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THE EFFECT OF DEPTH ON SURVIVAL AND GROWTH OF OYSTERS IN SUSPENSION CULTURE FROM A PETROLEUM PLATFORM OFF THE TEXAS COAST[1]

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ABSTRACT The effect of depth on oysters in suspension culture from a petroleum platform off the Texas coast was monitored for 20 months. Growth and condition was similar for adult oysters cultured at five levels down to 8 m. Oysters had a growth rate of 1.2 mm (level 3) to 1.4 mm (level 1) per month,representing an increase in length of 94% to 150% for the 20 months. The condition was best in June 1973 after five months placement offshore (condition index of 14.8, 15.5, 14.7, 13.5 and 13.2 for levels 1 through 5, respectively). The condition was lowest in June 1974 (2.2, 2.1, 1.3, 1.4 and 1.5 for levels 1 through 5, respectively). Ninety oysters died during the experimental period. Sixty-three percent were from the upper two levels. One hundred forty-five oysters disappeared. Fifty-eight percent were from the bottom two levels. Most oysters disappeared in February 1974 (47% of all disappearances).

INTRODUCTION

The effect of water depth on oyster growth has been little investigated. Oysters are known from a natural, deep water (40 m) reef in Chesapeake Bay (Merrill and Boss 1966). However Gunter and Geyer (1955) noted that *Crassostrea virginica* was limited to the upper few meters of water on petroleum platforms in the Gulf of Mexico off Louisiana and Texas. This was probably not a depth limitation at all, but rather a restriction of the setting oyster larvae to a shallow lens of bay water which floated out to sea (Gunter, personal communication).

In a previous study (Ogle, Ray and Wardle, in press) the growth of oysters in suspension culture for 12 months at two depths in lower Galveston Bay, Texas was compared with the growth of oysters suspended at similar depths from a Texas offshore petroleum platform. Growth in terms of length was comparable at both stations although oysters inshore gained more weight, possibly because that station was ordinarily richer and additionally was in an area receiving municipal pollution. This study, initiated in January 1973, suffered from the loss of the control oysters in the estuary due to vandalism. The oysters on the platform were retained for 20 months to follow growth and survival at depths to approximately 8 meters.

MATERIALS AND METHODS

Studies were conducted at the Atlantic Richfield Company (ARCO) platform B located 6 kilometers offshore from High Island, Texas (Figure 1) in approximately 10 meters of water.

Hydrographic Data

Water samples were taken 1 and 8 meters below the surface with a 250-ml water sampler (constructed of clear plastic tubing and closed by two rubber balls) for determination of hydrographic conditions. Temperatures of the samples were determined with a mercury thermometer to the nearest degree Celsius at the time of collection. Water samples were placed in clear glass 150-ml bottles and transported in a closed wooden case. Salinities were determined to the nearest parts per thousand (ppt) with a refractometer. Samples were refrigerated in the laboratory (ca 1°C) and analyzed within 8 hours from the time of collection for chlorophyll *a* content. After shaking, a 10-ml aliquot of the water sample was extracted according to the procedure of Strickland and Parsons (1968) for chlorophyll *a* determinations. The fluorescence was determined on a Turner Model

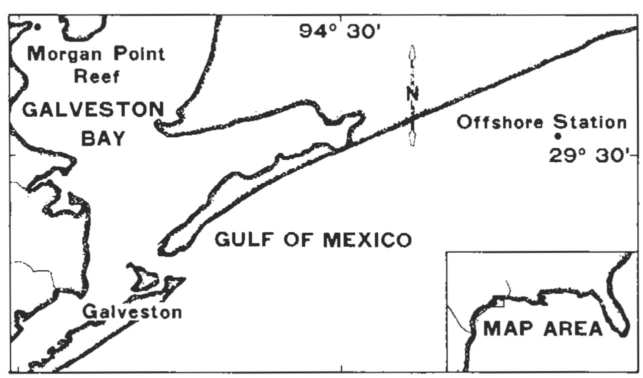

Figure 1. Location of the station in the northwest Gulf of Mexico along the Texas Coast.

[1]Based in part on a thesis submitted to Texas A&M University by John Ogle in partial fulfillment of the requirements for the Degree of Master of Science, May, 1975.

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III Fluorometer having a C-2-60 filter and a door modified for 16 x 125 tubes. The chlorophyll *a* content of the water was calculated in terms of milligrams per cubic meter of seawater.

Hardware

A chain shackled to a cable was passed through the center of 60-cm lengths of 2-cm mesh plastic "Vexar" bagging. A length of brass rod woven through the bag, passed through a link in the chain and bent on both ends was used to hold the bags in place. The bags were folded in the center in a "saddlebag" fashion, each bag containing 10 oysters. The open ends of each bag were closed at the bottom by passing lengths of rod through the mesh and the supporting chain (Figure 2). Ten saddlebags were positioned uniformly along a 6-m length of 95-mm stainless steel cable to which the chain was attached. Three such lengths of cable were attached to the end of a main support cable. Three 1.8-m lengths of 2.5-cm galvanized pipe were used to spread the three cables apart. One pipe was placed at the top, just above the first saddlebag. A second pipe was placed at the bottom below the last saddlebag. A third pipe was clamped midway between the top and bottom pipes. The cable was attached to the main support cable of 127-mm stainless steel wound onto a Beebe No. 10 winch (800-kg capacity) installed in the center of the upper deck of the platform. The entire support apparatus was positioned centrally under the platform by means of 64-mm stainless steel tether cables attached to the platform at three points (Figure 2). The apparatus was lowered into the water so bags were approximately 2 m from the surface and 2 m off the bottom at mean low water. Thus, benthic predators were intended to be excluded from the oyster bags, and the effect of wave action reduced.

Oysters

Collection. Oysters were dredged from a reef on a spoil bank adjacent to the Houston Ship Channel in the vicinity of Morgan Point near Houston, Texas. Oysters were culled to singles and cleaned of all superficial fouling by wire brushing. They were stored for three weeks in a seawater reservoir at the marine laboratory until placement offshore on January 15, 1973.

Placement of Oysters. Saddlebags of oysters were spaced approximately 30 cm apart and occupied approximately 30 cm of a 6-m long cable. Data were obtained by sacrificing samples of oysters. To reduce the number of oysters sacrificed the ten depths were considered as five levels. Mean depths for the levels when suspended were roughly three (1.8–3.0 m), four (3.4–4.3 m), five (4.6–5.5 m), six (5.8–6.7 m) and seven (7.0–7.9 m) meters from the surface. Length, the greatest shell dimension, obtained initially for 60 oysters from the population indicated a size range of 44 to 83 mm (mean 68 mm), 33% of which were of a legal marketable size (76 mm). An attempt was made to place an equivalent total biomass at each of the five levels. Six

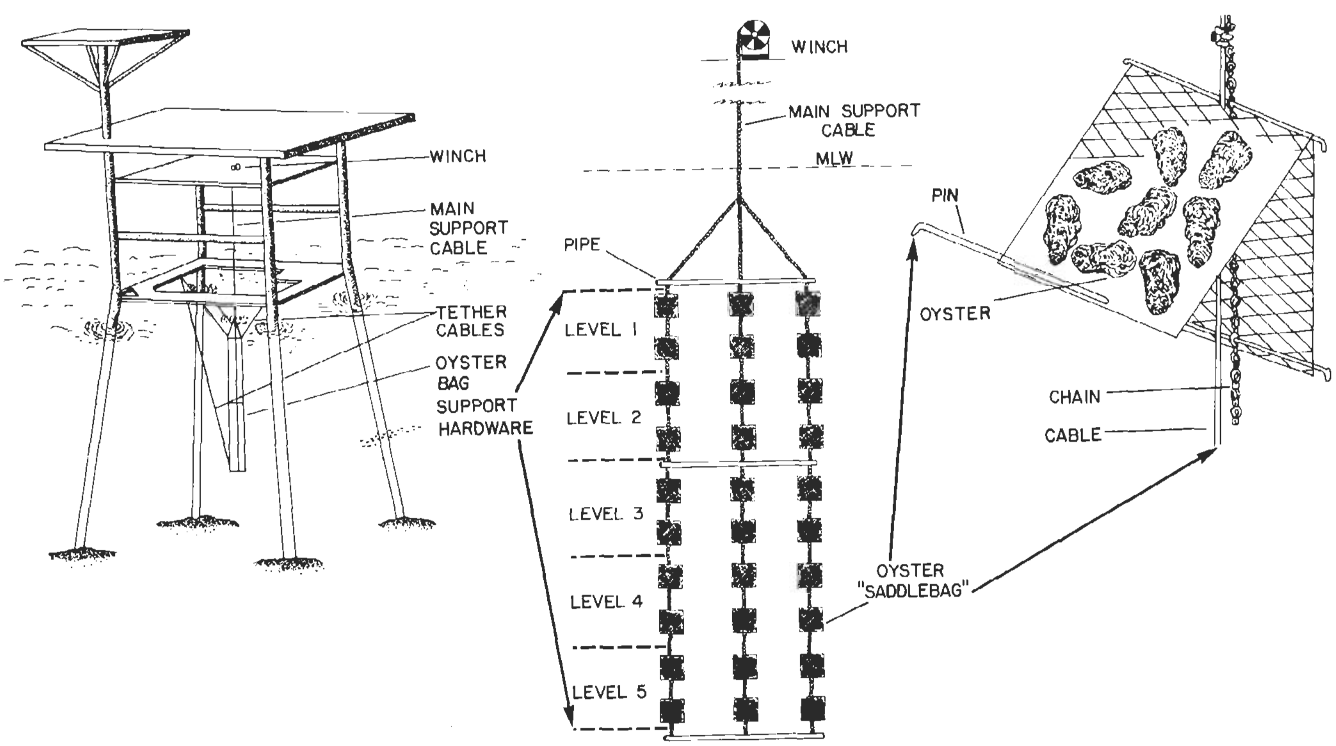

Figure 2. Method of containing oysters in Vexar bags and suspending bags from a petroleum platform offshore from Texas in the Gulf of Mexico

hundred oysters were separated into five groups of 120 oysters ranging in total weight from 10.2 to 10.8 kg. An additional 22 oysters were sacrificed in order to determine the initial level of infection by the fungus *Labyrinthomyxa marina*.

Sampling of Experimental Oysters. Monthly and quarterly samples were taken during a period of 20 months. The number of live oysters and oyster boxes (empty shells) was determined and the mortality calculated every month for oysters at each of the five levels. The monthly mortality of oysters at a level was used to estimate the mortality in oysters missing from the bags. Oysters sampled were considered lost the following month. The estimated mortalities were added to the recorded deaths to derive an adjusted mortality.

Beginning in March 1973, subsamples of ten oysters from each level were removed at quarterly intervals and sacrificed to determine the brushed weight, condition index and level of infection by *L. marina*. The ten oysters were selected to be similar (±17 g) in total fouled weight to the weight of ten average oysters at each level. During June and September 1974 only five oysters were removed due to the few remaining oysters.

Level of infection by the parasite *L. marina* was determined according to the technique of Ray (1952 and 1966). A single piece of the anterior mantle tissue was placed in fluid thioglycollate fortified with antibiotics (mycostatin and chloromycetin) and cultured for 7 days. After culture the tissue was blotted dry, teased, stained with Lugol's Iodine, examined microscopically at 100x and rated for infection intensity according to the procedure of Ray (1954). The weighted incidence (W.I.) was calcualted according to the procedure of Mackin (1962) and the incidence of infection (I.) noted.

An average condition index (CI) was calculated for oysters according to the equation of Hopkins (1949) as follows:

$$CI = \frac{\text{mean dry meat weight in grams}}{\text{volume of shell cavity in milliliters}} \times 100$$

The volume of the shells was determined by water displacement (Galtsoff 1964). The difference between the displacement of the intact oyster and the shell after removing the oyster meat was taken to be the volume of the shell's cavity. Dry meat weight was determined by drying the oyster meats in tared aluminum pans at 100°C until a constant weight (±0.01 g) was obtained.

RESULTS

Hydrographic Data

The greatest differences between surface and bottom values were 9 ppt for salinity, 2°C for temperature and 8.3 mg/m^3 for chlorophyll *a*. Surface and bottom salinities were within 1 ppt for ten of 20 months and chlorophyll *a* content was within 2 mg/m^3 for five of the 20 months (Table 1).

TABLE 1.

Temperature, salinity and Chlorophyll *a* content of water samples collected at monthly intervals from two depth.

	Temperature (°C)		Salinity (ppt)		Chlorophyll *a* (mg/M^3)	
	Top	Bottom	Top	Bottom	Top	Bottom
1973						
January	14.0	14.0	24.0	28.0	10.3	12.1
February	13.0	13.0	25.0	25.0	5.5	4.6
March	17.0	18.0	30.0	30.0	3.7	3.3
April	22.0	21.0	22.0	25.0	4.3	3.6
May	21.0	21.0	30.0	30.0	4.3	4.6
June	28.0	27.0	19.0	28.0	4.2	12.5
July	–	–	–	–	–	–
August	–	–	–	–	–	–
September	–	–	23.0	25.0	2.8	3.1
October	24.0	26.0	23.0	29.0	3.7	1.1
November	24.0	24.0	29.0	30.0	0.7	0.7
December	19.0	18.0	26.0	27.0	5.2	4.9
1974						
January	20.0	18.0	16.0	24.0	8.4	5.1
February	16.0	16.0	28.0	28.0	5.6	5.9
March	17.0	19.0	21.0	21.0	4.3	4.5
April	21.0	20.0	18.0	22.0	5.6	5.9
May	26.0	26.0	22.0	25.0	4.9	2.4
June	27.0	27.0	25.0	28.0	11.4	5.7
July	29.0	29.0	32.0	30.0	1.6	1.9
August	27.0	28.0	26.0	28.0	2.6	1.6
September	24.0	25.0	24.0	24.0	3.7	3.8
October	21.0	22.0	25.0	25.0	1.6	1.7

– indicates no samples were taken.

Seasonally, salinities varied from a low of 16 ppt (January 1974) to a high of 32 ppt (July 1974), temperatures varied from a low of 13°C (February 1973) to a high of 29°C (July 1974) and chlorophyll *a* content varied from almost none (0.7 mg/m^3, November 1973) to a high of 12.5 mg/m^3 (June 1973).

Growth and Survival

The growth patterns of oysters offshore were comparable at all five levels. Oysters at levels one and two were only slightly larger (1–3 mm) in mean length at termination than oysters held at other levels (3, 4 and 5) (Figure 3). The oysters increased in length from an initial size (estimated from sampling 60 of 600 oysters) of 68 mm to a final size (estimated from sampling surviving oysters) of 96 mm, representing a gain of 41% for oysters from the first and second level. The least growth occurred at the third level where oysters grew to a mean size of 93 mm, representing a length gain of 37%. Growth rates of oysters ranged from 1.2 mm per month (level 3) to 1.4 mm per month (levels 1 and 2) over the 20-month period. After four months, oysters were of a legal market size (76 mm). Initially only 33% of the oysters were of a legal size.

The oysters held at the first level increased in weight from an average of 85 g (for 120 oysters) to a final average

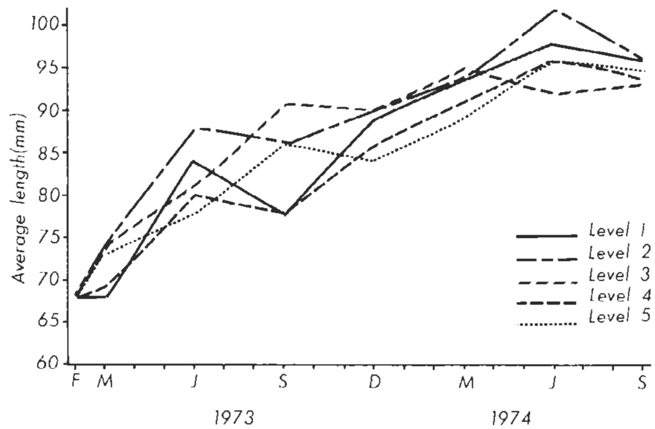

Figure 3. Growth of oysters in terms of average length in mm for 20 months. Initial length was based upon the average of 60 oysters. The values for June and September 1974 are based upon the average of 5 oysters, except level 4 for September 1974 based upon 2 oysters. All other values are based upon the average of 10 oysters.

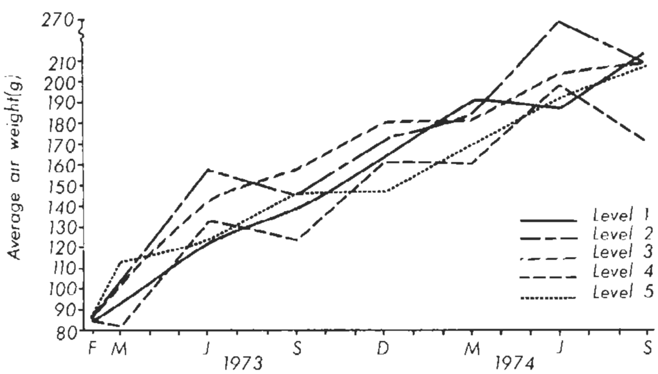

Figure 4. Growth of oysters in terms of average weight in g for 20 months. Initial weights were based upon average of 120 oysters. The values for June and September 1974 are based upon the average of 5 oysters except level 4 for September 1974 based upon 2 oysters. All other values are based upon the average of 10 oysters.

weight of 215 g (for 5 oysters), representing a gain in weight of 150% over the 20-month period (Figure 4). The five oysters sampled from each of the levels 2, 3 and 5 were of the same final average size (209 g), representing a gain of 139%. The two surviving oysters from the fourth level averaged 170 g.

Oysters were lost (due to bag failure) primarily from the two lower levels, while the greatest mortality occurred at the upper three levels (Figure 5). Ninety of the initial 600 oysters were known to have died during the 20 months of the study. Sampling removed 297 oysters from the study. An additional 145 oysters were missing from the bags, amounting to a total of 442 oysters either lost or eliminated from the study. The monthly mortality rate was used to estimate that eight deaths would have occurred in the 442 oysters had they been present throughout the study. The eight oysters considered to have died were added to the deaths actually recorded to obtain an adjusted number of deaths resulting in a total estimated mortality of 16%. Sixty percent of the total deaths occurred at the first two levels. Only 6% of the deaths were recorded from the fourth level. Seventeen percent of the total deaths occurred at both the third and fifth levels. The bottom two levels, however, accounted for 58% of all missing oysters, with level four accounting for 38% of all losses. For all levels, the greatest number of oysters lost (69) for a given month occurred during February 1974, amounting to 47% of all missing oysters.

Labyrinthomyxa marina Infection

Despite the attempt to secure disease-free oysters by collecting from a low-salinity area, incidence of the fungus parasite, *L. marina,* in oysters offshore was greater than for oysters at the collecting site (Figure 6). The Morgan Point Reef was sampled initially in November 1972 and the parasite was not found in 25 oysters assayed. Additional observations in December 1972 (22 oysters), May 1973 (25 oysters) and September 1973 (15 oysters) were also negative for the parasite. In October 1973, 3 of 24 oysters assayed showed a low level of infection (W.I., 0.1; I., 12%). Examination of

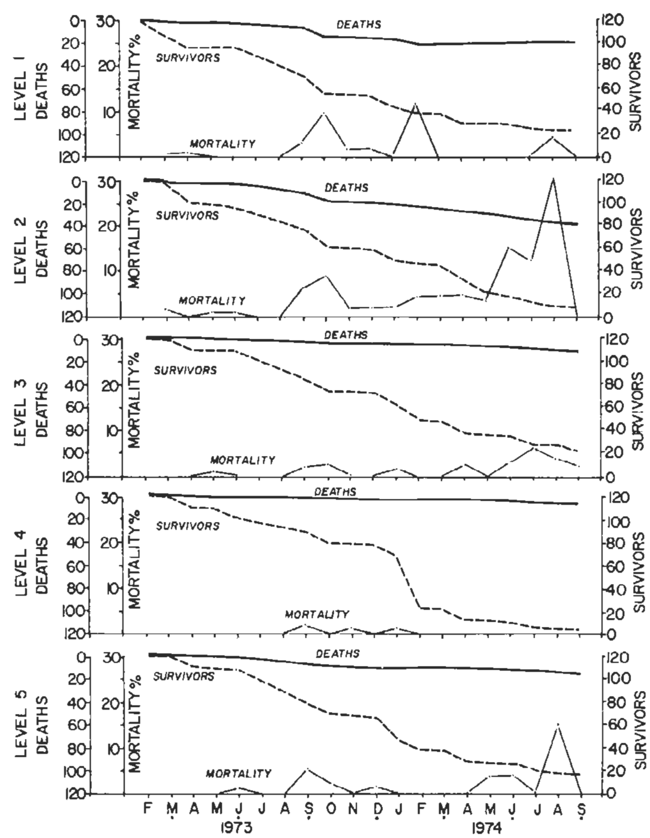

Figure 5. Number of survivors, adjusted number of deaths and monthly mortality. Months during which oysters were removed are noted by an asterisk. The area between the plots for deaths and survivors represents losses.

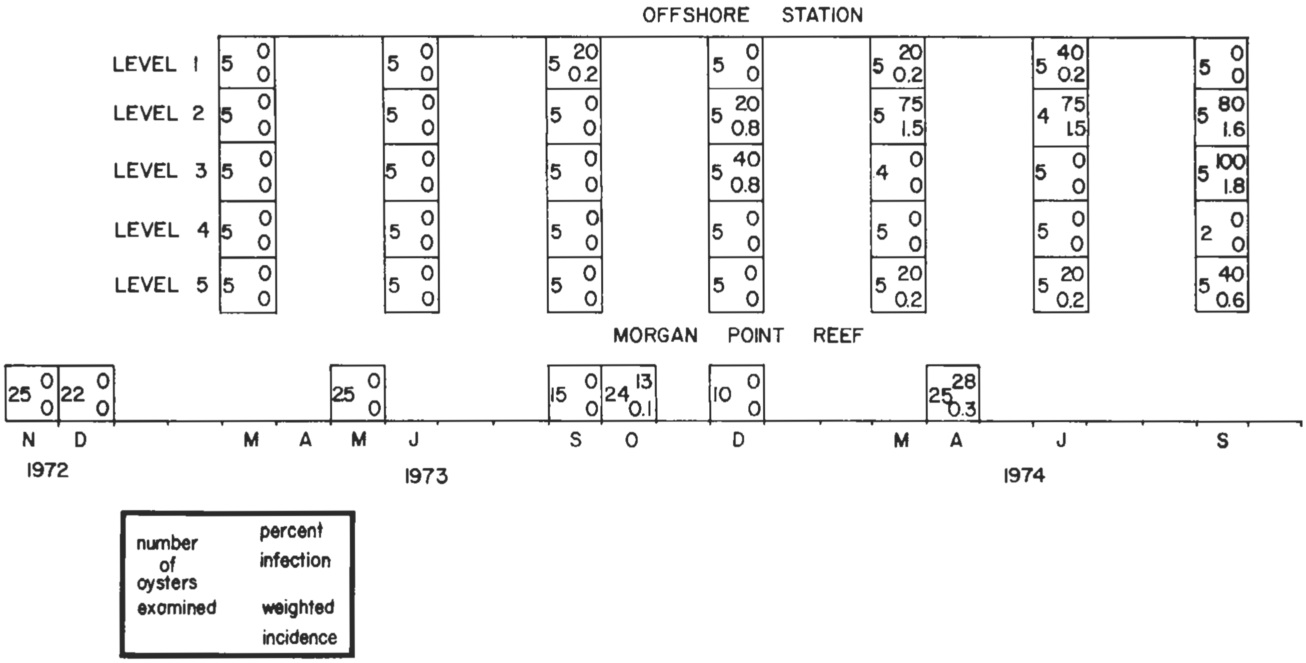

Figure 6. Incidence of infection by *Labyrinthomyxa marina* in oysters at two locations on the Texas coast.

10 oysters from the reef in December 1973 failed to detect the parasite and a final observation of 25 oysters in April 1974 revealed that the parasite was present at a higher level than previously detected (W.I., 0.3; I., 28%).

Oysters offshore remained free of the parasite until the seventh month (September 1973) when the fungus was detected in 1 out of 5 oysters assayed from the first level. By the tenth month (December 1973) the fungus was found in 1 out of 5 oysters from the second level, 2 out of 5 oysters from the third level and at 13 months (March 1974) in 1 out of 5 oysters from the fifth level. The fungus was not found in 32 oysters assayed at various times from the fourth level.

Condition Index

The seasonal pattern of condition index followed the same trends at each of the five levels (Figure 7). The value of 21 recorded for oysters from the first level for March 1973 is probably an error, as Butler (1949) reports that condition factors may range from 1 to 17 with 10 indicating a marketable oyster. Samples of ten oysters had their best condition index the first June (1973) after being placed offshore (14.8, 15.5, 14.7, 13.5, and 13.2 for levels 1 through 5, respectively). The condition index for samples of ten oysters declined in December 1973 (7, 5, 7, 5 and 5 for levels 1 through 5, respectively), improved slightly in March 1974 (9.3, 10.8, 10.4, 10.0 and 7.9 for levels 1 through 5, respectively), and then declined to the lowest values of the study in June 1974 (2.2, 2.1, 1.3, 1.4 and 1.5, respectively).

DISCUSSION

Growth of oysters in this study was not affected by the depth at which they were cultured, since growth was similar at the five arbitrary depths down to 8 meters. It is therefore considered biologically feasible to utilize the deeper water offshore from the Texas coast for suspension culture of oysters if techniques are developed to reduce losses from bag failures. The growth rate of 1.2 mm/month to 1.4 mm/month for oysters for this study was less than the growth rate of 5.1 mm/month to 8.1 mm/month reported by Gunter in 1951 for oysters found attached to templates off Texas and Louisiana. The report of Gunter (1951) represents growth from set to market size oysters while adult oysters (mean initial size 68 mm) were utilized in this study. Growth rates for comparable sized oysters as used in this study would be approximately 2 mm/month as predicted by Ingle and Dawson (1952). However, the growth rate of oysters (based upon length) will vary according to year and area. Hofstetter, Heffernan and King (1965) reported on tray studies from two reefs in Galveston Bay for two years (1963 and 1965). Growth of oysters in trays from Switchover Reef (an artificial reef) during eight months (May–December) was 3.7 mm/month during 1963 and 1.4 mm/month during 1965. Oysters from Hanna's Reef (a natural reef) grew 0.5 mm/month during 1963 and 1.9 mm/month during 1965. Growth of oysters offshore in this study is therefore considered consistent with that expected for comparable sized oysters from commercial reefs in Galveston Bay.

The seasonal pattern of condition exhibited by oysters from each of the five arbitrary depths was similar. This would be expected as Loosanoff and Engle (1942) noted that depths up to 30 feet did not affect the time of spawning (which influences seasonal condition) for oysters. In

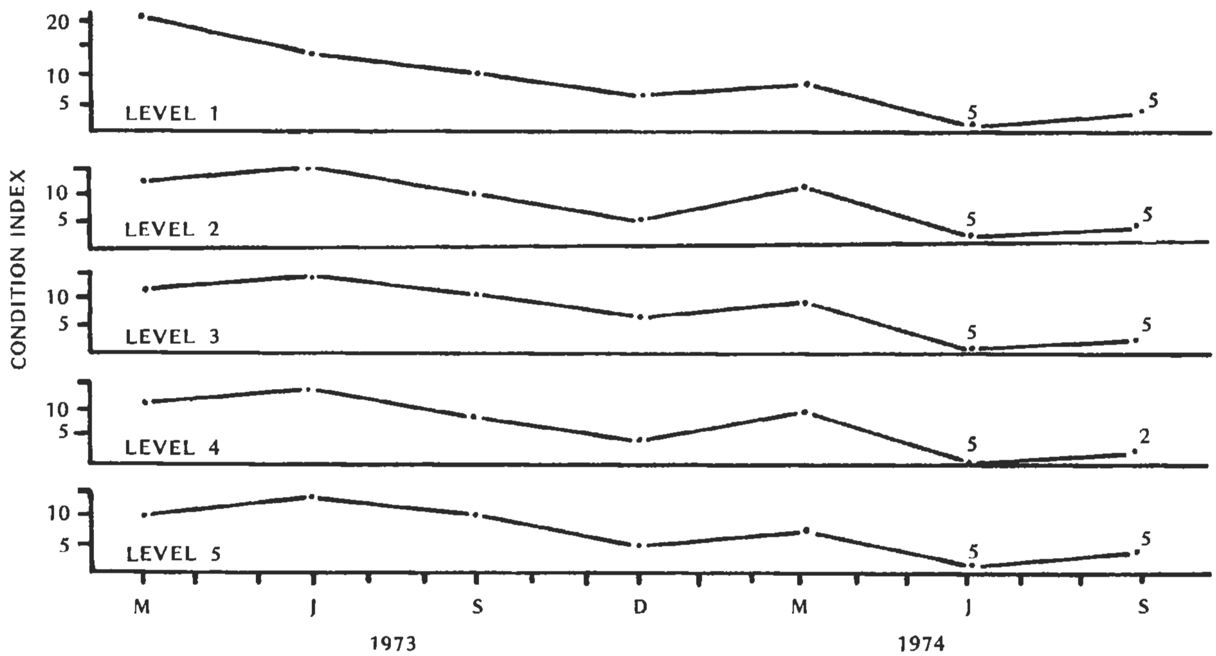

Figure 7. Average condition index of oysters. Each point represents the average of 10 oysters unless otherwise indicated by a number.

addition the amount of food available to the oysters in this study as evidenced by the chlorophyll *a* content of the water was similar for the surface and bottom water. However, the oysters were in best condition in June after being transferred offshore and in poorest condition in June of the following year. A lack of spawning due to their having been transferred would possibly account for the high condition during the first summer. Seasonally one would expect a low condition during the summer months as noted for the second summer.

There was no evidence of stratification of surface and bottom waters as indicated by hydrographic data. The hydrographic data suggest that the water was vertically uniform (to 10 meters) over most of the year. The oysters were probably in the same water mass as indicated by similarities in their growth and seasonal condition. There was no evidence of mortality associated with stratification as found by Kajikawa, Sano and Soguri (1953).

Both the flatworm *Stylochus* and the southern oyster drill *Thais haemastoma* were present in this study, but not in large numbers. The drills observed were all small and did not pose a problem to the large oysters. It is possible that the fungus *L. marina* was at least partially responsible for some of the mortality noted during this study. The fungus was more prevalent in the first three levels, corresponding to the greater number of deaths recorded from those levels (77% of total deaths). Increase in infection noted after October 1973 was possibly due to the spread of the fungus from diseased oysters placed on the platform at that time. The estimated total mortality of 16% for this study is less than the mortality expected on commercial beds where one bushel of oysters (300 oysters) is harvested for every bushel (2000 oysters) of seed oysters planted (McHugh and Andrews 1955). In Louisiana the "annual mortality rates of oysters more than a year old are usually in excess of 60% annually" (Mackin 1961).

Loss of oysters from torn bags was a major problem in this study. Bags were torn due to the constant wave action and strong currents and to growth of oysters whose sharp bills cut and abraded the mesh. Bags also tore due to pins catching on the grating during examination and on other bags when suspended. Some Vexar bags tore easily because of their faulty construction. The disappearance of a large number of oysters (47% of all oysters missing) during February 1974 from levels four and five was possibly due to some submerged object washing through the platform and knocking bags off, as entire bags were lost with bagging and pins swept clear of the chain and cable.

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