We have not yet adequate evidence to say with confidence that the animals were able to utilize the clay-sorbed material in their metabolism. It is, however, clear that a proportion of the radioactivity found its way off the clay and became associated with the animal tissues. There remains the possibility that the labeled organics were transferred from the montmorillonite to the animals by solution and re-adsorption; the high activity of the shed exoskeleton of *P. setiferus* demonstrates that this may be an important factor. However, the fact that the soft parts of the mollusks were radioactive during the first four days and some activity was detected in the internal tissues of the shrimp and fish suggests that surface adsorption is not the only process involved. The very high counts from the gills of the fish may also imply metabolic excretion of the C^{14} placed in the gut.

It now remains to repeat experiments in a quantitative basis measuring in absolute units of activity. This is being done.

We are indebted to the U. S. Atomic Energy Commission for financial assistance (Contract AT-40-1-2061), to many colleagues who are cooperating in the program, and in particular to Mr. Tom Duke, Mr. E. Traganza and Mr. J. B. Smith who undertook the experiments cited above.

TABLE 5

COUNTS PER MINUTE PER GRAM DRY WEIGHT OBTAINED FROM HOMOGENIZED PARTS OF *Penaeus setiferus* AFTER EXPOSURE TO 2 ML. OF LABELED CLAY IN 1500 ML. OF SEA WATER.

Tissue	After 48 hrs.	After 72 hrs.
Whole animal	449	394
Cephalothorax	560	376
Abdomen	165	96
Exoskeleton	672	*

*This specimen ecdysed during the first 48 hours. The shed skin showed relatively high activity at 1944 counts per minute per gram.

Commercial and Biological Uses of the Maryland Soft Clam Dredge[1]

J. H. MANNING

Chesapeake Biological Laboratory,
Department of Research and Education, Solomons, Maryland

FILES OF THE UNITED STATES PATENT OFFICE contain drawings of dozens of mechanized shellfish harvesting devices, some more or less resembling the Maryland soft clam dredge. The Maryland gear, however, is unique in its demonstrated capability of harvesting sub-tidal stocks of deeply burrowing shellfish on a commercial basis. Developed in the early 1950's and patented by Mr. Fletcher Hanks of Oxford, it has been used in Maryland exclusively for digging soft shell clams (*Mya arenaria*), with a degree of success which has

[1]Contribution No. 131, Maryland Department of Research and Education, Solomons, Maryland.

enabled the State to assume a position of leadership in soft clam production. Concurrently with development of the soft clam fishery in the Chesapeake area, considerable investigative attention has been given to the biological effects of the gear and to its potentials as a collector or harvester of various species of shellfish and other bottom-dwelling invertebrates. It will be the purpose of this report, after describing the gear and its operation, to review some of the results of these investigations and evaluate the usefulness of the Maryland soft clam dredge to the commercial fisherman and the biologist.

The dredge is shown in operating position in Figure 1. Jets of water erode and loosen the bottom immediately in front of the scoop, which is forced ahead by propeller thrust. Shoes on the side of the scoop, which is hinged to the conveyor, travel on and parallel to the bottom, limiting the depth to which the dredge will dig. The shoes are not necessary when dredging level bottom, and many Maryland dredgers do not use them, depending rather upon adjustment of the forward suspension line to limit the depth of dredging. Dislodged bottom materials, washed into the conveyor, either fall through the interstices of the belt or are elevated to the surface, where the catch is culled. The dredge advances only as fast as the water jets loosen the soil, inasmuch as no available amount of propeller thrust can force the scoop through 16 to 18 inches of solid bottom.

The capability of harvesting sub-tidal stocks of soft clams is only one aspect of the gear's utility. Because the dredge can cover an area more than ten times as fast as a man using hand tools, populations of relatively low density can be exploited profitably. The economically limiting factor is, of course, operational expense, which is rather high. Studies recently undertaken by the Maryland Department of Research and Education indicate that fuel costs, which constitute more than 50 per cent of operational expense, can be reduced substantially by supplying the power for pump operation and propeller thrust from a single engine instead of the two engines now employed by commercial dredgers. This is accomplished by use of a controllable-pitch propeller which permits delivery of optimal thrust at any necessary pump speed. It is not unlikely that additional significant gains in efficiency of the dredge can be achieved by systematic study and application of engineering knowledge. Evolving mainly through process of trial and error, the gear has undergone only minor changes during seven years of commercial use in Maryland. Experimentation with different sizes and types

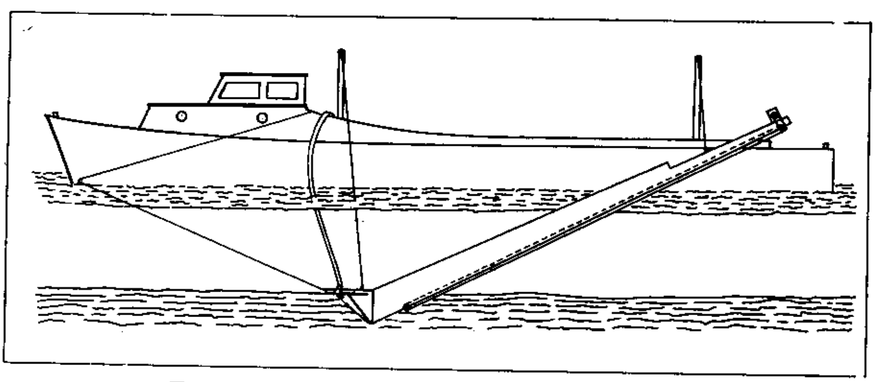

FIGURE 1. The Maryland soft-shell clam dredge.

of pumps, powering systems, conveyor belts, and jetting systems is expensive and time-consuming, and not apt to be undertaken by the individual dredge operator.

Maryland soft clam dredgers use centrifugal pumps exclusively, usually of end-suction, enclosed-impeller type with suction size ranging from 4 to 8 inches, seldom exceeding 6 inches. The pump is ordinarily driven by a 6- or 8-cylinder automobile engine capable of delivering power at several times the required rate. Pump discharge pressure of 30 to 50 pounds per square inch is normally employed by the commercial dredger, depending upon type of bottom and density of the clam population. Water is conveyed to the jet manifold through a flexible hose, usually of 4 inches diameter. The number and size of jets varies considerably; ten to fifteen pipes of one-half inch inside diameter are frequently used. Maryland law requires that the lateral jets be parallel to, and not farther apart than, the sides of the scoop, with the purpose of minimizing dislodgment of clams not directly in the path of the dredge. The rate at which the water jets erode the bottom is a function of velocity and volume of efflux, which vary interdependently with (1) pump discharge pressure and volume and (2) ratio of the cross-sectional area of the pump discharge line to the total cross-sectional area of the jet orifices. Capacity of a centrifugal pump varies directly with impeller width and in direct proportion to speed of rotation. Head varies directly with impeller diameter and in proportion to the square of the speed. The complexity of these relationships does not invite a desultory approach to the problem of selecting the right pump and designing the most efficient hydraulic system.

Conveyor belting used by commercial dredgers in Maryland, of 1-inch-square mesh, was not designed for the purpose and requires frequent replacement. The belt is usually driven by an air-cooled, 4-cycle gasoline engine of low horsepower. Power is transmitted by V-belt to a speed reducer, thence to the head pulley by chain-and-sprocket drive. Speed reduction is about 160 to 1, resulting in belt travel of 40 to 50 feet per minute. On some conveyors the drive pulley is lagged with rubber, but more commonly the pulley carries sprockets which engage the belt. Unless a torque limiter is included in the power transmission system (and usually one is not), overloading results in stalling the engine or tearing the belt, which does not have great tensile strength. A few dredgers have adopted electric or hydraulic powering of the conveyor, with gratifying results. The ability to vary rate of belt travel is a distinct advantage. In dredging sandy bottom relatively free of shell, stone, and debris, belt speed may be reduced to that of the boat, with resultant savings in belt wear. Where a high percentage of the bottom materials will not pass through the belt, as when very shelly bottom is dredged, overloading can be obviated by increasing belt speed. Hydraulic power transmission offers wide latitude in varying speed with constant torque, and torque limitation consistent with tensile strength of the belting is a simple matter.

Dredging rates with equipment now in use range ordinarily from 5 to 20 feet a minute. Higher rates are associated with sandy bottoms; lower rates, with predominantly clayey soils, which offer great resistance to erosion and cannot be dredged profitably unless clams are very abundant. Dredging is seldom attempted in sticky mud or fibrous peat bottoms, which are extremely difficult to dredge and seldom support dense populations of clams. Stony bottoms can be dredged more or less successfully by removing a section of the bottom of the scoop, allowing the stones to fall through and pass beneath the dredge. Dense growths of rooted vegetation, especially the claspingleaf pondweed, *Potamogeton perfoliatus*, present major difficulties to the dredger. The uprooted plants tend to roll up into a ball and block the lower end of the conveyor, leading to accumulation of bottom materials and overloading of the belt.

The cost of dredging soft clams varies widely from place to place, day to day, and dredger to dredger. Per-acre fuel costs range from a minimum of about $30 for dredging sandy bottom to $60 or more for dredging in hard clay. The cost of fuel constitutes somewhat more than 50 per cent of the total operational expense, not including wages of crewmen.

In an earlier report (Manning, 1957) it was estimated, on the basis of economic factors then prevailing, that profitable operation of the dredge required a minimum population density of about 50 bushels of marketable clams per acre. On the basis of current economic factors and dredge performance data, the estimate remains unchanged as an approximation applicable to the areas of predominantly sandy bottom which support the greater part of Maryland's clam fishery. It should not be interpreted as meaning that discrete populations of 50 bushels per acre are commercially exploitable. This is the level below which, usually, density cannot profitably be reduced by the almost completely random method of harvesting commonly practiced.

It is of interest to compare the minimum density required to support a hand-tool fishery with the same net profit to the digger. Dickie and MacPhail (1957) state that the average rate of digging with clam hoes is 275 square feet (0.00631 acres) per hour with efficiency of about 60 per cent. Data of Dow et al. (1954) indicate that about 65 per cent of the marketable clams are taken undamaged from Maine flats by hand-tool diggers. The Maryland clam dredge can turn about 0.073 acres of sandy bottom per hour, on the average. Studies reported by Medcof (1958, 1960) and Dickie and MacPhail (1957) indicate that the Maryland dredge catches more than 95 per cent of the marketable clams in its path with less than 1 per cent breakage of the catch. Our observations agree closely. Thus the effective areal harvesting rate of the dredge is approximately eighteen times that of the clam hoe. Operational expense of the dredger is substantial, however, and that of the hand-tool digger is negligible. Fuel and maintenance expenses of dredging are time-rate factors; labor cost varies in direct proportion to the number of bushels of clams caught. When dredging sandy bottom with population density of 50 bushels per acre, the total operational cost will be from $5 to $6 per hour and the value of the catch about $10 per hour at the current price of $3 per bushel. A hand-tool digger receiving the same price would have to work where population density exceeded 400 bushels per acre to earn $4 to $5 per hour of digging.

The ability of the clam dredger to reduce populations of market-size clams to relatively low levels has caused some concern lest spawning stocks be reduced to inadequacy. This capability is offset in some degree by the relative innocuity of the dredge with respect to clams of sub-marketable size. In meticulous experiments reported by Medcof (1960) more than 90 per cent of the small clams displaced by the dredge were deposited on or shallowly buried in the soft soil of the track within 75 feet of their points of origin. Only about 7 per cent suffered shell damage, and apparently all undamaged clams re-burrowed. In contrast, hand-tool digging destroys, on the average, about 50 per cent of the juvenile population (Dow et al., 1954; Medcof, 1958). After seven years of commercial dredging in Maryland, we have found no evidence of insufficient reproduction or replacement of harvested stocks. It should be noted, however, that in the five counties where dredging is permitted, not more than half the area within the ecological range of the soft shell clam and the operational range of the dredge is open to the dredgers. In addition, Maryland has substantial populations of clams beyond the range of the dredge, which is confined by legislatively imposed structural limitations to depths not exceeding 10 or 11 feet.

In Maryland, investigations have centered on the biological effects of soft clam dredging on tidewater resources in general. Early studies reported by Manning (1957) indicated that the effects were highly localized. Significant numbers of oysters were killed by excessive deposition of sediments within 25 feet of the periphery of an intensively dredged area, and enough sediment was deposited at a distance of 50 feet to jeopardize survival of oyster spat. No measurable deposition of sediment occurred at a distance of 100 feet. Rooted vegetation is virtually eradicated in the path of the dredge but otherwise unaffected. Revegetation requires greatly varying periods of time, depending chiefly upon the thoroughness with which an area is dredged and the degree of exposure to wave action. We have been unable through experimental or statistical approach to demonstrate any effect on distribution and abundance of blue crabs and fish. More recently attention has been focused on changes in physical and biotic structure of dredged bottoms and modifications to the dredging gear. These studies will be reported in 1960.

Personnel of the St. Andrews, New Brunswick, Biological Station of the Fisheries Research Board of Canada have conducted numerous and characteristically excellent experiments with the Maryland-type clam dredge since 1955. Especially pertinent to the intent of this report are their studies of the dredge as a harvester of species of shellfish other than *Mya arenaria*. By adjustment of the shoes and water jets they have adapted the dredge to the harvesting of bar clams and quahaugs with impressive results. Medcof (1958) estimated that production of bar clams, then harvested with forks, could be quadrupled by use of the dredge. The modified dredge fishes quahaugs 30 to 40 times faster than they can be taken with rakes, and 80 to 100 per cent faster than they can be harvested with hydraulic or rocker dredges. Equipped with rubber-tired wheels and with the jets directed parallel to the bottom, the dredge harvests oysters at a phenomenal rate without disturbing bottom soil or plants.[2]

Although reported investigations of the use and effects of the Maryland-type clam dredge have been confined to Canada and Maryland, its use for culture and harvesting of shellfish has not been so restricted. In Rhode Island the dredge has been used successfully to remove quahaugs from polluted areas for transplantation.[3] It has been employed commercially in Virginia for harvesting soft shell clams. Somewhat modified and constructed to larger scale, the dredge is now used successfully in the Long Island quahaug fishery. It has undergone apparently successful trials in the State of Washington (McLeod, 1958), and has been used for exploratory fishing in at least two other states where regulations prohibit commercial use of mechanical or hydraulic dredges.

---

[2]Personal communications, J. S. MacPhail, J. C. Medcof, St. Andrews, N. B., Biological Station, Fisheries Research Board of Canada.

[3]Personal communication, Robert Campbell, Div. of Fish and Game, Dept. of Agriculture and Conservation, State of Rhode Island.

The Maryland clam dredge, modified for surface fishing or shallow dredging, has intriguing potentials in shellfish culture. Medcof (1958) mentions its capacity for taking up oyster shells and starfish in an oyster-growing area devastated by the epidemic disease prevalent in New Brunswick. While surveying clam populations in Maryland we have dredged areas where buried oyster shells could be recovered in enormous numbers. We have estimated rate of catch in one area as exceeding 500 bushels per hour, at a cost, not including labor, of about one-half cent per bushel of thoroughly washed shells.

The possibility of employing the dredge in starfish control should be explored. Modified for surface fishing, a dredge with scoop width of 3 feet undoubtedly could cover level bottom at a rate of one acre per hour, and the catch could be subjected to chemical treatment and returned to the water in a continuous, possibly automatic process.

With conveyor belting of small mesh size, the dredge may be useful also in oyster drill control. We customarily use woven wire belting of 3/8-inch mesh for exploratory survey of clam bottoms, and it is not unlikely that belts of smaller mesh could be used for surface fishing or shallow dredging.

The catch of bloodworms (*Glycera dibranchiata*) incidental to clam dredging in Maryland, where the bloodworm population is sparse, suggests that the gear might be employed to great advantage in areas having commercial populations of bloodworms and sandworms. In fact, the demonstrated versatility of the Maryland-type clam dredge suggests that it may be adaptable to the harvesting of a wide variety of aquatic resources, including crabs and other crustaceans, sponges, seaweeds, and possibly some species of finfish. Motility *per se* does not exclude a species from capture. Several species of fish seem to be attracted to, rather than repelled by, the dredge, presumably because of the quantities of food which become available as the bottom is eroded by the jets. Among local fishes frequently caught are hog chokers (*Trinectes maculatus*), eels (*Anguilla rostrata*), spot (*Leiostomus xanthurus*), and white perch (*Roccus americana*). Blue crabs (*Callinectes sapidus*) and grass prawns (*Palaeomonetes vulgaris*) are sometimes taken in considerable numbers.

To the biologist, the Maryland clam dredge is an invaluable tool. Within its depth limitation, it offers a means of quantitative sampling of almost any type of bottom with speed, precision, and the convenience of a screened and washed sample. Even the most fragile organisms, such as the trumpet worm (*Cistenides gouldii*), are seldom damaged.

The technique of using the dredge as a quantitative sampling gear is simple but requires care and a little practice. With the dredge in operating position, pump speed and propeller thrust are reduced until the dredge is progressing steadily but very slowly. A pole is then thrust vertically into the bottom alongside the boat, a short distance ahead of the first of two marks on the rail. Collection of material from the conveyor belt begins when the pole is abreast of the first mark and ends when the pole comes abreast of the second mark. Sample size is a function of scoop width and linear progress of the dredge. We have found 20-square-foot samples generally convenient and, having a dredge with scoop width of 30 inches, use marks 8 feet apart. Depending upon the purpose of the sampling, material may be selected from the belt or collected *in toto* as it falls over the after end of the conveyor. We have found that collection in baskets held under the end of the conveyor often results in breakage of the more fragile animals. For collection of whole samples we prefer towing a float with wire mesh bottom under the end of the conveyor, deep enough that water cushions the impact of falling material.

This method of sampling requires that rate of travel of the conveyor belt exceed rate of linear progress of the dredge, and that these rates remain constant for a short time before and during the sampling. The dredge must, of course, travel in a straight line, a requirement which is easily met by steering so that the rail of the boat is kept a constant distance from the vertically-driven pole. If the rail is not essentially parallel to the keel-line of the boat, a "false rail" can be used as a reference plane.

Inasmuch as the dredge when carefully operated is virtually 100 per cent efficient, highly quantitative samples are obtainable by the method described. No other gear of which we have knowledge has equal utility in shoal-water surveys of commercial shellfish or in studies or distribution, abundance, and ecologic relationships of the littoral macro-benthos. To view the panorama of bottom communities passing on the conveyor belt is a unique and rewarding experience, one that challenges the biologist to make greater and better use of this remarkable machine, the Maryland clam dredge.

LITERATURE CITED

DICKIE, L. M. AND J. S. MACPHAIL
1957. An experimental mechanical shellfish-digger. Progress Reports of the Atlantic Coast Stations of the Fish. Res. Bd. of Canada, No. 66, pp. 3-9. September.

DOW, R. L., D. E. WALLACE AND L. N. TAXIARCHIS
1954. Clam (*Mya arenaria*) breakage in Maine. Dept. of Sea & Shore Fish., Augusta, Maine. Research Bull. No. 15. January.

MANNING, J. H.
1957. The Maryland soft shell clam industry and its effects on tidewater resources. Md. Dept. Research & Educ., Resource Study Rept. No. 11. January.

MCLEOD, K.
1958. Clam farming. Fisheries, Fish Farming, Fisheries Management. Wash. State Dept. of Fish., Seattle, Wash. pp. 53-60.

MEDCOF, J. C.
1958. Mechanized gear for shellfish harvesting and shellfish culture. Ex. MS Rep. Series (Biological) 644, Fish. Res. Bd. Canada, Biol. Sta., St. Andrews, N.B. 12 pp., 2 tables.
1960. Effect of escalator harvester on under-size soft-shell clams. Proc. Nat. Shellfish. Assoc. for 1959. In press. 9 pp., 3 tables.

The Biological and Economic Problems in Marine Fisheries Management[1]

RICHARD VAN CLEVE
University of Washington, Seattle, Washington

IN THE NORTHWEST we have, in spite of the Japanese, tended to view our fisheries management problems as of sole concern to ourselves and possibly Canada. Our complacency has recently been rudely shaken by the appearance of Russian trawlers off Alaska's coast.

[1]Contribution No. 79, College of Fisheries, University of Washington.