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Introduction and enhancement of vegetative cover at Lake Mead

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Table of Contents

Table of Contents (Continued)

List of Maps and Figures

List of Tables and Appendices

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EXECUTIVE SUMMARY

Studies done by the Nevada Department of Wildlife (NDOW) and the Arizona Fish and Game between 1978 and 1981 indicate that inadequate cover may be limiting the production and survival of largemouth bass at the Lake Mead National Recreation Area (LMNRA). As a result of these studies, NDOW initiated a contract in 1986 with the Lake Mead Research Center (LMRC) to investigate means of improving habitat for game fish by introducing natural and/or artificial cover.

During Phase I (1986-1987) of this contract, the shoreline of Lake Mead was surveyed for aquatic and terrestrial plant growth. Also during this time, submerged Christmas trees and Berkley Fish Habitat Modules were evaluated for their effectiveness in providing cover. Christmas trees appeared to provide cover for juvenile bluegill, a largemouth bass prey species. However, submerged trees lost their structure in about three years. Berkley Habitat Modules did not appear to be an effective form of cover. The National Park Service (NPS) asked that the introduction of artificial forms of cover not be continued until research was completed on the use of native plant material.

Methods for aquatic and terrestrial plant introductions were determined during Phase II (1987-1988) of this contract. Other agencies and individuals involved in revegetation of reservoir inundation zones were contacted, and the literature was reviewed for plant material collecting procedures, planting guidelines, and site maintenance. A "Plant Introduction Manual" was compiled based on this information and was approved by the National Park Service for use in the Lake Mead National Recreation Area. During the winter, dormant cuttings were taken of two

woody species, Goodding's Willow and seepwillow baccharis (*Salix gooddingii* and *Baccharis glutinosa*) to be planted in the spring of 1988. In addition, collections were made of three emergent species (*Typha angustifolia*, *Scirpus robustus*, and *Phragmites australis*). Plant material was transported to the Nevada Division of Forestry (NDF) nursery where it was rooted and placed on pots for planting in May 1988. Sago pondweed (*Potamogeton pectinatus*) tubers were introduced into small study plots in the spring of 1987. More tubers became established and were healthier in fertilized plots than in unfertilized plots.

During Phase III (1988-1989) of this study, plant material was introduced into one cove in the lower basin and two coves in the upper basin of Lake Mead in April and May of 1988. Unpredicted low lake levels resulted in the loss of many plants. Survival rates of rooted material, however, were better than those of direct cuttings of woody plants. Site selection, particularly the soils of the site, appears to play a large part in survival. Seepwillow baccharis had the highest survival rates. In addition, greenhouse studies indicate that emergent plant tubers have some tolerance to dessication.

Twelve hundred sago pondweed tubers were planted in April 1988 in one cove in the upper basin, and 1,200 tubers were planted in a cove in the lower basin. Tubers had 100 percent germination success and provided 70 percent cover for fish by July 1988. Approximately 10,000 sago pondweed tubers were planted in April 1989 in Waterbarge Cove in the lower basin. Tubers were planted in water depths ranging from very shallow to 12-15 meters deep. Germination and establishment of tubers were very good in depths less than 7 meters; however, little or no germination of tubers was noted at depths greater than 7 meters.

A one-acre area of shoreline was hydroseeded in October 1988. Germination and establishment of seedlings was highest where soil moisture was between 20 and 30 percent. However, many seedlings were lost when water levels began to rise in January 1989.

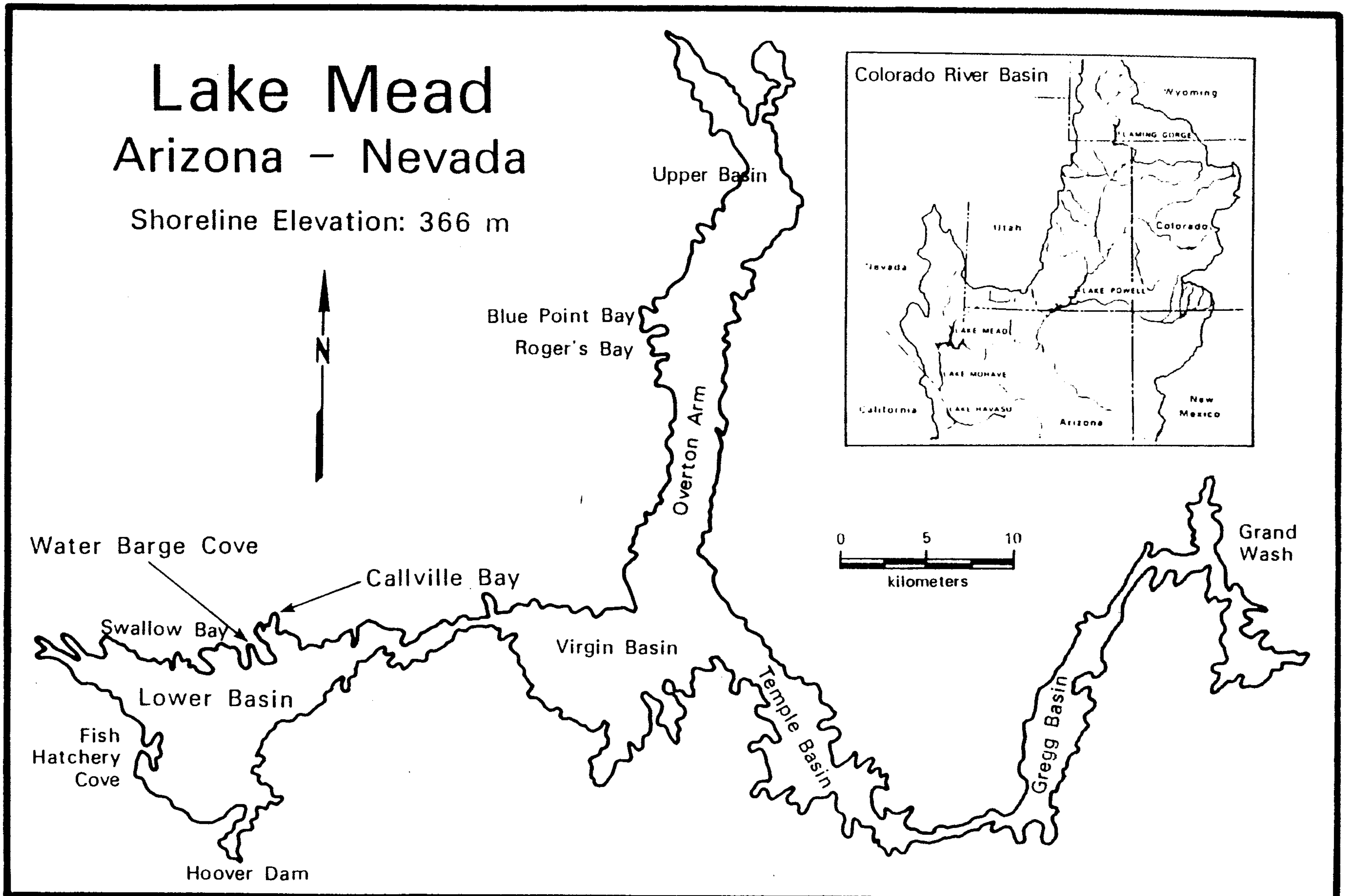
Conclusions and recommendations are presented at the end of this document.

I. INTRODUCTION

Lake Mead, located in the Mojave Desert, is one of the largest reservoirs in the United States, with a surface area of 660 km^2 (Map 1). The lake was formed in 1935 when Hoover Dam began impounding the Colorado River. Water levels are controlled by the Bureau of Reclamation (BOR) and typically fluctuate 4-5 m a year to elevations of between 336 m and 370 m. A typical water management pattern at Lake Mead from 1984 through 1987 was low water during early spring (March to April) followed by a rapid rise reaching a maximum level in early summer (June to July). However, in 1988 water levels were at a peak in March and fell through December 1989 (Figure 1). The primary purposes of the reservoir are to provide flood control protection, produce electricity for the West, and deliver water to Nevada, California, and Arizona for agricultural, industrial, and municipal use.

Lake Mead has an annual precipitation of less than 12.5 cm, a mean annual air temperature of 43°C between July and August, and a mean temperature of -1°C in January. As a result of low soil fertility and fluctuating water levels, vegetation is sparse along the 885 km of shoreline. Typical shoreline species include salt cedar (*Tamarix* spp.), seepwillow (*Baccharis glutinosa*), and cattails (*Typha angustifolia*).

For the purposes of this study, the inundation zone was divided into tiers based on period of inundation and type of vegetation present. Tier 1 is located adjacent to the waterline at low water level and is inundated for the longest period of time each year. Tier 1 is often devoid of vegetation or may have cattail or willow weed (*Polygonum lapathifolium*) growing on it. Tier 2 is located directly above Tier 1 and is inundated for a period intermediate to Tiers 1 and 3.



Map 1. Map of Lake Mead.

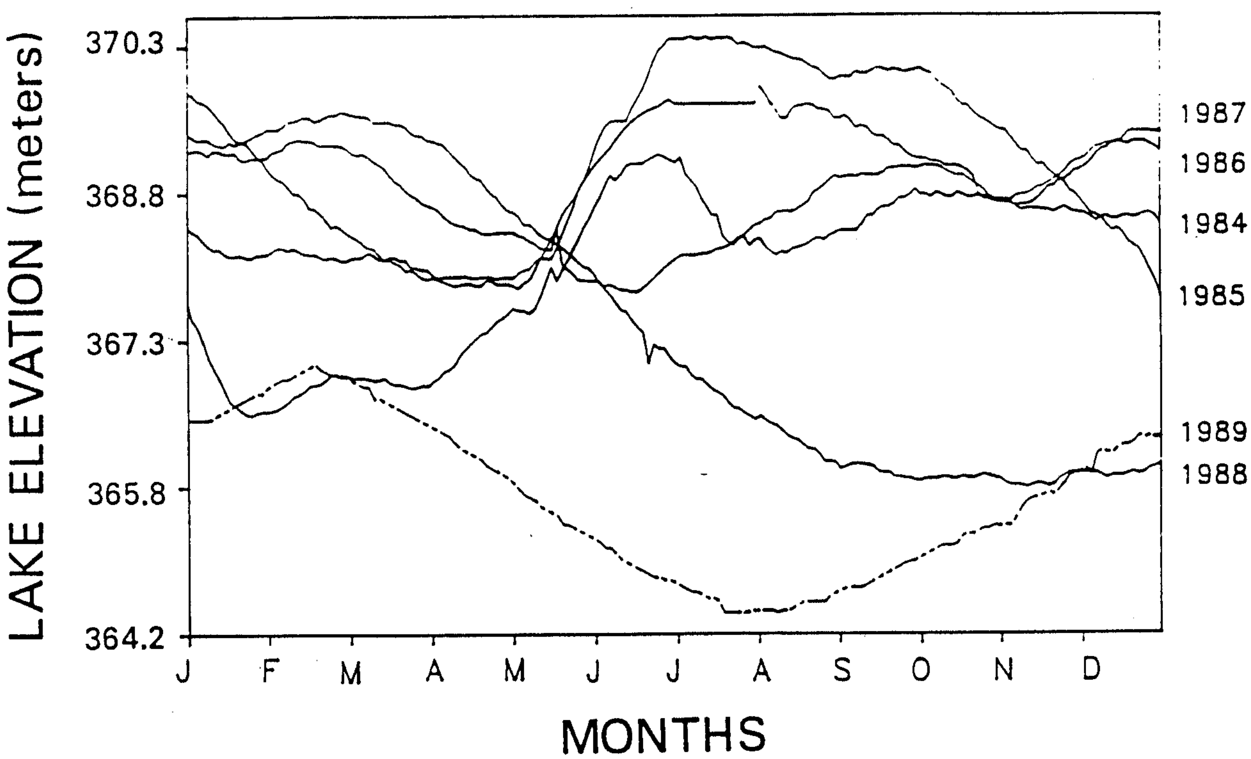


Figure 1. Lake Mead elevations from 1984-1989.

Vegetation in Tier 2 varies considerably. Tier 3 has not been inundated since 1983, and vegetation in this tier is usually dominated by seepwillow and salt cedar.

The land surrounding the reservoir is administered by the National Park Service (NPS) which, in addition to managing and protecting the recreational uses of the area, regulates research within the Lake Mead National Recreation Area (LMNRA). The states of Arizona and Nevada jointly manage the fisheries and wildlife resources. The LMNRA was created in 1936 specifically for recreational use. Fishing is a major recreational activity at Lake Mead, with an estimated annual economic value in excess of $70 million (Morgensen and Padilla, 1982). Major changes, however, have occurred in the fisheries of Lake Mead over the past two decades, and the quality of the once-famous largemouth bass fishery has declined dramatically since the late 1960s.

A. Cover Requirements for Largemouth Bass

Largemouth bass require adequate cover during certain stages of their life cycle in order to survive and spawn. A positive relationship has been observed between the amount of submerged vegetation, the standing crop of largemouth bass, and the numbers being recruited to harvestable size (Durocher *et al.*, 1984). In addition, a positive correlation exists between increases in the number of young-of-the-year largemouth bass and the duration of flooding of shoreline vegetation. Young bass were observed to have a higher survival rate and accelerated growth when extensive flooding of vegetation occurred (Aggus and Elliott, 1975).

Morgensen (1983) felt that an increased survival of young-of-the-year bass was due to increased cover and nutrient levels produced by inundated vegetation. Von Geldern (1971) stated that higher water levels incorporated more flooded vegetation, which in turn reduced the effects of

wave action, and thereby provided stable substrate for bass nesting. Largemouth bass consistently appeared to select home areas that contain cover in shallow water with deeper water nearby (Warden and Lorio, 1975).

Schlagenhaft and Murphy (1985) determined that coves with brush comprised 83 percent of all largemouth bass locations, even though these coves represented only 7.8 percent of the total area of a Texas lake. Both largemouth bass and bluegill have been observed in and around macrophyte patches (Savitz, 1981). Weaver and Ziebell (1976) observed young fish mostly in beds of spiny naiad (*Najas marina*), in a spiny naiad-cattail vegetation zone, and in submerged branches of overhanging mesquite (*Prosopis* sp.) trees.

The use of artificial reef structures for habitat enhancement has the potential to improve recreational fishing. Mitzner (1984) reported that largemouth bass concentrated at a rate of 1:28.5 in control versus artificial reef areas. Brouha (1974) determined that tire and Christmas tree reefs effectively concentrated fish; however, a preference for Christmas tree reefs was shown. Artificial reefs were immediately occupied by young fish with adults appearing later, and the peak usage of the reefs occurred during the summer (Prince and Brouha, 1975). Centrarchid bass were observed spawning on or around artificial reefs and often included the reef in their home ranges between spring and fall months (Prince *et al.*, 1975; Voegle and Rainwater, 1975). Tire, brush, clay pipe, stake beds, hay bales, concrete rubble, old boats and cars, Berkley Fish Habitat Modules, and evergreen trees have been used by various investigators in the construction of artificial structures. However, artificial structures made from brush and evergreen trees appear to be preferred by fish (Mosher, 1985; Pierce and Hooper, 1979; Wege and Anderson, 1979). It has been speculated that reefs may increase primary productivity in impoundments by providing additional substrate for periphyton colonization (Prince and Maughan, 1978). In addition, artificial structures tend to

stabilize bottom sediments, thereby providing areas in which aquatic vegetation may become established (Thomas and Bromley, 1968).

Aquatic plants including pondweeds, naiads, and algae also provide excellent cover for young fish (DeGruchy, 1938). However, submergent vegetation is negatively affected by turbidity due to the resulting reduction in light penetration. The depth of aquatic vegetation is also regulated by water turbidity (Wiebe, 1946).

B. Methods of Fish Cover Enhancement

Studies have been done at several reservoirs throughout the country on methods of fish cover enhancement. The Army Corp of Engineers (Hunt *et al.*, 1978), California Fish and Game (Lee and Gleason, 1987), and the Texas Parks and Wildlife Department (Howells, 1986) have printed guides to planting in lake and reservoir fluctuation zones. Brouha and von Geldern (1979) described methods of habitat manipulation for centrarchid production in western reservoirs. Floating artificial reefs, mid-water reefs, artificial seaweed, and revegetation of drawdown zones were examined as means of improving centrarchid production. Guidelines for revegetation programs include planting in the fall or winter when soils are moist, diligent watering during the first summer, and use of wire baskets to protect young plants from predation by animals.

Strange *et al.* (1982) found that fertilized rye seed grew well in a reservoir fluctuation zone in Georgia and was heavily utilized by young-of-the-year bass. Several methods for revegetation of disturbed areas were suggested by Wallace *et al.* (1977) including the use of fertilizers and irrigation. Fowler and Maddox (1974) used barge hydroseeding to successfully introduce three species into the inundation zone.

Anderson (1988a) found in his work on the Lower Colorado River that transplanted, rooted cuttings of Goodding's willow (*Salix gooddingii*) and cottonwood (*Populus fremontii*) had the greatest survival when holes were augured to the water table. Plants in holes tilled to the water table grew to an average of 8.9 meters during the first five years, three times the growth of trees planted in shallowly tilled holes at the same site. Anderson also found that the amount and rate of irrigation can affect root growth. For example, even with tillage, water tends to spread laterally, resulting in a perched root system. Therefore, when irrigation ceases, the roots may be too high to make contact with a deep water table. As a result, he recommended deep watering.

C. Project Objectives

The objectives of this study as defined in the Phase II proposal are to:

1. Continue reviewing existing literature and studies for effective methods of aquatic plant introduction and introduction of terrestrial vegetation into reservoir inundation zones;
2. Continue monitoring "permanent" study sites for changes in vegetation communities including observation of fish utilization of aquatic and inundated terrestrial vegetation;
3. Monitor enhancement experiments started in April 1987 for effects of watering and/or fertilization on existing stands of terrestrial vegetation and fertilization of existing stands of aquatic vegetation;
4. Introduce native terrestrial plant species into test plots;
5. Introduce aquatic vegetation into test plots with and without fertilization treatments;
6. Reduce turbidity in a cove with high silt and clay content sediments by introducing *Chara vulgaris*; and
7. Monitor aquatic plant and inundated terrestrial plant test plots for fish utilization of test plots compared to control areas.

II. PROJECT HISTORY

Studies performed by the Nevada Department of Wildlife (NDOW) and the Arizona Fish and Game between 1978 and 1981 indicate that inadequate cover may be limiting the production and survival of largemouth bass at the Lake Mead National Recreation Area. As a result of these studies, NDOW initiated a contract with the Lake Mead Limnological Research Center to investigate means of improving habitat by introducing natural and/or artificial cover.

A. Evaluation of Christmas Trees as Cover

In 1985 and 1986, under the direction of NDOW and the Lake Mead Enhancement Society, local bass clubs submerged Christmas trees in Callville Bay and nearby coves (Map 1). Fish utilization of trees and tree condition in three coves were determined by periodic underwater observations beginning in June 1986 and ending in April 1987.

These studies indicated that Christmas trees concentrate fish, especially juvenile bluegills (Figure 2). It appears that trees provide cover for small fish and these, in turn, attract predatory fish like largemouth bass. In addition, Christmas trees provide a surface for periphyton colonization which increases the productivity of a cove and serves as a food source for some fish (Prince *et al.*, 1975). However, some trees had a short period of effectiveness (about three years) before they lost their needles and some smaller branches. They also appear to be less effective when covered with silt or when aquatic vegetation is present (Haley *et al.*, 1987). Very few fish were seen associated with the trees in spring 1989.

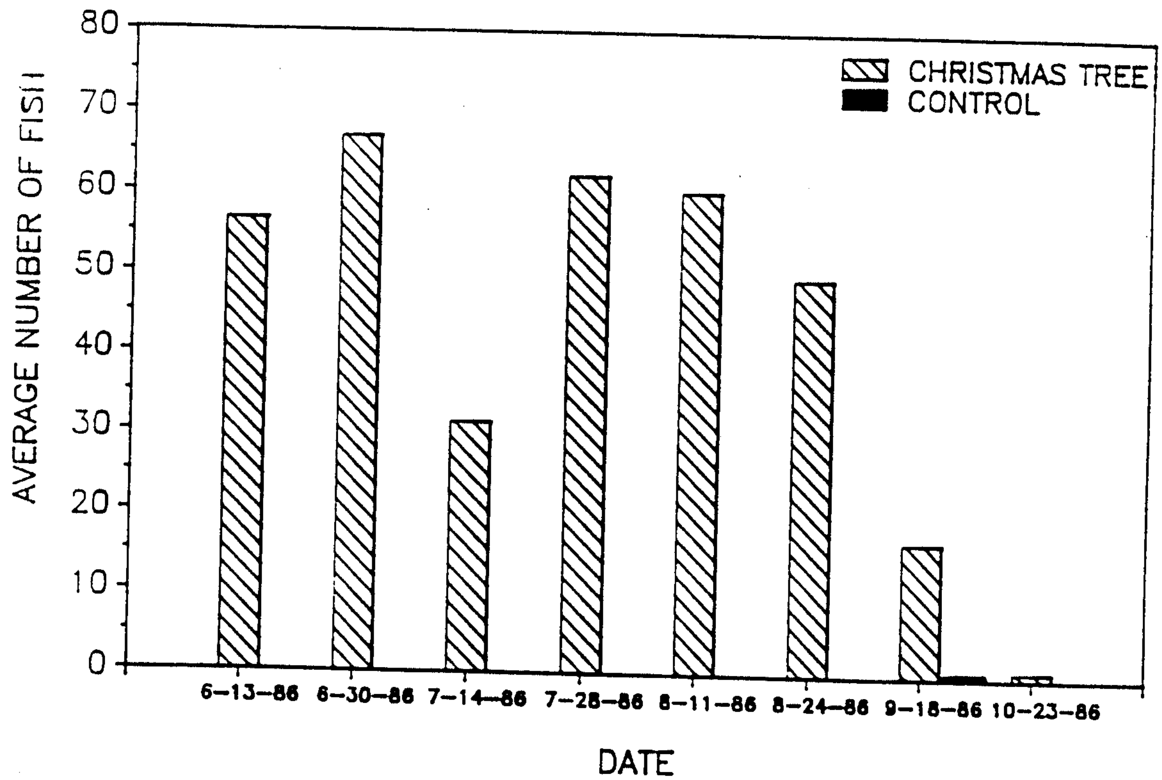


Figure 2. Average number of fish observed at a Christmas tree site compared to a control. Only one fish was counted at the control site in September 1986.

As a result of these studies, it was recommended to NDOW that Christmas trees have a limited large-scale application in Lake Mead and that their use be considered only in areas that are not suitable for aquatic and terrestrial plant introduction (Haley *et al.*, 1987).

B. Evaluation of Berkley Fish Habitat Modules as Cover

In 1983, three coves were chosen as sites for the introduction of Berkley Fish Habitat Modules by NDOW. Approximately 2,000 modules were placed in three coves in Lake Mead. Modules in two coves were periodically monitored between June and October 1988 for changes in appearance, position, and fish use.

These studies indicated that Berkley Fish Habitat Modules do not provide cover for fish in Lake Mead and are susceptible to vandalism, displacement, and loss of buoyancy due to a build-up of periphyton. As a result, it was recommended to NDOW that no further effort was warranted in the use of Berkley Fish Habitat Modules in Lake Mead (Haley *et al.*, 1987).

C. Lake Mead Inundation Zone Vegetation Reconnaissance

Terrestrial vegetation on the Nevada shoreline of Lake Mead was videotaped in June of 1986. Aquatic plants were surveyed with the use of a glass-bottom boat. Areas of dense and/or diverse aquatic and terrestrial plant growth were identified and recorded on the video tapes and on topographic maps.

Thirty coves were selected in August 1986 in various vegetation and soil types along the Nevada shoreline of Lake Mead. Water temperature, dissolved oxygen, conductivity, pH, and light transmittance were recorded at one-meter intervals from the surface of the water to the bottom of each cove. Soil and sediment samples were collected and analyzed for texture, percent organic matter, cation exchange capacity, total nitrogen, and total phosphorus. Cover of terrestrial and aquatic plant species was measured. In addition, species abundance, sociability, dominance, and age class were determined.

In 1987, eleven coves were selected for seasonal aquatic and terrestrial vegetation monitoring. Coves were selected based on several factors, including high cover values for terrestrial and aquatic vegetation. Cover of terrestrial and aquatic plant species was measured seasonally at these coves. Again, species abundance, sociability, dominance, and age class were determined. The pH, dissolved oxygen content, temperature, and clarity were also measured in each cove.

Terrestrial and aquatic vegetation and soils reconnaissance indicated that most of the inundation zone at Lake Mead is devoid of vegetation, probably as a result of low organic contents in the soils and sediments, low soil fertility (Figures 3 and 4), and fluctuating water levels. There are, however, several terrestrial vegetation species currently growing in isolated locations at Lake Mead in the inundation zone, including narrowleaf cattail, willow weed (*Polygonum lapathifolium*), seepwillow, and bermudagrass (*Cynodon dactylon*). These species appear to be tolerant of desiccation and inundation. Table 1 lists species identified growing in the inundation zone at Lake Mead.

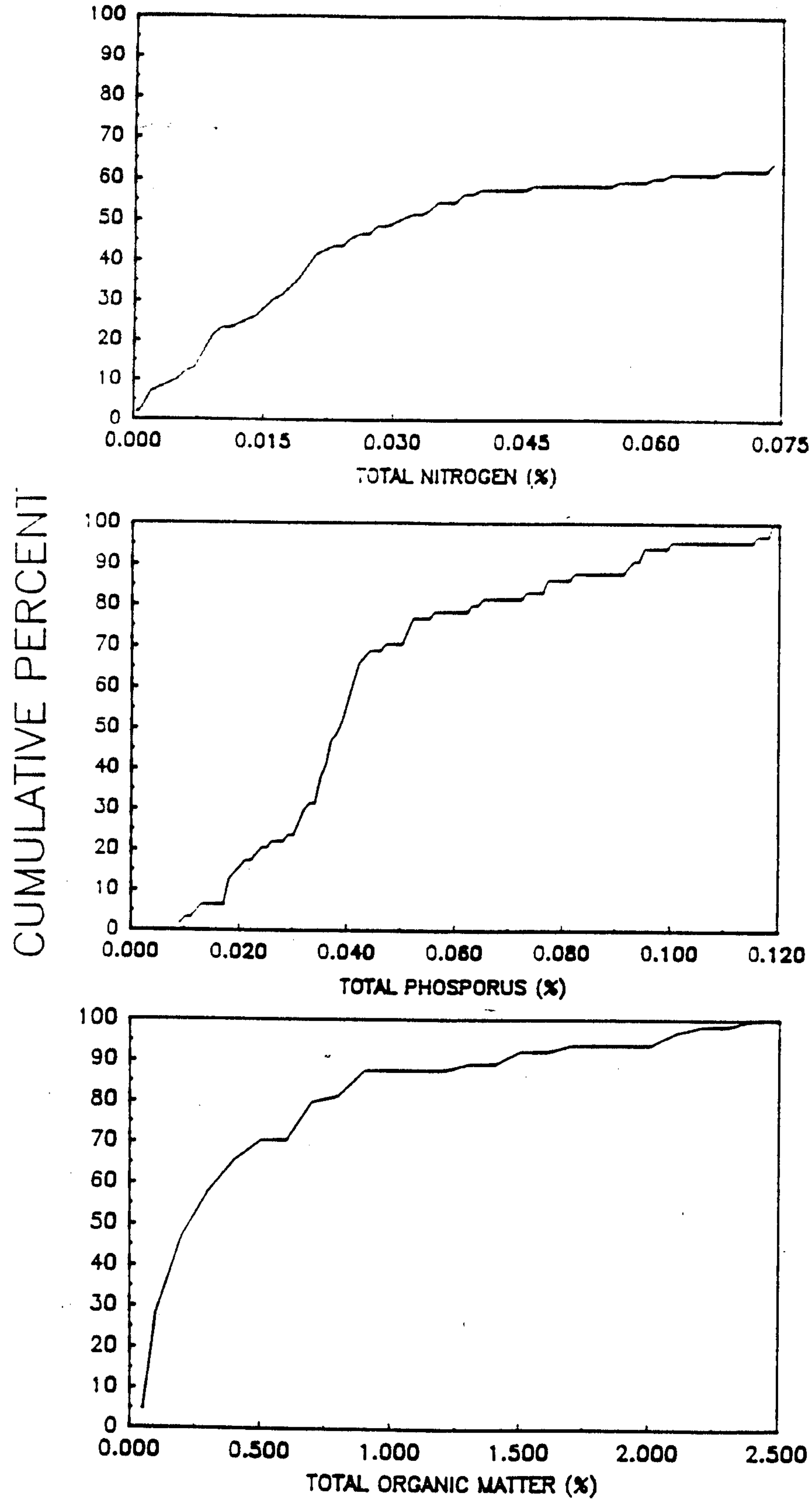


Figure 3. Percent total nitrogen, total phosphorous, and organic matter of soils collected from 30 locations at Lake Mead. These figures show the percent of soils analyzed with total nitrogen, total phosphorous, and organic matter contents less than or equal to a selected value.

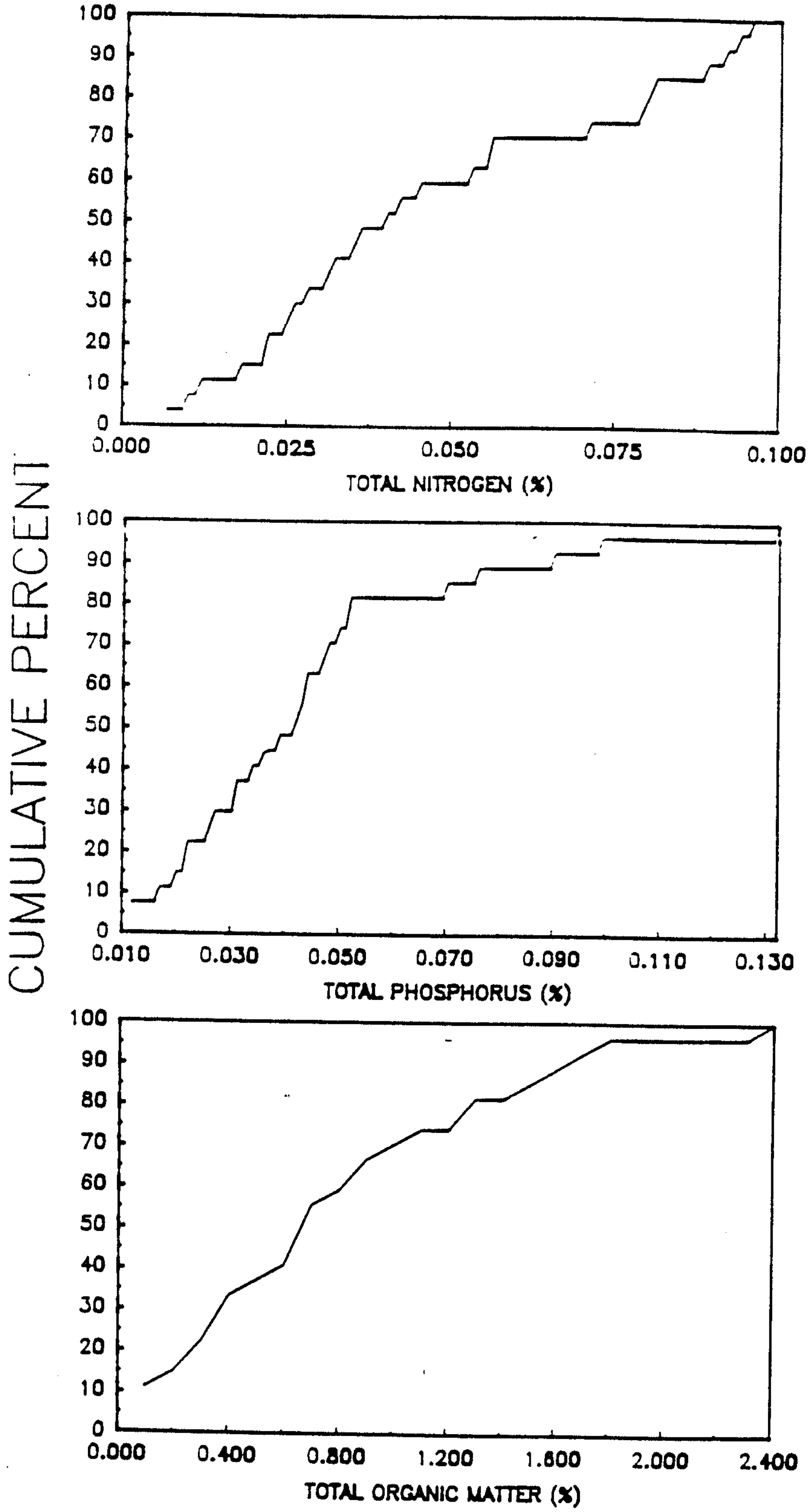


Figure 4. Percent total nitrogen, total phosphorous, and organic matter of lake sediments collected from 30 locations at Lake Mead. These figures show the percent of lake sediments analyzed with total nitrogen, total phosphorous, and organic matter contents less than or equal to a selected value.

Table 1. Plants encountered in the inundation zone at Lake Mead including symbol, Latin name, and common name.

Symbol Name	Latin Name	Common Name
AMAL	*Amaranthus albus*	tumble pigweed
AMDU	*Ambrosia dumosa*	white bursage
AMspp.	*Amaranthus* species	
ASspp.	*Astragalus* species	
ATHY	*Atriplex hymenelytra*	desert holly
BAEM	*Baccharis emoryi*	emory baccharis
BAGL	*Baccharis glutinosa*	seepwillow baccharis
BASA	*Baccharis sarathroides*	desert broom
BAHY	*Bassia hyssopifolia*	fivehook bassia
BEJU	*Bebbia juncea*	rush bebbia
CAWATO	*Camasonia walkeri tortilis*	Walker evening primrose
CHAL	*Chenopodium album*	lambsquarter
CHBE	*Chenopodium berlandieri*	pitseed goosefoot
CH sp.	*Chara* sp.	*Chara* sp.
COCA	*Conyza canadensis*	Canada horseweed
COCO	*Conyza coulteri*	
CYDA	*Cynodon dactylon*	bermudagrass
CYOD	*Cyperus odoratus*	umbrella sedge
DAME	*Datura meteloides*	jimson-weed
ECAL	*Eclipta alba*	
ENFA	*Encelia farinosa*	white brittlebush
ERDE	*Eriogonum deflexum*	skeletonweed
ERIN	*Eriogonum inflatum*	desert trumpet
ERPU	*Erioneuron pulchellum*	beard grass
EUPO	*Euphorbia polycarpa*	manyfruit spurge
EUUR	*Eucnide urens*	rocknettle
HECU	*Heliotropium curassavicum*	salt heliotrope
HIJA	*Hilaria jamesii*	galleta grass
HYSA	*Hymenoclea salsola*	
LADI	*Larrea divaricata*	creosotebush
NAMA	*Najas marina*	spiny naiad
NIGL	*Nicotiana glauca*	tree tabacco
NITR	*Nicotiana trigonophylla*	desert tabacco

(Continued)

Table 1. Plants encountered in the inundation zone at Lake Mead including symbol, Latin name, and common name (*continued*).

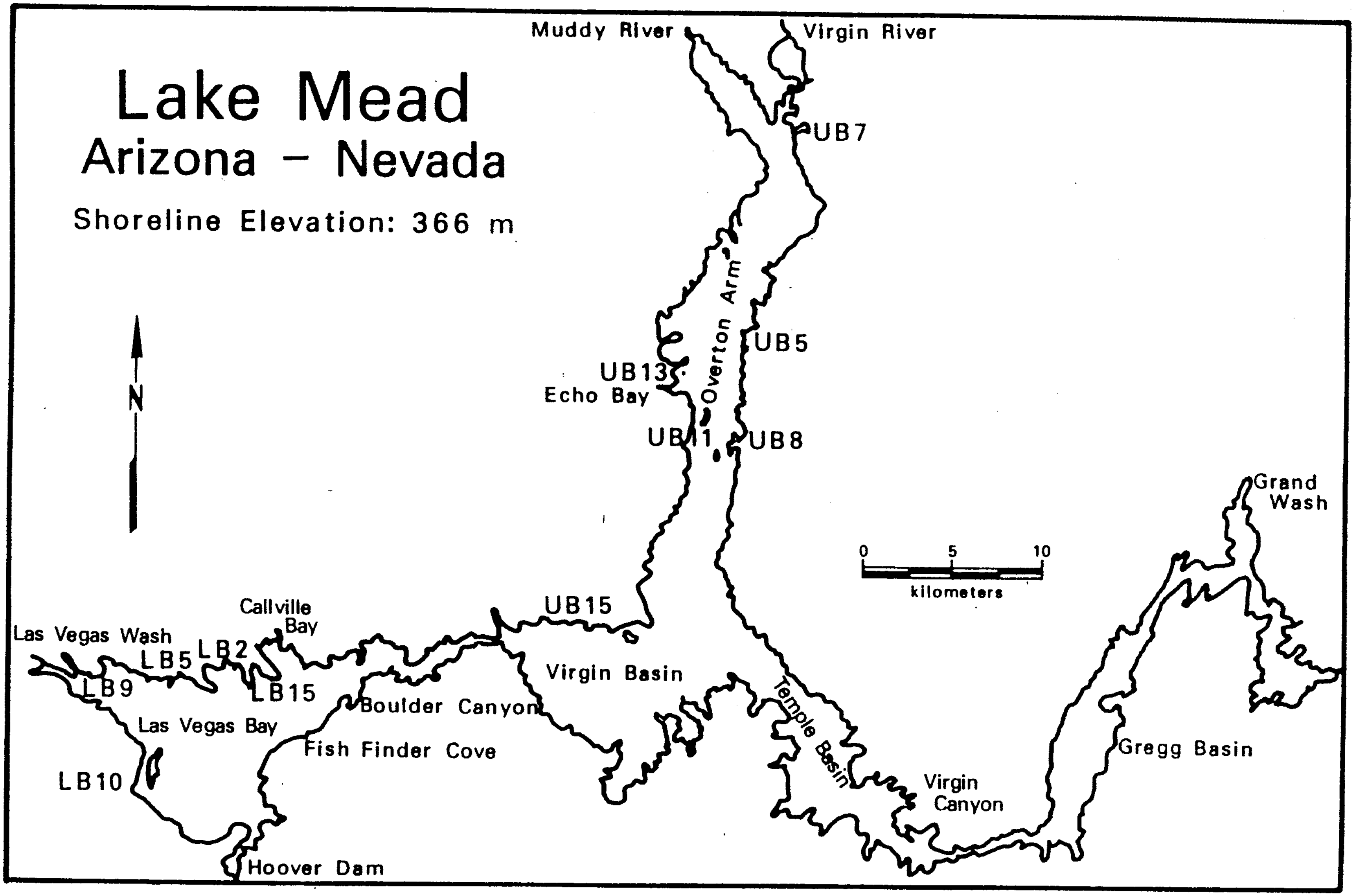
Symbol Name	Latin Name	Common Name
PAAR	*Palafoxia arida*	desert palafoxia
PEEM	*Perityle emoryi*	emory perityle
PHCO	*Phragmites communis*	reed
PHCR	*Physalis crassifolia*	thick groundcherry
PLPU	*Pluchea purpurascens*	arrow weed
POAR	*Polygonum argyrocoleon*	
POCR	*Potamogeton crispus*	curly pondweed
POLA	*Polygonum lapathifolium*	willow weed or nodding smartweed
POMO	*Polypogon monspeliensis*	rabbitfoot grass
POPE	*Potamogeton pectinatus*	sago pondweed
PSFR	*Psorothamnus fremontii*	fremont indigobush
RUMA	*Ruppia maritima*	widgeon grass
RUspp.	*Rumex* species	dock
SAEX	*Salix exigua*	coyote willow
SAGO	*Salix Gooddingii*	Goodding's willow
SCRO	*Scirpus robustus*	bulrush
SAKA	*Salsola kali*	Russian thistle
SEVE	*Sesuvium verrucosum*	seapurslane
SPAM	*Sphaerolcea ambigua*	desert globemallow
SPAI	*Sporobolus airoides*	alkali sacatone
SPCR	*Sporobolus cryptandrus*	sand dropseed
STPA	*Stephanomeria pauciflora*	slimflower wirelettuce
TAAP	*Tamarix aphylla*	athel tamarisk
TARA	*Tamarix ramosissima*	salt cedar
TESE	*Tessaria sericea*	arrow weed
TIHI	*Tiquilia hispidissima*	
TILA	*Tidestromia lanuginosa*	woolly tidestromia
TYANEL	*Typha angustifolia*	narrowleaf cattail
VEBR	*Verbena bracteata*	bigbract verbena

There is very little aquatic vegetation growth in the early spring in Lake Mead. Spiny naiad is, however, extremely abundant in the late summer and early fall. Sago pondweed (*Potamogeton pectinatus*) and curly pondweed (*P. crispus*) were observed growing in isolated locations in the early spring. Curly pondweed does not reproduce sexually in North America (Hunt and Lutz, 1959); consequently, its distribution is limited by its reproductive mechanisms.

III. METHODS

A. Seasonal Observations of Ten Selected Coves

Ten coves from the original 30 coves were selected for seasonal aquatic and terrestrial vegetation monitoring. The locations of these coves are identified on Map 2. Appendix A lists the inventory dates, water levels, legal descriptions, soil and lake sediment descriptions, and limnological features of the water in each of these coves. Coves were selected based on several factors, including high cover values for terrestrial vegetation in Tier 1 and/or high cover values for aquatic species. Diversity of terrestrial and aquatic vegetation and the presence of species proposed for introduction were also considered.



Map 2. Permanent study cove locations.

The ten coves were monitored in July and September of 1987 to complete a one-year cycle of observation. Terrestrial and aquatic vegetation communities were mapped during each of these periods. Cover was estimated for the dominant plant species in each tier, and qualitative parameters, including species abundance, sociability, dominance, and age class, were also evaluated during both of these months (Table 2). In addition, photographs were taken of the terrestrial plant communities during each of the sampling periods. Six of the coves were monitored in March and September 1988. The July 1988 sampling was canceled due to extremely high water turbidity and very low lake levels, resulting in poor visibility under water and no plant growth in the inundation zone. Water temperature, dissolved oxygen, conductivity, pH, and water transparency were measured at each cove during each sampling period.

B. Aquatic Plant Introduction Experiments

1. Small-Scale Introduction Experiments (1987)

A small scale aquatic plant introduction experiment began in April of 1987 at three locations in the lower basin of Lake Mead: Callville Bay, Water Barge Cove, and Swallow Bay (Map 1). Sago pondweed tubers and curly pondweed stem cuttings were each planted in two one-meter square plots at each site. Half of the plots were fertilized with three pounds of "Osmocote" 14-14-14, a slow dissolving fertilizer. Two additional plots were placed in each cove; one was fertilized, and the last was left untreated as a control.

Table 2. Relative scale used to determine abundance, sociability, dominance, denseness, and age class of plant species occurring in each of the permanent study coves.

Abundance expresses plentifulness or number of each species.
- 1 = very sparse (very rare)
- 2 = sparse (rare)
- 3 = not numerous (infrequent)
- 4 = numerous (abundant)
- 5 = very numerous (very abundant)

Sociability expresses the spatial relationship of individual plants of a species.
- 1 = growing one in a place
- 2 = grouped or tufted
- 3 = in troops, small patches, or cushions
- 4 = in small colonies, in extensive patches or forming carpets
- 5 = in great crowds

Dominance expresses the visual importance of a species.
- 1 = the species which can be seen only by searching for them in and around other plants
- 2 = the species which can be seen only by moving around
- 3 = the species which are easily seen by standing in one place
- 4 = the species which are codominate in the aspect of the layer
- 5 = the species which dominate the aspect of the layer

Age Class expresses the degree of maturation level of the species.
- 1 = established seedlings and small plants
- 2 = intermediate sized plants
- 3 = nearly mature plants
- 4 = mature plants
- 5 = decadent

Denseness of Aquatic Vegetation describes the floating portion of the aquatic species.
- 1 = open (fills 0-20% of the field of vision)
- 2 = scattered (fills 20-40% of the field of vision)
- 3 = moderate (fills 40-60% of the field of vision)
- 4 = dense (fills 60-80% of the field of vision)
- 5 = very dense (fills 80-100% of the field of vision)

Sago pondweed tubers were purchased from Wildlife Nurseries in Wisconsin. Curly pondweed cuttings were collected at Fishfinder Cove in the lower basin of Lake Mead. Thirty-six tubers and six one-meter stem segments were placed in their respective plots. The tubers were weighted with a poultry staple, and the stem cuttings were anchored with a bent wire. The sites were monitored on May 7 and July 20 in 1987, and again on May 11, 1988.

In addition, seventeen pounds of *Chara vulgaris* were transplanted into a cove at Stewart's Point in September 1987. Water clarity in the cove was to be compared to clarity in a control cove. However, water levels dropped very fast in the spring, and the *Chara* sp. was desiccated before turbidity measurements could be taken.

2. Large Scale Introduction Experiment (1988)

In March of 1988, 1200 sago pondweed tubers were placed in Fish Hatchery Cove in the lower basin and another 1200 tubers were placed in Roger's Bay (Map 1). Four tubers were put in cheesecloth bags and weighted with gravel. The bags were dropped from the side of a boat at depths of between two and ten meters. Since the small scale experiments indicated that fertilizer significantly improved establishment and growth rates, some sites were fertilized with "Osmocote" 14-14-14. Two similar adjacent coves were identified at each site. One of these coves was fertilized and one was left untreated as a control. All coves were approximately one acre in size.

Sites were monitored in April, May, July, and August 1988. Cover estimates were made at this time, and qualitative data on the plant communities at each cove were also taken (Table

2). Fish use of the introduced plant material was evaluated by SCUBA divers. High turbidity prevented fish counts in April and May. However, counts were done in July.

3. Large Scale Introduction Experiments (1989)

In April 1989, ten thousand sago pondweed tubers were introduced in four small coves in Waterbarge Cove. Tubers were wrapped in plastic mesh bags, weighted with gravel, and dropped over the side of the boat. Tubers were planted in water depths of between 1 and 15 meters. Two of the coves were fertilized with "Osmocote" 14-14-14 at a rate of approximately 20 pounds per acre. Fertilizer was sprinkled from the side of the boat. Tubers were observed by SCUBA divers two weeks and four weeks after planting.

4. Sago Pondweed Tuber Desiccation Studies

Desiccation studies were done on sago pondweed tubers in the laboratory. One hundred tubers were dried in an oven at 38° C for 24 hours and then planted in an outdoor tank at a depth of one meter. In another experiment, one hundred tubers were dried for 24 hours at 32° C. In a third experiment, approximately 50 tubers were wrapped in mud balls and then dried in an oven for 24 hours at 32° C. The viability of dried tubers was determined by planting them in an outdoor tank at a depth of one meter.

C. Watering and Fertilization Experiments

In April 1987, three study coves were selected in Water Barge Cove, Callville Bay, and Swallow Bay in the lower basin to test the effects of watering and fertilization on existing terrestrial plant communities. Areas at each site were fertilized or fertilized and watered once a week for one month. Osmocote 14-14-14 was applied at an approximate rate of 20 pounds per acre. Density of plants in each of these areas was visually compared to an untreated control.

D. Terrestrial Plant Introduction

1. Site Description

Three test coves were selected for the introduction of terrestrial and emergent plants; one site in the lower basin and two in the upper basin of Lake Mead. The lower basin site, Fish Hatchery Cove (Map 1), is a deep, narrow, "L"-shaped cove with southeastern exposure. The average slope of the narrow and rocky inundation zone (at lake elevation 1,199 feet) is 6 percent. Soils at this site are sandy. The back of the cove is very protected. Two small washes drain the slopes behind the cove. The Bluepoint Cove and Roger's Bay sites are located in the upper basin. Bluepoint Cove is a wide, flat cove with slopes no greater than 3 percent. The aspect is predominately southeastern. Two small coves were selected at Roger's Bay. The slope at each site is no greater than 2 percent. A wash drains one of the coves and, during the course of the summer, cuts a channel one meter deep. The exposure at Roger's Bay is east to southeast. Soils at Bluepoint Cove and Roger's Bay are higher in clay content than at the Fish Hatchery Cove site.

Terrestrial plants were planted at Fish Hatchery Cove, Bluepoint Cove, and Roger's Bay. Emergent species were planted at Roger's Bay and Fish Hatchery Cove.

2. Plant Material Collection and Preparation

Plant species used were selected according to NPS criteria and the species' ability to withstand fluctuating water levels. Species under consideration were observed at Lake Mead over a period of one year to evaluate individual species tolerance to flooding and desiccation.

Species selected are listed in Table 3. Willow weed seed was collected in the fall of 1987 at Crawdad Cove. Screwbean mesquite seed pods were collected from Flamingo Wash in the fall of 1988. Pods were mechanically broken open to remove seeds. Terrestrial and emergent plant materials were collected in the winter of 1987-1988. Woody cuttings were collected when dormant, if possible, to minimize shock and increase the chance of survival. Densmore and Zasada (1978) found that material collected when dormant survived almost four times better than material collected before dormancy. However, in the Mojave Desert, some plants do not enter a dormant state. To expedite field work, all material was collected at the same time. Cuttings were taken in two sizes, 10 cm and 40 cm.

Emergent plant material was collected by hand using methods adapted from several sources (Howells, 1986; Hunt *et al.*, 1978; and Whigham *et al.*, 1985). Plants were dug up, dead leaf material clipped back, and the root mass washed and clipped, saving only tubers that appeared viable and healthy. After collection, tubers and rhizomes were surface sterilized with a 1.5 percent solution of bleach, wrapped in black plastic garbage bags, and stored in a

refrigerator at 4° C. Cuttings and root stocks were taken to the Nevada Division of Forestry Nursery for immediate propagation and rooting in one-gallon containers. Plants remained in the greenhouse for 12-14 weeks.

Table 3. Summary of total number of terrestrial and emergent plants introduced at each site by species and type of propagule; "R" denotes rooted plant material; "D" denotes a direct, fresh cutting.

Plant Species	Fish Hatchery Cove	Blue Point Cove	Roger's Bay
Seepwillow baccaris *Baccharis glutinosa*	R 160 D 59	120 109	0 0
Fremont's cottonwood *Populus fremontii*	R 18 D 0	32 10	0 0
Coyote willow *Salix exigua*	R 22 D 62	0 116	24 103
Goodding's willow *Salix gooddingii*	R 59 D 60	34 119	0 0
Common reed *Phragmites communis*	R 75	0	75
Bullrush *Scirpus robustus*	R 103	0	104
Narrow leaf cattail *Typha angustifolia*	R 75	0	73

Material was brought from the greenhouse to the LMRC facility one day prior to planting. At this time, plants were numbered, measured for greenhouse growth, and pruned to reduce transplant shock. Cuttings for direct planting were taken one day prior to planting. Cuttings were wrapped in wet burlap and stored in water overnight. The size of the cuttings ranged from 40 cm for seepwillow and Goodding's willow to one meter for coyote willow.

3. Field Out-Planting

A total of 1,107 woody plants and 505 emergent plants were introduced. Table 3 provides a summary of the plantings at each site. Lake level predictions from BOR indicated that the 1988 water regime would be similar to previous years, with water levels receding in April and May and then rising in early summer. Consequently, planting took place in April and May. Woody material was planted at Fish Hatchery Cove and Bluepoint Cove. Holes were dug using a two-man power auger and then color coded with flags to indicate the species to be planted. Direct cuttings were treated with Hormodin #2, a rooting compound, prior to planting. Plants received fertilizer (14-3-3) in the form of slow-release Parex brickettes, and most were mulched. The mulch consisted of a layer of wet newspaper covered with straw, then anchored with wet burlap and rocks. Plants were tagged with diamond lock tags. However, tags broke down after only three weeks in the field. Emergent vegetation was planted at Roger's Bay and at Fish Hatchery Cove. Material was planted on exposed muddy shoreline and in the water to a depth of 0.5 meters.

Emergent vegetation was planted on one-foot centers in the wettest tier of the inundation zone closest to the water. Shrubs were placed on one- to two-foot centers and trees grouped into clusters on two- to three-foot centers in the tier above emergent vegetation. Spacing was dependent upon available soil and the morphology of the site. Existing vegetation was not removed from the planting sites.

Terrestrial and emergent plants introduced during the course of this study were never inundated. Consequently, fish use of these plants could not be determined.

E. Hydroseeding

One acre of shoreline at Water Barge Cove (Map 1) was hydroseeded in October 1988. Water Barge Cove was selected because of the diverse environments present within an accessible area. South-facing slopes are gentle with slopes of less than 4 percent. North-facing slopes are steeper, averaging approximately 10 percent.

Table 4 lists the species of native shrubs and grasses used. Seeding was done in the fall to take advantage of cooler air temperatures and the advent of winter rainfall patterns that normally occur at this time of year. Work was contracted to J&M Land Restoration in Bakersfield, California.

To evaluate the success of the hydroseeding, data were collected periodically for soil moisture (percent gravimetric water content) and seedling density in one-meter plots.

F. Dessication Tolerances of Emergent Species

Cattail tubers were collected from various natural stands at the lake in spring 1989. Tubers were collected from approximate lake elevations of 367.3 m, 369.4 m, and 372.8 m. Lake elevations were at 366.9 m when tubers were collected. Lake level records indicate that it had been approximately one week since tubers at the 367.3 m lake level had been inundated, one year since tubers at the 369.4 m elevation had been inundated, and more than three years since tubers at the 372.8 m lake level had been inundated. All tubers were taken to a greenhouse rooting bed where they were planted and observed for three weeks.

Bulrush and cattail tubers were collected from the Fish Hatchery Cove planting site in May 1989, one year after planting. These tubers had been planted either in the water or in very moist soil in May 1988. However, immediately after planting, water levels began to recede and remained low. Consequently, these plants had not been inundated for a year. Collected tubers were planted in a rooting bed at a greenhouse and observed for three weeks.

Cattails were collected from two different stands planted in May 1988; one was slightly closer to the water's edge. However, all tubers were collected from very dry soil. Tubers were again planted in a rooting bed and observed for three weeks.

Table 4. Plant species used in the October 1988 hydroseeding at Water Barge Cove.

LATIN NAME	COMMON NAME
Grasses	
Bouteloua curtipendula	side oats grama
Hilaria jamesii	galleta grass
Sitanion hysterix	bottlebrush squirreltail
Sporobolus airoides	alkali sacaton
Sporobolus cryptandrus	sand dropseed
Shrubs	
Atriplex lentiformis	quail bush
Baccharis sarathroides	desert broom
Polygonum lapathifolium	willow weed
Prosopis pubescens	screwbean mesquite

G. Inundation Tolerances of Selected Species

A literature search was done to find information on the inundation tolerances of species that may be used for shoreline planting at Lake Mead.

IV. RESULTS

A. Seasonal Observation of Selected Coves

Observation of selected terrestrial and aquatic plant communities from August 1986 to September 1988 indicates that the effects of water level fluctuations are species specific; i.e., each species responds differently to water level changes. Appendix A contains diagrammatic representations of the extent and amount of cover of vegetation species at 11 sites over a one-year period. Photographs and field notes of these sites are on file at the LMRC.

1. Terrestrial Plant Species

The following is a summarization of the dominant terrestrial and emergent species responses to water level fluctuations based on field maps, photographs, and observations.

Trees and Shrubs

Seepwillow (*Baccharis glutinosa*): Seeds of this species were rarely seen germinating in the inundation zone. Adult plants were, however, very common in the upper tiers of the inundation zone. This plant appears to be tolerant of desiccation and flooding. During periods of high water, submerged seepwillow were noted surviving in water up to 0.5 m deep.

Fremont's cottonwood (*Populus fremontii*): Young cottonwood trees were occasionally observed in the inundation zone at Lake Mead. The tolerance of these young trees to flooding and desiccation was not observed.

Arrow weed (*Pluchea purpurascens*): This species was observed germinating and growing in moist soils in the inundation zone, especially at the Meadows in the upper basin. It appears to tolerate flooding of approximately 0.25 m and short periods of desiccation.

Goodding's willow (*Salix gooddingii*): This species was not observed growing in the inundation zone until July 1988. At this time, it was observed growing in the lowest shoreline tier which had been submerged for at least six years.

Tamarisk (*Tamarix ramosissima*): This species germinates rapidly in the inundation zone as water levels recede. Seedlings and young plants were observed at all times of the year where soils were moist and of a fine texture. Young plants appeared to have very little resistance to flooding, however. Adult plants are common in the upper tiers of the inundation zone.

Arrow weed (*Tessaria sericea*): This species was occasionally observed growing in the upper tiers of the inundation zone. This species is very drought tolerant and appears to withstand inundation for an undetermined amount of time.

Grasses and Forbs

Bermuda grass (*Cynodon dactylon*): An introduced species common on Big Horn Island, bermuda grass appears to tolerate water level fluctuations extremely well, surviving both in a very hot and dry environment as well as submerged to depths of approximately 0.5 m.

Umbrella sedge (*Cyperus oderatus*): This plant was commonly observed growing in moist soils in the inundation zone. It does not appear to tolerate inundation or desiccation.

Skeleton weed (*Eriogonum deflexum*): This plant is common in the upper tiers of the inundation zone on sandy soils. It does not tolerate inundation.

Common reed (*Phragmites communis*): Common reed was observed occasionally growing in the upper tiers of the inundation zone in Las Vegas Bay. Possible tolerance to inundation was not observed during the period of this study.

Alkalai sacatone (*Sporobolus airoides*): This species was commonly observed growing in moist soil of the inundation zone. It does not appear to survive desiccation or inundation.

Emergents

Willow weed (*Polygonum lapathifolium*): Willow weed was observed germinating and growing on moist soils in the inundation zone. It is not tolerant of desiccation. It is, however, tolerant of inundation; extensive stands of this species were observed growing in up to 1.5 meters of water.

Bulrush (*Scirpus robustus*): This species was not observed growing in the inundation zone until May 1988 when it was seen growing in small isolated stands. It appears to be tolerant of inundation. A stand of bulrush was observed expanding in the direction of receding water levels.

Narrowleaf cattail (*Typha angustifolia*): Stands of this species were observed in all tiers of the inundation zone. Cattails were observed growing in over 2.0 m of water. Lowering of water levels appears to stimulate growth, and dramatic increases in stand size were noted in late 1988 after a six-month period of low water. This indicates that tubers remain dormant while submerged and resume growth when water recedes. Water level records suggest that some of these tubers may have been submerged for as long as six years.

2. Aquatic Plants

Observation of aquatic plants at 11 selected coves over a one-year period indicates that spiny naiad and sago pondweed are the most common aquatic plant species in Lake Mead (Table 5). Widgeon grass (*Ruppia maritima*), curly pondweed, and *Chara* sp. also occur in the lake but are less common.

Aquatic plant communities at each of the 11 sites responded differently to changing seasons and water levels (Appendix A). Changes in cover values, abundance, and species dominance are most likely related to changes in water temperature, water clarity, depth of water, and substrate. Each of these factors is slightly different in each cove and, as a result, a general lake-wide trend in aquatic plant community changes could not be determined.

Table 5. Number of permanent study sites at which various aquatic plant species occurred over a one-year period in Lake Mead. Eleven total sites were observed for occurrence of aquatic species.

	Number of Sites					
	August	October	January	March	July	September
Spiny naiad (*Najas marina*)	8	9	6	2	9	7
Sago pondweed (*Potamogeton pectinatus*)	6	8	6	5	7	8
Widgeon grass (*Ruppia maritima*)	3	3	4	0	3	2
Chara sp.	3	4	3	1	3	0
Curly pondweed (*P. crispus*)	0	1	2	2	1	3

Table 6 gives the average water temperature, minimum and maximum depths of occurrence, average abundance rating, average age class, and number of sites at which sago pondweed was present during a one-year period. Temperatures of occurrence ranged from 13.0° C to 26.4° C. Depths of occurrence ranged from 0-7 meters. Sago pondweed occurred at the greatest number of sites (8 out of 11 possible) in October 1986 and September 1987. Abundance ratings were highest in October 1986, July 1987, and September 1987. Occurrence and abundance ratings were lowest in March 1987. The average age class was lowest in March, indicating that this was approximately the time of germination.

Table 6. Water temperature and depth at which sago pondweed was found during various sampling dates over a one-year period. Number of sites at which this species was found during each sampling period out of a total of eleven possible sites. Average age class and average abundance rating are also noted.

Date	Average Water Temperature (°C)	Water Depth Min/Max (meters)	Average Age Class	Average Abundance Rating	Number of Sites Present
10/86	19.8	0.0-5.5 m	2.5	3.5	8
01/87	13.0	0.6-7.0 m	1.5	2.8	6
03/87	13.9	0.9-4.0 m	1.0	1.7	5
07/87	26.4	0.0-4.6 m	4.0	3.9	7
09/87	26.3	0.6-5.2 m	3.8	3.8	8

B. Aquatic Plant Introduction Experiments

1. Small Scale Introduction Experiments (1987)

Overall, the fertilized plots had a higher percent survival and healthier plants than the unfertilized plots in both May and July (Figures 5 and 6). In May, sago pondweed had an average survival rate of 74 percent in the fertilized plots and 29 percent in the unfertilized plots. Curly pondweed had an average survival rate of 66 percent in the fertilized plots and 17 percent in the unfertilized plots. Plants in the fertilized plots appeared to be in better condition and were almost twice as tall as those in the unfertilized plots.

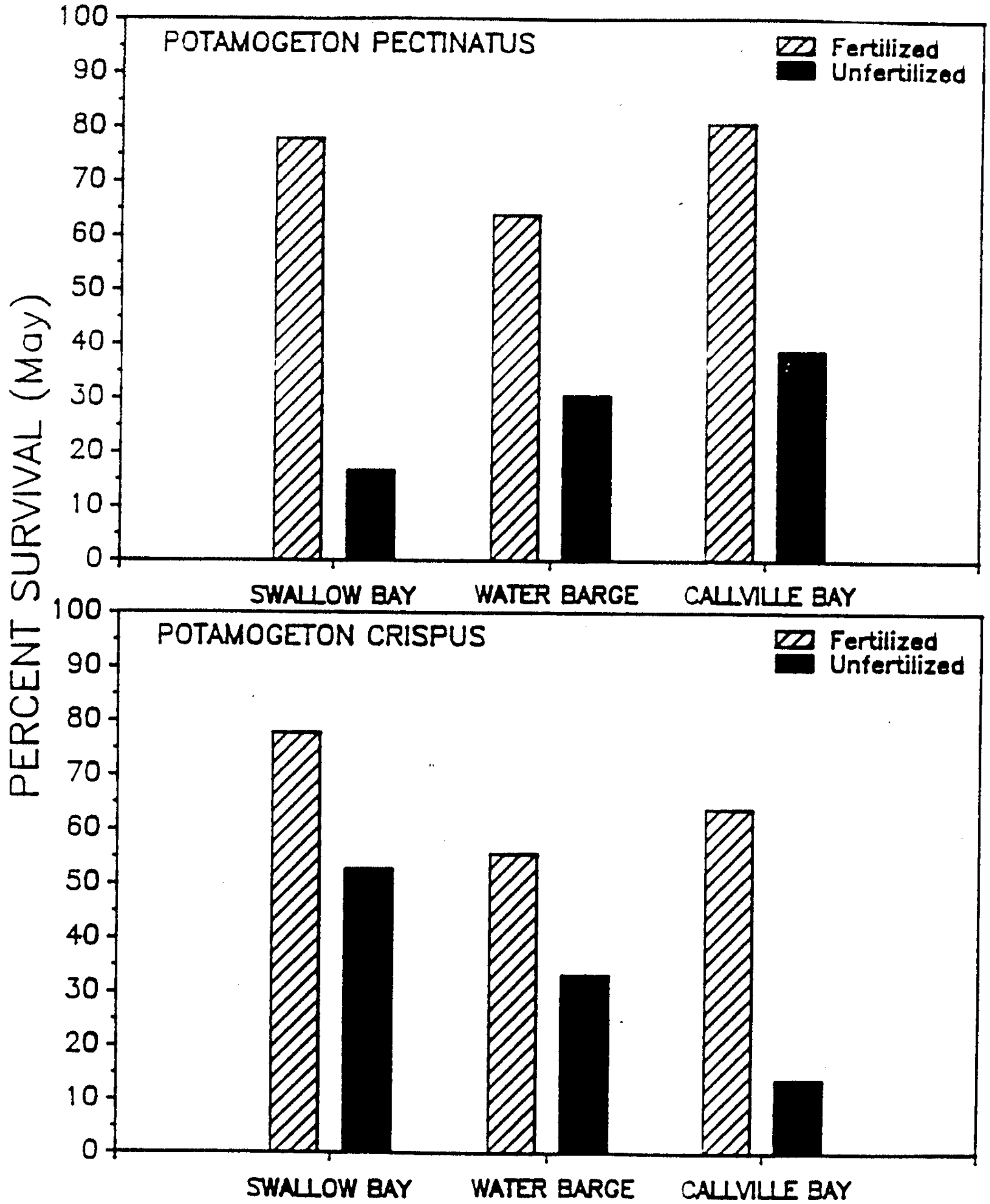


Figure 5. Percent survival of sago pondweed (*Potamogeton pectinatus*) and curly pondweed (*P. crispus*) at three sites in fertilized and unfertilized plots in May 1987, one month after planting.

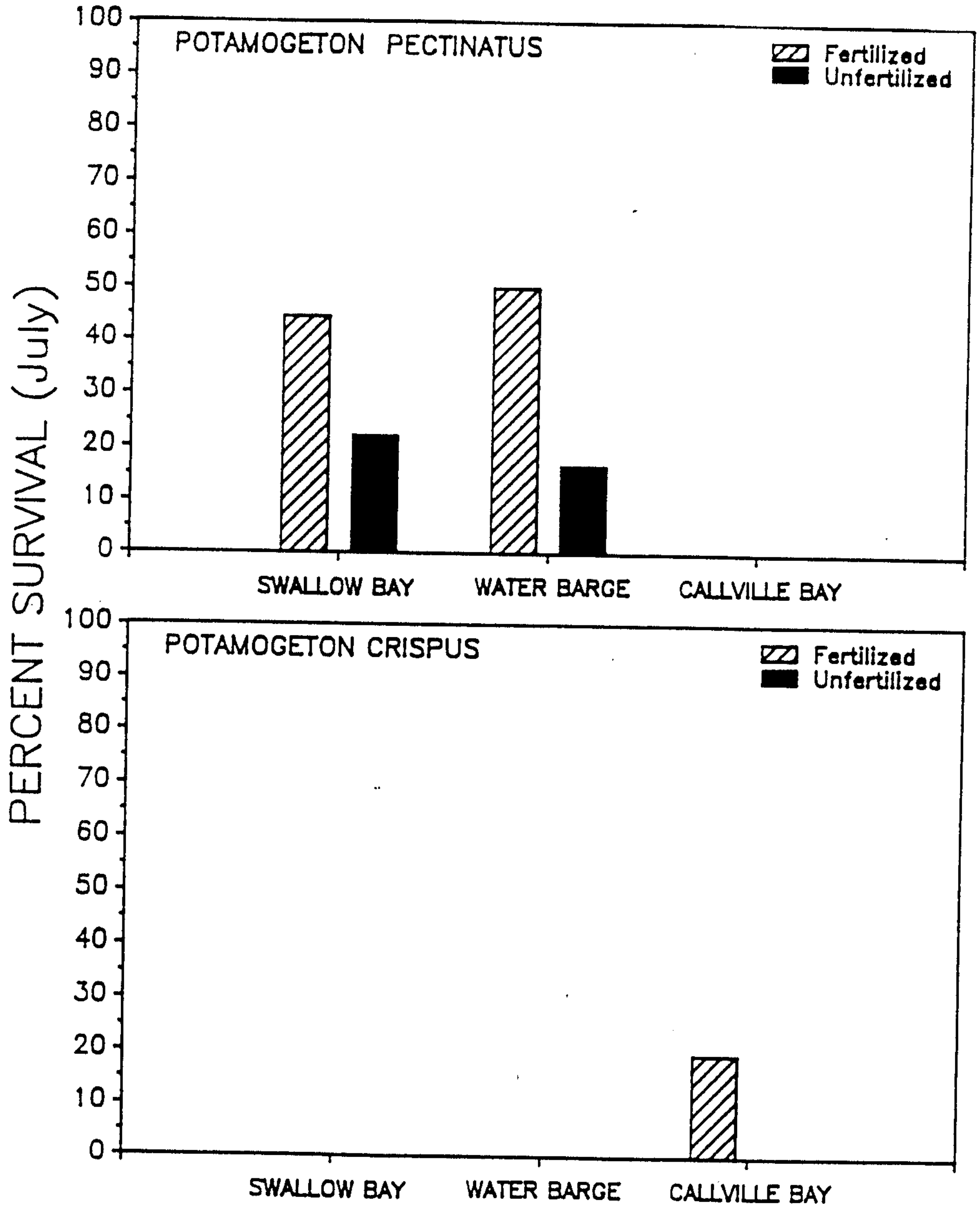


Figure 6. Percent survival of sago pondweed (*Potamogeton pectinatus*) and curly pondweed (*P. crispus*) at three sites in fertilized and unfertilized plots in July 1987, four months after planting.

High turbidity in the study area between May and July 1987 prevented further observation of the plants until July 1987. Fewer plants were observed in the plots at this time; however, those present appeared to be in good condition. Average survival rates for fertilized and unfertilized plots in July were 31 percent and 13 percent for sago pondweed, and 19 percent and 0 percent for curly pondweed, respectively. There was no plant growth in the control plots in May 1987 at any of the sites. However, in July, control plots contained populations of sago pondweed, *Chara* sp., and spiny naiad.

Plots were re-examined in May 1988 for growth of introduced tubers. All the plots at the Callville Bay site had been lost due to sedimentation or vandalism. Fertilized plots in Waterbarge Cove exhibited no plant growth. Other plots at this site had been vandalized. Fertilized plots at the Swallow Bay site had no plant growth. One unfertilized plot remained at this site, but it also had no plant growth in it. The other plots were lost due to sedimentation or vandalism.

2. Large Scale Introduction Experiments (1988)

After one month, there was approximately 100 percent germination of introduced sago pondweed tubers observed at both the Roger's Bay and Fish Hatchery Cove sites. Plants were healthy and sending out runners, with growth between 15 and 30 cm. During the monitoring period (April-September 1988) the pondweed continued to grow and spread throughout the planting sites. At the peak of their recorded growth, the plants were uniformly distributed, provided approximately 70 percent cover, and were about 2 m high. Shad, bluegill, and largemouth bass were noted utilizing the plants as cover. The introduced pondweed produced

seed in late July and started to die back in early August. Unfortunately, lower than predicted lake levels resulted in the desiccation of many tubers.

The fertilized and control sites at Fish Hatchery Cove and Roger's Bay, where no tubers were introduced, had no growth during the first month of the study. By June, both sites exhibited patchy distributions of spiny naiad, widgeon grass, and sago pondweed. The maximum vegetative cover recorded in late July at both the fertilized and control sites was only 25-30 percent. Therefore, fertilizer did not appear to promote the growth of naturally occurring plant populations.

Tubers planted in the spring of 1988 were checked for over-wintering capabilities. However, extremely low lake levels resulted in the desiccation of all of these tubers prior to the 1989 growing season.

3. Large Scale Introduction Experiments (1989)

There appeared to be approximately 100% germination of tubers planted in 0-7 meters of water after two weeks; however, germination of tubers in deeper water was very limited. There was no observable difference in germination or health of plants in fertilized and unfertilized coves. This probably was the result of the difficulty in applying fertilizer directly to tubers by spreading from a boat.

Plants in 0-7 meters of water were well established after a period of 4 weeks. However, there was still very limited germination (less than 5 percent) of plants in water deeper than 7 meters. SCUBA divers retrieved ungerminated tubers at this time and planted them in a tank

D. Terrestrial and Emergent Plant Introduction

1. Plant Material Collection and Preparation

Table 7 summarizes the number of cuttings and root stock collected and the number of hours expended in the collection of each species. Emergent vegetation, particularly cattails, were the most labor intensive to collect. Two hundred and sixty cattail tubers were collected in 22 man-hours. A backhoe was used for the collection of common reed and greatly expedited the process. If a backhoe can be used for the collection of all emergent plants (Kadlec, 1974), hours expended for collection would be significantly less.

2. Greenhouse Propagation Success

Figure 7 summarizes the greenhouse propagation success data. Seepwillow had a propagation success rate of 70 percent. The two willow species used, coyote willow and Goodding's willow, showed dramatically different results, 90 percent and 22 percent success, respectively. The Goodding's willow cuttings collected for propagation in December 1987 were taken from older branches, which may account for poor propagation success. Some of the wood was four years old with a stem diameter of 4 cm. Bulrush had the highest success rate of the emergent species (88 percent).

Table 7. Summary of plant collection in winter 1987-1988, including species collected and number of hours expended to collect[1] and store[2] material.

Species	Number Collected	Task	Manhours
seepwillow (*Baccharis glutinosa*)	402	collect	3.75
coyote willow (*Salix exigua*)	150	collect,store	1.00
Goodding's willow (*Salix gooddingii*)	415	collect	10.00
common reed (*Phragmites communis*)	200	collect, store	3.00
bulrush (*Scirpus robustus*)	234	collect, store	6.00
cattail (*Typha angustifolia*)	260	collect, store	22.50
willow weed (*Polygonum lapathifolium*)	5 lbs.	collect	18.00
mesquite (*Prosopis pubescens*)	.5 lb.	collect	2.00

[1]Collecting is defined as: all field work including; pruning, digging, cleaning, trimming, clipping to size, bundling, wrapping, packing. Collecting does not include crew transport time to and from field, transport of material to NDF and preparation of emergent material for long-term storage.

[2]Storing is defined as: cleaning, disinfecting, packaging and monitoring of emergent material for storage.

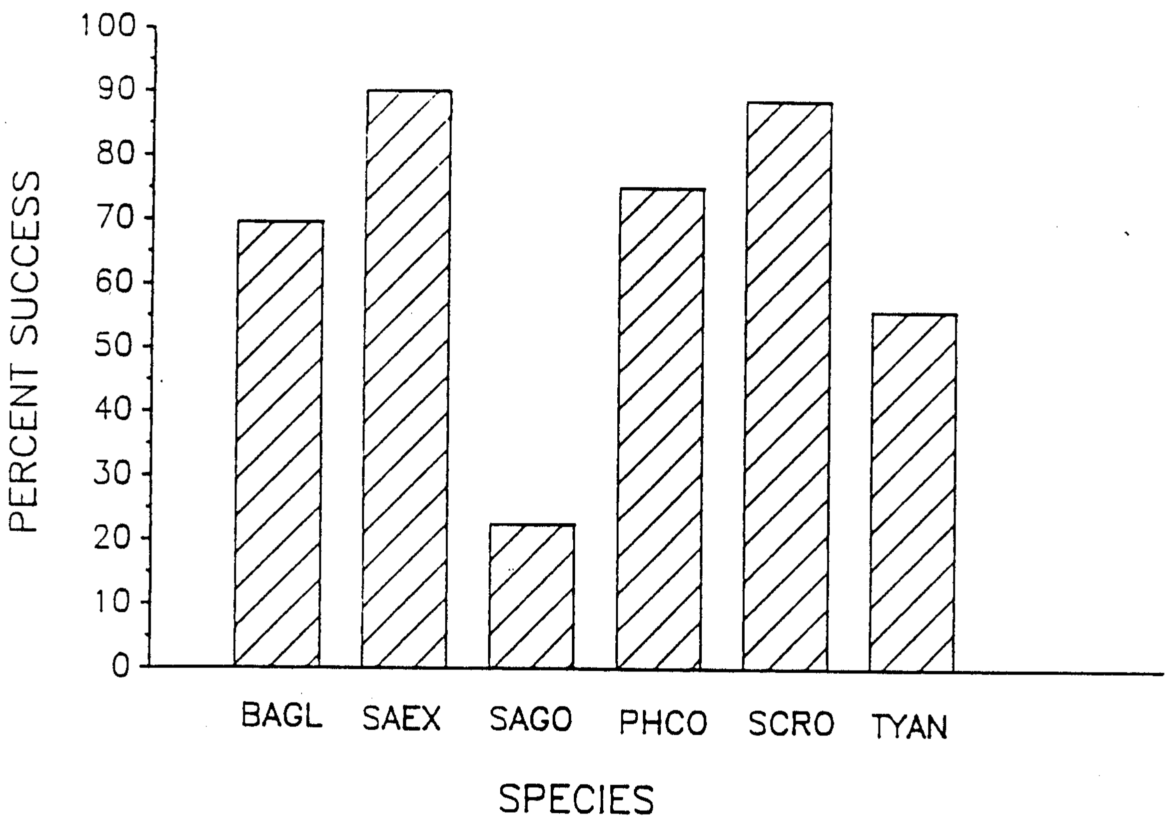


Figure 7. Propagation success of plant material after 12 weeks in the greenhouse. BAGL = seepwillow baccharis; SAEX = coyote willow; SAGO = Goodding's willow; PHLO = common reed; SCRO = bulrush; TYAN = cattail.

3. Field Out-Planting Success

Survival rates for rooted material of all species were higher than survival rates of direct cuttings in June. Figure 8 compares the survival of rooted material with direct cuttings for the month of June for all sites and all woody species. Rooted coyote willow had a survival rate of 93 percent, followed by rooted seepwillow with 76 percent. Direct cuttings of these species had survival rates of only 62 percent and 50 percent, respectively. It was not possible to plant dormant direct cuttings because lake levels were very high during the winter planting season. Survival rates of direct cuttings may have possibly been higher had dormant cuttings been used.

The direct cuttings of coyote willow were typically one meter in length and, ideally, should have been planted to a depth of 0.8 meters (Neiland *et al.*, 1981). The planting sites did not always have soils deep enough, and cuttings were occasionally planted to depths of only 0.3-0.5 meters, which could have resulted in low survival. Low survival could also be due to desiccation since a sealant was not used on the cuttings.

In general, the survival rate of plants at the Blue Point Cove site was greater than those at Fish Hatchery Cove (Figures 9 and 10). For example, cottonwood trees had a 59 percent survival rate at Blue Point Cove in August, and none were surviving at the Fish Hatchery Cove site. One year after planting, there was a 21% survival of cottonwood trees at Bluepoint Cove. This is most likely due to differences in soil texture. Soils with a higher clay content, like those at the Blue Point Cove site, retain more water than sandier soils like those at the Fish Hatchery Cove site.

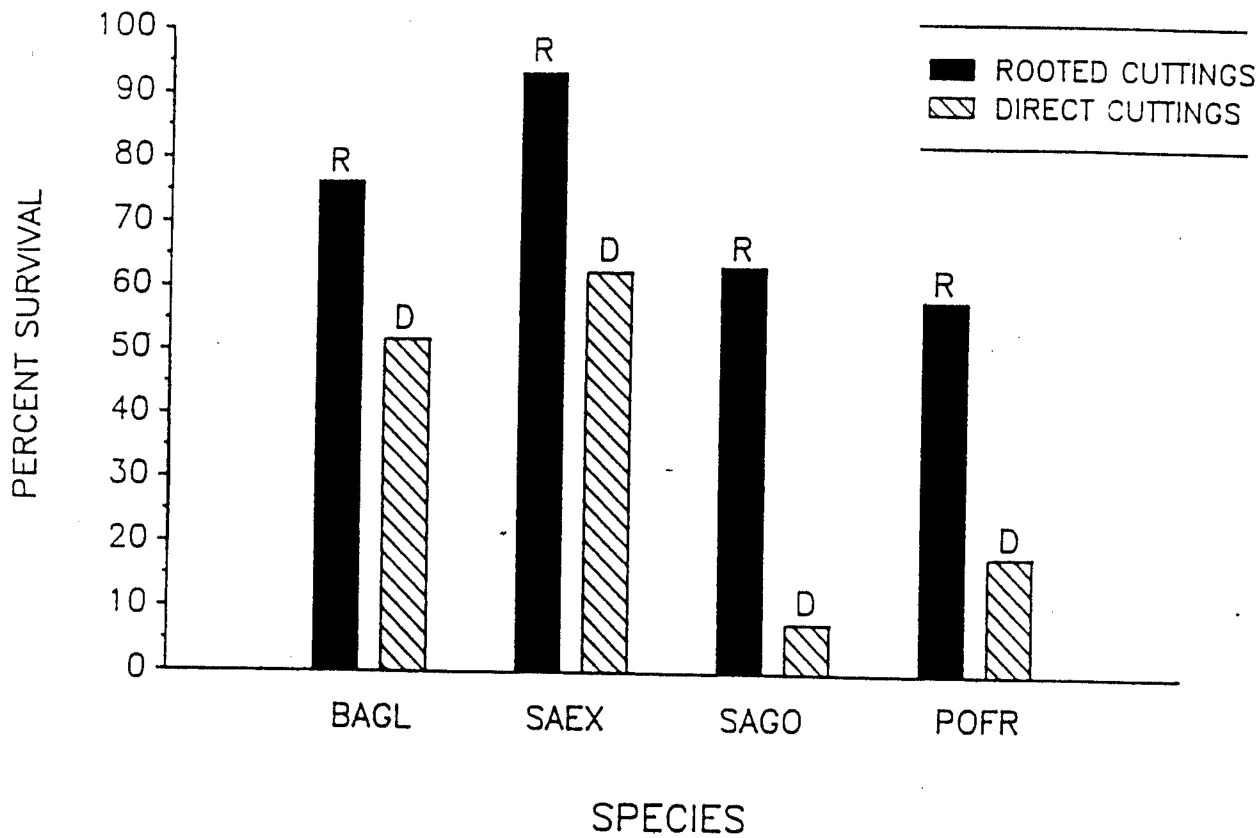


Figure 8. A comparison of survival rates of rooted (R) and direct (D) cuttings of four species during the month of June. All sites are included. BAGL = seepwillow baccharis, SAEX = coyote willow, SAGO = Goodding's willow, and POFR = cottonwood.

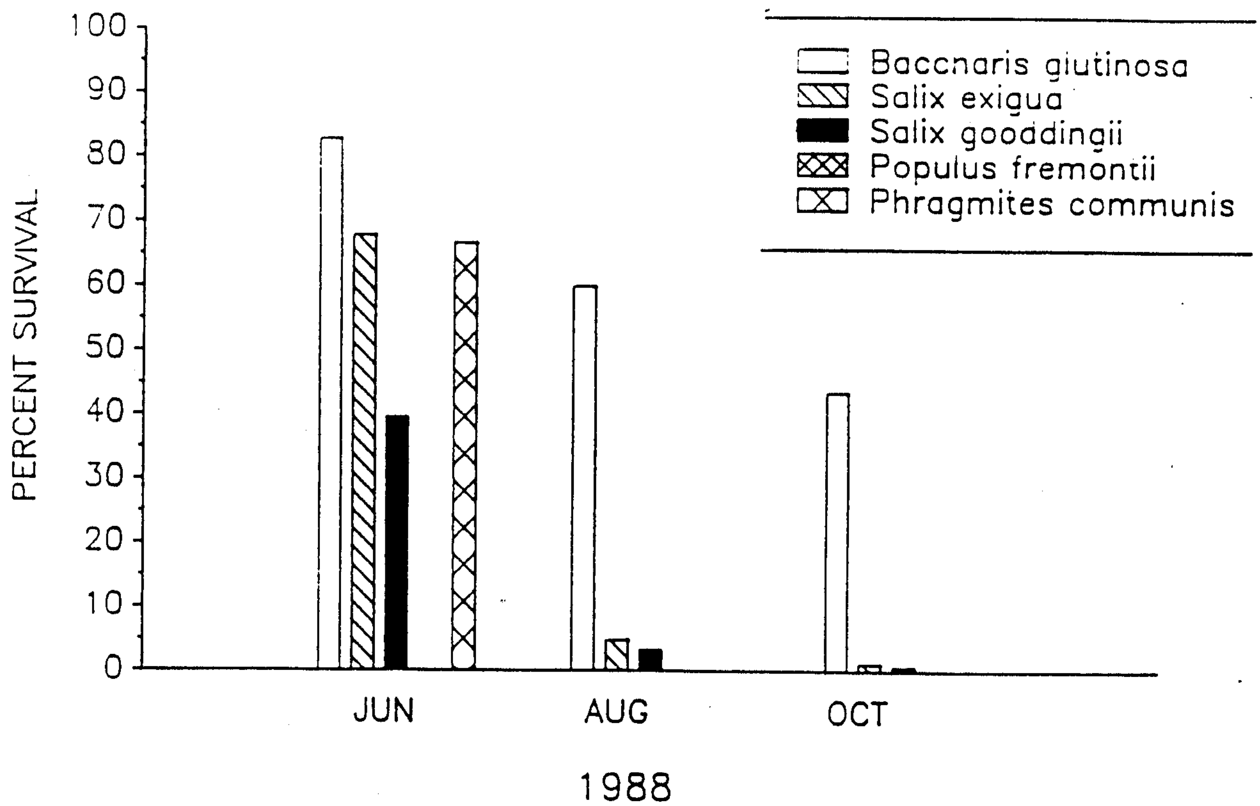


Figure 9. Percent survival of introduced plant material at Fish Hatchery Cove in June, August, and October 1988.

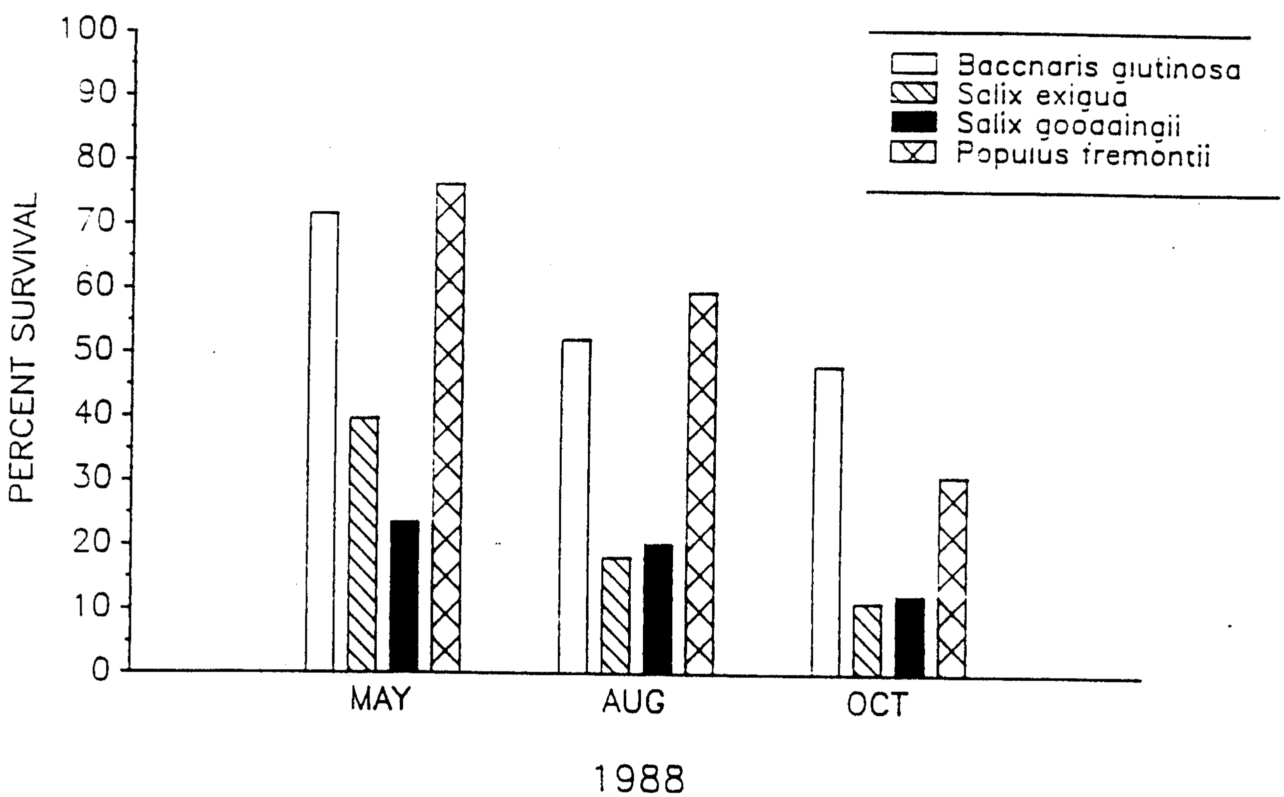


Figure 10. Percent survival of introduced plant material at Blue Point Cove in May, August, and October 1988.

Some species such as seepwillow appear to be better adapted to utilizing a deep water table. This is reflected in seepwillow survival rates for August (60 percent at Fish Hatchery Cove and 52 percent at Blue Point Cove for all treatments totaled). Overall, survival rates of seepwillow were greater than those of any other species planted (Figures 9 and 10). One year after planting, there was a 19 percent survival rate at Fish Hatchery Cove and a 44 percent survival rate at Blue Point Cove.

Establishment rates for Goodding's willow were low. Within five weeks of planting, survival rates were 39 percent at Fish Hatchery and 23 percent at Blue Point for all treatments totaled. Survival of Goodding's willow continued to decrease during the summer, with plants at Blue Point surviving better than those at the Fish Hatchery. Again, this may be the result of better access to the water table. Survival at Bluepoint through May 1989 was 11 percent, with none surviving at Fish Hatchery Cove.

Haslam (1970) found common reed (*Phragmites communis*) surviving by utilizing a low-lying water table two meters down. However, in this study, the survival of common reed was low, with none alive at Fish Hatchery Cove in August (Figure 9), again probably due to the sandy soils at the site and rapidly dropping water levels. Reed planted at Roger's Bay had a higher survival rate (Figure 11): 56 percent in August. These plants had the advantage of a supplemental watering from summer flashflooding.

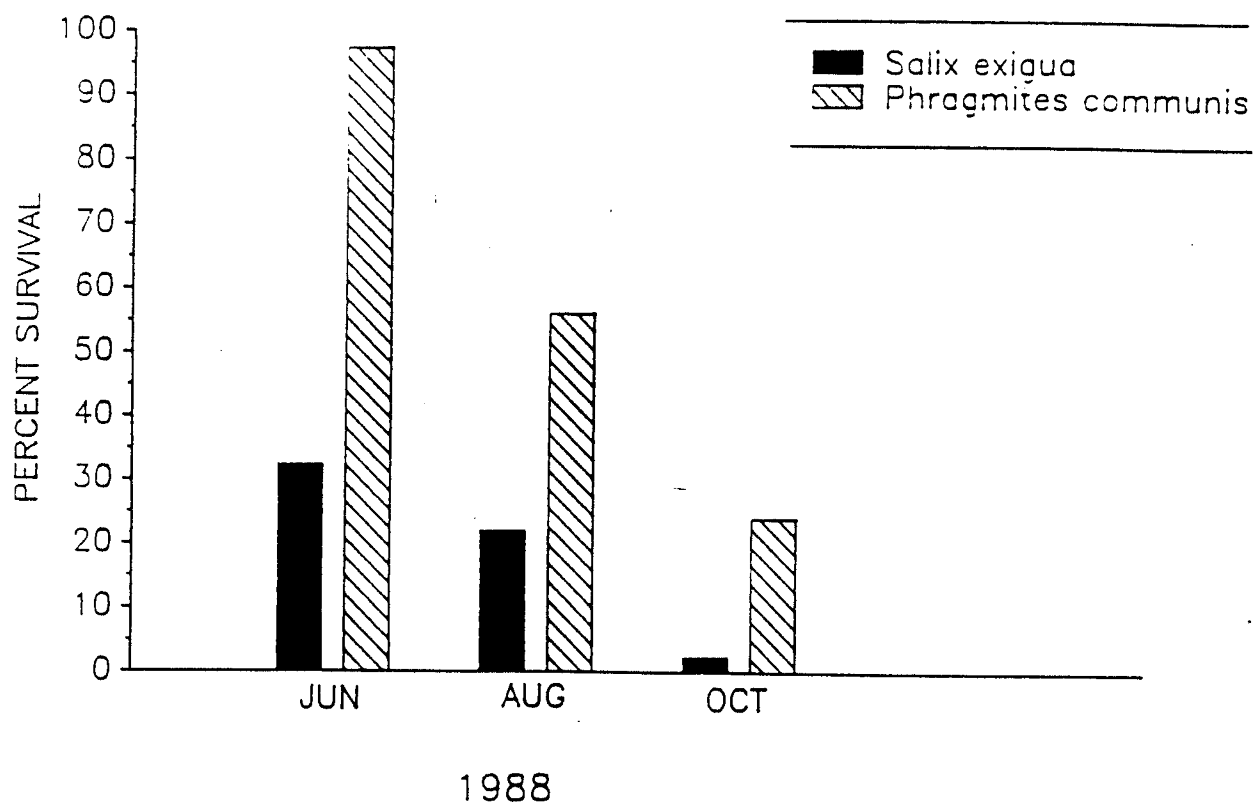


Figure 11. Percent survival of introduced plant material at Roger's Bay in June, August, and October 1988.

Bulrush became established and spread quickly. The ability of some species of *Scirpus* to increase cover rapidly in the inundation zones of reservoirs has been documented by Comes and McCreary (1986). One month after planting, cover estimated from percent of green, live material had increased from 45 percent at planting to 80 percent at Fish Hatchery Cove, and from 30 percent to 70 percent at Roger's Bay (Figure 12). Population expansion was in the direction of receding lake levels. Cattails, after four weeks, did not respond as well; cover increased only five percent at Roger's Bay and did not increase at all at Fish Hatchery Cove. In addition, cattail populations did not exhibit the same ability to expand down the slope toward dropping lake levels that bulrush did.

Overall, all species and types of plant material showed fair survival rates (Figures 9, 10, 11, and 12) until July, when lake levels dropped five feet lower than the projected levels. This event and higher-than-normal July temperatures resulted in rapid mortality. After one year, there was a 19% survival rate of seepwillow baccharis at Fish Hatchery Cove and a 44% survival rate at Bluepoint. Goodding's willow had an 11% survival rate at Bluepoint after one year, and coyote willow and cottonwood had a 5% and 12% survival rate, respectively, at this site.

E. Hydroseeding

Figure 13 shows density after hydroseeding of monocots, quailbrush (*Atriplex lentiformis*), and desert broom (*Baccharis sarathroides*) in November 1989, in relationship to the naturally occurring soil moisture gradient at the site. Highest densities of all plant species was found at soil moisture contents of between 20 and 30 percent. Densities dropped off rapidly with lower soil moisture contents and more gradually on wetter soils. Grasses and quailbush

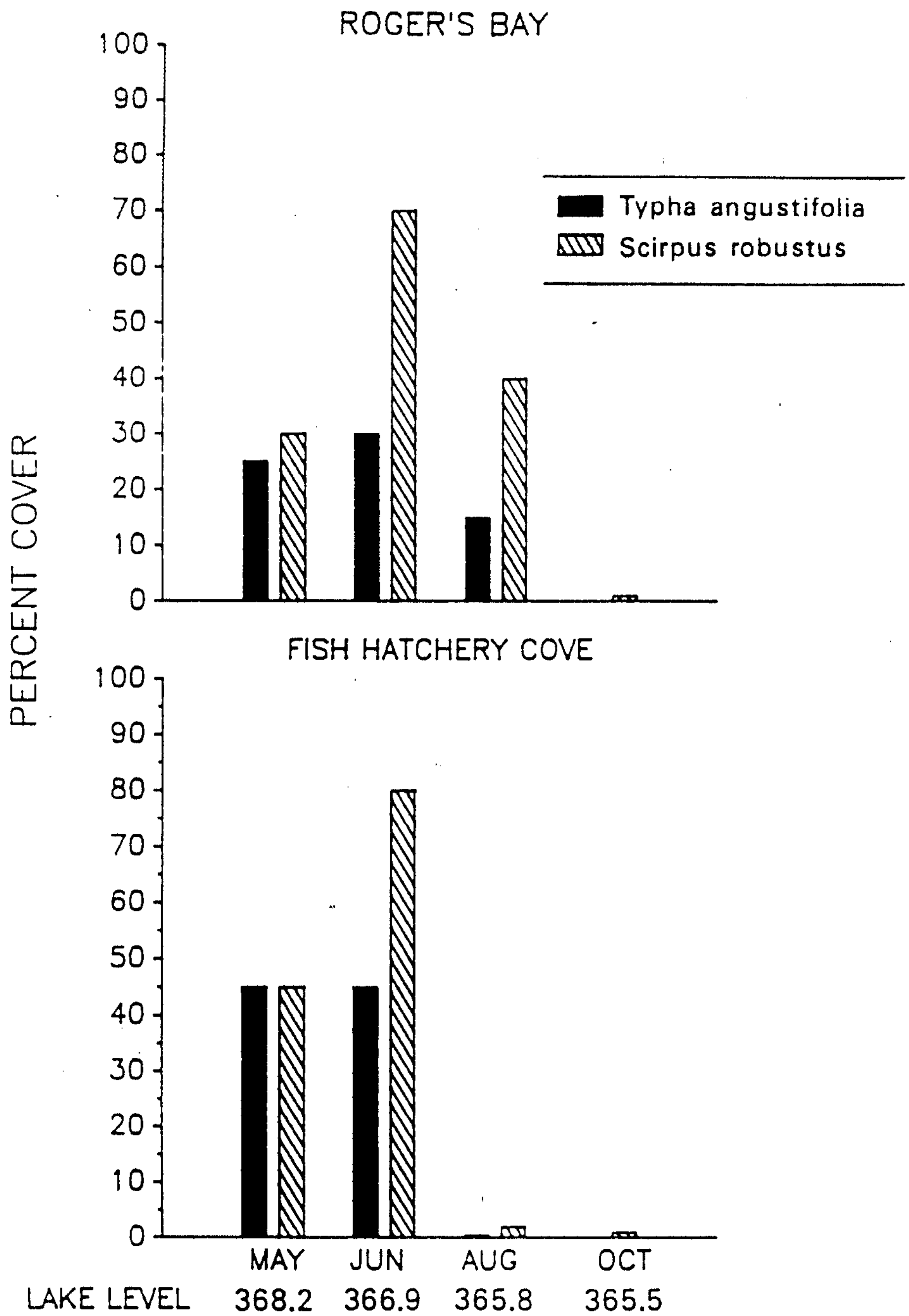


Figure 12. Percent cover of cattails (*Typha angustifolia*) and bulrush (*Scirpus robustus*) at Roger's Bay and Fish Hatchery Cove on the initial planting date in May and in the months of June, August, and October 1988.

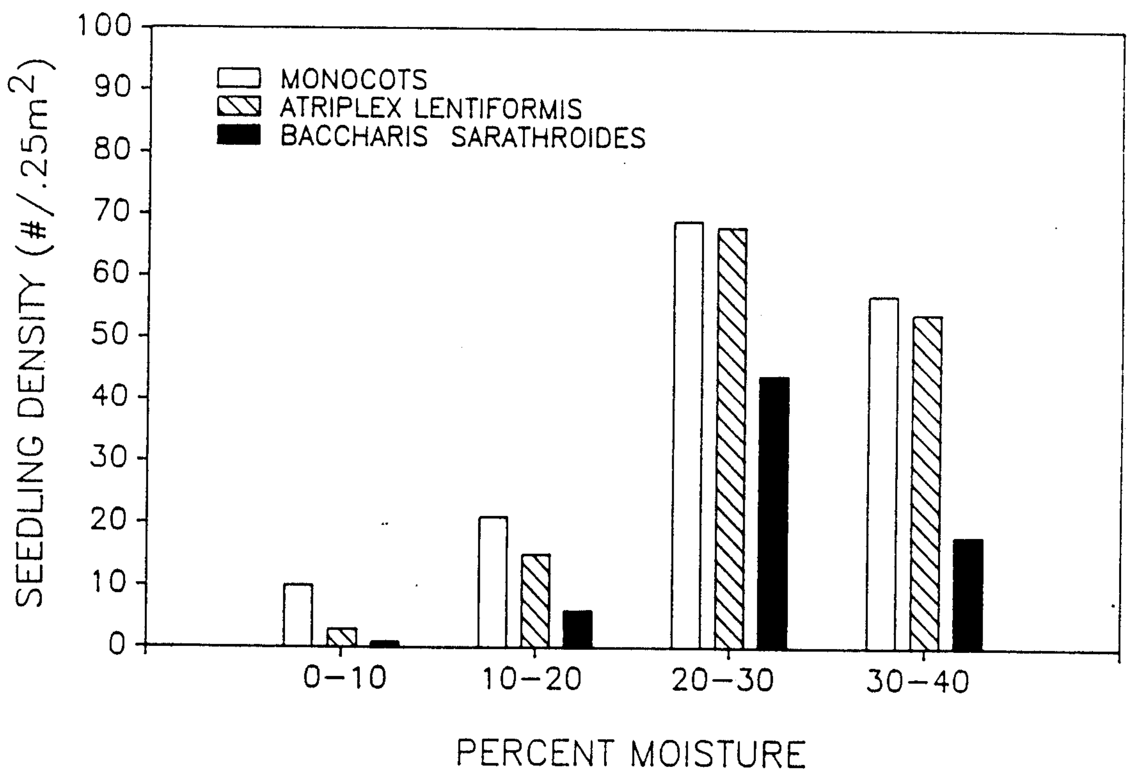


Figure 13. Percent survival of monocots, quailbush (*Atriplex lentiformis*), and desert broom (*Baccharis sarathroides*) one month after hydroseeding in relation to soil moisture contents.

had higher densities than desert broom. By January 1989 water levels began to rise and inundate the young plants. The hydroseeding site was observed one year after seeding in November 1989. Two quailbrush plants had become established, and several small plants of this species were observed. However, there was no evidence that any other seeded species had become established.

F. Dessication Tolerances of Selected Species

Cattail tubers were collected from various natural stands at the lake in spring 1989. Tubers were collected from approximate lake elevations of 367.3 m, 369.4 m, and 372.8 m. Lake elevation was at 366.9 m when tubers were collected. Lake level records indicate that it had been approximately one week since tubers at the 367.3 m lake level had been inundated, one year since tubers at the 369.4 m elevation had been inundated, and more than years since tubers at the 372.8 m lake level had been inundated. These tubers were taken to a greenhouse rooting bed where they were planted and observed for three weeks. After three weeks, there was 100 percent germination of tubers collected from the 367.3 m elevation, 40 percent germination of tubers collected from the 369.4 m elevation, and 0 percent germination of tubers collected from the 372.8 m elevation (Table 8). These data indicate that cattail tubers can withstand some degree of desiccation.

Table 8. Germination of cattail tubers collected from natural stands after various periods of time since inundation.

Lake elevation at which tubers were collected	Period of time since inundation	Percent germination
367.3 meters	1 week	100%
369.4 meters	1 year	40%
372.8 meters	>3 years	0%

Bulrush and cattail tubers were collected from the Fish Hatchery Cove planting site in May 1989, one year after planting. These tubers were planted either in the water or in very moist soil in May 1988. However, immediately after planting, water levels had receded. Consequently, these plants had not been inundated for a year. Collected tubers were planted in a rooting bed at a greenhouse and observed for three weeks. Bulrush tubers had 100% germination after a three-week period and grew very aggressively. Therefore, it can be concluded that bulrush tubers can withstand desiccation for at least one year.

Cattails were collected from two different stands planted in May 1988; one was slightly closer to the water's edge. However, all tubers were collected from very dry soil. Tubers were again planted in a rooting bed and observed for three weeks. Tubers collected from the stand nearest the water had a 70 percent survival rate. Those collected further away had a 40 percent survival rate. Again, it appears that cattail tubers can withstand some degree of desiccation.

G. Inundation Tolerances of Selected Plant Species

The literature was reviewed to evaluate the inundation tolerances of selected plant species. Since water levels remained low throughout much of the study, it was not possible to

field test inundation tolerances of Lake Mead species. A plant's ability to withstand inundation depends on many variables including its adaptation to soil anaerobiosis; plant age and size; flood depth, duration, and timing; substrate composition; and wave action. The primary differences between well drained and flooded conditions, however, are related to the depletion of free oxygen in the soil. Environmental factors and characteristics common to each plant species are generally of secondary importance in a plant's ability to survive inundation; however, these factors may have overriding importance in the field (Whitlow and Harris, 1979).

The near absence of oxygen in the soil creates a reducing environment that favors the activities of anaerobic bacteria. These organisms produce a variety of organic and inorganic by-products, many in toxic concentrations. Therefore, a plant living under flooded conditions must adapt to an anaerobic rooting medium that may also be toxic. Many plants can survive these conditions temporarily, but few are genetically adapted to flooded conditions. Adaptations may be made by either morphological or anatomical means (Whitlow and Harris, 1979).

All adaptations to flooding have one thing in common; they facilitate the conductance of oxygen to the root system and enable the plant to avoid the possible toxicities of anaerobic soil. Anatomical adaptations include hollow stems, porous cell structure, and adventitious root development. Metabolic adaptations include the ability to use anaerobic pathways for energy production and the removal of certain anaerobic by-products from the roots (Whitlow and Harris, 1979).

A plant's physical attributes are obviously important in determining its ability to withstand flooding. In addition, hydrological factors including the timing, duration, and depth

of the flood are extremely important. For instance, the seasonal timing of a flood is important to the survival of woody vegetation. Dormant season flooding usually does not affect woody plants and may even have a positive effect by increasing the moisture content of the soil through the dry summer season (Whitlow and Harris, 1979).

Many of the plants appropriate for planting at Lake Mead have been evaluated for flood tolerance capabilities. This information was synthesized by Walters *et al.*, 1980. Table 9 lists these capabilities for some species that may be used for shoreline plantings at Lake Mead. Very tolerant plants were defined as those that can withstand flooding for periods of two or more growing seasons. These species generally exhibit good adventitious or secondary root growth during this period. Tolerant plants can withstand flooding for most of one growing season. Some new root development can be expected during this period. Intermediately tolerant plants are able to survive flooding for periods from one to three months during the growing season. The root systems of these plants may produce few new roots or will be dormant during flooding. Species described as intolerant to flooding cannot withstand flooding for short periods (1 month or less) during their growing season. The root systems die during this period (Walters *et al.*, 1980).

Table 9. Plant species tolerance to flooding (Walters *et al.*, 1980).

Latin Name	Common Name	Flood Tolerance
Acacia greggii	catclaw	intermediately tolerant
Atriplex sp.	atriplex	tolerant
Baccharis sp.	baccharis	very tolerant
Chilopsis linearis	desert willow	intermediately tolerant
Phragmites communis	common reed	very tolerant
Pluchea sericea	arrowhead	intermediately tolerant
Populus fremontii	Fremont cottonwood	very tolerant
Prosopis sp.	mesquite	intermediately tolerant
Salix exigua	coyote willow	very tolerant
Salix gooddingii	Goodding willow	tolerant

In 1987, data were collected by Gamble and Rhoades on flood tolerance of a variety of grass species in the Southern Great Plains. Data covering location, age of stand, and duration of inundation were collected from 99 observations of grasses that were flooded after widespread, severe storms. Table 10 presents a summary of these observations which show the average time these grasses would be expected to survive inundation with cool water in the spring.

Table 10. Spring inundation tolerance of selected grass species.

Grass Species	Aver. no. days inundation survived
Bermudagrass (*Cynodon dactylon*)	45-90
Buffalograss (*Buchloe dactyloides*)	45-90
Knotgrass (*Paspalum distichum*)	45-90
Vine mesquite (*Panicum obtusum*)	36-75
Western wheatgrass (*Agropyron smithii*)	30-60
Florida paspalum (*Paspalum floridanum*)	30-60
Barnyardgrass (*Echinochloa crusgalli*)	30-60
Virginia wildrye (*Elymus virginicus*)	20-45
Beaked panicum (*Panicum anceps*)	20-45
Switchgrass (*Panicum virgatum*)	15-30
Purpletop (*Tridens flavus*)	10-20
Johnsongrass (*Sorghum halepense*)	10-20
Tall fescue (*Festuca arundinacea*)	10-20
Indiangrass (*Sorghastrum nutans*)	7-14
Big bluestem (*Andropogon gerardi*)	7-14
Silver bluestem (*Andropogon saccharoides*)	5-10
Little bluestem (*Andropogon scoparius*)	3-6
KR bluestem (*Andropogon ischaemum* var.)	3-6
Weeping lovegrass (*Eragrostis curvula*)	3-6

Sharma and Gopal (1979) found that cattail (*Typha angustifolia*) seedlings grew best in shallow water (10 cm). Small increases in the water depth during the latter part of the growth period had a favorable influence on the growth and development of the rhizome. However, continuous growth of seedlings under deep water (50 cm) or large, sudden fluctuations in the water level affected the growth adversely.

Mall (1969) found that for cattail to be dominant in the field, the plant required, in part, long periods of flooding ranging from 6-11 months of continued submergence. Long submergence effectively restrained all competitors except Olney bulrush (*Scirpus olneyi*). Olney bulrush was more tolerant of shorter periods of flooding than cattail. Dominant stands of alkali bulrush were observed on soils that were submerged between 3 and 11 months, and it did not grow on soils that were submerged for less than 2 months. Saltgrass (*Distichlis* sp.) stands were characterized by soils that were submerged between 0 and 10 months. No submergence appeared to provide optimum competitive ability, while increasing submergence resulted in the reverse situation. Saltgrass was least competitive on sites submerged for 6 months or longer.

V. DISCUSSION

A. Naturally Occurring Plant Communities at Lake Mead

Fluctuating lake levels play the largest role in determining vegetation community composition in the inundation zone. Observations of existing communities over the past 2½ years indicate that the inundation zone is a very stressful environment for plant life. No naturally-occurring species observed during this study exhibited the ability to withstand desiccation and inundation, together with the ability to germinate and become established in the inundation zone.

There are, however, species that show some tolerance to these harsh conditions. Seepwillow, for example, can tolerate long periods of desiccation and appears to be able to withstand some degree of flooding. However, this species does not become established from seed

in the inundation zone. Tamarisk seed readily becomes established on exposed soil surfaces, but young tamarisk shows little tolerance for flooding. Cattail and Goodding's willow root masses appear to be able to survive long periods of inundation. Both species were found growing on recently exposed soils that had been inundated since approximately 1982. However, unlike Goodding's willow, cattails cannot withstand long periods of desiccation, and neither species was observed becoming established from seed in the inundation zone. Therefore, observations of existing plant communities at Lake Mead indicate that several species show potential for survival in conditions with widely fluctuating water levels.

Fertilization and weekly watering of existing stands of vegetation do not appear to increase the number or size of plants occurring in the inundation zone. Consequently, enhancement of naturally occurring plant populations at Lake Mead must be done by transplanting selected species.

Observation of aquatic plants at permanent study coves indicates that species composition and changes in plant communities are very site-specific and are probably related to water temperature, depth and clarity, and to cove substrate. Each of these factors is different at every location and, as a result, a general trend in aquatic plant community changes in relation to fluctuating water levels could not be determined in this study.

B. Aquatic Plant Introduction

Planting sago pondweed tubers is an easy, effective means of increasing cover in shallow water at Lake Mead. Small-scale experiments indicate that fertilizer promotes the growth of tubers; however, it is difficult to apply fertilizer directly to planted tubers from the side of a boat.

Therefore, it is recommended that further research be done on methods and optimum rates of fertilizer application.

Laboratory studies and field observations suggest that sago pondweed tubers do not withstand desiccation. Consequently, tubers must be planted when there is little chance for lake levels to recede significantly. In addition, field research indicates that tubers do not germinate well in water deeper than 7 meters. Tubers that were planted in deeper water in April did not germinate as water levels receded during the summer, indicating that photoperiod and water temperature may be important factors in germination. It is recommended that further research be done into sago pondweed tuber requirements for germination.

It was not possible to evaluate the over-wintering capabilities of sago pondweed tubers due to drops in lake levels over the course of this study. Therefore, it is recommended that observations be made in 1990 of tubers planted in Waterbarge Cove in April 1989.

The ease of introduction and the relatively small investment needed for covering significant areas indicate that aquatic plant introductions should be seriously considered in future management planning at Lake Mead.

C. Introduction of Terrestrial and Emergent Plant Species

Unpredicted changes in lake water levels greatly impact the success of terrestrial and emergent plantings in the inundation zone. In the short term, plants can be lost before they become established if they are flooded or desiccated. It may also be possible to have long-term

losses of established plants if lake levels recede quickly to very low levels or if plants are inundated for lengths of time or depths greater than that species' tolerance level.

The predicted water level regime must be taken into consideration when planning the time of planting and the form and species of plant material to be used. Short-term losses of plant material due to desiccation can be avoided by planting as lake levels recede. The lake will provide water to plants, and roots will follow the water table as levels recede. However, if lake levels drop too quickly or too low, irrigation systems will need to be constructed to provide water to trees and shrubs to encourage deep rooting (Anderson, 1988b). Short-term losses resulting from inundation can only be avoided by planting in the upper tiers of the inundation zone.

Site selection appears to be extremely important. In particular, the soil type at the site appears to play an important role in the availability of the water table to plant roots. If planting of terrestrial and emergent plant species is to be used as a tool in species management at Lake Mead, further research into site selection criteria is recommended.

Seepwillow shows excellent potential for use in revegetation work. Greenhouse propagation rates were good, and survival averaged 45 percent in the field after a summer with no irrigation. In addition, bulrush, Goodding's willow, coyote willow, and cottonwood all showed potential for use in a shoreline revegetation project. However, unpredicted low lake levels over a one-year period resulted in the loss of most plant material. Review of the literature indicates that these species are tolerant to flooding. Field observations indicate that bulrush and cattail tubers can withstand at least a one-year period without flooding.

Rooted cuttings survived better and may be more cost-effective in the long run than the use of direct cuttings. In June 1988 rooted plants of coyote willow had a survival rate of 93 percent followed by seepwillow with 76 percent. Direct cuttings of these species had survival rates of only 62 percent and 50 percent, respectively.

We believe that it is possible to establish terrestrial and emergent plants on the shoreline of Lake Mead. However, a revegetation project needs to be highly flexible in terms of time of planting, choice of plant material, and propagule type. In some years under certain water level regimes, it will be necessary to irrigate. Loss of plant material can be anticipated in years when lake levels are extraordinarily high or low or when they vary from predictions. In addition, planting terrestrial material can be highly labor-intensive.

Survival of understory plants, including emergents, may be greater if an "ecosystem" approach to revegetation is adopted. In this approach, trees would be planted in the upper tiers when water levels are high. After the trees have become established, understory plants including emergent vegetation would be planted in their shade. Understory vegetation would benefit from cooler soil temperatures and reduced soil moisture loss. Although it could take several years to complete revegetation in a cove, we believe that the potential for medium- to long-term survival would be considerably increased.

D. Hydroseeding

Highest seedling density, six weeks after hydroseeding, was found at soil moisture contents of between 20 and 30 percent. Seedling density dropped off sharply at lower moisture tensions. Soil moisture levels will need to be maintained at an optimum level either by watering or by

natural weather patterns or, most likely, a combination of both. Again, hydroseeding activities must coincide with a predicted, long, low water period so that seedlings may become established before water levels rise.

VI. CONCLUSIONS AND RECOMMENDATIONS

1. Introduction of sago pondweed tubers is an easy, effective method of increasing cover for game fish at Lake Mead. However, over-wintering success of these tubers and germination requirements should be more fully understood before large-scale management activities begin. Loss of tubers as a result of desiccation is possible when lake elevations go to unpredicted low levels, and tubers do not appear to germinate in greater than 7 meters of water. Although fertilization appears to have a substantial impact on plant growth, optimum rates for fertilizer application have not yet been determined, and experimentation with application techniques is recommended.

2. Shoreline revegetation at Lake Mead is highly dependent on lake level fluctuations. Unpredicted changes in water levels can result in losses of plant material. Therefore, it is recommended that any revegetation project include close coordination with the BOR so that planting decisions are based on information that is as accurate as possible. It should be recognized that even with BOR coordination, there will still be the potential for loss of plant material if lake levels become extremely high or low and if they vary from predictions.

3. Any revegetation project planned for the shorelines of Lake Mead will have to be extremely flexible in terms of times of planting, propagule type, and tier to be planted. These factors should be determined in light of predictions for lake level fluctuations.

4. Losses of plant material due to low water levels can be mitigated by utilizing irrigation systems. It is recommended that investigation into possible irrigation systems be initiated. Anderson (1988b) found that only 90 days of irrigation was necessary before cottonwood roots reached the water table at a depth of 3 m. When roots reach the water table, irrigation systems can be removed and mortality is very low. Therefore, it is also recommended that investigation into water table depths and irrigation systems be done.

5. Emergent species appear to be able to withstand flooding and desiccation, and are highly recommended for use in further shoreline plantings. Other species that are recommended for planting include seepwillow bacchariis, Goodding's willow, coyote willow, and cottonwood.

6. Germination and establishment of seedlings after hydroseeding is highest where soil moisture is between 20 and 30 percent. Consequently, it is recommended that soil moistures after hydroseeding be maintained by watering or by natural weather patterns or, most likely, a combination of both.

7. It is recommended that further revegetation efforts evaluate the potential for an ecosystem approach to shoreline revegetation.

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APPENDIX A

Permanent Study Cove Profiles

Cove Profile

Name: UB5

Location: The Meadows

Legal Description: T18S R68E Sec 6

Inventory Dates: 8/5/86, 10/25/86, 1/7/87, 3/13/87, 7/14/87, 9/15/87, 3/25/88

Soil Description: Cobbles and stones on surface. Tier 1-sandy loam; Tier 2 near PLPU-loam.

Sediment Description: 7 ft. sandy loam.

Disturbance: Area is not disturbed.

Degree of Protection: Area is not protected/west facing.

Table A. Mean temperature (C), dissolved oxygen (DO-mg/l), conductivity (EC-micro mho/cm) and pH at UB5 from the surface of the water to the bottom of the cove. Light transmittance (light-microeinsteins/m^2/sec) is presented as a range from conditions at the surface of the water to 4 meters in depth. Vertical extinction coefficients (K, m^{-1}) were calculated from vertical profiles of light intensity by using linear regressions of natural log transformed data.

Date/Time	**Temp**	**DO**	**EC**	**pH**	**Light**	**K**
8-5-87/0645	28.8	8.1	890	8.6	450-130	0.40
10-25-86/1100	19.1	8.5	816	8.3	840-190	0.36
1-7-87/0950	12.2	10.3	818	8.3	variable clouds	
3-13-87/----	No Data					
7-14-87/0800	27.4	9.5	824	8.5	360-083	0.29
9-15-87/1140	26.6	8.5	858	7.4	650-130	0.32
3-25-88/0935	13.2	11.0	841	8.4	580-120	0.29

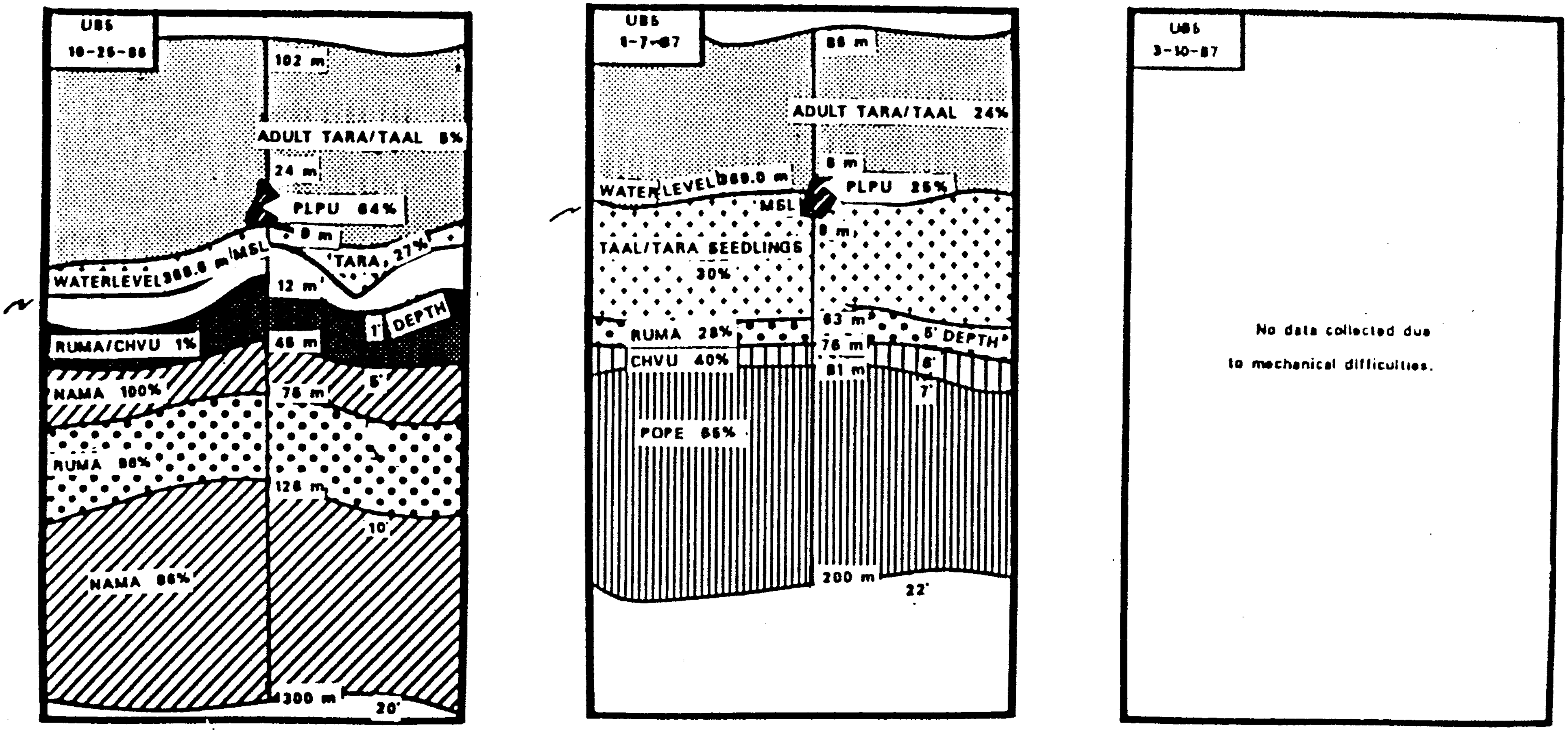


Figure A. Diagrammatic representation of the extent and amount of cover of vegetation communities at UB5 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

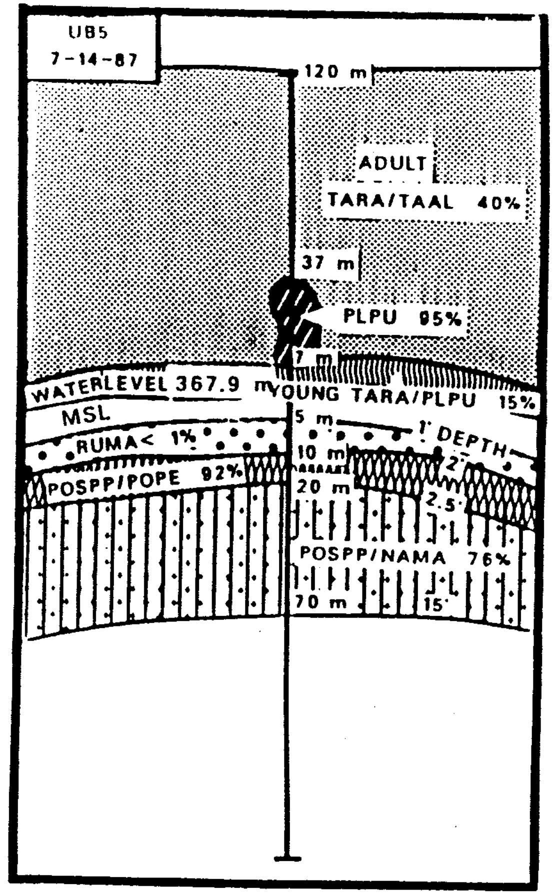


Figure A *(Continued)*.Diagrammatic representation of the extent and amount of cover of vegetation communities at UB5 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

Cove Profile

Name: UB7

Location: Mud Wash

Legal Description: T17S R69E Sec 18

Inventory Dates: 8/5/86, 10/25/86, 1/7/87, 3/13/87, 7/14/87, 9/15/87

Soil Description: Tier 1-sandy loam; Tier 2 near TARA-loam.

Sediment Description: 3 ft. loam.

Disturbance: Very disturbed by burros.

Degree of Protection: Protected from wind and wave action.

Table B. Mean temperature (C), dissolved oxygen (DO-mg/l), conductivity (EC-micro mho/cm) and pH at UB7 from the surface of the water to the bottom of the cove. Light transmittance (light-microeinsteins/m^2/sec) is presented as a range from conditions at the surface of the water to 4 meters in depth. Vertical extinction coefficients (K, m^{-1}) were calculated from vertical profiles of light intensity by using linear regressions of natural log transformed data.

Date/Time	**Temp**	**DO**	**EC**	**pH**	**Light**	**K**
8-5-86/0110	29.7	8.3	890	8.3	960-038	0.85
10-25-86/0930	18.8	8.3	830	8.4	580-042	0.65
1-7-87/1354	12.6	10.3	821	8.2	variable clouds	N/D
3-13-87/0910	13.5	11.2	804	8.0	490-092	0.49
7-14-87/0710	27.3	8.2	833	8.4	230-019	0.50
9-15-87/0925	26.4	7.6	878	7.3	420-004	0.76

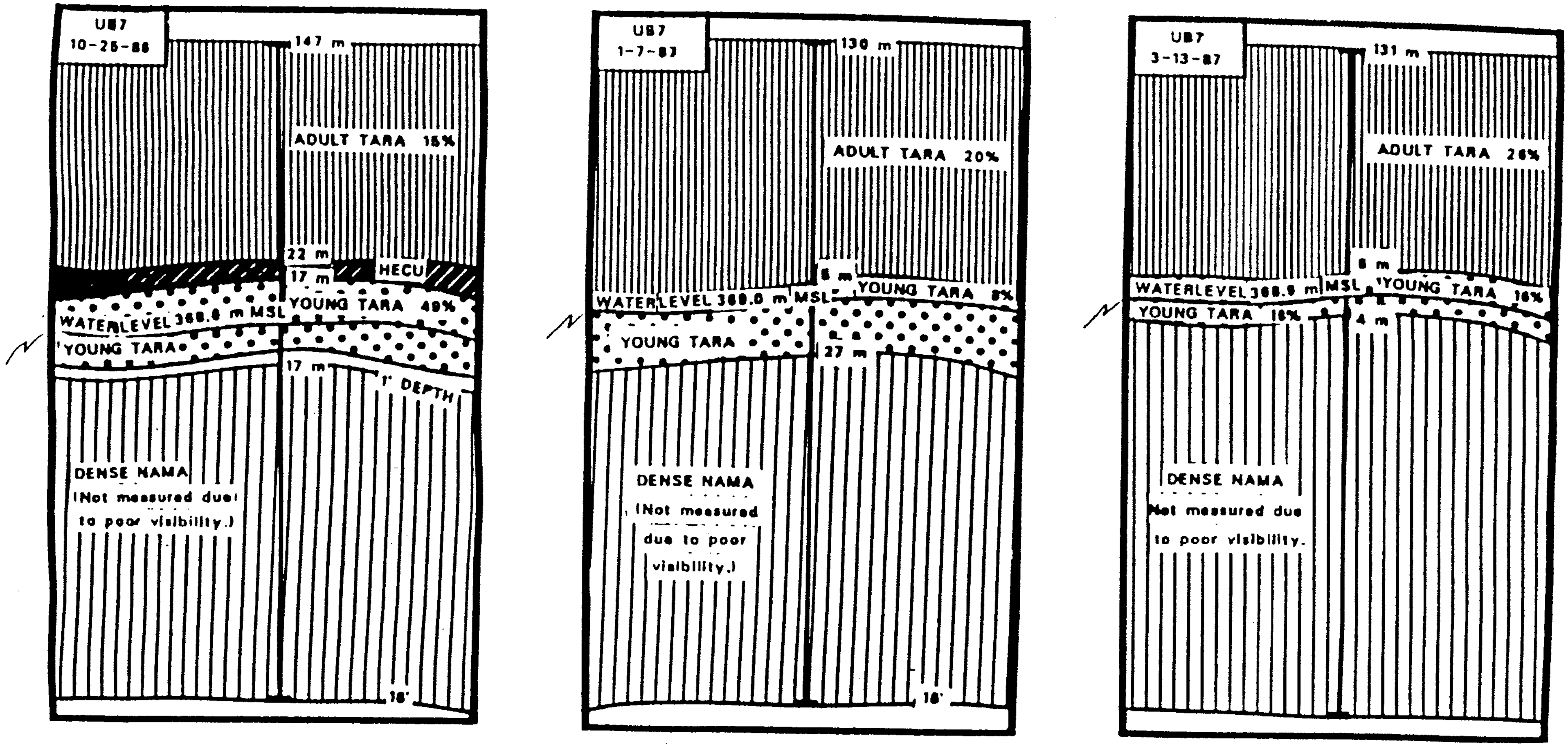


Figure B. Diagrammatic representation of the extent and amount of cover of vegetation communities at UB7 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

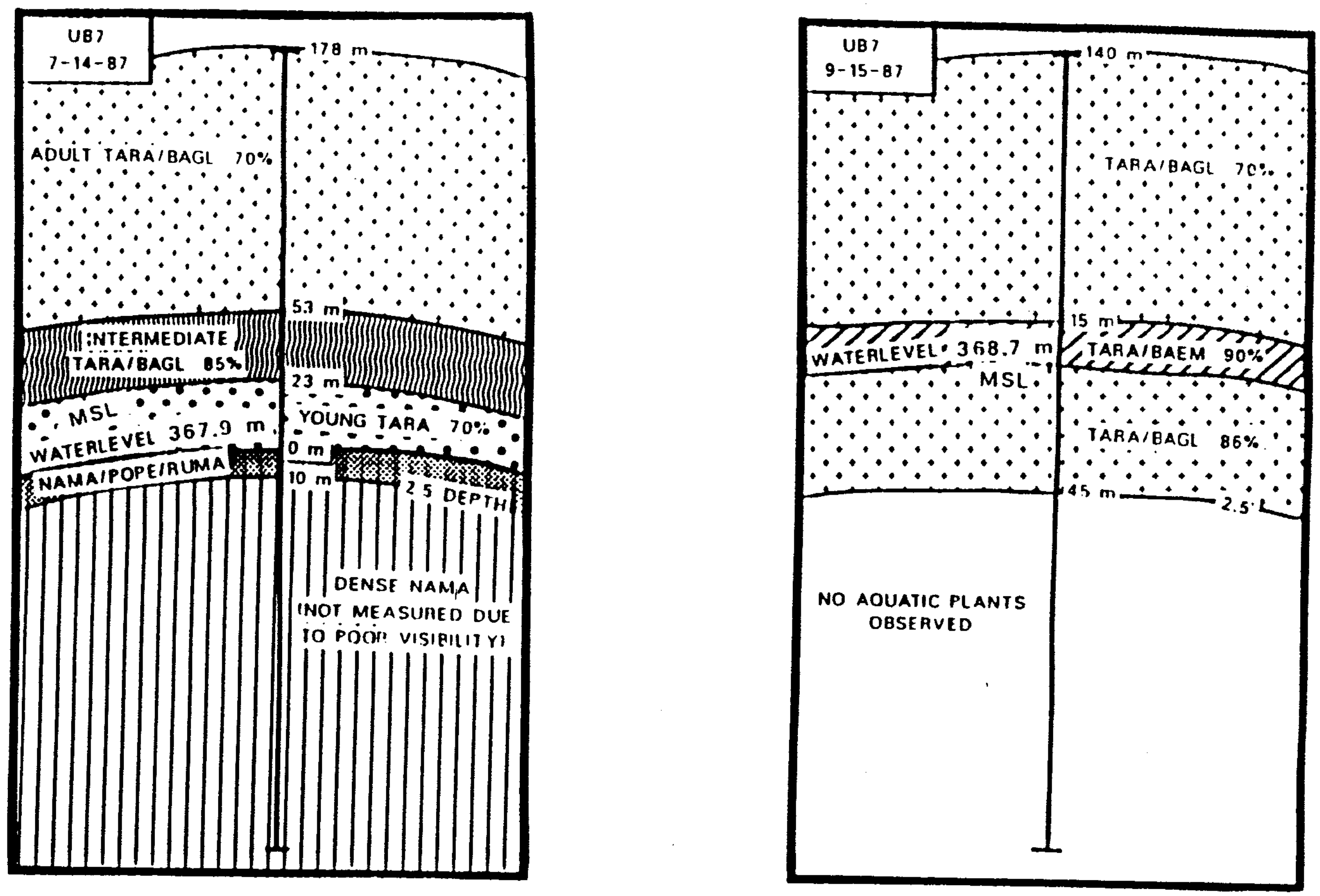


Figure B *(Continued)*.Diagrammatic representation of the extent and amount of cover of vegetation communities at UB7 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

Cove Profile

Name: UB8

Location: North of Catclaw Cove

Legal Description: T19S R68E Sec 27

Inventory Dates: 8/5/86, 10/25/86, 1/8/87, 3/12/87, 7/14/87, 9/14/87

Soil Description: Tier 1- sandy; Tier 3 - near ERDE - sandy; Tier 3 - loamy sand.

Sediment Description: 15 ft. sandy loam.

Disturbance: No disturbance is noted.

Degree of Protection: Moderately protected from wind and wave action.

Table C. Mean temperature (C), dissolved oxygen (DO-mg/l), conductivity (EC-micro mho/cm) and pH at UB8 from the surface of the water to the bottom of the cove. Light transmittance (light-microeinsteins/m^2/sec) is presented as a range from conditions at the surface of the water to 5 meters in depth. Vertical extinction coefficients (K, m^{-1}) were calculated from vertical profiles of light intensity by using linear regressions of natural log transformed data.

Date/Time	**Temp**	**DO**	**EC**	**pH**	**Light**	**K**
8-5-86/1245	28.5	8.4	865	8.1	850-170	0.25
10-25-86/1435	19.0	8.4	775	8.3	680-110	0.29
1-8-87/0950	13.1	10.5	790	8.2	590-082	0.29
3-12-87/----	12.8	13.3	779	7.9	780-160	0.35
7-14-87/0930	26.4	8.8	815	8.5	700-052	0.26
9-14-87/1250	26.1	8.1	832	7.6	510-013	0.31

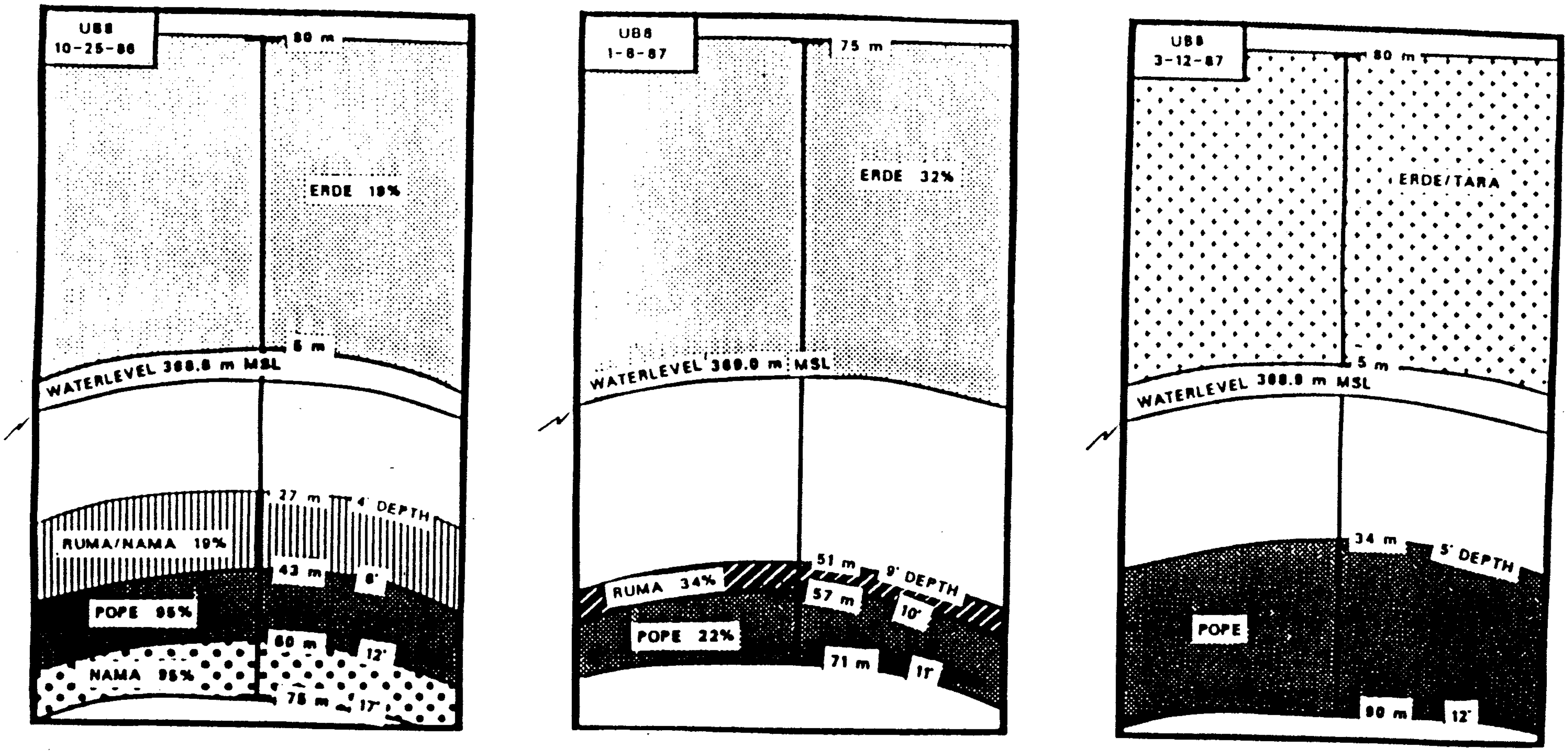


Figure C. Diagrammatic representation of the extent and amount of cover of vegetation communities at UB8 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

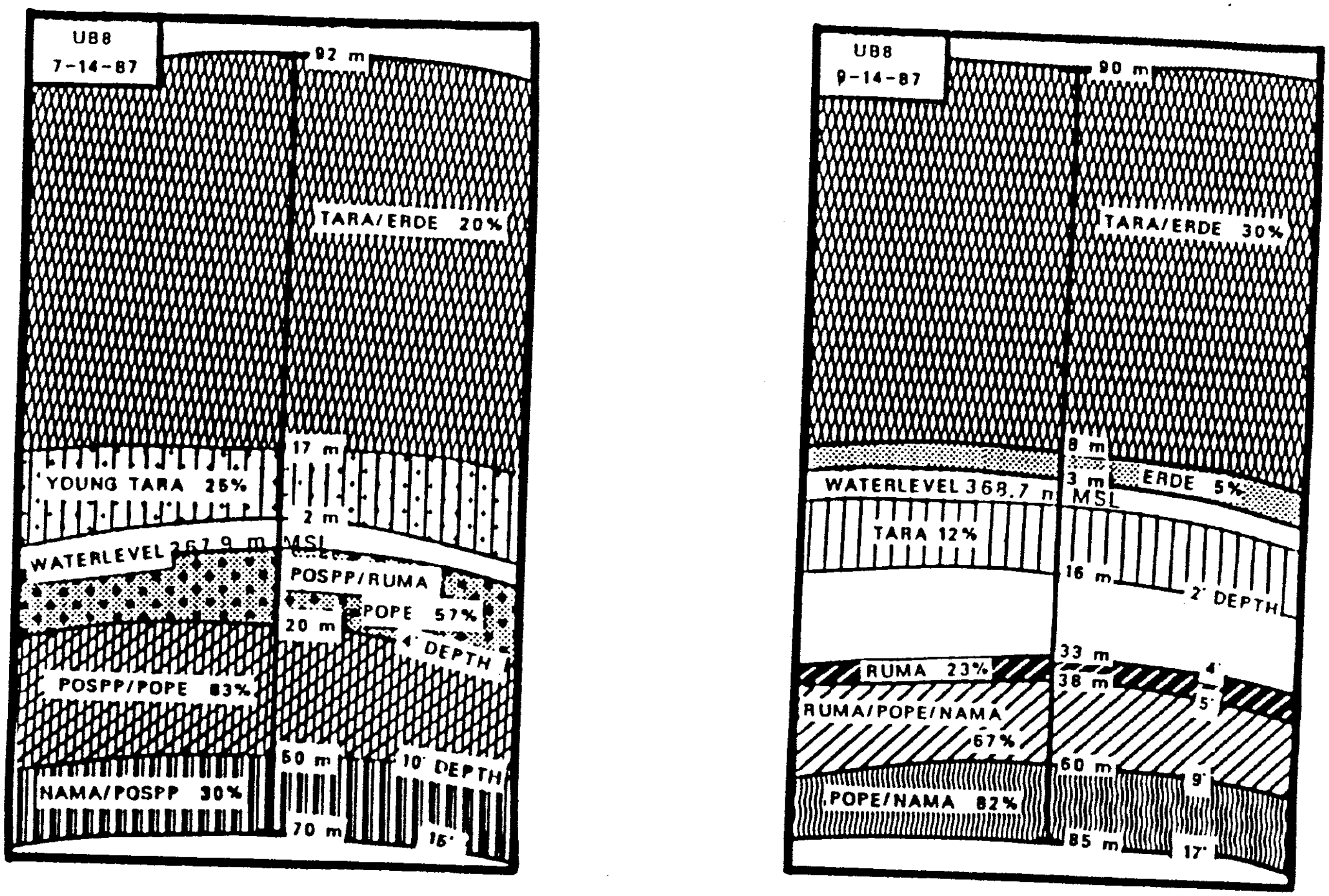


Figure C *(Continued)*.Diagrammatic representation of the extent and amount of cover of vegetation communities at UB8 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

Cove Profile

Name: UB11

Location: Bighorn Island

Legal Description: T19S R68E Sec 16

Inventory Dates: 8/6/86, 10/24/86, 1/6/87, 3/12/87, 7/13/87, 9/14/87, 3/25/88

Soil Description: Very stony. No samples collected.

Sediment Description: 15 ft. sandy loam.

Disturbance: Undisturbed.

Degree of Protection: Moderately protected from wind and wave action.

Table D. Mean temperature (C), dissolved oxygen (DO-mg/l), conductivity (EC-micro mho/cm) and pH at UB11 from the surface of the water to the bottom of the cove. Light transmittance (light-microeinsteins/m^2/sec) is presented as a range from conditions at the surface of the water to 10 meters in depth. Vertical extinction coefficients (K, m^{-1}) were calculated from vertical profiles of light intensity by using linear regressions of natural log transformed data.

Date/Time	Temp	DO	EC	pH	Light	K
8-6-86/0915	27.5	8.0	879	8.4	540-044	0.24
10-24-86/1445	19.3	8.0	788	8.1	630-033	0.26
1-6-87/1100	13.3	9.4	798	8.2	494-026	0.28
3-12-87/1400	13.3	10.8	785	7.9	670-442	0.26
7-13-87/1720	27.0	9.0	814	8.5	380-016	0.29
9-14-87/----	26.0	8.3	842	7.9	430-009	0.30
3-25-88/1125	12.7	10.5	849	8.3	810-011	0.17

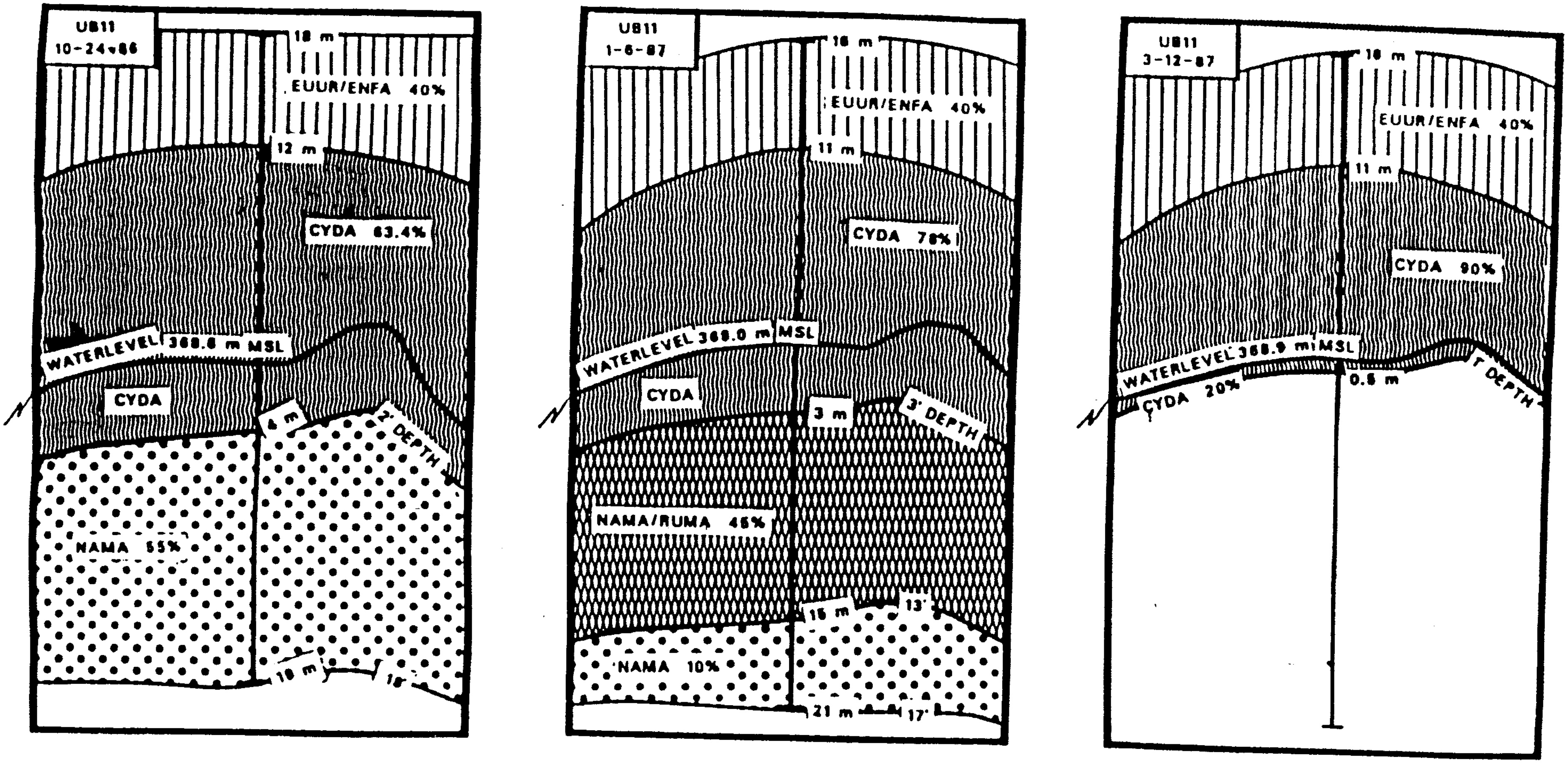
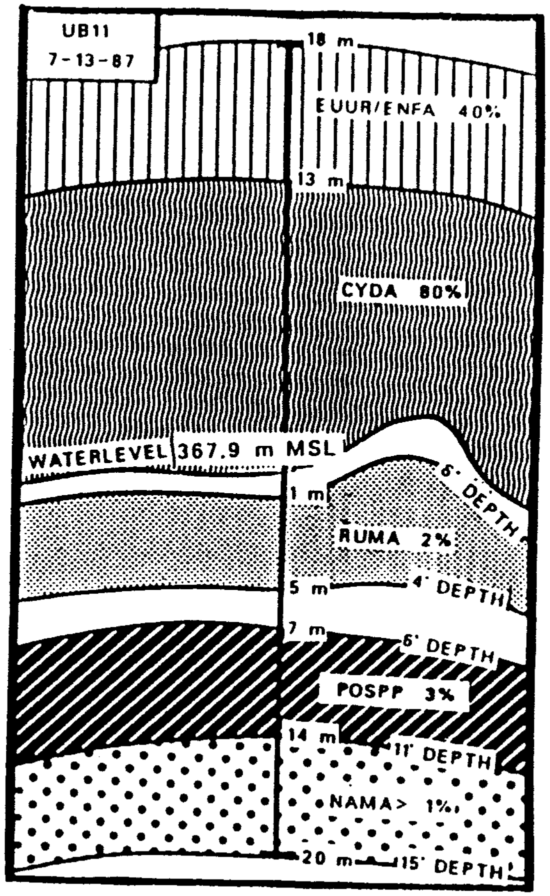


Figure D. Diagrammatic representation of the extent and amount of cover of vegetation communities at UB11 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.



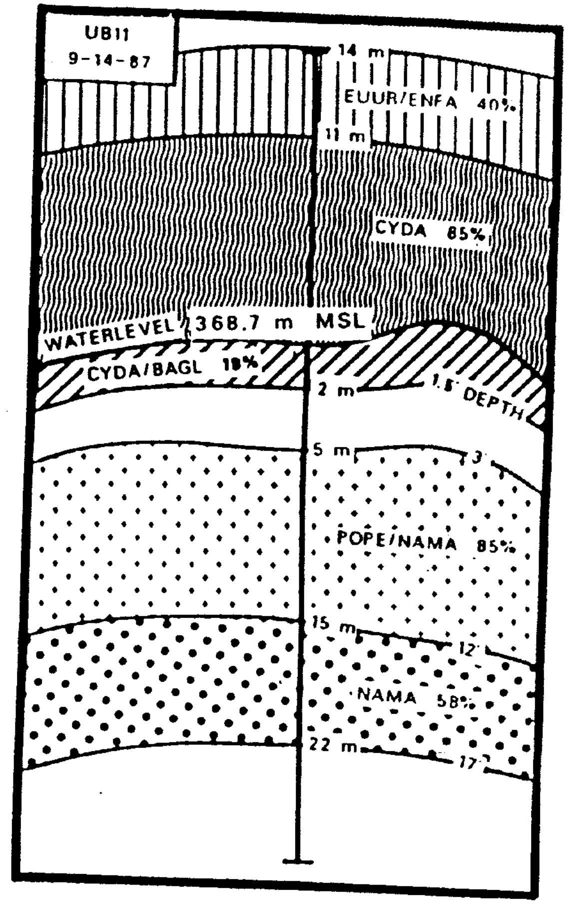


Figure D *(Continued)*.Diagrammatic representation of the extent and amount of cover of vegetation communities at UB11 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

Cove Profile

Name: UB13

Location: Calico Basin Island

Legal Description: T18S R68E Sec 32

Inventory Dates: 8/6/86, 10/25/86, 1/8/87, 3/13/87, 7/13/87, 9/14/87, 3/25/88

Soil Description: Cobbles on surface. Tier 1 near TYANEL-sandy loam; Tier 1-sandy loam; Tier 2 near TARA-loamy sand; Tier 3-sandy loam.

Sediment Description: 10 ft. silty loam.

Disturbance: Cove is undisturbed.

Degree of Protection: Cove is protected from wind and wave action.

Table E. Mean temperature (C), dissolved oxygen (DO-mg/l), conductivity (EC-micro mho/cm) and pH at UB13 from the surface of the water to the bottom of the cove. Light transmittance (light-microeinsteins/m^2/sec) is presented as a range from conditions at the surface of the water to 8 meters in depth. Vertical extinction coefficients (K, m^{-1}) were calculated from vertical profiles of light intensity by using linear regressions of natural log transformed data.

Date/Time	**Temp**	**DO**	**EC**	**pH**	**Light**	**K**
8-6-86/1300	28.2	8.5	889	7.7	790-092	0.30
10-25-86/1605	19.5	8.5	800	8.1	340-027	0.37
1-8-87/1113	12.7	10.4	810	8.3	830-004	0.36
3-12-87/----	----------	----------	No Data	----------	----------	
7-13-87/1815	27.6	8.8	830	8.5	130-002	0.39
9-14-87/0750	26.1	8.5	822	7.8	170-008	0.35
3-25-88/1045	13.0	10.8	845	8.4	700-051	0.23

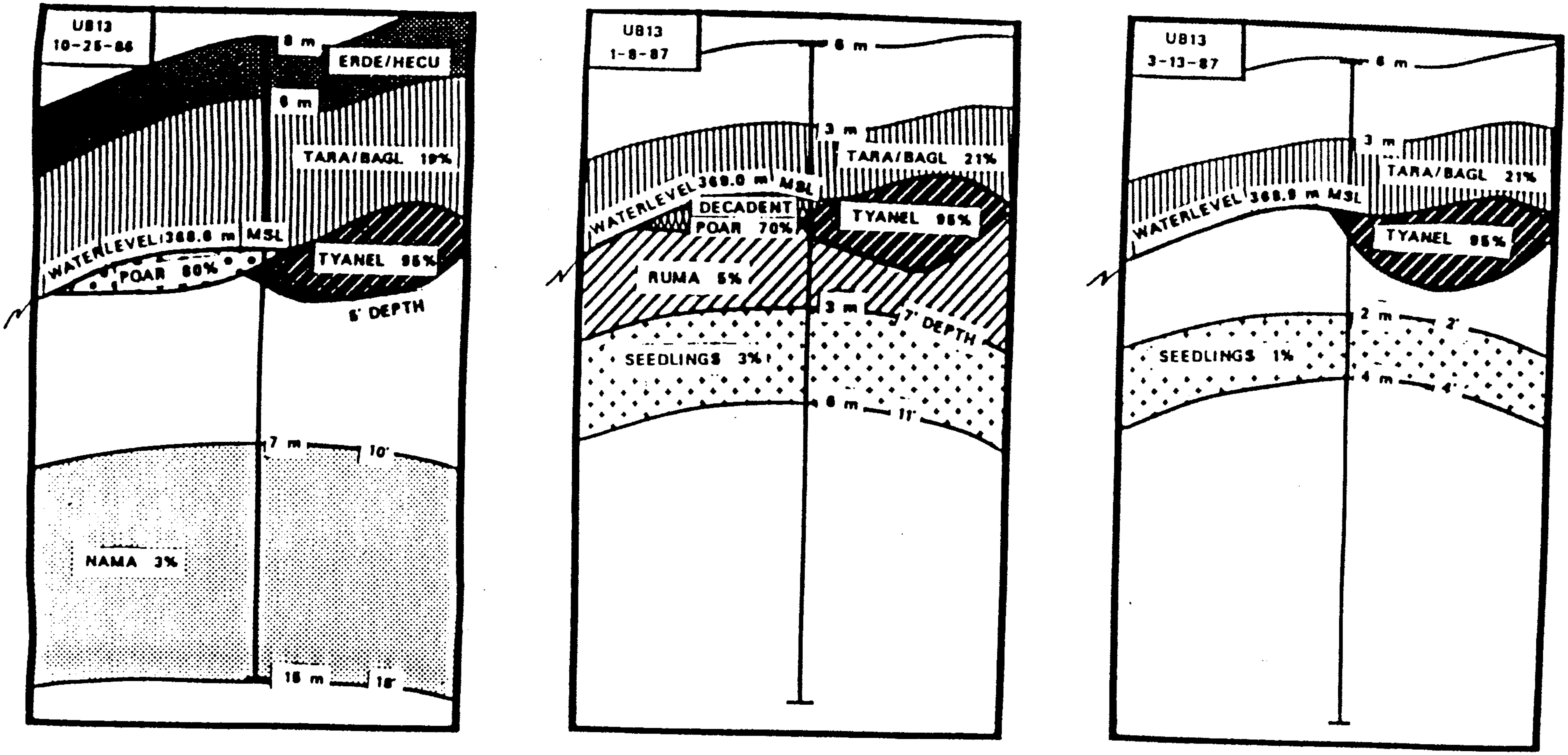


Figure E. Diagrammatic representation of the extent and amount of cover of vegetation communities at UB13 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

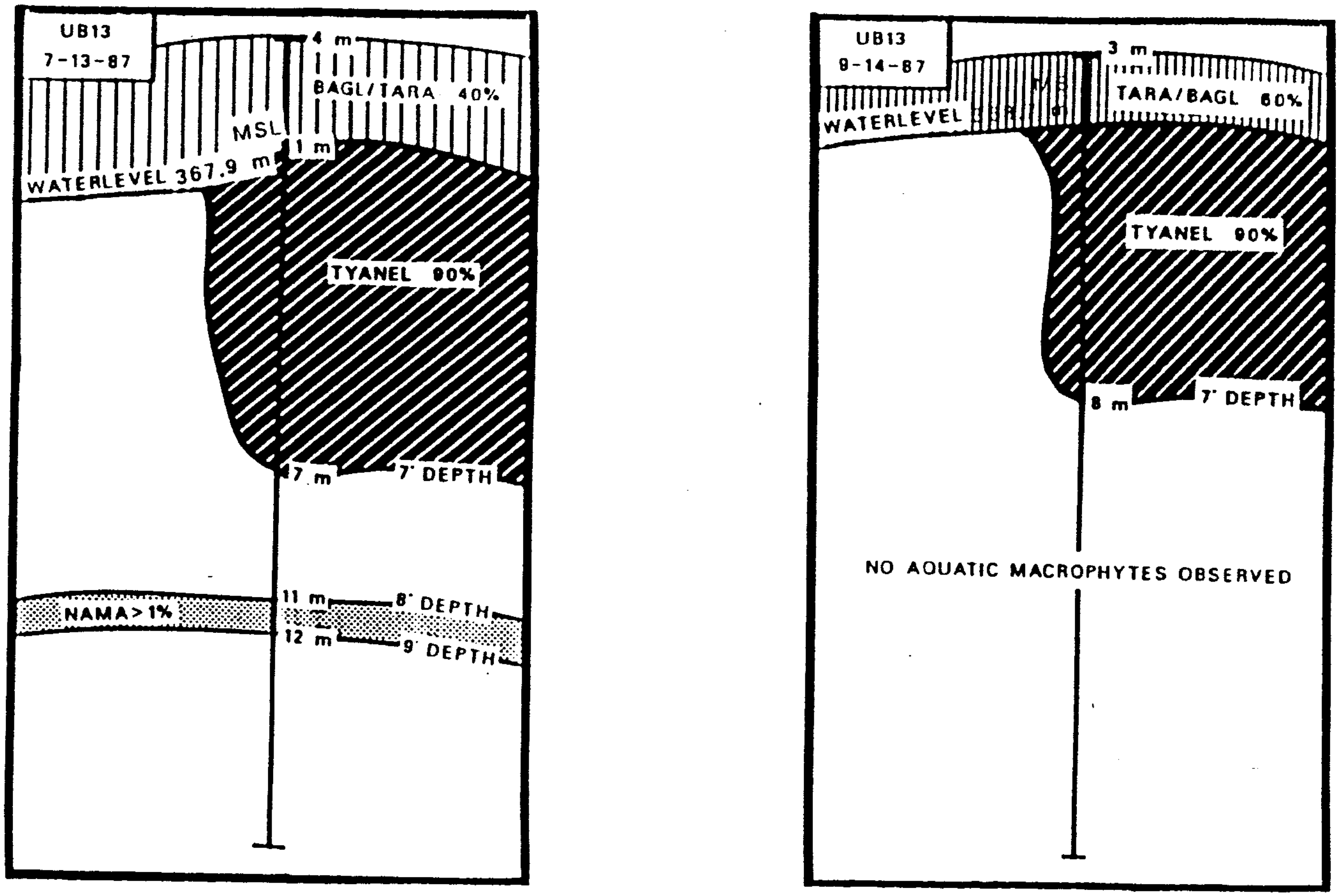


Figure E *(Continued)*.Diagrammatic representation of the extent and amount of cover of vegetation communities at UB13 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

Cove Profile

Name: UB15

Location: Little Gyps

Legal Description: unsurveyed

Inventory Dates: 8/12/86, 10/26/86, 1/9/87, 3/11/87, 7/17/87, 9/14/87

Soil Description: Very stony and cobbly on surface. Tier 2 - sandy loam.

Sediment Description: 8 ft. sandy loam.

Disturbance: Cove is very disturbed by burro and big horn sheep use. NDOW sheep trapping site.

Degree of Protection: Cove is moderately protected from wind and wave action. However, flash flood activity is possible in wash.

Table F. Mean temperature (C), dissolved oxygen (DO-mg/l), conductivity (EC-micro mho/cm) and pH at UB15 from the surface of the water to the bottom of the cove. Light transmittance (light-microeinsteins/m^2/sec) is presented as a range from conditions at the surface of the water to 4 meters in depth. Vertical extinction coefficients (K, m^{-1}) were calculated from vertical profiles of light intensity by using linear regressions of natural log transformed data.

Date/Time	Temp	DO	EC	pH	Light	K
8-12-86/1000	28.8	7.9	863	8.3	750-180	0.31
10-26-86/1025	19.2	9.2	775	7.7	880-170	0.39
1-9-87/1005	13.4	10.1	771	8.3	870-140	0.29
3-11-87/1135	15.0	11.8	803	7.7	870-130	0.34
7-27-87/----	---------------------------- No Data ----------------------------					
9-14-87/1010	26.0	8.0	840	7.7	390-015	0.27

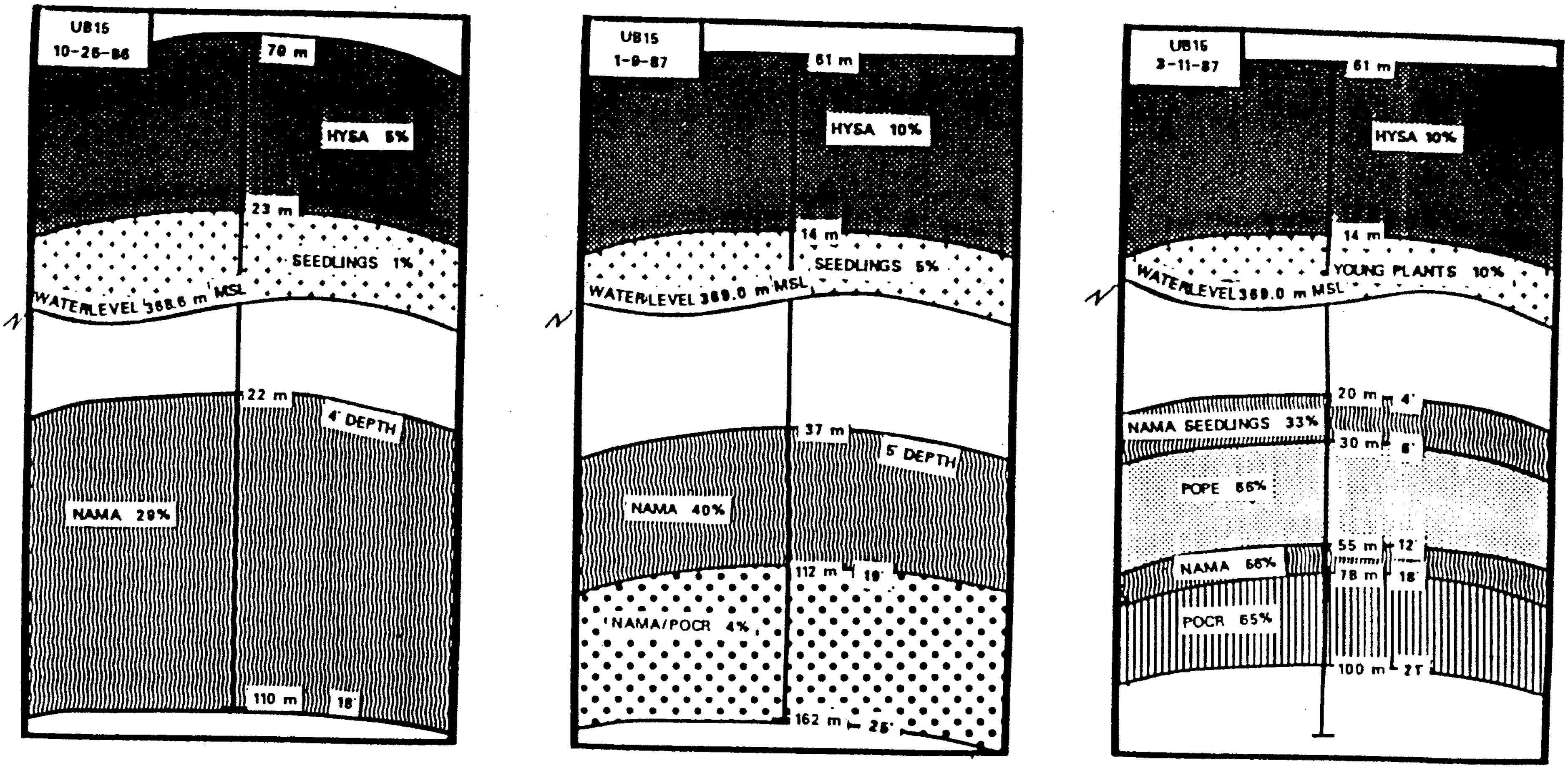


Figure F. Diagrammatic representation of the extent and amount of cover of vegetation communities at UB15 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

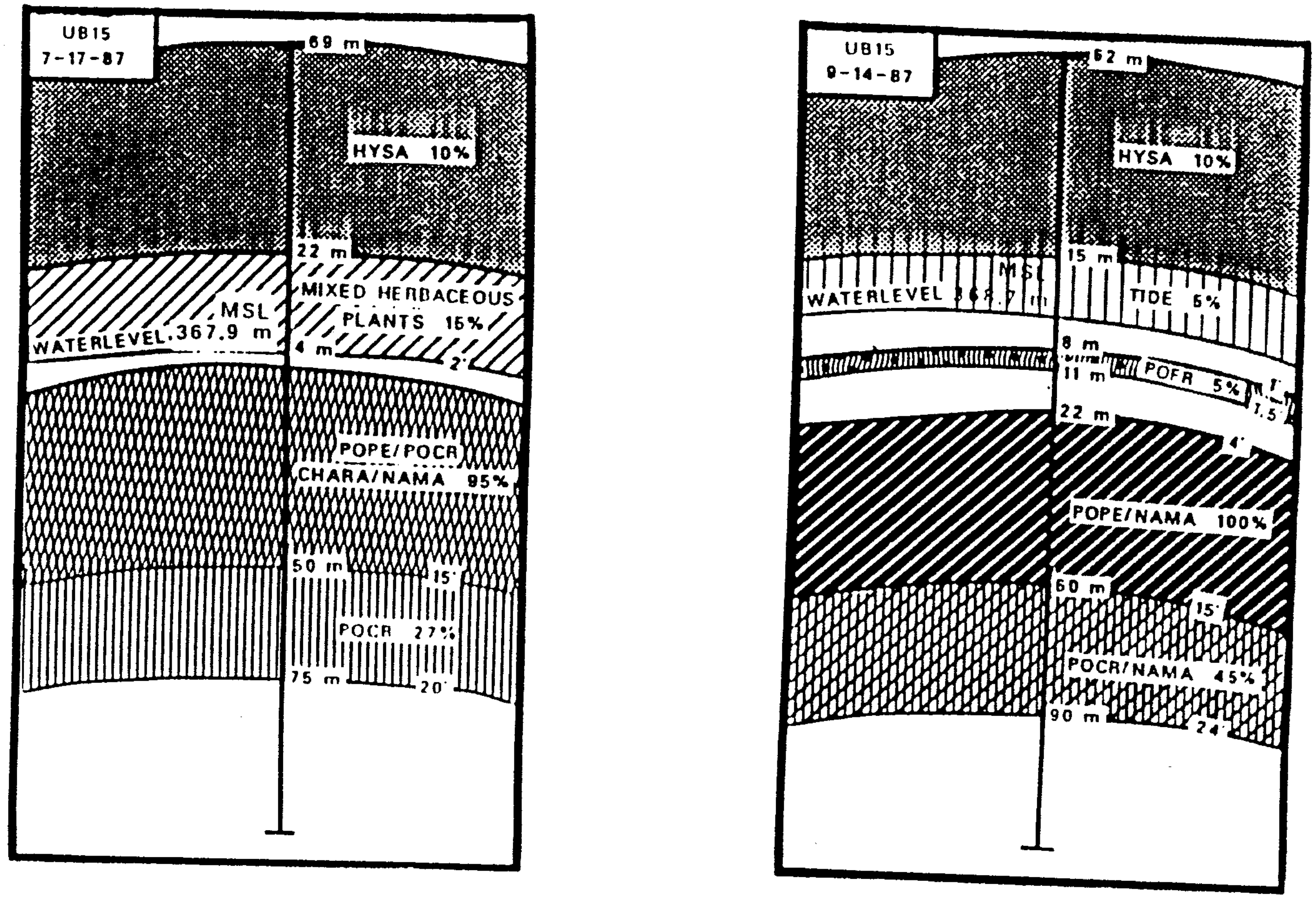


Figure F *(Continued)*.Diagrammatic representation of the extent and amount of cover of vegetation communities at UB15 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

Cove Profile

Name: LB2

Location: Swallow Bay

Legal Description: T20S R65E Sec 8

Inventory Dates: 8/13/86, 10/26/86, 1/9/87, 3/10/87, 7/20/87, 9/16/87, 3/22/88, 9/7/88

Soil Description: Gravel on surface. Tier 1 near POAR - sand loam; Tier 1 near TYANEL - sandy loam. Tier 1 and 3 - sandy loam.

Sediment Description: 10 ft. silty loam.

Disturbance: Cove is undisturbed.

Degree of Protection: Cove is well protected.

Table G. Mean temperature (C), dissolved oxygen (DO-mg/l), conductivity (EC-micro mho/cm) and pH at LB2 from the surface of the water to the bottom of the cove. Light transmittance (light-microeinsteins/m^2/sec) is presented as a range from conditions at the surface of the water to 4 meters in depth. Vertical extinction coefficients (K, m^{-1}) were calculated from vertical profiles of light intensity by using linear regressions of natural log transformed data.

Date/Time	Temp	DO	EC	pH	Light	K
8-13-86/0800	28.4	8.0	864	8.3	-- No Data --	
10-26-86/1517	20.7	7.7	798	7.9	690-170	0.50
1-9-87/----	13.8	10.0	790	8.2	-- No Data --	
3-10-87/1245	14.8	10.1	798	7.9	540-120	0.43
7-20-87/----	----------	----------	No Data	----------	----------	
9-16-87/1230	26.5	7.9	846	7.2	680-046	0.34
3-22-88/0940	14.1	10.4	825	8.3	500-100	0.24
9-7-88/1057	29.3	8.6	831	8.4	540-055	0.21

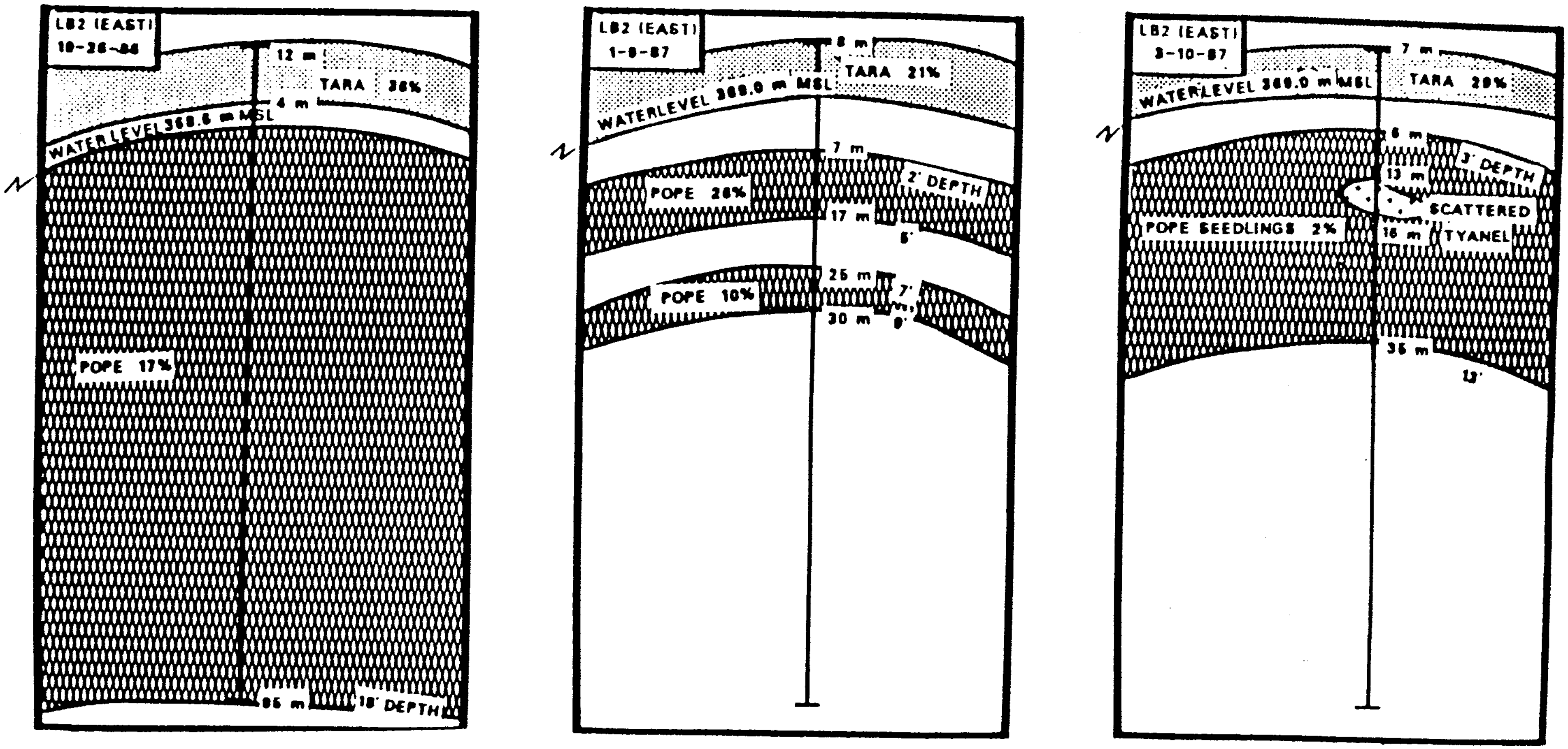


Figure G. Diagrammatic representation of the extent and amount of cover of vegetation communities at LB2 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

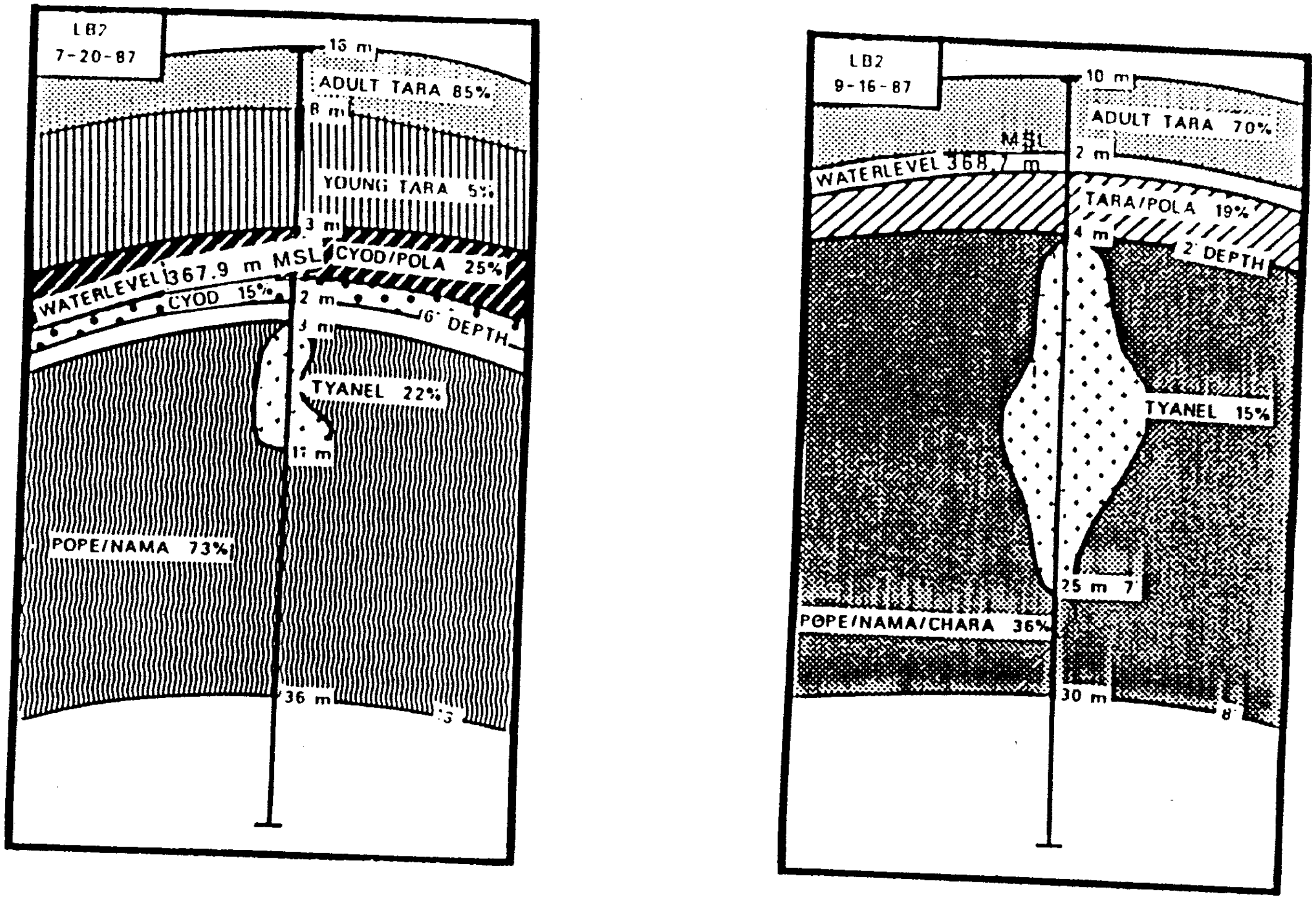


Figure G *(Continued)*.Diagrammatic representation of the extent and amount of cover of vegetation communities at LB2 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

Cove Profile

Name: LB5

Location: Crawdad Cove

Legal Description: T21S R64E

Inventory Dates: 8/14/86, 10/30/86, 1/13/87, 3/06/87, 7/16/87, 9/16/87, 3/22/88, 9/7/88

Soil Description: Tier 1 near POLA - sandy loam; Tier 2 near POLA - loamy sand.

Sediment Description: 6 ft. silty loam.

Disturbance: Cove is slightly disturbed by human activities.

Degree of Protection: Cove is well protected.

Table H. Mean temperature (C), dissolved oxygen (DO-mg/l), conductivity (EC-micro mho/cm) and pH at LB5 from the surface of the water to the bottom of the cove. Light transmittance (light-microeinsteins/m^2/sec) is presented as a range from conditions at the surface of the water to 2 meters in depth. Vertical extinction coefficients (K, m^{-1}) were calculated from vertical profiles of light intensity by using linear regressions of natural log transformed data.

Date/Time	**Temp**	**DO**	**EC**	**pH**	**Light**	**K**
8-14-86/0750	27.7	7.4	868	8.4	-- No Data --	
10-30-86/0930	19.4	9.0	788	8.3	580-120	0.62
1-13-87/1010	13.4	9.9	807	8.1	190-060	0.32
3-06-87/1035	12.9	10.1	809	8.1	200-079	0.30
7-16-87/0745	27.3	8.4	853	8.6	-- No Data --	
9-16-87/1100	26.4	8.2	861	7.8	560-120	0.31
3-22-88/1030	14.2	10.4	828	8.3	640-130	N/D
9-7-88/1154	29.4	9.2	837	8.5	640-200	N/D

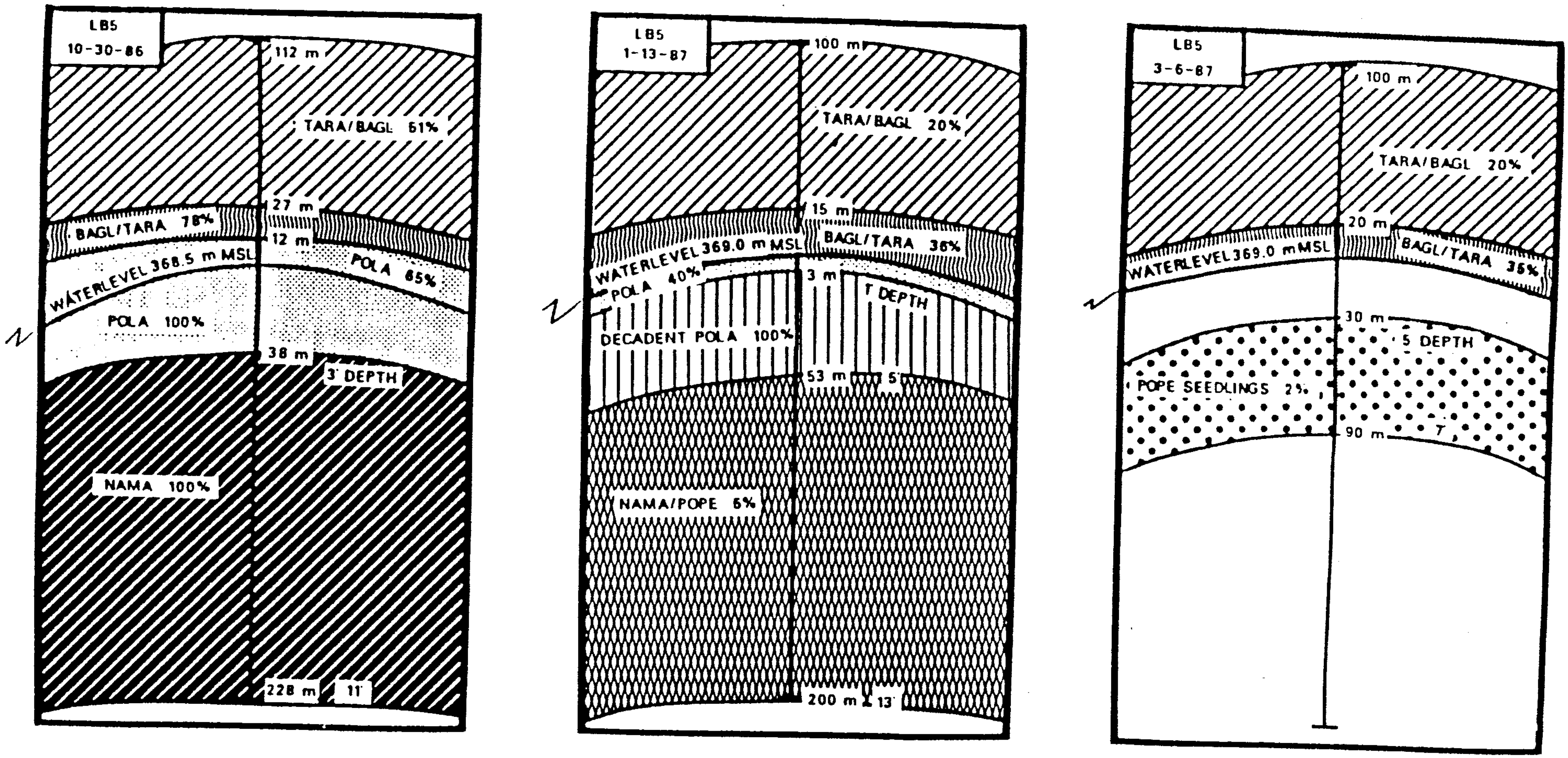
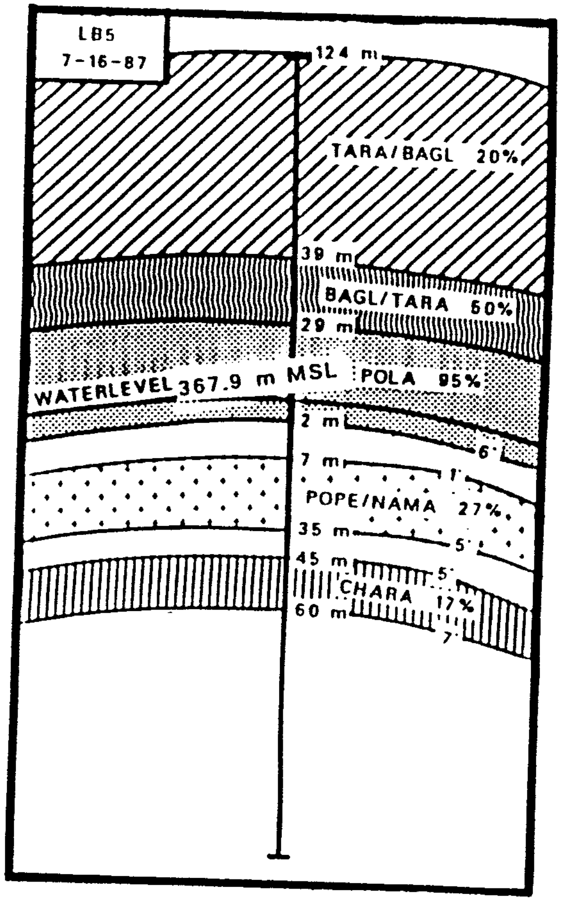


Figure H. Diagrammatic representation of the extent and amount of cover of vegetation communities at LB5 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.



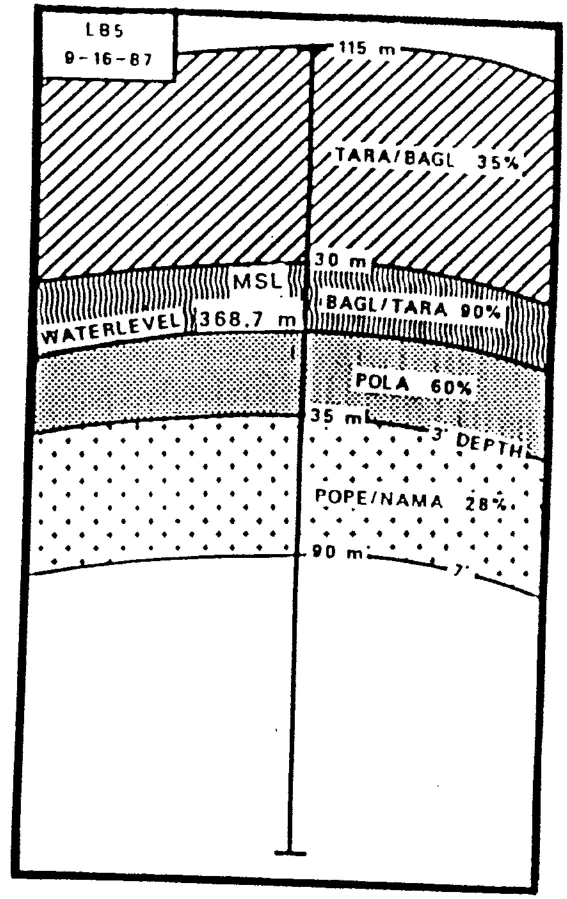


Figure H *(Continued)*. Diagrammatic representation of the extent and amount of cover of vegetation communities at LB5 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

Cove Profile

Name: LB9

Location: North of Gypsum Wash

Legal Description: T21S R64E

Inventory Dates: 8/14/86, 10/30/86, 1/12/87, 3/06/87, 7/16/87, 9/16/87

Soil Description: Tier 1 near POLA - loam; Tier 3 near TYANEL-loamy sand.

Sediment Description: 9 ft. silty loam.

Disturbance: Cove is has not been significantly disturbed.

Degree of Protection: Cove is well protected.

Table I. Mean temperature (C), dissolved oxygen (DO-mg/l), conductivity (EC-micro mho/cm) and pH at LB9 from the surface of the water to the bottom of the cove. Light transmittance (light-microeinsteins/m^2/sec) is presented as a range from conditions at the surface of the water to 3 meters in depth. Vertical extinction coefficients (K, m^{-1}) were calculated from vertical profiles of light intensity by using linear regressions of natural log transformed data.

Date/Time	**Temp**	**DO**	**EC**	**pH**	**Light**	**K**
8-14-86/1330	29.7	9.1	905	8.5	-- No Data --	
10-30-86/0945	19.3	8.4	797	8.2	500-120	0.40
1-12-87/1128	13.2	9.7	824	8.1	450-110	0.48
3-06-87/0940	13.1	10.3	812	8.2	250-068	0.35
7-16-87/0650	28.1	10.0	875	8.6	-- No Data --	
9-16-87/1020	26.5	8.3	893	7.7	540-065	0.42

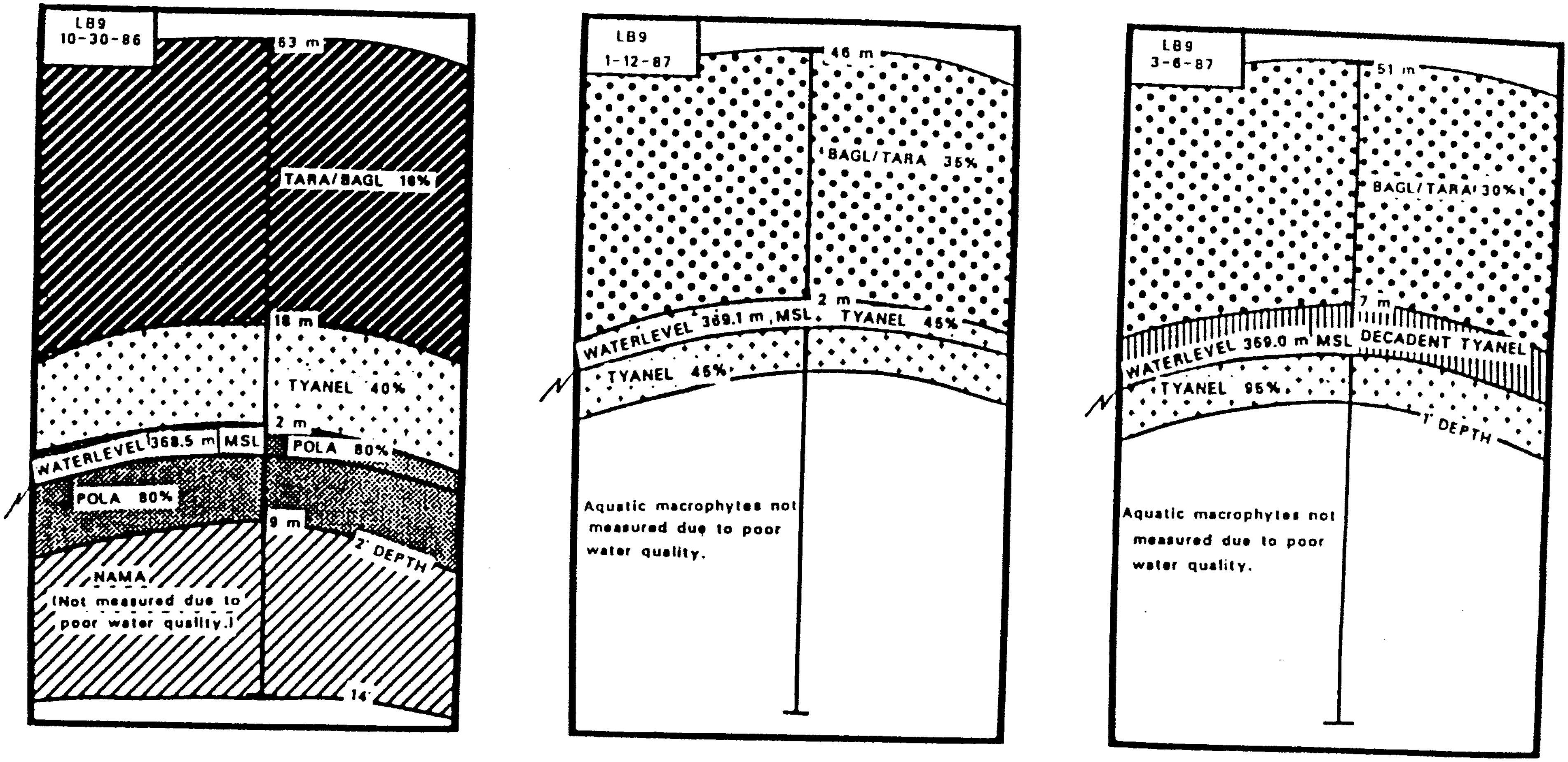


Figure I. Diagrammatic representation of the extent and amount of cover of vegetation communities at LB9 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

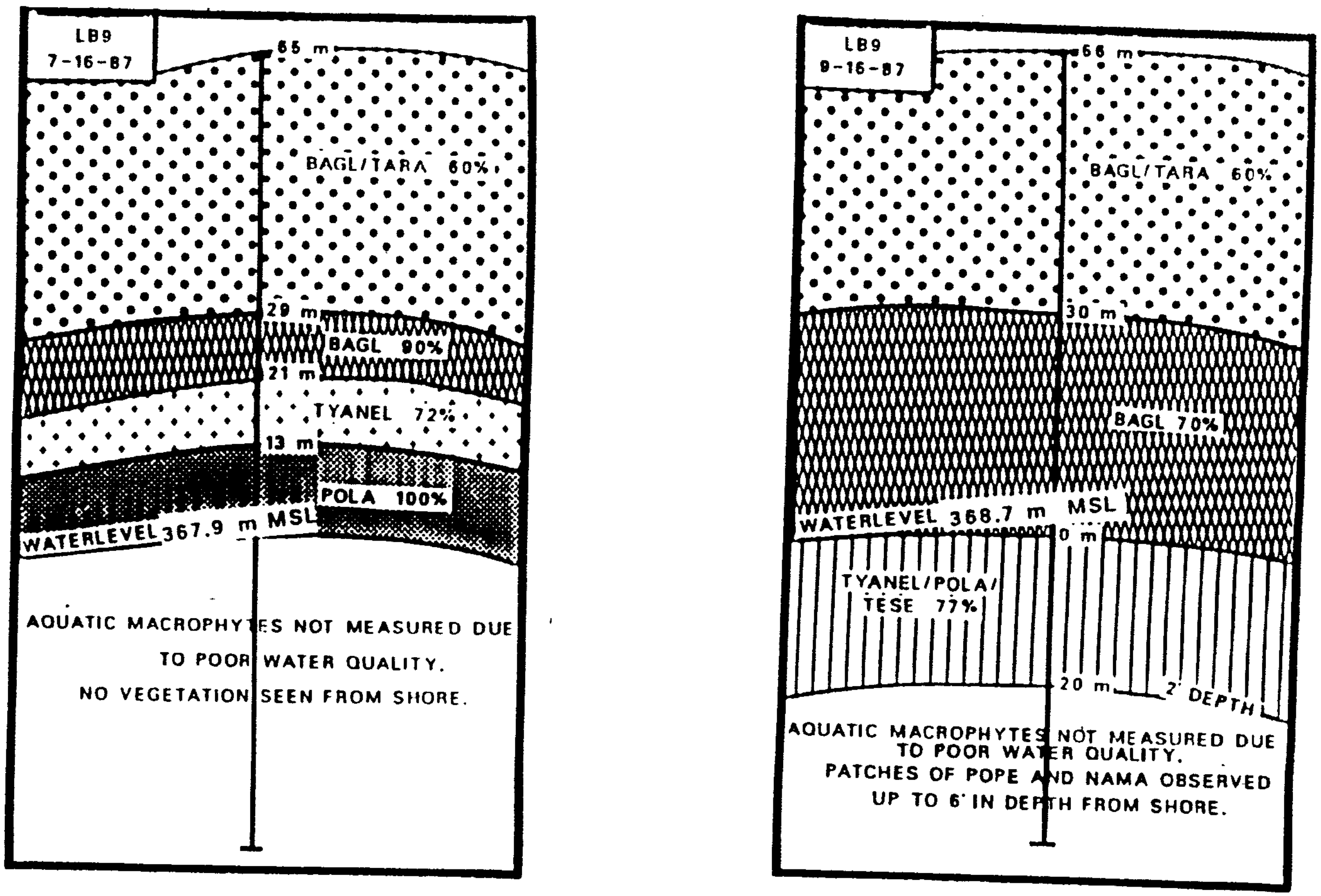


Figure I *(Continued)*. Diagrammatic representation of the extent and amount of cover of vegetation communities at LB9 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

Cove Profile

Name: LB10

Location: West of Saddle Island

Legal Description: T22S R64E Sec 3

Inventory Dates: 8/18/86, 10/30/86, 1/13/87, 3/6/87, 7/16/87, 9/16/87, 3/22/88, 9/7/88

Soil Description: Tiers 1 and 2-sandy loam.

Sediment Description: 5 ft. loamy sand.

Disturbance: Very disturbed by human activities.

Degree of Protection: Moderately protected.

Table J. Mean temperature (C), dissolved oxygen (DO-mg/l), conductivity (EC-micro mho/cm) and pH at LB10 from the surface of the water to the bottom of the cove. Light transmittance (light-microeinsteins/m^2/sec) is presented as a range from conditions at the surface of the water to 3 meters in depth. Vertical extinction coefficients (K, m^{-1}) were calculated from vertical profiles of light intensity by using linear regressions of natural log transformed data.

Date/Time	**Temp**	**DO**	**EC**	**pH**	**Light**	**K**
8-18-86/0730	27.4	8.0	876	8.4	-- No Data --	
10-30-86/1245	19.3	8.9	797	8.2	380-110	0.41
1-13-87/1330	13.6	9.7	804	7.9	130-035	0.30
3-6-87/1125	13.2	10.5	806	8.2	269-050	0.53
7-16-87/0845	25.5	8.2	836	8.5	-- No Data --	
9-16-87/1345	27.0	7.9	871	7.6	570-077	0.40
3-22-88/1115	13.7	10.3	824	8.3	680-220	0.43
9-7-88/0916	28.3	9.1	847	8.4	380-050	0.16

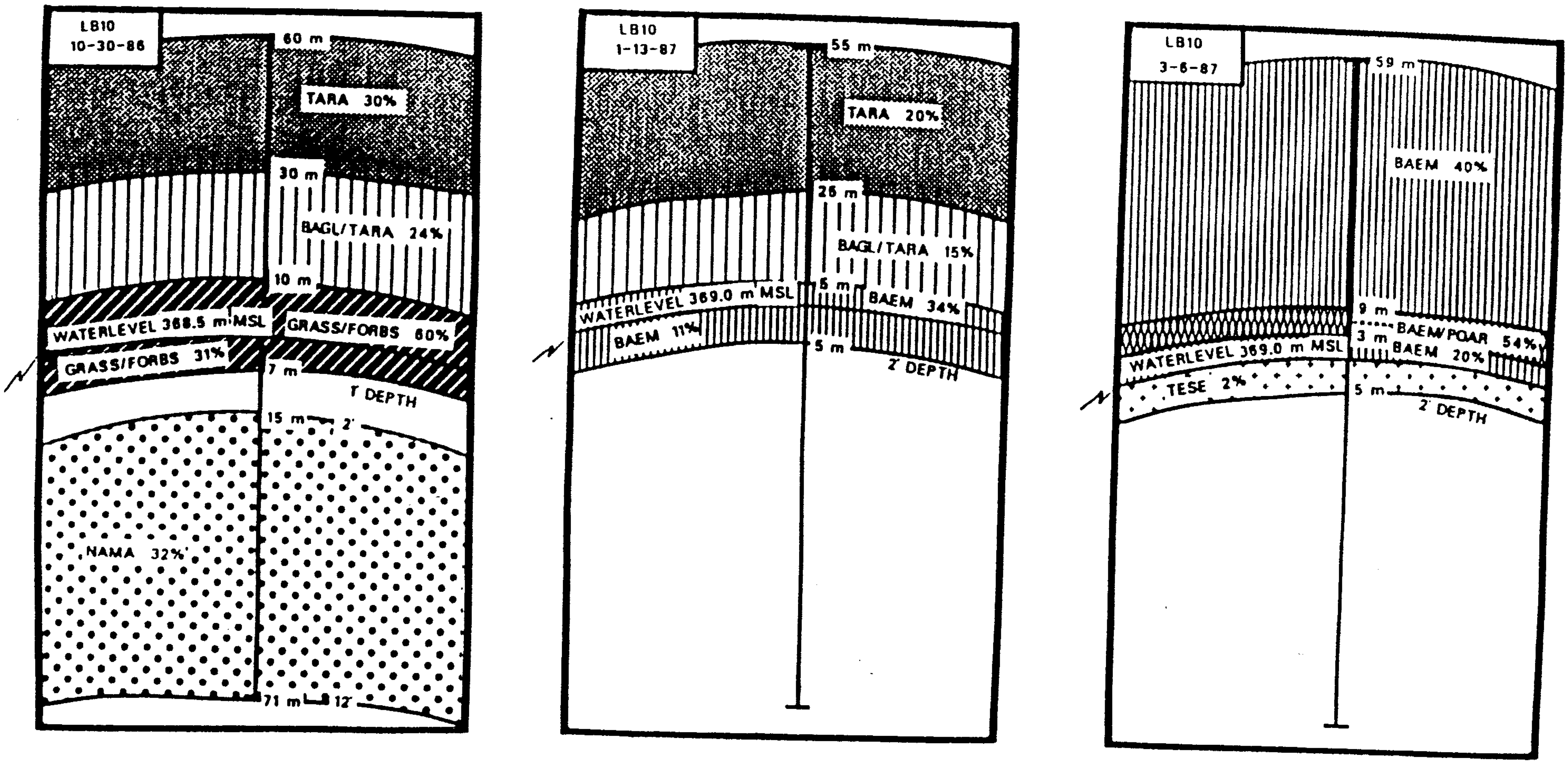


Figure J. Diagrammatic representation of the extent and amount of cover of vegetation communities at LB10 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

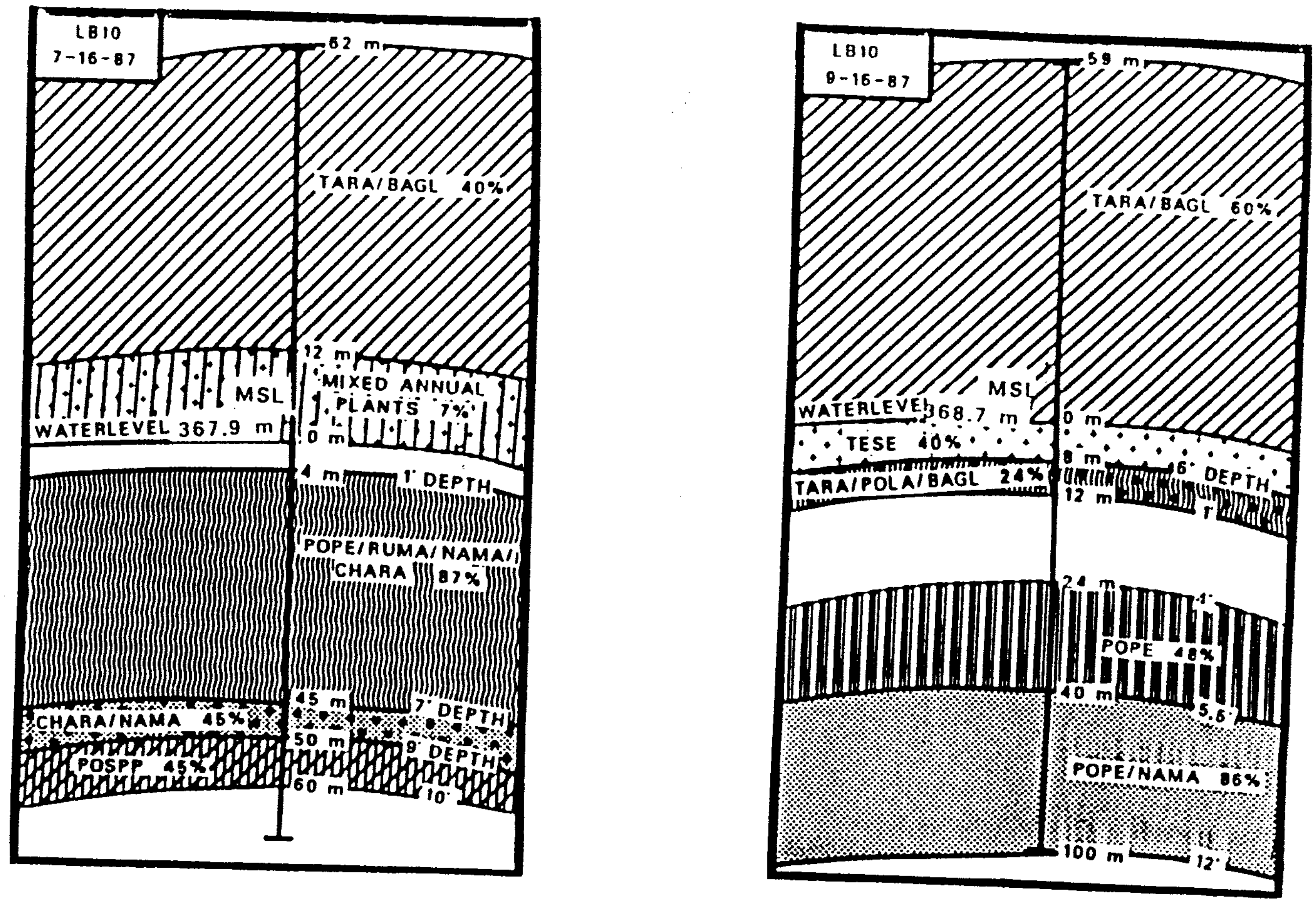


Figure J *(Continued)*. Diagrammatic representation of the extent and amount of cover of vegetation communities at LB10 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

Cove Profile

Name: LB15

Location: Waterbarge Cove

Legal Description: T21S R65E Sec 16

Inventory Dates: 9/06/86, 10/26/86, 1/09/87, 3/09/87, 7/20/87, 9/16/87

Soil Description: Tiers 1 and 2 - sand.

Sediment Description: 10 ft. loam.

Disturbance: Cove is slightly disturbed by human activities.

Degree of Protection: Cove is moderately well protected.

Table K. Mean temperature (C), dissolved oxygen (DO-mg/l), conductivity (EC-micro mho/cm) and pH at LB15 from the surface of the water to the bottom of the cove. Light transmittance (light-microeinsteins/m^2/sec) is presented as a range from conditions at the surface of the water to 3 meters in depth. Vertical extinction coefficients (K, m^{-1}) were calculated from vertical profiles of light intensity by using linear regressions of natural log transformed data.

Date/Time	Temp	DO	EC	pH	Light	K
9-06-86/1100	29.0	8.6	850	8.0	780-130	0.56
10-26-86/1340	21.0	7.7	794	7.2	820-220	0.39
1-09-87/1230	13.8	10.1	789	7.8	410-100	0.37
3-10-87/1050	14.4	10.4	795	7.9	730-100	0.44
7-20-87/	No data					
9-16-87/1300	26.8	7.9	846	7.6	720-110	0.27

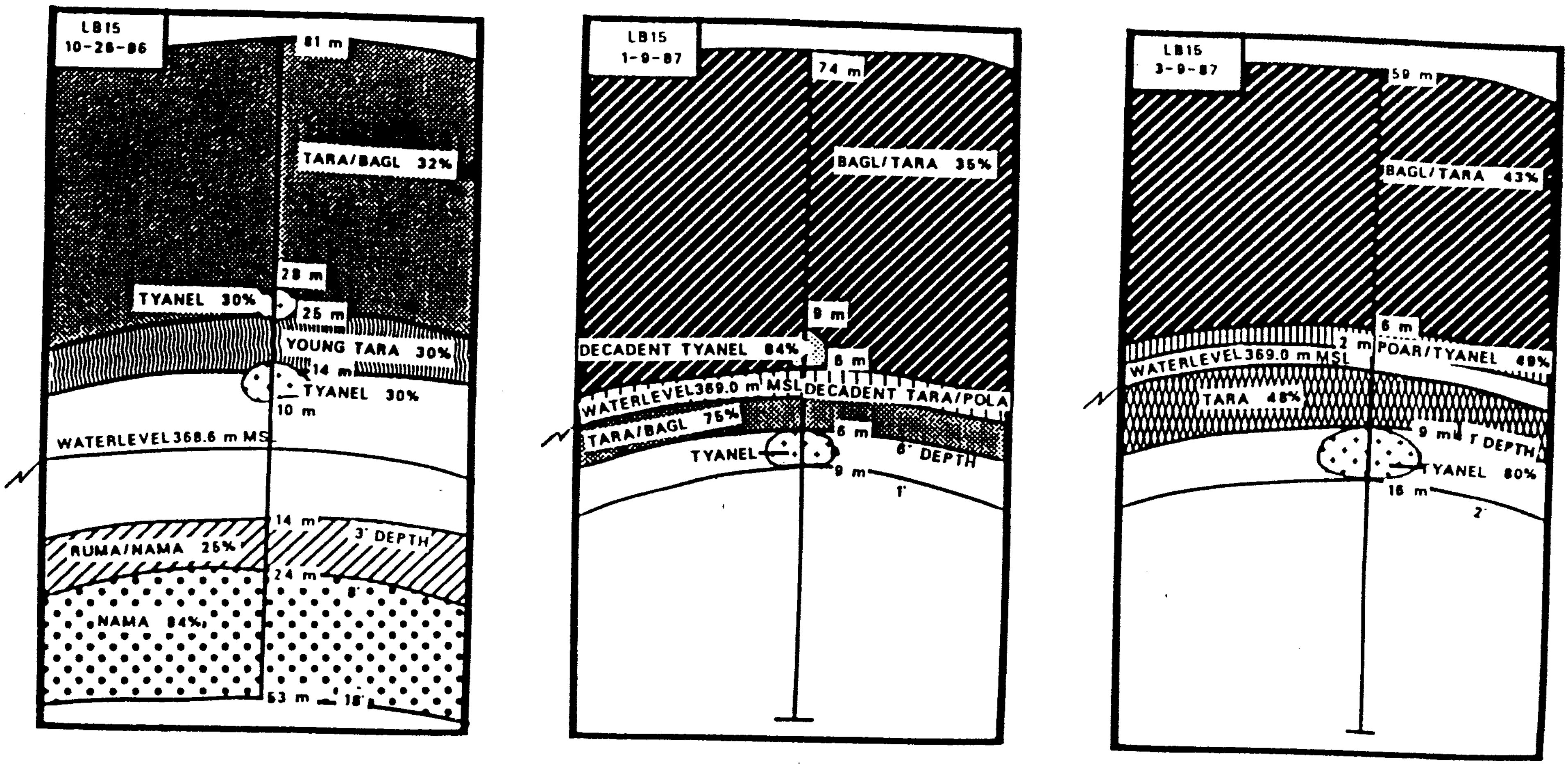


Figure K. Diagrammatic representation of the extent and amount of cover of vegetation communities at LB15 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.

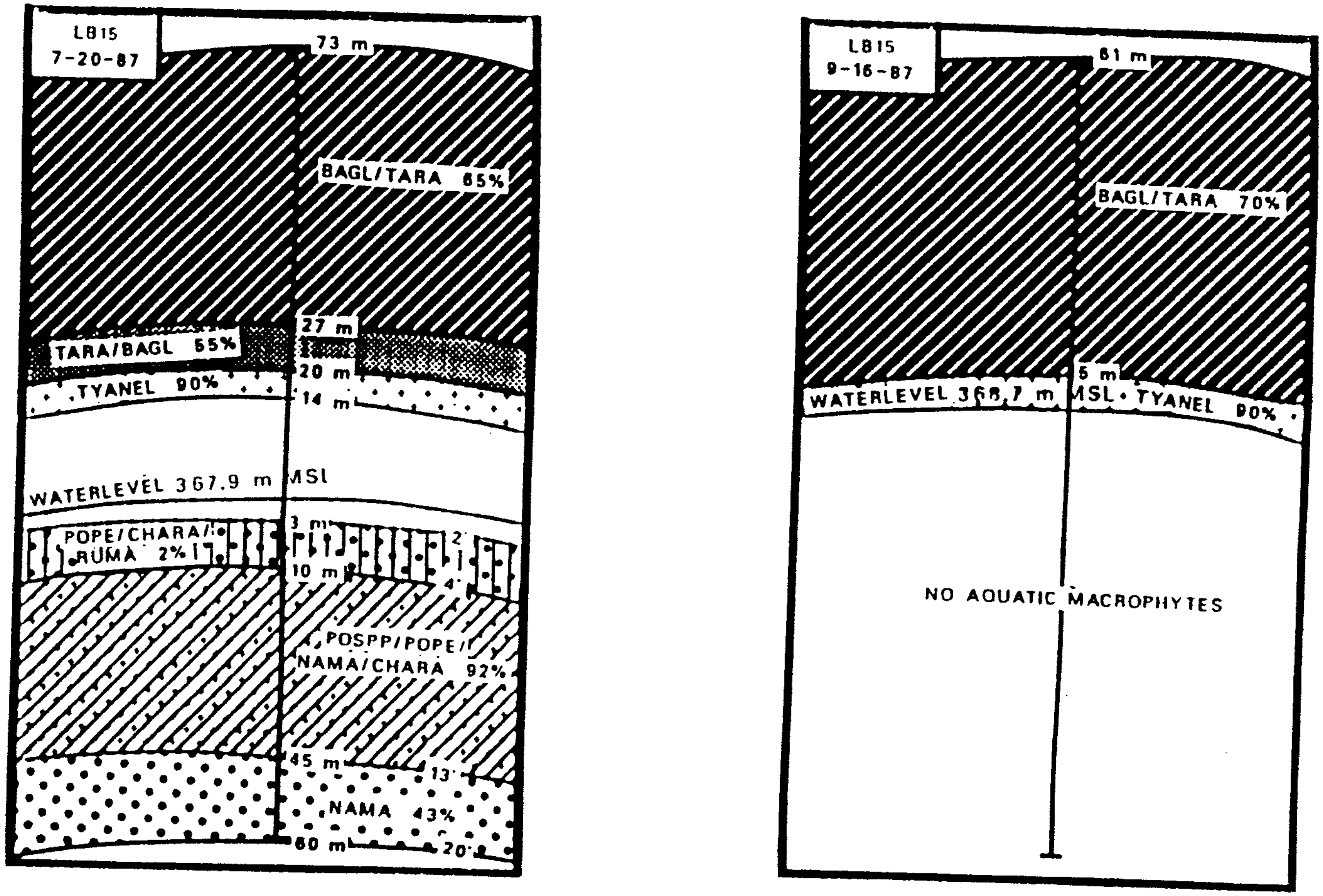


Figure K *(Continued)*. Diagrammatic representation of the extent and amount of cover of vegetation communities at LB15 on various sampling dates. The extent of terrestrial and aquatic communities are depicted in meters from the waterline. Boundaries of aquatic communities are also described by depth in feet.