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TAMU-SG-71-211

JUNE 1971

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Partially supported by the National Sea Grant Program
Institutional Grant GH-101 to
Texas A&M University

Sea Grant Publication No. TAMU-SG-71-211

June, 1971

This research was funded jointly the Texas Agricultural Extension Service's Advisory Program, supported by the Sea Grant Program of the National Oceanic and Atmospheric Administration within the U.S. Department of Commerce; the Department of Wildlife and Fisheries Sciences' Agricultural Experiment Station Project 1612; and the Brazoria County Mosquito Control District.

ABSTRACT

Crustacea from two marsh embayments, Oyster and Alligator Lakes, were collected twice a month for two years, identified, and their seasonal abundance determined with respect to temperature and salinity. Collections included commercial penaeid shrimp, grass shrimp (Palaemonetes), sergestid shrimp, and mysid shrimp.

During the summer of 1969, three tests were conducted on the effects of aerial application of malathion, in concentrations used in mosquito control, on the juvenile commercial shrimp Penaeus aztecus Ives and Penaeus setiferus (Linn.). Dead and live shrimp samples, and water samples taken before and during the test were analyzed by means of gas-chromatography and thin-layer chromatography. In all three tests the commercial shrimp suffered mortalities ranging from 14 to 80 percent while the control shrimp suffered no deaths attributable to the pesticide. Water analysis demonstrated a high concentration of malathion immediately after application and a progressive reduction 24, 33, and 48 hours after application. Malathion

values in live shrimp taken from boxes during the test were consistently greater than the values obtained from dead shrimp removed during the same period. It was hypothesized that shrimp demonstrating a tolerance to malathion, could continue to accumulate the pesticide, whereas a dead shrimp could no longer actively accumulate the pesticide or even may lose pesticide through leaching to the surrounding medium. Field tests indicated that P. aztecus possesses a faster and, in most cases, a greater sensitivity to malathion than P. setiferus. Tidal activity was shown to alter the exposure of the shrimp to malathion by moving target water into or out of the area, or by concentrating the affected water on the shrimp.

The length-weight relationship and condition of P. aztecus and P. setiferus were determined using the methods of Le Cren. In the length-weight analysis P. aztecus proved to be in better condition in the Oyster Lake complex, as opposed to the Alligator Lake complex, throughout the observed size range. Small P. setiferus were in better condition in the Oyster Lake complex, but as size increased this difference shifted, for the larger shrimp were in better condition in the Alligator Lake complex. The cause of the variation is unknown, but could represent environmental differences such as available food. In both bay complexes the condition of both P. aztecus and P. setiferus decreased with increasing size. The condition of P. aztecus in both bay complexes, for the calendar year 1968, was highest in September, and lowest in May, June, and July. Shrimp taken in 1967 exhibited a condition factor equal to shrimp in the best of condition in 1968. The highest condition of P. aztecus was observed in April and July, 1969. Condition of P. setiferus, in the Oyster Lake complex, for the calendar year 1968, was highest in August and October. Shrimp taken in July and September were in better condition than those taken in May and June. During 1968 the condition of P. setiferus was lowest in November. Shrimp taken in late 1967 exhibited a condition factor equal to those in the best of condition in 1968. Condition of P. setiferus in the Alligator Lake complex, for the calendar year 1968, was highest in October. Shrimp taken in August and September were in better condition than those taken in July. Condition of P. setiferus was lowest in May, June, and November. Shrimp taken in November, 1967 and in February, March, and August, 1969 were in good condition. In both lake complexes the condition of P. aztecus decreased with increasing temperature; however, condition increased with increasing salinity. Condition of P. setiferus, in the Oyster Lake complex, decreased with decreasing temperature and salinity; however, in the Alligator Lake complex, the condition of P. setiferus increased with increasing temperature and salinity. This contradiction is either inexplicable or indicates that other factors, such as available food, are more significant.

ACKNOWLEDGMENTS

I wish to express my gratitude and appreciation to Dr. John G. Mackin, under whose directions this study was conducted, for his advice, helpful criticism and encouragement, and to the members of my graduate committee, Drs. Merrill H. Sweet, George M. Krise, Leo Berner, Jr., and John J. Sperry for their constructive criticism and guidance.

Grateful acknowledgment is made to the Department of Wildlife Science whose sponsorship, cooperation, and financial support made this research possible.

My sincere appreciation goes to Mr. James C. McNeill, IV, director of the Brazoria County Mosquito Control District, for his cooperation, the use of his equipment, and for the time he most generously gave during the course of the study, to Mr. Marvin Riewe, director of the Texas A&M Agricultural Experiment Station, Angleton, Texas, for his cooperation and permitting the use of station facilities, to Dr. Paul D. Ludwig, director of the Biological Research Division, Dow Chemical Company, for his encouraging advice and for the equipment he most generously provided, to Dr. Howard G. Applegate for use of his laboratory, equipment, and for his technical assistance in analyzing pesticide samples, and to Dr. Darrell Baker for his assistance in analyzing the pesticide data.

I wish to extend special thanks to Dr. Jack C. Parker, Texas Agricultural Extension Service, for his technical advice, cooperation, and time that he most generously gave throughout the course of this study, and to Mr. Royce Jurries for his invaluable aid in conducting field collections and field pesticide analyses throughout the study.

Sincere thanks go to Dr. Thomas E. Bowman, of the Smithsonian Institution, for verification of identification and identification of mysid shrimp. Mr. K. N. Baxter, U. S. Bureau of Commercial Fisheries Biological Laboratory, Galveston, and Dr. Frank M. Truesdale, Louisiana State University, made helpful suggestions in identifying postlarval penaeid shrimp. Dr. Walter Thames and Mr. Walter Walla provided technical advice on the analysis of tissue samples.

Finally, my warmest thanks to my wife, Beth, for her patience during the course of this research.

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INTRODUCTION

Within the past few decades, our coastal marshlands have been subjected to increasing encroachment by man and his activities. This invasion, whether by urbanization, industrialization, or any other factor that alters the ecosystem, threatens the life forms that utilize this habitat. Unfortunately, at this time, we can only speculate about the harmful effects that these activities may have on the fisheries resources that are inseparably linked to this environment. An efficient and wise utilization of this environment will be possible only when we thoroughly understand the biology of the species present, both commercial and non-commercial. Only with this information can we make any reasonable predictions about the effects of man's activities on the marshlands.

The purposes of this research were to sample and identify the assemblage of Crustacea collected by means of otter trawl and liner in two high salinity marsh embayments near West Bay, Texas, to determine the seasonal abundance of these organisms with respect to temperature and salinity, and to compare the seasonal variation in abundance, the coefficient of condition, and the size distribution of each of the commercial penaeid shrimp, *Penaeus setiferus* (Linnaeus) and *Penaeus aztecus* Ives. It is also aimed to determine to what extent the commercial shrimp utilize the marsh bayous as nursery grounds and to study the effect of the pesticide malathion, following aerial application of concentrations used in mosquito control, on the commercial penaeid shrimp in nursery areas.

LITERATURE REVIEW

Many marine and brackish water crustacea have life histories that are inseparably linked to coastal and estuarine marshlands. The importance of these environments as nursery areas for the commercial penaeid shrimp, white shrimp, *Penaeus setiferus* (Linn.), and brown shrimp, *Penaeus aztecus* Ives have been noted by many authors (Spalding, 1908; Viosca, 1920; Weymouth, 1933; Burkenroad, 1934, 1939, 1949; Pearson, 1939; Anderson, King, and Lindner, 1949; Broad, 1950, 1951; Williams, 1955; Skud and Wilson, 1960; Kutkuhn, 1966).

Penaeidae

Penaeus setiferus ranges along the Atlantic coast of the United States from Fire Island, New York, to Saint Lucie Inlet in east Florida. Its center of abundance is in Georgia and northern Florida. Its range along the coast of Florida is discontinuous. It is absent around the southernmost portion of the peninsula and along the Gulf coast to the mouth of the Ochlockonee River in the west portion of Apalachee Bay where it reappears in the mouth of the Ochlockonee River. In the Gulf, *P. setiferus* has a center of abundance in Louisiana and continues uninterrupted southward around the Golfo de Campeche to the vicinity of Cuidad Campeche. There is a second center of abundance off northeast Tabasco and the adjacent waters of Golfo de Campeche (Farfante, 1969).

P. aztecus ranges from Martha's Vineyard south to the Florida Keys, north along the west coast of Florida to the northwest Sanibel grounds to the vicinity of Apalachicola Bay, along the northern and western coast of the Gulf of Mexico, to the northwestern coast of Yucatan. The distribution of *P. aztecus* is somewhat similar to that of *P. setiferus*, but it ranges farther north and farther south along the eastern United States (Farfante, 1969).

Studies are now being conducted to ascertain the role of ocean currents in the movement of young shrimp from offshore waters to inshore bays and marshes (Kimsey and Temple, 1963; Kutkuhn, 1966). Currents on the continental shelf and tidal currents are believed to be instrumental in dispersal and in aiding *Penaeus* larvae to reach their nursery grounds (Kimsey and Temple, 1964; Jones, Dimitriou, and Ewald, 1964). Tidal currents have also been implicated as aiding the movement of subadult shrimp from marsh embayments and estuaries back to the sea (Idyll, Iversen, and Yokel, 1966).

Estuaries serve as nutrient traps by collecting terrigenous material from fresh water tributaries, thereby promoting high productivity (Schelske and Odum, 1962). Although the productivity of marsh bays is somewhat less than estuaries, marsh drainage adds some nutrients to the system, thus supporting a substantial fauna (Skud and Wilson, 1960; Diener, 1964).

P. aztecus spawns in the Gulf of Mexico in all seasons, with the greatest activity occurring between January and early April. After entering the Galveston nursery areas, the postlarvae peak in abundance between mid-March and mid-April. Following the spring peak, comparatively few postlarvae are found until mid-June, when postlarval abundance rises to a second peak in August or September, then rapidly drops off in late September or early October (Baxter, 1963; Baxter and Renfro, 1967). P. setiferus postlarvae peak in abundance twice each summer, the relative abundance in each peak being variable (Baxter and Renfro, 1967). The number of postlarvae taken in the bay entrance is a good index to the success of a shrimping season (Baxter, 1963, 1965).

During and shortly after the passage of cold fronts, P. aztecus postlarvae disappear in nursery areas only to reappear when the water temperature rises again (St. Amant, Corkum, and Broom, 1963). Burrowing activity has been implicated as a protective function beneficial to P. aztecus postlarvae when low temperatures render them defenseless to predation. Diurnal burrowing into the substrate is part of the normal behavior of adult penaeid shrimp but no such postlarval activity has been observed in the field (Aldrich, Wood, and Baxter, 1968). In the laboratory, a high percentage of P. aztecus postlarvae burrowed at temperatures between 12°C and 16.5°C and emerge between 18°C and 21.5°C. No such activity was observed with P. setiferus postlarvae.

P. setiferus postlarvae are not subject to such low temperatures as they do not enter the bays until the summer months (Aldrich, Wood, and Baxter, 1968).

Substrate is also a factor in shrimp distribution. *P. setiferus* and *P. aztecus* both prefer substrates of soft mud, loose peat, sandy mud, and muddy sand. Young *P. setiferus* prefer softer substrates than young *P. aztecus* (Hildebrand, 1955; Williams, 1958). Food content in the substrate could be an additional factor, although the attraction to substrate supersedes attraction to food (Williams, 1958). Shrimp are also more attracted to protective cover than to bottom food content (Williams, 1958).

Optimum low salinities, or unknown factors governed by salinity, were emphasized by some authors as the "controlling agent" in shrimp distribution (Gunter, 1950, 1956, 1961; Gunter and Hildebrand, 1954; Gunter, Christmas, and Killebrew, 1964; Hildebrand and Gunter, 1953). Other authors feel that within certain areas salinity over a broad range is inconsequential to shrimp distribution. Juvenile shrimp can populate areas of high salinity if other environmental factors are optimal (Hoese, 1960). Such factors might include substrate, protective cover, or runoff supplying nutrients to the environment (Hildebrand, 1955; Williams, 1958; Skud and Wilson, 1960; Schelske and Odum, 1962; Diener, 1964).

It has been suggested that lower salinities are necessary for growth and survival of penaeid shrimp (Gunter, Christmas, and

Killebrew, 1964), but laboratory studies indicate that normal environmental variations in salinity *per se* should have little effect on growth and survival of penaeid postlarvae (Zein-Eldin, 1963; Zein-Eldin and Aldrich, 1965; Zein-Eldin and Griffith, 1966). *P. setiferus* and *P. aztecus* which were held at salinities of 2, 5, 10, 25, and 40 ppt showed no significant difference in growth rate when temperatures were maintained between 23°C and 25°C. Survival was excellent at all salinity levels tested (Zein-Eldin, 1963). Combined salinity and temperature studies indicate an increased growth rate by *P. aztecus* postlarvae at temperatures above 11°C (Zein-Eldin and Aldrich, 1965). Growth increased with temperature up to 32.5°C, with maximal increases of growth rate per unit of temperature occurring between 17.5°C and 25°C. *P. aztecus* survived temperatures up to 35°C, but showed a marked decrease in survival at 32.5°C (Zein-Eldin and Griffith, 1966).

P. aztecus in the field shows little growth at temperatures below 18°C. The highest rate of growth in relation to the highest rate of survival is between 25°C and 27°C. The laboratory and field data agreed reasonably when allowances were made for the differences between the maximum daily temperatures recorded in the field and average temperatures tested in the laboratory (Ringo, 1965).

Palaemonidae

The grass shrimps *Palaemonetes vulgaris* (Say) and *Palaemonetes pugio* Holthuis are important species in the diet of numerous fish of the Gulf coast (Gunter, 1945; Miles, 1949; Moody, 1950; Darnell, 1958). *P. vulgaris* has been reported as ranging from Barnstable County, Massachusetts, to Cameron County, Texas. *P. vulgaris* has also been recorded from Gaspe Quebec, Canada to Rio Champoton and near Progresso, Yucatan, Mexico (Williams, 1965). *P. pugio* has been reported from Essex County, Massachusetts to Port Aransas, Texas (Williams, 1965). *P. vulgaris* and *P. pugio* have been taken from Copano Bay and Aransas Bay, Texas, the salinity ranging from 2.0 to 34.2 ppt and with temperatures fluctuating between 12.5 and 34.0°C (Gunter, 1950). Holthuis (1949) suggested that *P. pugio* may prefer lower salinities than *P. vulgaris*.

Although the ecological requirements of *P. vulgaris* have not been studied, some work on the physioecology of *P. pugio* has been conducted in the Galveston Bay, Texas estuarine system. *P. pugio* appears throughout the year in Galveston Bay, with the greatest abundance in July and October. Abundance is greatest in waters of 10 to 20 ppt salinity and the least in waters below 1 ppt salinity. *P. pugio* can survive a wide range of temperatures but survives best in waters of temperatures between 18 and 25°C (Wood, 1967). Both species, *P. vulgaris* and *P. pugio*, are included in several ecological surveys made within their geographical range (Gunter, 1945, 1950; Miles, 1949; Moody, 1950; Baldauf, 1953; Reid, 1955; Simmons, 1957; Darnell, 1958; Hildebrand, 1958; Chambers and Sparks, 1959; Arnold, Wheeler, and Baxter, 1960; Pullen, 1961).

Periclimenes longicaudatus (Stimpson) has been reported from Hatteras, North Carolina to southwestern Florida; throughout the West Indies to the state of Paraiba, Brazil. There are doubtful records from the Indian Ocean and from the deeper waters of the Gulf of Mexico. Last larval, postlarval, and early juvenile stages, doubtfully assigned to this species, have been described from Bermuda. *P. longicaudatus* has been collected throughout the year near Beaufort, North Carolina. It occurs in Cuba in January and March and in Texas in May (Williams, 1965).

Hippolytidae

Tozeuma carolinense Stimpson has been reported from Martha's Vineyard Sound, Massachusetts to Colon, Panama. Within this distribution, this species has been reported in North Carolina from May to October, with one doubtful record in February, and from Bimini in March. In Louisiana and Florida, it has been reported from March to November, and in December from Puerto Rico (Ewald, 1969; Williams, 1965).

Sergestidae

Acetes americanus Hansen is known from Cape Lookout, North Carolina to the mouth of the Para River, Brazil. In Bogue Sound, near Beaufort Inlet, North Carolina, specimens have been taken the year-round, with massive numbers occurring in late summer and early fall (Williams, 1965). This species has been reported as completely clogging shrimping nets off the northern coast of Florida and has been mistaken, by shrimpers, for postlarvae of commercial shrimp in that area (Joice, 1965).

Mysidacea

Mysidopsis almyra Bowman is a euryhaline mysid species that has been taken in salinities varying between 1.2 ppt to more than 40.0 ppt (Tattersall, 1969). This species is an important food source for a number of fish in Lake Pontchartrain, Louisiana (Darnell, 1958). *M. almyra* has been reported from Lake Pontchartrain at salinities of 2.0 to 5.2 ppt (Bowman, 1954) and at 1.2 to 18.6 ppt with an average of less than 6 ppt and a maximum of less than 9 ppt (Darnell, 1958). Specimens have been taken from the St. Andrews Bay system of Florida at low salinities in the upper reaches of the bay and at salinities only slightly below 35 ppt in St. Andrews Bay proper, West Pass, and East Pass (Jones and Ichyie, 1960; Ichyie and Jones, 1961). Hopkins (1963) collected *M. almyra* in St. Andrews Bay and West Pass, the salinities at the time being 33.1 ppt and 27.3 to 33.7 ppt, respectively. Specimens were collected from the north end of Buttonwood Canal, connecting Florida Bay with Coot Bay at Flamingo, and in the Cape Sable region of southern Florida at salinities fluctuating from less than 18 ppt to more than 40 ppt (Tabb, Dubrow, and Manning, 1959).

Mysidopsis bahia Molenock has been collected in November near the northwest shore of Galveston Island, Texas; in West Bay at a salinity of 28 ppt and temperature of 24°C; Lake Como, West Bay, from July through September, at salinities varying between 22 and 29 ppt and temperature ranging from 24 to 32°C; Clear Lake, Galveston Bay in September at a salinity of 18 ppt and a temperature of 29°C (Molenock, 1969).

Taphromysis louisiana Banner has been previously reported only from static, fresh water in Louisiana (Banner, 1953; Bowman, personal communication).

Bowmaniella brasiliensis Bacescu has been previously reported from marine waters on the coast of Brazil (Bacescu, 1968a; Bowman, personal communication).

Brasilomysis castroi Bacescu has been previously reported from coastal, marine waters of Brazil and southern Florida (Bacescu, 1968B; Bowman, personal communication).

The Problem of Pesticides

Biologists have repeatedly warned against irresponsible application of pesticides and have indicated problems that will result if this is continued (Anderson, 1963; Hayes and Dale, 1963; Hunter, Robinson, and Richardson, 1963; Breidenbach, 1965; Wheatly and Hardman, 1965). Only if we take responsible means to understand the effect of our activities on the world ecosystem can we effectively approach equilibrium between man's activity and the rest of nature (personal communication from Mr. James C. McNeill, director of the Brazoria County Mosquito Control District). Not only are direct mortalities a major concern, but so are sublethal effects involving behavior, vigor, growth, reproduction, or any other factor leading to an inbalance among natural populations (Bucher, 1965; Dustman and Stickel, 1966). The need for extensive and continued research to determine the effects of pesticides on wildlife is of greatest necessity (Butler, 1960a). Information concerning the effects of pesticides on marine species is incomplete. In the south where marshes are sprayed, more information would be especially valuable (Chin and Allen, 1957). Due to wind and water dissipation, aerially applied sprays reach the target in amounts equal to less than 50 percent of the quantity distributed (Cope and Bridges, 1963; Pillmore and Finly, 1963; Hitchcock, 1965). Mixing of pesticides in the water can result in the formation of a new chemical combination more toxic than the initial pesticides. The toxicity of pesticides in combination usually follows the pattern predicted from the knowledge of their independent actions. Exceptions have been noted in that the combined action of some pesticides is significantly greater or less than would be expected from their individual toxicities; consequently, it is difficult to test in the laboratory the end results of field application (Butler, 1960a; Niering, 1968; Dubois, 1969).

Malathion has been described as a relatively safe pesticide (Rudd and Genelly, 1956; Niering, 1968). Degradation of the pesticide occurs rather quickly in the ecosystem especially above 60°F (Culley and Applegate, 1967). Rice paddies, sprayed with ^{32}P-labeled malathion, exhibited a strong radioactivity in the surface waters. This radioactivity gradually diffused into deeper layers of the water; some parts of the radioactive material were absorbed in the muddy soil-particles of the bottom. At the end of the two days, 95 percent of the radioactivity had disappeared from the rice paddy (Sato and Kubo, 1965).

Organic phosphorus insecticide poisoning affects most animals by inhibiting the synaptic enzyme cholinesterase, resulting in tetany and death (Weiss and Gakstatter, 1964). Application of this principle to the study of crustacean transmission systems is not fully understood. Although cholinesterase has been reported in the sensory axons of some Crustacea, it has not been found in the motor or inhibitory fibers. Analysis of the end plate junction potentials of crustacean muscles indicates that they are produced by the release of quanta packets of a transmitter similar to acetyl choline. The exact nature of the motor end plate transmitter is as yet uncertain especially as cholinesterase has not been demonstrated as being present. Glutamic acid has been considered as a possible transmitter as it mimicks the action of acetyl choline (Lockwood, 1967).

Usually pesticide toxicity is evaluated in terms of mortality; however, in shrimp, toxicity is indicated first by an increased irritability, then a loss of equilibrium that would render them defenseless to predation. These types of observations can readily be made in the laboratory where most of the research concerning commercial shrimp and pesticides have been conducted (De Silva, 1954; Butler, 1960a, 1960b, 1963, 1965; Chin, 1961). Very little research has been conducted on the effects of malathion on commercial shrimp. Butler (1963), in testing the effects of malathion on Penaeus duorarum Burkenroad reported EC_{50}* values of 0.82 ppm and 0.50 ppm at 24 and 48 hours, respectively. Difficulty in determining shrimp mortalities in the field has prevented much research in this area. Accurate estimates of field mortalities, of most organisms, are difficult to obtain as corpses are not easily found and do not persist long (Stickel and Chura, 1964). In the majority of instances the evidence of field pesticide mortalities are circumstantial. In relatively few cases have attempts been made to demonstrate experimentally that the pesticide

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*EC_{50} - Medium effective concentration. The concentration of pesticide in sea water causing mortality or equilibrium loss in 50 percent of shrimp tested.

residues found in corpses are equitable with the taking of a lethal dose (Davis, 1965).

Length-Weight Relationships and Coefficient of Condition in Penaeid Shrimp

Length-weight relationships of male and female *Penaeus aztecus* from Galveston Bay were computed by Chin (1960). Parker (1965) described the length-weight relationship of *P. aztecus* in three nursery areas in Galveston Bay, and compared the condition of these shrimp based on the analysis of covariance of their length-weight regressions. He found that condition varied significantly between nursery areas in Trinity, East, and upper Galveston Bays. Condition also varied seasonally, and with population density, but the results were not consistent in individual nursery areas. Parker suggested that these inconsistencies reflected the effects of environmental factors correlated with neither season nor population density.

MATERIALS AND METHODS

Description of the Area

The area selected for this study is located in a salt-marsh west of the West Bay, Texas. The study areas consist of two high salinity marsh embayments, Alligator and Oyster Lakes, and three marsh bayous, Alligator, Oyster, and Elbow Sloughs (Figure 1, page 17).

Alligator Lake is a shallow marsh embayment, approximately nine-tenths of a mile in diameter, with a maximum depth of five feet. The lake is completely surrounded by marsh grass (*Spartina spartinae* (Trin.) Merr.) and has a bottom consisting of mud, clay, and scattered patches of oyster shell. The lake is linked to the Gulf of Mexico by marsh bayous connecting with the Intracoastal Waterway, which in turn connects with Bastrop Bay, Christmas Bay, and West Bay. Salinity in the lake ranges between 0.0 ppt to 27.0 ppt. Extreme low salinities occur during the fresh water flooding which may occur with winter storms.

Oyster Lake is a shallow marsh embayment, approximately one mile in diameter, with a maximum depth of six feet. The lake is surrounded on three sides by marsh grass with the elevated spoil bank of the Intracoastal Waterway forming the fourth side. The sediment of Oyster Lake consists of mud mixed with sand and shell, and oyster reefs are scattered throughout the lake. Oyster Lake is linked through the Intracoastal Waterway to West Bay and

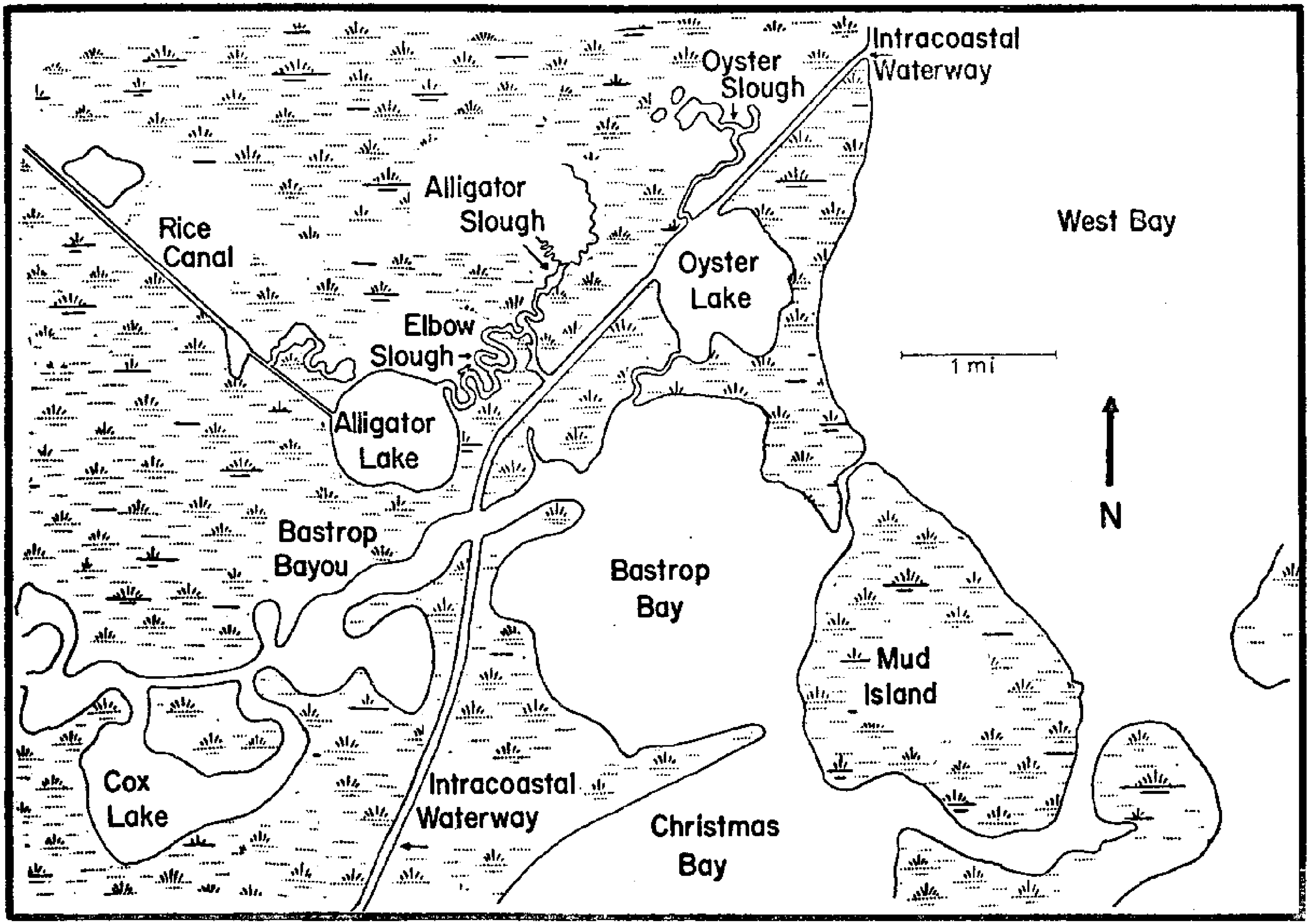

Figure 1. The area west of West Bay, Galveston, Texas. Study area includes Alligator Lake, Oyster Lake, Elbow Slough, Alligator Slough, and Oyster Slough.

Bastrop Bay, and directly to Bastrop Bay by a pass in its western shore. The salinity of Oyster Lake ranges from 2 ppt to 32 ppt.

Alligator Slough is a side branch of the marsh bayou system leading from the Intracoastal Waterway to Alligator Lake. Alligator Slough divides into two branches; each branch extends deep into the marsh and drains much of the marsh during heavy rains. The maximum depth of the slough is four feet (Figure 2, page 19).

Oyster Slough is a marsh bayou that extends into the marsh from the northern end of Oyster Lake. The maximum depth of the slough was three feet, but it diminished during the study due to wash from the spoil bank of the Intracoastal Waterway (Figure 3, page 20).

Elbow Slough is a small, dead end side branch of the bayou system which leads from the Intracoastal Waterway to Alligator Lake. The maximum depth of this slough during the study was two feet (Figure 2, page 19).

Procedure

Crustacea were collected twice a month, October, 1967 through August, 1969, from six stations in the study area. Two replicate stations were located in both Alligator and Oyster Lake. The position of the stations in each lake was determined by the wind direction as collections were made near the lee shore. Collections were not made in mid-lake or near the unprotected shore as wave action, in these shallow waters, affected the fishing

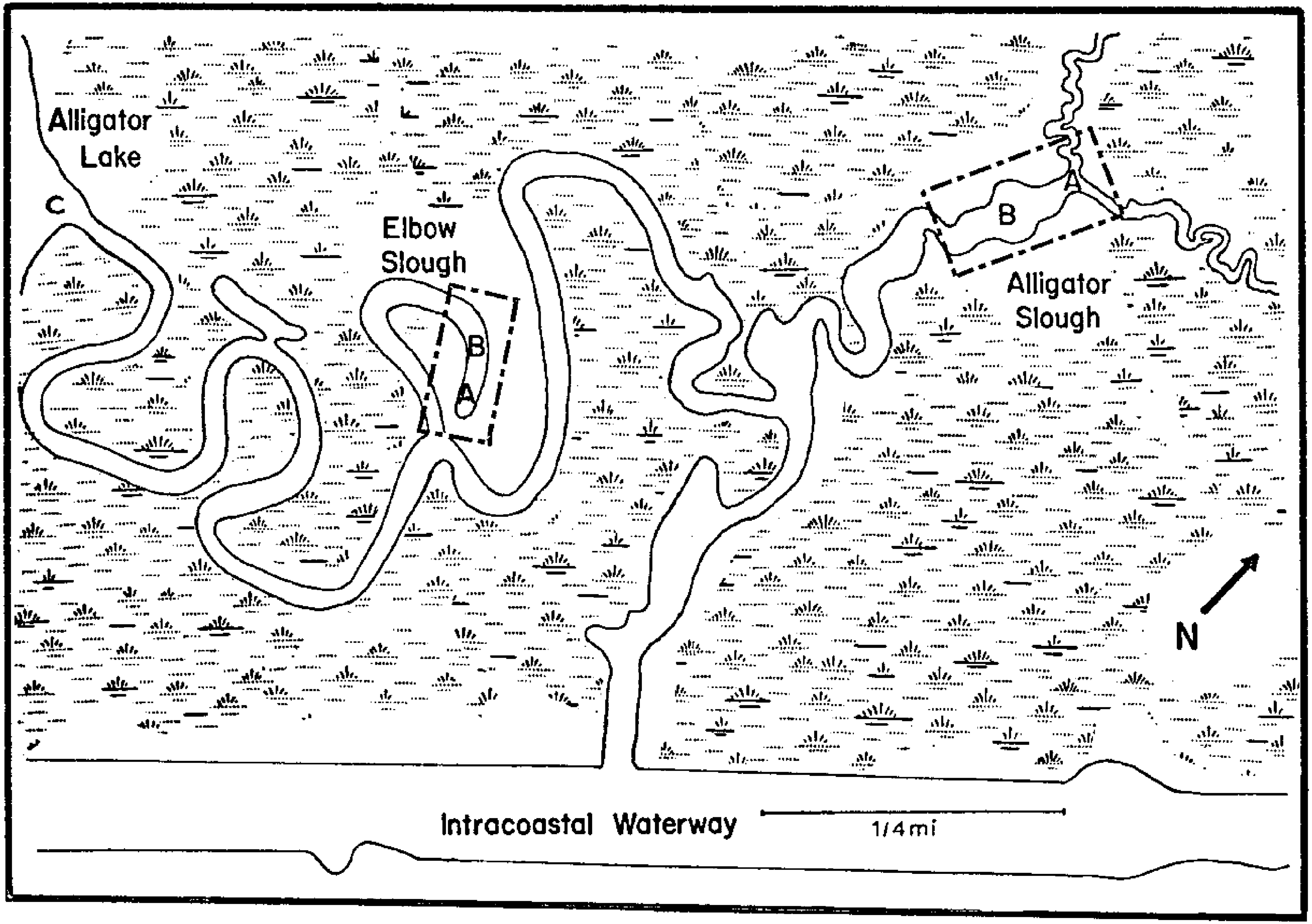

Figure 2. Target plots for the aerial application of malathion with positions of shrimp Boxes A and B used in field tests 1, 2 and 3 in Alligator Slough, and shrimp Boxes A and B used in field tests 2 and 3 in Elbow Slough. Position C in Alligator Lake indicates the location of one control box used in field test 3.

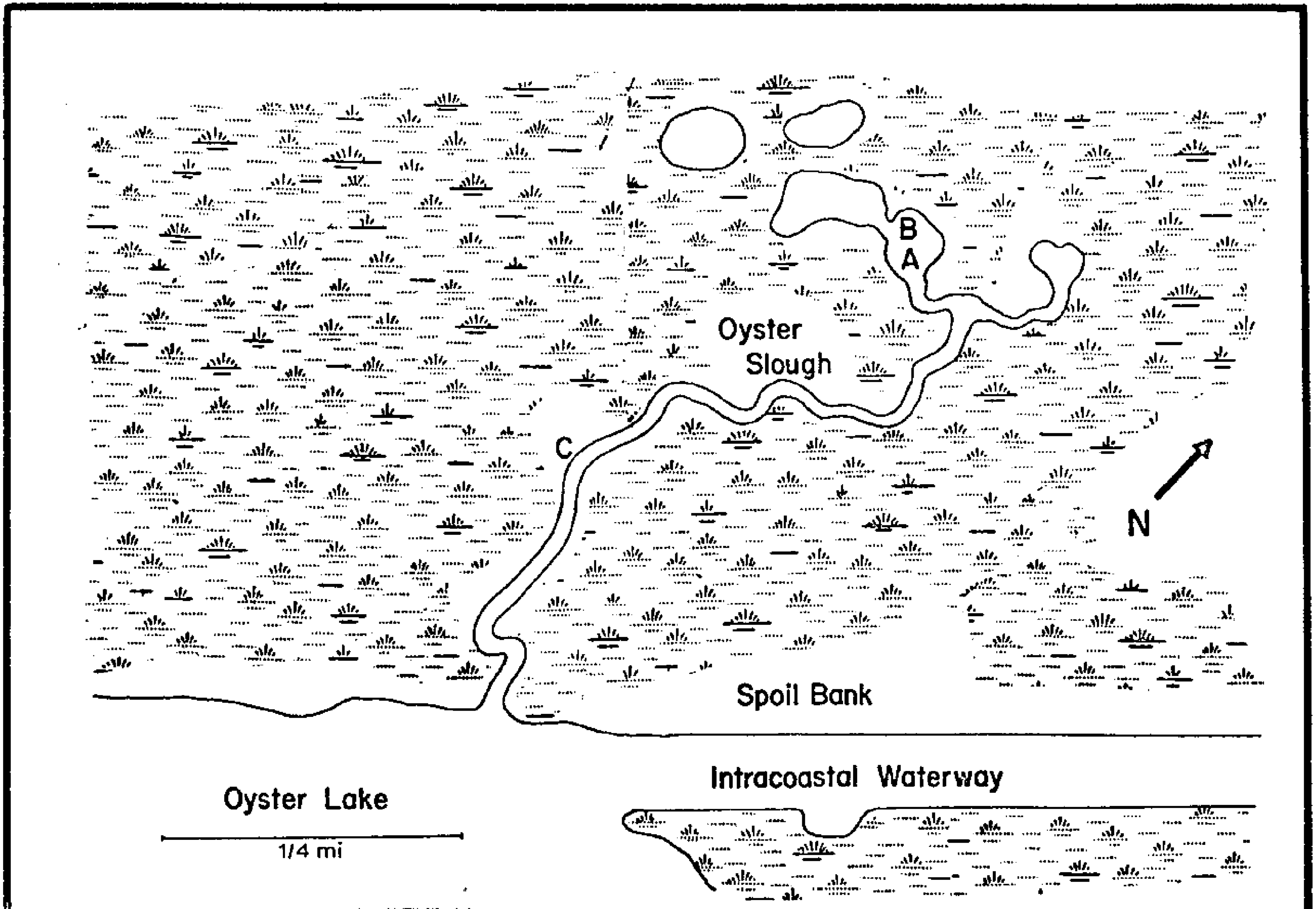

Figure 3. Position of shrimp Boxes A and B used as controls in malathion field tests 1 and 2, C indicates the position of the shrimp box used as a control in malathion field test 3.

ability of the trawl and the stability of the boat. One station was located in each of the marsh bayou systems, Alligator and Oyster Slough. Here, collections were taken only when the water was deep enough to trawl.

Special collecting permits were obtained from the Texas Parks and Wildlife Department to cover all commercial shrimp caught in restricted waters.

Collections were made using a 10-foot otter trawl of 2 cm mesh with a 1 cm mesh in the cod end. An additional liner of 3 mm mesh was placed over the cod end to capture smaller organisms that pass through the main trawl. The trawl, with its liner, was then pulled through the water by an airboat, powered by a 110 hp. Corvair engine, at a constant speed of about 5 mph for three minutes. Trawl and liner samples were placed in separate sealed plastic buckets, containing a 10 percent solution of formalin. In the laboratory, the samples were transferred to jars containing 70 percent ethyl alcohol and stored for later study. During massive algal blooms of _Ectocarpus siliculosus_ in the bays, qualitative samples were taken without the liner. Clumps of algae were also placed in formalin and examined in the laboratory. The physical data taken at each station included temperature, salinity, tide, and wind. Water temperature was taken with a field Celsius thermometer. Salinity was determined with an A. O. Goldberg refractometer. Tide was recorded as storm tide, high tide, medium tide, or low tide. Wind data included direction and estimated velocity to pinpoint lee-shore trawl stations for future reference (Table 1, page 23; Table 2, page 25; Table 3, page 27; and Table 4, page 28).

In the laboratory, the Crustacea were separated from both the liner and trawl samples. Penaeid shrimp were identified to species using the keys of Williams (1953, 1959, and 1965) and Ringo and Zamora (1968). Problems in identification of postlarval penaeid shrimp, 10 to 25 mm in length, have persisted for many years (Baxter and Renfro, 1967). Separation of *P. aztecus* and *P. setiferus* postlarvae is based on the presence of spines on the dorsal carina of the sixth abdominal segment in *P. aztecus* and the absence of these spines in *P. setiferus* (Ringo and Zamora, 1968; Zamora and Trent, 1968). There is no practical method of distinguishing between postlarval grooved shrimp, *P. duorarum* Burkenroad and *P. aztecus* (personal communication from K. N. Baxter, U. S. Bureau of Commercial Fisheries, Galveston, Texas). Although the occurrence of postlarval *P. duorarum* in the West Bay, Galveston area is rare (personal communication from K. N. Baxter, U. S. Bureau of Commercial Fisheries, Galveston, Texas), and no adult *P. duorarum* were found in this study, a mixture of *P. setiferus*, *P. aztecus*, and *P. duorarum* exists in certain Gulf coast nursery areas (Christmas, Gunter, and Musgrave, 1966). A total of 68 postlarval shrimp collected in mid-summer of 1968 and 1969 could not be identified. Due to the uncertain nature of these shrimp, they were excluded from the data; however, it should

TABLE 1. Physical data taken from Oyster Lake from October 29, 1967 through August 29, 1969.

Collection Date	Water Temperature °C	Salinity ppt	Tide	Wind Direction and Velocity
10/29/67	23	25	High	8 - 10 SE
11/12/67	22	24	Low	3 - 5 SE
11/28/67	17	28	High	10 - 12 N
12/12/67	18	17	Low	6 - 8 SE
12/28/67	9	22	Low	8 - 10 N
1/15/68	6	3	Low	1 - 3 S
1/31/68	22	26	Medium	6 - 8 SE
2/13/68	12	16	High	12 - 15 N
2/26/68	17	16	Low	5 - 7 W
3/11/68	21	26	Low	12 - 15 N
3/25/68	20	24	Low	8 - 12 S
4/ 7/68	22	19	Medium	8 - 10 NE
4/23/68	24	20	Medium	8 - 10 NE
5/ 6/68	26	20	Medium	16 - 18 SE
5/28/68	29	10	Medium	3 - 5 SE
6/13/68	30	6	Low	3 - 5 SE
6/26/68	30	2	Storm tide	5 - 7 SE
7/10/68	30	6	High	5 - 8 SE
7/23/68	31	9	Medium	1 - 5 S
8/14/68	34	22	Low	14 - 16 SE
8/27/68	29	26	High	9 - 10 NE
9/11/68	28	19	Medium	8 - 10 NE
9/26/68	26	17	High	10 - 12 NE
10/26/68	22	12	Low	5 - 8 SE
11/13/68	14	21	Low	10 - 12 SE
11/27/68	13	23	Low	4 - 7 SE
12/12/68	12	14	Medium	3 - 5 SE
12/30/68	9	18	Medium	2 - 5 N
1/15/69	11	13	Low	4 - 7 N
1/29/69	13	16	Medium	3 - 5 N
2/15/69	--	--	--	--
2/28/69	15	20	High	5 - 8 N
3/15/69	18	11	High	12 - 15 E
3/27/69	16	11	Low	8 - 15 SE
4/10/69	26	23	Medium	3 - 5 SE
4/26/69	24	15	High	15 - 20 S
5/22/69	30	13	Medium	4 - 6 S
6/17/69	29	13	Medium	3 - 5 S

TABLE 1. Continued.

Collection Date	Water Temperature °C	Salinity ppt	Tide	Wind Direction and Velocity
7/ 4/69	31	24	Low	2 - 5 S
7/16/69	29	25	Low	5 - 7 W
8/12/69	31	32	Medium	3 - 6 S
8/29/69	30	29	High	10 - 11 SE

TABLE 2. Physical data taken from Alligator Lake from October 29, 1967 through August 29, 1969.

Collection Date	Water Temperature °C	Salinity ppt	Tide	Wind Direction and Velocity
10/29/67	24	20	High	10 - 15 SE
11/12/67	22	20	Low	3 - 5 SE
11/28/67	17	27	High	10 - 12 N
12/12/67	16	10	Low	10 - 12 SE
12/28/67	9	12	Low	8 - 10 N
1/15/68	7	0	Low	1 - 3 S
1/31/68	24	24	Medium	5 - 8 SE
2/13/68	13	16	High	12 - 15 N
2/26/68	17	8	Low	3 - 5 NW
3/11/68	22	16	Low	12 - 15 N
3/25/68	15	22	Low	5 - 8 S
4/ 7/68	19	10	Medium	8 - 10 NE
4/23/68	25	4	Low	8 - 10 SE
5/ 6/68	26	12	Medium	10 - 12 SE
5/28/68	28	6	Medium	3 - 5 SE
6/13/68	30	0	Low	0
6/26/68	28	0	Storm tide	12 - 15 SE
7/10/68	31	2	High	5 - 8 SE
7/23/68	30	3	Medium	1 - 3 S
8/14/68	34	10	Low	14 - 16 SE
8/27/68	29	18	High	10 - 12 NE
9/11/68	28	16	Medium	10 - 12 NE
9/26/68	25	10	High	10 - 12 NE
10/26/68	22	5	Low	5 - 8 SE
11/13/68	17	16	Low	6 - 8 SE
11/27/68	12	18	Low	4 - 7 SE
12/12/68	11	10	Medium	3 - 5 SE
12/30/68	9	10	Medium	2 - 5 N
1/15/69	10	4	Low	4 - 7 N
1/29/69	11	10	Medium	3 - 5 N
2/15/69	15	22	Storm tide	8 - 10 N
2/28/69	14	16	High	5 - 8 N
3/ 5/69	18	10	High	10 - 15 E
3/27/69	14	9	Low	8 - 15 SE
4/10/69	25	21	Medium	3 - 5 SE
4/26/69	25	7	High	15 - 20 S
5/22/69	32	4	Medium	4 - 6 S
6/17/69	29	8	Medium	3 - 5 S

TABLE 2. Continued.

Collection Date	Water Temperature °C	Salinity ppt	Tide	Wind Direction and Velocity
7/ 4/69	32	19	Low	2 - 5 S
7/16/69	30	19	Low	5 - 7 W
8/12/69	30	27	Medium	3 - 6 S
8/29/69	30	27	High	10 - 11 SE

TABLE 3. Physical data taken from Oyster Slough from October 29, 1967 through March 5, 1969.

Collection Date	Water Temperature °C	Salinity ppt	Tide
10/29/67	22	26	High
11/12/67	25	13	Low
11/28/67	16	28	Medium
12/12/67	18	11	Low
1/31/68	26	26	Medium
2/13/68	11	4	High
5/ 6/68	29	19	Medium
5/28/68	34	6	Medium
6/26/68	29	1	Storm tide
7/10/68	34	5	High
8/27/68	33	23	High
9/11/68	28	16	Medium
9/26/68	28	14	High
3/ 5/69	18	11	High

TABLE 4. Physical data taken from Alligator Slough from October 29, 1967 through April 26, 1969.

Collection Date	Water Temperature °C	Salinity ppt	Tide
10/29/67	23	26	High
11/12/67	23	7	Low
11/28/67	17	29	High
12/12/67	16	4	Low
12/28/67	9	4	Low
1/31/68	25	22	Medium
2/13/68	12	12	High
3/11/68	24	4	Low
4/23/68	25	2	Low
5/ 6/68	25	5	Medium
5/28/68	34	2	Medium
6/13/68	28	1	High
6/26/68	30	0	Storm tide
7/10/68	32	2	High
7/23/68	30	1	Medium
8/27/68	31	20	High
9/11/68	28	14	Medium
9/26/68	26	17	High
3/ 5/69	18	4	High
4/10/69	28	5	Medium
4/26/69	25	1	High

be noted that these few unidentified specimens do not change the overall distribution of P. aztecus in the study area.

The grass shrimp, Palaemonetes vulgaris (Say) and P. pugio Holthuis, were identified using the keys of Holthuis (1952). The seasonal distributions of the grass shrimps were compared with temperature and salinity in Oyster Lake, Oyster Slough, Alligator Lake, and Alligator Slough.

The sergestid shrimp, Acetes americanus Hansen were identified by Williams' keys (1965); and the seasonal distribution compared with temperature and salinity in Oyster Lake, Oyster Slough, Alligator Lake, and Alligator Slough.

Mysid shrimp, Mysidopsis almyra Bowman, Mysidopsis bahia Molenock, Taphromysis louisiana Banner, Bowmaniella brasiliensis Bacescu, Brasilomysis castroi, and Mysidopsis spp. were identified folowing Tattersall (1951, 1969), Bowman (1964), Molenock (1969), Banner (1953), and Bacescu (1968a, 1968b). Representatives of each species were then sent to Dr. Thomas E. Bowman, Smithsonian Institution, for verification. The mysids' seasonal distributions were compared with temperature and salinity in Oyster Lake, Oyster Slough, Alligator Lake, and Alligator Slough.

Other Crustacea that appeared only once in the collections, Periclemens longicaudatus (Stimpson) and Tozeuma carolinense Stimpson, were identified following Williams (1965) and recorded as to collection period.

Insecticide Study

During the summer of 1969, three tests were conducted on the effects of aerial application of malathion, in concentrations used in mosquito control, on the commercial shrimp *P. setiferus* and *P. aztecus*. The area chosen for the study was an established nursery area for both species of shrimp.

Test 1. The first test was conducted from June 15 through June 19, 1969. Live juvenile shrimp, *P. aztecus*, 60 to 85 mm in length were obtained from a bait barge in Bastrop Bayou. These shrimp were transported in large plastic containers to Alligator and Oyster Sloughs, enclosed in 3' by 3' live boxes constructed from 2" by 2" wood framing and covered with quarter-inch mesh hardware cloth. The tops of the boxes were hinged to allow access to the shrimp. Two boxes, each containing 25 *P. aztecus*, were submerged in Alligator Slough and marked test Box A and test Box B (Figure 2, page 19). Two more boxes, containing the same number of shrimp, were submerged in Oyster Slough and designated control Boxes A and B (Figure 3, page 20). The shrimp were allowed to acclimate for 36 hours.

One liter water samples were taken from the middle of each site, placed on ice, and transported to the laboratory for analysis of pesticide content. Shrimp samples were placed in aluminum foil, wrapped in polyethylene bags, and placed on ice for future tissue analysis. Temperature and salinity data were taken.

On the morning of June 17, the test plot, Alligator Slough, was sprayed with technical grade malathion, 3 oz. per acre, from a 235 hp. Piper Pawnee, PA 25 at a height of 30 ft., at 90 mph.

The boxes containing the shrimp, in both the test and control plots, were examined at 9, 24, 33, and 48 hours after the application of malathion. During each check period, all dead shrimp and two live shrimp were removed, packaged, and placed on ice for pesticide analysis. During the examination, a one liter water sample was taken from the middle of the plot and placed on ice for pesticide analysis. Temperature, salinity, and tidal activity were recorded during each check period.

Test 2. The second test was conducted from July 15 through July 19. Juvenile shrimp, *P. aztecus* and *P. setiferus*, 60 to 85 mm in length were obtained from a bait barge in Bastrop Bayou. The shrimp were transported to Alligator, Elbow, and Oyster Sloughs and enclosed in live boxes. Two boxes, marked A and B, were submerged in each slough (Figure 2, page 19; Figure 3, page 20). Boxes, containing shrimp, submerged in Oyster Slough were maintained as controls. A mixture of 27 to 37 *P. aztecus* and *P. setiferus* were enclosed in each box and allowed to acclimate for 48 hours. Shrimp samples and water samples were taken for pesticide analysis. Temperature and salinity data were also taken.

On the morning of July 17, the test plots, Alligator and Elbow Sloughs, were sprayed with technical grade malathion by the same procedure as in Test 1.

The boxes containing the shrimp, in the test and control plots, were examined at 1, 3, 6, 9, 25, 33, and 49 hours after application of malathion. The number and species of all dead shrimp were recorded and removed from the boxes at each check period. No shrimp or water samples were taken for pesticide analysis. Water temperature, salinity, and tidal activity were recorded at each check time.

Test 3. The third test was conducted from August 12 through August 15, 1969. Live juvenile shrimp, *P. setiferus*, 60 to 130 mm length were obtained from a bait barge in Bastrop Bayou. These shrimp were transported to Alligator and Elbow Sloughs, enclosed in live boxes; and two boxes, marked A and B, were submerged in each plot (Figure 2, page 19). One box containing shrimp was submerged in both Alligator Lake (Figure 2, page 19) and Oyster Slough (Figure 3, page 20) and maintained as controls. Twenty-five shrimp were enclosed in each box and allowed to acclimate for 48 hours. Shrimp samples and water samples were taken for pesticide analysis. Temperature and salinity data were taken.

On the morning of August 14, 1969, the test plots, Alligator and Elbow Sloughs, were sprayed with technical grade malathion by the same procedure as in Test 1 and Test 2. Boxes of shrimp in Alligator Lake and Oyster Slough were maintained as controls.

The boxes containing the shrimp were examined at 1, 3, 8, and 24 hours after the application of malathion. During each examination, all dead shrimp and two live shrimp were removed, packaged and placed on ice for pesticide analysis. During each examination, a one liter water sample was taken from each plot and placed on ice for pesticide analysis. Water temperature, salinity, and tidal activity were recorded at each check time.

Water Analysis

Water samples analyzed for malathion content were removed from cold storage and allowed to reach room temperature. The water samples were then analyzed for pesticides using the techniques of Burchfield and Johnson (1965). Each sample was filtered through a Buchner vacuum filter, divided into two 500 ml portions, and each portion poured into a separate 1000 ml separatory funnel. To one 500 ml portion was added 10 ml of distilled hexane and marked NX. To the remaining 500 ml portion was added 10 ml of distilled hexane containing 100 ppm malathion from a known standard. This sample was designated the spiked sample. To each sample was added 100 ml of chloroform and the sample was shaken for two minutes. The solutions were then allowed to settle and the bottom layers of chloroform containing extracted malathion from each sample were drawn off into separate beakers. This process was then repeated four more times using 50 ml of chloroform. Each sample, spiked and NX, was then filtered through a separate column of anhydrous sodium sulfate to remove excess water and collected in separate beakers. The filtrates were evaporated to dryness, 5 ml of distilled hexane was added to each sample, and samples were then put in cold storage.

The malathion analysis for water samples was performed with a Barber-Colman 5360 pesticide analyzer equipped with a 6-foot, ¼-inch I. D. column packed with a 50:50 mixture of 7 percent OV-17 and 9 percent QF-1 on 80/100 chromosorb W. AW, DMCS, HP. The column temperature was 190°C; the injector temperature was 220°C and the detector temperature was 210°C. The effluent was monitored with a tritium electron capture detector. Pre-purified nitrogen was used as the mobile gas phase, with a flow rate of 80 ml per minute.

Known standards of distilled hexane containing 100, 50, 10, 5, 2½, and 1 ppm malathion were then prepared and 2 ml of each injected into the pesticide analyzer. Peaks were obtained for each injection and the area under each peak was obtained by the formula $A = h \times w$ at ½ h where h = height and w = width. The peak area of each standard was then plotted on semilogarithmic paper, three cycles X ten to the inch, with the abscissas in mm^2 and the ordinates in ppm malathion.

Two ml of each extraction from the water samples, NX and spiked, were then injected into the pesticide analyzer and peaks obtained for each. The area under each peak was calculated and a ratio of recovery was determined between the NX and spiked sample. This figure was then compared to the standard graph and the amount of malathion present in the water sample was determined in ppm.

Tissue Analysis

The penaeid shrimp were analyzed for pesticides using the techniques of Burchfield and Johnson (1965). Each shrimp to be analyzed was measured and weighed. The tail tissue was then removed from the carapace, weighed, divided into two portions, and ground with anhydrous sodium sulfate. The mixtures were then placed in separate filter-paper cones and suspended over 125 ml separatory funnels. Ten ml of distilled hexane was added to one cone labeled NX. To the other cone was added 10 ml distilled hexane containing 10 ppm malathion standard to form a spiked sample. To each cone was added 30 ml of petroleum ether followed by 25 ml of acetonitril saturated with petroleum ether. The cones containing the tissue were discarded and the contents of the separatory funnels shaken thoroughly. The bottom layer of each separatory funnel was then drawn off and poured into separate 1000 ml separatory funnels containing 500 ml of a 2-percent solution of sodium chloride. To the top layer of each 125 ml separatory funnel was added 25 ml of acetonitril saturated with petroleum ether. This solution was then mixed and the bottom layer removed and added to the 1000 ml separatory funnel containing the sodium chloride. This process was repeated three times. The contents of the 125 ml separatory funnels were then discarded. To the 1000 ml separatory funnel 100 ml of petroleum ether was added, mixed, and the bottom layer containing the 2 percent sodium chloride was discarded. To each 1000 ml separatory funnel was added 500 ml of a 2-percent sodium chloride solution, mixed, and the bottom layer discarded. The salting process was then repeated. The top layer containing the extracted malathion was then filtered through separate solumns containing anhydrous sodium sulfate and washed with 10 ml portions of petroleum ether. The filtrate was evaporated just to dryness and dissolved in 5 ml of ethylacetate. Each sample was placed in screw-top tubes and refrigerated.

The malathion tissue analysis was performed with a Barber-Colman pesticide analyzer with a 6-foot, ¼-inch, I. D. column packed with 80/100 mesh chromosorb WPH 4 percent SE-30, 6 percent QF-1. The column temperature was 180°C, the injector temperature was 240°C, and the detector temperature was 210°C. The effluent was monitored with a tritium electron capture detector. Pre-purified nitrogen was used as the mobile gas phase, with a flow rate of 65 ml per minute.

Known standards of distilled hexane containing 50, 10, 5, 2½, 1, and .5 ppm malathion were prepared and 2 ml of each was then injected into the pesticide analyzer. Peaks were obtained for each injection and the area under each peak was calculated and plotted on semilogarithmic paper.

Two ml of each extraction from the tissue samples, NX and spiked, were injected into the pesticide analyzer and peaks obtained for each. The area under each peak was calculated and a ratio of recovery between the NX and spiked sample was determined. This figure was compared with the standard graph and the amount of malathion present in the tissue sample was determined in parts per million.

Spot checks of both the water samples and shrimp samples were run on thin layer chromatographs to verify that peaks obtained by gas chromatograph were malathion. The absorbent used was silica gel; the solvent, isopropanol and acetic acid in a 10 to 1 ratio. Spots were developed by exposure to iodine vapors.

Length-Weight Relationship and Condition of Penaeid Shrimp

Individual shrimp were measured to the nearest millimeter from the tip of the rostrum to the tip of the telson and weighed to the nearest 0.1 gram, using a Mettler balance.

The analysis of the length-weight data was directed towards two objectives: to describe the regression of length on weight so that one may be converted to the other, and to measure the variation in weight for length of individuals as indications of condition. The term "length-weight relationship" is applied to the first category, and the term "condition" is applied to length-weight analysis of the second category. The length-weight relationship and condition of penaeid shrimp were determined using the methods described by Le Cren (1951). A detailed analysis of the methods is given in the results and discussion of the length-weight data.

SECTION I

ECOLOGICAL ASPECTS OF SELECTED CRUSTACEA: COMPARISON OF CRUSTACEA IN OYSTER AND ALLIGATOR LAKE AND OYSTER AND ALLIGATOR SLOUGHS

Results

Water Temperature: Oyster Lake (Figure 4, page 39; Table 1, page 23)

The surface water temperature dropped from 23°C in October, 1967 to 6°C in early January of 1968. This was the lowest temperature recorded during the study. The temperature rose in late January, 1968 to 22°C then dropped to 12°C in early February. There was a steady rise in temperature from early February to August when the highest temperature, 34°C, was recorded. The temperature remained above 20°C from early March through October, 1968; the average temperature during this period being 27°C. The temperature dropped below 20°C in October, and reached a low of 9°C in late December. There was a steady rise in water temperature from late December, 1968 through August, 1969 with the highest temperature, 31°C, recorded in early July and early August.

Water temperature in Oyster Lake ranged between 6 and 34°C. The mean water temperature, from October, 1967 through August, 1969, was 21.2°C. The mean water temperature for the calendar year 1968 was 21.0°C.

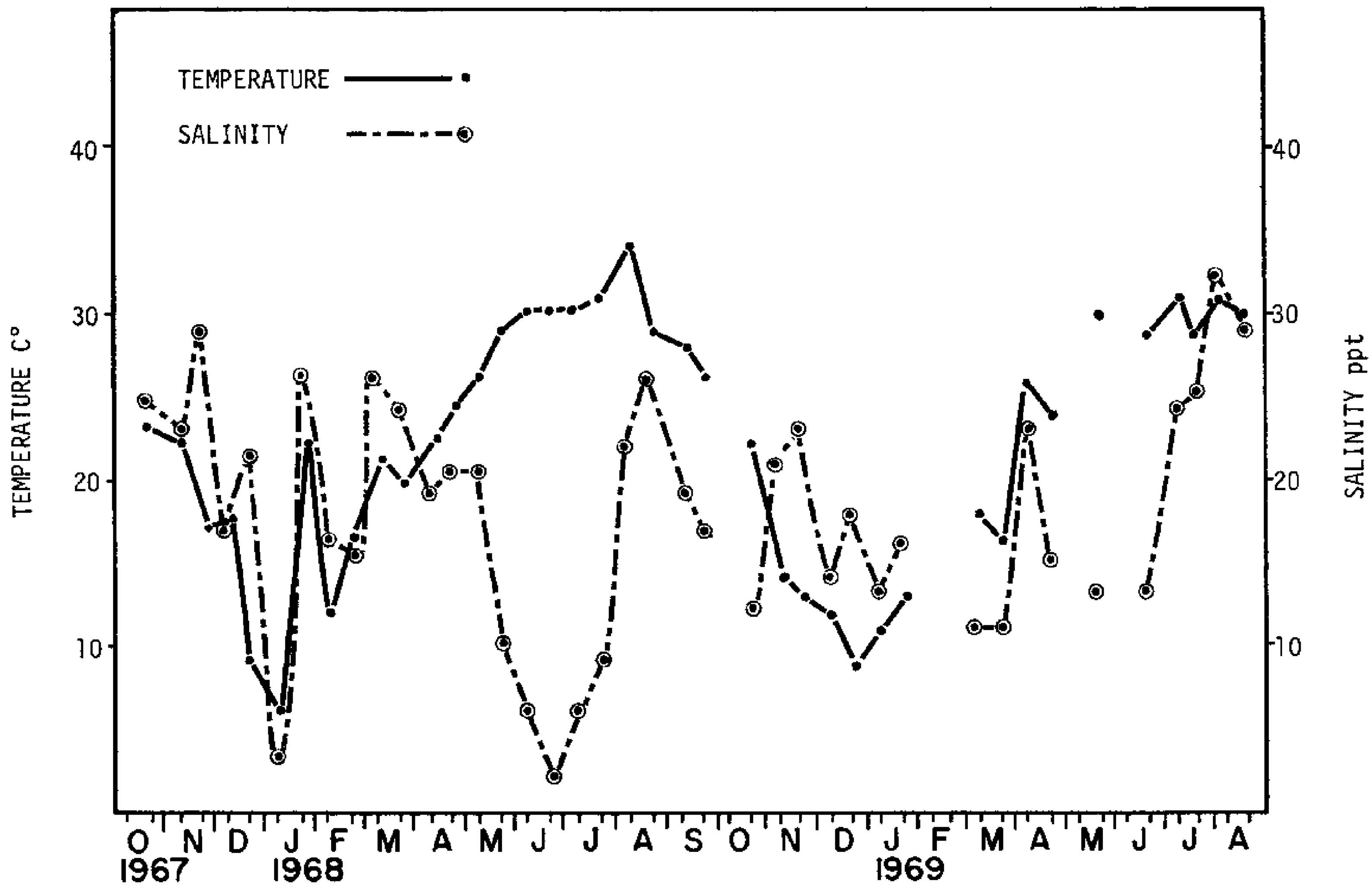

Figure 4. Temperature and salinity values obtained from Oyster Lake during the period from October, 1967 through August, 1969.

Salinity: Oyster Lake (Figure 4, page 39; Table 1, page 23)

The salinity fluctuated from late October to late November, 1967. Due to heavy winter rains, salinity dropped from 28 ppt in late November, 1967 to 3 ppt in early January of 1968. Salinity rose sharply in late January, 1968 to 26 ppt, dropped through February to 16 ppt, then rose to 26 ppt in early March. Salinities declined in May and June of 1968 due to heavy rains. In late June, the salinity reached 2 ppt. This was the lowest level recorded during the study and was due to heavy rains and flooding of the marsh north of the bay. Salinities rose in early July through August, 1968 to 26 ppt, then decreased in early September through October. Erratic fluctuations in salinity were recorded from October, 1968 through May, 1969, then then rose in June and remained high through August, 1969.

The salinity in Oyster Lake ranged between 3 and 29 ppt. The mean salinity from October, 1967 through August, 1969 was 17.9 ppt. The mean salinity for the calendar year 1968 was 15.0 ppt.

Water Temperature: Alligator Lake (Figure 5, page 41; Table 2, page 25)

Surface water temperature in Alligator Lake followed closely the temperature pattern exhibited in Oyster Lake. Temperatures dropped from 24°C, in October, 1967, to 7°C in early January, 1968. This was the lowest temperature recorded in Alligator Lake

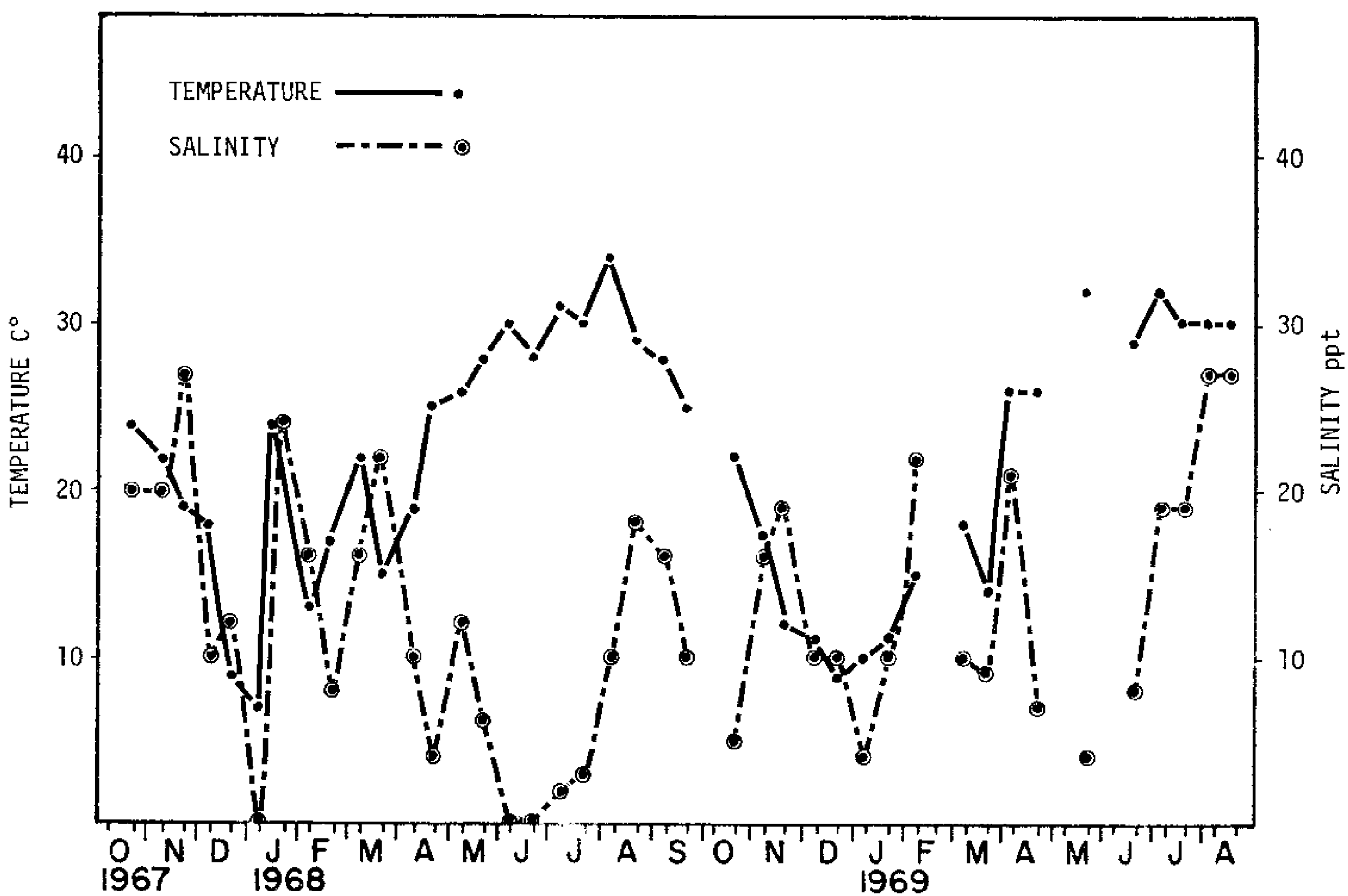

Figure 5. Temperature and salinity values obtained from Alligator Lake during the period from October, 1967 through August, 1969.

during the course of the study. Temperatures rose sharply, to 24°C, in late January, 1968 then dropped to 13°C in early February. There was a steady rise in temperature from late February until early August when the maximum temperature, 34°C, was recorded. The temperature remained above 20°C from April, 1968 through October, 1968; the average temperature during this period was 28°C. There was a steady decline in water temperature from late October until late December when a low of 9°C was reached. Temperatures rose from late December, 1968 through May, 1969 and remained around 30°C through August, 1969.

The water temperature in Alligator Lake ranged between 7 and 34°C. The mean temperature from October, 1967 through August, 1969 was 21.6°C. The mean temperature, for the calendar year 1968, was 21.0°C.

Salinity: Alligator Lake (Figure 5, page 41; Table 2, page 25)

Salinity rose in Alligator Lake from 20 ppt to 26 ppt in late November, 1967, then, due to heavy rains, declined sharply from late November, 1967 to early January, 1968 when the water became virtually fresh due to flooding from the surrounding marsh and the drainage from the rice canal entering the northwest end of the bay. The salinity rose sharply in late January to 24 ppt then declined in late February to 8 ppt. Salinities rose again in March to 22 ppt then dropped again in late April to 4 ppt. The salinity rose in early May then low recordings were observed through June due to heavy rains. During the month of July, the bay was fresh due to heavy flooding from the marsh. In August, 1968 the salinity rose again to 18 ppt then dropped through October. From October, 1968 through April, 1969 the salinity fluctuated with highs in late November, 18 ppt, early February, 22 ppt, and early April, 21 ppt. The high salinity reading in early February resulted from a storm, with onshore winds from the east which blew water from West Bay into the marsh and Alligator Lake. From October, 1968 through April, 1969 low salinities were recorded in January, 4 ppt to 10 ppt, March, 10 ppt, and late April, 7 ppt. From late June to August, 1969 the salinity rose gradually then stabilized at 26 ppt through August.

The salinity in Alligator Lake ranged between 0.0 and 27.0 ppt. The mean salinity, from October, 1967 through August, 1969 was 12.6 ppt. The mean salinity, for the calendar year 1968, was 10.2 ppt.

Water Temperature: Oyster Slough (Figure 6, page 44; Table 3, page 27)

As data were taken only when tides were high enough to permit trawling, it is difficult to establish a continuous pattern of temperature or salinity in Oyster Slough.

In 1967, low temperatures were recorded in Oyster Slough in late November (16°C), and early December (18°C), in 1968, in early November (11°C), and in 1969, in early March (18°C). High

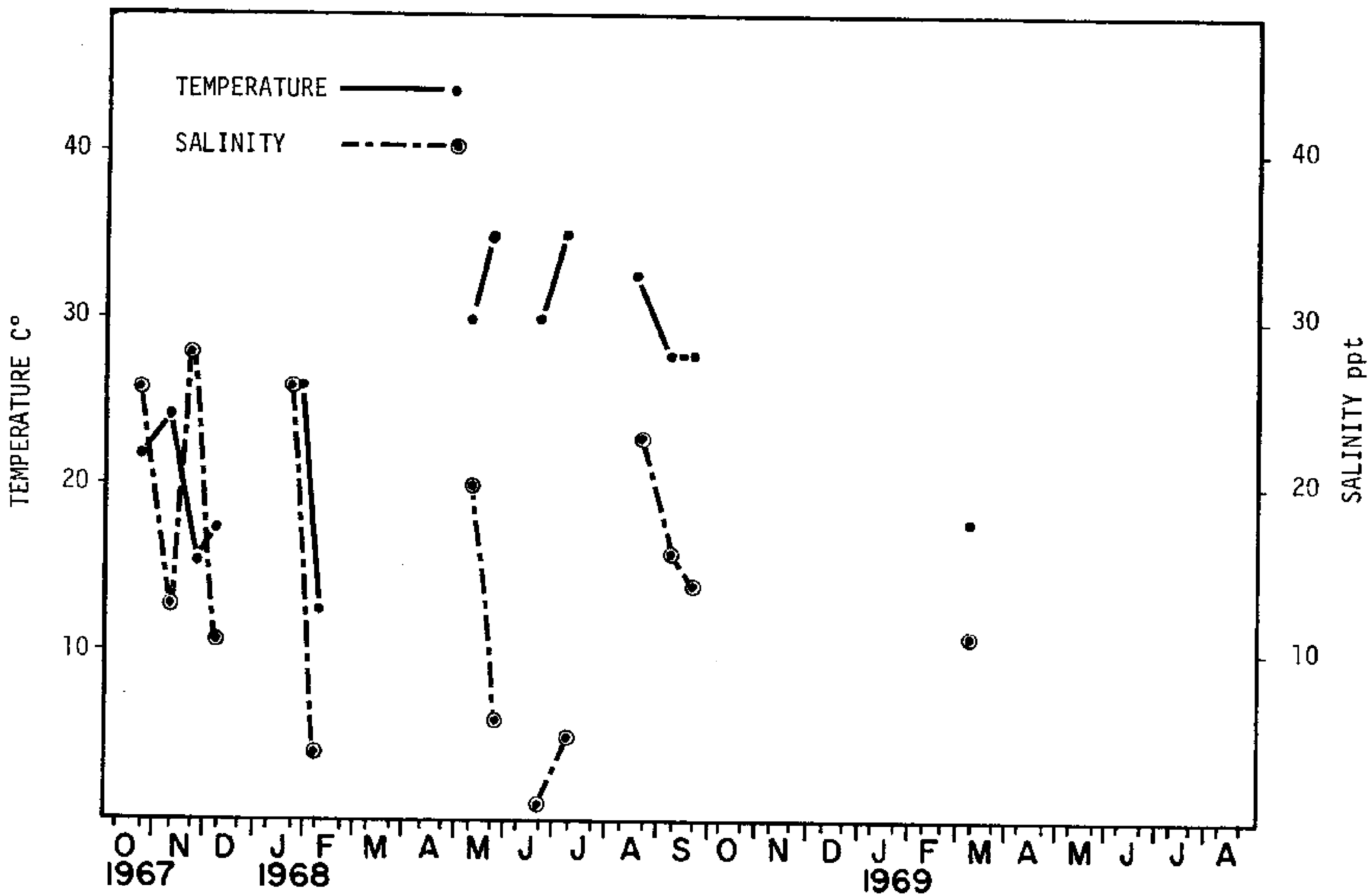

Figure 6. Temperature and salinity values obtained from Oyster Slough during the period from October, 1967 through August, 1969.

temperatures were recorded, in 1968, in early May (29°C), late May (34°C), late June (29°C), early July (34°C), late August (33°C), early September (28°C), and late September (28°C).

The water temperature in Oyster Slough ranged between 11 and 34°C. The mean temperature during the study was 25°C. The mean temperature for the calendar year 1968 was 28°C.

Salinity: Oyster Slough (Figure 6, page 44; Table 3, page 27)

In 1967, low salinities were recorded in early November (13 ppt) and early December (11 ppt). In 1968 low salinities were recorded in early February (4 ppt), late May (6 ppt), early June (5 ppt), and late September (14 ppt). In 1969 a low salinity of 11 ppt was recorded. High salinities were recorded, in 1967, in late October (26 ppt) and late November (28 ppt), in 1968, late January (26 ppt), and late August (23 ppt).

The salinity of Oyster Slough ranged between 1 and 28 ppt. The mean salinity during the study was 14.5 ppt. The mean salinity for the calendar year, 1968, was 12.6 ppt.

Water Temperature: Alligator Slough (Figure 7, page 46; Table 4, page 28)

The surface water temperature remained stable, at 23°C, from late October through early November, 1967, then gradually declined to 9°C in late December. In late January, 1968, the temperature was 25°C, but dropped sharply to 12°C by early February. In early March the temperature was 24°C, remained at 25°C in late

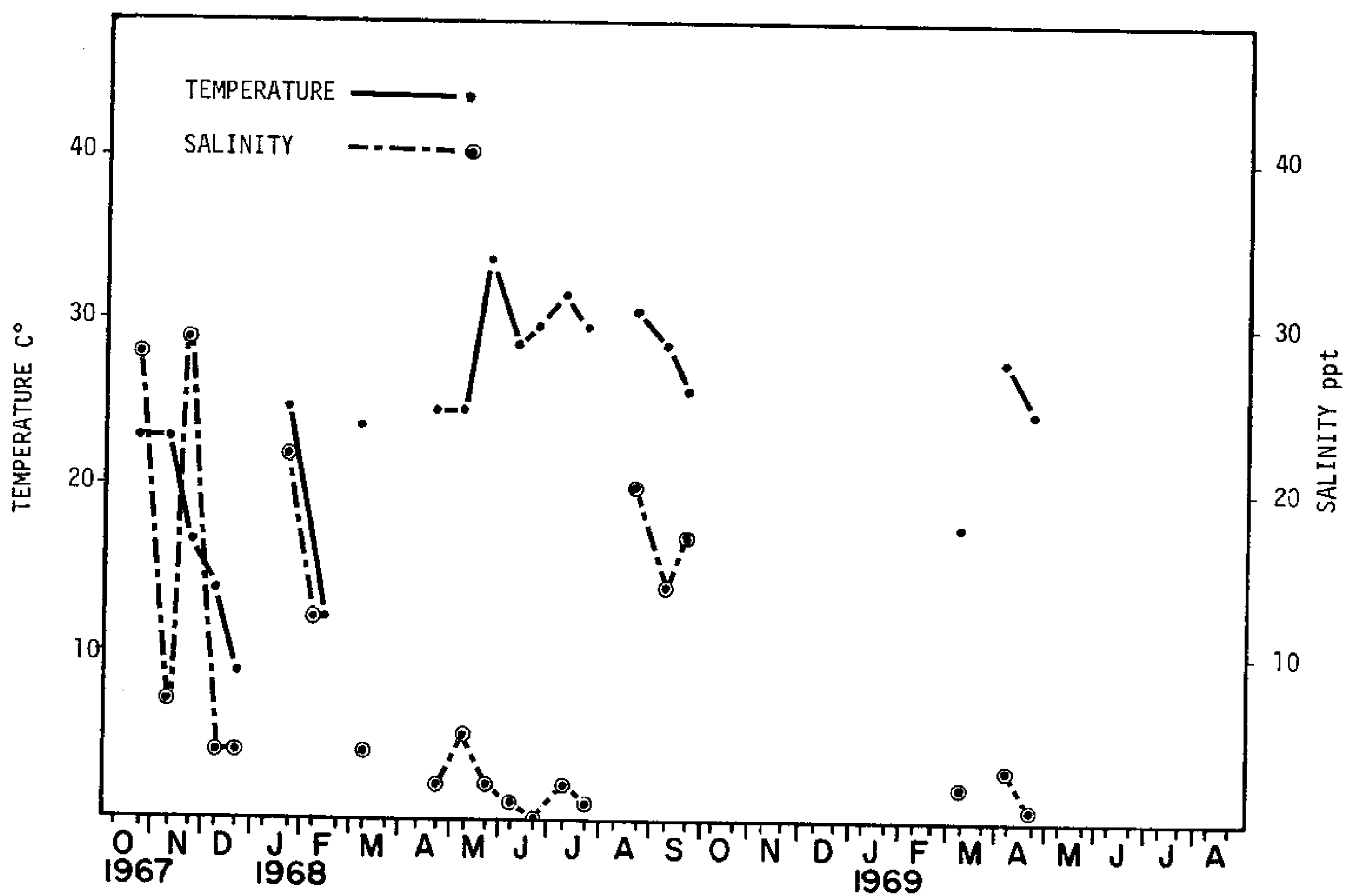

Figure 7. Temperature and salinity values obtained from Alligator Slough during the period from October, 1967 through August, 1969.

April through early May, then rose to 34°C by late May. The temperature fluctuated between 26°C and 32°C from early June through late September, 1968. The lowest temperature of 1969, 18°C, was recorded in early March. Temperatures of 28°C and 25°C were recorded in early and late April.

The water temperature of Alligator Slough ranged between 9 and 34°C. The mean water temperature during the study was 24.2°C. The mean water temperature for the calendar year, 1968, was 26.1°C.

Salinity: Alligator Slough (Figure 7, page 46; Table 4, page 28)

In 1967 the salinity dropped from 26 ppt, in late October, to 7 ppt, in early November. In late November, the salinity rose sharply to 29 ppt then dropped sharply in early December to 4 ppt where it remained stable through the month. In late January, 1968, the salinity was 22 ppt, but dropped to 12 ppt by early February. In early March, the salinity was 4 ppt. From late April through late July, the salinity fluctuated between 0.0 ppt and 5.0 ppt with a high record in early May and a low recorded in late June. In late August, the salinity was 22 ppt. It then dropped to 14 ppt in early September, and by late September rose to 17 ppt. In 1969 recorded salinities remained low, 4 ppt in early March, 5 ppt in early April, and 1 ppt in late April.

The salinity of Alligator Slough ranged between 0.0 and 29.0 ppt. The mean salinity during the study was 8.7 ppt.

The mean salinity for the calendar year, 1968, was 7.8 ppt.

In both the lake and bayou systems water temperature, on several occasions, was recorded as high as 34°C (Table 1, page 23; Table 2, page 25; Table 3, page 27; and Table 4, page 28). Gunter (1957) states that the thermal death point for poikilothermic marine animals is usually from 30 to 35°C, although for most shore animals the lethal temperature may be as high as 42 to 45°C. Zein-Eldin and Aldrich (1965) show an excellent survival of postlarval Penaeus aztecus at 32°C for 24 hours, and suggest a broad zone of short-term tolerance to temperature. Survival declined at 35°C, and they suggest a limiting (maximum) temperature only slightly above 35°C. Optimum nor lethal temperatures are fixed points, even for a given individual, and many animals can be acclimatized to temperatures beyond their usual tolerance by intermittent or continuous exposure to sublethal extremes. Acclimatization to high temperatures can last for some time after the return of the organism to lower temperatures (Gunter, 1957).

<u>Palaemonetes vulgaris: Oyster Lake</u>

The grass shrimp, <u>Palaemonetes vulgaris</u> (Figure 8, page 49). was first observed in trawl samples from Oyster Lake in early November, 1967 and appeared in samples through January, 1968. During this period, small peaks in sampled abundance appeared in early November, early December, 1967 and in late January, 1968.

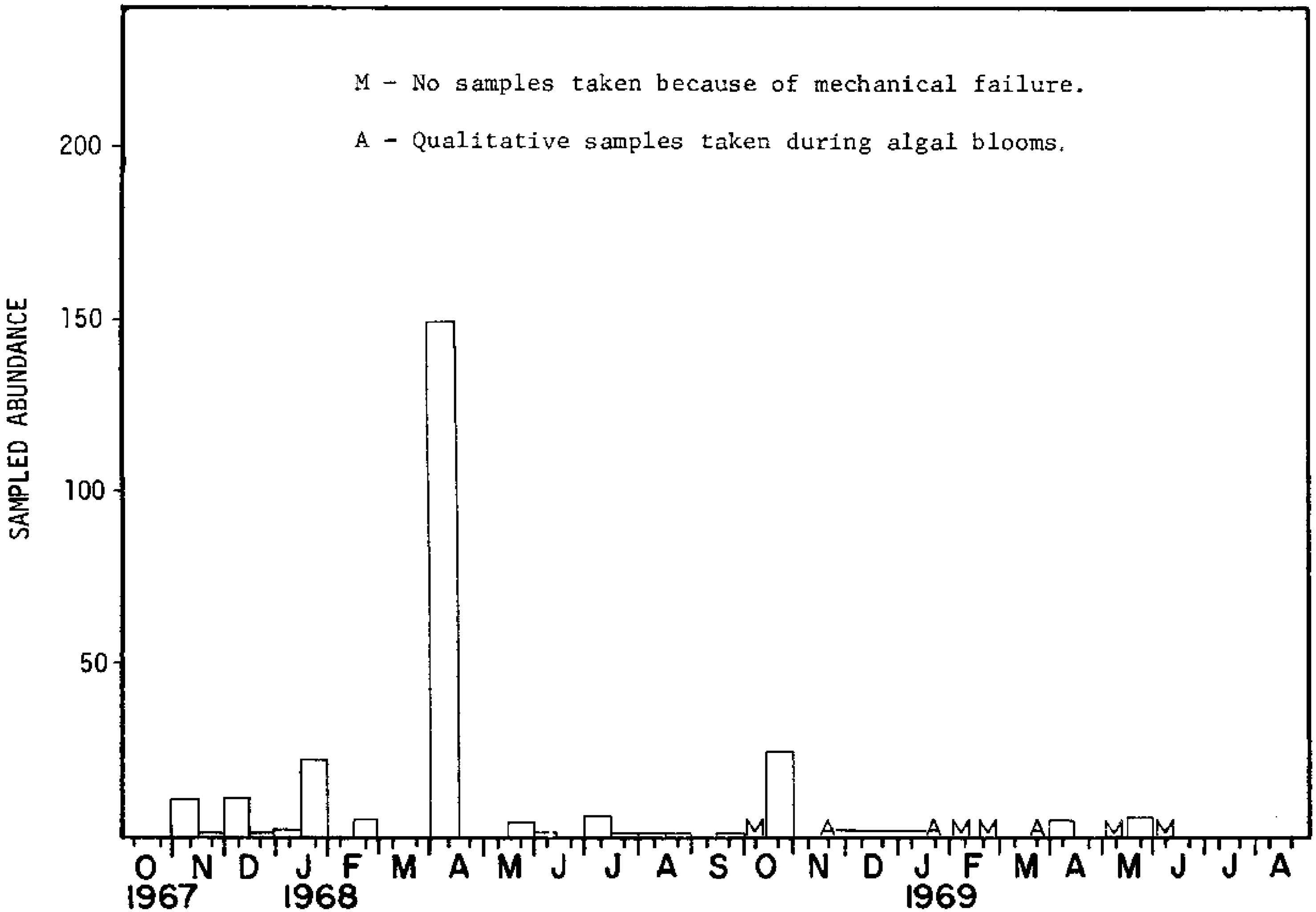

Figure 8. Abundance of Palaemonetes vulgaris obtained from trawl samples taken in Oyster Lake during the period from October, 1967 through August, 1969.

A few specimens were taken from trawl samples in late February and none were collected through the month of March, 1968. In early April, 1968 the number of P. vulgaris taken from trawl samples rose sharply, representing the largest number of specimens taken from Oyster Lake during the study. At this time, the greater number of P. vulgaris observed in trawl samples, as compared to the liner samples, was not due to the size difference of the shrimp but due to the large number of fish that clogged the trawl and prevented many specimens of P. vulgaris from entering the liner sample. From late March through early October, the abundance of P. vulgaris was again low although a small peak of abundance was observed in late October, 1968. P. vulgaris was present in qualitative samples taken during algal blooms from late November, 1968 through late January, 1969. From early February, 1969 through August, 1969, low numbers of P. vulgaris were collected in early March and late May.

In liner samples from Oyster Lake, P. vulgaris (Figure 9, page 51) appeared in late October, 1967 and was present through late January, 1968, with small peaks in sampled abundance appearing in early November and early December, 1967, and late January, 1968. P. vulgaris was observed in appreciable numbers in late February and early March, 1968; however, no specimens were collected in late March. The abundance of P. vulgaris rose sharply in early April representing the largest number of this species observed in liner samples from Oyster Lake. No specimens

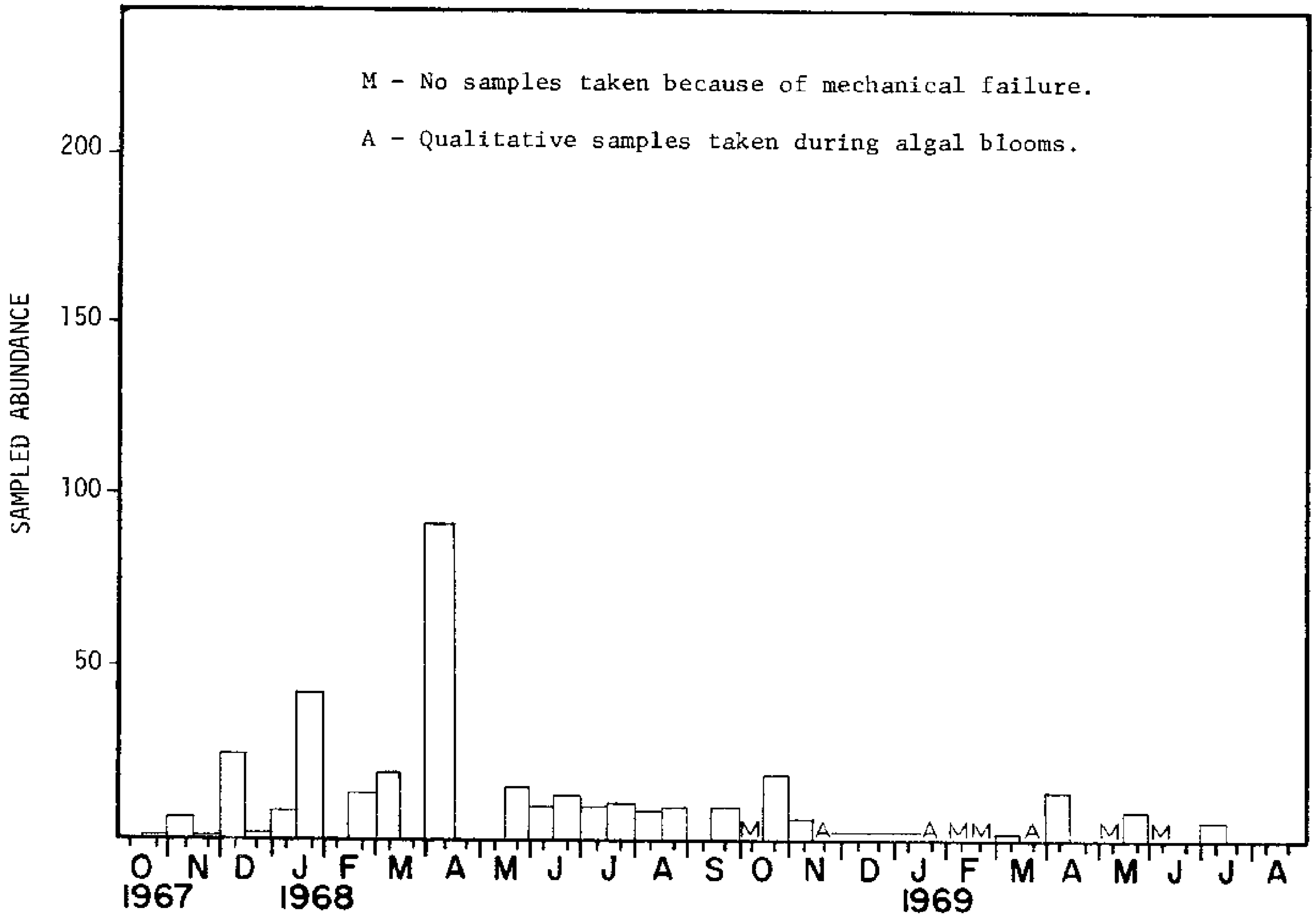

Figure 9. Abundance of <u>Palaemonetes vulgaris</u> obtained from liner samples taken in Oyster Lake during the period from October, 1967 through August, 1969.

of P. vulgaris were collected from late April through early March, 1968. Substantial numbers of this species were taken from late May through late August; however, no P. vulgaris were observed in liner samples taken in early September, 1968. The abundance of P. vulgaris rose again in late September, attaining a small peak in late October; then declined by early November, 1968. The numbers of P. vulgaris increased from early March to a small peak in early April, 1969, however, no P. vulgaris were found in late April. From late April through August, 1969, P. vulgaris were observed in late May and early July.

P. vulgaris: Alligator Lake

Compared with Oyster Lake, a few specimens of P. vulgaris were observed in trawl and liner samples taken from Alligator Lake. P. vulgaris was observed in trawl samples in late December, 1967; early January, and early March, 1968; and in early March, 1969 (Figure 10, page 53). In liner samples, taken from Alligator Lake, P. vulgaris was observed in late November, 1967; late July, 1968; early March; late April, and late June, 1969 (Figure 11, page 54).

Palaemonetes pugio: Oyster Lake

Few specimens of Palaemonetes pugio were observed in trawl samples taken from Oyster Lake (Figure 12, page 55). P. pugio was present from late December, 1967 through late January, 1968; late July, 1968 and early April, 1969. P. pugio appeared in late

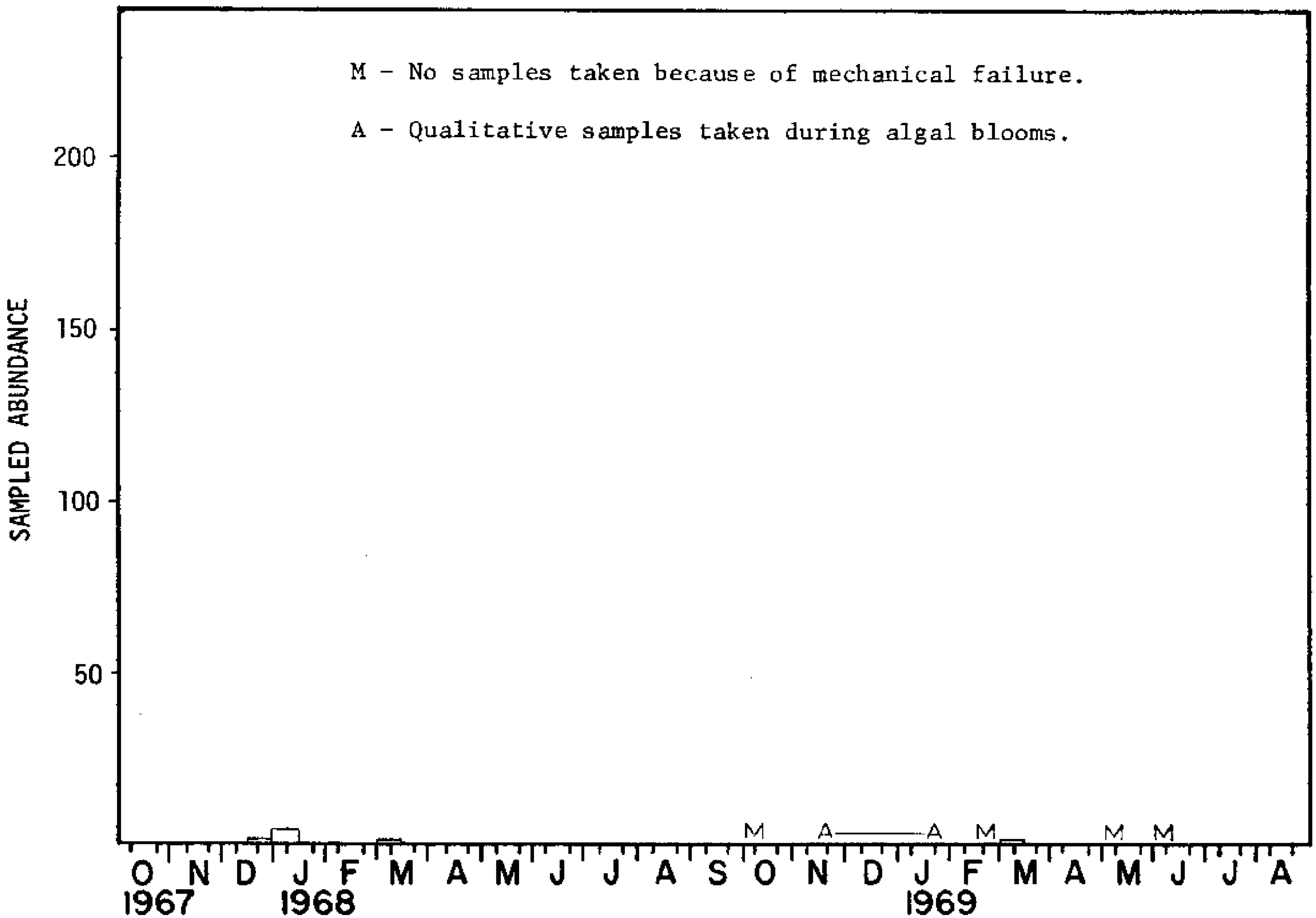

Figure 10. Abundance of <u>Palaemonetes vulgaris</u> obtained from trawl samples taken in Alligator Lake during the period from October, 1967 through August, 1969.

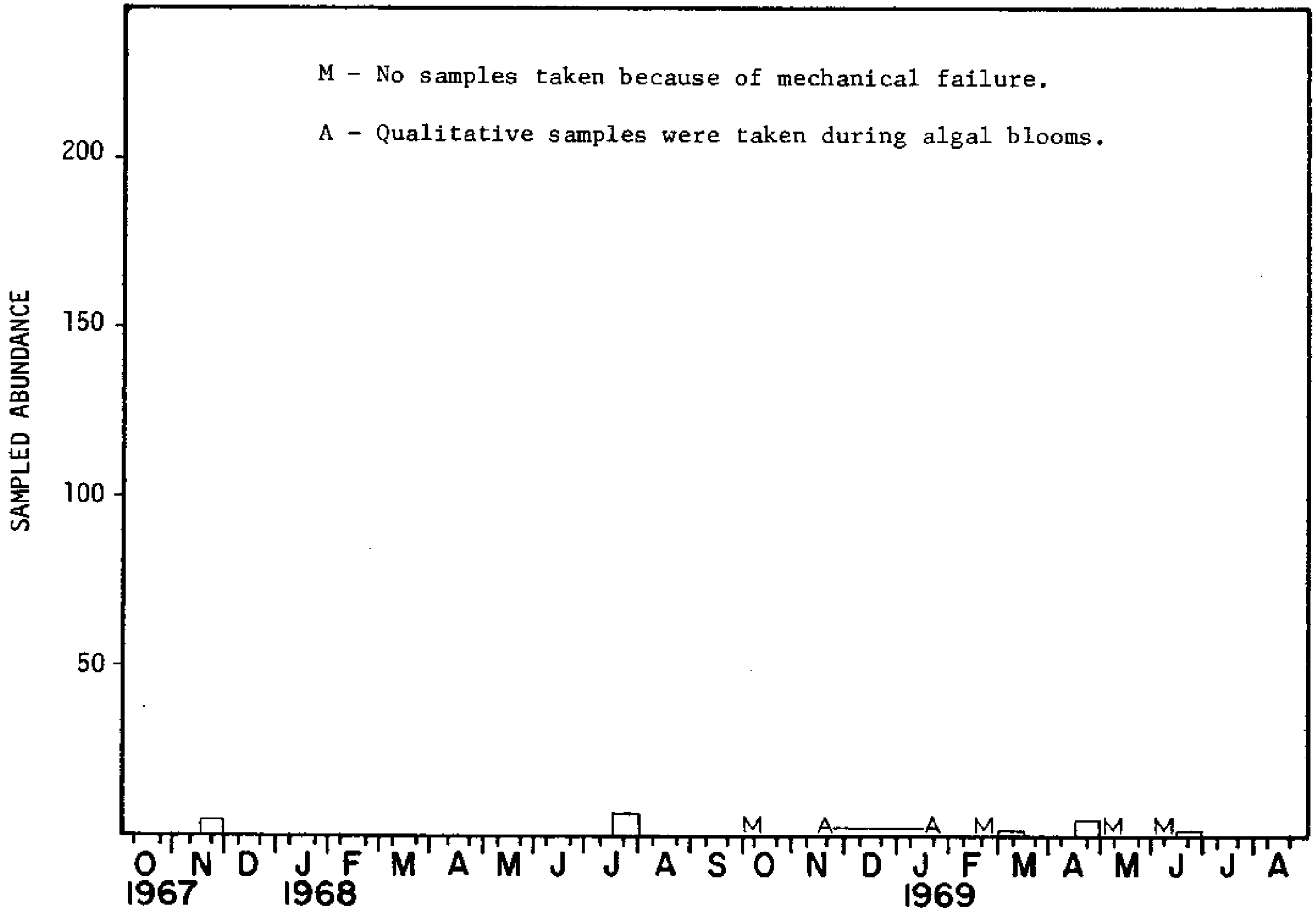

Figure 11. Abundance of Palaemonetes vulgaris obtained from liner samples taken in Alligator Lake during the period from October, 1967 through August, 1969.

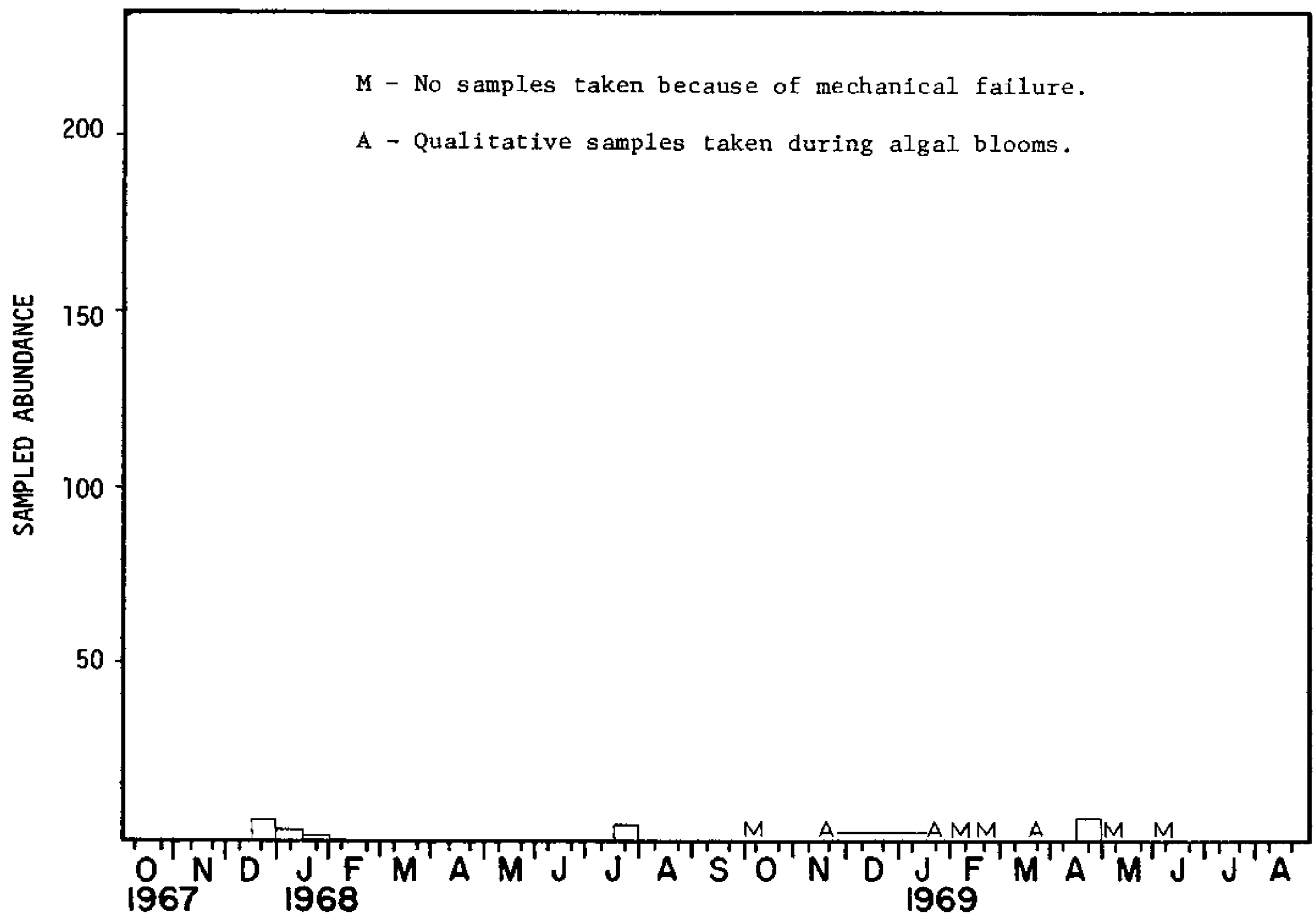

Figure 12. Abundance of Palaemonetes pugio obtained from trawl samples taken in Oyster Lake during the period from October, 1967 through August, 1969.

December, 1968 and early January, 1969 in qualitative samples taken during algal blooms.

P. pugio was first observed in liner samples from Oyster Lake (Figure 13, page 57) in early December, 1967, and continued to be collected through late January, 1968, with a small peak in abundance appearing in early January, 1968. Other scattered observations of *P. pugio* appeared in late February, early April, late May through late June, late August, late September and early November, 1968. In 1969, *P. pugio* was observed in early March, late April, late May, and late July.

P. pugio: Alligator Lake

P. pugio was first observed in trawl samples (Figure 14, page 58) from Alligator Lake, in early December, 1967. The abundance of *P. pugio* rose to a small peak in late December, 1967, however, no *P. pugio* was collected in early January, 1968. This species appeared again in low numbers in late January through early April, rose sharply to a peak in late April, and declined gradually through early June, 1968. Again, the greater number of *P. pugio* taken by trawl as opposed to the number of specimens taken by liner was not due to a size difference in the shrimp but the clogging effect of fish in the trawl bag. *P. pugio* appeared in early January and was present in quantitative samples taken during algal blooms from late November, 1968 through late January, 1969. The abundance of *P. pugio* increased gradually from early February

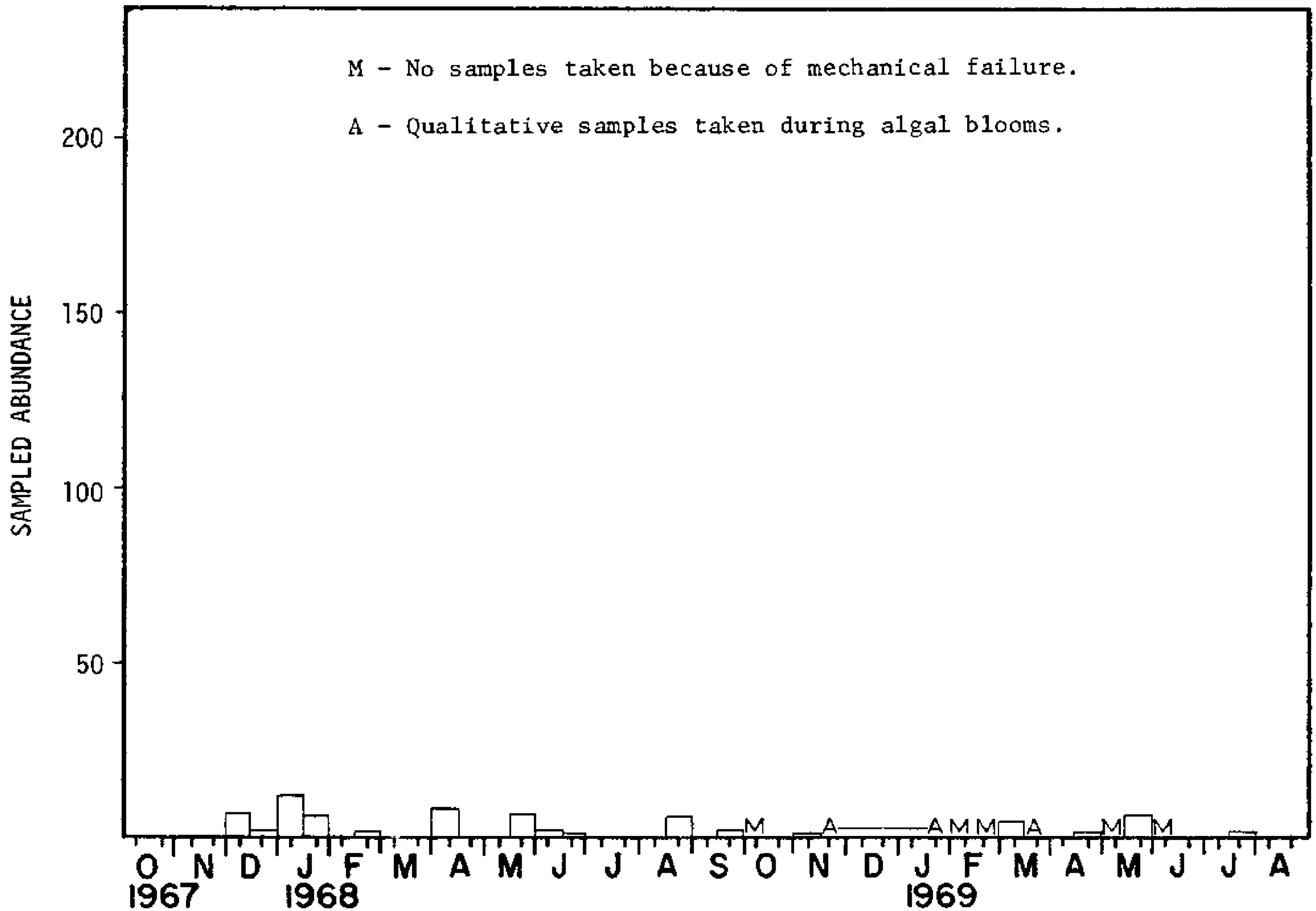

Figure 13. Abundance of Palaemonetes pugio obtained from liner samples taken in Oyster Lake during the period from October, 1967 through August, 1969.

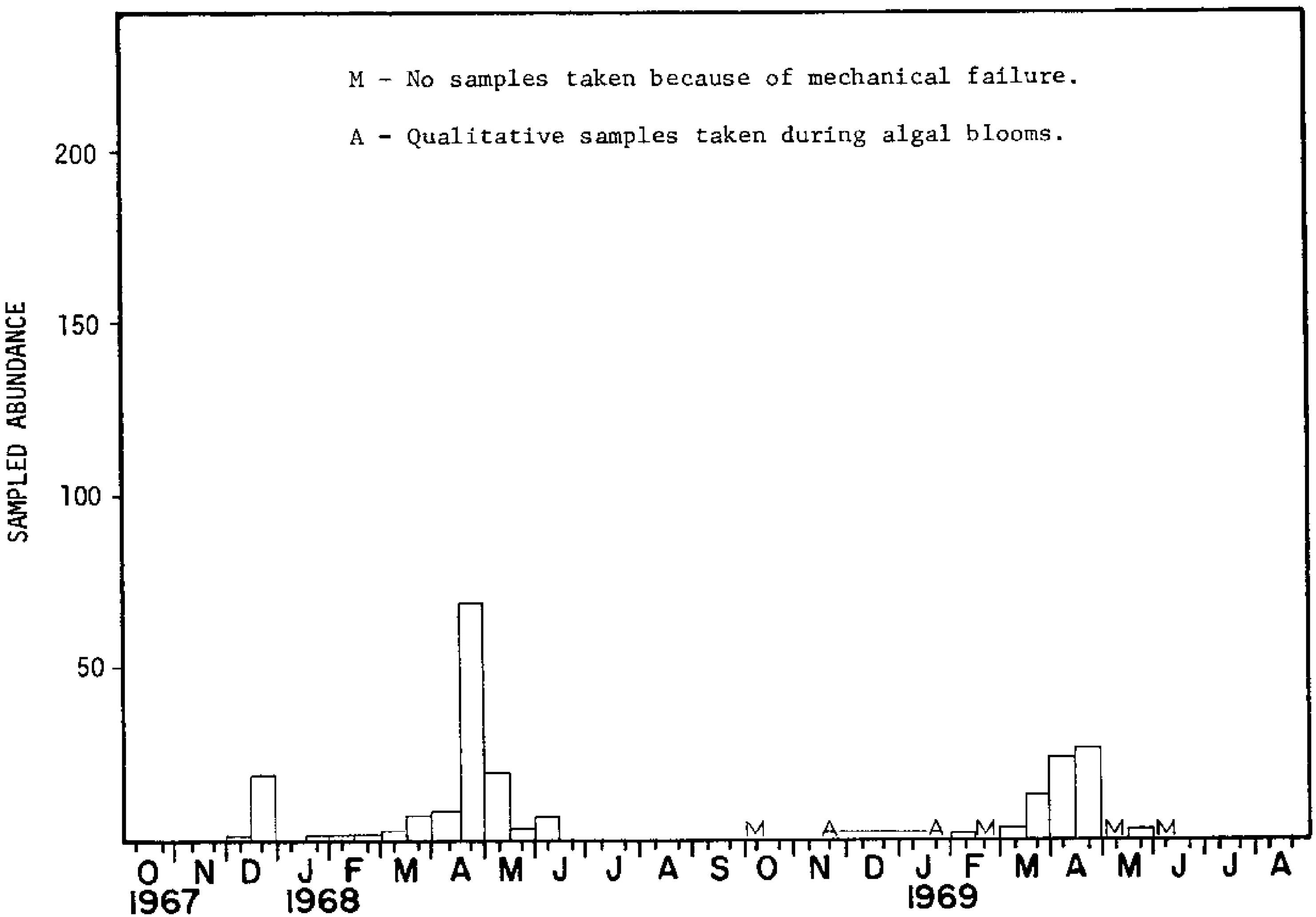

Figure 14. Abundance of Palaemonetes pugio obtained from trawl samples taken in Alligator Lake during the period from October, 1967 through August, 1969.

through late April, 1969, with peaks appearing in the month of April. From early May through August, 1969, *P. pugio* appeared once in liner samples taken in late May.

P. pugio appeared in liner samples from Alligator Lake (Figure 15, page 60) from early December, 1967 through early May, 1968; peaks appeared in early January, 1967 and late April, 1968. A few specimens of *P. pugio* were collected in late June and early November, 1968. *P. pugio* was present in samples taken from early February through late June, 1969. During this period, the abundance of this species gradually rose from early February to a peak in late April and gradually declined through late June.

Periclimenes longicaudatus

One specimen of the shrimp, *Periclimenes longicaudatus* was collected in a liner sample, from Oyster Lake, in late November, 1967.

Tozeuma carolinense

Two specimens of the shrimp *Tozeuma carolinense* were collected from a liner sample, from Oyster Lake, in late November, 1967.

Acetes americanus: Oyster Lake

The sergestid shrimp, *Acetes americanus*, was first collected from Oyster Lake in liner samples in early June, 1968 (Figure 16, page 61). This species was collected in large numbers from late July through late October, the largest collection, 2,263 specimens,

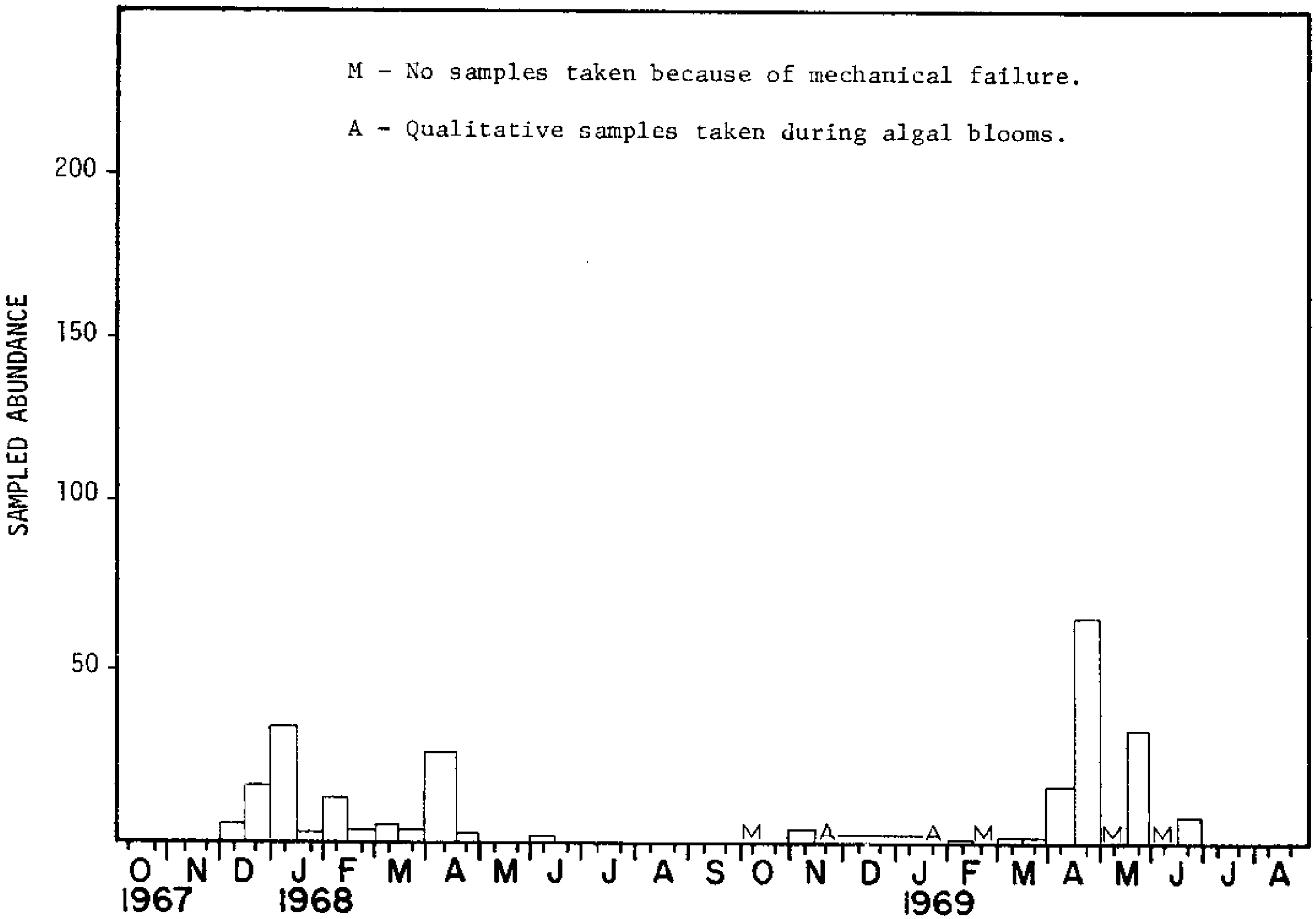

Figure 15. Abundance of <u>Palaemonetes pugio</u> obtained from liner samples taken in Alligator Lake during the period from October, 1967 through August, 1969.

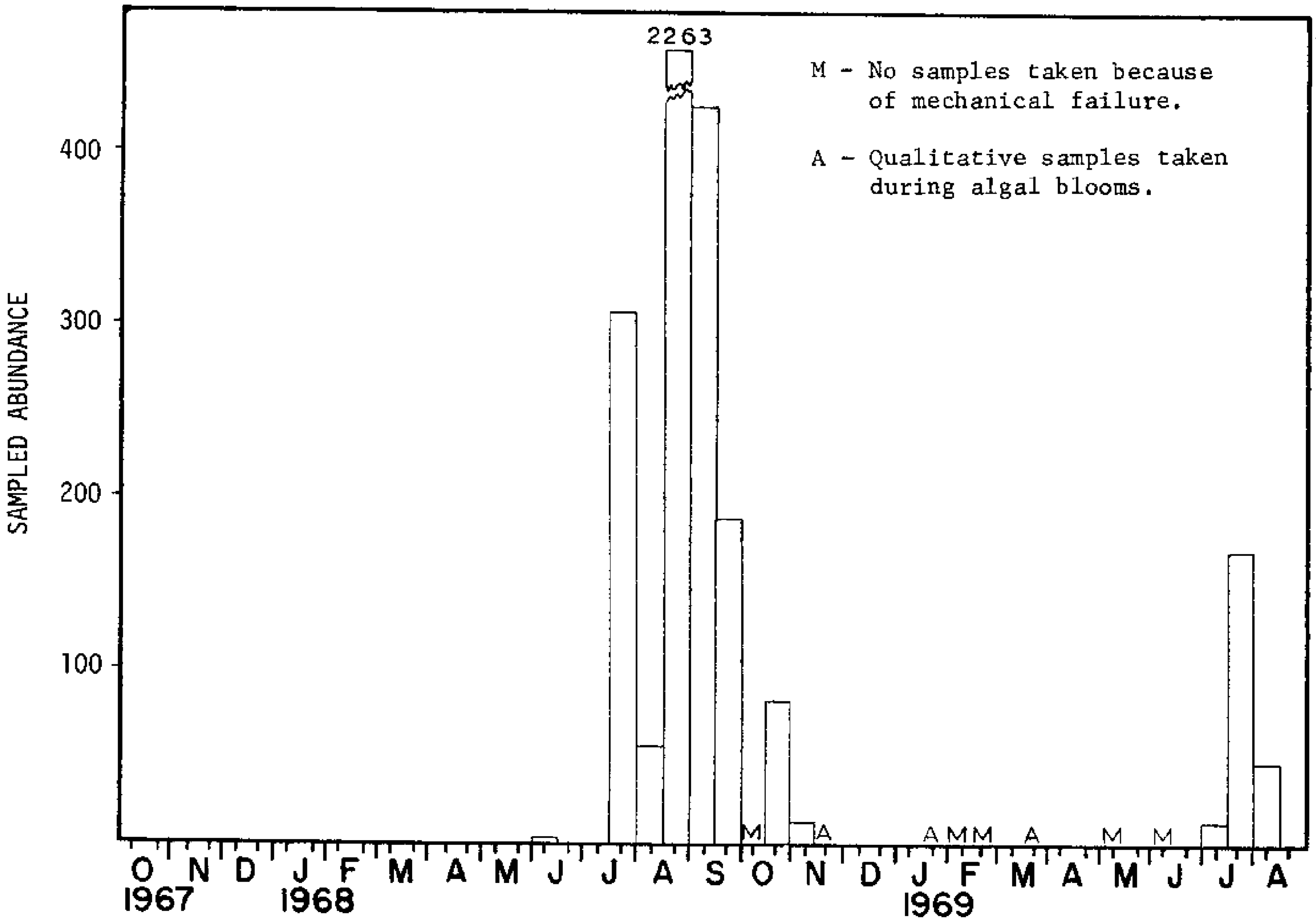

Figure 16. Abundance of Acetes americanus obtained from liner samples taken in Oyster Lake during the period from October, 1967 through August, 1969.

was taken in late August, 1968. No specimens of A. americanus were found in qualitative samples taken during algal blooms from late November, 1968 through late January, 1969. A. americanus appeared in collections taken in early July through early August, 1969. The largest collection of 1969 was made in late July, but it appeared in numbers far below the peak collection taken in the previous year.

A. americanus: Alligator Lake

A. americanus were first observed from Alligator Lake in liner samples, taken in late November and early December, 1967 (Figure 17, page 63). A few specimens were taken in early June and late July, 1968. Large collections of this species were taken in early August through early September, 1968; the peak abundance occurred in late August. The only other 1968 appearances of this species were in late September, late October, and late November; only one specimen was taken in each month. No specimens of A. americanus were found in qualitative samples taken during the algal bloom period from late November, 1968 through late January, 1969. A. americanus was collected in low numbers in early February, 1969; it was not found again until a few specimens were taken in late June through late July, 1969.

Mysidopsis almyra: Oyster Lake

Mysidopsis almyra was present in liner sample collections from Oyster Lake (Figure 18, page 64) in all seasons throughout

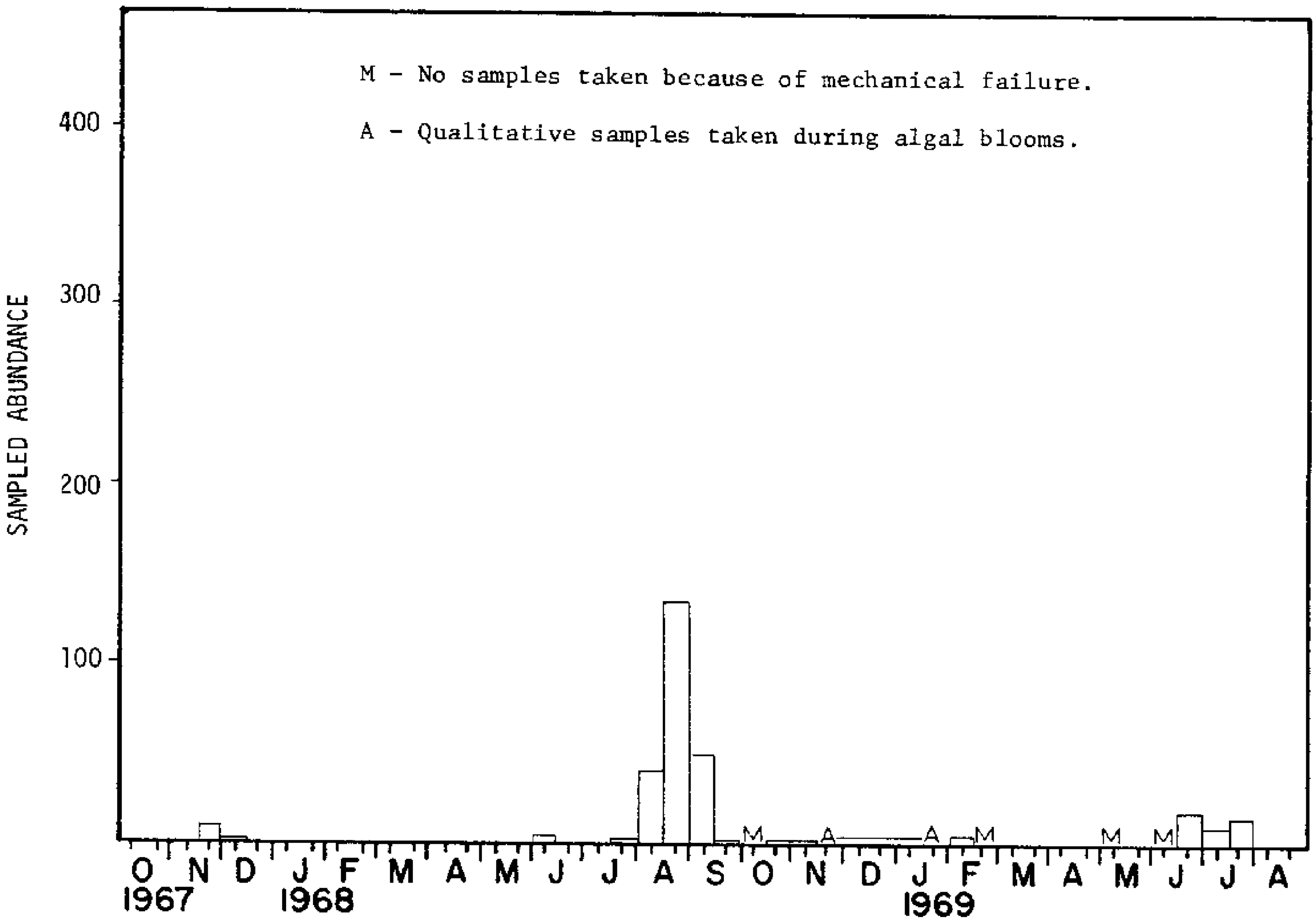

Figure 17. Abundance of <u>Acetes americanus</u> obtained from liner samples taken in Alligator Lake during the period from October, 1967 through August, 1969.

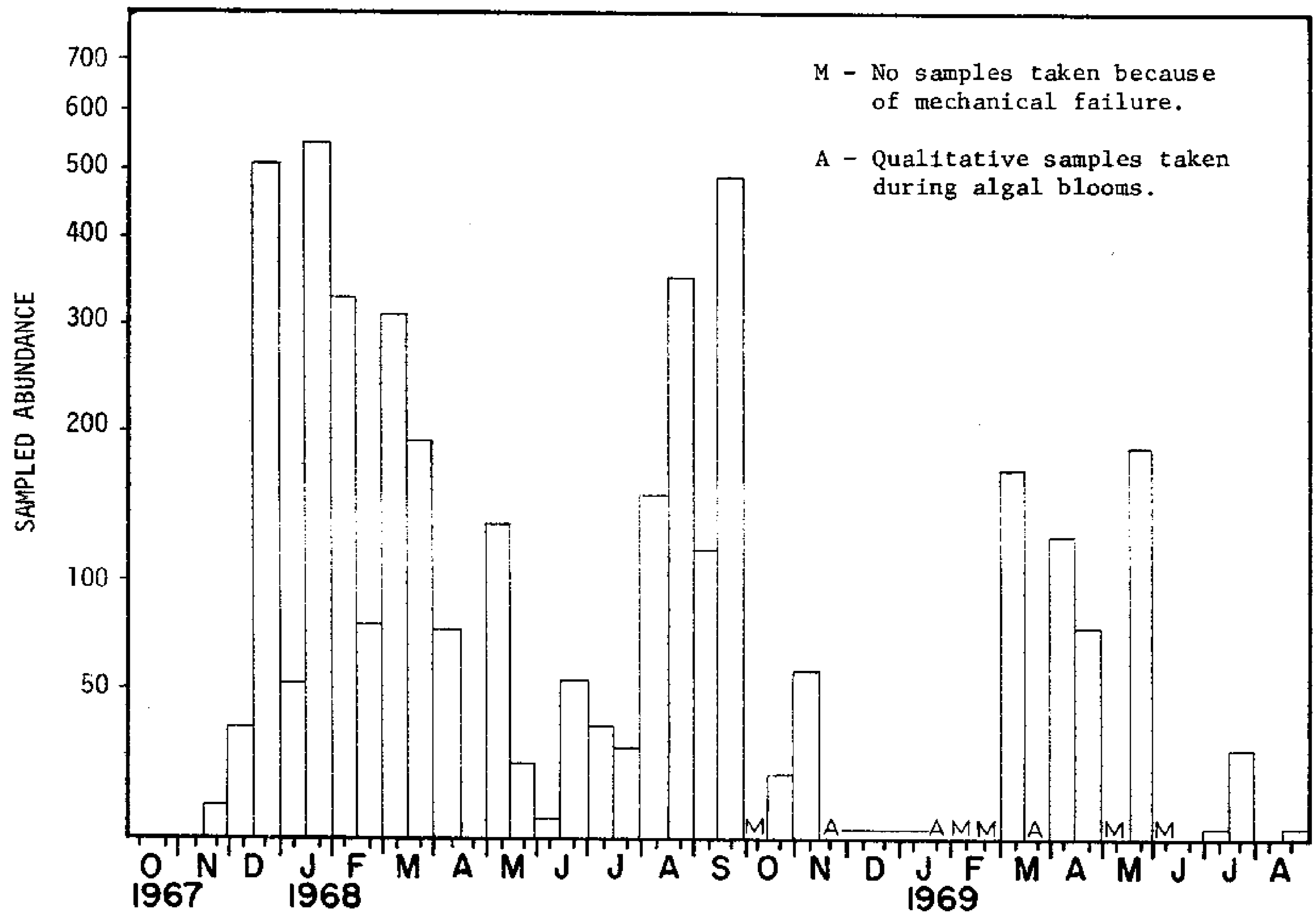

Figure 18. Abundance of <u>Mysidopsis almyra</u> obtained from liner samples taken in Oyster Lake during the period from October, 1967 through August, 1969.

the study. This species was abundant from early December, 1967 until early May, 1968. During this period, peak abundances of the species were observed in late December, 1967, late January, early February, and early May, 1968. The population declined from late May through late July, then rose sharply from early August through late September, 1968. During this period, large populations were observed in late August and late September. Fewer specimens of M. almyra were taken in October and November. From late November, 1968 through late January, 1969, during algal blooms in the bay systems, M. almyra was found in qualitative samples. This species was observed, in relatively large numbers, from early March through late May, 1969. M. almyra was observed again in July and late August, 1969.

Mysidopsis almyra: Alligator Lake

In Alligator Lake, M. almyra (Figure 19, page 66) was similarly found in liner samples in all seasons throughout the study. The species was first observed in late October, 1967. The abundance rose sharply in late November, 1967, and it was found in large numbers through late May, 1968. During this period, massive numbers were collected in early February, late March, and early May. The population began to decline through June, but a second, smaller peak was observed from early July through early September, 1968. Small numbers of M. almyra were observed in late September and late October, 1968. The

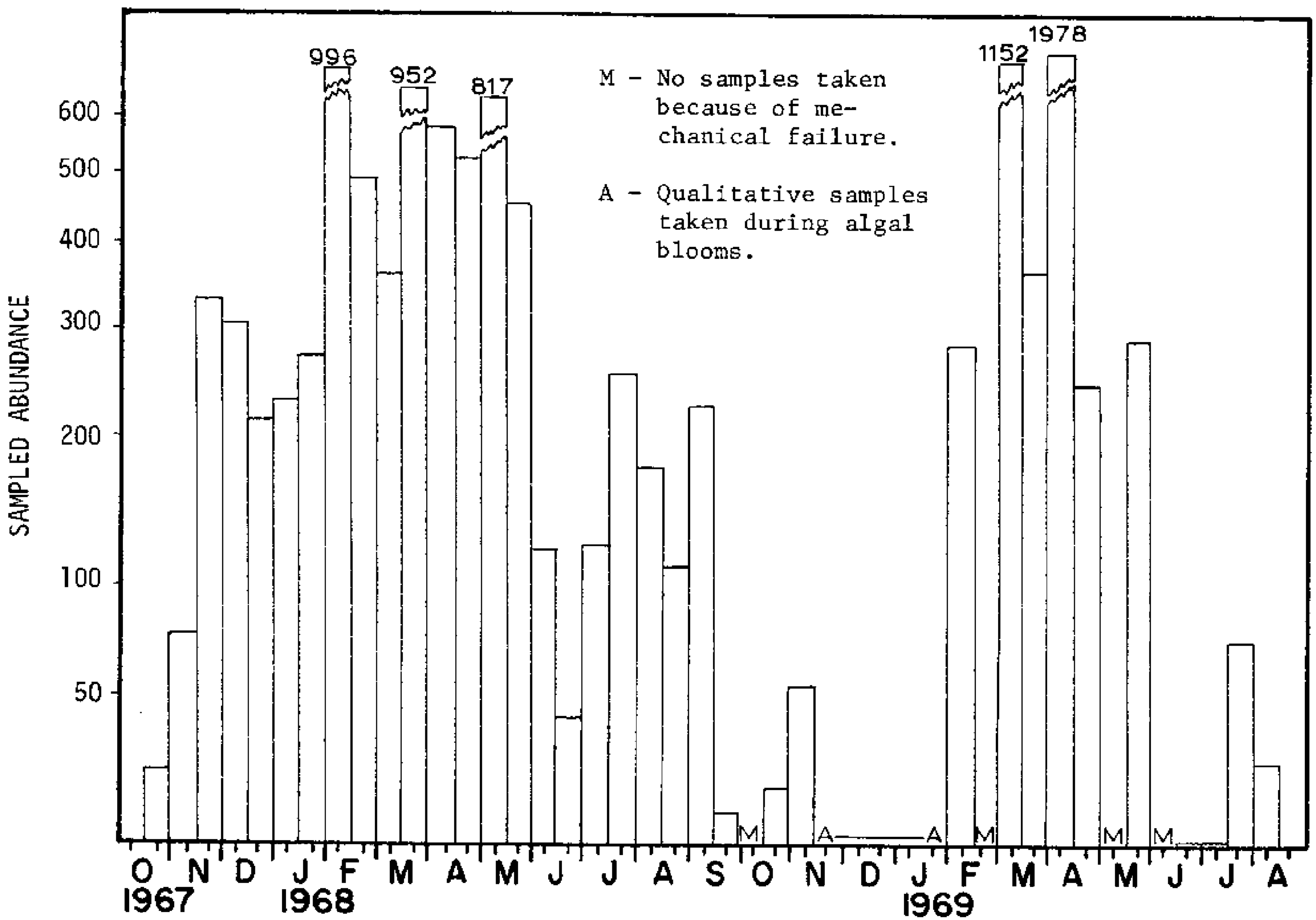

Figure 19. Abundance of Mysidopsis almyra obtained from liner samples taken in Alligator Lake during the period from October, 1967 through August, 1969.

population began to rise in early November, and was found in qualitative samples taken during algal blooms from late November, 1968 through late January, 1969. The population rose sharply in early February through late May, 1969. During this period, massive numbers of this species were observed in early March and early April. The number of specimens far exceeded the peaks observed in 1968. The abundance dropped sharply in late June through early July, 1969, rose slightly in late July and declined in early August. No specimens of M. almyra were observed in late August, 1969.

Mysidopsis bahia: Oyster Lake

M. bahia was first observed in liner samples, from Oyster Lake (Figure 20, page 68), in late November, 1967. The population rose gradually to a small peak in late December, 1967 then declined through January, 1968. A few specimens of M. bahia were observed in late February, increased by early March then decreased by late March, 1968. The largest number of this species were taken in early April. A few specimens were taken in late May, late June, late July, and early November, 1968, however, none were observed in qualitative collections taken during algal blooms from late November, 1968 through late January, 1969. M. bahia was observed in early March, and from qualitative samples taken in late March, 1969. The abundance increased slightly in early

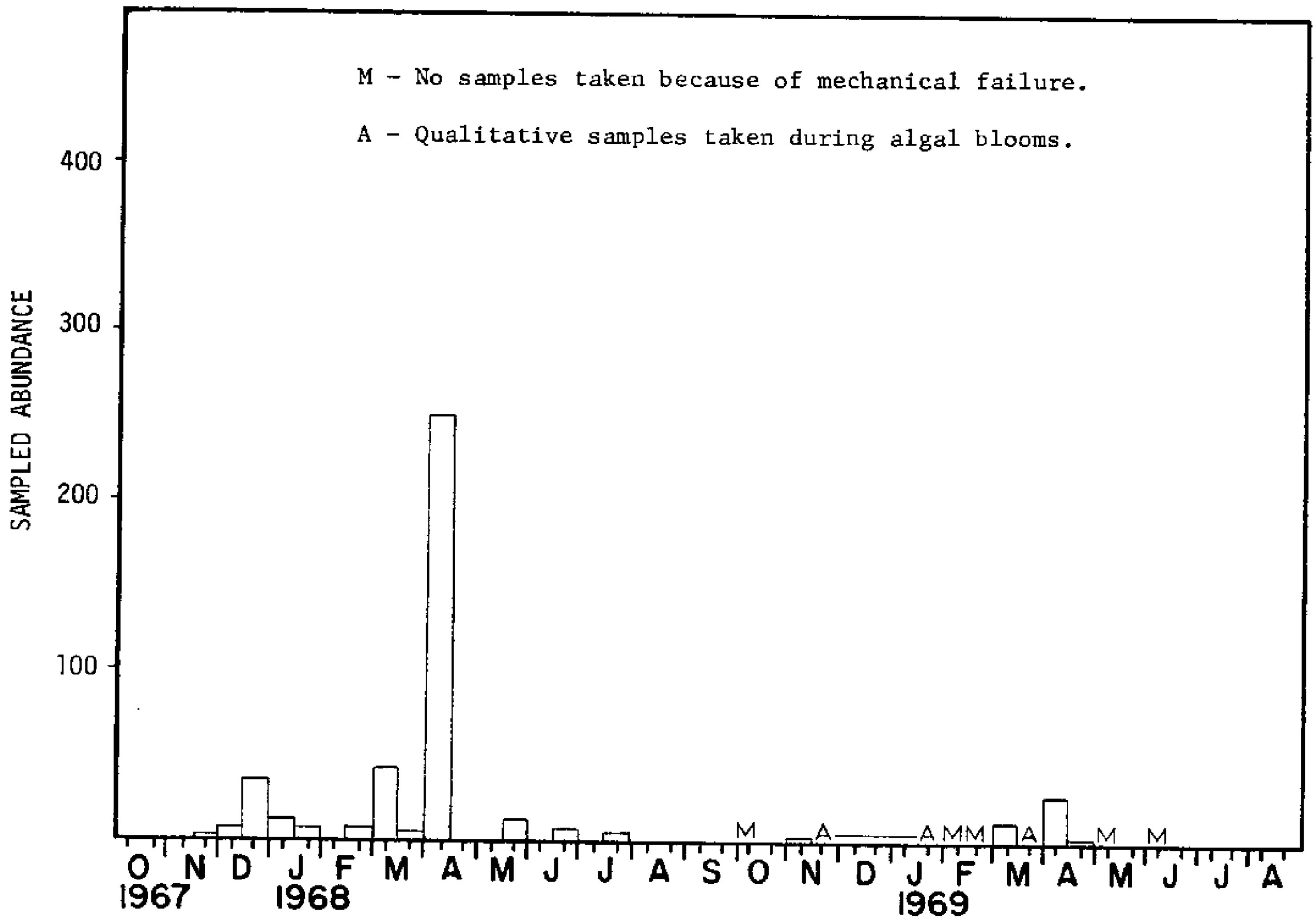

Figure 20. Abundance of Mysidopsis bahia obtained from liner samples taken in Oyster Lake during the period from October, 1967 through August, 1969.

April, but declined by the end of the month. No other specimens were observed in the samples from April through August, 1969.

M. bahia: Alligator Lake

M. bahia were observed in liner samples from Alligator Lake (Figure 21, page 70) through January and early February, 1968. The largest collection of this species, from Alligator Lake, was made in early January, 1968. A few specimens of *M. bahia* were taken in early April, late July, 1968, and early February, 1969. No specimens were found in qualitative samples taken during algal blooms from late November, 1968 through late January, 1969.

Taphromysis louisiana

T. louisiana was first observed in liner samples, from Oyster Lake, in early December, 1967 (Figure 22, page 71). A few specimens were also collected in late January, early February, 1967, late July, 1968, and in early March, 1969. No specimens were observed in qualitative samples taken during the algal blooms in the bay.

T. louisiana was first collected from Alligator Lake in early November, 1967 (Figure 23, page 72), and was collected through December, 1967, and early January, 1968. *T. louisiana* peaked in sampled abundance in early February, 1968, however, it declined in abundance by the end of the month. A second smaller peak in abundance was observed in late March. Several specimens were taken in late July, 1968.

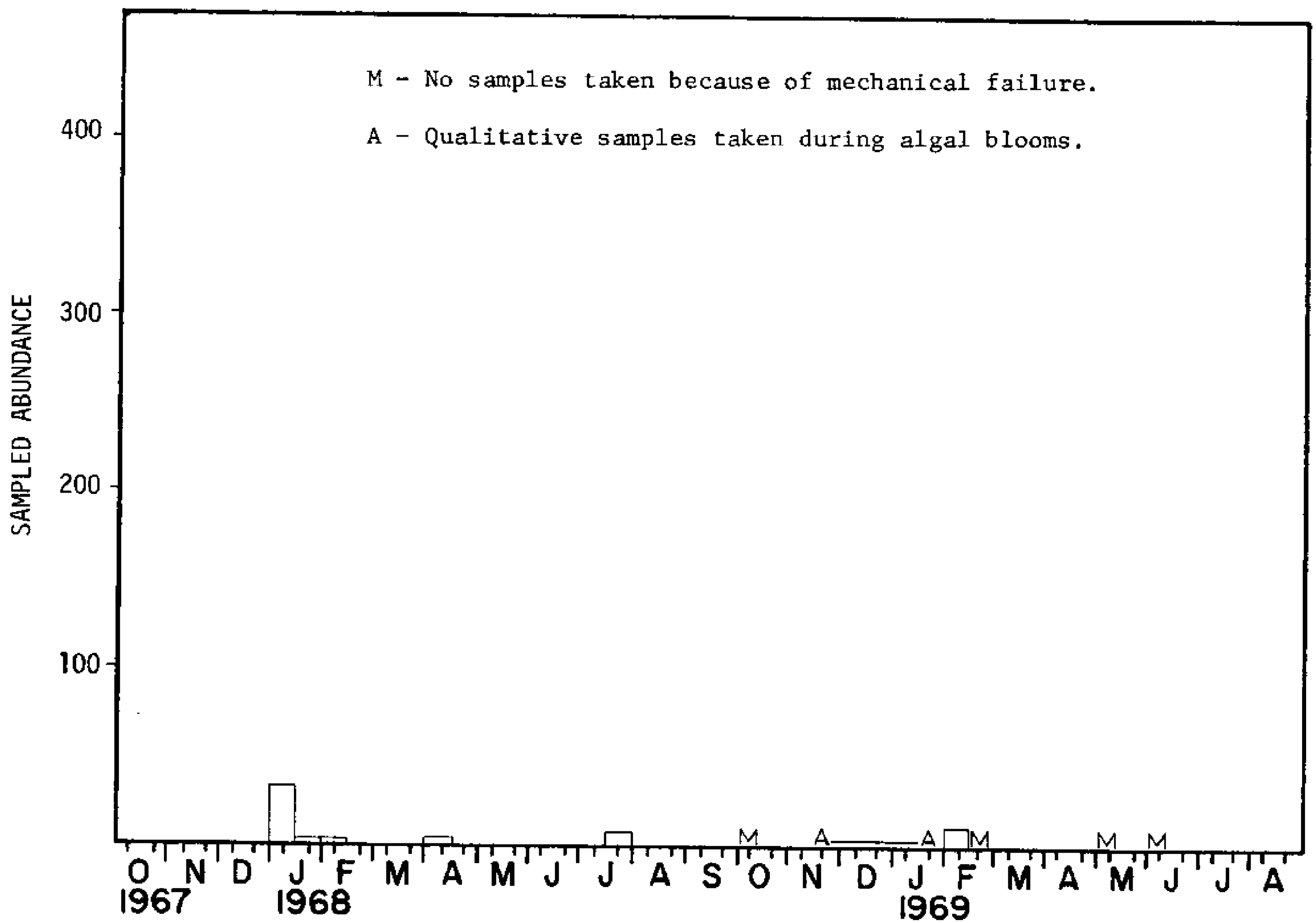

Figure 21. Abundance of *Mysidopsis bahia* obtained from liner samples taken in Alligator Lake during the period from October, 1967 through August, 1969.

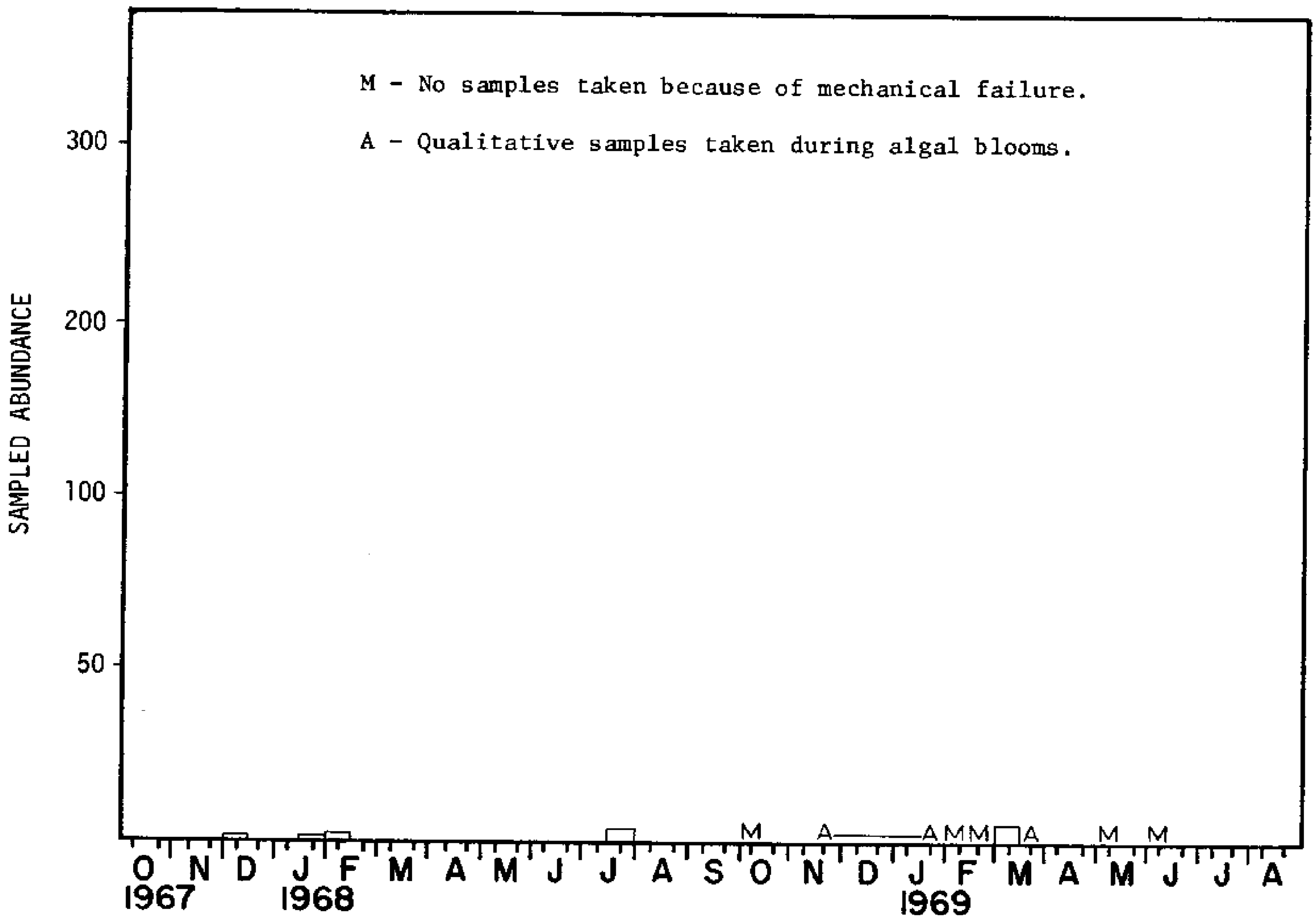

Figure 22. Abundance of _Taphromysis louisiana_ obtained from liner samples taken in Oyster Lake during the period from October, 1967 through August, 1969.

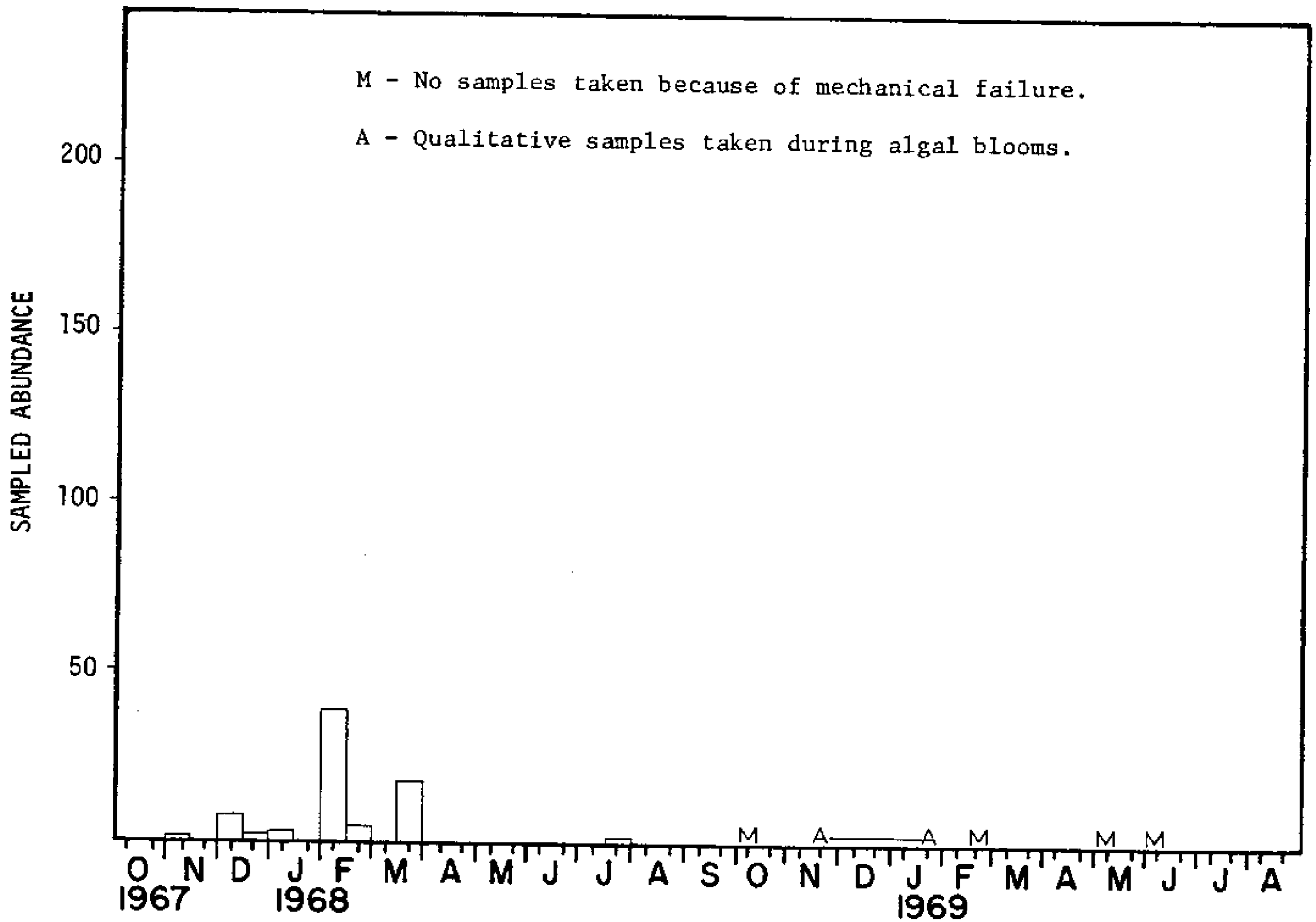

Figure 23. Abundance of <u>Taphromysis louisiana</u> obtained from liner samples taken in Alligator Lake during the period from October, 1967 through August, 1969.

Bowmanella brasiliensis

B. brasiliensis appeared three times in liner samples, from Oyster Lake, from October, 1967 through August, 1969 (Figure 24, page 74). One specimen of this mysid appeared in each collection made in early January, 1968, late September, 1968, and from qualitative samples taken in early February, 1969. In Alligator Lake, four specimens were collected from liner samples taken in early December through early January, 1968. One other specimen was collected in early November, 1968 (Figure 25, page 75).

Brasilomysis castroi

One specimen of the mysid *B. castroi* was collected in a liner sample, from Oyster Lake, in late December, 1967.

Unidentified Mysids

Two specimens of unidentified mysids, *Mysidopsis* spp., were collected from liner samples taken in Oyster Lake and Alligator Lake, the first from Oyster Lake in early December, 1967, and the second from Alligator Lake in early March, 1969.

Penaeus aztecus: Oyster Lake

A few specimens of juvenile *P. aztecus* were observed in trawl samples taken in Oyster Lake in early December, 1967, and in late January, 1968 (Figure 26, page 76). In early April, 1968, the sampled abundance of *P. aztecus* increased slightly but no specimens were observed in trawl samples in late April and early May. The

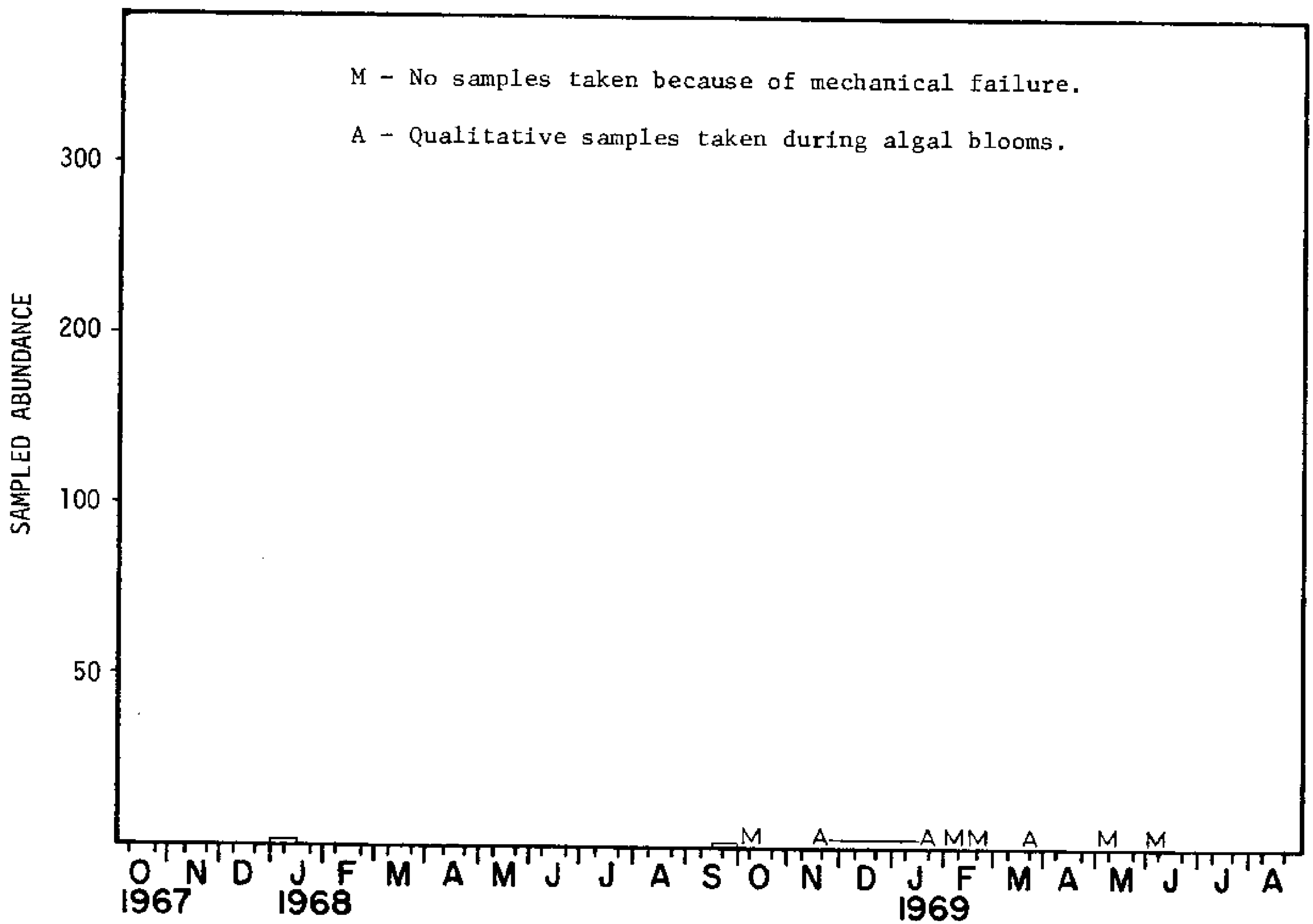

Figure 24. Abundance of *Bowmaniella brasiliensis* obtained from liner samples taken in Oyster Lake during the period from October, 1967 through August, 1969.

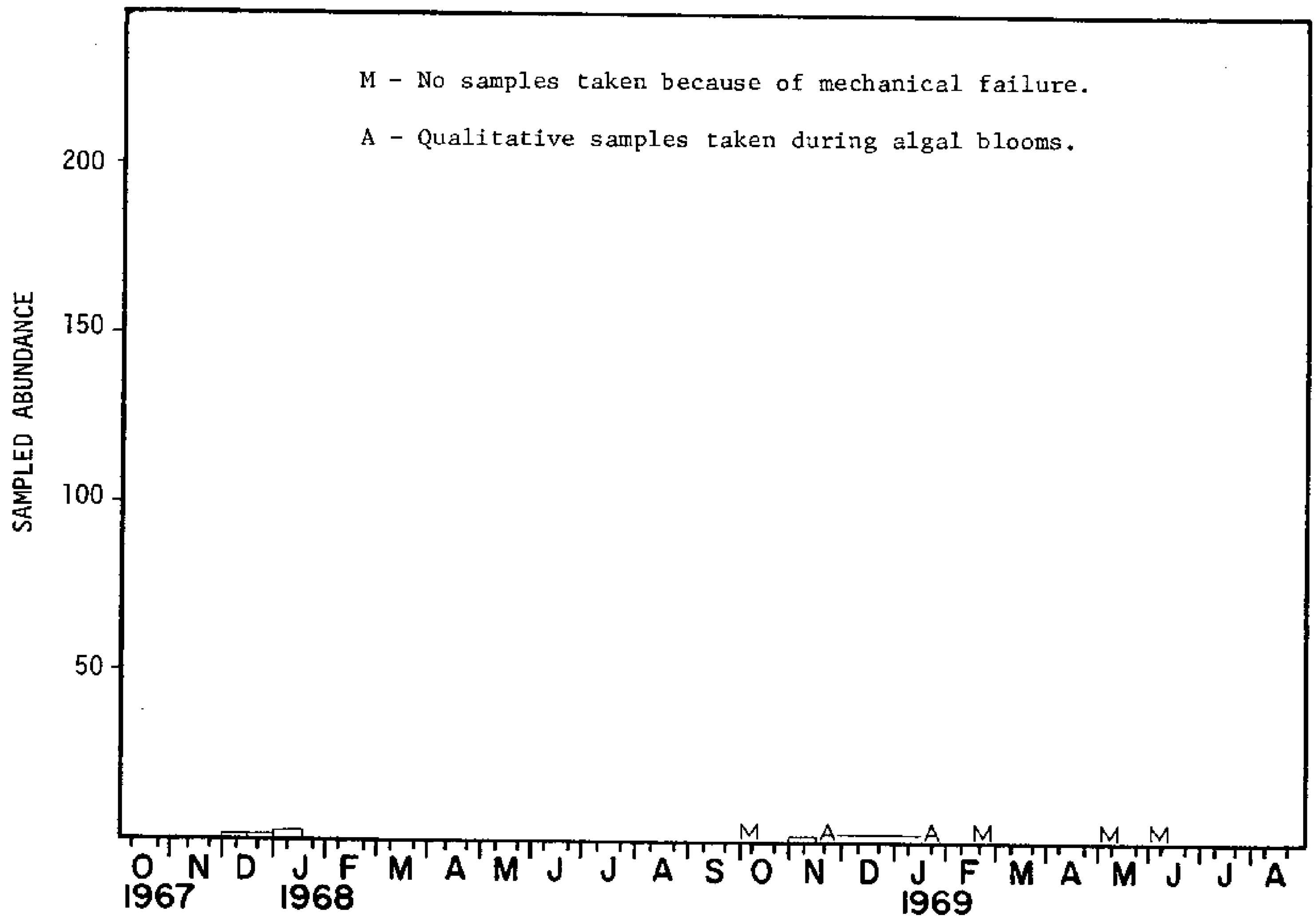

Figure 25. Abundance of _Bowmaniella brasiliensis_ obtained from liner samples taken in Alligator Lake during the period from October, 1967 through August, 1969.

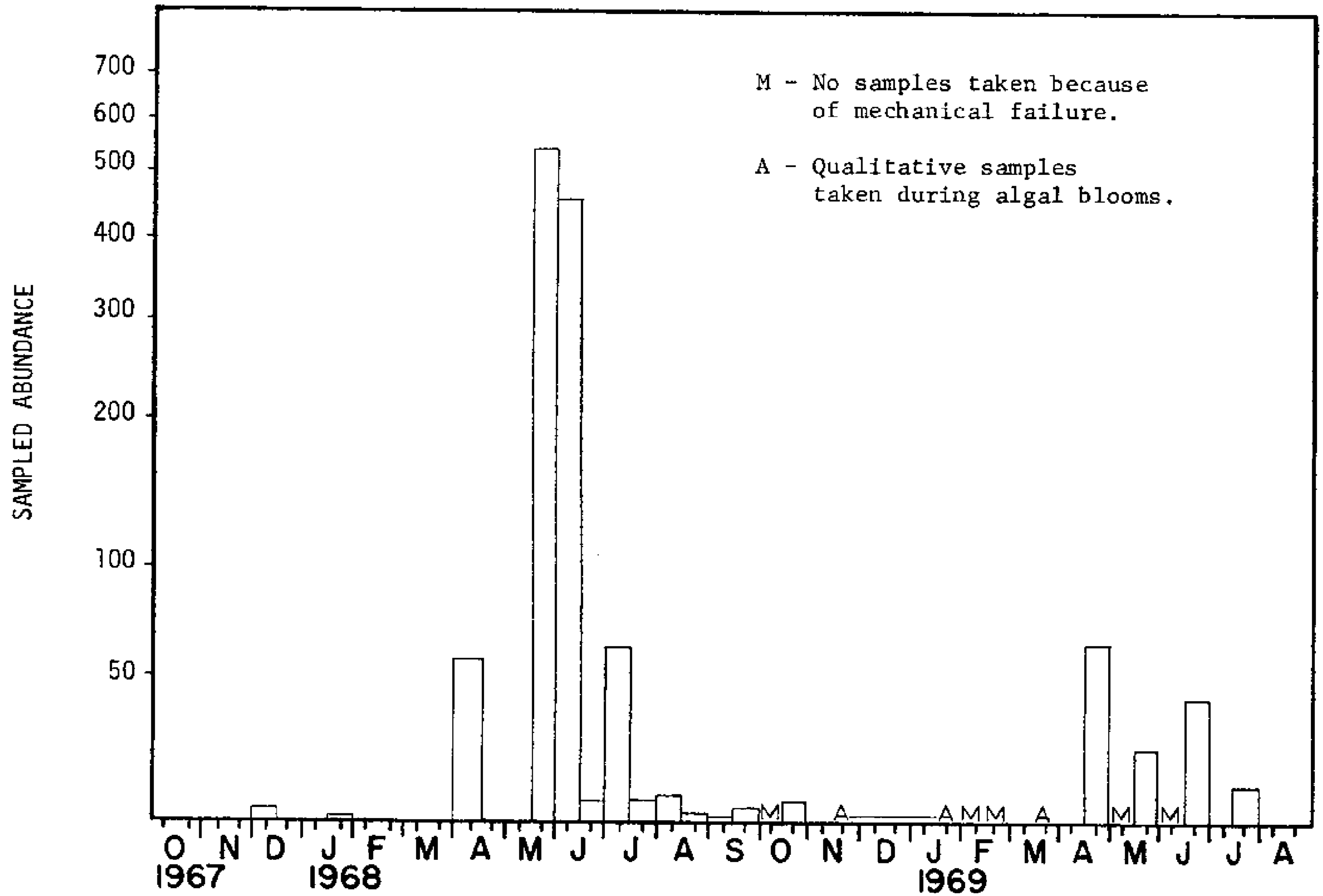

Figure 26. Abundance of Penaeus aztecus obtained from trawl samples taken in Oyster Lake during the period from October, 1967 through August, 1969.

largest trawl catches were taken in Oyster Lake in late May and early June, 1968. The population declined in late June, rose slightly in early July, and persisted in low numbers through October, 1968. No specimens were observed in qualitative samples taken during algal blooms from late November, 1968 through late January, 1969. P. aztecus was observed in trawl samples taken in late April, May, June, and July, 1969 although in numbers far below those observed in the previous year. During this period, small increases in abundance were observed in late April and late June.

Postlarval and juvenile specimens of P. aztecus were first observed in liner samples collected in early March, 1968 (Figure 27, page 78). The number of postlarvae and juveniles rose sharply through March to a peak in abundance in early April, 1968, however, the number of specimens taken dropped sharply and remained low through the remainder of the summer. A few postlarval specimens were taken in early November, 1968 and from qualitative collections in late January, 1969. The sampled abundance of postlarval and juvenile specimens rose gradually through March to a peak in early April, 1969 although in numbers far below those recorded in the previous year. The number of postlarval and juvenile P. aztecus decreased through late June but a secondary peak in abundance was observed in early July. No specimens were observed in liner samples taken in August.

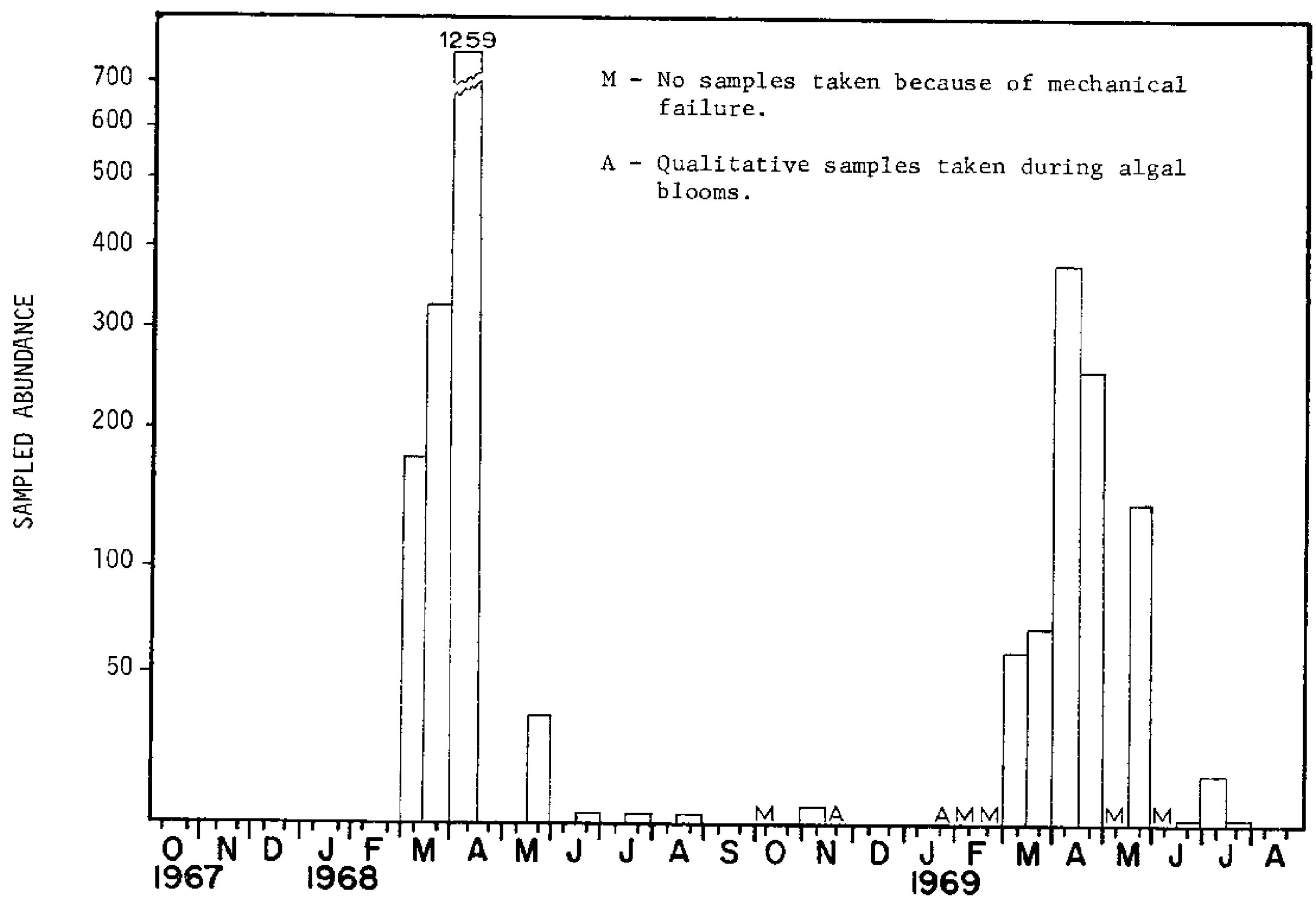

Figure 27. Abundance of Penaeus aztecus obtained from liner samples taken in Oyster Lake during the period from October, 1967 through August, 1969.

P. aztecus: Alligator Lake

P. aztecus was first observed in trawl samples taken in late December, 1967 and in early January, 1968 (Figure 28, page 80). The number of specimens taken rose sharply in late April and peaked in abundance in early and late May, 1968. The population declined through early July and was observed in low numbers through early September. No specimens were taken in qualitative collections made during algal blooms from late November, 1968 through early February, 1969. In 1969, P. aztecus was first observed in early March. Substantial numbers were taken in late May, late June, and in late July, although they were far below those observed in 1968.

Postlarval specimens of P. aztecus were first observed in liner samples taken from Alligator Lake in late October, 1967 (Figure 29, page 81). They were present through December, 1967 and in early February, 1968. The sampled abundance of postlarval P. aztecus rose sharply in early March, however, the population declined towards the end of the month. The peak abundance of postlarval and juvenile specimens occurred in early April then gradually declined through late May, 1968. Postlarval and juvenile specimens were observed in low numbers in early June, early and late August, and in early November, 1968. P. aztecus was not observed in qualitative samples taken during the algal blooms. In 1969, the sampled abundance of postlarvae and juveniles rose in

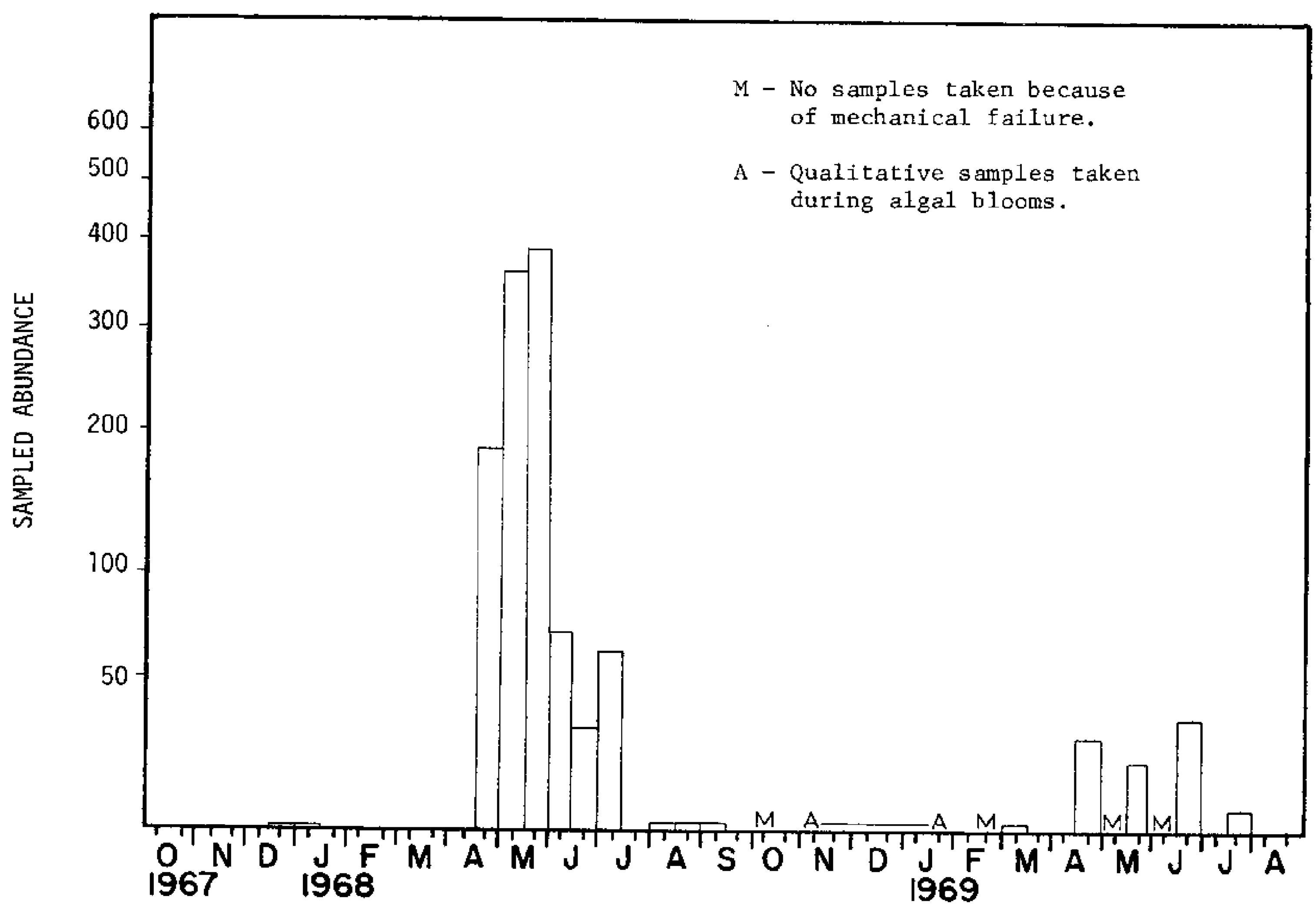

Figure 28. Abundance of Penaeus aztecus obtained from trawl samples taken in Alligator Lake during the period from October, 1967 through August, 1969.

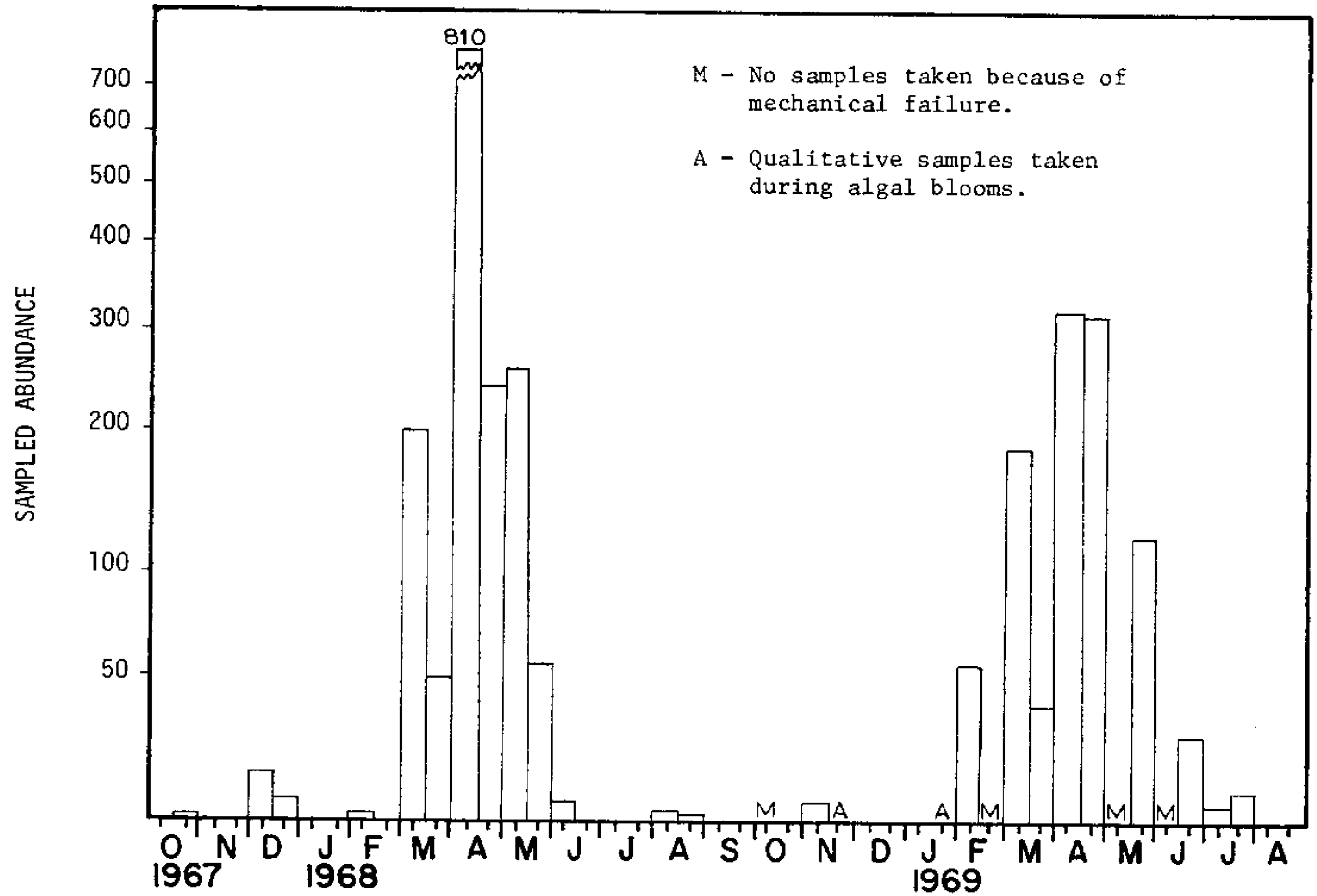

Figure 29. Abundance of Penaeus aztecus obtained from liner samples taken in Alligator Lake during the period from October, 1967 through August, 1969.

early February and peaked in early March. The population declined in late March, then rose to a second higher peak in abundance through April. The number of postlarval and juvenile specimens gradually declined through July and none were taken in August.

P. aztecus: Oyster Slough

P. aztecus was first observed in trawl samples in early May, 1968 (Figure 30, page 83). The population increased sharply to a peak in abundance in late May then disappeared by the time collections were taken in early June. Only a few specimens were recorded in early June, 1968 and early March, 1969.

Postlarval and juvenile P. aztecus were observed in liner samples in low numbers from early November through early December, 1967 (Figure 31, page 84). In 1968, a substantial number of postlarval and juvenile forms were observed in late May, however, P. aztecus was not observed again until late August. In 1969, postlarval specimens were observed in substantial numbers in early March.

P. aztecus: Alligator Slough

Large numbers of P. aztecus were observed in trawl samples in late April, 1968 (Figure 32, page 85). The population increased through early May and in late May peaked in abundance. A slight decline in the abundance was recorded in early June. P. aztecus was not observed again until September, 1968 when a few specimens were taken throughout the month. In 1969, a few specimens were

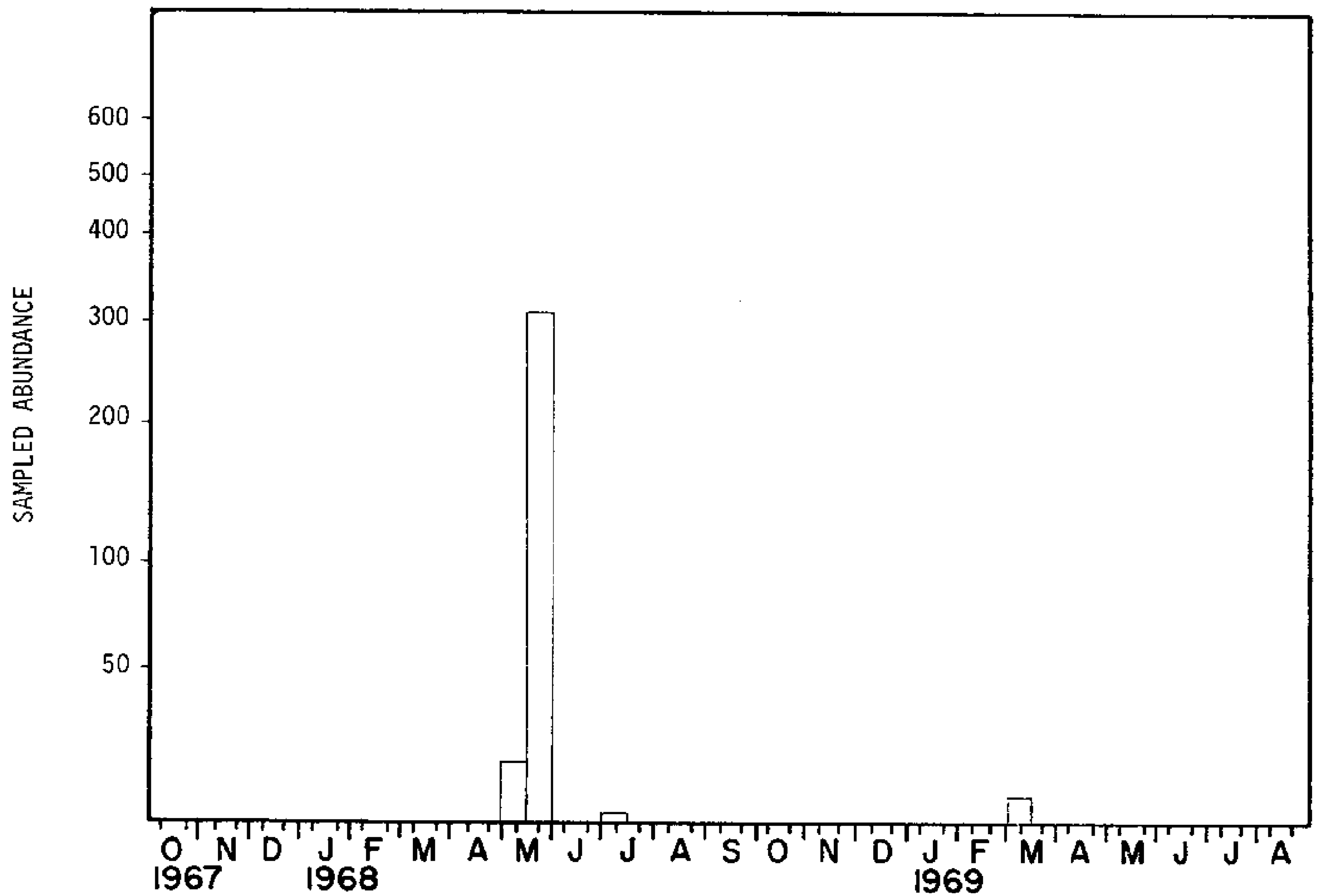

Figure 30. Abundance of *Penaeus aztecus* obtained from trawl samples taken in Oyster Slough during the period from October, 1967 through March 5, 1969.

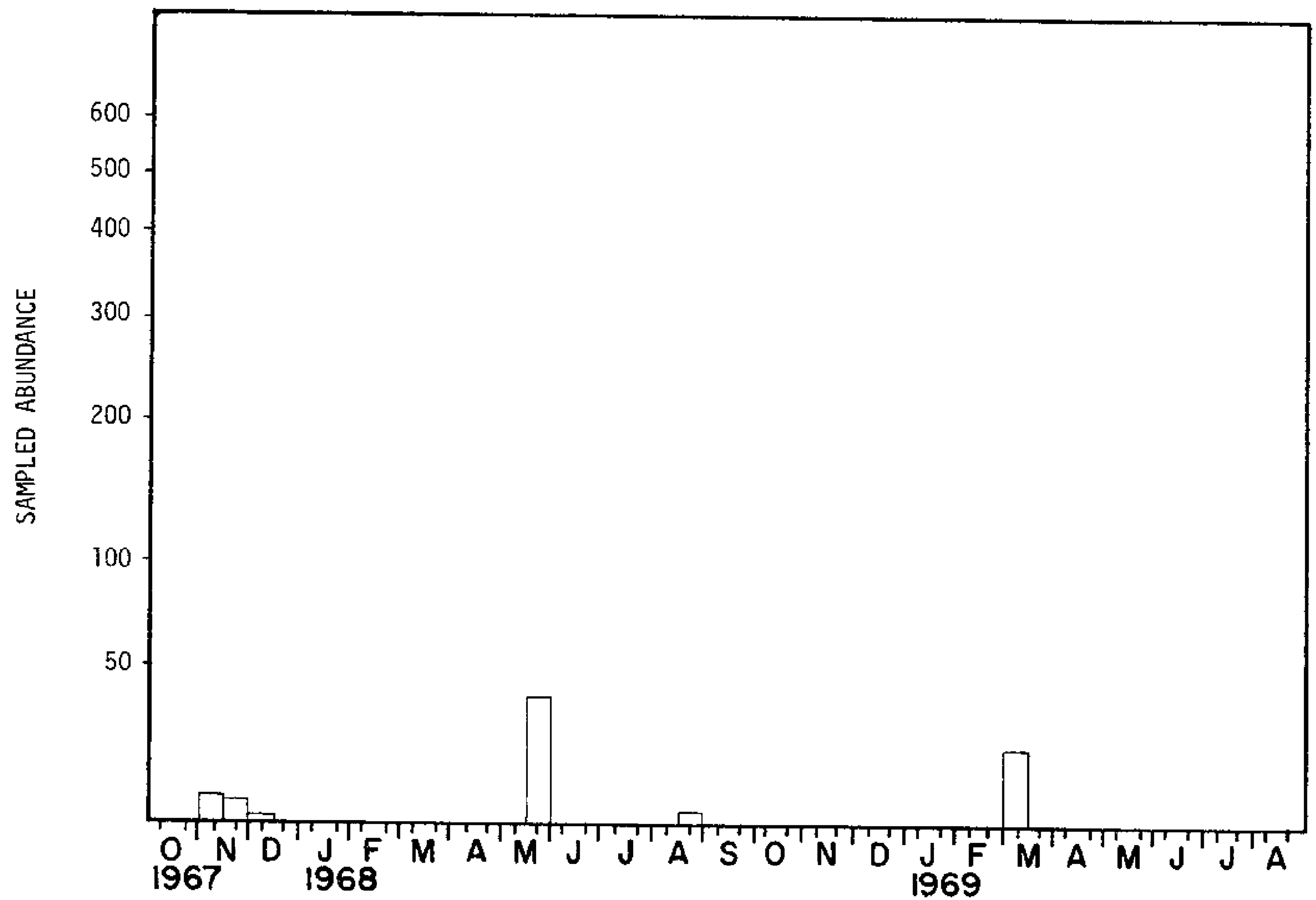

Figure 31. Abundance of *Penaeus aztecus* obtained from liner samples taken in Oyster Slough during the period from October, 1967 through March 5, 1969.

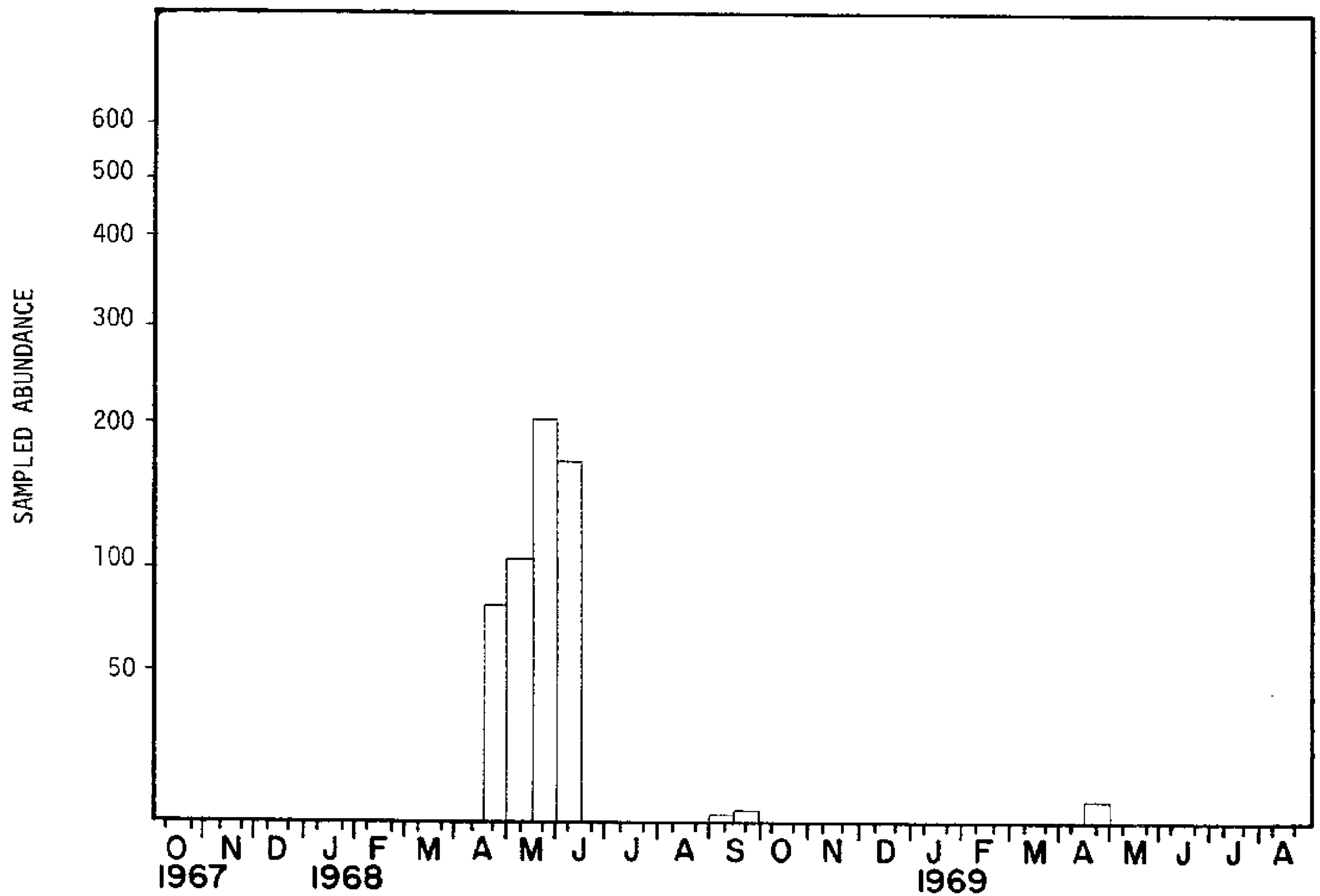

Figure 32. Abundance of Penaeus aztecus obtained from trawl samples taken in Alligator Slough during the period from October, 1967 through April 26, 1969.

observed in late April, but in trawl samples there were no large peak abundances in contrast to liner samples.

Postlarval and juvenile P. aztecus were observed in liner samples from late October through late November, 1967 (Figure 33, page 87). In 1968, postlarvae were observed in low numbers in early February. The number of postlarval forms increased in early March and juvenile forms were first observed at this time. In early April, the number of postlarval and juvenile forms rose sharply to the greatest abundance of P. aztecus observed in Alligator Slough. The number of specimens declined by late April but persisted in large numbers through late May. Several juvenile forms were observed in late July, and in late August, 1968 post-larval and juvenile forms were taken in relatively low numbers. In 1969, large numbers of postlarval and juvenile P. aztecus were observed in early March. The number of postlarval and juvenile forms rose to a considerable abundance in April but in numbers far below those recorded in the previous year.

Penaeus setiferus: Oyster Lake

P. setiferus was observed in trawl samples from late October through early December, 1967 (Figure 34, page 88). The population increased slightly in early December but disappeared by the end of the month. A few specimens were taken in late January, 1968 but none were observed in trawl samples from early February through early March. In late March, the population rose sharply

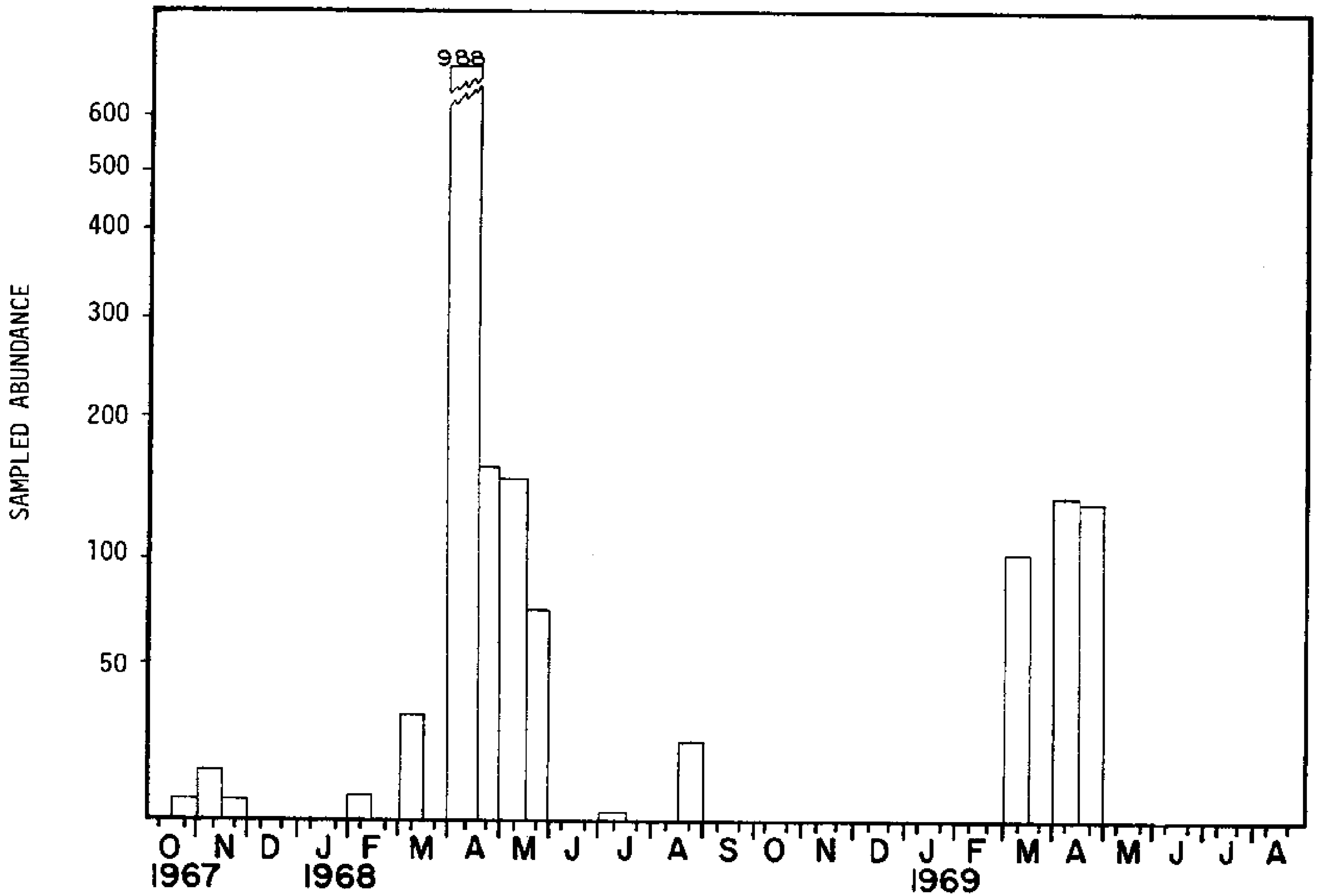

Figure 33. Abundance of <u>Penaeus aztecus</u> obtained from liner samples taken in Alligator Slough during the period from October, 1967 through April 26, 1969.

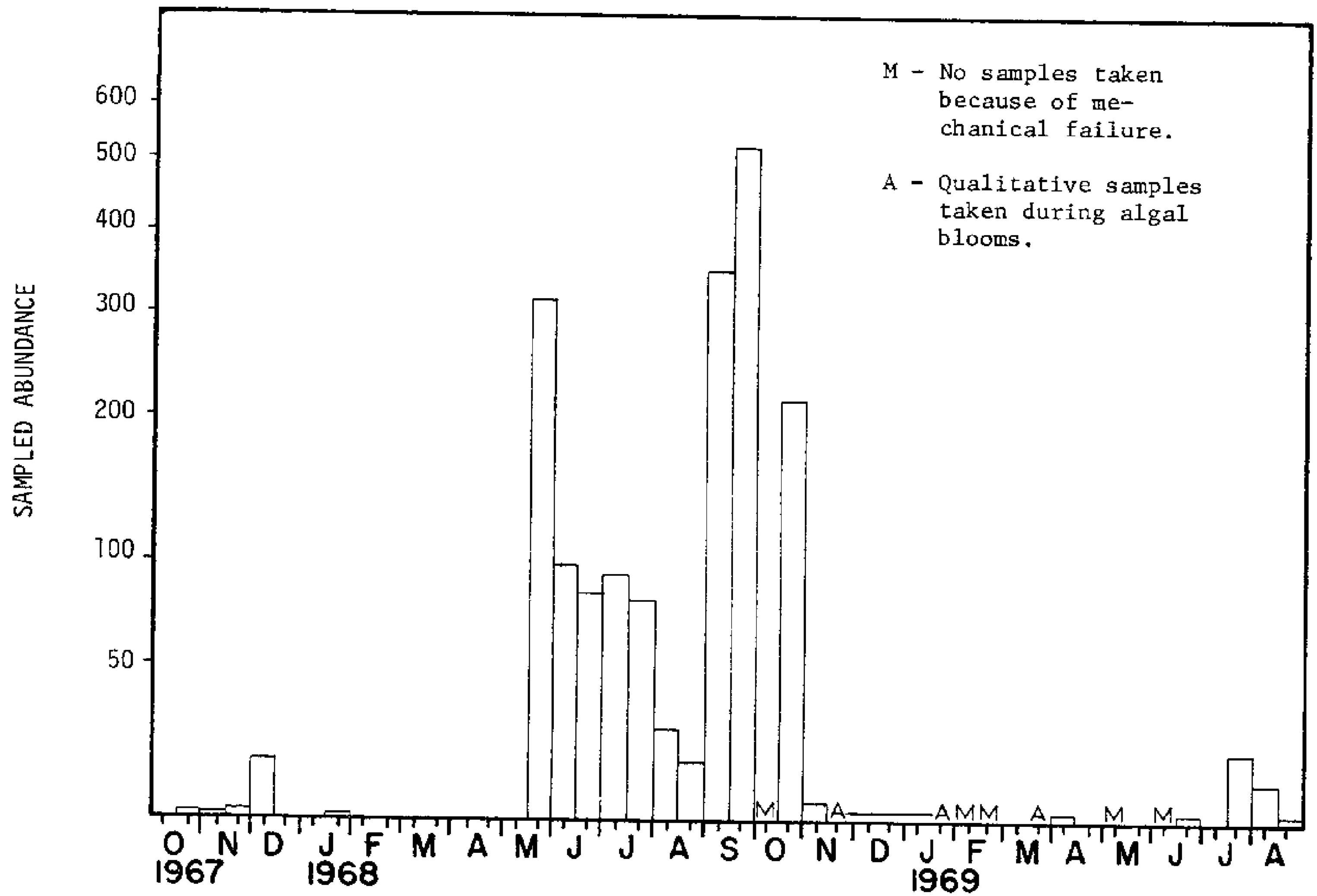

Figure 34. Abundance of *Penaeus setiferus* obtained from trawl samples taken in Oyster Lake during the period from October, 1967 through August, 1969.

to a peak in abundance and then declined gradually through late August. In early and late September the population rose sharply to abundances greater than those observed in the previous March. The abundance of P. setiferus gradually declined through October then dropped sharply by early November, 1968. It was not observed in qualitative samples taken during algal blooms in late 1968 and early 1969. In 1969, low numbers were observed in early April and late June. In late July, the abundance rose to a moderate peak and then gradually declined through late August.

Postlarval and juvenile P. setiferus were observed in liner samples in late October, late November, and early December, 1967 (Figure 35, page 90). In early December, their abundance rose slightly, but they had disappeared from liner samples by the end of the month. In 1968, postlarval P. setiferus were first observed in late April and early May. In late May, the number of postlarval and juvenile specimens rose sharply and the population peaked in abundance by late June. The samples population remained high through early July, but had declined sharply by the end of the month and disappeared in early August. In late August, postlarval and juvenile P. setiferus specimens appeared in low numbers. The population rose sharply in early September and in late September reached the greatest abundance of commercial shrimp recorded in Oyster or Alligator Lake. The population declined through October then disappeared in November. In 1969, postlarval and juvenile specimens were first observed in late June. The

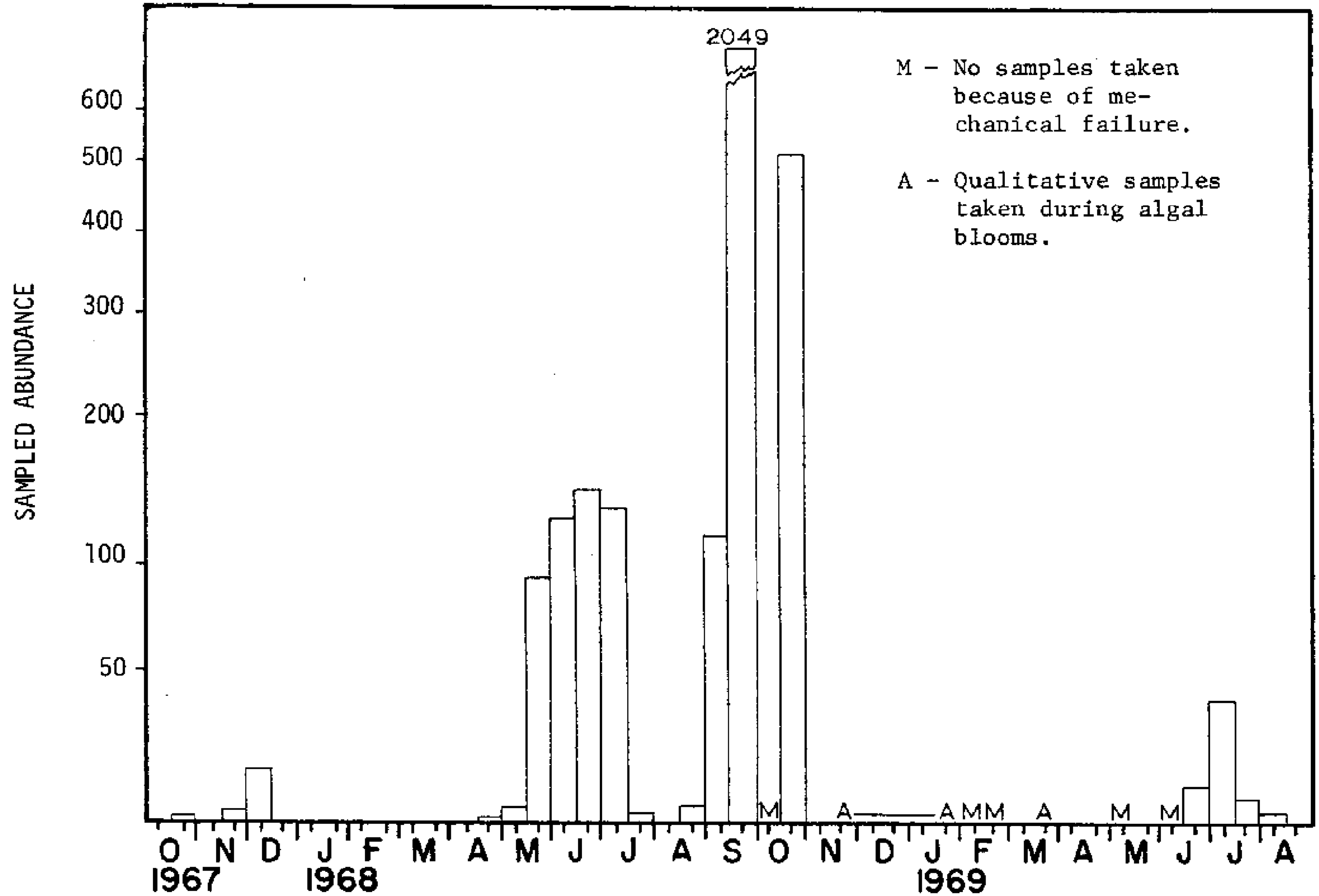

Figure 35. Abundance of <u>Penaeus setiferus</u> obtained from liner samples taken in Oyster Lake during the period from October, 1967 through August, 1969.

population peaked in abundance in early July and then declined through early August. The population of *P. setiferus* in 1969 remained far below the sampled abundance in the previous year.

P. setiferus: Alligator Lake

P. setiferus was observed in trawl samples from late October through late December, 1967 with small increases in abundance recorded in late October and late November (Figure 36, page 92). In 1968, a few specimens were observed in early May. The abundance rose sharply in late May and then fluctuated erratically through early September, exhibiting no extreme peaks or extreme lows. The population gradually declined from late September through late October then rose in early November to the highest abundance taken by trawl in Alligator Lake. *P. setiferus* disappeared from samples by late November, 1967, and no specimens were taken by trawl until early March, 1969. From early March through early April, 1969, a few specimens were taken at each collection. Specimens disappeared from collections in late April but reappeared in collections taken in late July through late August, 1969.

Postlarval and juvenile *P. setiferus* were observed in liner samples from late October thr ough late December, 1967 with peaks in abundance recorded in late October and early December (Figure 37, page 93). In 1968, postlarval specimens were first observed in early May. The number of postlarvae increased in late May and during this period juvenile forms became more numerous. A small

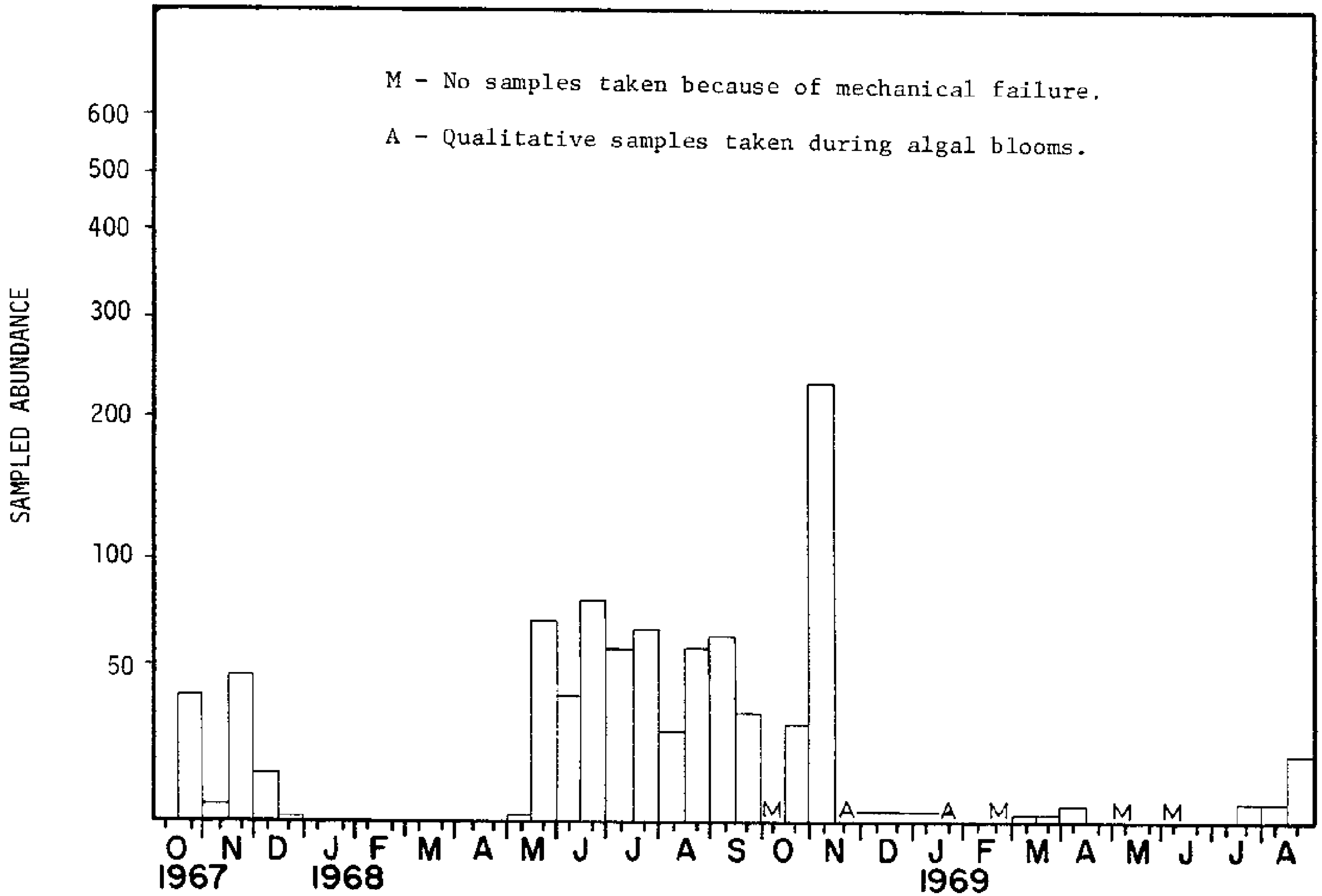

Figure 36. Abundance of <u>Penaeus setiferus</u> obtained from trawl samples taken in Alligator Lake during the period from October, 1967 through August, 1969.

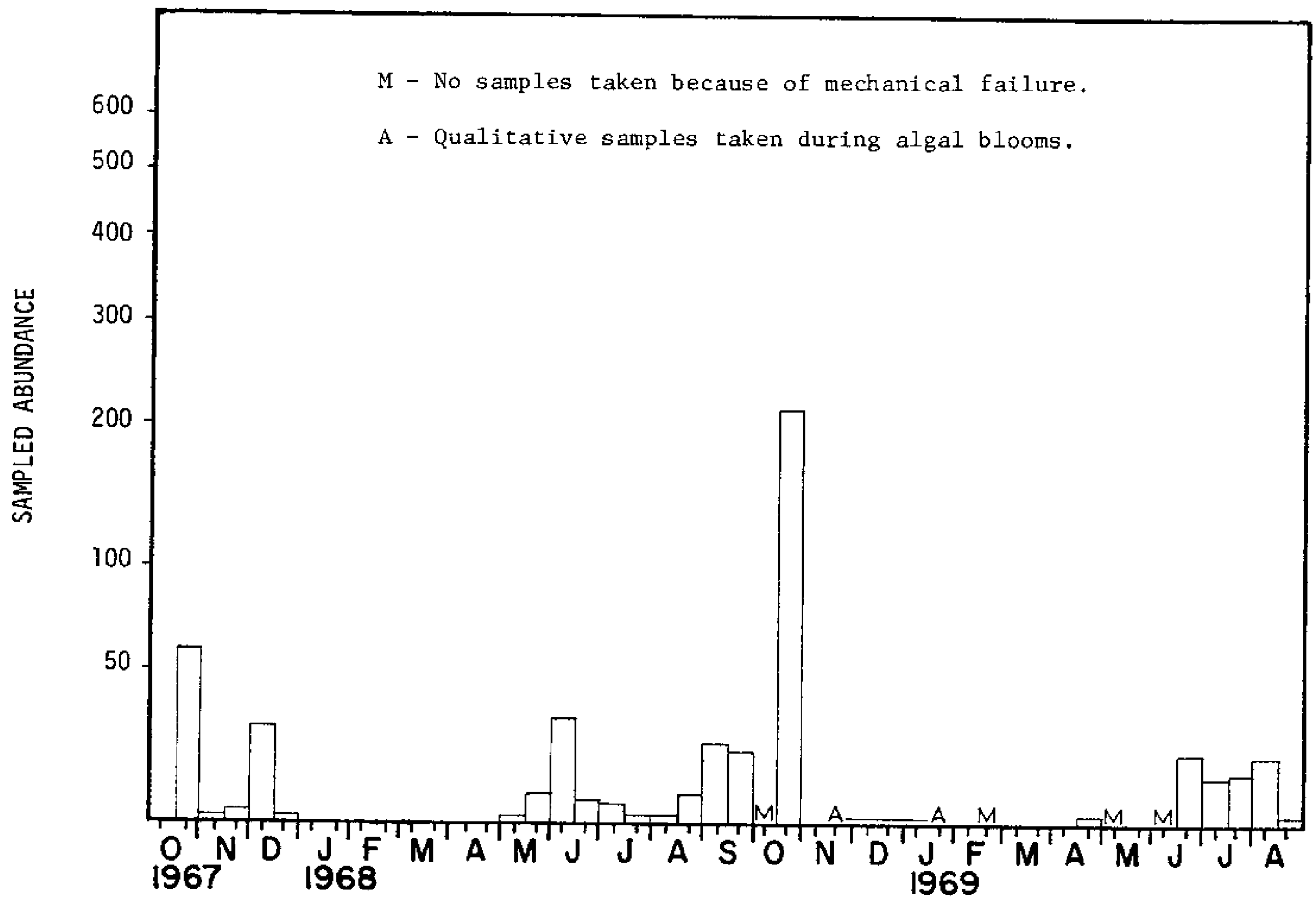

Figure 37. Abundance of Penaeus setiferus obtained from liner samples taken in Alligator Lake during the period from October, 1967 through August, 1969.

increase in abundance was observed in early June, after which it declined through early August. In late August, the number of postlarvae and juveniles taken increased, remained relatively high through September, and then peaked in abundance in late October. Specimens disappeared from liner collections taken in early November, 1968 and did not reappear until late April, 1969. At this time, a few postlarval specimens were taken. No *P. setiferus* were observed in liner collections taken in May and early June but both postlarval and juvenile forms were observed from late June through late August, 1969. During this period, the abundance was greater than that observed during comparable periods during the previous year, however, in 1969, the peak abundances were lower than the peaks in early June and October of 1968.

P. setiferus: Oyster Slough

P. setiferus specimens were observed in substantial numbers in trawl samples from late October through early December, 1967 (Figure 38, page 95). In 1968, it was observed in substantial numbers in early March, but the population declined by the end of the month. A peak abundance was observed in early July. *P. setiferus* was not taken by trawl in Oyster Slough in 1969.

Postlarval and juvenile *P. setiferus* were observed in liner samples from late October through early December, 1967 (Figure 39, page 96). During this period a peak in abundance was observed

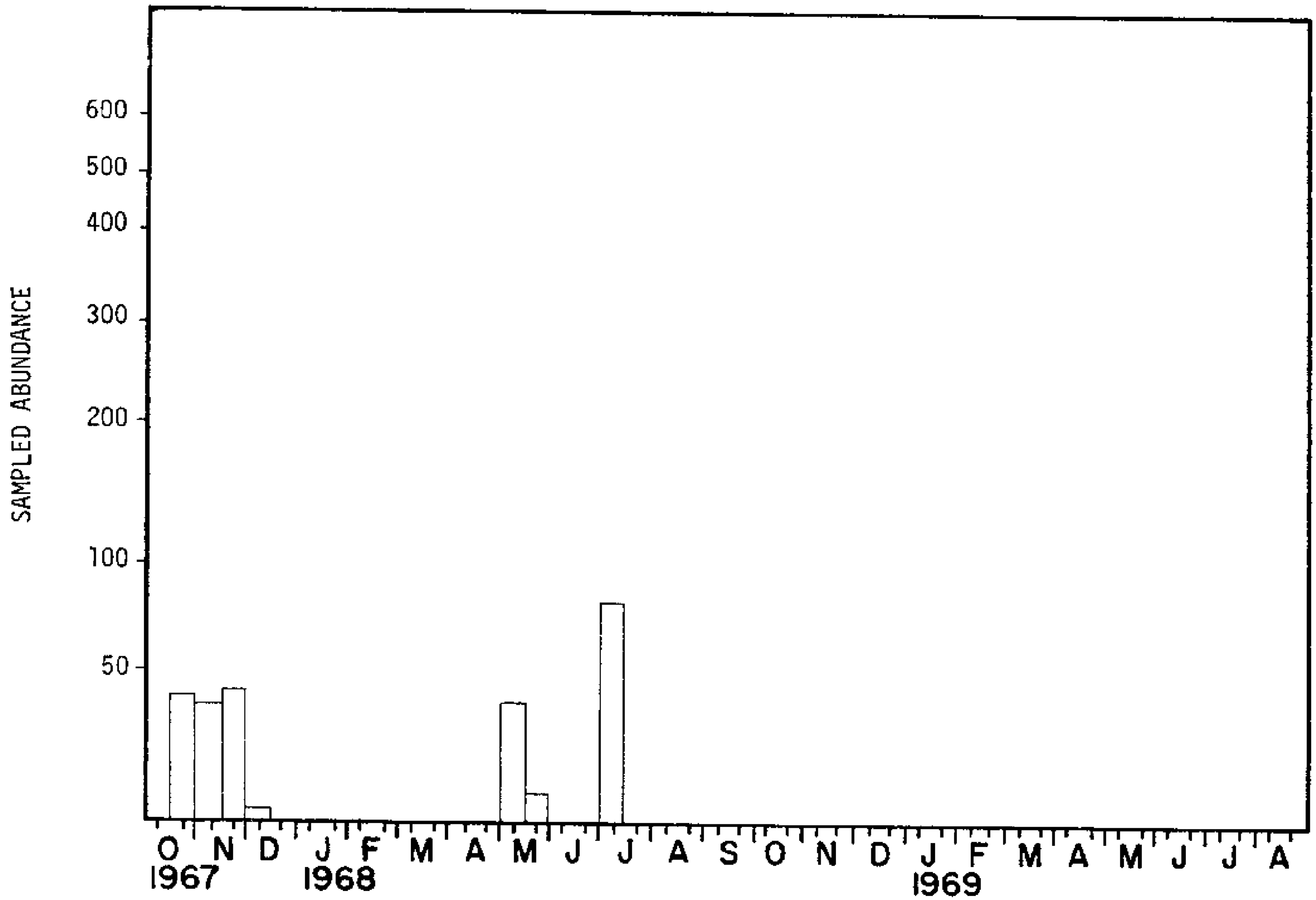

Figure 38. Abundance of *Penaeus setiferus* obtained from trawl samples taken in Oyster Slough during the period from October, 1967 through March 5, 1969.

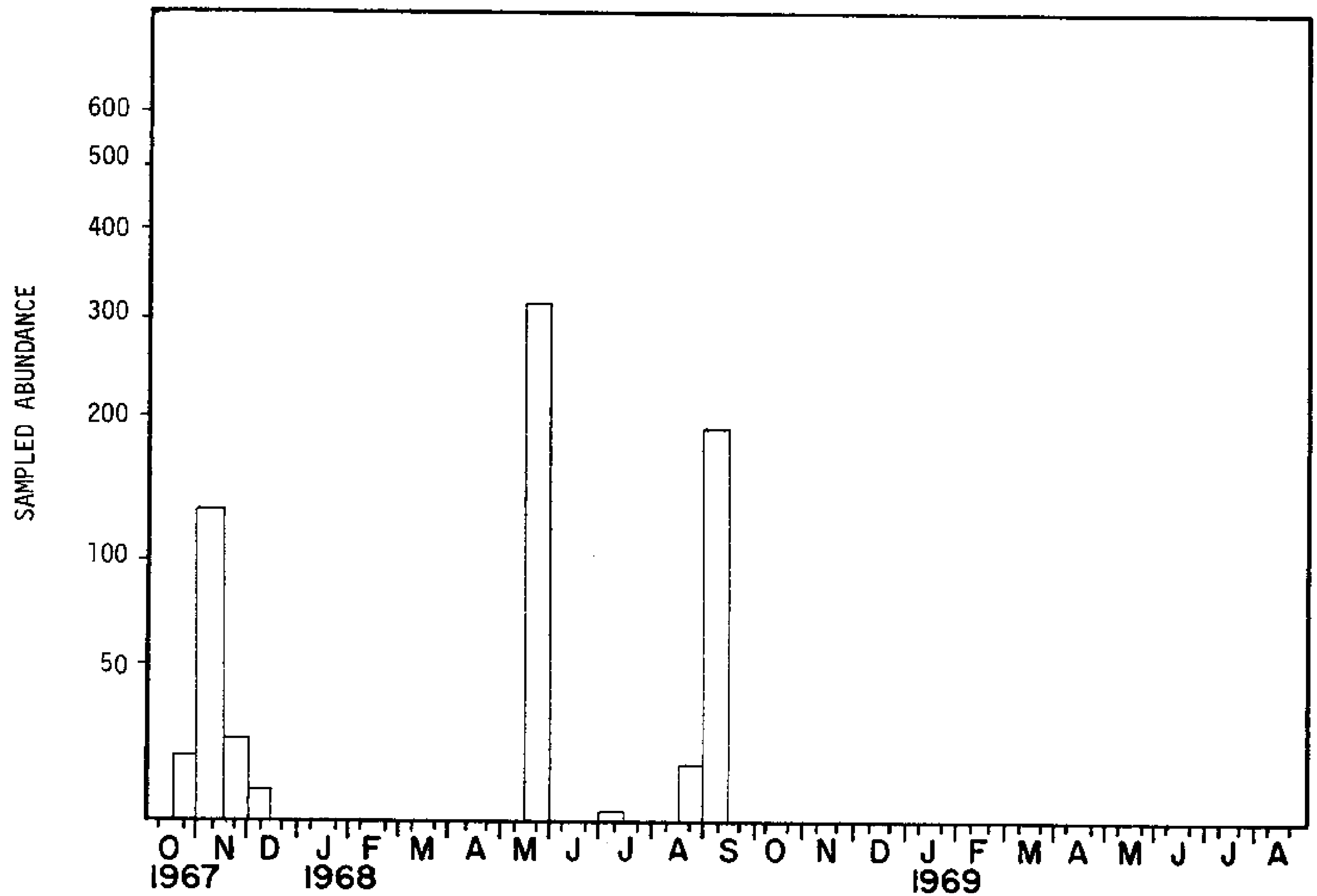

Figure 39. Abundance of Penaeus setiferus obtained from liner samples taken in Oyster Slough during the period from October, 1967 through March 5, 1969.

in early November. In 1968, large numbers of postlarval and juvenile specimens were collected in late May, however, by early July the abundance dropped sharply. A substantial number of postlarval and juvenile specimens were collected in late August, and by early September the population rose to a second smaller peak.

P. setiferus: Alligator Slough

P. setiferus was observed in trawl samples in substantial numbers in late October, 1967, dropped sharply in early November, then peaked in abundance in late November (Figure 40, page 98). In 1968, specimens were observed in relatively low numbers in early June and in late July. In late August, *P. setiferus* was observed in low numbers, however, the population increased sharply through early September to a peak in abundance in late September. *P. setiferus* was not observed in trawl samples taken in 1969.

Postlarval and juvenile *P. setiferus* were observed in liner samples in substantial numbers from late October through late November, 1967, however, the abundance dropped sharply in early December (Figure 41, page 99). In 1968, large numbers of postlarvae and juveniles were observed in late August. In early September, the postlarval and juvenile populations rose sharply and in late September reached numbers greater than any other

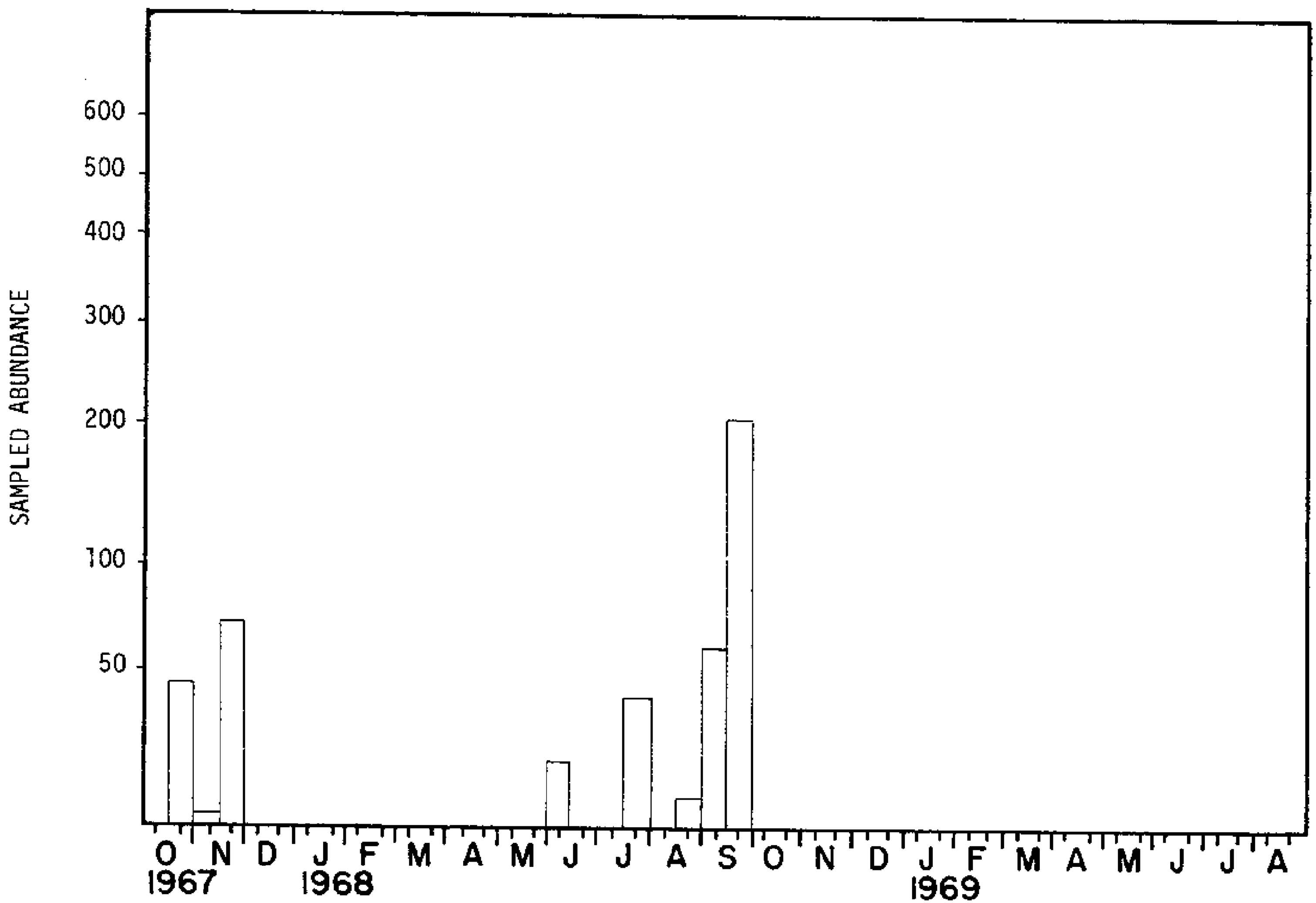

Figure 40. Abundance of <u>Penaeus setiferus</u> obtained from trawl samples taken in Alligator Slough during the period from October, 1967 through April 26, 1969.

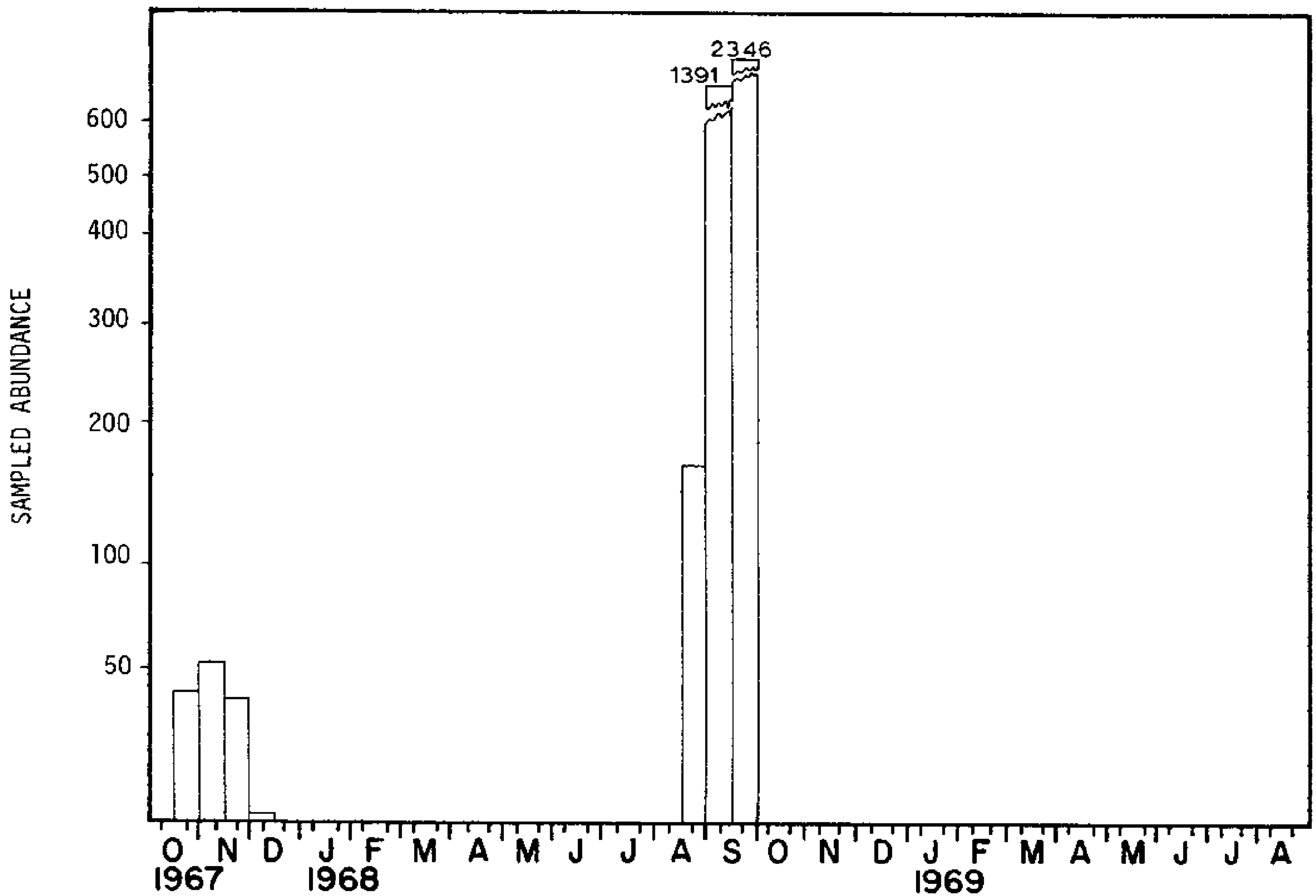

Figure 41. Abundance of _Penaeus setiferus_ obtained from liner samples taken in Alligator Slough during the period from October, 1967 through April 26, 1969.

recorded for commercial shrimp in the bay and slough systems during the study. No P. setiferus specimens were observed in liner collections taken in 1969.

Discussion of Section I

Palaemonetes vulgaris and Palaemonetes pugio can survive in waters with a wide range of temperature and salinity. Average salinity may be an important factor influencing the distribution of the two species. The greater abundance of P. vulgaris in Oyster Lake, with a mean salinity of 17.9 ppt, contrasts with the greater abundance of P. pugio in Alligator Lake, with a mean salinity of 12.6 ppt. Gunter (1950) states that P. pugio preferred waters of lower salinity than that of P. vulgaris. It may not be a simple preference of salinity ranges separating the two species, but possibly a combination of salinity and other physical factors such as substrate preference, or available food that enhances one or the other species ability to compete in the environment. These two species may offer an example of interspecific competition that limits their ecological distribution.

One specimen of Periclimenes longicaudatus and two specimens of Tozeuma carolinense were collected in Oyster Lake. Although these species have been reported from Texas (Williams, 1965), they do not seem to inhabit Oyster or Alligator Lake in any abundance.

Acetes americanus appeared more frequently in both bays during periods of high water temperature and increased salinities following periods of increased freshets due to heavy rains. Its distribution appears to be governed by salinity as it is found in greater numbers in the higher salinity exhibited by Oyster Lake. The large numbers of this species observed during peak abundances were probably the result of increased productivity of the bays, due to the influx of terrigeous materials during the period of heavy rainfall.

Mysidopsis almyra was found in Oyster and Alligator Lake in all seasons throughout the study. Peak abundances in Alligator Lake were more intense and longer in duration than those observed in Oyster Lake, except for the period from early June through early September, 1968. This was the only period during the study in which peak abundance of M. almyra in Oyster Lake exceeded that observed in Alligator Lake.

M. almyra has been described as a euryhaline species (Tattersall, 1969) and in this study specimens were collected in salinities ranging between 0.0 and 29.0 ppt. Greater numbers of M. almyra were collected in Alligator Lake, with a mean salinity of 12.6 ppt recorded during the study, than in Oyster Lake, with a mean salinity of 17.0 ppt. Even though euryhaline, M. almyra apparently inhabits bay waters of relatively lower salinities to a greater extent than relatively higher salinities of inshore marine waters. There seems to be a relation in the distribution of M. almyra and the water temperature of the bays. In both Oyster and Alligator Lakes, the abundance of M. almyra was greater in the colder months, November through May when water temperatures were lower, than in warmer months, June through October, when water temperatures were higher.

Throughout the study there was a strong relation between salinity values and abundance of M. almyra. In almost every case, the pattern of abundance of this species corresponds closely with the pattern of salinity fluctuations in both bays. With an increase in salinity, there is a corresponding increase in sampled abundance of M. almyra. Conversely, with a decrease in salinity there is a decrease in abundance of this species. In Oyster Lake, the only exceptions to this pattern occurred in late June and late September, 1968. In Alligator Lake the exceptions were noted in early February and August, 1968.

Compared to the abundance of M. almyra, the abundance of M. bahia was relatively low. Although greater abundances of M. bahia were observed in bays of relatively higher salinity, Oyster Lake and areas of higher salinity in the Galveston Bay System (Molenock, 1969), it appears, nevertheless, to be a euryhaline species that can survive large fluctuations in salinity.

Taphromysis louisiana, previously reported from "fresh static" waters of Louisiana (Banner, 1954; Bowman, personal communication) was collected from Oyster and Alligator Lakes with salinities ranging between 0.0 and 26.0 ppt. T. louisiana appears to be a euryhaline species, not exclusively fresh water as reported by Banner (1954), but it does appear to be more abundant in waters of lower salinity.

A few specimens of *Bowmaniella brasiliensis*, previously collected only from Brazil, were collected from both Oyster and Alligator Lakes. No peak abundances of this species were observed during the study. All but one of the specimens were collected during the cooler months, November, January, and February, when water temperatures were relatively low.

One specimen of *Brasilomysis castroi* was collected from Oyster Lake in late December, 1967. Previously, this species was reported only from coastal marine waters of Brazil and southern Florida.

Penaeus aztecus exhibited one peak abundance per year in both Oyster and Alligator Lakes. In Oyster Lake, in each case, postlarval and juvenile forms peaked in abundance one month prior to peak abundances observed in Alligator Lake. Postlarval and juvenile *Penaeus setiferus* exhibited two peak abundances per year, the first appearing in early summer and the second in the fall. The first peak abundances appeared at the same time in Oyster and Alligator Lakes. The second peak abundance in Oyster Lake appeared one to two months previous to that observed in Alligator Lake.

There appears to be no relation between salinity and seasonal distribution exhibited by *P. aztecus* and *P. setiferus*.

Temperature response can best be related to *P. setiferus*. In the fall when temperatures dropped, *P. setiferus* disappeared from both trawl and liner samples. Other temperature and salinity factors related to the penaeid shrimp will be discussed in Section III.

The marsh bayou system, as represented by Oyster and Alligator Sloughs, are utilized as nursery areas for both *P. aztecus* and *P. setiferus*. Oyster Slough proved to be the least productive of the two systems. Alligator Slough exhibited a high productivity of commercial shrimp.

SECTION II

MALATHION FIELD TESTS ON

PENAEUS AZTECUS AND *PENAEUS SETIFERUS*

Results

Malathion Field Test No 1.

Analysis of water samples and tissue samples of shrimp, *P. aztecus*, taken from Bastrop Bay showed no measurable trace of malathion (Table 5, page 106; Table 6, page 107). Water samples taken from the test plot, Alligator Slough, and the control plot, Oyster Slough, at the time of stocking and water and shrimp samples taken from both the test and control plots one hour before the application of malathion exhibited no trace of the pesticide. Two shrimp were examined at each check period (Table 5, page 106; Table 6, page 107). Water temperatures in all three sites were approximately the same, but salinity in the control site was higher than either Bastrop Bay or Alligator Slough (Table 5, page 106).

Nine hours after the application of malathion, ten dead shrimp were found in Box A and fourteen dead shrimp were found in Box B. This was the maximum mortality recorded during the test. Mortalities continued in Box A with three deaths at 24 hours and two deaths at 33 hours; and in Box B, two deaths at 24 hours and one death at 33 hours and 48 hours, respectively

TABLE 5. Malathion field test No 1. indicating the amount of pesticide present in water samples and shrimp samples obtained from Bastrop Bay, test plot, and control plot, at the time they were stocked and one hour before the application of malathion.

	Malathion ppm Water Sample	Malathion ppm *P. aztecus*	Water Temperature °C	Salinity ppt	Tide
Bastrop Bay	0.00	(1) 0.00 (2) 0.00	29	8	High
Alligator Slough Test Plot When Stocked	0.00		31	11	High
Alligator Slough Test Plot 1 Hour Before Application of Malathion	0.00	(1) 0.00 (2) 0.00	26	4	Medium
Oyster Slough Control Plot When Stocked	0.00		31	14	High
Oyster Slough Control Plot 1 Hour Before Application of Malathion	0.00	(1) 0.00 (2) 0.00	27	13	Medium

TABLE 6. Malathion field test No 1. Tissue analysis of shrimp obtained from Bastrop Bay, test plot, and control plot one hour before the application of malathion.

	Species *P. aztecus*	Length mm	Weight gr	Weight of Tail gr	Malathion ppm
Bastrop Bay	(1)	72	2.37	1.12	0.00
	(2)	76	2.74	1.25	0.00
Alligator Slough Test Plot 1 Hour Before Application of Malathion	(1)	67	1.68	0.97	0.00
	(2)	69	1.84	1.05	0.00
Oyster Slough Control Plot 1 Hour Before Application of Malathion	(1)	70	2.46	1.21	0.00
	(2)	71	2.42	1.19	0.00

(Table 7, page 109). Shrimp in Box A exhibited a 60 percent mortality rate, those in Box B a 72 percent mortality. An average of 66 percent mortality was observed in both boxes (Table 7, page 109). Temperatures and salinities in the test plot were higher at the end of the day, at 24 hours and 48 hours, and lower in the mornings, at 9 and 33 hours (Table 7, page 109).

Analysis of water samples showed 3.0 ppm of malathion at the end of nine hours with a gradual reduction in the pesticide occurring towards the end of the test (Table 7, page 109). Tissue analysis of the ten shrimp found dead in Box A, at the end of nine hours, showed no measurable trace of malathion in two shrimp and concentrations ranging from 0.47 to 1.25 ppm in the remaining eight shrimp. Dead shrimp found at the end of 24 hours exhibited higher malathion concentration, 1.96 to 2.39 ppm, than those collected at nine hours. Dead shrimp taken at the end of 33 hours exhibited slightly lower values, 1.60 ppm and 1.67 ppm, than the shrimp taken at 24 hours (Table 8, page 110). Of fourteen dead shrimp, collected from Box B, at nine hours, three showed no malathion, but the remaining eleven exhibited malathion values ranging from 0.38 to 1.35 ppm. Shrimp taken at the end of 24 hours exhibited malathion values of 0.94 to 1.36 ppm, at 33 hours, 1.01 ppm, at 48 hours, 1.68 ppm (Table 8, page 110).

Tissue anaylsis of live shrimp taken from Box A at nine hours exhibited higher malathion concentrations, 1.57 and 1.80

TABLE 7. Malathion field test No 1. indicating the amount of pesticide present in water samples, the cumulative mortality counts of shrimp in the test plot, Alligator Slough, at specified time intervals after the application of malathion, and the percentage of mortality of shrimp in each box.

Hour	Malathion ppm Water Sample	Mortality of *P. aztecus* (25 *P. aztecus* in each box) Box A	Box B	Water Temperature °C	Salinity ppt	Tide
9 hr.	3.00	10	14	32	8	Low
24 hr.	1.50	13	16	26	7	Medium
33 hr.	1.00	15	17	33	6	Low
48 hr.	0.80	15	18	26	2	Medium
Percent Mortality		60%	72%			
Total Percent Mortality		66%				

TABLE 8. Malathion field test No 1. Tissue analysis of dead shrimp obtained from Boxes A and B of Alligator Slough after the application of malathion.

Hour	Species *P. aztecus*	Length mm	Weight gr	Weight of Tail gr	Malathion ppm
Box A					
9 hr.	1	73	2.43	0.97	0.52
	2	74	2.18	0.84	0.71
	3	74	2.05	1.17	0.60
	4	75	2.21	1.26	
	5	76	2.49	1.45	1.25
	6	76	2.38	1.27	0.56
	7	77	2.39	1.53	0.63
	8	78	2.12	1.22	
	9	79	3.21	2.02	0.84
	10	79	2.42	1.68	0.47
24 hr.	1	63	2.12	1.18	1.96
	2	75	2.65	1.39	2.39

TABLE 8. Continued.

Hour	Species *P. aztecus*	Length mm	Weight gr	Weight of Tail gr	Malathion ppm
24 hr.	3	76	2.78	1.22	2.04
33 hr.	1	66	1.67	1.04	1.67
	2	77	3.01	1.78	1.60
Box B					
9 hr.	1	64	1.22	0.72	0.56
	2	66	1.46	0.81	0.43
	3	66	0.53	0.86	
	4	68	0.61	0.94	0.52
	5	69	0.70	0.96	0.80
	6	69	1.59	0.83	0.38
	7	70	1.78	1.00	1.01
	8	70	1.96	1.09	
	9	72	2.57	1.30	

TABLE 8. Continued.

Hour	Species *P. aztecus*	Length mm	Weight gr	Weight of Tail gr	Malathion ppm
9 hr.	10	74	2.37	1.37	0.17
	11	77	2.64	1.48	0.66
	12	78	2.71	1.40	1.25
	13	79	2.82	1.53	0.57
	14	80	3.19	1.51	0.35
24 hr.	1	66	1.28	0.81	0.94
	2	78	2.32	1.51	1.36
33 hr.	1	68	1.70	1.01	1.01
48 hr.	1	65	1.59	0.67	1.16

ppm, than the dead shrimp taken at the same time (Table 8, page 110; Table 9, page 114). Tissue analysis of live shrimp taken from Box A, at 24 hours yielded malathion concentrations of 1.97 and 2.40 ppm, the highest malathion level recorded during the test. At the end of 33 and 48 hours, the malathion level in live shrimp taken from Box A declined sharply to values similar to dead shrimp with low pesticide content taken at the end of nine hours (Table 8, page 110; Table 9, page 114 Analysis of shrimp taken alive from Box B of the test plot exhibited a similar trend as the live shrimp taken from Box A. The highest malathion concentration observed from live shrimp taken from Box B occurred at the end of 24 hours (Table 9, page 114). Live shrimp taken at 33 and 48 hours exhibited a marked reduction of malathion from the previous high values. The malathion values obtained from live shrimp taken from Box B were higher than the values obtained from live shrimp taken from Box A at comparable times (Table 9, page 114).

No mortalities occurred in Box A or Box B of the control plot at 9, 24, 33, or 48 hours (Table 10, page 116). Analysis of water samples and tissue analysis of live shrimp taken during the same time periods showed no malathion to be present.

In the control plot, the temperatures were very close to the values obtained in the test plot. High temperatures were recorded in the afternoons (9 and 33 hours), and lower in the mornings (24 and 48 hours). Salinity recorded on the first, 9th and 24th

TABLE 9. Malathion field test No 1. Tissue analysis of shrimp taken alive from Boxes A and B of Alligator Slough, test plot, after the application of malathion.

Hour	Species *P. aztecus*	Length mm	Weight gr	Weight of Tail gr	Malathion ppm
Box A					
9 hr.	1	85	4.12	2.44	1.80
	2	86	3.94	2.40	1.57
24 hr.	1	80	3.65	2.10	2.40
	2	81	3.59	2.04	1.97
33 hr.	1	77	2.50	1.39	0.51
	2	74	2.28	1.05	0.43
48 hr.	1	80	3.41	1.76	0.40
	2	83	3.62	1.94	0.68
Box B					
9 hr.	1	82	3.81	2.21	2.00
	2	84	3.78	2.22	1.84

TABLE 9. Continued.

Hour	Species *P. aztecus*	Length mm	Weight gr	Weight of Tail gr	Malathion ppm
24 hr.	1	74	2.49	1.35	2.53
	2	75	2.56	1.48	2.37
33 hr.	1	78	2.79	1.56	1.35
	2	80	2.85	1.62	1.21
48 hr.	1	80	3.41	1.76	1.05

TABLE 10. Malathion field test No 1. indicating the amount of pesticide present in water samples, and mortality counts of shrimp in control plot after the application of malathion.

Hour	Malathion ppm Water Sample	Mortality of *P. aztecus* (25 *P. aztecus* in each box) Box A	Box B	Water Temperature °C	Salinity ppt
9 hr.	0.00	0	0	33	14
24 hr.	0.00	0	0	27	14
33 hr.	0.00	0	0	33	33
48 hr.	0.00	0	0	28	28

hours, remained stable at 14 ppt, but increased on the second day to 33 ppt, at 33 hours, and 28 ppt, at 48 hours (Table 10, page 116).

Malathion Field Test No 2.

Analysis of water samples and tissue samples of shrimp, *P. aztecus* and *P. setiferus*, taken from Bastrop Bay exhibited no measurable trace of malathion. Water samples taken from the test plots, Alligator and Elbow Sloughs, and the control plot, Oyster Slough, at the time of stocking, and water and shrimp samples taken from both the test plots and control plots one hour before the application of malathion exhibited no measurable trace of the pesticide (Table 11, page 118). The water temperatures in all three sites were approximately the same, but the salinity in Bastrop Bay was higher than the test plots and the control plot at the time of stocking (Table 11, page 118).

In Box A of the test plot, Alligator Slough, the first mortalities, four *P. aztecus* and one *P. setiferus*, were observed 25 hours after the application of malathion. The only other mortality of *P. aztecus* was observed at the end of 49 hours (Table 12, page 120).

In Box B the first mortality, *P. aztecus*, was observed three hours after the application of malathion. Other mortalities were observed at 3, 6, and 9 hours. Only one mortality of

TABLE 11. Malathion field test No 2. indicating the amount of pesticide present in water samples and shrimp samples obtained from Bastrop Bay, test plot, and control plot, when stocked, and one hour before the application of malathion.

	Malathion ppm Water Samples	Malathion ppm Shrimp Samples *P. aztecus*	Malathion ppm Shrimp Samples *P. setiferus*	Water Temperature °C	Salinity ppt
Bastrop Bay	0.00	(1) 0.00	(1) 0.00	33	28
Alligator Slough Test Plot When Stocked	0.00			29	16
Alligator Slough Test Plot 1 Hour Before Application of Malathion	0.00	(1) 0.00	(1) 0.00	27	10
Elbow Slough Test Plot When Stocked	0.00			30	12
Elbow Slough Test Plot 1 Hour Before Application of Malathion	0.00	(1) 0.00	(1) 0.00	27	8
Oyster Slough Control Plot When Stocked	0.00			32	24

TABLE 11. Continued.

	Malathion ppm Water Samples	Malathion ppm Shrimp Samples *P. aztecus*	Malathion ppm Shrimp Samples *P. setiferus*	Water Temperature °C	Salinity ppt
Oyster Slough Control Plot 1 Hour Before Application of Malathion	0.00	(1) 0.00	(1) 0.00	28	28

TABLE 12. Malathion field test No 2. indicating the cumulative number of mortalities present in Boxes A and B of the test plot, Alligator Slough, after the application of malathion, and at specified time intervals.

Hour	BOX A		BOX B		Salinity	Water Temperature	Tide
	P. aztecus	*P. setiferus*	*P. aztecus*	*P. setiferus*	ppt	°C	
1 hr.	0	0	0	0	10	27	Medium
3 hr.	0	0	1	0	11	29	Medium
6 hr.	0	0	2	0	13	33	Medium
9 hr.	0	0	3	0	14	32	High
25 hr.	4	1	3	1	10	27	Medium
33 hr.	4	1	3	1	15	34	Low
49 hr.	5	1	3	1	10	27	Medium

P. setiferus was observed, that occurring at the end of 25 hours (Table 12, page 120).

Temperature, in Alligator Slough, fluctuated between 10 and 15°C. Salinity fluctuated between 27 and 33 ppt (Table 12, page 120).

In Box A of Alligator Slough, P. aztecus suffered 55 percent mortality and P. setiferus, 6 percent mortality. The combined percent of mortality of both shrimp, P. aztecus and P. setiferus, in Box A was 22 percent. In Box B, 43 percent of the shrimp, P. aztecus, died, however, P. setiferus suffered only 5 percent mortality. The combined percent mortality of shrimp in Box B was 14 percent (Table 13, page 122).

In Box A of the test plot, Elbow Slough, the first mortalities, two P. aztecus, were observed at the end of one hour. Mortality of P. aztecus continued in Box A with deaths observed at the end of 3, 6, 25, and 49 hours. The peak mortality occurred at the end of 6 hours. The first mortality of P. setiferus, in Box A, was noted at the end of 3 hours and the mortalities continued through 24 hours. The largest mortality was observed at the end of 9 hours (Table 14, page 123).

In Box B of the test plot, Elbow Slough, the first mortality of P. aztecus was observed at the end of 3 hours. The only other mortalities of P. aztecus observed, in Box B, was recorded 25 hours after the application of malathion. A dead specimen

TABLE 13. Malathion field test No 2. indicating mortality and percentage of mortality of shrimp by box, in test plot, Alligator Slough.

ALLIGATOR SLOUGH
TEST PLOT

Box A Stocked With 27 Shrimp				Box B Stocked With 28 Shrimp			
Species	No. of Shrimp	Mortality	Percent Mortality	Species	No. of Shrimp	Mortality	Percent Mortality
P. aztecus	9	5	55%	*P. aztecus*	7	3	43%
P. setiferus	18	1	6%	*P. setiferus*	21	1	5%
		Total Mortality	22%			Total Mortality	14%

TABLE 14. Malathion field test No 2. indicating the number of mortalities present in Boxes A and B of the test plot, Elbow Slough, after the application of malathion, and specified time intervals.

	BOX A		BOX B				
Hour	*P. aztecus*	*P. setiferus*	*P. aztecus*	*P. setiferus*	Salinity ppt	Water Temperature °C	Tide
1 hr.	2	0	0	0	17	28	Medium
3 hr.	3	1	1	0	18	20	Medium
6 hr.	5	2	1	1	20	33	Medium
9 hr.	5	6	3	3	18	33	High
25 hr.	6	8	3	8	18	27	Medium
33 hr.	6	8	3	8	20	35	Low
49 hr.	8	8	3	9	18	27	Medium

of *P. setiferus* was observed at the end of 6 hours. The mortality increased through 25 hours (Table 14, page 123).

Temperature in Elbow Slough, during the test, fluctuated between 20 and 35°C with highs recorded in the late afternoon and lows recorded in the morning. Salinity fluctuated between 17 and 20 ppt (Table 14, page 123).

In Box A of Elbow Slough, *P. aztecus* suffered 74 percent mortality and *P. setiferus*, 31 percent mortality. The combined percents mortality of both shrimp, in Box A, was 43 percent. In Box B, *P. aztecus* suffered 25 percent mortality, *P. setiferus*, 37 percent mortality, both shrimp exhibiting a combined mortality of 30 percent (Table 15, page 125).

In Box A and Box B of the control plot, Oyster Slough, no mortalities were attributed to malathion. At the end of 33 hours, extreme low tides, in the control plot, exposed Box B killing all the shrimp. No other deaths occurred in the control plot (Table 16, page 126).

Temperature in the control plot ranged between 27 and 33°C with lows recorded in the mornings and highs recorded in the late afternoons. Salinity fluctuated between 10 and 28 ppt.

Malathion Field Test No 3.

Analysis of water samples and tissue samples of shrimp, *P. setiferus*, taken from Bastrop Bay exhibited no measurable trace of malathion. Water samples taken from the test plots,

TABLE 15. Malathion field test No 2. indicating the mortality and percentage of mortality of shrimp in Elbow Slough after the application of malathion.

ELBOW SLOUGH TEST PLOT

Box A Stocked With 37 Shrimp				Box B Stocked With 36 Shrimp			
Species	No. of Shrimp	Mortality	Percent Mortality	Species	No. of Shrimp	Mortality	Percent Mortality
P. aztecus	11	8	74%	*P. aztecus*	12	3	25%
P. setiferus	26	8	31%	*P. setiferus*	24	9	37%
		Total Mortality	43%			Total Mortality	30%

TABLE 16. Malathion field test No 2. indicating the mortality and percentage of mortality of shrimp in Oyster Slough, control plot, after the application of malathion.

OYSTER SLOUGH CONTROL PLOT							
	Box A Stocked With 37 Shrimp				Box B* Stocked With 27 Shrimp		
Species	No. of Shrimp	Mortality	Percent Mortality	Species	No. of Shrimp	Mortality	Percent Mortality
P. aztecus	12	0	--	*P. aztecus*	12	0	--
P. setiferus	24	0	--	*P. setiferus*	15	0	--

*Low tide completely exposed Box B at 33 hours and all shrimp were lost.

Alligator and Elbow Sloughs, and the control plots, Oyster Slough and Alligator Lake, at the time of stocking and water and shrimp samples taken from the test and control plots one hour before the application of malathion exhibited no trace of the pesticide (Table 17, page 128; Table 18, page 129).

Water temperatures in the test and control plots at the time of stocking and one hour before the application of malathion were approximately the same, but the salinity in Bastrop Bay was lower than the salinity in the test and control plots (Table 17, page 128; Table 18, page 129).

The first mortalities, two shrimp, were observed in the Box A of the test plot, Alligator Slough, 3 hours after the application of malathion. The only other death in Box A was observed at the end of 24 hours. In Box B of Alligator Slough, only one death occurred, this at the end of 24 hours (Table 19, page 130).

Shrimp in Box A exhibited a 12 percent mortality, and Box B, 4 percent mortality; shrimp in both boxes exhibited an 8 percent total mortality. The temperature in Alligator Slough ranged between 27 and 32°C. Salinity fluctuated between 23 and 25 ppt (Table 19, page 130).

Analysis of water samples showed the presence of malathion, 2.0 ppm, at the end of one hour, and a reduction of the pesticide occurring through 24 hours (Table 19, page 130). In the tissue analysis of the shrimp found dead in Box A at the end of 3 hours,

TABLE 17. Malathion field test No 3. indicating the amount of pesticide present in water samples and shrimp samples obtained from Bastrop Bay and test plots, when stocked, and one hour before the application of malathion.

	Malathion ppm Water Samples	Malathion ppm *P. setiferus*	Water Temperature °C	Salinity ppt
Bastrop Bay	0.00	(1) 0.00 (2) 0.00	30	11
Alligator Slough Test Plot When Stocked	0.00		28	22
Alligator Slough Test Plot 1 Hour After Application of Malathion	0.00	(1) 0.00 (2) 0.00	27	23
Elbow Slough Test Plot When Stocked	0.00		28	23
Elbow Slough Test Plot 1 Hour After Application of Malathion	0.00	(1) 0.00 (2) 0.00	28	27

TABLE 18. Malathion field test No 3. indicating the amount of pesticide present in water samples and shrimp samples obtained from the control plots, when stocked, and one hour before the application of malathion.

	Malathion ppm Water Samples	Malathion ppm *P. setiferus*	Water Temperature °C	Salinity ppt
Oyster Slough Control Plot When Stocked	0.00		34	32
Oyster Slough Control Plot 1 Hour Before the Application of Malathion	0.00	(1) 0.00 (2) 0.00	28	22
Alligator Lake Control Plot When Stocked	0.00		32	29
Alligator Lake Control Plot 1 Hour Before the Application of Malathion	0.00	(1) 0.00 (2) 0.00	26	22

TABLE 19. Malathion field test No 3. indicating the amount of pesticide present in water samples, the cumulative mortality counts of shrimp in the test plot, Alligator Slough, at specified time intervals after the application of malathion, and the percentage of mortality of shrimp in each box.

Hour	Malathion ppm Water Samples	Mortality of *P. setiferus* (25 *P. setiferus* in each box) Box A	Box B	Water Temperature °C	Salinity ppt	Tide
1 hr.	2.00	0	0	28	23	Low
3 hr.	2.00	2	0	31	25	Medium
8 hr.	1.50	2	0	32	25	High
24 hr.	1.20	3	1	27	24	Medium
Percent Mortality		12%	4%			
Total Percent Mortality		8%				

malathion ranged from 0.88 to 1.09 ppm. The one shrimp found dead in Box A, at 24 hours had a malathion concentration of 1.22 ppm (Table 20, page 132).

Tissue analysis of live shrimp taken from Box A, at 1 hour, exhibited malathion values of 0.51 and 0.65 ppm (Table 21, page 133). Tissue analysis of live shrimp taken at 3 hours exhibited malathion concentrations ranging higher than in dead shrimp taken at a comparable time (Table 20, page 132; Table 21, page 133). The amount of malathion extracted from live shrimp, taken at 8 and 24 hours after the application of malathion, continued to rise in amounts above the malathion content of dead shrimp taken at the same check periods. The highest malathion concentration extracted from the shrimp, 2.61 ppm, was obtained from a live shrimp taken at the end of 24 hours (Table 21, page 133).

Tissue analysis of the one dead shrimp found at the end of 24 hours in Box B of Alligator Slough had a malathion content of 0.94 ppm (Table 20, page 132).

Analysis of live shrimp taken from Box B of Alligator Slough exhibited a similar trend as the live shrimp taken from Box A. Live shrimp taken from Box B, one hour after the application of malathion, exhibited malathion contents ranging from 0.28 to 0.32 ppm. The amount of malathion extracted from live shrimp taken at 3, 8, and 24 hours continued to increase, as the time

TABLE 20. Malathion field test No 3. Tissue analysis of dead shrimp obtained from Boxes A and B of Alligator Slough, test plot, after the application of malathion.

Hour	Species *P. setiferus*	Length mm	Weight gr	Weight of Tail gr	Malathion ppm
Box A					
3 hr.	1	78	1.80	1.30	1.09
	2	80	2.51	1.39	0.88
24 hr.	1	74	2.27	1.04	1.22
Box B					
24 hr.	1	70	1.27	0.58	0.94

TABLE 21. Malathion field test No 3. Tissue analysis of shrimp taken alive from Boxes A and B of Alligator Slough, test plot, after the application of malathion.

Hour	Species *P. setiferus*	Length mm	Weight gr	Weight of Tail gr	Malathion ppm
<u>Box A</u>					
1 hr.	1	75	1.88	0.94	0.65
	2	77	1.89	0.97	0.51
3 hr.	1	64	1.45	0.72	2.10
	2	65	1.39	0.67	1.65
8 hr.	1	84	3.35	1.79	2.60
	2	87	3.52	1.84	2.23
24 hr.	1	70	1.38	0.69	2.01
	2	72	1.32	0.64	2.61
<u>Box B</u>					
1 hr.	1	79	2.65	1.39	0.32
	2	80	2.58	1.24	0.28
3 hr.	1	77	2.23	1.25	1.00

TABLE 21. Continued.

Hour	Species *P. setiferus*	Length mm	Weight gr	Weight of Tail gr	Malathion ppm
3 hr.	2	78	2.52	1.46	0.78
8 hr.	1	87	3.84	2.28	0.97
	2	89	3.94	2.37	1.72
24 hr.	1	86	3.40	1.89	1.70
	2	86	3.59	1.93	1.57

of exposure increased but in amounts below those obtained from comparable live shrimp taken from Box A (Table 21, page 133).

In Box A of the test plot, Elbow Slough, three dead shrimp were observed 3 hours after the application of malathion. At the end of 8 hours, seventeen dead shrimp were observed in Box A, representing the highest mortality observed in all three field tests conducted. No more deaths were observed in Box A. In Box B, three dead shrimp were observed at the end of 3 hours. The number of mortalities decreased to two deaths at 8 hours and one death at 24 hours (Table 22, page 136).

Shrimp in Box A of Elbow Slough exhibited a mortality rate of 80 percent; Box B, 24 percent; the average percent mortality of shrimp in both boxes was 52 percent (Table 22, page 136).

The temperature in Elbow Slough fluctuated between 27 and 35°C with the highest temperatures recorded in the afternoon and the lowest recording in the morning. Salinity fluctuated between 25 and 37 ppt (Table 22, page 136).

Analysis of water samples showed the presence of 2.5 ppm malathion at the end of one hour. Malathion content in the water increased to 3.2 ppm at 3 hours, dropped to 2.4 ppm by the end of 8 hours and decreased to 2.2 ppm by the end of 24 hours (Table 22, page 136).

Tissue analysis of dead shrimp found in Box a of Elbow Slough, at the end of 3 hours, showed no measurable trace of malathion in one shrimp and 0.92 ppm in the remaining two shrimp.

TABLE 22. Malathion field test No 3. indicating the amount of pesticide present in water samples, the cumulative mortality counts of shrimp in the test plot, Elbow Slough, at specified time intervals after the application of malathion, and the percentage of mortality of shrimp in each box.

Hour	Malathion ppm Water Samples	Mortality of *P. setiferus* (25 *P. setiferus* in each box) Box A	Box B	Water Temperature °C	Salinity ppt	Tide
1 hr.	2.50	0	0	28	27	Low
3 hr.	3.20	3	3	33	37	Medium
8 hr.	2.40	17	2	35	27	High
24 hr.	2.20	0	1	27	25	Medium
Percent Mortality		80%	24%			
Total Percent Mortality		52%				

Dead shrimp taken at the end of 8 hours showed no measurable trace of malathion in two shrimp and values ranging between 0.55 and 1.21 ppm in the remaining fifteen shrimp (Table 23, page 138).

Tissue analysis of live shrimp from Box A of Elbow Slough one hour after the application of malathion exhibited values ranging from 0.78 to 1.00 ppm. These values were comparable to values obtained from dead shrimp taken during the same time period. Analysis of live shrimp taken at 3 hours ranged from 1.92 to 2.36 ppm. The one live shrimp taken at the end of 8 hours exhibited a malathion concentration of 2.67 ppm, the highest malathion level in a shrimp, dead or alive, taken from Box A (Table 24, page 141).

Tissue analysis of shrimp found dead in Box B, 3 hours after the application of malathion, exhibited values ranging from 0.41 to 0.97 ppm. The malathion content of dead shrimp taken at 8 hours ranged from 1.21 to 1.37 ppm. At 24 hours, the one shrimp examined contained 0.89 ppm (Table 23, page 138).

Tissue analysis of two live shrimp taken from Box B one hour after the application of malathion showed no malathion in one and a value of 0.39 ppm in the other (Table 24, page 141). Live shrimp examined from collections at 3, 8, and 24 hours showed increased uptake of malathion with increased exposure. The highest malathion concentration recorded from live shrimp taken from Box B, at the end of 24 hours, was 2.27 ppm. In Elbow

TABLE 23. Malathion field test No 3. Tissue analysis of dead shrimp found in Boxes A and B of Elbow Slough after the application of malathion.

Hour	Species *P. setiferus*	Length mm	Weight gr	Weight of Tail gr	Malathion ppm
Box A					
3 hr.	1	78	2.42	1.37	0.92
	2	78	2.57	1.43	
	3	80	2.57	1.50	0.92
8 hr.	1	62	1.50	0.79	1.05
	2	63	1.42	0.75	0.90
	3	64	1.55	0.75	0.81
	4	64	1.56	0.84	0.67
	5	65	1.49	0.77	0.73
	6	65	1.60	0.87	0.65
	7	67	1.43	0.81	
	8	68	2.05	1.08	0.90
	9	70	1.87	1.12	0.55

TABLE 23. Continued.

Hour	Species *P. setiferus*	Length mm	Weight gr	Weight of Tail gr	Malathion ppm
8 hr.	10	68	1.56	0.84	1.21
	11	69	1.71	0.92	0.72
	12	72	2.01	1.06	0.57
	13	77	1.84	1.21	0.93
	14	78	2.57	1.53	0.88
	15	78	2.71	1.32	
	16	80	3.27	1.94	1.14
	17	90	3.73	2.21	1.01
Box B					
3 hr.	1	72	1.74	0.92	0.41
	2	80	2.57	2.31	0.41
	3	130	13.30	7.38	0.97
8 hr.	1	60	0.90	0.30	1.21

TABLE 23. Continued.

Hour	Species *P. setiferus*	Length mm	Weight gr	Weight of Tail gr	Malathion ppm
8 hr.	2	61	0.94	0.39	1.37
24 hr.	1	76	2.61	1.59	0.89

TABLE 24. Malathion field test No 3. Tissue analysis of shrimp taken alive from Boxes A and B of Elbow Slough, test plot, after the application of malathion.

Hour	Species *P. setiferus*	Length mm	Weight gr	Weight of Tail gr	Malathion ppm
Box A					
1 hr.	1	74	2.38	1.31	1.00
	2	75	2.46	1.44	0.78
3 hr.	1	70	1.91	1.09	1.92
	2	71	1.87	1.15	2.36
8 hr.	1	73	1.84	1.06	2.67
Box B					
1 hr.	1	65	1.51	0.79	
	2	67	1.43	0.57	0.39
3 hr.	1	65	1.67	0.54	0.46
	2	65	1.46	0.47	0.37
8 hr.	1	68	1.81	0.76	1.64
	2	72	1.55	0.41	2.08

TABLE 24. Continued.

Hour	Species *P. setiferus*	Length mm	Weight gr	Weight of Tail gr	Malathion ppm
24 hr.	1	67	1.72	0.83	1.63
	2	68	1.69	0.71	2.27

Slough, analysis of live shrimp taken from Box A gave malathion values far exceeding those obtained from tissue analysis of live shrimp taken from Box B (Table 21, page 133; Table 24, page 141).

No mortality was observed in the control plots, Oyster Slough and Alligator Lake, during the test. Water analysis of samples taken from Oyster Slough at 1, 3, 8, and 24 hours, after the application of malathion, showed no measurable trace of the pesticide. Water samples from Alligator Lake showed a low concentration of malathion at the end of 24 hours (Table 25, page 144). Tissue analysis of live shrimp taken from the control plots at 1, 3, 8, and 24 hours exhibited no measurable trace of malathion.

Temperatures in Oyster Slough ranged from 30 to 35°C; salinity fluctuated between 32 and 34 ppt. In Alligator Lake the temperature ranged between 28 and 32°C; salinity fluctuated between 30 and 32 ppt (Table 25, page 144).

Spot checks of both the water samples and shrimp tissue samples were run on thin layer chromatographs to verify the gas chromatography. These showed malathion to be present in both and demonstrated that the peaks obtained by gas chromatography were malathion.

TABLE 25. Malathion field test No 3. indicating the amount of pesticide present in water samples taken from the control plots Oyster Slough and Alligator Lake after the application of malathion.

	OYSTER SLOUGH			ALLIGATOR LAKE		
Hour	Malathion ppm Water Samples	Water Temperature °C	Salinity ppt	Malathion ppm Water Samples	Water Temperature °C	Salinity ppt
1 hr.	0.00	31	32	0.00	31	32
3 hr.	0.00	32	32	0.00	32	32
8 hr.	0.00	30	33	0.00	31	30
24 hr.	0.00	35	34	0.19	28	30

Discussion of Section II

In all three mosquito control malathion tests, the commercial shrimp *Penaeus aztecus* and *Penaeus setiferus* suffered mortality rates ranging from 14 to 80 percent, while the control shrimp suffered no deaths attributed to the pesticide. Variations in the mortality rate are attributed to other factors and will be discussed. As tissue analyses were performed on shrimp in tests No 1. and 3., these tests will be discussed first.

Malathion Field Test No 1.

In malathion field test No 1., high mortalities of *P. aztecus* were observed in both boxes of the test plot at the end of 9 hours and continued, at a diminishing rate, through 48 hours. Water analysis demonstrated a parallel high concentration of malathion 9 hours after the application and a progressive reduction of the pesticide at 24, 33, and 48 hours after application.

Tissue analysis of dead shrimp, removed from test plot Boxes A and B at 9 hours, showed the presence of malathion; the amount increasing at 24 hours, and a decreasing at 33 hours after the application of the pesticide. Concentrations of pesticide in dead shrimp from Boxes A and B were approximately the same at the end of 9 hours, but at 24 and 33 hours after the application of the pesticide its concentration in dead shrimp from Box B was somewhat higher than the concentration found in dead shrimp from

Box A. It seems probable that dead shrimp with higher concentrations of malathion, collected at the same time as dead shrimp with lower pesticide values, had died at a later time and as a result had more time in which to accumulate the pesticide. While it is impossible to tell exactly when a shrimp died during the test from pesticide values of live shrimp taken during the study, it is possible to pinpoint the concentration of pesticide around each box during the study. Tissue analysis of live shrimp taken from Boxes A and B of the test plot at 9, 24, 33, and 48 hours after the application of malathion followed the same pattern as dead shrimp taken during the same period. Malathion values in live shrimp taken from boxes during the test were consistently higher than the values obtained from dead shrimp removed during the same period, as would be expected if malathion levels are proportional to exposure time. Malathion concentrations in live shrimp increased to a peak 24 hours after the application of the pesticide then declined through 48 hours. At each check period following the application, live shrimp from Box B exhibited higher malathion values than comparable shrimp taken from Box A. This very likely indicates a higher concentration of malathion around Box B during the test. There was a medium tide at the time of application and a low tide 9 hours later. The slightly higher mortalities and higher malathion concentration of live shrimp taken from Box B were most probably due to receding tidal currents moving the major target waters through Box B when the concentration of malathion in the water was at its peak.

Malathion Field Test No 3.

Malathion field test No 3., on *P. setiferus*, exhibited parallel results with test No 1., on *P. aztecus*, even though a new test was introduced in Elbow Slough. The mortality of *P. setiferus* in Alligator Slough was lower, due to tidal activities during the test. At the time of application of the pesticide the tide was low but it rose sharply during the first 8 hours and thereby pushed much of the target water out of the test plot into the marsh. Water analysis showed the presence of malathion one hour after the application and a marked decline at the end of 24 hours. In Elbow Slough as there was no free flow of water, the tide had an opposite effect. A rise in tide pushed the target waters into the upper end of the slough thereby concentrating the malathion on the shrimp in Box A. The extremely high mortalities of *P. setiferus* in Box A of Elbow Slough at the end of 8 hours were due to the high concentration of malathion in the water. Substantial mortalities of *P. setiferus* were also observed in Box B.

Tissue analysis of dead shrimp taken from Alligator and Elbow Sloughs in test No 3. showed parallel results to dead *P. aztecus* taken from boxes in test No 1. The dead specimens of *P. setiferus* showed the presence of malathion 3 hours after the application of the pesticide and an increase in malathion concentration 24 hours after the application. As test No 3. was terminated at the end of 24 hours, no reduction of malathion content in shrimp in Boxes A and B from Alligator Slough and Box A from Elbow Slough was recorded. Only one dead shrimp taken from Box B of Elbow Slough, taken at 24 hours, exhibited a reduction of malathion content.

Analysis of live shrimp taken from the test plots, Alligator and Elbow Sloughs, showed parallel results to test No 1. The live specimens of _P. setiferus_ removed from the boxes exhibited an increased malathion content with increase in time of exposure. Amounts were above the values observed in dead shrimp taken at comparable times. The malathion values exhibited by these shrimp were above the laboratory EC_{50} values exhibited by _P. duorarum_ reported by Butler (1963). As an EC_{50} value is the concentration of pesticide in sea water causing the loss of equilibrium or death in 50 percent of the shrimp tested, this indicates that the other 50 percent of the shrimp tested suffered no apparent ill effects. The shrimp that survived Butler's test and the shrimp in this study may have possessed a resistance to the pesticide. Tolerance of Crustacea to pesticides has been demonstrated in the field and in the laboratory (Naqvi and Ferguson, 1968). It could be hypothesized that shrimp demonstrating a tolerance to malathion, could continue to accumulate the pesticide, whereas a dead shrimp could no longer actively accumulate the pesticide or even lose pesticide through leaching to the surrounding medium. The loss of pesticide in the living shrimp, as observed towards the end of the field test No 1., is probably due to malathion breakdown with the passage of time and the shrimp's ability to rid its system of the pesticide when the level of pesticide in the surrounding medium dropped to a lower value.

Malathion Field Test No 2.

As the field conditions, tide, temperature, and salinity were different in test No 1. and test No 3., no reasonable comparison in sensitivity of *P. aztecus* and *P. setiferus* to malathion can be made. In field test No 2., where the two shrimp were tested simultaneously, some indication to the comparative sensitivity can be made. In field test No 2., *P. aztecus* and *P. setiferus* were checked one hour after application of malathion. In both Box A and B of Alligator Slough, the highest mortality was exhibited by *P. aztecus* even though there was a lower percentage of *P. aztecus* in the cages. The first mortalities of *P. aztecus* were recorded 3 hours after the application of malathion. The first and only death of *P. setiferus*, in Box B, was observed at the end of 25 hours. In Box A, the first mortalities of both shrimp were observed at the end of 25 hours with a 3 to 1 mortality ratio of *P. aztecus* to *P. setiferus*. In Box A of Elbow Slough, the highest mortality was exhibited by *P. aztecus* even though it was present in a lower percentage in the box.

Mortalities of *P. aztecus* were observed 1 hour after the application of malathion.

At 6 hours the peak mortality of *P. aztecus* was observed. The first mortality of *P. setiferus* was observed at the end of 3 hours, and the peak mortality of this shrimp was not observed until the end of 9 hours. In Box B, the first death of *P. aztecus* was found 3 hours after the application of malathion and the peak mortality occurred at the end of 9 hours. No dead specimens of *P. setiferus* were observed until the end of 6 hours, but by the end of 25 hours, this shrimp exhibited a higher mortality than *P. aztecus* in Box B.

These field tests indicate that *P. aztecus* possess a faster and, in most cases, a greater sensitivity to malathion than *P. setiferus*. It is obvious that tidal activity can alter the exposure of the shrimp to malathion by moving the target water in or out of the area or by concentrating the affected water on the shrimp. Salinity probably had no effect on the tests. Higher temperatures could possibly alter the effects of malathion on shrimp by causing higher metabolic activity, thereby, facilitating a more rapid uptake of the pesticide.

SECTION III

LENGTH-WEIGHT RELATIONSHIPS AND COEFFICIENT OF CONDITION IN *PENAEUS AZTECUS* AND *PENAEUS SETIFERUS*

Results and Discussion

As discussed by Le Cren (1951), the length-weight relationship of most fish can be described by the exponential function:

$$W = aL^n$$

where *W* is weight, *L* is length, *a* is a constant, and *n* is an exponent usually lying between 2.5 and 4.0 (Hile, 1936; Marlin, 1949). For an ideal fish, which maintains the same shape over the size range under consideration, $n = 3$. Most species, including the penaeid shrimp, however, change shape as they grow, and the cube relationship between length and weight does not hold ($n \neq 3$) (Chin, 1960; Parker, 1966). In order to deal with these data in terms of regression some means of linear transformation is necessary. When the log of length is plotted against the log of weight this relationship becomes linear and can be dealt with by simple linear regression techniques. Rewriting the above equation in terms of this log transformation an equation in the linear form $Y = a + nx$ is obtained.

$$W = aL^n$$

$$\log W = \log (aL^n)$$

$$\log W = \log a + n \log L$$

Log a represents the point at which the regression line intercepts the log W axis and n represents the slope of the line. The log a intercept is computed as:

$$\log a = \overline{\log W} - n\ \overline{\log L}$$

and the slope of the line (n) as:

$$n = \frac{\Sigma \log L \log W - \dfrac{\Sigma \log L\ \Sigma \log W}{n}}{\Sigma \log L^2 - \dfrac{(\Sigma \log L)^2}{n}}$$

The length-weight relationship can be used to compare the condition of different groups of shrimp provided the shrimp within the groups span a wide size range and the groups do not differ significantly in size. The procedure involves first, the computation of the length-weight relationship for each group, second, a test for homogeneity of n between groups (if the values of n differ significantly, further analysis will have little relevance); and third, a comparison of the log a values. When it can be shown that n is the same for different groups of shrimp, the values of a for each group represent a direct measure of their condition relative to each other (Le Cren, 1951).

Individual variations of fish or variations of groups spanning a small size range are usually analyzed by means of a condition factor. The condition factor usually applied by fishery researchers is computed by the formula:

$$K = \frac{W \times 10^5}{L^3}$$

This equation is based on the ideal form of a fish where, in the length-weight relationship formula $W = aL^n$, $n = 3$, and the cube law is obeyed. When $n \neq 3$, as in shrimp, K computed by this formula changes with size (Le Cren, 1951). The effect of length on K, however, can be eliminated by computing a condition factor based on the empirical length-weight relationship. The condition factor in this case is called the "relative condition factor" (proposed by Le Cren, 1951) and is calculated from the formula:

$$K_n = \frac{W}{aL^n}$$

which in practice is calculated from the formula:

$$K_n = \frac{W}{\hat{W}}$$

where $\hat{W}$ is the antilog of log W in the length-weight equation. The difference between K_n and K is that the former is measuring the deviation of an individual from the average weight for length, while the latter is measuring the deviation from a hypothetical ideal fish. The choice of which condition factor to be used must be based to some extent on which of these two comparisons is most relevant. Hile (1936) contended that a condition factor calculated from an empirical formula (K_n) fails to measure any change in form associated with change in length. Le Cren (1951) noted that a change in form or condition associated with length is accurately described by the value of the exponent n. With the relative condition factor it is possible to distinguish between and measure separately the influences on condition of factors not associated with length, whereas these are not readily separated when the ordinary factor (K) is used. Legler (1956) acknowledged the validity of Le Cren's proposal within populations in which the length-weight relationship does not vary too erratically with year of season, but noted difficulty when comparing indices based on different regressions and favored the use of K in spite of its limitations.

For the purposes of this study the arguments of Le Cren (1951) were accepted, and K_n was used as a measure of relative condition.

In an effort to further evaluate the condition of penaeid shrimp within the bays the length-weight relationships and condition factors for P. aztecus and P. setiferus were computed for the Oyster Lake and Alligator Lake complexes. The Oyster Lake complex consists of Oyster Lake and Oyster Slough. The Alligator Lake complex consists of Alligator Lake and Alligator Slough.

The length-weight relationships are presented in Table 26, page 156. A comparison of condition between areas for each species was accomplished by comparing the length-weight regression lines (Figure 42, page 157).

For P. aztecus a comparison of variances ($s^2y.x$) revealed significant differences. A comparison of slopes was made using Pearson and Hartley's (1958) test criterion (v) which considers variances which must be separately estimated.

$$v = \frac{n_1 - n_2}{\sqrt{\frac{s^2y.x_1}{\Sigma x_1^2} + \frac{s^2y.x_2}{\Sigma x_2^2}}}$$

For my data

$$v = \frac{2.91423 - 2.90952}{\sqrt{\frac{0.00341}{68.92888} + \frac{0.00505}{59.93971}}} = 0.4081 \quad d.f. = 2,123;\ 1,847$$

This value is not significant; therefore, the slopes of the lines can be assumed to be homogeneous and a comparison of the elevations of the lines is warranted. This was accomplished using Pearson and Hartley's test criteria (v) as follows:

$$v = \frac{\bar{d}_a}{\sqrt{s^2\bar{d}_a}}$$

TABLE 26. Length-weight data for *Penaeus aztecus* and *Penaeus setiferus* from the Oyster Lake and Alligator Lake complexes.

	Number of Shrimp	Length in mm	log a	n	Σx^2	Σxy	Σy^2	$s^2 y.x$
P. aztecus Oyster Lake Complex	1848	10 - 79	4.0919	2.9143	68.9288	200.8448	591.6811	.003405
P. aztecus Alligator Lake Complex	2124	10 - 79	4.0953	2.9095	59.9397	147.3955	518.1165	.005047
P. setiferus Oyster Lake Complex	3294	10 - 149	3.8704	2.7775	105.9811	294.3647	838.7384	.00642
P. setiferus Alligator Lake Complex	1611	10 - 149	4.0617	2.8917	95.9707	277.5146	817.7215	.00883

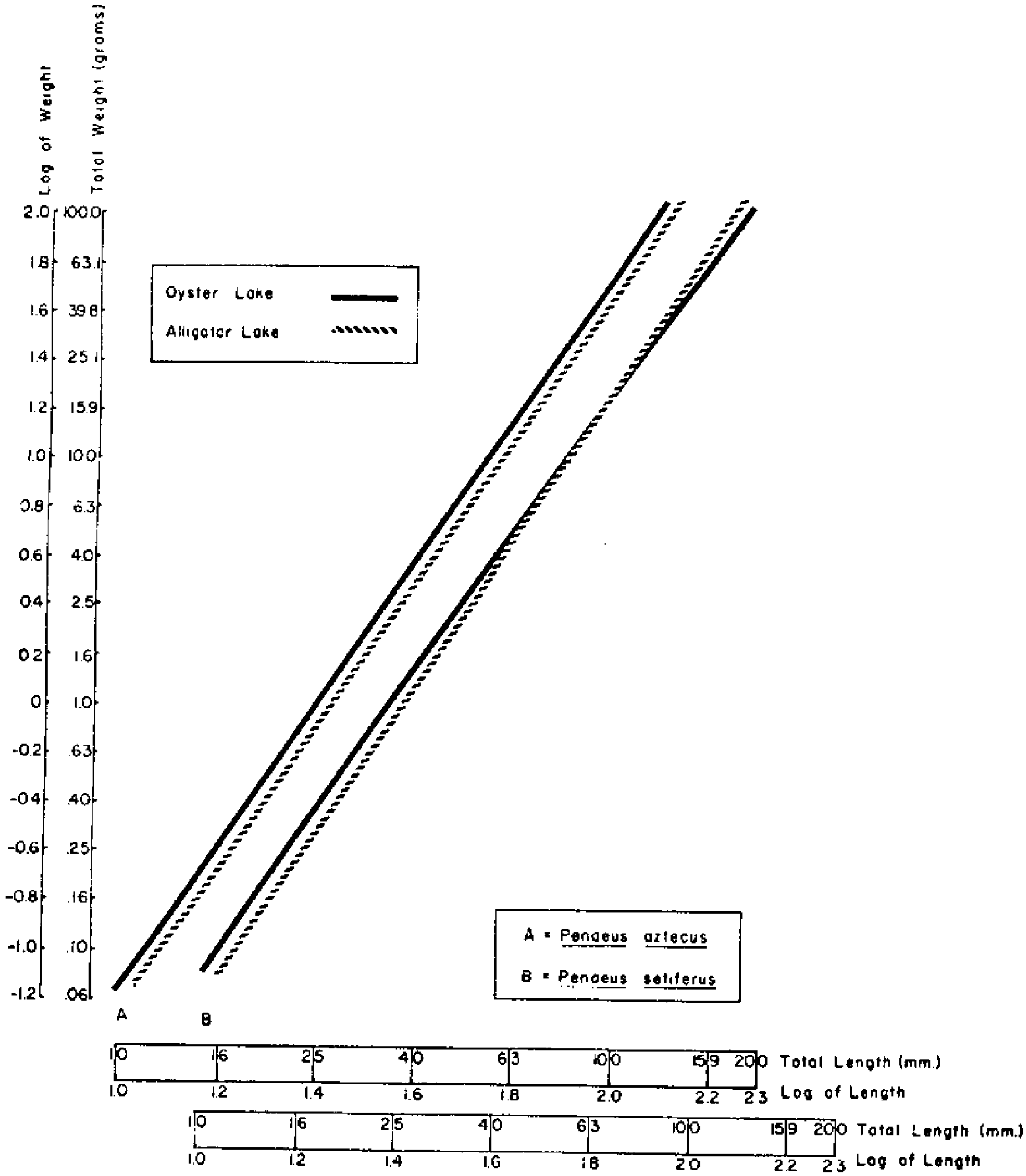

Figure 42. A comparison of length-weight regression lines for Penaeus aztecus and Penaeus setiferus in the Oyster Lake and Alligator Lake complexes.

For my data

$$v = \frac{0.0111}{0.00209} = 5.3099^{**}$$

As this value is significant at the .01 level, it can be concluded the elevations of the lines differ, significantly, indicating P. aztecus was in better condition in the Oyster Lake complex throughout the observed size range.

For P. setiferus a comparison of variances ($s^2y.x$) revealed that they differed significantly, and a comparison of slopes was made using Pearson and Hartley's test criterion (v).

$$v = \frac{2.89166 - 2.77752}{\sqrt{\frac{.00642}{105.9811} + \frac{.00883}{95.97609}}} = 9.2078 \quad \text{d.f.} = 3,294;\ 1,727$$

This value is significant at the .01 level, indicating that the difference in condition of P. setiferus from the Oyster Lake and Alligator Lake complexes varied with size. The extent of the variability can be seen in Figure 42, page 199. Small P. setiferus were in better condition in the Oyster Lake complex, but as size increased this difference shifted, for the larger shrimp were in better condition in the Alligator Lake complex. In the two areas shrimp were essentially the same size, same age class and were collected during the same time of year, and were not sexually mature. The cause of variation between the length-weight relationships is not known, but could represent environmental differences such as available food.

Further efforts to analyze the condition of the penaeid shrimp in both bay complexes involved an evaluation of change in condition with size, over time, and with temperature and salinity.

If condition changes with size ($n \neq 3$) the "cube-law" does not apply. The following t-test is used to determine the validity of the "cube-law" for both species of shrimp in both bay complexes.

$$t = \frac{n - 3}{\sqrt{s^2_{y.x} / \Sigma x^2}}$$

For my data

P. aztecus, Oyster Lake complex.

$$t = \frac{2.9142328 - 3}{\sqrt{\frac{.003405}{68.92888}}} = -12.03^{**} \quad \text{d.f.} = \infty$$

P. aztecus, Alligator Lake complex.

$$t = \frac{2.9095156 - 3}{\sqrt{\frac{.005047}{59.93971}}} = -9.8607^{**} \quad \text{d.f.} = \infty$$

P. setiferus, Oyster Lake complex.

$$t = \frac{2.7775214 - 3}{\sqrt{\frac{.00642}{105.9811}}} = -28.5848^{**} \quad d.f. = \infty$$

P. setiferus, Alligator Lake complex.

$$t = \frac{2.8916600 - 3}{\sqrt{\frac{.00883}{95.97069}}} = -11.2946^{**} \quad d.f. = \infty$$

In both bay complexes the t-values, significant to the .01 level, indicated that n was less than 3, and implied, according to Le Cren's (1951) interpretation, that condition decreased with increasing size.

An analysis of variation of condition over time was accomplished by comparing the monthly mean condition factors. A modification of Duncan's method (Kramer, 1956) was used to distinguish between means. The resulting differences and the confidence levels at which these differences were declared are presented in Table 26, page 156. As there was little difference separating the two slopes for *Penaeus aztecus* from the Oyster and Alligator Lake complexes (Figure 42, page 157), the data for both complexes were combined to provide a more comprehensive view of the condition of these shrimp by month. Condition of *P. aztecus*, over the entire study, is presented in Table 27, page 161). For the

TABLE 27. Analysis of monthly mean K_n for *Penaeus aztecus* from both the Oyster Lake and Alligator Lake complexes.

Analysis of Variance for K_n

Sources of Variation	d.f.	SS	MS	F
Among Month	14	27.060729	1.93290924	101.982106
Within Months	3959	75.03644	.018953383	
Total	3973	1.0209717		

Month	Number of Shrimp	Mean K_n	Confidence Level .05
July 68	124	0.95884	
May 68	1933	0.97905	
June 68	747	1.00078	
April 68	827	1.00522	
Aug. 68	15	1.02461	
Dec. 67	21	1.04141	
Nov. 67	19	1.05120	
Oct. 67	6	1.06302	
Sept. 68	11	1.15697	
Jan. 68	2	1.24232*	
May 69	76	1.24417	
Mar. 69	1	1.28873*	
April 69	170	1.32713	
July 69	18	1.32735	
Oct. 68	4	1.56691*	

*Mean K_n not included in confidence level comparison because of low number of observations.

calendar year 1968 condition was highest in September, and lowest in May, June, and July. Shrimp collected in January and October, although exhibiting a high condition factor, were excluded due to the low number of observations. Shrimp taken in late 1967 exhibited a condition factor equal to shrimp in the best of condition in 1968. The highest condition of _P. aztecus_ was observed in April and July, 1969.

Condition of _P. setiferus_, in the Oyster Lake complex (Table 28, page 163), for the calendar year 1968 was highest in October and August. Shrimp taken in July and September were in better condition than those taken in May and June. During 1968 the condition of _P. setiferus_ was lowest in November. Shrimp taken in late 1967 exhibited a condition factor equal to those in the best condition in 1968. Although few observations were made on _P. setiferus_ in 1969, shrimp taken in sufficient numbers in July, exhibited a high condition factor.

Condition of _P. setiferus_, in the Alligator Lake complex (Table 29, page 164), for the calendar year 1968, was highest in October. Shrimp taken in August and September were in better condition than those taken in July. Condition of _P. setiferus_ was lowest in May, June, and November. Shrimp taken in 1967 were in the best condition in November. _P. setiferus_ taken in February, March, and August of 1969 were in the best condition.

The effect of temperature and salinity on condition of penaeid shrimp was determined through a multiple regression of

TABLE 28. Analysis of monthly mean K_n for <u>Penaeus setiferus</u> from the Oyster Lake complex.

Analysis of Variance for K_n

Sources of Variation	d.f.	SS	MS	F
Among Month	13	14.3463076	1.02473626	37.9809954
Within Months	3281	88.4951777	.0026980237	
Total	3294	102.841489		

Month	Number of Shrimp	Mean K_n	Confidence Level .05
Nov. 68	6	0.710194	]
June 68	108	0.933597	⌉
May 68	450	0.944381	⌋
July 68	231	0.988439	⌉
Sep. 68	1822	1.003649	⌋
Nov. 67	266	1.067611	⌉
Dec. 67	36	1.108780	|
Oct. 67	68	1.110403	|
Oct. 68	219	1.160132	|
July 69	35	1.188056	|
Aug. 68	46	1.200506	⌋
Mar. 69	2	1.315148*	
Jan. 68	1	1.416920*	
Aug. 69	3	1.435405*	
May 69	2	1.584876*	

*Mean K_n not included in confidence level comparison because of low number of observations.

TABLE 29. Analysis of monthly mean K_n for *Penaeus setiferus* from the Alligator Lake complex.

Analysis of Variance for K_n

Sources of Variation	d.f.	SS	MS	F
Among Month	13	32.179881	2.4753755	72.9913815
Within Months	1715	58.161235	3.3913256	
Total	1728	90.341149		

Month	Number of Shrimp	Mean K_n	Confidence Level .05
Nov. 68	229	0.774085	
May 68	78	0.855035	
June 68	138	0.873381	
July 68	109	0.954597	
Sept. 68	573	1.07096	
Oct. 67	191	1.07927	
Dec. 67	52	1.081226	
Aug. 68	95	1.120550	
July 69	13	1.198090	
Mar. 69	5	1.198274	
Oct. 68	33	1.206711	
Nov. 67	189	1.206879	
Feb. 69	2	1.233101*	
Aug. 69	22	1.240185	

*Mean K_n not included in confidence level comparison becuase of low number of observation.

these parameters on K_n. The analysis of variance, the t-test used to test the partial regression coefficients, and the regression equations for *P. aztecus* in both complexes are presented in Table 30, page 166; for *P. setiferus* in the Oyster Lake complex, Table 31, page 167; and for *P. setiferus* in the Alligator Lake complex, Table 32, page 168. In both lake complexes the condition of *P. aztecus* decreased with increasing temperature; however, condition increased with increasing salinity (Table 30, page 166). Condition of *P. setiferus*, in the Oyster Lake complex, decreased with increasing temperature and salinity (Table 31, page 167), however, in the Alligator Lake complex the condition of *P. setiferus* increased with increased temperature and salinity (Table 32, page 168). This contradiction is either inexplicable or indicates that other factors, such as available food, are more significant.

TABLE 30. Multiple regression analysis of temperature and salinity on the condition of *Penaeus aztecus* from both the Oyster Lake and Alligator Lake complexes.

Analysis of Variance for K_n

Sources of Variation	d.f.	SS	MS	F
Due to Regression	2	2.613641	1.3068199	50.811386
Error	3434	88.319168	.025719035	
Total	3436	90.932823		

K_n = 1.16387 + -0.00613 X_1 + 0.00313 X_2

t for b_1 = -6.74655

t for b_2 = 5.14484

X_1 = Temperature °C

X_2 = Salinity °/oo

TABLE 31. Multiple regression analysis of temperature and salinity on the condition of *Penaeus setiferus* from the Oyster Lake complex.

Analysis of Variance for K_n

Sources of Variation	d.f.	SS	MS	F
Due to Regression	2	7.099962	3.5499811	122.06343
Error	3292	95.741516	.02908308	
Total	3294	102.84149		

K_n = $1.47373 - 0.01544\ X_1 - 0.00295\ X_2$

t for b_1 = -15.02386

t for b_2 = - 4.39830

X_1 = Temperature °C

X_2 = Salinity °/oo

TABLE 32. Multiple regression analysis of temperature and salinity on the condition of Penaeus setiferus from the Alligator Lake complex.

Analysis of Variance for K_n

Sources of Variation	d.f.	SS	MS	F
Due to Regression	2	9.6841726	4.8420858	101.50618
Error	1609	76.753113	.047702368	
Total	1611	86.437287		

$K_n = 0.536171 + 0.01346783\ X_1 + 0.010875885\ X_2$

t for b_1 = 10.860768

t for b_2 = 12.988596

X_1 = Temperature °C

X_2 = Salinity $^o/oo$

SUMMARY

1. Palaemonetes vulgaris and Palaemonetes pugio can survive in waters with a wide range of temperature and salinity. P. vulgaris was found in Oyster Lake throughout the study with its greatest sampled abundance in early April, 1968. Few P. vulgaris were found in Alligator Lake. P. pugio was found to be abundant in Alligator Lake, especially in late April, 1968 and 1969. Few P. pugio were found in Oyster Lake.
2. Average salinity may be an important factor influencing the distribution of Palaemonetes vulgaris and Palaemonetes pugio. The greater abundance of P. vulgaris in Oyster Lake, with a mean salinity of 17.9 ppt, contrasts with the greater abundance of P. pugio in Alligator Lake, with a mean salinity of 12.6 ppt.
3. Periclimenes longicaudatus was collected once in Oyster Lake in late December, 1967, but probably does not inhabit Oyster and Alligator Lakes in any abundance.
4. Tozeuma carolinense was collected once in Oyster Lake in late November, 1967, but probably does not inhabit Oyster and Alligator Lakes in any abundance.
5. Acetes americanus appeared in abundance in both bays during periods of high water temperature and increased salinities following periods of increased freshets due to heavy rains.

Its largest sampled abundance appeared in Oyster Lake in late August, 1968. Its distribution appears to be governed by salinity as it is found in greater numbers in the higher salinity of Oyster Lake.

6. Mysidopsis almyra was collected in Oyster and Alligator Lakes in all seasons throughout the study. In Oyster Lake this species exhibited three peak abundances, from late December, 1967 through early May, 1968, early August through late September, 1968, and early March, 1969 through late May, 1969.

7. Mysidopsis almyra peaked in abundance in Alligator Lake, from early November, 1967 through early June, 1968, early July through early September, 1968, and early February through late March, 1969.

8. In general peak abundances of M. almyra, in Alligator Lake, were more intense and longer in duration than those observed in Oyster Lake. Even though euryhaline, this species to a greater extent inhabits bay waters of relatively lower salinity, Alligator Lake, as opposed to relatively higher salinities of Oyster Lake. In both bays the abundance of M. almyra was greater in the cooler months, November through May, then in warmer months, June through October.

9. Mysidopsis bahia was observed in relatively low abundances in both bays. In Oyster Lake peak abundances were observed in the cooler months; in late December, 1967; in early March

and early April, 1968; and in early April, 1969. In Alligator Lake, M. bahia peaked in abundance once, in early January, 1968. Although greater abundances of M. bahia were observed in Oyster Lake, where the average salinity was higher, it appears, nevertheless, to be a euryhaline species.

10. Taphromysis louisiana appears to be a euryhaline species and not exclusively fresh water as reported by Banner (1954). This species was collected in waters of salinities ranging between 0.0 and 26.0 ppt. It appears to be more abundant in Alligator Lake with waters of lower salinity. Peak abundances of T. louisiana, in Alligator Lake, occurred in early February and late March, 1968. Average salinity during peak abundances was 11.3 ppt. No peak abundance of T. louisiana appeared in Oyster Lake.

11. Bowmaniella brasiliensis, previously collected only from Brazil, was collected from both Oyster and Alligator Lakes during the cooler months, November, January, and February, when water temperatures were relatively low. No peak abundance of this species was observed.

12. Brasilomysis castroi was collected once from Oyster Lake in late December, 1967.

13. Penaeus aztecus exhibited one peak abundance per year in both Oyster and Alligator Lakes. In Oyster Lake, in each case, postlarval and juvenile forms peaked in abundance

one month prior to peak abundances observed in Alligator Lake.

14. Penaeus setiferus exhibited two peak abundances per year, the first appearing in early summer and the second in the fall. The first peak abundance appeared at the same time in Oyster and Alligator Lakes. The second peak abundance in Oyster Lake appeared one to two months previous to that observed in Alligator Lake.

15. The marsh bayou systems, as represented by Oyster and Alligator Sloughs, are utilized as nursery areas for both Penaeus aztecus and Penaeus setiferus.

16. In all three mosquito control malathion tests, the commercial shrimp Penaeus aztecus and Penaeus setiferus suffered mortality rates ranging from 14 to 80 percent while the control shrimp suffered no deaths attributable to the pesticide.

17. Water analyses demonstrated a high concentration of malathion immediately after application and a progressive reduction 24, 33, and 48 hours after application.

18. Tidal activity can alter the exposure of the shrimp to malathion by moving the target water into or out of the area, or by concentrating the affected water on the shrimp. In Alligator Slough where there is no restriction to water flow, low mortalities were observed when tidal activity pushed the target water out of the plot. In Elbow Slough,

a dead end slough, high mortalities were observed when tidal activity pushed the target water into the upper end of the slough where shrimp were caged.

19. Malathion values in live shrimp taken from boxes during the test were consistently greater than the values obtained from dead shrimp removed during the same period, as would be expected if malathion levels are proportional to exposure time.

20. It could be hypothesized that shrimp demonstrating a tolerance to malathion, could continue to accumulate the pesticide, whereas a dead shrimp could no longer actively accumulate the pesticide or even lose pesticide through leaching to the surrounding medium.

21. Field tests indicate that Penaeus aztecus possess a faster and, in most cases, a greater sensitivity to malathion than Penaeus setiferus.

22. High temperatures could possibly affect the results of malathion on shrimp by causing a higher metabolic activity in the shrimp, thereby, facilitating a more rapid uptake of the pesticide.

23. In the length-weight analysis Penaeus aztecus proved to be in better condition in the Oyster Lake complex, as opposed to the Alligator Lake complex, throughout the observed size range.

24. The condition of *Penaeus setiferus*, in the Oyster and Alligator Lake complexes varied with size. Small *P. setiferus* were in better condition in the Oyster Lake complex, but as size increased this difference shifted, for the larger shrimp were in better condition in the Alligator Lake complex. The cause of the variation is unknown, but could represent environmental differences such as available food.

25. In both bay complexes the condition of both *Penaeus aztecus* and *Penaeus setiferus* decreased with increasing size.

26. The condition of *Penaeus aztecus* in both lake complexes, for the calendar year 1968, was highest in September, and lowest in May, June, and July. Shrimp taken in late 1967 exhibited a condition factor equal to shrimp in the best of condition in 1968. The highest condition of *P. aztecus* was observed in April and July, 1969.

27. Condition of *Penaeus setiferus*, in the Oyster Lake complex, for the calendar year 1968, was highest in August and October. Shrimp taken in July and September were in better condition than those taken in May and June. During 1969 the condition of *P. setiferus* was lowest in November. Shrimp taken in late 1967 exhibited a condition factor equal to those in the best of condition in 1968.

28. Condition of *Penaeus setiferus*, in the Alligator Lake complex, for the calendar year 1968, was highest in October. Shrimp taken in August and September were in better condition

than those taken in July. Condition of *P. setiferus* was lowest in May, June, and November. Shrimp taken in November, 1967 and in February, March, and August, 1969 were in good condition.

29. In both lake complexes the condition of *Penaeus aztecus* decreased with increasing temperature; however, condition increased with increasing salinity.

30. Condition of *Penaeus setiferus*, in the Oyster Lake complex, decreased with increasing temperature and salinity; however, in the Alligator Lake complex, the condition of *P. setiferus* increased with increasing temperature and salinity. This contradiction is either inexplicable or indicates that other factors, such as available food, are more significant.

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