off-bottom culture of oysters in lower Chesapeake Bay might be commercially feasible.

Sieling, F. W. 1950. Intensity and distribution of oyster set in Chesapeake Bay and tributaries. Proc. Natl. Shellfish. Assoc. (1949): 28-32.

Counts of oyster spat using one-half bushel random samples from oyster bars were used to monitor oyster set (which was low in 1947 and 1948). Best area was the eastern shore of the Bay from Love Point to Tangier Sound. Average values of spat per bushel on dredging bars were: 1947 - eastern shore 61.2; western shore 2.2; upper Bay 5.5; 1948 - eastern shore 15.5; western shore 3.4; upper Bay 0.3. Best sets were in tributaries of the Choptank River, Tangier Sound, Eastern Bay and St. Mary's River. In Eastern Bay, 2002 spat per bushel were recorded on planted shell in fall 1947. Slag which had been planted as cultch in the Eastern Bay seed area yielded 2280 spat per bushel. Counts in 1948 were lower. The Patuxent River continued to be a poor setting area, as was the Potomac River (except for St. Mary's River).

Sieling, F. W. 1951. Influence of seasoning and position of oyster shells on oyster setting. Proc. Natl. Shellfish. Assoc. (1950): 57-61.

Experiments in St. Mary's River revealed that the majority of oyster larvae settled on the underside of oyster shell held horizontally in wire mesh bags. Barnacles exhibited the same preference whereas bryozoans seemed to show no preference. Although inconclusive, experiments also indicated that clean shell obtained slightly more spat than did shell that was fouled with barnacles and bryozoans.

Sindermann, C. J. 1968. Oyster Mortalities, with Particular Reference to Chesapeake Bay and the Atlantic Coast of North America. U. S. Fish. Wildl. Serv., Spec. Sci. Rep. - Fisheries, No. 569. 10 pp.

Reviewed oyster mortalities, including those resulting from MSX in Chesapeake Bay.

Sindermann, C. J. and A. Rosenfield. 1967. Principal diseases of commercially important marine bivalve mollusca and crustacea. Fish. Bull. 66: 335-385.

In the course of this review, the authors used as examples incidents of disease noted in species taken from Chesapeake Bay.

Smith, R. S. 1953. A water quality survey of Hampton Roads shellfish areas. Proc. Natl. Shellfish Assoc. (1952): 121-134.

The authors described the pollution history of the Hampton Roads area of Virginia's Chesapeake Bay. The implementation of sewage treatment led to improvement of water quality in the late 1940's. The authors' own survey led to a recommendation for the reopening of three areas to oyster fishing.

Sprague, V., E. A. Dunnington, Jr., and E. Drobeck. 1969. Decrease in incidence of *Minchinia nelsoni* in oysters accompanying reduction of salinity in the laboratory. Proc. Natl. Shellfish. Assoc. 59: 23-26

Sick oysters collected from a population heavily infected by *M. nelsoni* were held for about 6 months at 7-8 ppt, 14-16 ppt, and 19-22 ppt. Continuing histological monitoring indicated that incidence of infection in these salinities was 5.5%, 63.1% and 88.8%, respectively. This information provided some corroborative evidence that the parasite responsible for the infection does not thrive at lower salinities.

State Planning Commission. 1935. Conservation Problems in Maryland. Unpublished Report of Sub-Committee on Conservation, A. Wolman, Chairman. Maryland Emergency Relief Administration. 64 pp.

The 51% decline in oyster yield in Maryland from 1910 to 1932 has resulted from "a continuation of the unsound conditions and short-sighted policies that have characterized and controlled the industry's operations over a long series of years." Among the reasons for the decline were overfishing, wholesale export of seed oysters out-of-state (e.g. over 2 million bushels in 1879), and failure to return cultch to the oyster grounds. This led to loss of a $750,000 canning industry with resultant loss of employment for workers. Larger-sized oysters also became uncommon and other states filled the demand. Previous shell-planting and seed-planting efforts were reviewed. Private culture was declared to be an important rehabilitation measure. For example, from 1929-1932 in the U.S., 47% of the volume and 68% of the value of Atlantic and Gulf state landings came from private beds. Harvested oysters from private culture sold for $0.99 per bushel compared with $0.47 per bushel for publicly harvested oysters.

Steinberg, P. D. and V. S. Kennedy. 1979. Predation upon Crassostrea *virginica* (Gmelin) larvae by two invertebrate species common to Chesapeake Bay oyster bars. Veliger 22: 78-84.

Prefeeding and feeding behavior of the sea anemone *Diadumene leucolena* in the presence of oyster larvae was described. As larval density increased, sea anemone feeding rates increased, with larger individuals generally feeding at a greater rate than smaller individuals. Few larvae survived in the presence of sea anemones. Also, numbers of surviving larvae decreased significantly in the presence of the barnacle *Balanus improvisus*.

Stevenson, C. H. 1894a. The oyster industry of Maryland. U. S. Fish Comm. Bull. No. 12: 203-298.

The author discussed the oyster industry in Maryland from many angles, from the operations of the oystermen through to the processing of the shucked oyster. In addition, the mass of regulations that had built up since 1820 were briefly but completely considered.

Stevenson, C. H. 1894b. A bibliography of publications in the English language relative to oysters and the oyster industries. U. S. Comm. Fish, Report of the Commissioner (1892), pp. 305-359. Washington, D.C.

This formed the most complete oyster bibliography of the time.

Suttor, R. E. and T. D. Corrigan. 1970. The Chesapeake Bay Oyster Fisheries: an Econometric Analysis. U. Maryland, Agricultural Experiment Station, Rep. No. MP-740. 50 pp.

An econometric (five-equation recursive) model was developed to analyze and project landings, price, employment and income in Maryland and Virginia oyster fisheries. Certain projections concerning landings and income were made using the model. An increase in oyster taxes to generate increased state revenues for program management was found not to hinder landings. The oyster seeding program was found to lead to increases in landings and employment, to the benefit of oystermen.

Suttor, R. E., T. D. Corrigan and R. H. Wuhrman. 1968. The Commercial Fishing and Seafood Processing Industries of the Chesapeake Bay Area. U. Maryland, Agricultural Experiment Stn., Rep. No. MP-676. 81 pp.

Described the commercial fishing and seafood processing industries in Chesapeake Bay, with emphasis on economic trends. An economic analysis of the oyster industry was recommended, with focus on evaluation of the effects of seeding of public oyster beds. The writers stated that the goals of the oyster management program were not clear-were they to increase oyster production, to increase employment or to increase income to watermen? These goals may be conflicting. The impact of private culture on income and retail oyster prices needed to be examined, according to the authors.

Truitt, R. V. 1921. A policy for the rehabilitation of the oyster industry in Maryland. Ann. Rep. (1920), Maryland Conservation Commission, pp. 1-5.

Maryland's oyster grounds had been generally destroyed by constant working with limited attention paid to restoring them to their former state of cultch and brood abundance. The replacement of sail boats by motor boats resulted in elimination of the shell ballast once dumped from the former as oysters were harvested and taken aboard. Solutions included an organized and systematic return of shell to natural bars. Shell should be placed only where it is known that spat settlement is reliable and where aspects of survival and growth of spat, as well as adult fattening prospects, are well understood. Truitt bemoaned the loss of shell to lime dealers, road builders and chick-grit sellers. Yet it was not clear that oystermen and oyster dealers supported the need to return shell to the bottom. Further, the legislature refused to provide the additional funds necessary for other than stopgap conservation measures.

Truitt, R. V. 1927. Aspects of the Oyster Season in Maryland Involving Labor Conflicts Detrimental to both Seafood and Cannery Industries, with Special Reference to the Latter. Maryland Ag. Expt. Station. 15 pp.

Truitt noted that the tremendous historical oyster depletion was due to overworking of oyster beds (one-fifth total oyster grounds completely exhausted with one-third nearly exhausted), removal of cultch and too small a legal size (resulting in mortality of unshucked seed dumped on shell piles). Further, at the time of writing, the oyster season began in September. This resulted in spat mortality from harvesting, mortality or loss of quality from heat spoilage, poor meat quality due to the fact spawning season had just ended, and competition of oyster harvesting with September vegetable canning labor needs. Tongers, dealers, dredgers and vegetable canners all recommended banning oyster harvesting in September.

Truitt, R. V. 1929. Biological contributions to the development of the oyster industry in Maryland. Ph.D. Dissertation American University, Washington, D.C. 56 pp.

Prepared during a period of harvest decline, this report concluded that, because salinity, temperature and pollution values (low) in Maryland's Chesapeake Bay had remained essentially unchanged over 3 or 4 decades, overfishing was the probable reason for the decline. Truitt compared various materials for suitability as cultch. Oyster shell caught about twice as many spat (33 per basket of shell) as did glass (1 to 5 in^2 in area), which caught about 16 spat per basket. Numbers of spat on other substrates (per basket) were: cinder and coal lumps - 4; 3/8” to 1/2” diameter pebbles - 3; egg-sized brickbats - 3; twigs or chips of various trees - 0 to 1. Thus Truitt recommended use of shell as a spatting substrate. He also estimated larval abundance in the water, finding a positive correlation of larval number to spat settlement. Spawning occurred from June to October, with the main peak usually in July (in 1925—an excellent year for spat—there was an additional larger peak in September). He established the fact that oyster fecundity increased with increasing age. Intense summer storms were shown to lead to the presence of fewer oyster larvae in the water (for reasons unknown). Truitt indicated that his findings on the importance of shell to successful oyster spat settlement had led to legislation requiring return of 10% of all harvested shell to the Bay. Similarly, his findings that oysters in their second year produced only small quantities of gametes had led to the establishment of a 3” market size limit.

Truitt, R. V. 1931a. The oyster and the oyster industry of Maryland. State of Maryland Conservation Dept., Conservation Bull. 4:1-48.

The biology of the oyster was described in non-technical terms, followed by a description of the past and present (to 1931) condition of oyster production in Maryland. There was a good description of various oyster fishing gears. In the section on oyster farming, Truitt indicated that the fact that legislative bodies were involved in management action had been detrimental to use of potentially productive grounds that were Iying fallow. As to seed planting, he noted that seed running 700-800 per bushel required 300-400 bushels per acre for optimum yield. Seed of this size should yield 2-3 bushels for each one planted. Grounds rounds should not be planted continuously, but should be rotated. Four acres of oyster ground can produce about 4,000 bushels of oysters in three years. Truitt recommended an enlightened program of private culture to encourage scientific farming.

Truitt, R. V. 1931b. Recent Oyster Researches on Chesapeake Bay in Maryland. Official Publication, Chesapeake Biological Laboratory, Solomons, Md. 28 pp.

This report summarized findings from 1918 to 1930 on oyster studies in Maryland. This research progressed in spite of the opposition of watermen to investigation of factors governing oyster abundance. Apparently they felt that natural restoration had to be depended upon. Truitt noted that two factors were responsible for oyster decline. The first was reduction of brood stock and the second was removal of cultch. Oysters of too small a size had been harvested. Based on the results of past work, the market size was raised from 2 1/2 inches to 3 inches. Also, legislation had been passed reserving 10% of shucked shell for planting by the state. Unfortunately, shell planting site selection did not consider (1) presence of brood stock to assure reproduction; (2) spat survival; (3) if the planting grounds really were good setting grounds or if they were better for growing and fattening; (4) whether shell was actually the best substrate and how it should be placed on the bottom; (5) when planting should occur; and (6) the effects of local salinity regime on growth and survival. Since watermen were asked to provide recommendations for sites for shell planting, these sites were generally barren bars, rather than even moderately producing beds.

Research showed that larval concentrations over once productive areas (e.g., Great Rock, Cornfield Harbor, Flag Pond, Governor's Run, Dry Rock in Tar Bay) never exceeded 9 larvae per 200 liters of water. One to three larvae were more typical. Contrarily, on Seminary Bar, Crab Alley, Mill Hill, etc., hundreds of larvae (e.g., 11,400 in 50 gal. at Dry Rock, July 1, 1924) per sample were collected. Areas of intermediate larval densities included lower Honga River, Fishing Bay, Holland Straits, Poplar Island Narrows, and Buoy Rock. Truitt stated that such information is vital for proper shell planting and that testing for spat settlement success is important before large plantings are made.

It was not determined just what brood stock concentrations were needed to provide for 400+ spat per bushel (the arbitrary level for commercial production) but it was known that breeding success was higher if the adults

were close together as on Seminary Bar, Dry Rock, Crab Alley and Mill Hill. Setting and survival was also found to vary within the seasons and from year to year. Further, high brood stock levels alone did not assure a satisfactory strike in all regimes of the Bay. Shells planted in June did not foul sufficiently to prevent a strike.

For shell planting in open water, Truitt recommended no less than 1,000 bushels per acre, with 1,200-3,500 bushels per acre optimum. Heavy concentrations of brood stock rather than scatterings seemed desirable. Research indicated that oyster shell was the most efficient, abundant and inexpensive cultch that could be used.

Truitt, R. V. 1945. The oyster. Maryland Board of Natural Resources. Dept. of Research and Education, Solomons Island, Md., Educational Series No. 7: 1-12 (Reprinted from Bios, 15(3); Oct. 1944).

In this lay guide to oyster biology, the author indicated that the 15 million bushels of oysters harvested in 1883 in Maryland would have yielded about 15 million gallons or 120 million pounds of oyster meat. This is the equivalent of about 200,000 dressed beef steers, the entire yield from New Jersey, Delaware, Maryland and West Virginia farms (at the date of writing) combined.

Truitt, R. V. and P. V. Mook. 1925. Oyster problem inquiry of Chesapeake Bay. Third Ann. Rep. Conservation Dept., State of Maryland. Baltimore, Md. pp. 25-55.

This report describes studies on prevalence of oyster larvae in plankton, spawning of adult oysters, temperature effects on spawning and larval production, experimental planting of shell as cultch, and the possible relationships among abundances of sea nettles, ctenophores and oyster larvae.

Tubiash, H. S., R. R. Colwell and R. Sakazaki. 1970. Marine vibrios associated with bacillary necrosis, a disease of larval and juvenile bivalve mollusks. J. Bacteriol. 103: 272-273.

Bacillary necrosis of larval and juvenile oysters was determined to be caused by members of the bacterial genus *Vibrio*.

Tubiash, H. S., S. V. Otto and R. Hugh. 1973. Cardiac edema associated with *Vibrio anguillarum* in the American oyster. Proc. Natl. Shellfish. Assoc. 63: 39-42.

The incidence of “cardiac vibriosis” (greatly enlarged and edematous pericardia) in over 10,000 oysters from Chesapeake Bay which were examined between 1967-1970 was 0.04% (4 animals). The animals were collected in the Manokin, St. Mary's and South Rivers. Examination of the pericardial fluid revealed heavy concentrations of gram-negative motile rods resembling *Vibrio* anguillarum.

Ulanowicz, R. E., W. C. Caplins and E. A. Dunnington. 1980. The forecasting of oyster harvest in central Chesapeake Bay. Est. Coastal Mar. Sci. 11: 101-106.

Forty years of data on oysters were analyzed with a multivariate analysis. Variations in spat density and seed plantings explained 56% of the variation in annual harvest. Spat density varied directly as the cumulative high salinity during the spawning season and inversely as the harvest of the previous season. The analysis allowed for the estimation of oyster harvest four years into the future.

Vaughn, M. W. and A. W. Jones. 1964. Bacteriological survey of an oyster bed in Tangier Sound, Maryland. Chesapeake Sci. 5: 167-171.

From August to October 1959, water, oyster and mud samples were collected irregularly from three cliff Brent sections of Hall's Bar, Tangier Sound, and examined for populations of bacteria, including coliforms and *E. coli*. Mud samples had higher plate counts than did oyster samples, which in turn were higher than water samples. Plate counts were low as were coliform counts. No. *E. coli* were detected.

Webster, J. R. 1953. Operations and problems of an oyster census on Swan Point Bar, Upper Chesapeake Bay. Proc. Natl. Shellfish. Assoc. (1952): 113-120.

Swan Point bar on the upper Eastern Shore was once self-sustaining and productive until prolonged lower salinities occurred in 1945 and 1946. The State began seeding the bar annually beginning in 1947. The author discussed problems associated with a census attempt on the bar using a hand-scrape (small oyster dredge).

Webster, J. R. and R. Z. Medford. 1961. Flatworm distribution and associated oyster mortality in Chesapeake Bay. Proc. Natl. Shellfish. Assoc. 50: 89-95.

Sampling of oyster beds for age studies of oysters in Chesapeake Bay, Maryland, produced evidence of *Stylochus ellipticus* presence on 73 widely scattered locations. Greatest numbers were noted in the lower Potomac River and its tributaries (although the survey was not quantitatively performed). No other species was collected (identifications were by Dr. L. H. Hyman, Amer. Mus. Nat. Hist). The worms were occasionally found in empty spat "boxes" (hinged valves with no oyster meat present). In a field experiment using bags of oyster shell in the Potomac River (Smith Creek),

95% of the worms collected from the bags when they were harvested in the fall were found in fresh spat boxes. The authors concluded that this flatworm was probably a cause of spat mortality.

Webster, J. R. and W. N. Shaw. 1968. Setting and First Season Survival of the American Oyster, Crassostrea *virginica*, Near Oxford, Maryland, 1961-62. U. S. Fish Wildl. Serv., Spec. Sci. Rep. Fisheries. No. 567, 6 pp.

Spat monitoring in 1961 and 1962 revealed that settlement was greater in Broad Creek than in Tred Avon River, adjacent tributaries of the Choptank River. First-season survival rates varied from 1 to 27%. Three times more spat were caught on shells clumped in bags than on shells broadcast on the bottom.

Wharton, B. H. 1963. The Maryland oyster industry. Thesis, Stonier Graduate School of Banking, Rutgers - The State University. 64 pp.

A general review of oyster biology and the commercial industry. Concluded that having 3 million Marylanders support 5,000 oystermen to the tune of 1 million dollars annually was inequitable and suggested that private culture of oyster grounds would help improve productivity. Blamed a history of lack of concern for conservation, inadequate law enforcement and the undue political influence of tidewater politicians for the decline in oyster production.

Wharton, J. 1957. The Bounty of the Chesapeake. Fishing in Colonial Virginia Univ. Press of Virginia, Charlottesville, Va. 78 pp.

A compilation of historical accounts of the past immense bounty of the Chesapeake Bay, especially Virginia waters. Although fishes were emphasized, oysters were mentioned as being in such accumulations as to be a navigational hazard in places. In the colonial period, oysters were generally preserved by pickling.

Wheatley, J. J., C. L. Quittmeyer and L. A. Thompson. 1959. The Economic Implications of the York River Oyster Industry. Bureau Pop. and Econ. Res., U. Virginia, Charlottesville, Va. 119 pp.

At the time of writing, overfishing had led to stock depletion in the York River, per capita oyster consumption had declined, and floods, pollution and disease had made inroads into the resource. The authors suggested the need to encourage consumer consumption coupled with increased production of oysters by opening new areas to fishing, renting ground, developing new seed areas and encouraging efficiency and conservation simultaneously. An aquaculture experimental program was recommended.

Wheaton, F. W. 1970. An engineering study of the Chesapeake Bay area oyster industry. Proc. Natl. Shellfish. Assoc. 60: 75-85.

Operational research techniques were used in development of an operations-process chart of the Chesapeake Bay oyster industry. Information was collected using personal interviews, time studies and on-site observations. The time studies found that an average oyster shucker shucked 7.7 oysters per minute or produced about 1.7 gallons of oysters meat per hour. Economic data were used to determine that an oyster processor could economically invest $33,000 in a machine which could shuck 60 oysters per minute. Such a machine would help solve processing problems caused by a declining pool of human oyster shuckers.

Winslow, F. 1881. Deterioration of American oyster-beds. Pop. Sci. Monthly 20: 29-43; 145-156.

Winslow based this semi-popular report on his own research in 1878 and 1879 on the oyster beds of Tangier and Pocomoke Sound and on the research by Brooks into artificial propagation of the oyster. At the time of his commissioned study, the oyster beds in the two Sounds had been heavily fished, to the point of great decline. In addition, the beds occupied a much greater area of the bottom than before, a fact Winslow proved to be due to the dredging and culling activities of the fishermen. He described the differences between unfished beds (clustered oysters, with clean shells, often with attached tufts of red sponge; the oysters being long and narrow with thin sharp bills and thin bodies) and fished beds (single oysters predominated, being broader and thicker than on unfished beds and with fatter bodies; shells dirty, with little attached sponge and more worms and boring clams in association). As evidence of deterioration in quality and fecundity of an oyster bed he listed: (1) the above description of a worked bed; (2) a ratio of small to mature oysters that was greater than 2:1 or less than 1:1; (3) a large (greater than 50%) amount of debris (shell, etc.); (4) decreasing numbers of oysters on the bar every year; (5) marked changes in the fauna of the bed. For rehabilitation, he recommended use of cultch (stones, earthenware, water pipes, shell) to extend old beds. Cultch should be placed on suitably hard bottom in the direction of currents from established beds. Mature oysters should be deposited with the shell to provide larvae. Cultch should be placed late in the spring to ensure its cleanliness. A commission of intelligent and knowledgeable (concerning oysters) people with considerable power and insulation from politics was recommended to be appointed to (1) prevent exhaustive dredging and the wasting of young growth by their being dredged or removed from the beds with market oysters, and to (2) provide for cleansing the beds of fouling organisms, pests and predators. He warned against inattention and misuse of the resource, which would result in a situation similar to the overfishing and destruction of European oyster stocks.

Winslow, F. 1882. Report on the oyster beds of the James River, Virginia Coast Survey Report for 1881. U. S. Navy, Washington. 87 pp. Reviewed in Science 1883, Vol. 2, No. 34, pp. 440-443.

Dredging extended the area of otherwise vertical oyster beds by spilling cultch over on mud making increased surface area available for spat settlement. Further dredging "thins out" the oysters and allowed for far better, more well-shaped growth. Reviewer remarked that dredging had been carried on in Chesapeake "to a disastrous extent." Oyster laws were ignored and flouted in the eyes of the "oyster police." Winslow determined the area of numerous oyster beds and approximate quantity of oysters per square yard over much of this area. Reviewer predicted the precipitous decline of the oyster beds, resulting in 40,000 people becoming unemployed. The reviewer deplored the vandalism by watermen of experimental tile-collectors, thermometers, etc., that had been deployed by Winslow in his study. From the surviving tiles it could be concluded: (a) in 1879, spat settlement on tiles set out July 9 had occurred by mid-July, continuing for about a month; (b) 50% mortality occurred within 6 weeks by unknown predators or factors; (c) attachment was greater on the concave underside of the tiles (which apparently were on or near the bottom); (d) growth rate was rapid, with some oysters being 2" long after 3 months.

Winslow, F. 1884. Present condition and future prospects of the oyster industry. Trans. Amer. Fish. Soc. 13: 148-163.

Winslow reviewed the continued deterioration of the oyster industry, especially that of Chesapeake Bay, which employed 75% of Americans in the U. S. industry and 67% of the capital and provided 77% of the harvested oysters. Evidence of continued depletion (decreasing numbers of oysters per square yard; decreasing bushels of oysters per bushel of shell; increasing price per bushel) was presented. Because of pressure from the watermen to preserve the status quo, the response of legislators of both states to the problem of declining catch was limited to the addition of a few more police boats. Winslow recommended an encouragement of private oyster culture. The state could not afford to culture oysters because of costs. Although Maryland employed 10 times as many people and produced 10 times as many oysters as did any other state (except Virginia), and although the gross value of the product was 2-4 times as large as elsewhere and the capital was 5 times as great, and there were at work 2-3 times as many vessels as other states, the percentage of capital returned was the smallest of all states. The yield per acre was only 40 bushels, compared with 120 bushels per acre in New England where the private industry prevailed. In conclusion, Winslow lamented, "The goose will be killed; the golden eggs will be laid no more. And the vast fleet of pungies and canoes, and multitudes of men and women will have no employment beyond picking out the pinfeathers of the inanimate carcass."

Wood, L. and W. J. Hargis, Jr. 1971. Transport of bivalve larvae in a tidal estuary. In: D. J. Crisp (ed.), Fourth European Mar. Biol. Symposium, pp. 29-44. Cambridge Univ. Press.

An extensive plankton sampling survey in James River, Virginia was accomplished in late August-early September 1965. Hourly samples were collected from 2-4 depths on five stations around the clock for 7 days. Mature bivalve larva were found in negligible quantities. Passive coal particles seemed to exhibit four concentration maxima which were related to the time of maximal tidal current. Concentration minima occurred at or near slack tide. Contrarily, bivalve larvae concentrations were bimodal at or near slack water after maximum flood. Minimum larval concentrations occurred on the slack following ebb. The authors claimed that larval maxima coincided in most cases with the salinity increase which accompanies flood tide.

Yates, C. 1913. Summary of Survey of Oyster Bars of Maryland (1906-1912). Government Printing Office. 75 pp.

From 1906 to 1912 the Maryland Shell Fish Commission, headed by Dr. Caswell Grave of Johns Hopkins University, cooperated with the U. S. Bureau of Fisheries, the U. S. Bureau of Chemistry and the U. S. Coast and Geodetic Survey to perform the Maryland Oyster Survey. During this period, over 200,000 acres of natural oyster bars were surveyed, technically defined and charted (along with over 40,000 acres of crab bottom and 506 acres of clam beds); in addition, over 1/2 million acres of oyster bottoms suitable for oyster culture (by leaseholders) were determined. At a cost of about $200,000, this survey involved 1112 triangulation stations; 159,530 soundings; 11,006 oyster investigation stations for examination of bottom, etc.; 3,060 miles of examination of shell bottoms with chain apparatus; 8,600 hydrographic positions plotted; 63 large-scale leasing charts prepared; 900 printed pages of Maryland Shell Fish Commission reports; 1,560 printed pages in U.S.C.G.S. publications; and 43 charts of public oyster grounds. Given the annual landings in Maryland of 5 million bushels of oysters at that time, the cost was about 4 cents a bushel. This summary presented some of the highlights of this immense and informative effort.

Annotated Bibliography Index