THE PERSISTENCE OF NEW JERSEY’S OYSTER SEEDBEDS IN THE PRESENCE OF OYSTER DISEASE AND HARVEST: THE ROLE OF MANAGEMENT

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ABSTRACT New Jersey’s Delaware Bay oyster fishery developed along a pathway common to many fisheries. Perennially large harvests led to depletion of the oyster resource, which led to increasing, but ineffective, harvest restrictions and cumbersome management. In the 1950s, two events altered the management structure. In the beginning of the decade, a university researcher dedicated himself to having oystermen and the state regulatory agency use information from research and monitoring programs directly in their decision making. He achieved limited success until a previously unknown oyster disease, eventually called MSX, occurred that threatened to drive the oyster fishery to extinction. The presence of MSX led oyster harvesters to become dependent on the information provided by the university. In addition, the regulatory agency and its regulations had to be responsive to short-term changes in the intensity and prevalence of disease. A tripartite management structure developed in which: 1) the oystermen, researchers, and state regulatory agency acted cooperatively and 2) flexible guidelines were developed that could respond to annual variation in oyster abundance and disease. Several aspects of this management arrangement could prove useful in other fisheries.

KEY WORDS: oyster, management, fishery

INTRODUCTION

Over the past decade, an increasing sense of urgency to develop effective, nontraditional approaches to fisheries management has developed. Too frequently, government-directed management has had problems sustaining fisheries resources at harvestable levels while providing economic and social stability for the fishery participants (McGoodwin 1990, Hannesson 1996). Alternative management models that have been suggested include adaptive management (Walters 1986), ecosystem management (Schramm & Hubert 1996), and responsible management (FAO 1995). All alternative management models suggested to date involve greater participation by fishery participants in the management decision processes, a management structure generally referred to as co-management. Many observers of and participants in fisheries are wary of including the principal users of the resource: they doubt that those who would gain immediate benefit from using a resource would sacrifice current profit for future sustainability (Jenofet et al. 1998). In contrast, Jenofet et al. (1998) have argued that there are numerous social and institutional elements that allow a more positive expectation of the outcome of co-management models.

Co-management has developed in some fisheries without a deliberate effort to develop a nontraditional management program (Jenofet & McCay 1995). Contingent needs can lead all participants in a fishery to search for an operating environment to solve certain problems. Such is the case with New Jersey’s Delaware Bay oyster fishery. A detailed examination of the ontogeny and structure of this particular fishery provides several benefits. First, it allows those who are considering developing co-management programs to learn from the successes and failures of those who have already incorporated co-management. Co-management programs are emerging. For example, in the state of Maine, co-management has been legislated recently for the lobster fishery (Acheson et al. 2000). Other fisheries in the region are expected to follow the same path. Second, the contingent need that had to be solved in New Jersey’s Delaware oyster fishery was the presence of diseases that affected the resource. Apparently several populations of marine species have an increasing incidence of disease-induced mortality (Harvell et al. 1999). Managing in the presence of disease may be a more common feature of fisheries in the future. Accordingly, we present the following case study.

Historically low abundances of the eastern oyster, Crassostrea virginica, presently occur throughout much of the middle Atlantic US coast. Many factors have contributed to the decline of the large oyster populations that existed in Chesapeake and Delaware Bays, including management that failed to prevent overharvesting (Haven et al. 1978, Kennedy & Breisch 1983). A major factor contributing to recent declines of midcoast oyster populations and frustrating restoration efforts is the presence of one or more oyster diseases. Disease-induced mortalities have been so intense that in some areas oysters are rare and local oyster fisheries have become extinct (Bosch & Shabman 1989).

In Delaware Bay, the principal oyster disease organism for most of the past four decades has been the MSX parasite Haplosporidium nelsoni. Since 1990, a southern oyster parasite, Perkinsus marinus, which causes Dermo disease, has invaded the Bay becoming the principal disease agent affecting oysters. Epizootics produced by both parasites have caused extensive oyster mortalities in Delaware Bay; however, large numbers of oysters persist. Continued high abundances of oysters in Delaware Bay have been possible because many natural oyster beds occur in a spatial refuge from disease in the upper regions of the Delaware estuary. Salinities in this area frequently fall below levels necessary to sustain MSX infections. The Dermo parasite survives in these reduced salinities but does not produce lethal infections. The natural beds have been a primary source of seed oysters for the industry since the mid 1800s. Until recently, direct marketing from the beds had been prohibited. All seed oysters had to be transplanted to private leases in the lower bay where their growth and meat quality would be greatly enhanced before marketing. With the advent of Dermo...
disease, movement of oysters into the lower Bay became unecono-

mical, and limited direct marketing from the beds began (Ford 1997).

Because the natural beds are located in the upper estuary, the
seed resource would have survived the depredations of oyster dis-

ease without human intervention. However, a management scheme
that developed shortly before the 1957–1959 MSX outbreak sta-

bilized postepizootic yields from seed oysters. Oysters still had to
be transplanted onto leased grounds where enhanced growth and
fattening was now countered by higher disease pressure that in-

creased mortality. After the outbreak of Dermo disease, an entirely
new strategy had to be developed to sustain the industry in the face
of a disease with very different characteristics. We believe that a
description of New Jersey’s management structure provides in-

sights for those desiring an effective management structure for
many fisheries. Below we describe the physical and biologic con-
text of the seed oyster fishery in Delaware Bay. Next, we provide
a brief history of the fishery and describe the development of the
present management structure and how it functions. We then sum-
marize important aspects of the role of oyster diseases and how the
management scheme responded to challenges from the diseases.
We conclude by highlighting the unique elements of the manage-
ment structure that we feel led to its success. It is important to note
that the authors were participants in many events described below
and may be burdened with preconceptions as to the value and
importance of different aspects of the management structure. How-
ever, our direct and extensive knowledge of the inner workings of
the management structure allows us to place events and circum-
stances in a context that would not be available to an outsider.

Physical Description of Delaware Bay

Detailed descriptions of the physical and bathymetric charac-
teristics of Delaware Bay are available elsewhere (Shuster 1959,
Maurer & Watling 1973, Galperin & Mellor 1990a, 1990b). Dela-
ware Bay is bounded on the north and east by New Jersey and on
the south and west by Delaware (Fig. 1). The bay extends 75.2 km
from its southeastern-facing mouth between Cape May and Cape
Henlopen to the entrance of the Delaware River in its northwestern
corner. The average depth is ca. 10 m with the greatest depths
occurring near the central long axis of the bay. The eastern side of
the bay has extensive tidal flats. The bottom consists largely of
soft-substrates (sands and muds) with hard substrate limited to
spatially discrete oyster beds and cobbled aggregates.

Delaware Bay experiences predominately semi-diurnal tides
with a 1–1.25 m tidal range near its mouth. Around 72% of the
annual freshwater input enters the bay from the Delaware and
Schuylkill Rivers. Salinity near the mouth ranges from 30–31 ppt
and decreases with distance in a roughly uniform fashion up the
bay to 0–4 ppt near Wilmington, DE. Water temperatures range from −1.8 to 29.0°C annually.

Oysters in Delaware Bay

Historically, natural oyster beds existed throughout Delaware
Bay (Ford 1997). Before the mid-1800s, however, harvest prac-
tices and the distribution of oyster predators (primarily oyster
drills, *Urosalpinx cinerea* and *Eupleura caudata*) eliminated beds
in the lower bay. The geographic location of extant natural (seed-
oyster) beds has remained fairly constant and predates the appear-
ance of MSX in Delaware Bay (Engle 1953, Maurer et al. 1971). These oyster beds occur in several small rivers entering the bay

\[ \text{Figure 1. Location of the seedbeds (shaded areas) and the planting (leased) grounds (areas inside the broken lines) in Delaware Bay. The double line extending down the center of the bay represents the shipping channel. It separates the New Jersey and Delaware portions of the bay. Abbreviations for the seedbeds are the same as in Table 1. The labels of five small beds, located inland of EIS and NWB-STR, are indicated by letters (a—NPT, b—HGS, c—HWN, d—VEX, and e—BDN). DPW is the Deepwater site.} \]
ductive activity occurring from mid June to mid July. The larvae remain in the water column from 10 to 20 d, depending on water temperature. Oyster spat set over most of the bay. The densest sets generally occur in the eastern portion of the bay south of Egg Island Point, where no beds exist and where oysters rarely survive to adulthood because of high predation, disease, and winter ice mortalities (Engle 1953, Ford & Haskin 1988).

**Oyster Fisheries in Delaware Bay**

Several detailed accounts of the history of Delaware Bay oyster fisheries exist (Miller 1962, Maurer et al. 1971, Ford 1997). The following description, based on these histories, concentrates on the New Jersey portion of the fishery.

In colonial times, natural oyster beds occurred throughout the bay although then, as now, most beds were located in the eastern (New Jersey) portion. Oysters were harvested directly from the beds and most were taken directly by ship to markets in Philadelphia. The concept of planting small “seed” oysters onto private leases for growth and fattening before taking them to market was introduced to Delaware Bay in the mid 1800s. Leases were established in the lower bay because the market quality of oysters was better there and because the local, natural beds had been largely destroyed by that time. Transplanted oysters were usually left on these relatively high-salinity leased grounds for 1–3 y before they were marketed. The seed oysters came primarily from the extant natural “seed” beds in the upper bay and in the creeks where low salinity protected small-sized oysters from predation. These beds remained a “public” resource. The practice of planting oysters was codified independently by laws in the States of Delaware and New Jersey. Until recently, planting seed oysters was the principal means of producing oysters in Delaware Bay. As planting became more widespread, the oyster fishery became dominated by companies that owned large schooners and used dredges to harvest oysters; hand tongers oystering from small boats have remained a marginal component of the fishery since that time (Fig. 2).

From 1900 to 1930, Delaware Bay oyster landings produced between one million and two million bushels annually (Ford 1997). After 1930 and until the mid 1950s, the productivity of the industry declined slightly and annual landings remained at or just below one million bushels (~40 million L, Fig. 3). Landings of this magnitude, although supplemented by planting of seed oysters collected from outside of the estuary (primarily Chesapeake Bay and Long Island Sound), removed tremendous numbers of oysters from the natural seeds. By the early 1900s, seedbeds near the planting grounds were reported to be out of production. Subsequent harvest practices (e.g., failure to return oyster shell to the seedbeds and the introduction of engines into the sailing schooners used to dredge seed oysters) and physical-biologic interactions (e.g., persistent droughts that increased the range and abundance of oyster drills) led to further degradation of the seedbeds. Finally, several years of poor recruitment onto the seedbeds and some unexplained mortalities of adult oysters in the 1940s and 1950s left oyster abundances on the seedbeds at historical lows.

**Development of Oyster Seed Fishery Management**

Legislation enacted by the States of New Jersey and Delaware during the 19th century attempted to regulate oyster fisheries in both states (Ford 1997). The overall goal was to preserve the oyster resource. Specific laws introduced culling (returning oyster shells to the bottom), restricted taking oysters from public seedbeds to a specific season, allowed the first private leasing of grounds, and created a variety of organizations to monitor and enforce the legislation. Enforcement was a perennial problem and, at the request of many oystermen, the State of New Jersey took control of both the public and private grounds in 1899 (the State of Delaware had done so in 1873, just two years after private grounds were developed there).

The principal regulation affecting the New Jersey seedbeds limited the period for oyster dredging to May and June. During this period, known as bay season, licensed vessels were permitted to take as many oysters as they could dredge and carry from the seedbeds for transplanting onto private leased grounds. Beyond limiting the length of bay season, there were no attempts to restrict the numbers of oysters taken from the beds. Prior to the 1950s, the seedbeds were closed to harvest only once, in 1928, to protect a large set of spat (newly settled oysters up to one year of age; Nelson 1929). During this time, information on year-to-year changes in oyster abundance on the seedbeds was not gathered. Few data were available to provide a basis for decisions by management.

Management of New Jersey’s oyster resource can be traced to 1888. In that year Julius Nelson, a member of Rutgers University’s New Jersey Agricultural Experimental Station, convinced the school to create the Department of Oyster Culture. Julius Nelson, and later his son, Thurlow, became leaders in the field of oyster biology and established a tradition of using scientific methods to produce information useful to the oyster industry (Nelson 1913, 1928, 1947). In the early 1950s, when oyster abundances on the Delaware Bay natural seedbeds reached historical lows, the Department of Oyster Culture, then under the direction of Harold Haskin, began studying the factors limiting oyster abundance on the seedbeds and gathering data that would suggest management strategies to rehabilitate the beds. The collection of data on oyster life-history in Delaware Bay in a regular and consistent manner
Collected data is now an accepted element. Both components have cally collected data in decision-making. The use of scientifically restrictions on seed transplants and of the usefulness of scientifi-cally obtained data has continued for 45 y and has provided the basis for what we believe has been an effective management scheme.

At its inception the seedbed rehabilitation program consisted of two key elements: gathering quantitative data on oysters (Research Component) and advocating the use of these data in making management decisions (Applied Component). The research component consisted of several studies conducted yearly including: (1) determining the temporal and spatial abundance patterns of oyster larvae, (2) determining the temporal and spatial patterns of oyster spat settlement and fouling organisms (invertebrates that compete with spat for space) onto artificial collectors, (3) detecting annual changes in the abundances of spat, yearlings, and older oysters on the seedbeds, and (4) estimating the volume of seed oysters transplanted from the beds. Much of the funding for monitoring in the early years derived from University sources, a condition that is uncommon in our experience. The applied component entailed a determined effort on the part of the Director of the Department of Oyster Culture (Haskin) to convince the state management agency of the need for additional restrictions on seed transplants and of the usefulness of scientifically collected data in decision-making. The use of scientifically collected data is now an accepted element. Both components have had continued importance in the overall management of the resource.

Research Component

Of the several studies in the research component, two have been consistently of greatest use to management of the resource: collecting dredge samples from seedbeds and estimating the amount of oyster seed transplanted during bay season. Since the onset of Dermo disease, data on infection levels and oyster mortality rates have also been used on a regular basis in making management decisions.

For dredge sampling, several grids, each consisting of contigu-ous 275-m × 370-m rectangles (approximately 0.2 min of longitude by 0.2 min of latitude, respectively), were created for each of the 25 spatially largest seedbeds that had historically contributed the bulk of oyster production. Each year, generally between No-vember and March, approximately 10% of the grids were chosen from each bed using a stratified random sampling design. Samples were taken from the middle of each grid. In the grid an oyster dredge (with a 71-cm tooth bar and a bag capacity of ~80 L) was towed on the bottom for one minute at constant boat speed (i.e. approximately constant effort) three separate times. Approximately 13–14 L of the contents of each of the three hauls were retained, pooled, and returned to the laboratory as a single sample. First, the volumes of live oysters (adults, yearlings, and spat), cultch (oyster shell with no live oysters attached), and debris (sponges, algae, wood, etc.) of each sample were estimated. Then the following quantitative attributes were determined by direct examination: (1) the number of oysters older than 1 y, (2) the number of “yearlings” (oysters that were about 1 y old), (3) the number of spat, (4) the number of “boxes” (articulated but empty oyster valves), (5) the number of “gapers” (recently or nearly dead oysters that do not fully close their valves when handled), and (6) the number of dead spat and, if any distinctive drill or crab valve damage was apparent, the source of spat mortality.

Estimates of seedbed yields were made by research crews every day that dredging occurred on the seedbeds from 1956 to 1991. How many and which boats dredged, which beds the boats dredged, and estimates of the volume of oysters moved to the planting grounds at the end of the day were obtained by direct inspection. Estimating the volume of oysters harvested was done by noting the size of the pile on the deck and the position of the water line on the oyster boat. In several years research crew esti-mates were compared with estimates of seed oyster volume made by the boat captain and by direct measurements. Remote observer estimates were generally within 10% of the captain’s estimates and of direct measures.

Estimates of the percent composition of commercial dredge samples were also made during bay season. On Thursday (usually) of each week of seed planting season unculled 40 L samples of oysters and shell were taken directly from the decks of oyster boats. Boats were selected on the basis of which beds they dredged. The beds of interest were those that had experienced the greatest amount of dredging activity during the week or that had begun the week with relatively low percentage (by volume) of oysters. On shore a committee composed of industry members, managers, and laboratory personnel sorted the samples into oyster (live adults, yearlings, and spat) and shell (anything without an oyster attached) and estimated the relative volumes of the two portions. This information was then used to decide whether to...
close some of the beds or to end the seed transplant early. If the average percent of oysters by volume was less than 40% for a bed the committee gave serious consideration to closure.

The 40% value was a “rule of thumb” benchmark that was never supported by statute or regulation. It was not supported by scientific evidence. When the seedbed rehabilitation program began the approximate percent oyster on many beds was around 40% and many felt that it should not go lower. The industry members understood this measure (as opposed to more complex statistical indices) that required simple math and that they could derive on their own via examination of dredge hauls. Also, when percent oyster did drop much below 40% harvesting oysters became prohibitively expensive for boats using manual culling. Use of the 40% rule was flexible. Depending on other factors (abundance of oysters elsewhere, number of spat in the sample, perceived economic needs of the oystermen) a bed could be closed before the percent oyster measure reached 40% or at a considerably lower percentage (as low as 20% in a few cases).

Applied Component

A shellfish council, officially consisting of industry members appointed by the Governor, had long been in place to advise the state agency in charge of the seedbeds (the council also supervised the private leases approving transfers, vacancies, boat licenses, etc.). In the early 1950s incorporating research results into the council’s decision-making proved difficult. The concept of managing oyster beds with recently collected data was foreign to both the state agency (NJ Bureau of Shellfisheries) and the oystermen. However, the greatly depleted condition of the beds indicated that restrictions on seed transplants would be austere for some time to come. The patent threat to the fishery by the condition of the seedbeds and the persistent efforts of the Director of the Department of Oyster Culture advocating the utility of research results led to the development of a tripartite management scheme. An independent source of information, Rutgers University, was added, in an informal advisory role, to the shellfish council and state regulators (Fig. 4). This system remains in effect today.

In late winter, several months prior to the beginning of bay season, data collected from the seedbeds by the university researchers are presented to the shellfish council and representatives of the state management agency. The primary concerns are the relative compositions of dredge samples taken from the seedbeds (percent oyster) and the seedbed spat abundances. An oral presentation of these data (usually supplemented with a written summary) is made to the shellfish council members who use this information and, in some years, their own direct observations of the beds, to decide (1) whether there will be a bay season, (2) how long the season will be, and (3) whether any beds will be excluded from fishing. The council’s recommendations are then submitted to the state management agency (specifically the Commissioner of New Jersey Department of Environmental Protection who directs the Bureau of Shellfisheries), where they have generally been approved.

Onset of MSX Disease

In the spring of 1957, widespread mortalities of oysters planted the previous year occurred on the New Jersey leased grounds. Within two years the epizootic had killed over 90% of the oysters on the planted grounds and almost half of those on the seedbeds (Haskin et al. 1966). The causative agent, *H. nelsoni* (popularly referred to as MSX), was identified in 1958 and has remained enzootic in the estuary (Ford 1997). Since 1957, dockside landings of oysters from Delaware Bay have remained well below a half a million bushels (~20 million L) of oysters annually (Fig. 3), although significant underreporting of these landings may be occurring (Haskin & Ford 1983).

Uninfected oysters residing in salinities greater than 15 ppt can become infected with *H. nelsoni* from June to early November. The disease progresses to a lethal stage within several weeks in susceptible oysters. Mortalities are delayed in Delaware Bay native stock; it has developed a degree of resistance to the disease (Ford & Haskin 1987). Some oyster deaths occur in late summer or fall of the first year of planting, but these are usually tolerably low (Ford & Haskin 1982). Mortalities are cumulative, however, and become unacceptably high if oysters are not marketed within a year. The large oyster mortalities produced by MSX on the planted grounds altered the practices of the Delaware Bay oyster fishery. First, importation of oyster seed from other regions ended. Second, only relatively large oyster seed could be transplanted from the seedbeds to the planting grounds because only a single growing season was likely to be available to growers. It was no longer possible for small oysters to survive in the lower bay for the two to three years necessary to reach market size. Planters could not stockpile oysters on their leases anymore. Third, oystermen concentrated their planted oysters in a relatively small area of the bay less prone to disease. Leased bottom was made available that encroached onto the lower seedbeds in an attempt to provide less saline and less disease-ridden planting grounds. Fourth, oyster boats decreased operating costs by using automatic culling machines instead of manual labor to separate oysters from cultch. Fifth, regulations were changed to permit marketing oysters earlier in the year. This allowed planters to land oysters as soon as they reached market size instead of waiting until 1 September as they had previously. Sixth, a limited fishery based on boat size was established in 1981 to prevent a large influx of participants during good times who had no commitment to preservation of the resource.

The onset of MSX disease initiated a long-term monitoring program that followed the spatial and temporal patterns of the disease in the bay and consequent oyster mortality (Ford and Haskin, 1982). Results garnered from this effort helped interpre-
tation of data acquired from the annual seedbed sampling program. At approximately one month intervals, oysters were dredged, using the same device described above, from the larger seedbeds and several locations on the planting grounds. The dredge samples were taken only from the most productive grids on the seedbeds. In contrast to the fall/winter seedbed sampling procedure, several successive dredge hauls were conducted until a bushel (∼40.7 L) containing only live oysters, gapers, and boxes was obtained. All gapers and boxes were examined for evidence of shell damage that could be attributed to crabs, drills, or dredging. Gapers and boxes with undamaged valves were assigned to the nonpredation mortality category. The interiors of the boxes were further inspected to determine whether any fouling organisms had recruited onto the inner surfaces of the valves. Boxes with no fouling on the inner valve surfaces were considered “recently dead.” Spatial and temporal variation in the rates of valve fouling were estimated by placing clean valves in the field at regular intervals and examining them at subsequent intervals for the presence of fouling organisms. Seasonal “fouling intervals” ranged from 2 to 3 wk in the summer and up to 10 wk in the winter (Ford & Haskin 1982). Estimation of the annual mortality from predation and nonpredation sources were made by accumulating mortalities determined over short intervals.

MSX disease prevalence and intensity was determined via histologic procedures in live oysters and gapers collected during the mortality sampling. After sectioning and staining, the abundance and location of MSX parasites in the tissues were determined via microscopic examination. In local infections (nonlethal at the time of collection) the parasites occur only in the gills. In systemic infections parasites are distributed through all oyster tissues. Systemic infections are found in 90% of oysters that die of MSX disease (Ford & Haskin 1982).

**Onset of Dermo disease**

Infections by the southern oyster parasite, *P. marinus*, causative agent of Dermo disease, had been historically of little consequence in Delaware Bay. During the mid 1950s light infections were found in planted oysters after parasitized seed was imported from Virginia where the disease was endemic. Dermo infections became rare in the bay after importation of seed ended. The water temperatures in Delaware Bay were generally believed to be too cold for Dermo disease to persist (Ford & Haskin 1982) and sampling specifically for Dermo disease ended in 1963. In the late summer of 1990, oyster mortalities that did not fit the pattern associated with MSX disease were documented in several locations in Delaware Bay (Ford 1996). The causative agent was quickly identified as *P. marinus*. Since 1990, Dermo infections have been persistent, widespread, and responsible for continuing oyster mortality in the bay. In contrast to the pattern of MSX distribution, Dermo infections have extended onto the seedbeds and caused substantial mortalities of seed oysters. *P. marinus* is much more tolerant of low salinity than *H. nelsoni*. It survives on most of the seedbeds, even though it does not cause many lethal infections on the uppermost beds. Parasites proliferate rapidly in oysters transplanted to the planting grounds in spring, stimulated by both high temperature and high salinity. Under these conditions, transplanted oysters typically die before the fall market season. The consequences of a mortality pattern quite different from the delayed mortalities induced by MSX disease was forcefully demonstrated to the planters shortly after the onset of the Dermo epizootic. Planters were advised of the presence of Dermo disease in Delaware Bay immediately after it was identified in the summer of 1990. During the remainder of the summer and fall, the disease spread to all planting areas and to the lower seedbeds, but caused relatively little mortality and yields from planted oysters were the best in many seasons. The following year, the abundance of oysters on the seedbeds was the best since the early 1980s and nearly 300,000 bushels (1.2 × 10⁷ L) were moved to the planted grounds. A large majority of these oysters were already infected with *P. marinus*, which quickly proliferated. Despite advisories about relatively high infection levels by researchers (including warnings by oyster disease researchers from institutions other than Rutgers University expressed in a special public meeting), most planters, remembering the profitable results of the previous year, chose to leave their oysters on their leases rather than to harvest early. Mortalities, when they began, were severe and only about a quarter of the oysters survived to the fall market season.

The MSX surveillance program was severely diminished after the mid 1980s because of funding limitations and an expressed hesitation by university administrators to commit to long-term monitoring programs. The advent of Dermo disease, however, raised enough concern within the industry that limited monitoring was resumed. It centered primarily on disease diagnosis in oysters collected during the fall seedbed survey, which provided information on the spatial distribution and intensity of Dermo disease on the natural beds at a time of peak prevalence and intensity (Ford & Tripp 1996). Because it is likely that oysters rarely, if ever, completely rid themselves of *P. marinus*, even under the low temperature and low salinity conditions that are unfavorable to the parasite (Ragone-Calvo & Burreson 1994, Ford et al. 1999), the fall sampling provided a good estimate of what percentage of oysters are infected on each bed. Subsequent sampling in the spring before bay season, provided additional information on infection intensity, which typically decreases over the winter in proportion to temperature and fresh-water influx. Infection intensity in oysters likely to be transplanted provided a rough measure of whether infections would progress to the lethal stage relatively sooner or later after planting.

The results from the Dermo disease surveillance program and from the earlier MSX program were presented to the shellfish council and to individual planters. In recent years, mailings to all lease holders describing the most recent levels of oyster mortality and disease prevalence were made.

**Delaware Bay Oyster Fishery Activity, 1953 to 1991**

Seed dredging has occurred in most years since the first MSX epizootic (Fig. 5). Generally all of the beds were open, but oystermen concentrated their efforts in just a few beds. The 1960s harvests were relatively small and came primarily from the uppermost beds. By the end of the 1960s most oyster seed came from the beds in the midsize of the seedbed region. Four beds, Cohansey, Shell Rock, Bennies, and New Beds, produced 68.2% of the oyster seed from 1958 to 1991. These are among the largest beds and perennially have relatively high abundances of moderately large oysters (Table 1).

As would be expected, samples collected for the weekly estimation of relative oyster volume during bay season were taken from where most of the harvest activity occurred. During the 1960s and early to mid 1980s the relative volumes of oysters in the samples were generally less than 40% (Table 2). Only a quarter of these samples (11 of 42 instances) was less than 30% and in only
three instances were the proportions less than 20%. During the mid
to late 1970s the relative oyster volume frequently exceeded 40%,
but these data were never used to extend a seedbed harvest season
beyond the length that had been agreed upon earlier in the year.
Individual seedbeds were closed before the end of bay season only
four times (Shell Rock Bed, 1961; Cohansey Bed, 1967; Shell
Rock Bed, 1972; and Bennies Bed, 1974). Low percent oyster was
the reason in half of these closures, while protection of spat led to
the other early closures.

The fishery benefited from very successful recruitment in 1972
although relative abundances of oysters on the beds were increas-
ing before this year (Fegley et al. 1994). The large 1972 set pro-
vided oysters until the early 1980s. The persistence of harvestable
oyster seed for almost a decade after the 1972 set was aided by the
management and harvest practices of the fishery participants. For
instance, despite large abundance of oysters in 1974 the length of
bay season was not extended to take immediate advantage of this
bounty either that year or in any successive year. Within years, the
efficiency of seed harvest (actual harvest/potential harvest ×
100%) remained near 60% throughout the period (the potential
harvest was based on estimates of the total abundance of oysters
present on the seed bed large enough to be suitable for transplant).
The observed efficiency was most likely a function of boat harvest
limitations rather than conscious efforts of the harvesters. Oyster
recruitment onto the seedbeds was relatively low in the years after
1972; another "large" set (only a third the size of the 1972 set) did
not occur until 1986. Restricted harvesting of the large 1972 set by
the fishery, combined with average or above-average annual Dela-
ware River flow into the bay, remains the most likely explanation
for the continued presence of oysters on the seedbeds into the late
1970s and early 1980s.

In the mid 1980s seedbed harvests began to decline. During this
time there were increased prevalences and intensities of MSX
disease throughout the bay (Fig. 6); widespread mortality of oys-
ters followed. This was the first time since the mid 1960s that the
seedbeds exhibited such high levels of disease and predation. The
mid 1980s were also the first time since the mid 1960s that the
annual mean Delaware River flow remained below the long-term
average for several successive years (Fegley et al. 1994). No seed
dredging occurred for 3 yr (1987–1989). During this protracted
closure of the fishery there were modest increases in the abun-
dances of oysters on the beds and seed transplants began again in
1990. Unfortunately that was also the first year of a Dermo disease
epizootic.

The effects of Dermo disease upon the New Jersey oyster fish-
ery have been substantial. Data provided by university researchers
informed oystermen that most of the oysters they would plant were
infected with the Dermo parasite and would not survive long after
planting. Based on this monitoring information, the shellfish coun-
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received a quota (of equal size, regardless of boat size). Vessel owners were required to buy a tag costing $1.25 per bushel for each bushel they expected to harvest up to their quota. A time period was set in which the quota was to be used. After this period the status of the resource, markets and other factors were evaluated, and another quota decision was made. In most cases the quota per boat was increased. This activity has generated a considerable amount of revenue (Table 3). Purchase of tags alone totaled $374,615 (through the fall of 1998). This money was deposited because of high subsequent mortality, only 63,000 bushels (2.6 × 10^3 L × 10^3) were landed, producing a total return of $1,189,190. For each bushel removed from the seedbeds, direct marketing has returned nearly seven times more in dockside value compared with typical planting returns during periods of high Dermo disease (Table 4).

The presence of Dermo disease has increased the reliance of oystermen and state officials on the results of university research and monitoring. In the past, information about MSX prevalence was of secondary importance to the shellfish council when they were deciding whether to have a bay season (MSX was generally uncommon on the seedbeds). In contrast, the high prevalences of Dermo disease in oysters on the seedbeds raised concerns about transplanting infected oysters, which could result in rapid proliferation of the disease and high oyster mortalities before they could be marketed. Data on Dermo disease prevalence has been the primary information leading to limited seed transplanting in the past few years. A 4-week bay season was agreed to in 1995, but the shellfish council closed the beds after two weeks. Shellfish council deliberations cover a range of issues when the council makes decisions on closures (Appendix 1).

**DISCUSSION**

Aspects of the Delaware Bay Management Structure

Management of the Delaware Bay New Jersey oyster fishery has the elements common to many fishery management structures. It consists of a management agency, an industry, a means of data collection and evaluation, an industry council, and a set of statutes and regulations. The difference between this system and other fishery management structures is the way these entities relate to each other. Although these special relationships cannot, by themselves, be credited with the continued persistence of harvestable oyster populations in Delaware Bay, we believe their implementation has developed an atypical management program.

There are at least six basic differences—some obvious, others subtle—between the Delaware Bay New Jersey management scheme and many others. First, as for several estuarine shellfish-

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**TABLE 1.**

Some characteristics of the seed beds related to seed harvest. The area of the seed bed includes nonproductive bottom. Mean percent oyster is based on dredge samples taken in the random sampling program (1953–1991). Mean individual size is estimated by dividing the volume of a dredge sample consisting of oysters by the number of oysters present. The harvest data are the total volume of seed removed from each bed between 1958 and 1991. The five largest values in each category appear in boldface. The names of the beds, which are listed from those uppermost in the bay to those that are lowermost, are given below.

<table>
<thead>
<tr>
<th>Bed*</th>
<th>Area (Hectare)</th>
<th>% Oyster (±1 SD)</th>
<th>Indiv. Size (mL)</th>
<th>Harvest L × 10^3</th>
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</thead>
<tbody>
<tr>
<td>RIS</td>
<td>162</td>
<td>73.6 (13.5)</td>
<td>37</td>
<td>3,066</td>
</tr>
<tr>
<td>UAR</td>
<td>121</td>
<td>74.1 (14.3)</td>
<td>51</td>
<td>787</td>
</tr>
<tr>
<td>ARN</td>
<td>232</td>
<td>70.7 (18.4)</td>
<td>49</td>
<td>8,249</td>
</tr>
<tr>
<td>UMD</td>
<td>20</td>
<td>49.9 (27.7)</td>
<td>63</td>
<td>1,855</td>
</tr>
<tr>
<td>MID</td>
<td>374</td>
<td>64.9 (17.2)</td>
<td>70</td>
<td>17,617</td>
</tr>
<tr>
<td>COH</td>
<td>545</td>
<td>62.2 (17.5)</td>
<td>78</td>
<td>43,735</td>
</tr>
<tr>
<td>SHJ</td>
<td>454</td>
<td>66.5 (18.5)</td>
<td>74</td>
<td>16,251</td>
</tr>
<tr>
<td>SHR</td>
<td>404</td>
<td>61.7 (20.6)</td>
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<td>59.9 (22.3)</td>
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<tr>
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<td>636</td>
<td>48.0 (25.2)</td>
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<td>HGS</td>
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<td>76</td>
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<tr>
<td>NWB-STR</td>
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<td>53.4 (26.9)</td>
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<td>BDN</td>
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<td>43.4 (25.9)</td>
<td>135</td>
<td>203</td>
</tr>
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<td>VEX</td>
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<td>LDG</td>
<td>222</td>
<td>33.0 (23.0)</td>
<td>146</td>
<td>3,479</td>
</tr>
</tbody>
</table>

* RIS, Round Island; UAR, Upper Arnold’s; ARN, Arnold’s; UMD, Upper Middle; MID, Middle; COH, Cohansey; SHJ, Ship John; SHR, Shell Rock; BNS, Bennies’ Sand; BEN, Bennies; NPT, Nantuxent Point; HGS, Hog Shoal; NWB, New; STR, Strawberry; HKN, Hawk’s Nest; BDN, Beadon’s; VEX, Vexton; EIS, Egg Island; LDG, Ledge.
eries, there is no formally written and passed management plan, nor has there ever been one. Only a number of very basic provisions are encoded in State statute and regulations. Second, the fishery has been closed to new entries since 1981. Third, all of the major participants are housed in close proximity to each other and have been for nearly a century (the Haskin Shellfish Research Laboratory is located at the home port of the New Jersey oyster fleet and the State Bureau of Shellfisheries has an office in the Laboratory building). Fourth, these three groups have worked, and continue to work, together closely in various combinations. Fifth, a tripartite relationship exists in which each entity has a specific role: the industry is represented by the Delaware Bay Shellfish Council, the State Bureau of Shellfisheries provides the administrative support for the Shellfish Council and the Commissioner of the Department of Environmental Protection makes final decisions based on Council recommendations, and an independent group (in this case the Haskin Shellfish Research Laboratory) collects and provides data to the other two. Sixth, formal, informal, and personal information exchange between all three parties takes place on a regular basis. The actual importance of these six differences in the development, evolution, and execution of the management strategy is not easily evaluated; however, the salient features of each are described below.

1. The lack of a written plan provides flexibility. The process required to make changes can be adapted to the situation at hand and, with the exception of those portions that are encoded in law, most issues are settled in Council meetings. All decisions are made openly (regularly scheduled shellfish council meetings are advertised in the paper, anyone may attend the meetings and express their opinions to the gathering, minutes are taken and distributed at the next meeting, newspaper journalists generally attend and publish articles on decisions within one to two days, and special unscheduled meetings are held after all industry members have received notification by direct mailings.). The decision process however is not burdened by regulatory needs for formal hearings, published notices, comment periods, etc. If all three parties (industry, State, and the Laboratory) agree, even major changes can be accomplished relatively rapidly. The change to harvest practices brought about by Dermo disease provides an example of this flexibility. This disease caused such high losses in oysters that by 1995 it was obvious that the traditional movement of oysters from the seedbeds to the planted grounds in spring was neither commercially viable nor biologically desirable. Discussion began in the fall Council meetings about harvesting directly from the seedbeds. This was in direct opposition to over 100 years of practice and the proposal generated a great deal of heated debate. In general, the older members of the fishery were opposed and the younger members thought that the new approach should be tried. At the end of March, after five to six meetings and an industry evaluation of the seedbeds, there was a consensus that the proposal should be implemented immediately.

2. The fishery has been closed to new entries since 1981. This prevents the dilution or replacement of the current oyster population and provides a stable situation for managing the fishery. However, it also limits the potential for expansion of the fishery and must be considered in any long-term planning.

3. All of the participants are housed in close proximity to each other and have been for nearly a century (the Haskin Shellfish Research Laboratory is located at the home port of the New Jersey oyster fleet and the State Bureau of Shellfisheries has an office in the Laboratory building). This provides a unique opportunity for close cooperation and exchange of information.

4. All three groups have worked, and continue to work, together closely in various combinations. This provides a unique opportunity for close cooperation and exchange of information.

5. A tripartite relationship exists in which each entity has a specific role: the industry is represented by the Delaware Bay Shellfish Council, the State Bureau of Shellfisheries provides the administrative support for the Shellfish Council and the Commissioner of the Department of Environmental Protection makes final decisions based on Council recommendations, and an independent group (in this case the Haskin Shellfish Research Laboratory) collects and provides data to the other two. This provides a unique opportunity for close cooperation and exchange of information.

6. Formal, informal, and personal information exchange between all three parties takes place on a regular basis. This provides a unique opportunity for close cooperation and exchange of information.

### TABLE 2.
Weekly estimations of average percent oyster volume during seed bed harvest season. Values below 40% are shaded. Bed designations are the same as in Table 1. ND = no data.

<table>
<thead>
<tr>
<th>Year</th>
<th>RIS</th>
<th>ARN</th>
<th>MID</th>
<th>COH</th>
<th>SHJ</th>
<th>SHR</th>
<th>BNS</th>
<th>BEN</th>
<th>OB</th>
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</tr>
</tbody>
</table>

**ND** = no data.
interests control a significant part of the industry because they have local representatives who act in much the same fashion as other local fishery participants.

3. The importance of all groups having significant on-site representation cannot be overemphasized in fostering the flow of information and appreciation of differing outlooks. The close proximity permits daily contact among the parties, but more importantly, nurtures a sense of community. It allows each individual and group to become aware of the other’s point of view and to understand their biases. This does not mean all groups agree on every issue, but it does allow interested participants to evaluate what is being said in a context broader than that of a formal meeting.

4. Working together in various capacities is partly an outgrowth of the close proximity of the different parties and adds to their overall ability to understand and communicate with each other. For instance, since 1989 the industry has donated a boat and captain for the Laboratory’s annual survey of the seedbeds. Without this donation continuation of the annual shellbed survey would have not occurred given the existing University resources during that time. The State often collects samples for the laboratory, has collected samples of interest to the industry, and often allows industry members to sample the beds “out of season.” Laboratory representatives regularly attend Shellfish Council meetings where they present results of ongoing projects or simply answer questions on issues of immediate interest.

5. The tripartite scheme, with a party independent of the management authority collecting basic data, holds in check the belief common to many fishermen that data obtained by management agencies are biased, or that the interpretation of those data is biased. In the current scheme, both the management agency and the industry are free to criticize data collection and/or evaluation in any way they see fit. This provides a check and balance, somewhat equivalent to “peer review” on the data collection and presentation process. In addition, a research organization can use funds from competitive funding sources to support research that does not have an immediate interest to management or the industry. However, these “pure” research projects can occasionally provide new information to the attention of the industry and the management agency that they would not have otherwise.

6. The formal, informal, and personal relationships, as with the close physical proximity, allows communication and information exchange to take place on many different levels. What is said in private conversations is often not representative of the positions presented in public meetings. This is because each group has personal views that may not be appropriate for expression in a formal meeting. For instance, the formal role of the researchers is to present the facts and to elucidate potential biologic risks. Their opinion on management alternatives is frequently sought, and they may endorse certain options, but they generally refrain from advocating a specific action. These scientists may have views on whether the industry is making optimal economic use of the resource, but this would be not be expressed in a formal presentation of the data on the status of the resource. Similarly, an individual in the industry may think the resource is being exploited too heavily, but because of social relationships in a small community, not wish to express this view in
TABLE 3.
Direct marketing of oysters from Delaware Bay, New Jersey Seed Oyster Beds.

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Number ofBushels Landed (vol. in L)</th>
<th>Approximate Value of Bushels Landed</th>
<th>Value of Tags Sold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring 1996 (10 weeks)</td>
<td>17,828 (7.3 × 10⁶)</td>
<td>$320,904</td>
<td>$22,285</td>
</tr>
<tr>
<td>Fall 1996 (7 weeks)</td>
<td>42,570 (1.7 × 10⁸)</td>
<td>$893,970</td>
<td>$52,213</td>
</tr>
<tr>
<td>Spring 1997 (10 weeks)</td>
<td>27,479 (1.1 × 10⁷)</td>
<td>$577,059</td>
<td>$34,349</td>
</tr>
<tr>
<td>Totals</td>
<td>87,877 (3.6 × 10⁷)</td>
<td>$1,791,933</td>
<td>$108,847</td>
</tr>
</tbody>
</table>

Time period includes the length of the dredging season. We present the harvest in the fishery’s traditional bushels but we also convert those volumes into L.

...a formal meeting. The industry members look to the Laboratory or the State to present this view in the formal context.

Two obvious characteristics of management for the New Jersey seed oyster fishery has been the high degree of cooperation and mutual respect among the oystermen, State officials and university researchers. In formal Council discussions each entity generally honors each other’s expertise and role. The relationship has been uneasy, particularly when the resource was scarce. In recent years, however, the restrictions on the fishery imposed by severe oyster disease have been important in maintaining a mutual dependency of the three parties. Scientific data have become recognized as being more significant than ever in the management process. Cooperation of all parties has been crucial in implementing and testing new practices. The persistence of disease and its potential to kill oysters has forced the industry to proceed cautiously and to husband the oyster resource thoughtfully. The industry may have acted in an equally prudent way in the absence of the existing management structure, although pre-1950s fishery practices suggest otherwise. We believe that the interactive management structure, described above, has fostered effective decisions about the use of the oyster resource in the presence of disease.

Scientific Data: Formal Use

Critical to the management structure has been the availability of current population data, collected in a consistent manner over a prolonged period. Although the data are clearly used, the manner of use has varied, depending on the status of the resource and the industry at the time. Below, we provide instances where the biologic data can be shown to have influenced Council decisions, others where more informal uses of the data are evident, and still others where the data were generally ignored.

Prior to 1991 (when the Dermo disease epizootic became a decisive factor) the abundance of oysters and spat, and to a lesser degree MSX disease prevalence, were considered when decisions were made about the length of seedbed season. A general, direct relationship of these measures and the resultant occurrence or length of the season is apparent (short or no season when percent oyster <40%, longer seasons when percent oyster >40%; Fig. 5). On specific occasions, the data clearly influenced decisions. In 1997 Bennies Bed was closed to dredging. At that time the relative abundance of oysters was over 40% and the proportion of oysters infected with MSX in the preceding two springs was low; however, oysters were available on other beds and the opportunity to allow previous good sets on Bennies Bed to mature undisturbed by dredging was realized. The usefulness of this decision was never formally tested because in 1972 that bed and the remainder of the bay experienced another, even larger, recruitment event that proved to be an important source of oysters for years to come.

Data use has been amply illustrated since 1991 when it was recognized that planting oysters infected with the Dermo parasite would likely result in unacceptably high losses of planted oysters and loss of shell from the seedbeds. This realization closed the seed fishery for 3 consecutive years despite lost income to the fishery and the opposition by some industry members. The desire of these members to continue to plant as usual was muted because most participants in the fishery shared beliefs that restrained the degree of risk that the fishery as a whole would take. The shared beliefs included the following: 1) that the “disease problems” would eventually lessen (as they did with MSX), making preservation of the resource until that time an important and common goal; 2) that data gathered and presented by the “third-party” researchers were accurate and unbiased (although conclusions about the data were not always widely shared); and 3) that the experience of oystermen concerning when and where to plant, and when to harvest, were important in making decisions about the advisability of dredging seed oysters.

Scientific Data: Informal Use

There is no clear correlation in the long-term data between MSX prevalence and oyster mortality on private leases. A major reason is because the total mortality on a particular ground is only partly a function of disease levels. It is also influenced by decisions of the lease holders who transplanted oysters. Oystermen frequently solicited information about MSX prevalence and intensity from the Laboratory. If MSX prevalence and intensity seemed to be increasing on the leased grounds, some planters would equip extra boats to harvest oysters to insure they retrieved all marketable individuals before they died (L. Jeffries, pers. comm., 1995). Not all lease owners availed themselves of the data or, if they did, acted on them. Oystermen were free to ignore the monitoring data and gamble that the disease would be less destructive than expected.

TABLE 4.
Comparison of returns per bushel of oysters removed from the seedbeds by planting (1991 and 1995) and by direct marketing (1996–1997) during periods of high Dermo disease.

<table>
<thead>
<tr>
<th>Seedbed Oysters Fate</th>
<th>Bushels (vol. in L)</th>
<th>Total Sales</th>
<th>Average Return per Bushel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leased grounds</td>
<td>390,000 (1.6 × 10⁷)</td>
<td>$1,189,190</td>
<td>$3.05</td>
</tr>
<tr>
<td>Direct marketing</td>
<td>87,877 (3.6 × 10⁷)</td>
<td>$1,791,933</td>
<td>$20.39</td>
</tr>
</tbody>
</table>

We present the harvest in the fishery’s traditional bushels but we also convert those volumes into L (vol. in L).
Little or No Data Use

The “40% rule” was ignored on several occasions during the 1960s and late 1980s (2 and Fig. 5). The industry was still reeling from the financial losses caused by the initial MSX epizootic in the 1960s and was severely stressed again in the 1980s because of a drought that stimulated renewed MSX activity. Economic pressures clearly predominated over the biologic data; however, the data were not entirely ignored because the length of bay season was restricted to only 2 wk in most of these years.

Economic and Financial Pressures

Economic considerations continually threatened this management strategy. Oystermen had to maintain cash flow during prolonged periods when oyster harvests were small or impossible; most responded by diversifying their activities. Boat owners who also owned shucking houses kept the houses active by shucking oysters from other locations (primarily Connecticut, but also from the Gulf Coast) or by processing surf (Spisula solidissima) and mahogany clams (Arctica islandica). Some oystermen moved boats into the Atlantic surf clam fishery or used them to harvest finfish, blue crabs (Callinectes sapidus), whelks (Busycon spp.), or horseshoe crabs (Limulus polyphemus) in Delaware Bay. Others diversified economically by direct marketing of multiple seafood products or managing marinas. Some of the older oystermen possessed sufficient cash reserves to temporarily retire. Many younger participants left the industry; the on-again off-again nature of the fishery restricted their ability to reenter. The large costs of preparing a boat to work in the fishery when economic return was so uncertain resulted in a de facto limited entry fishery prior to the establishment of a regulatory limited fishery. Only those who could risk substantial financial losses could continue to participate.

CONCLUSION

New Jersey’s management of the Delaware Bay oyster seed fishery demonstrated an ability to respond relatively quickly to both threatening and promising changes in the dynamics of oyster populations and oyster mortality sources. Despite this flexibility and the fact that management is largely in the hands of the industry itself, the resource has been generally well conserved. In fact, the impact of seed dredging on the oyster population cannot be statistically measured (Fegley et al. 1994). We suggest that the primary reasons for the persistence of the resource include (1) the high degree of communication among the three parties involved in the management strategy, (2) the presence within the industry of a few individuals who took a long-term and relatively conservative management view and who were generally respected by others in the industry; and (3) the perception of a shared risk among industry members, which also constrained their activities.

Not all aspects of the Delaware Bay management system may apply to other fisheries. For example, the fishery has relatively few participants who operate in a geographically constrained area. Part of the resource lies within an area where diseases and predators are absent or reduced by prevailing environmental conditions. Both of these conditions reduced the scale of management complexity in the present case. However, several characteristics of this fishery and its management structure could be exported to other locations. We argue they include the following: Human harvest activities on some parts of the resource need to be limited. Long-term, reliable, third-party monitoring of the resource, diseases, and harvest activities should be integrated as a consistent part of the decision processes of the management structure. Continued personal contact through meetings, discussions and working together is essential in transmitting information. Last and most importantly, the participants in the fishery should agree on the basic goals of the program and all must play a role in the management of the bed and its dependent fishery. Participating groups must agree on their respective formal roles, restrain themselves from “stepping beyond” their areas of expertise, and respect the role and viewpoints of the other participants.

ACKNOWLEDGMENTS

A large number of individuals contributed to the projects described in this paper. Three contributed more than the rest: Laboratory biologist, Donald Kunkle, and the two boat captains over the period from 1953 to 1990, William Richards and Clyde Phillips. In recent years, the supportive efforts of J. Dobarro and R. Reed of the New Jersey Bureau of Shellfisheries have been substantial. Financial support was received for much of this research from the State of New Jersey and from Public Law 88-309 funds. The authors thank Walt Canzonier for his comments and insight. This is New Jersey Agricultural Experiment Station Publication No. D-32405-1-03 and contribution no. 2003-19 from the Institute of Marine and Coastal Sciences, Rutgers University.

APPENDICES

I. An Example of Shellfish Council Deliberations Before the Advent of Large-Scale, Direct Marketing from the Seedbeds

The following account describes deliberations by the Delaware Bay Shellfish Council during bay season of 1995. Oyster planters, representatives of the New Jersey State management agency, Rutgers University personnel, and shellfish council members participated in what was often a chaotic discussion. However, a consensus was reached. A cursory description is presented here to provide an example of the issues considered when making decisions and of how biologic information provided by the University was integrated with economic realities faced by planters.

Bay season had begun on 10 April and was scheduled to last for a minimum of two weeks. A decision on the closing date was to be made near the end of the second week. On 20 April 1995, the shellfish council met to examine dredge samples that had been collected from the beds that day and to consider extending bay season. By that date approximately 3000 bu of oysters had been marketed directly from the beds at approximately $15–$17 per bushel. A little more than 20 boats harvested (seed for planting plus direct market) a total of about 100,000 bushels. Most of the harvest was from New, Bennies, and Bennies Sand Beds. Some harvest was from Ledge Bed. Sampling to determinepercent oyster on the beds was conducted on 13 April and 20 April from Bennies Sand and New Beds, and from New Beds on 20 April. Mean percent oyster was high on both dates (Bennies Sand = 61% and New Beds = 63% on the 13th and New Beds = 62% on the 20th).

Although there was general agreement that plenty of oysters remained on all of the beds, several other concerns were discussed. First, prices for oysters marketed directly from the beds were low and only 3’ oysters were acceptable. This meant that a good deal of costly on-board sorting was required to produce a marketable product. Second, as nearly all seed was infected with P. marinus, any oysters planted on the leased grounds would have to be marketed before July to avoid mortality. Third, the season had been
good so far. Transplanting more oysters to the planting grounds would likely lead to decreases in profit because summer prices are usually low and the cost of moving oysters might not be recovered if subsequent mortality was high. Fourth, if oysters were not moved and they died on the seedbeds, at least the shells would remain as cultch. Fifth, if the beds remained open, everyone would keep fishing in spite of the economic risk. After listening to all these issues the shellfish council opted for a conservative strategy and decided to close the seedbeds for the season.

II. An Example of Shellfish Council Deliberations After the Advent of Direct Marketing from the Seedbeds

Direct marketing of oysters from the seedbeds has had mixed results. This process provided $4.3 million in revenues to the industry for harvests in 1996, 1997, and the spring of 1998, and allowed the industry to maintain a presence in the markets and maintain boats. Tag fees provided for an enhanced shelling effort. The down side to this form of landing was that the industry was restricted to the time period agreed to and could not stockpile oysters on the planted grounds to satisfy markets at other times. Because the oysters were harvested from lower salinity waters, the meat quality was not as good as in oysters from farther down bay and the price received for the product was not as high as it might have been. Chiefly because of these latter conditions, some industry members wished to plant oysters.

The State achieved direct revenue ($1.25/bu) from oysters removed from the seedbeds for market, but would only receive payment on planted oysters once they were landed. Thus in the former case the State (and directly the oyster industry accounts) received payment up front, while in the latter case the State took on the majority of the risk. If the oysters died on the planted grounds the resource would not be paid for, the shell would no longer be on the seedbeds, and no funds would have been generated to replace it.

In 1997 the State and industry agreed to a spring direct harvest followed by an evaluation of the seedbeds to determine if a planting season could be allowed in the summer of 1998. The chief reason for the planting would be to allow meat quality to improve during the late summer and fall. The chief worry was the level of the oyster disease Dermo. University researchers sampled for Dermo and reported to the council in an open meeting. Samples were removed in July from the five beds deemed by the industry to have the greatest probability of being harvested. The samples revealed that oysters on all beds were heavily infected with Dermo. The summer had been hot and dry and the forecast was for a continuation of these conditions.

The discussion in the August 1998 council meeting was heated because some segments of the industry wished to move oysters anyhow, while others were reluctant to risk the resource. The latter group said that the resource would remain for later harvest if it was not moved. The group finally agreed to wait and monitor conditions further. Laboratory researchers took samples in August. Conditions had not improved and the Council deferred a seed move and decided to allow direct market harvest to begin (1500 bu/ license) beginning on 17 August. The council requested a September sample of disease prevalence: it remained high. The council decided to have a 5-d transplant in an 8-d period beginning 7 October. To participate each boat would have to participate in a one day intermediate transplant (5 and 6 October) in which oysters from up bay would be moved to an intermediate bed. Direct market harvest would cease when the transplant began. A meeting was scheduled for 1 October to make final adjustments to this plan. In October the direct market program allocation was increased by 1000 bu/license, otherwise the transplant program was to occur as decided earlier.

As of the November council meeting the direct market program had landed approximately 73,000 bu: 10,000 bu were moved in the intermediate transplant and 58,800 bu were transplanted to the leases.

LITERATURE CITED


