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VEGETATION CHANGES IN THE DELTA MARSH, MANITOBA BETWEEN 1948-80

BY

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ABSTRACT

Historically, under the influence of climatic cycles, water levels in Lake Manitoba and the adjacent Delta Marsh fluctuated with a range of more than 2.2 m. In 1961, a regulation regime was imposed on the lake and water level fluctuations were dampened to less than 0.6 m. Aerial photographs taken in 1948 (low water) and 1954 (high water) were used to determine changes in the distribution of three dominants (_Typha_ species, _Phragmites_ _australis_, and _Scolochloa festucacea_) and water and mudflats along elevational gradients in response to fluctuating water levels. Post-regulation changes were determined from aerial photographs taken in 1964, 1972 and 1980. Pre-regulation marsh shorelines were dominated by _Phragmites_. After regulation was imposed there was a change to a _Typha_-dominated marsh. _Typha_, probably the hybrid _T_. _glauca_, expanded its range up the elevation gradient by encroaching upon _Phragmites_ and down the gradient by invading shallow water. Lattice profile analysis provided an objective assessement of the trends involved in these changes. This study suggests that with continued stable water levels _Typha_ will expand along the elevational gradient. In the absence of occasional flooding to set back

the process of succession, this expansion may lead to the eventual in-filling of the Delta Marsh.

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GENERAL INTRODUCTION

Freshwater prairie marshes are dynamic ecosystems characterized by alternating flooding and drying cycles. Marsh water levels are influenced by climatic cycles of 5-20 years, which produce variations in precipitation and surface runoff (Kiel _et_ _al_. 1972). During average years within the cycle, evaporation losses exceed available water input resulting in a drop in water levels throughout the growing season (Millar 1969). Decreasing water levels encourage highly productive plant communities to expand down the elevational gradient. Organic material and sediments accumulate on the marsh bottom and reduce water depths.

The process of marsh in-filling is reversed when flooding occurs. The depth, duration, frequency, and season of flooding influence the outcome (Harris and Marshall 1963; Kadlec 1962; McDonald 1955; Walker and Coupland 1968). Emergent vegetation is eliminated when water levels exceed the tolerance limits of the species involved (Harris and Marshall 1963). It is at this stage that the production and accumulation of organic material is stopped and sediments may be redistributed.

Vegetation is re-established only when water levels recede (drawdown) to expose mudflats (Kadlec 1962; Walker

1959, 1965). These drawdowns may be due to natural drought (i.e. low precipitation) or human manipulation. The speed of drainage, duration and season are important factors determining the establishment of individual species (Harris and Marshall 1963). Revegetation from the seed bank, with seeds of both emergent and mudflat species, requires mudflat conditions for germination (Pederson 1981; van der Valk 1981). Exposure of the mudflats also aerates the soil and promotes the rapid decomposition of organic material that has accumulated within the marsh basin (Kadlec 1962). The latter process not only deepens the marsh basin but increases its fertility. The newly available nutrients promote the revegetation cycle of the marsh.

In contrast to most prairie marshes, water levels in the Delta Marsh have traditionally been tied to Lake Manitoba levels. Lake levels fluctuated under natural regimes that coincided with climatic cycles of high and low water (Last 1980). Palaeoecological and seed bank studies within the marsh indicate fluxes in pollen of submerged, emergent and upland species which reflect past water level fluctuations (Pederson 1981; Pederson and van der Valk 1984; Sproule 1972). Because of these fluctuations, the marsh has existed for approximately 2,500 years (Sproule 1972), and has not suffered the in-filling characteristic of many shallow freshwater marshes.

The presence of a 33km forested barrier ridge (Teller and Last 1981) complicates the relationship between the lake and the marsh. The ridge to a large extent prevents water exchange between the two, but exchange is maintained through a number of deep channels that traverse the ridge. Historically many such channels existed (as seen on aerial photographs) and water was freely exchanged when lake levels differed from those in the marsh. Over time, many channels became silted up or were purposely blocked, until currently only four exist. The degree of exchange between the lake and the marsh was further reduced when a control structure to regulate lake levels was completed at Fairford in 1961. Currently lake level fluctuations have been dampened from a range of more than 2.2 m to a range of less than 0.6 m (Anon. 1973; Crowe 1974). This regime, in turn, has stabilized water levels in the adjacent Delta Marsh (Ducks Unlimited 1981).

Stablilized marsh water levels and their effect on vegetation and wildlife have fostered the concerns of both governmental (Bodnaruk 1976; Bossenmaier _et_ _al_. 1968; Jones 1978) and private agencies (Ducks Unlimited 1981). Delta Marsh is a valuable natural resource. Situated on the Mississippi flyway it is an important staging and breeding area for waterfowl. Muskrat production and harvests at Delta Marsh between 1943 and 1956 fluctuated dramatically in response to natural high and low water levels (Bossenmaier et al. 1968). The marsh has also been a natural spawning area for commercially important fish, especially pickerel (Bossenmaier et al. 1968; Jones 1978). The productivity of the marsh has, however, deteriorated since the lake regulation was imposed (Ducks Unlimited 1981). Unfortunately, despite its apparent importance, relatively few studies during either the pre- or post-regulation period have been carried out, but there have been a number of vegetation studies. A qualitative study by Löve and Löve (1954) provides a floristic description of pre-regulation marsh communities. Quantitative studies were limited to one period in time. Dillon (1958: in Bossenmaier et al. 1968) estimated that 21% of the emergent marsh vegetation had been eliminated during the 1954-57 period of high water. Walker (1959) described the colonization of denuded mudflats as water levels began to fall. Species succession was described as water levels continued to fall between 1959 and 1961 (Walker 1965). In addition, Evans (1972) and Ducks Unlimited (1980) produced vegetation categories for mapping purposes but their categories differed in composition, making comparisons difficult.

The paucity of information on vegetation change during the post- regulation period has not deterred the development of complex management proposals (e.g. Bodnaruk 1976; Ducks Unlimited 1981; Jones 1978). Bossenmaier et al. (1968) recognized the need for indepth studies to determine the effect of stabilized water levels on marsh vegetation. This is essential for effective management planning but to date no such research has been implemented.

My study was initiated to examine the response of pre-regulation vegetation to water level fluctuations and to assess the impact of stabilized water levels on marsh vegetation. Historic aerial photographs taken in 1948, 1954, 1964, 1972 and 1980 were used to quantify changes in vegetation distribution along elevational gradients.

Chapter I

PRELIMINARY STUDIES FOR AN AERIAL PHOTOGRAPH STUDY AT DELTA MARSH.

1.1 INTRODUCTION

Delta Marsh, located in the Aspen Prairie wetland district (Zoltai and Pollett 1983), is characterized by a mild to cool continental climate. The mean January temperature is -18.3° C, and the mean July temperature is 20.0° C. Mean annual precipitation is 544.9 mm, with 70% of this falling between May and October (Anon. 1984).

Climatic conditions have influenced the development of marsh soils on the lacustrine (sedimentary) clays and silts deposited in glacial Lake Agassiz during the late Quaternary (Fenton 1970). Marsh soils are composed of a complex of gleysols and regosols (Walker 1965) which support the extensive matrix of marsh vegetation.

The Delta Marsh occupies approximately 15,000 ha of water and emergent and upland vegetation bordering the south shore of Lake Manitoba (Walker 1965). The marsh is separated from the lake by a forested barrier ridge (Teller and Last 1981). Behind this ridge the marsh is composed of a network of variously sized, shallow bays (0.3 - 2.0 m deep) that are connected by channels or creeks and separated by vegetation. Shorelines are fringed by Scirpus acutus [1] and extensive monodominant stands of Typha species (a complex of T. latifolia, T. angustifolia and the hybrid T. glauca) along the shoreline, backed by Phragmites australis (Walker 1965). These species are associated with the emergent deep marsh zone, which is normally inundated throughout the growing season (Millar 1976). This zone is backed by a shallow marsh zone (Millar 1976) which is dominated by Scolochloa festucacea and lesser amounts of Carex atherodes (Walker 1965). Species in this zone are normally inundated only until July or August. The lower range of Scolochloa demarcates the upper boundary of the dynamic marsh shoreline. It is along these shorelines that the effect of fluctuating water on the distribution of the three dominants (Typha, Phragmites and Scolochloa) will be determined. Alternating cycles of flooding and drying are reflected in the spatial shifts of marsh vegetation. Such cycles have a particularly marked effect along elevational gradients. A strong gradient will produce distinct zones of vegetation while a weak gradient will result in a mosaic of vegetation.

The hydrologic budget of Lake Manitoba directly influences the Delta marsh which lies along its southern border. Until 1961, the lake fluctuated within a range of over 2.2 m (Anon. 1973). However, since 1961, the Fairford River control structure has greatly reduced the magnitude of lake

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[1] Nomenclature follows Scoggan (1978).

fluctuations (Last 1980). This control structure currently regulates the lake with a target level of 247.5 m and a range of only 60 cm (Anon. 1973; Crowe 1974).

Vertical aerial photographs of marsh vegetation record wetland conditions at one point in time (Carter _et al_. 1979 Lovvorn and Kirkpatrick 1982). Photographs taken at intervals can be used to examine changes over time. Photo interpretation of marsh vegetation should be verified through ground truthing usually the same year (e.g. Carter _et al_. 1979; Gammon and Carter 1979; Howland 1980). In this study, _Typha_, _Phragmites_ and _Scolochloa_ zones tentatively identified on 1980 black and white (B/W) aerial photographs were verified by ground truthing in the summer of 1984, despite the four year period between photographs and field work. Corroboration of these data was used to develop a signature key [2] for the B/W aerial photographs taken in 1948, 1954, 1964 and 1980.

This chapter deals with (1) the identification of the stereoscopic characteristics (signatures) of the three species (_Typha_, _Phragmites_ and _Scolochloa_). This represents the preliminary step in monitoring vegetation changes in Delta Marsh between 1948 and 1980, and (2) the establishment of the relationship between lake and marsh levels, because it is assumed that lake levels are the main factor influencing

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[2] The 1972 aerial photographs were true color imagery. The signature key developed by Hathout and Simpson (1982) was used.

marsh levels (Ducks Unlimited 1981; Walker 1965). This relationship will be used to determine the effect of marsh water levels on the distribution of vegetation during the pre- and post-regulation periods of Lake Manitoba.

1.2 METHODS

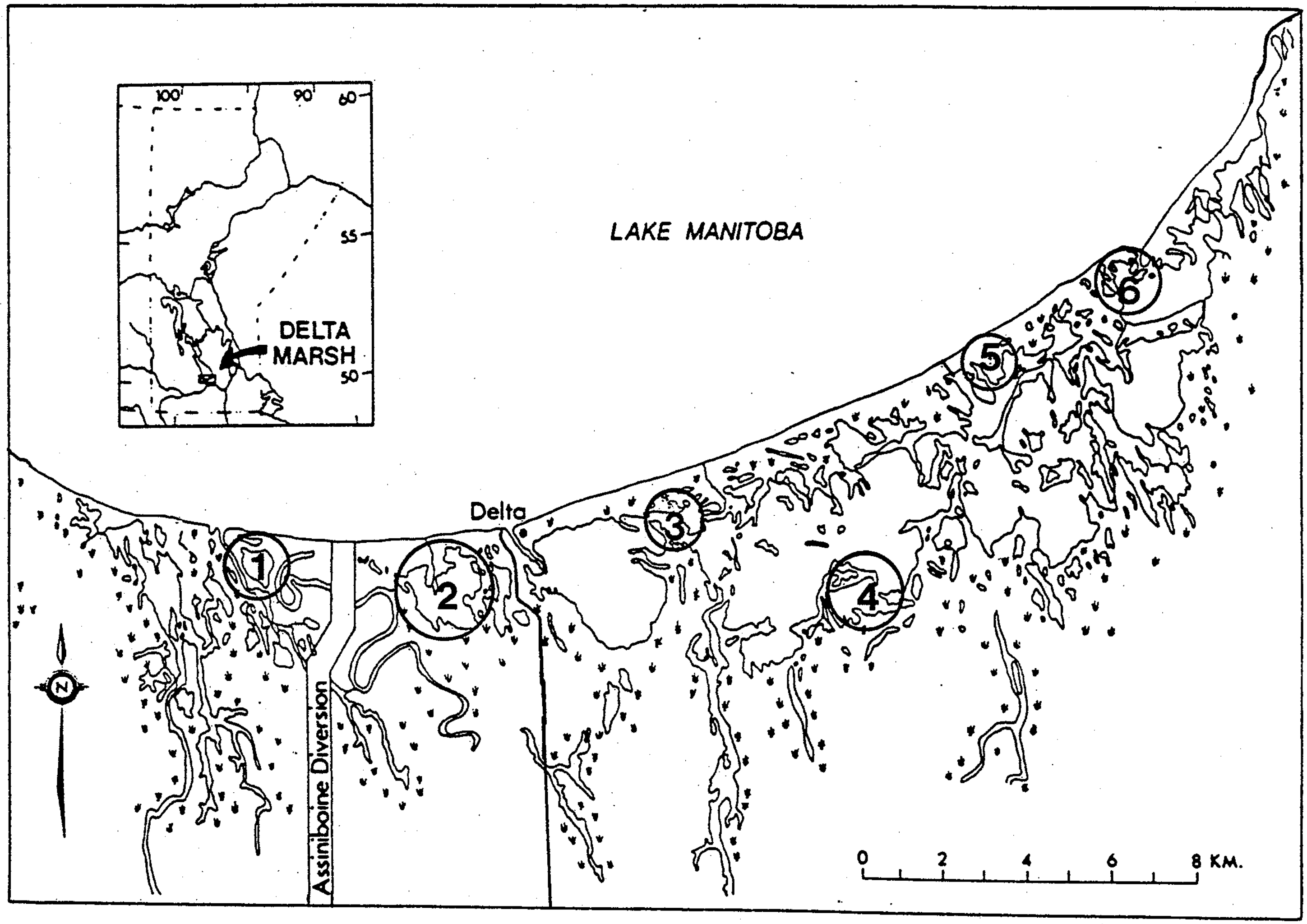
1.2.1 Study Sites

Jones (1978) subdivided the 15,000ha Delta Marsh into three large management units: (1) the West Marsh unit, situated west of the Assiniboine Diversion, (2) the School Bay unit, situated between the Assiniboine Diversion and Provincial Road 240 (P.R. 240), and (3) the East Marsh unit, situated between P.R. 240 and Clandeboye Bay. The latter is the largest of the three, with larger expanses of open water than the West and School bay units. Study sites representative of the diversity within each unit were selected for ground truthing (Fig. 1.1). Units 1 and 2 were relatively small and thus only one site was selected from each, while in the third and largest unit, four sites were selected. The sites are described below:

A: Forster's Bay is an open bay (100 ha) fringed by vegetation, approximately 0.21 km south of Lake Manitoba. It receives water directly from the lake via Cram Creek.

B: Centre Marsh is a large, shallow open bay (266 ha) approximately 0.38 km south of the lake. Drainage to Lake

Figure 1.1. Study sites within West Marsh, School Bay and East Marsh Management areas.



LAKE MANITOBA
DELTA
MARSH
100'
90'
60
55
50
Delta
Assiniboine Diversion
N
1
2
3
4
5
6
0
2
4
6
8 KM.

Manitoba was blocked by the Assiniboine Diversion in 1969. This was partly corrected by construction of a ditch east of and parallel to the diversion. This site receives lake water indirectly from the Delta Channel by means of a culvert under P.R. 240 (Jones 1978).

C: The Gap consists of a series of small convoluted bays (84 ha) approximately 0.31 km south of the lake. It receives lake input indirectly via the Delta Channel.

D: Tin Town (192 ha), located along the southern boundary of Bluebill Bay, is approximately 1.6 km south of the lake. It receives indirect input from Lake Manitoba via Clandeboye and Delta Channels.

E: Chimney Marsh is the northern shore of a narrow elongate bay (90 ha) located approximately 0.13 km south of the lake. This site receives water from Clandeboye Bay.

F: Clandeboye Bay is part of the northern shore of an open bay (70 ha), linked with Lake Manitoba by Clandeboye Channel. A control structure at 247.6 m elevation was built in 1944, but removed in 1983. It precluded exchange between the marsh and the lake except when marsh or lake levels were higher than the structure.

1.2.2 Signature Verification

A comparison of stereo-pairs from the 1980 B/W aerial photographs (1:16,590) and 1980 vegetation maps (Ducks Unlimited; 1:14,630), produced tentative zone signatures. These were based on the stereoscopic characteristics of tone, texture and height (Avery 1968; Brown 1978). Vegetation zones and their respective boundaries were delimited using a Dietzgen mirror stereoscope (3x magnification). Zone boundaries were traced onto clear mylar overlays. These zones were then compared to the 1980 vegetation map categories for tentative identification, which was verified by ground truthing in 1984.

In the field, transects were used to identify vegetation zones and locate zone boundaries during July and August of 1984. The 1980 aerial photographs were used as field maps. A major factor dictating the number and location of transects was the difficulty in locating reference points in the field. Transects were located near islands, points of land and other references that were readily identifiable in the field and on the aerial photographs. A second major factor limiting field work was time. This problem was composed of several factors: (1) the short growing season (June to August), (2) the time required to reach sites accessible only by canoe, and (3) the time needed to complete each transect. The area of each site and the complexity of the vegetation (i.e. many small stands versus large stands) influenced the number of transects at each site. In total 17 transects were sampled (Table 1.1).

The canopy composition along each transect was determined using the line intercept method. This method was used because: (1) it identified zones on aerial photographs by their canopy characteristics, (2) it allowed rapid cover assessment in long transects, (3) it was more practical than quadrats, and (4) it minimized habitat damage. Transects were oriented perpendicular to expected zone boundaries and parallel with expected elevational gradients. Transects were drawn to scale on the overlays.

At Chimney Marsh and Clandeboye Bay, transects began at a measured distance from the forested ridge and proceeded until open water was reached. Most transects, however, began at the water's edge and proceeded inland until all expected zones and zone boundaries were intercepted. Sampling was terminated when data indicated a monodominant stand in the last expected zone. Minimum transect length determination was not carried out, but the scale of the 1980 aerial photographs (1:16,590) required a minimum mapping unit of 5 m (in the field) to stereoscopically verify a stand signature.

A 100m tape was used to mark the transect. The canopy overlapping the tape was recorded in the first 0-50 cm segment of every second meter; sampling began at 0 m and the

Table 1.1: Chi-squared analysis of vegetation zone widths, within study sites, determined from ground truthing (observed) and 1980 black and white aerial photographs (expected).

site	no. transects sampled	transect(s) analyzed '	zone ●	df	observed width (m)	expected width (m)	Chi-squared •
Forster's Bay	3	1	SCFE	2	59	64	1.64
			PHAU		36	30	
			THYP		20	21	
		2	SCFE	2	21	17	3.9
			PHAU		44	39	
			TYPH		26	35	
		3	PHAU	3	61	58	1.42
			TYPH		18	21	
			SCFE		10	21	
			TYPH		10	8	
Centre Marsh	5	1	TYPH	2	31	39	2.25
			PHAU		76	70	
			SCFE		43	41	
		2	TYPH	1	21	23	0.28
			PHAU		78	77	
		3	TYPH	1	77	83	1.9
			PHAU		22	17	
		4	TYPH	2	37	30	2.45
			PHAU		54	54	
			SCFE		60	64	
		5	TYPH	2	45	43	0.32
			PHAU		28	30	
			SCFE		27	27	
The Gap	2	1	TYPH	1	47	41	1.5
			PHAU		52	58	
Tin Town	4	1	PHAU	3	27	22	4.13
			TYPH		7	12	
			SCFE		31	35	
			TYPH		35	31	
		2	PHAU	1	73	65	2.09
			TYPH		80	90	
Chimney Marsh	1	1	PHAU	1	25	20	1.34
			TYPH		261	266	
Clandeboye Bay	2	1	MEAD	1	13	20	2.75
			TYPH		168	161	
		2	TYPH	2	71	65	3.01
			PHAU		26	22	
			TYPH		48	58	

' transects analyzed with at least 1 degree of freedom

● TYPH = TYPHA spp.
PHAU = PHRAGMITES AUSTRALIS
SCFE = SCOLOCHLOA FESTUCACEA
MEAD = mixture of meadow species including SONCHUS ARVENSIS and CAREX ATHERODES

• *significantly different at = 0.05

water depth was recorded at 25 cm. The accumulated cover of each species within a sample was expressed as a percentage and the height of each species was estimated.

On the aerial photographs, zone widths were calculated by measuring the distance between boundaries. This became difficult, however, when zones on the photographs were less than 10 m wide (1 mm on photograph = 16.6 m in field). To facilitate measurements, the photographs were enlarged 3x with a Kargl Reflecting Projector. From the ground truthing data, zone widths were determined using histograms of percent cover along a transect; a shift in percent cover indicated the boundary location between zones. Chi-squared analysis (Steele and Torrie 1980) tested whether zone widths obtained from the 1980 aerial photographs (expected) and the 1984 ground truthing data (observed) were significantly different ($\alpha = 0.05$). Zone boundaries were verified when expected and observed zone widths were not significantly different (Table 1.1). The data for each transect were analyzed if there was at least 1 degree of freedom (i.e. the transect intercepted a minimum of two vegetation zones).

1.2.3 Relationship Between Lake and Marsh Levels

Water depths (recorded to the nearest cm) were measured at 2m intervals along vegetation transects. The corresponding elevations were obtained from 1980 contour maps (1:7,200; 30cm intervals) produced by Ducks Unlimited in

1980; these maps were compiled from ground surveys and photo interpretation of 1979 color infrared aerial photographs. Transects were then drafted onto the maps. Where contour lines intercepted the transect, the elevation and distance along the transect were recorded.

The slope along each transect was determined by simple linear regressions (Neter and Wasserman 1974) of transect distance versus elevation. The slope along individual transects was determined when three or more data points were recorded. Less than three data points precluded subsequent calculation of mean water levels. If a significant relationship or slope was indicated ($\alpha = 0.05$), the elevation at each 2m sampling interval was interpolated. Water levels along each transect were determined using simple linear regression analysis, where estimated elevation was the independent variable and water depth was dependent. If a significant relationship was shown ($\alpha = 0.05$), the water level at each sampling interval was estimated. For each transect, the mean water level in that site was calculated for a specific sampling day. From daily lake level records, the mean lake level on the day of sampling, as well as 1, 2 and 3 days prior to sampling, were obtained (Table 1.2).

The nature of the relationship between marsh and lake levels was determined using the normal correlation model. For the case of two variables this method was based on the

Table 1.2: Calculated mean water levels along vegetation transects and the corresponding mean lake levels, the day of sampling, as well as a lag period of up to three days prior to sampling.

site/transect no. *	date	mean marsh level (mASL)	mean lake levels (mASL)			
			same day	1 day	2 days	3 days
FOBA2	15/8/84	247.31	247.44	247.46	247.45	247.48
CEMA3	24/7/84	247.41	247.5	247.51	247.52	247.52
CEMA4	25/7/84	247.41	247.51	247.51	247.51	247.51
CEMA5	26/7/84	247.46	247.51	247.49	247.48	247.51
THGA3	20/8/84	247.32	247.48	247.48	247.47	247.46
TITO1	28/7/84	247.61	247.52	247.51	247.51	247.52
CHMA1†	30/7/84	-	-	-	-	-
CLBY1	19/8/84	247.35	247.47	247.46	247.45	247.45

* FOBA = Forster's Bay
CEMA = Centre Marsh
THGA = The Gap
TITO = Tin Town
CHMA = Chimney Marsh
CLBY = Clandeboye Bay
† insuffient number of data points

bivariate normal distribution [3] (Neter and Wasserman 1974). The two variables, lake levels and marsh levels, were assumed to be jointly normally distributed; thus each of the two variables alone was normally distributed. The coefficient of correlation (r) between the two variables indicated whether lake and marsh levels were independent, positively related or negatively related.

1.3 RESULTS

1.3.1 Signature Verification

Dominant canopies were typical of the *Typha*, *Phragmites* and *Scolochloa* zones. *Typha* zones were dominated by the hybrid *T. glauca* although they were composed of a complex of *T. angustifolia*, *T. latifolia* and the hybrid. This zone had a uniform physiognomy; the dark green leaves and brown inflorescences were linear and vertically oriented. Plants attained a height of 1 - 3 m. *Phragmites* zones also had a uniform physiognomy, with linear light green leaves almost perpendicular to an erect rigid stem. A large, light-coloured, feathery inflorescence developed at the stem apex. Plants grew to a maximum of 3 m. *Scolochloa* stands had a hummock-like physiognomy. The stems were flexible and easily bent in the wind, with the result that some parts of the stand were flattened while others remained erect. *Scolo-*

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[3] Correlation analysis was performed by the BASIC program CORRELATION. This program was available for the Apple IIe microcomputer and is described in Orloci and Kenkel (1985).

chloa's linear, dark green leaves were not vertically oriented and its inflorescence was a white, open panicle. Plants were 1 - 1.5 m tall.

Vegetation zones were arranged along the expected elevation gradient of each transect. In general, Typha was adjacent to open water, Phragmites occupied an intermediate position, while Scolochloa occurred in drier areas. Analysis of the 1980 aerial photographs demonstrated sharp (Fig. 1.2a) but convoluted boundaries. In the field, however, the transition zone between monotypic stands of Typha and Phragmites was often as wide as 10 m, while the transition to Scolochloa was typically up to 2 m wide (Fig. 1.2b). The boundary between vegetation zones was defined where one species represented more than 50% of the cover.

Chi-squared analysis indicated no significant differences between expected and observed zone widths (Table 1.1), thereby verifying zone boundaries. From this analysis a signature key for Typha, Phragmites and Scolochloa was developed (Table 1.3).

1.3.2 Relationship Between Lake and Marsh Levels

Correlation analysis (Steele and Torrie 1980) demonstrated a strong relationship between mean water levels from all sites (pooled data) and their corresponding mean lake levels (Table 1.4). Mean water levels demonstrated the

Figure 1.2. Vegetation zones along transect 5 - Centre Marsh: (A) zones determined from aerial photographs, and (B) zones determined from ground truthing.

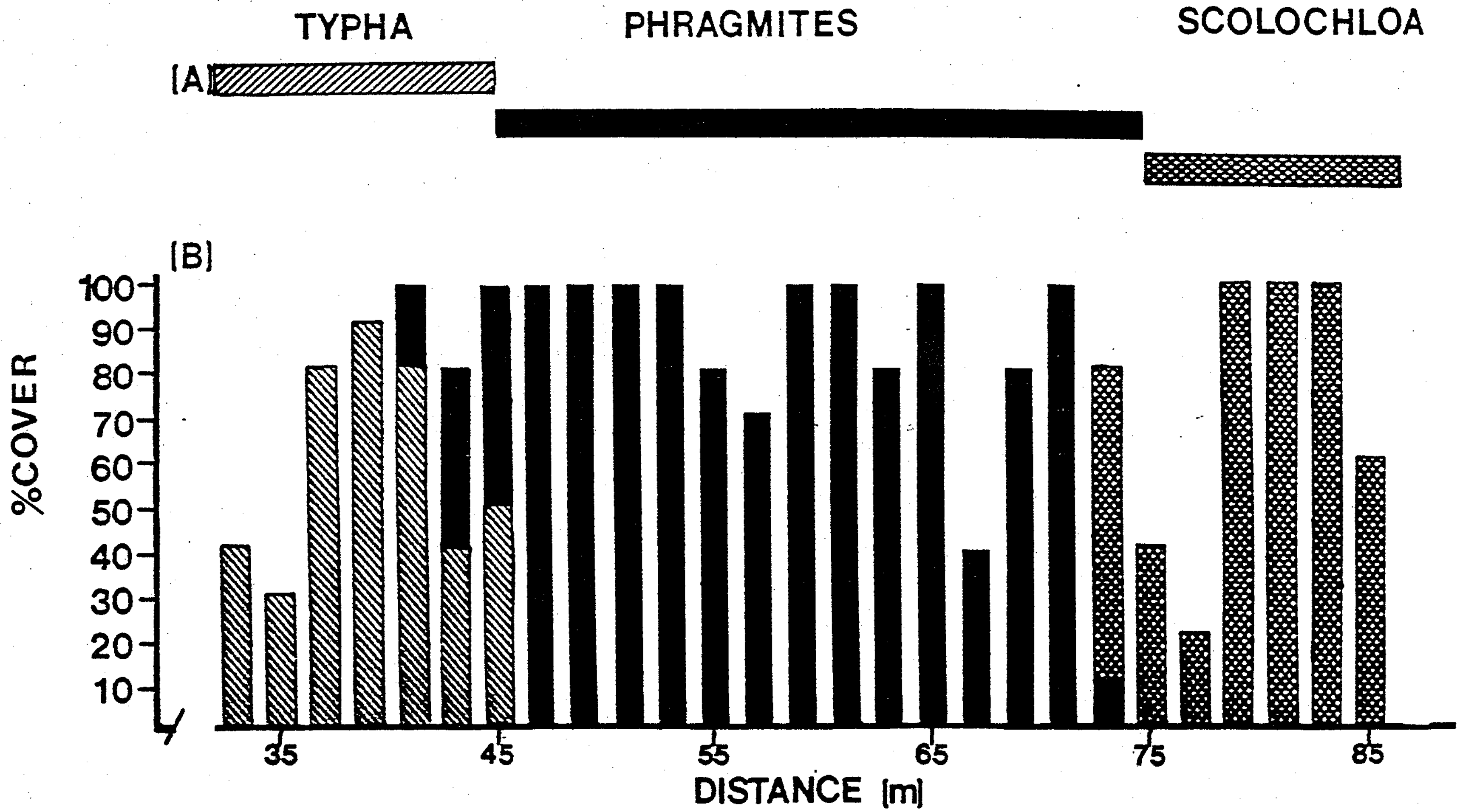

TYPHA
PHRAGMITES
SCOLOCHLOA
(A)
(B)
%COVER
100
90
80
70
60
50
40
30
20
10
35
45
55
65
75
85
DISTANCE (m)

Table 1.3: Black and white aerial photograph signature key for vegetation zones in the Delta Marsh.

cover type	tone	texture	height
Typha spp.	dark grey	fine	intermed.: 1-3 m.
Phragmites australis	light grey	smooth; velvety	very tall: > 3 m.
Scolochloa festucacea	light grey	coarse	short: to 1 m.

Table 1.4: Correlations between mean marsh levels and mean lake levels of Table 2.1.

site	mean lake levels			
	same day	1 day	2 days	3 days
all sites (pooled data)	0.83	0.81	0.67	0.61
isolated sites *	0.89			
directly linked sites †	1			

* isolated sites = Centre Marsh, The Gap, Tin Town, Chimney Marsh
† directly linked sites = Forster's Bay, Clandeboye Bay

highest correlation (r=0.83) with mean lake levels on the day of sampling; correlation between marsh levels and earlier mean lake levels steadily decreased. Mean lake levels on the day of sampling were highly correlated (r=0.89) with levels at isolated sites (Centre Marsh, The Gap, Tin Town and Chimney Marsh) and perfectly correlated (r=1.00) with directly linked sites (Forster's Bay and Clandeboye Bay).

1.4 DISCUSSION

1.4.1 Signature Verification

Tone, texture, and height are used in recognizing signatures on aerial photographs (Avery 1968; Brown 1978). They require a knowledge of plant morphology and leaf orientation (Brown 1978; Grainger 1981). In addition, a knowledge of the habitat requirements of each species is useful for interpretation.

Monodominant stands of *Typha*, *Phragmites* and *Scolochloa* have easily recognizable photographic signatures. The vertically oriented leaves and inflorescences of *Typha* expose a small surface area to sunlight, with the resultant signature characterized by a dark grey tone and fine texture. In contrast, *Phragmites*' leaves, which expose a greater surface area to sunlight, and its large, distinct inflorescence result in a light grey tone. This inflorescence together with the lack of lodging also produces a characteristic smooth velvety texture. *Scolochloa* exhibits maximum leaf, stem and inflorescence exposure in certain parts of the stand which results in a light grey tone and a coarse texture. The flexible stems of *Scolochloa* bend in the wind to produce a random pattern of flattening. Stereoscopic viewing also differentiated these three species by their height: *Phragmites* is the tallest, *Typha* is intermediate, and *Scolochloa* is the shortest species.

Each wetland species has its own level of tolerance to inundation (Millar 1969). *Typha* was the first emergent and typically occurred at low elevations in shallow water, backed by *Phragmites* and then *Scolochloa* at higher elevations. The majority of basin slopes at Delta Marsh are gradual (contour maps; Ducks Unlimited 1980). Analysis of the 1980 aerial photographs demonstrated irregular vegetation zone boundaries indicative of local variations in elevation (Brown 1978; McDonald 1955).

In the field, transitions between vegetation zones could be as wide as 10 m, even though boundaries on the aerial photographs appeared to be sharp. The scale of the 1980 aerial photographs did not readily permit the detection of a mixture of species characteristic of the narrow transitions. Chi-squared analysis demonstrated no significant differences between expected and observed zone widths. This indicates that 1984 ground truthing data could still be applied to the 1980 aerial photographs. During the intervening years changes in species distribution were not detected if the scale of these changes was less than the minimum mapping unit of 5 m. This may lead to information loss that could be corrected by using larger-scale photography unavailable for this study. The aerial photographs used to monitor vegetation trends in 1948, 1954, 1964, 1972 and 1980 were approximately the same scale and information level, therefore boundaries on the aerial photographs were considered reliable within the data base available.

1.4.2 Relationship Between Lake and Marsh Levels

Water levels in the Delta Marsh are maintained mainly by inflow from Lake Manitoba rather than by precipitation or runoff from bordering farmlands. Last (1980) reported that mean annual evaporation from the south basin of the lake exceeded mean annual precipitation by more than 25% and it can be assumed that evaporation losses from the large shallow bays within the marsh are of the same magnitude. The marsh, with an area of approximately 15,000 ha, has a total catchment basin of 25,350 ha; this includes 5,630 ha in the West Marsh, 6,200 ha in the School Bay unit, and 13,500 ha in the East Marsh unit (Jones 1978). Without inflow from the lake, water levels would decline by approximately 18 cm every year (Jones 1978) and this would have a dramatic effect on the shallow marsh.

Marsh water levels in 1984 were positively correlated with lake levels on the day of sampling, regardless of whether a site was isolated from or directly influenced by lake water input. This strong correlation allows use of lake levels in the absence of marsh level records for previous years. These strong inferences between marsh and lake levels can be extrapolated to historic conditions. This seems to be corroborated by pre-regulation studies of Hochbaum (1944), Löve and Löve (1954) and Walker (1959, 1965), all of whom describe, albeit subjectively, a strong relationship between lake and marsh levels.

1.4.3 Conclusions

Verification of vegetation zones on the 1980 B/W aerial photographs produced a signature key for Typha, Phragmites and Scolochloa. This key is the prerequisite for a study that monitors vegetation changes in Delta Marsh between 1948 and 1980, based on black and white aerial photographs. In this study lake levels will be used to represent marsh water levels, because no marsh level data exist.

Chapter II

VEGETATION CHANGES ALONG ELEVATION GRADIENTS, BETWEEN 1948 AND 1980.

2.1 INTRODUCTION

Freshwater wetland communities are closely tied to their water regime (Gosselink and Turner 1978; Weller 1978). As water levels change, individual species are redistributed independently along elevational gradients, with each species demonstrating tolerances to a specific set of conditions (Gleason 1926).

In Chapter I, Delta Marsh water levels were shown to be strongly correlated with those of Lake Manitoba, and fluctuate synchronously. Such fluctuations, combined with basin slope, are two factors affecting the spatial and temporal changes in vegetation (Walker 1965). To determine the historic effects of Lake Manitoba water levels on marsh vegetation, it was necessary to establish the relationship between historic water levels and the extent of wetland areas. Walker (1959, 1965) demonstrated a direct relationship between receding water levels and the presence and distribution of wetland communities.

This aerial photograph study at Delta Marsh was undertaken to quantify the changes in distribution of Typha, Phragmites and Scolochloa along dynamic marsh shorelines during the pre- and post-regulation periods of Lake Manitoba. Monitoring vegetation changes in the Delta Marsh using aerial photography and a minimum of ground truthing (Chapter I) is a practical and relatively inexpensive technique. Aerial photographs can be used to provide a quantitative account of vegetation status at a specific point in time. Aerial photographs taken in 1948, 1954, 1964, 1972 and 1980 were used (Table 2.1). These photographs corresponded to various lake levels (Fig. 2.1): low water (1948, 1964), high water (1954), and relatively stable water levels (1972, 1980).

2.2 METHODS

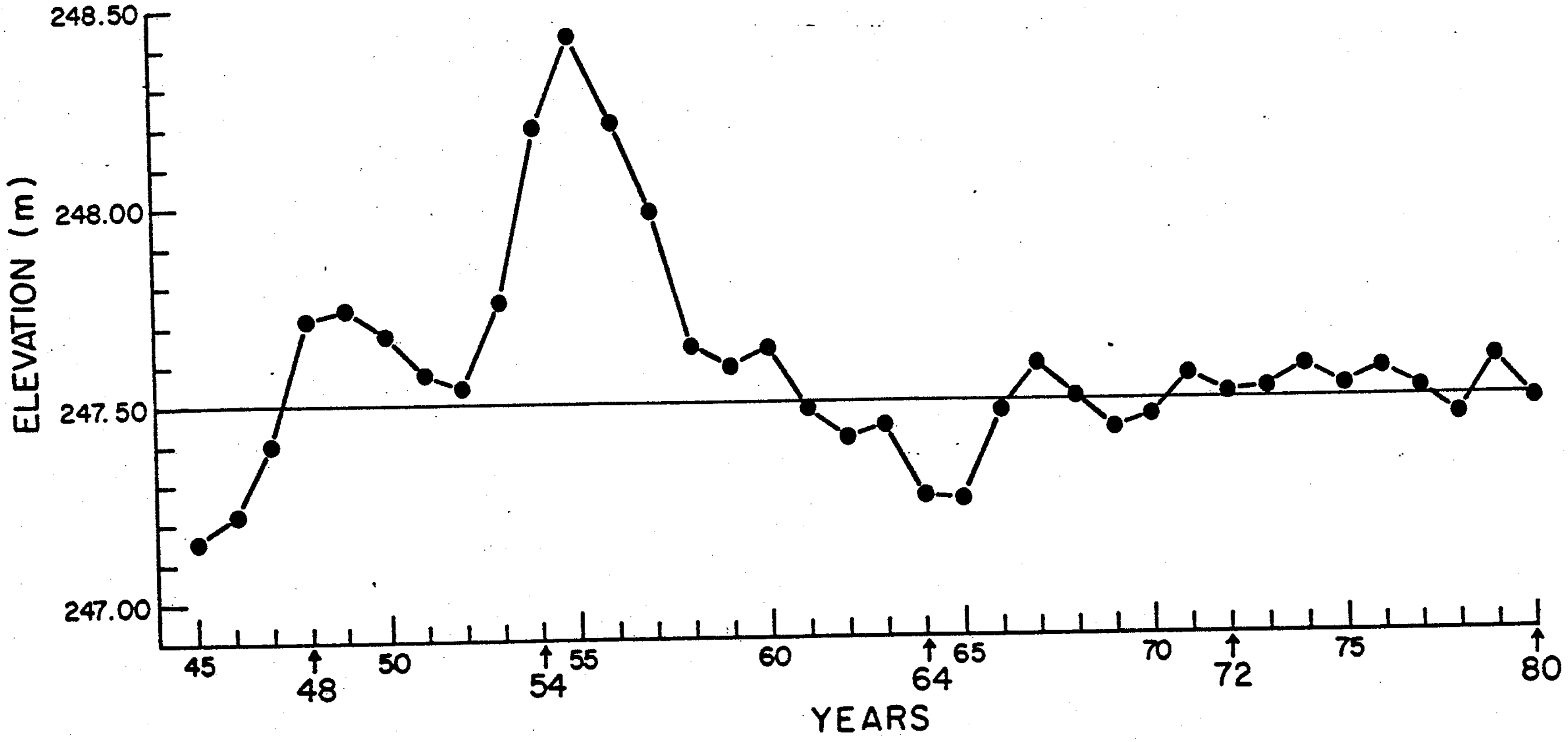
2.2.1 Study Plot Selection and Stereoscopic Analysis

Stereo-pairs from the 1948, 1954, 1964, 1972 and 1980 photographs were obtained for six study sites: Forster's Bay, Centre Marsh, The Gap, Tin Town, Chimney Marsh and Clandeboye Bay. Approximately 10 percent of each site's area was subsampled using 41 randomly selected 1 ha study plots (windows) for each photograph year. One ha windows were used because the area could be conveniently converted to the scale of each of the five aerial photograph years (Table 2.1). Water boundaries and permanent references such

Table 2.1: Aerial Photograph Descriptions.

year	catalog number	type of imagery	scale
1948	A11616 A11617	black and white	1:16,940
1954	A14458 A14462	"	1:20,240
1964	A18609 A18621	"	1:17,300
1972	A30531	true color	1:18,700
1980	A25601 - 604	black and white	1:15,690

Figure 2.1. Mean annual Lake Manitoba levels between 1945 and 1980 (Anon. 1985).


248.50
248.00
247.50
247.00
ELEVATION (m)
45
48
50
54
55
60
64
65
70
72
75
80
YEARS

as roads, ditches, buildings and islands were traced onto frosted mylar overlays. A grid with 100 x 100 m blocks was drafted to the scale of the 1980 aerial photographs (Table 2.1) and photocopied onto clear mylar sheets. These grids were then placed under each of the overlays and aligned along the north/south axis using the permanent reference points. Window coordinates were generated randomly; only windows on marsh shore lines were included. Grids were then drafted to the scale of the remaining aerial photograph years (Table 2.1).

The aerial photographs for the five years under investigation were taken at the end of the growing season in either late August or early September when the maximum morphological differentiation between species, necessary for accurate stereoscopic analysis, had occurred. The three vegetation zones (Typha, Phragmites and Scolochloa) were identified using a Zeiss Interpreskope [4] and the signature key for black and white aerial photographs developed in Chapter I. Vegetation zones on the true color 1972 aerial photographs were identified using the signature key produced by Hathout and Simpson (1982) for Netley Marsh, Manitoba.

Within each window the area of water, mudflats, Typha, Phragmites and Scolochloa (cover types) was calculated using a Hi-State Precision Coordinate Digitizer. A hand-held cur-

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[4] The Zeiss Interpreskope was used because, unlike a mirror stereoscope (see Chapter I), it could magnify an image up to 15x and had a light table. The minimum mapping unit was 3m, beyond which image resolution deteriorated.

sor traced zone perimeters; the length of the perimeter was was calculated, and in combination with the aerial photograph's scale, these data were converted into hectares. The area determinations for each cover type were replicated three times and a mean calculated ($s \leq 5.0 \times 10^{-3}$). Within each site the mean total area for each cover type was determined for each time period, and its percent cover was calculated and tabulated. In addition, the data for each cover type at all sites were pooled and tabulated.

2.2.2 Data Analysis

2.2.2.1 Lattice Profile Analysis

It was expected that, within a complex natural system such as the Delta Marsh, interpretation of the major trends would be prone to the interpretor's bias. To help alleviate this bias lattice profile analysis was used to reveal the major trends within the cover types, and to clarify which environmental and biotic factors were the most important in dictating changes over time. This method is based on correspondence analysis (Hill 1974), an ordination technique which offers a simultaneous and symmetric analysis of the rows and columns of a contingency table (Feoli and Orloci 1979; Greenacre and Degos 1977). Correspondence analysis [5] produces an additive, factorial partitioning of the total

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[5] Correspondence analysis and lattice profile analysis were performed by the BASIC programs CONCENTRATION and LATTICE, respectively. These programs were available for the Apple IIe microcomputer and are described in Orloci and Kenkel (1985).

contingency chi-squared (Lancaster 1949). These additive components are often treated as ordination axes in ecology (e.g. Hill 1974; Greenacre and Vrba 1984). Orloci (1981) illustrated how, through spectral decomposition of the total contingency chi-squared, the output of correspondence analysis can be used to generate lattice profiles which reveal the contribution of a cover type to a given component. The contribution of an individual cover type to a given component (trend) is determined from the shape of its lattice profile (see Feoli and Orloci 1985).

In this study, seven q by t tables were prepared, where q represented the temporal sequence (i.e. aerial photograph years) and t the individual cover types. A separate table was generated for each of the six study sites and for the pooled data. The percent cover plots for each cover type in the temporal sequence, together with the lattice deviation profiles for the first two correspondence analysis components (CI and CII), were interpreted based on a knowledge of lake and marsh levels during this study (see Chapter I) and correlations between respective cover type profiles. Orloci (1981) and Feoli and Orloci (1985) present examples of other ecological applications of the method.

2.2.2.2 Elevation Profile Analysis

Marsh elevations were obtained from the 1980 contour maps (Ducks Unlimited 1980). Using the overlays of the 1980 aerial photographs for reference, windows were located and drafted to scale (1:7200) on the contour maps. As earlier contour maps were unavailable, it was assumed that contours in 1980 were representative of historic marsh elevations. Elevations were sampled using the point intercept method (Mueller-Dombois and Ellenberg 1974). An overlay grid (100m x 100m), with nodes separated by 16.7 m, was placed over each window outline. The elevation at each node was recorded. If a node occurred between two contour intervals, a mean elevation was calculated.

The cover type at each node was recorded from the stereoscopically analyzed windows (section 3.2.1). The aerial photographs and their corresponding overlays were not the same scale as the 1980 contour maps (Table 2.1), but this was resolved by enlargement of the overlays using an overhead projector. The overlays were photocopied onto clear acetate sheets and their image projected onto a rigid, white screen, on which was mounted a window outline. The overhead projector was moved forward or backward, perpendicular to the screen until the window's image and the mounted outline were the same scale. The window outline and cover type boundaries were then traced. The overlay grid was placed over the window outlines and the cover types present at each node recorded. In the case that two cover types formed a mosaic at a given node, each cover type was accorded one half count. This procedure was followed for the 1948, 1954, 1964, 1972 and 1980 aerial photographs. In total, data from 5,125 nodes were assembled.

Five q by t tables were generated for each site; one for each aerial photograph year. In these tables, q represented the elevational range and t the individual cover types. In addition, the data for each cover type at all sites were pooled. The percent cover of each cover type at a specific elevation was calculated. The elevation profiles showed the distribution of each cover type along the elevational gradient during the 1948-80 study period. These profiles were used to determine the spatial dynamics underlying the trends revealed by lattice profile analysis. Cover data were therefore generated from two sources, the 'windows' and elevation nodes.

2.3 RESULTS

The 1948 aerial photographs depicted marsh vegetation after a prolonged period of low water (Table 2.2). Between 1948 and 1955, lake levels slowly increased to peak in 1955 at 1.65 m above the 80-year mean of 247.5 m. The area of marsh covered by water increased at all sites at the expense of both mudflats and vegetation. Indeed, the mudflats completely disappeared from both Chimney Marsh and Clandeboye Bay, while total vegetation decreased at all sites. The 1964 aerial photographs depicted marsh vegetation after a prolonged period of high water (1954-1958) followed by a

Table 2.2 : The percent cover represented by water (W), mudflats (M),, and total vegetation (TV) during the study period 1948-1980.

site	no. windows	1948			1954			1964			1972			1980		
		W	M	TV	W	M	TV	W	M	TV	W	M	TV	W	M	TV
Forster's Bay	7	23.28	0	78.55	36.07	0	66.49	32.48	11.45	61.09	20.52	0	79.48	20.72	0	88.02
Centre Marsh	10	16.49	0	95.21	37.76	0	69.04	31.19	15.35	63.43	35.04	0	75.32	23.14	0	86.92
The Gap	5	13.55	0	86.41	29.03	0	71.23	18.15	14.38	68.31	23.88	0	76.08	10.89	0	90.96
Tin Town	10	47.09	0	64.54	55.88	0	54.06	38.77	9.87	61.22	39.72	0	70.71	27.94	0	76.94
Chimney marsh	4	33.18	7.83	59.01	54.77	0	44.53	64.45	13.83	21.73	65.38	0	34.63	30.35	0	69.43
Clandeboye Bay	5	6.01	3.29	92.32	21.53	0	78.48	23.78	2.45	67.23	18.69	0	69.81	5.48	0	94.97
all sites pooled	41	25.96	1.17	79.47	41.43	0	64.62	34.74	43.26	58.97	34.28	0	69.49	24.52	0	83.99

period of slowly declining water levels (1958-1964). Inundation generally decreased except at Chimney Marsh and Clandeboye Bay. Extensive tracts of mudflats were exposed at all sites except at Clandeboye Bay. The 1972 aerial photographs represented vegetation after five years (1967-1972) of relatively stable water levels (range reduced to 60 cm). Mudflats disappeared from all sites while the total vegetation area increased. The 1980 aerial photographs showed vegetation cover had increased to levels equal to or exceeding those in 1948.

In 1948, Phragmites was the dominant emergent macrophyte (i.e. the species with the highest percent cover) except at Clandeboye Bay, where Typha dominated. Between 1948 and 1954 Phragmites remained dominant at Centre Marsh, Forster's Bay and Tin Town, while Typha remained dominant at Clandeboye Bay and assumed dominance at Chimney Marsh and The Gap. Between 1954 and 1964, Delta Marsh began a transition from a Phragmites to a Typha marsh. Phragmites remained dominant at Centre Marsh and increased to become codominant with Typha at Chimney Marsh. Typha remained dominant at Clandeboye Bay and The Gap and became codominant with Phragmites at Forster's Bay and Tin Town. Between 1964 and 1972 Phragmites was dominant at Centre Marsh however Typha, which was dominant Clandeboye Bay and The Gap, assumed dominance at Chimney Marsh and Forster's Bay, while Tin Town continued to be a Typha-Phragmites dominated site.

Between 1972 and 1980, Typha continued to increase and became the dominant at all sites except Centre Marsh where it was codominant with Phragmites.

2.3.1 Data Analysis

Correspondence analysis partitioned the total contingency chi-squared into a number of additive components (i), which revealed the existence of a dominant trend (Component I) and two or three lesser trends (Components II-IV) (Table 2.3). Following the example given in Orloci and Kenkel (1985, p. 222), tests to determine the significance (α = 0.05) of these components were performed. These demonstrated that Components I and II were significant for the individual sites and for the pooled data for all sites. Components I and II together represented 83-99% of the total contingency chi-squared (Table 2.3). The remaining components varied in significance.

Each component in Table 2.3 has a pair of variables associated with it. Of interest are the canonical scores for aerial photograph years (Appendix I - column canonical scores). These scores establish the type of trend associated with each component, whether it is monotonic or cyclic.

The relative importance of a cover type's contribution to a component is indicated by the degree of deviation from random expectation displayed by its lattice profile. A

Table 2.3: Significance tests for components derived from lattice profile analysis

site	i†	DF*	Ri2°	Xi2 = F..Ri2††	Li%●
Forster's Bay	1	7	0.42	85.91**	55.93
	2	5	0.37	67.74**	42.79
	3	3	0.06	1.93	1.26
Centre Marsh	1	7	0.38	80.04**	64.63
	2	5	0.23	29.73**	24.01
	3	3	0.15	12.85**	10.37
The Gap	1	7	0.41	80.92**	51.53
	2	5	0.34	54.84**	36.83
	3	3	0.19	18.09**	11.47
Tin Town	1	7	0.31	51.69**	58.09
	2	5	0.21	22.98**	25.83
	3	3	0.14	11.12*	12.49
	4	1	0.08	3.18	3.58
Chimney Marsh	1	6	0.49	119.29**	62.29
	2	4	0.34	57.07**	29.81
	3	2	0.17	15.13**	7.91
Clandeboye Bay	1	6	0.31	43.55**	56.29
	2	4	0.23	26.55**	34.31
	3	2	0.12	7.27*	9.41
All Sites Pooled	1	7	0.51	145.21**	80.91
	2	5	0.21	25.64**	14.29
	3	3	0.12	8.06**	4.49

† canonical variable

* (q-1) + (t-1) - (2i-1)

° canonical correlation coeficient

†† amount of total contingency chi-squared accounted for;
* a = 0.05, ** a = 0.01, level of significance for each component.

● percent total contingency chi-squared accounted for cover type is considered to be independent of a component if it demonstrates little or no deviation (i.e. no trend). Elevation profiles show the changing distribution of each cover type along the elevational gradient, which dictates the trends revealed by the lattice profile analysis. The elevational gradient within each site provides an indication of the variability among sites. General vegetation trends are represented by the pooled data for all sites, while individual site data illustrate deviations from trends.

2.3.1.1 All Sites - Pooled

The cover data plots [6] reflected two principal responses (Fig. 2.2A). Changes shown by mudflats and Phragmites between 1954 and 1964 were in response to increasing, then decreasing, water levels (Fig. 2.1) that in turn affected the marsh. Monotonic change from 1964 to 1980 in Typha (hybridization of T. latifolia and T. angustifolia and subsequent introgression was first reported after 1961 (Shay and Shay 1986)) was in response to stabilized lake levels. Lattice profile analysis partitioned these changes into Components I and II; both are significant (Table 2.3).

Component I demonstrated the response of cover types to fluctuations in water level between 1954 and 1972 (Fig. 2.2B). The strongest factor in this component was the

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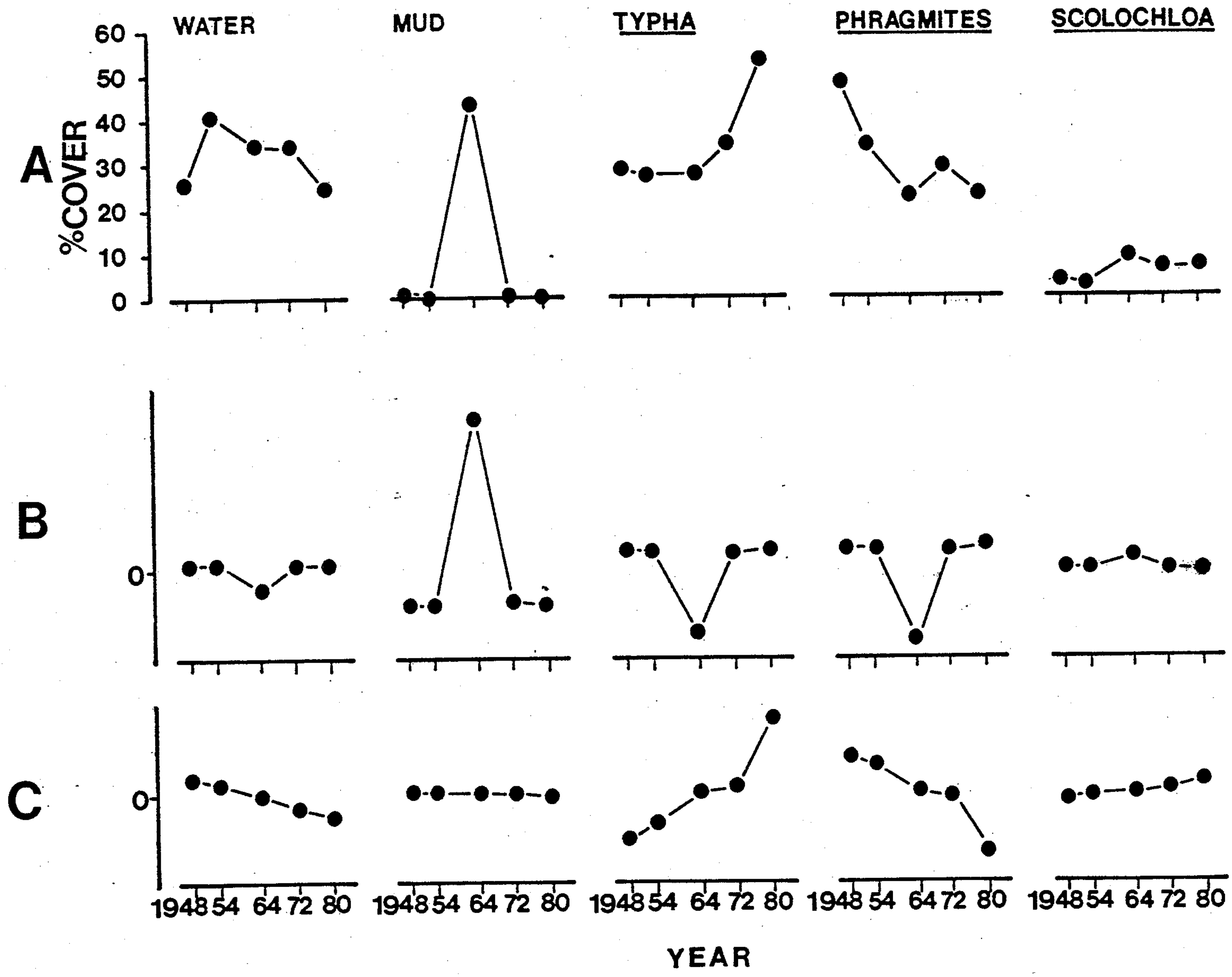
[6] The data for the cover plots should be presented in histograms, but are joined by lines to provide consistency in appearance to lattice profiles for Components I and II. These lines however do not imply continuity.

Figure 2.2. All Sites - Pooled data.

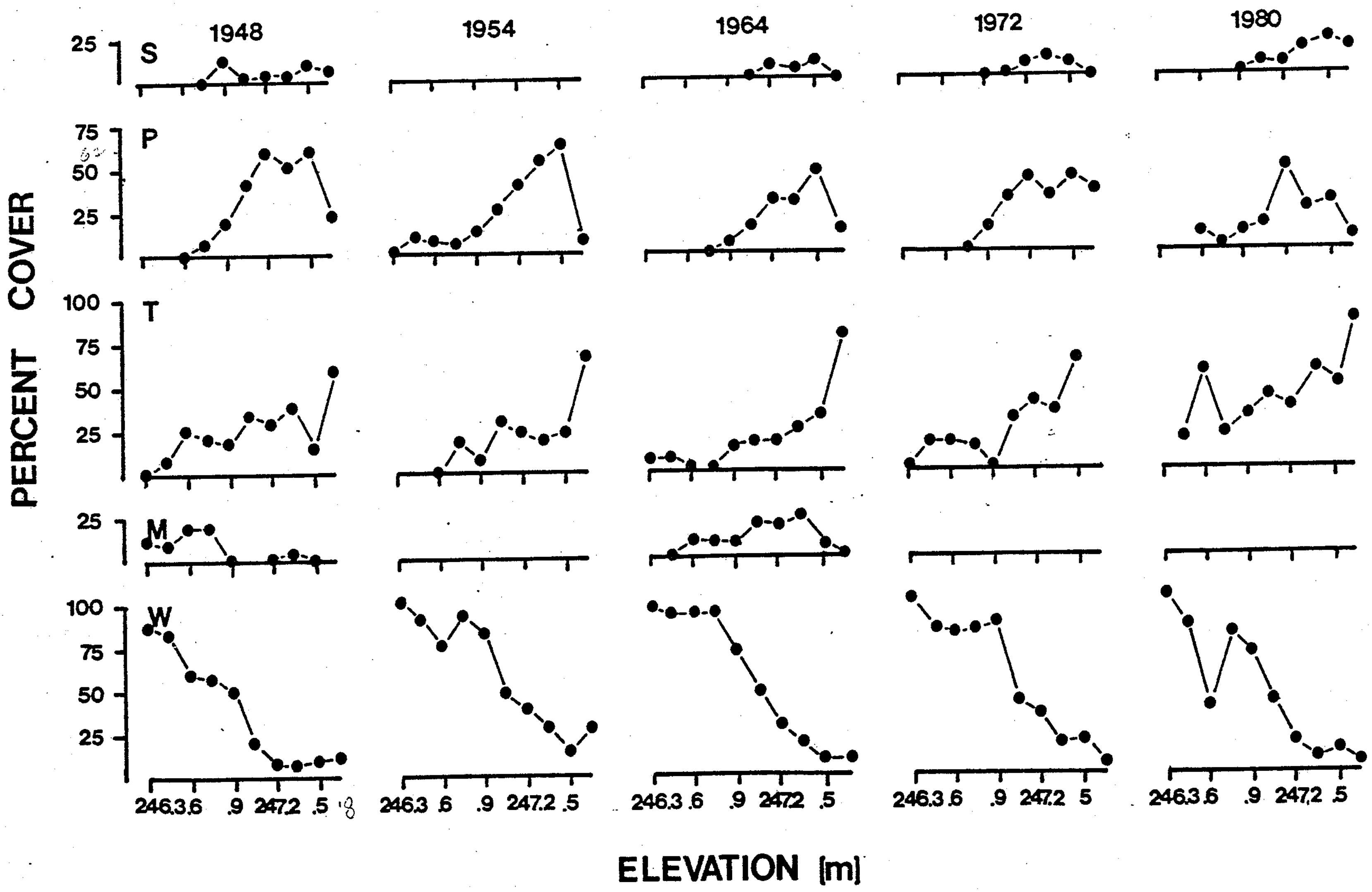
(A) Percent cover of water, mudflats, _Typha_, _Phragmites_ and _Scolochloa_ in 1948, 1954, 1964, 1972 and 1980. (B) Lattice profiles of all cover types showing contribution to Component I: 0 = random expectation. (C) Lattice profiles of all cover types showing contribution to Component II: 0 = random expectation.


WATER
MUD
TYPHA
PHRAGMITES
SCOLOCHLOA
A
%COVER
60
50
40
30
20
10
0
B
0
C
0
1948
54
64
72
80
YEAR

cyclic trend demonstrated in the profile for mudflats, which reflected an inverse relationship with water levels. Water and Scolochloa both demonstrated slight but contrasting responses and both were considered to be minor contributors (i.e. showed little deviation from random expectation) to Component I. Typha and Phragmites were important contributors to Component I. This component revealed a reduction in both Typha and Phragmites. Both species showed a strong inverse response to mudflats, reflecting a prolonged period of high water in the mid-1950's, which resulted in dieback of extensive tracts of vegetation. Declining water levels during the early 1960's exposed large areas of previously vegetated mudflats. Component II clearly demonstrated that Typha increased monotonically to become the dominant emergent macrophyte at the expense of Phragmites and, to some extent, water (Fig. 2.2C).

The general temporal trends revealed by lattice profile analysis were dictated by the spatial dynamics of cover types along the elevational gradient (Fig. 2.3). Declining water levels during the early 1960's exposed extensive mudflats which were colonized at lower elevations by Typha (246.30 m - 246.45 m) and at upper elevations by Typha, Phragmites and Scolochloa (247.2 m - 247.65 m). Between 1964 and 1972, Typha and Phragmites increased at most elevations within their ranges, at the expense of both water and mudflats. During the next period, 1972-80, Typha continued

Figure 2.3. All Sites - Pooled: Elevation profiles indicating distribution of each cover type along the coenocline in 1948, 1954, 1964, 1972 and 1980. W = water, M = mudflats, T = *Typha*, P = *Phragmites*, and S = *Scolochloa*.


1948
1954
1964
1972
1980
S
P
T
M
W
25
75
50
25
100
75
50
25
25
100
75
50
25
PERCENT COVER
246.3.6 .9 247.2 .5
246.3 .6 .9 247.2 .5
246.3 .6 .9 247.2 .5
246.3 .6 .9 247.2 5
246.3 .6 .9 247.2 .5
ELEVATION (m)

to increase along its entire range at the expense of both water and Phragmites.

2.3.1.2 Forster's Bay

Cover data suggested cyclic changes in all cover types (Fig. 2.4A). Component I demonstrated a marked increase in the cover of Typha as it became the dominant emergent at the expense of both water and Phragmites (Fig. 2.4B). Component II demonstrated cyclic responses in all cover types between 1954 and 1972 (Fig. 2.4C). It was similar to the trend indicated by Component I of the pooled data, except water showed a stronger inverse response to mudflats and Typha showed little deviation from random expectation. Prolonged high water levels during the mid-1950's resulted in the die-back of Phragmites. Declining water levels in the early 1960's exposed large tracts of mudflats.

To some extent the elevation profiles (Fig. 2.5) simultaneously reflected both lattice profile trends. The slope of the shoreline was gradual with elevations ranging from 246.75 m to 247.5 m. In 1948 Typha was dominant at middle elevations, Phragmites at slightly higher elevations, but Scolochloa was not present. Between 1954 and 1964 Phragmites decreased at all elevations (247.05 m - 247.5 m), while Typha decreased between 247.05 m - 247.35 m, but increased at higher elevations. Declining water levels in the early 1960's exposed mudflats along the upper portion of

Figure 2.4. Forster's Bay.

(A) Percent cover of water, mudflats, _Typha_, _Phragmites_ and _Scolochloa_ in 1948, 1954, 1964, 1972 and 1980. (B) Lattice profiles of all cover types showing contribution to Component I: 0 = random expectation. (C) Lattice profiles of all cover types showing contribution to Component II: 0 = random expectation.

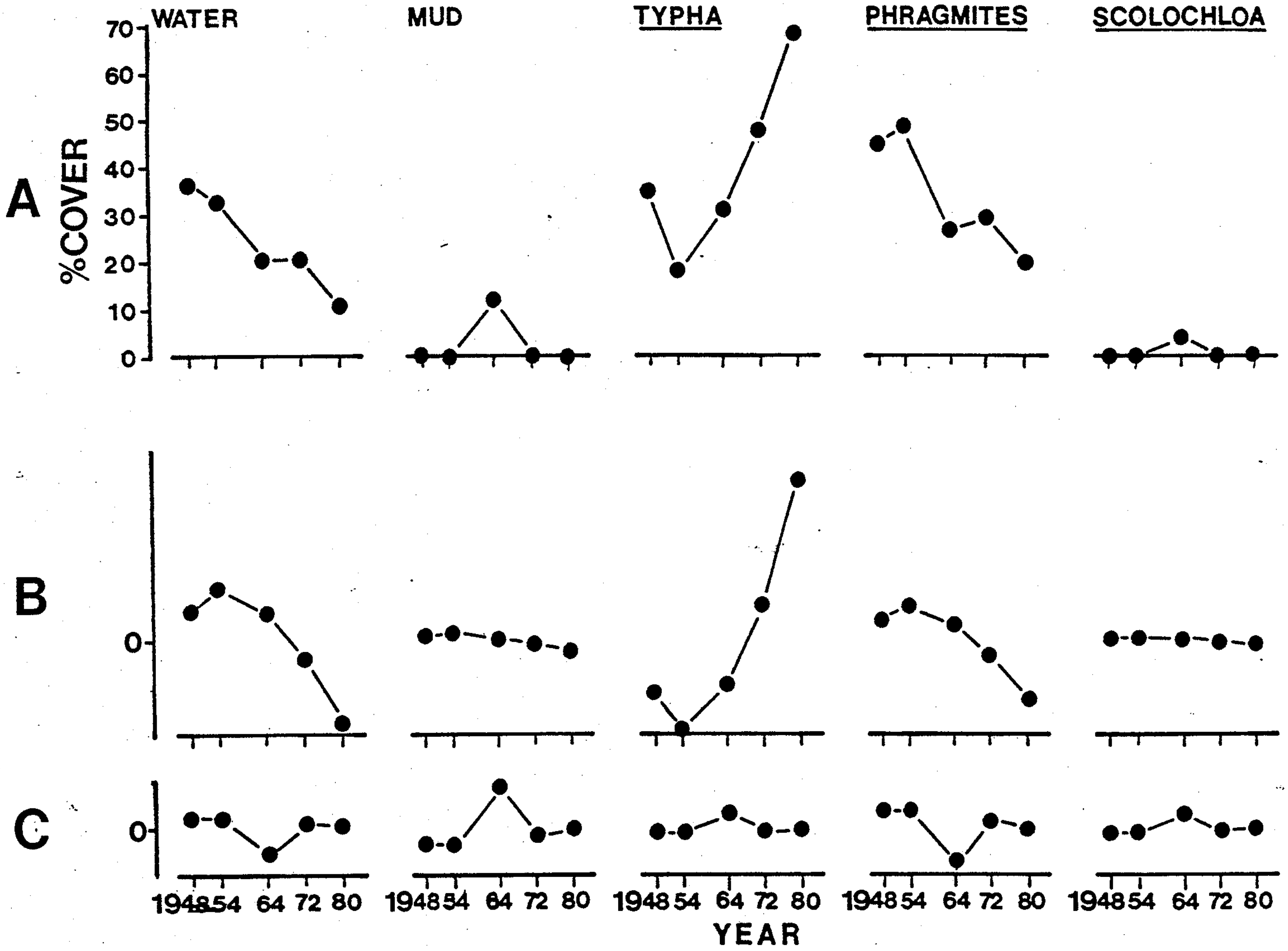
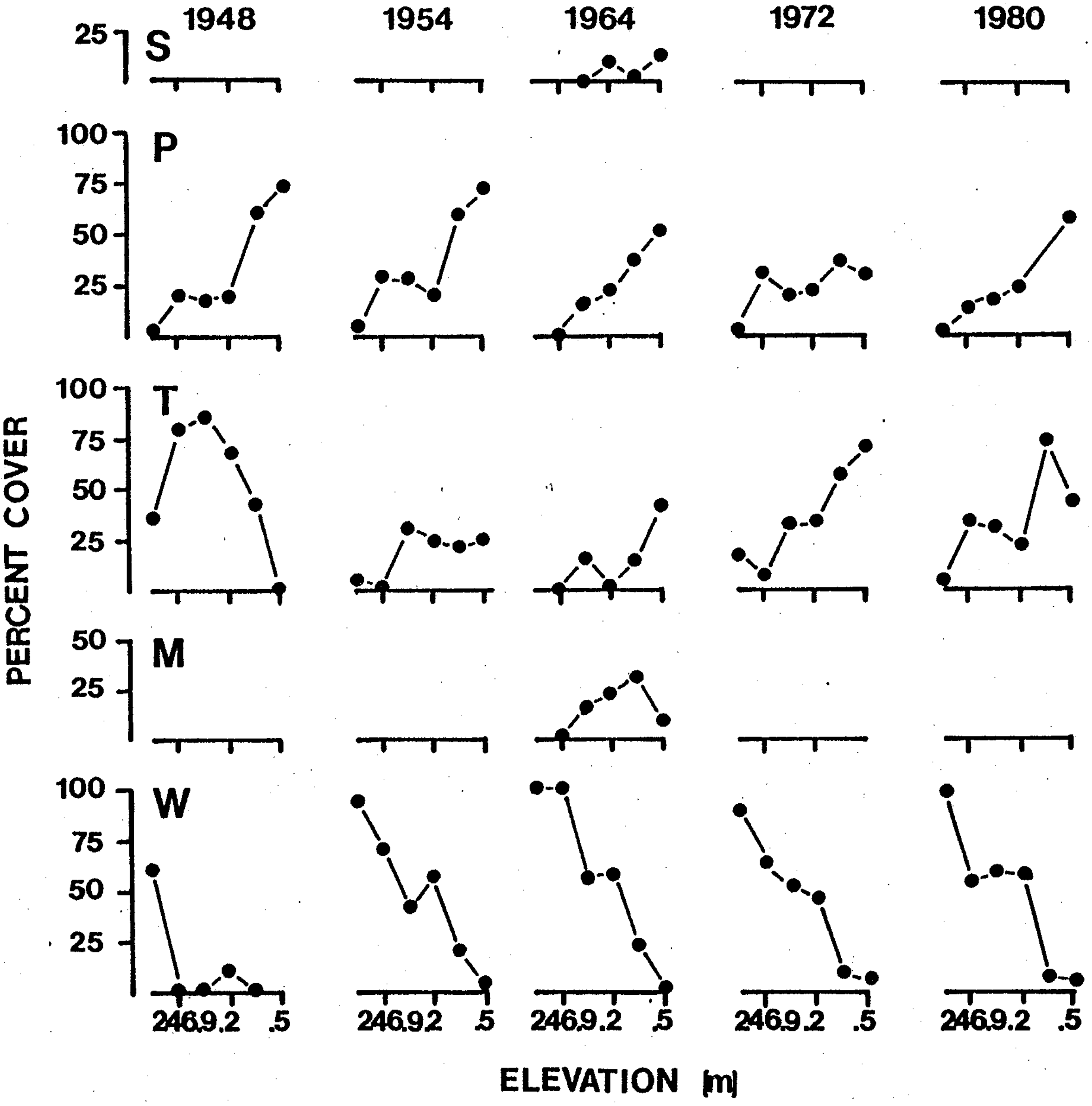

A
B
C
%COVER
70
60
50
40
30
20
10
0
0
0
WATER
MUD
TYPHA
PHRAGMITES
SCOLOCHLOA
1948 54 64 72 80
1948 54 64 72 80
1948 54 64 72 80
1948 54 64 72 80
1948 54 64 72 80
YEAR

Figure 2.5. Forster's Bay: Elevation profiles indicating distribution of each cover type along the coenocline in 1948, 1954, 1964, 1972 and 1980. W = water, M = mudflats, T = *Typha*, P = *Phragmites*, and S = *Scolochloa*.


1948
1954
1964
1972
1980
25
S
100
75
50
25
P
100
75
50
25
T
50
25
M
100
75
50
25
W
PERCENT COVER
246.9.2
.5
ELEVATION (m)

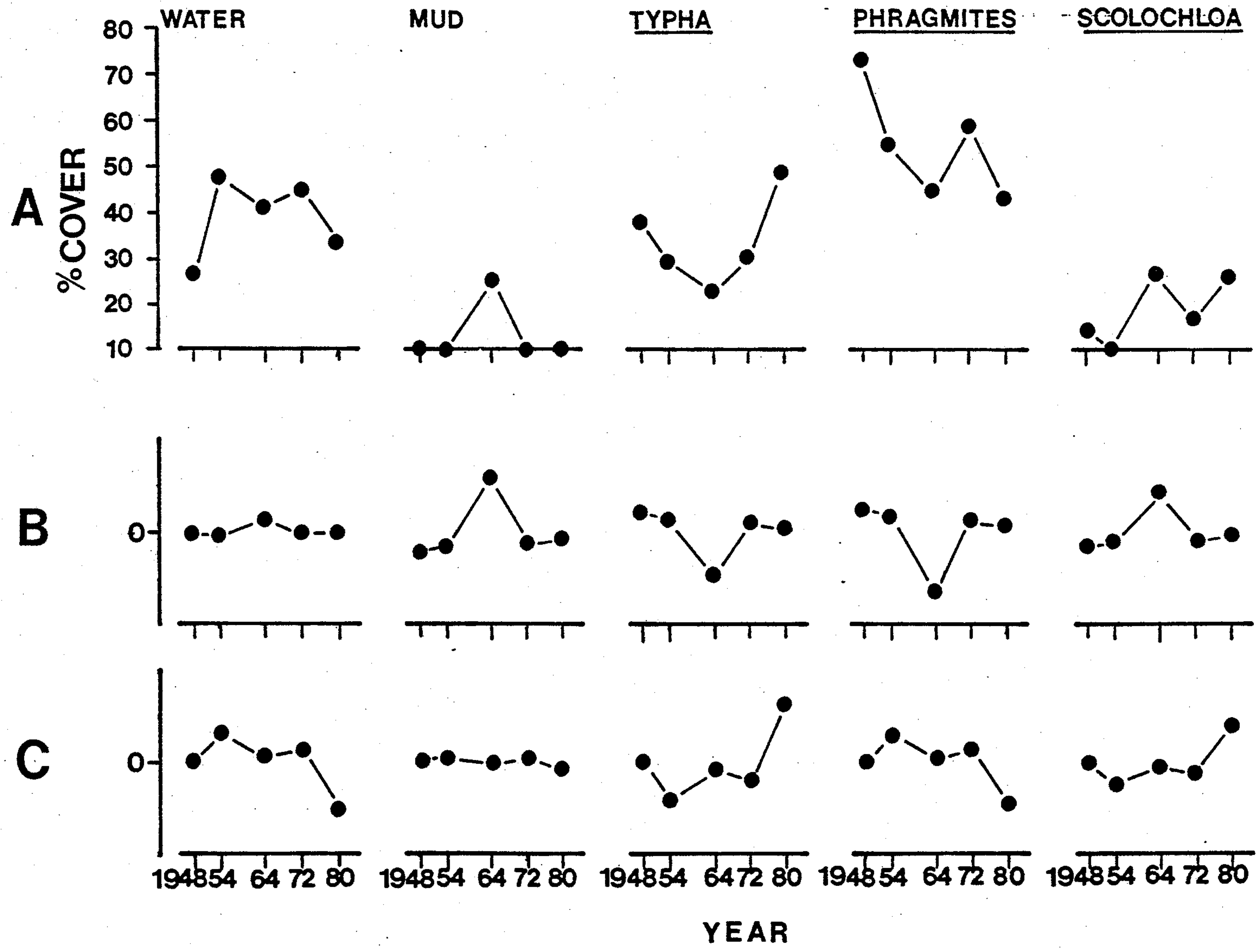
the gradient (247.05 m - 247.5 m). They appeared at the expense of both vegetation and water and were colonized by Typha and Scolochloa. Between 1964 and 1972, the elevational range of both Typha and Phragmites increased to 246.75 m -247.5 m. Typha increased at all previously occupied elevations at the expense of all other cover types. Phragmites decreased at upper elevations (247.35m - 247.5 m) and increased at lower elevations (247.05 m - 247.2 m). Between 1972 and 1980 Typha continued to increase at the expense of both water and Phragmites except at 247.5 m.

2.3.1.3 Centre Marsh

The cover data suggested cyclic changes (Fig. 2.6A). Between 1954 and 1964 all cover types responded to fluctuating water levels. Between 1964 and 1972 Typha and Phragmites responded to higher water levels by expanding, while Scolochloa declined. For Component I, all cover types except water showed a strong response to the presence of mudflats (Fig. 2.6B). Water was a minor contributor to this component. Typha and Phragmites displayed a strong inverse response to mudflats, and Scolochloa displayed a positive response. This trend was similar to Component I for the pooled data. Component II demonstrated the response of cover types to fluctuating lake levels between 1954 and 1964, and 1972 and 1980 (Fig. 2.6C). By 1972 lake levels were regulated, but fluctuations occurred that were independent

Figure 2.6. Centre Marsh.

(A) Percent cover of water, mudflats, Typha, Phragmites and Scolochloa in 1948, 1954, 1964, 1972 and 1980. (B) Lattice profiles of all cover types showing contribution to Component I: 0 = random expectation. (C) Lattice profiles of all cover types showing contribution to Component II: 0 = random expectation.

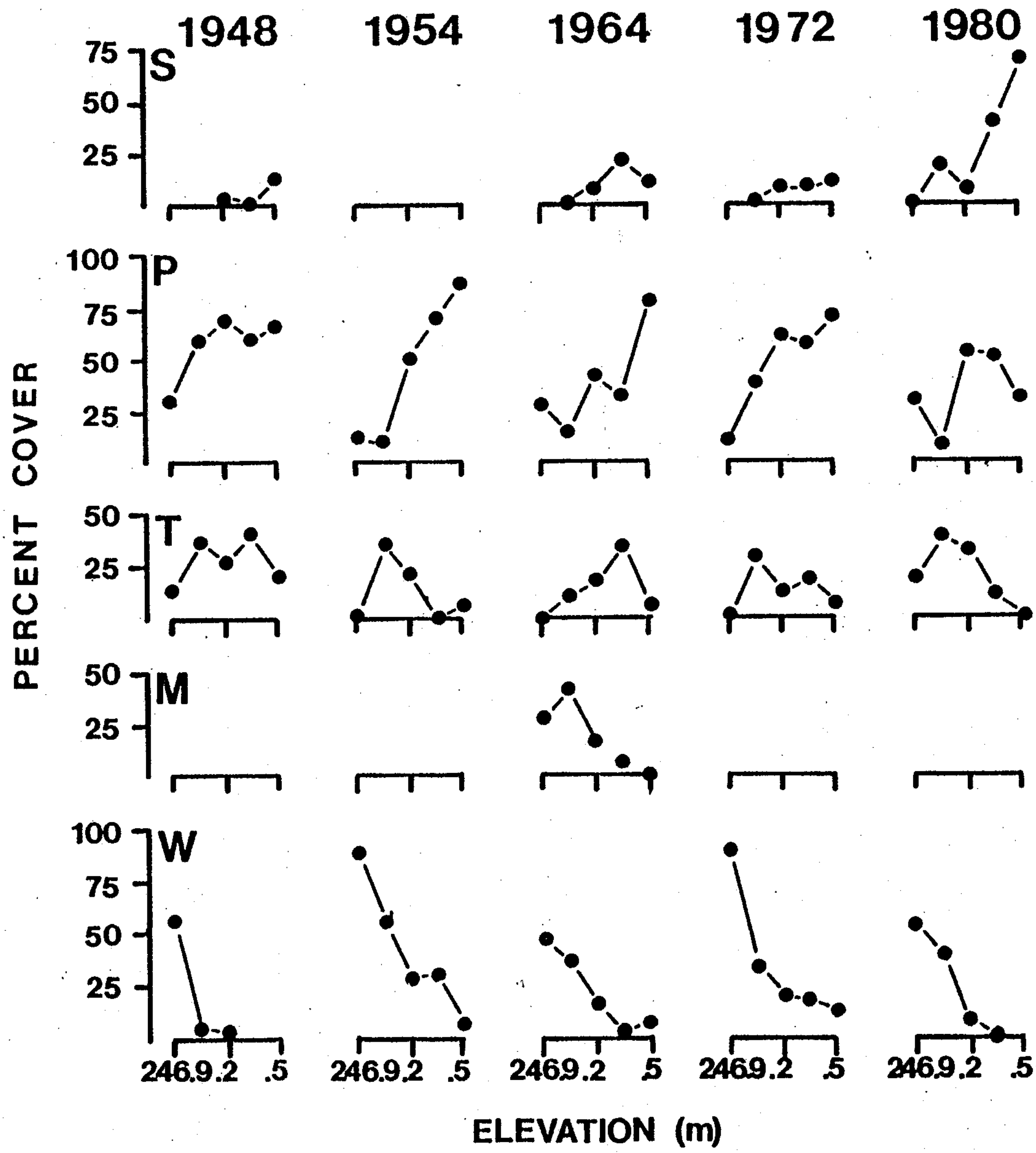


WATER
MUD
TYPHA
PHRAGMITES
SCOLOCHLOA
A
B
C
% COVER
80
70
60
50
40
30
20
10
0
1948 54 64 72 80
YEAR

of lake levels. These were due to the Assiniboine Diversion, completed in 1969, which obstructed drainage from Cram Creek eastwards and from farmlands south of the marsh. This resulted in spring flooding within the site. Vegetation responded to these fluctuating water levels, with *Typha* and *Scolochloa* showing a positive response and *Phragmites* an inverse response.

These temporal trends were dictated by their spatial dynamics along a gradual gradient between 246.9 m - 247.5 m (Fig. 2.7). In response to prolonged high water during the mid-1950's *Typha* decreased at lower elevations (247.05 m - 247.2 m), while *Phragmites* decreased along most of its range. In response to declining water levels in the early 1960's, mudflats were exposed along the entire elevational gradient. These were colonized by *Typha* and *Scolochloa* from 247.2 m - 247.5 m. Between 1964 and 1972, water levels increased at all elevations, *Phragmites* increased at all elevations (except 246.9 m), *Typha* decreased at higher elevations (247.2 m - 247.5 m) but increased at lower elevations (246.9 m; probably due to random variation), and *Scolochloa* displayed little change. Between 1972 and 1980 *Typha* continued to increase at lower elevations (246.9 m - 247.2 m), while *Scolochloa* increased at all elevations; both increased at the expense of water and *Phragmites*.

Figure 2.7. Centre Marsh: Elevation profiles indicating distribution of each cover types along the coenocline in 1948, 1954, 1964, 1972 and 1980. W = water, M = mudflats, T = *Typha*, P = *Phragmites*, and S = *Scolochloa*.


1948
1954
1964
1972
1980
S
P
T
M
W
75
50
25
100
75
50
25
50
25
50
25
100
75
50
25
PERCENT COVER
246.9.2 .5
246.9.2 .5
246.9.2 .5
246.9.2 .5
246.9.2 .5
ELEVATION (m)

2.3.1.4 The Gap

The cover data indicated the presence of cyclic changes (Fig. 2.8A). Component I demonstrated cyclic responses in all cover types between 1954 and 1972 (Fig. 2.8B). Typha showed a strong positive response to mudflats, while Phragmites showed a strong inverse response. Water and Scolochloa were not important contributors to this component, showing little deviation from random expectation. Dieback of Phragmites after high water levels in the mid-1950's, combined with declining water levels in the early 1960's, exposed large tracts of mudflats that were colonized by Typha. Component II indicates that after 1964 Typha and Scolochloa increased at the expense of water and Phragmites (Fig. 2.8C). Phragmites and mudflats showed little deviation from random expectation.

The two major trends determined by lattice profile analysis are dictated by the spatial dynamics of cover types along the elevation gradient from 246.75 m to 247.5 m (Fig. 2.9). The lower portion of the shoreline (246.75 m - 247.2 m) is relatively steep, while the upper portion (247.2 m - 247.2 m) has a gradual slope. Prolonged high water during the mid-1950's resulted in the retreat of Phragmites to a range of 247.05 m - 247.5 m. Declining water levels during the early 1960's exposed extensive tracts of mudflats which were initially colonized by Typha. Between 1964 and 1972, Typha increased at higher elevations at the expense of

Figure 2.8. The Gap.

(A) Percent cover of water, mudflats, _Typha_, _Phragmites_ and _Scolochloa_ in 1948, 1954, 1964, 1972 and 1980. (B) Lattice profiles of all cover types showing contribution to Component I: 0 = random expectation. (C) Lattice profiles of all cover types showing contribution to Component II: 0 = random expectation.

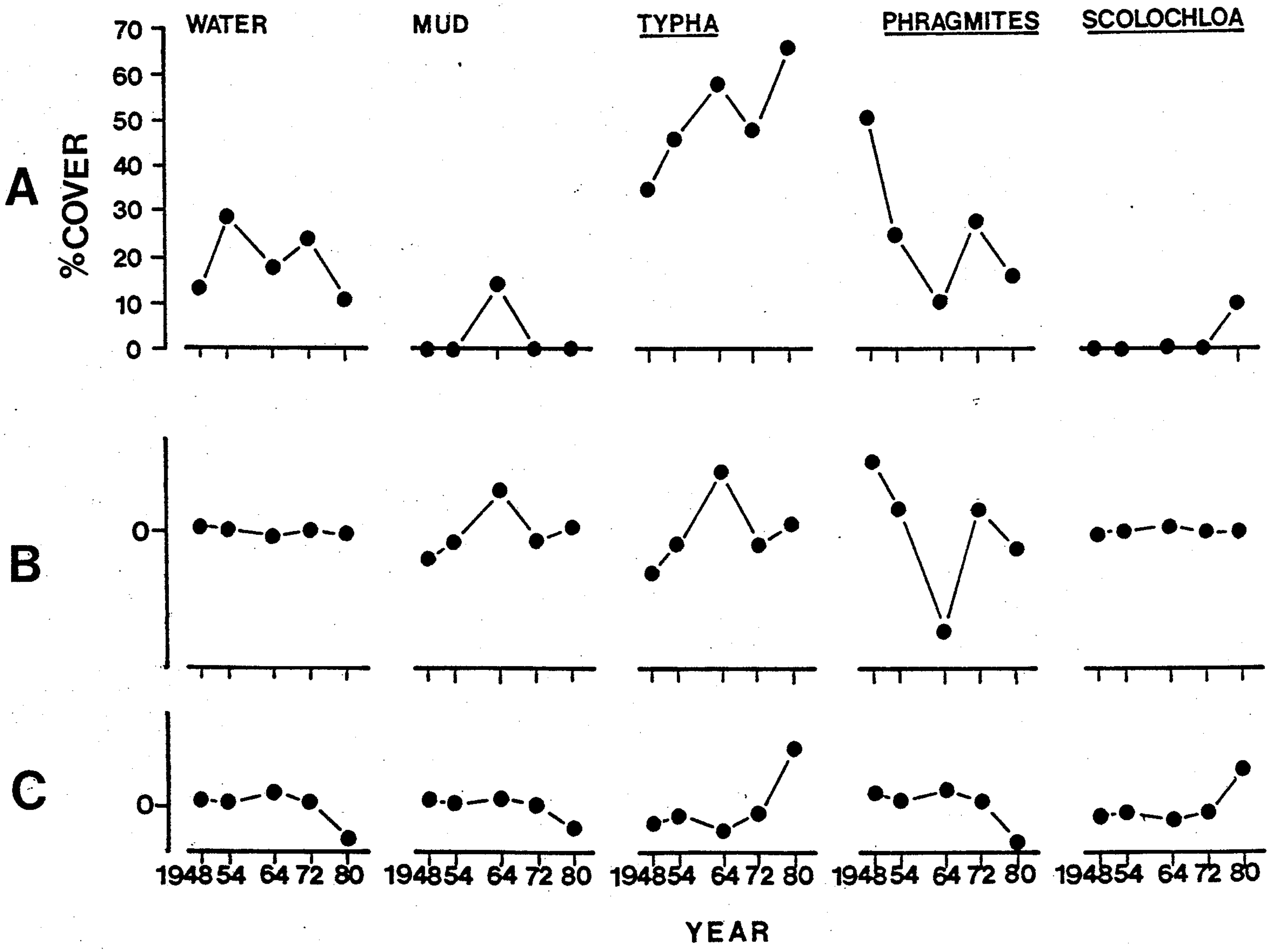
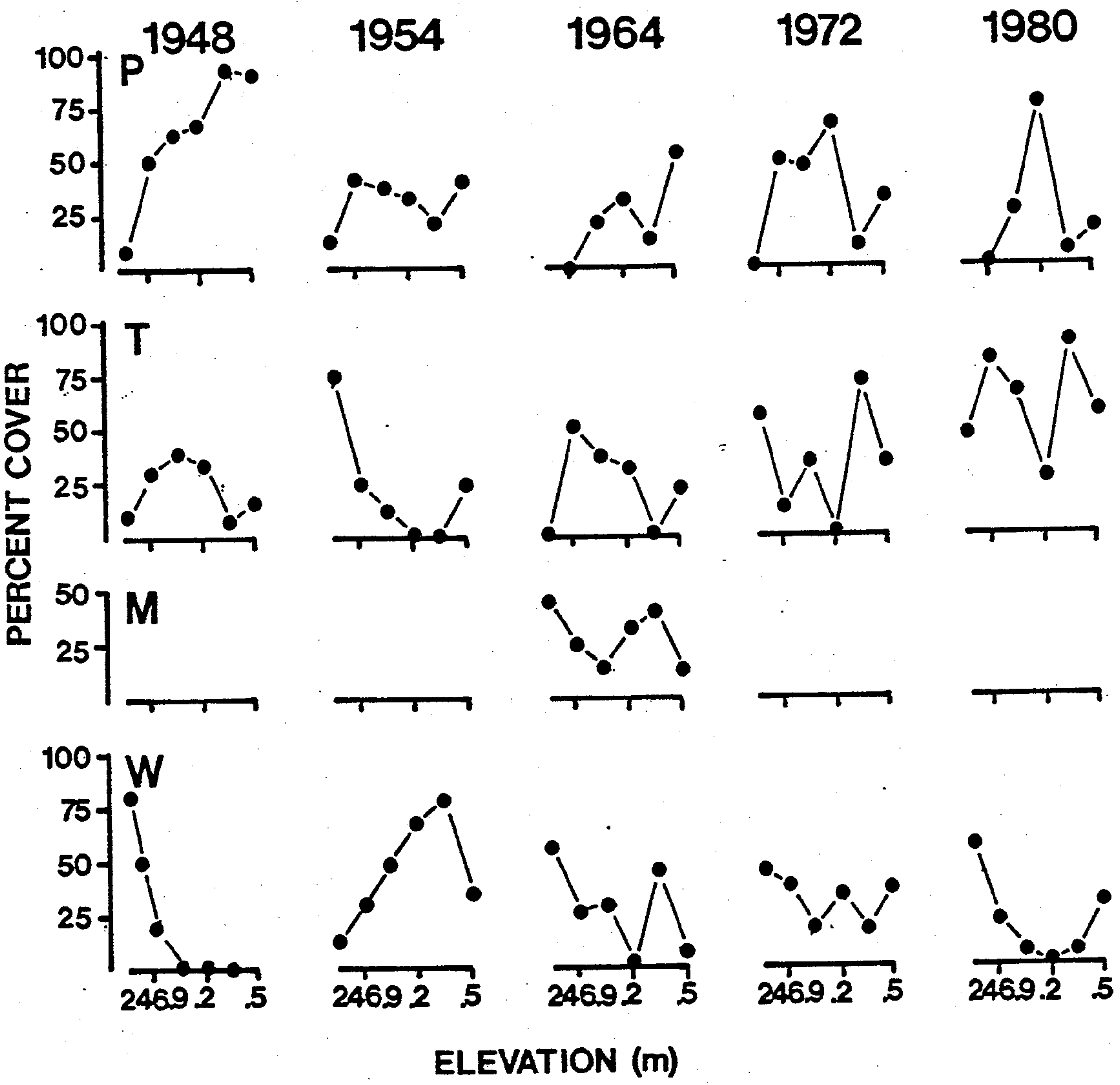

WATER
MUD
TYPHA
PHRAGMITES
SCOLOCHLOA
A
%COVER
70
60
50
40
30
20
10
0
B
0
C
0
1948 54 64 72 80
YEAR

Figure 2.9. The Gap: Elevation profiles indicating distribution of each cover type along the coenocline in 1948, 1954, 1964, 1972 and 1980. W = water, M = mudflats, T = *Typha* and P = *Phragmites*.


1948
1954
1964
1972
1980
P
T
M
W
100
75
50
25
PERCENT COVER
246.9 .2 .5
ELEVATION (m)

Phragmites and recolonized mudflats at lower elevations, but at intermediate elevations *Typha* decreased while *Phragmites* increased and advanced to 246.9 m. Between 1972 and 1980 *Typha* continued to increase at all elevations at the expense of both water and *Phragmites*.

2.3.1.5 Tin Town

Examination of the cover data plots indicated two responses which were confounded (Fig 2.10A). Between 1948 and 1980 cyclic changes displayed by mudflats, *Phragmites* and *Scolochloa* were in response to fluctuating water levels, but *Typha* demonstrated a monotonic increase. Component I demonstrated cyclic responses in all cover types between 1954 and 1972, with little deviation from expectation in *Typha*. (Fig. 2.10B). This component demonstrated a trend similar to Component II of Forster's Bay, except that in this case *Scolochloa* showed a strong positive response to mudflats. Prolonged high water during the mid-1950's resulted in dieback of *Phragmites*. Declining water levels during the early 1960's exposed large areas of mudflats which were colonized by *Scolochloa*. Component II demonstrated a strong interaction between *Typha* and water (Fig. 2.10C), indicating *Typha* increased to become the dominant emergent macrophyte, at the expense of water.

To some degree the elevation profiles (Fig. 2.11) simultaneously reflected the trends in Components I and II.

Figure 2.10. Tin Town.

(A) Percent cover of water, mudflats, <u>Typha</u>, <u>Phragmites</u> and <u>Scolochloa</u> in 1948, 1954, 1964, 1972 and 1980. (B) Lattice profiles of all cover types showing contribution to Component I: 0 = random expectation. (C) Lattice profiles of all cover types showing contribution to Component II: 0 = random expectation.

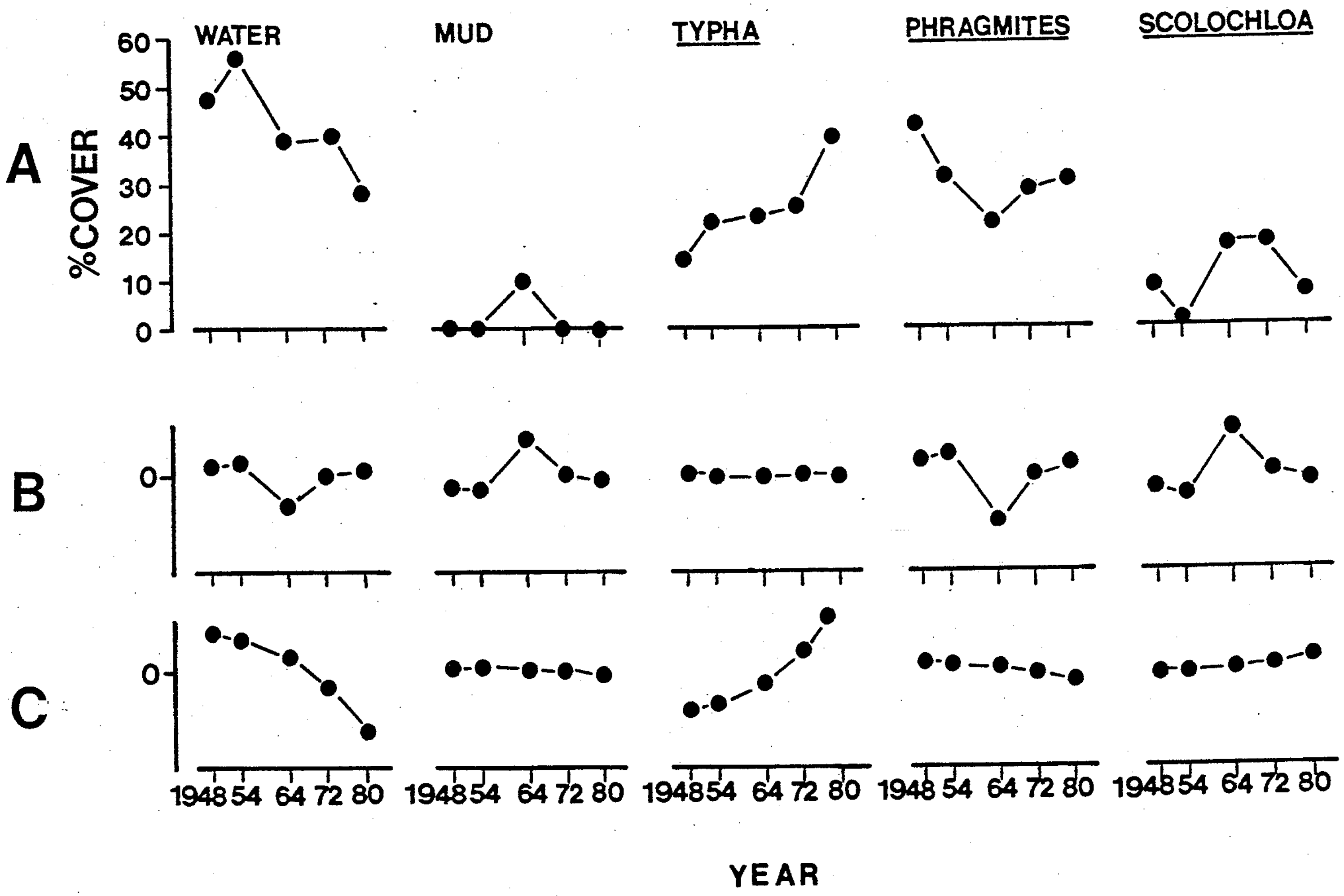
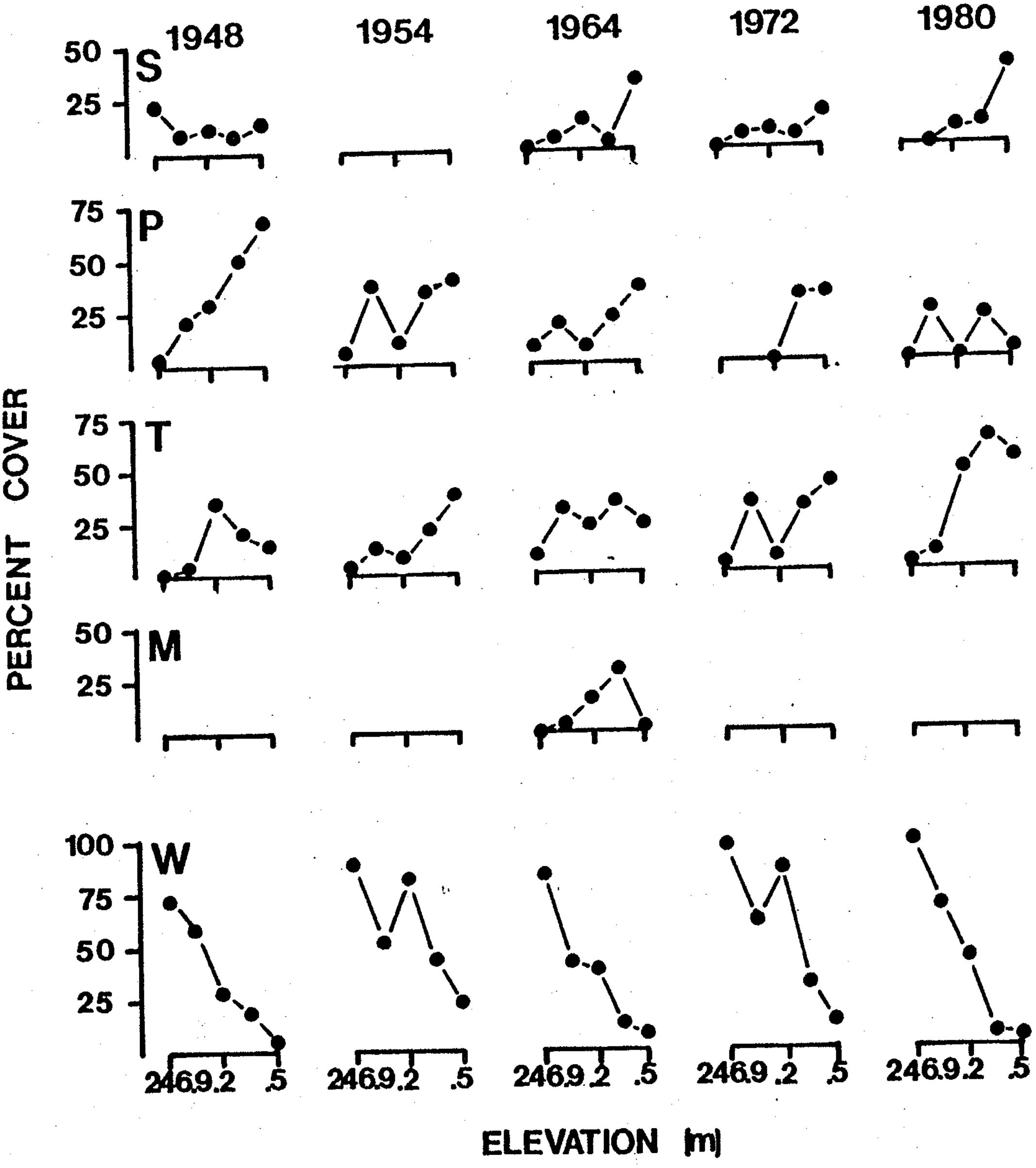

WATER
MUD
TYPHA
PHRAGMITES
SCOLOCHLOA
A
B
C
%COVER
60
50
40
30
20
10
0
0
0
1948 54 64 72 80
1948 54 64 72 80
1948 54 64 72 80
1948 54 64 72 80
1948 54 64 72 80
YEAR

Figure 2.11. Tin Town: Elevation profiles indicating distribution of each cover type along the coenocline in 1948, 1954, 1964, 1972 and 1980. W = water, M = mudflats, T = *Typha*, P = *Phragmites*, and S = *Scolochloa*.


1948
1954
1964
1972
1980
S
P
T
M
W
50
25
75
50
25
100
PERCENT COVER
246.9.2 .5
ELEVATION (m)

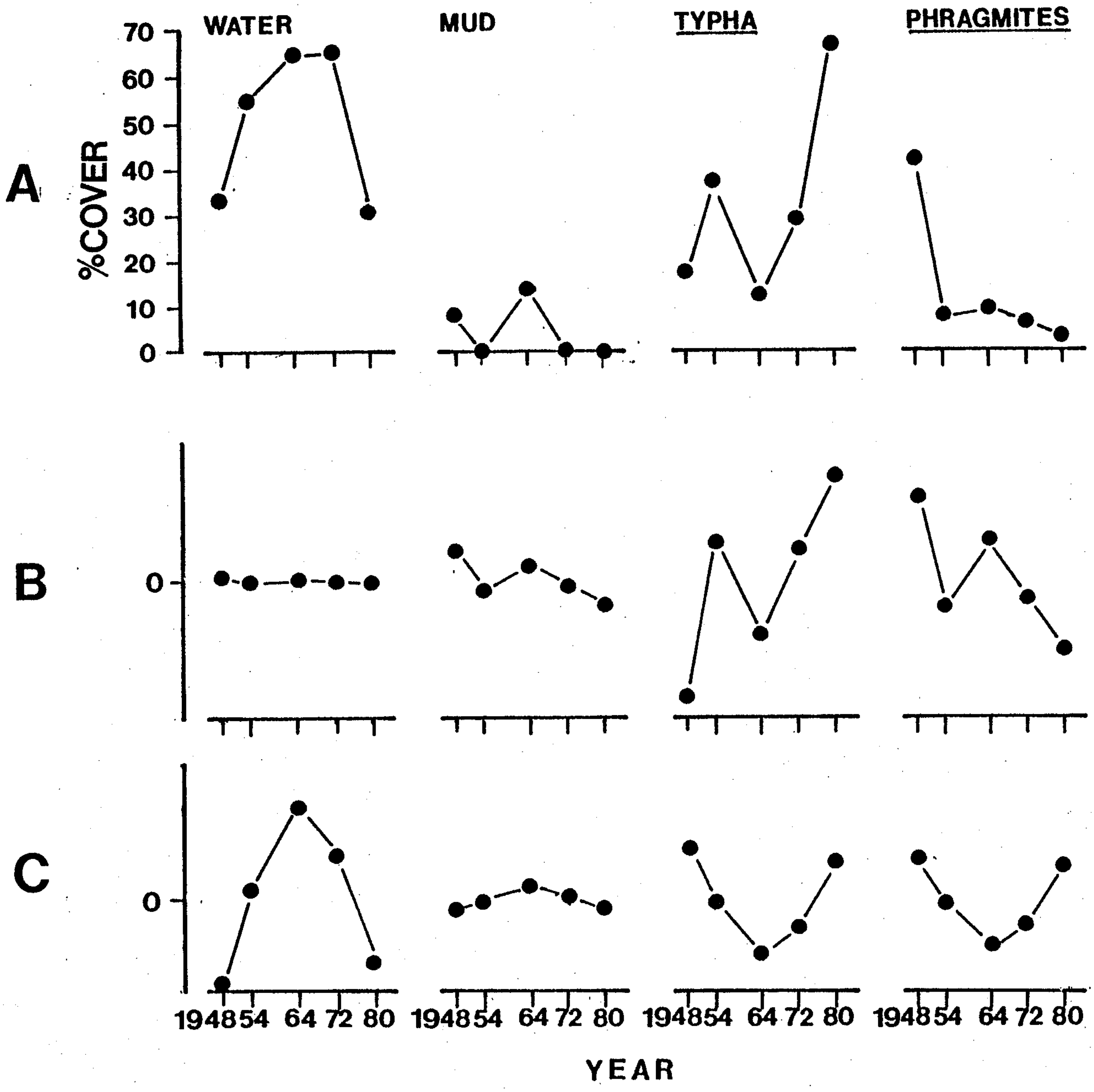
The vegetated shoreline was relatively steep, with contours ranging from 246.9 m - 247.5 m. Prolonged high water levels during the mid-1950's resulted in Phragmites loss at all elevations. Declining water levels during the early 1960's exposed mudflats along the upper portion of the gradient (247.05 m - 247.5 m), which were colonized by Scolochloa. Between 1964 and 1972 inundation increased. Mudflats were either inundated or colonized by Phragmites which increased at all elevations. Scolochloa displayed little change. Between 1964 and 1972, Typha retreated to a range of 247.35 m - 247.5 m, but displayed a slight increase at 247.5 m. Between 1972 and 1980, Typha increased at all elevations and expanded down the elevational gradient at the expense of water.

2.3.1.6 Chimney Marsh

The cover data suggested complex cyclic changes (Fig. 2.12A). Component I demonstrated that Typha had a strong inverse response to Phragmites (Fig. 2.12B). It showed a dramatic increase in Typha between 1948 and 1954 and between 1964 and 1980 at the expense of Phragmites. Water and mudflats showed little deviation from expectation. Low water levels in the mid-1940's were indicated by the presence of some mudflats, eliminated when lake levels slowly rose between 1948 and 1954. High water levels during the mid-1950's killed Typha, while declining water levels in the

Figure 2.12. Chimney Marsh.

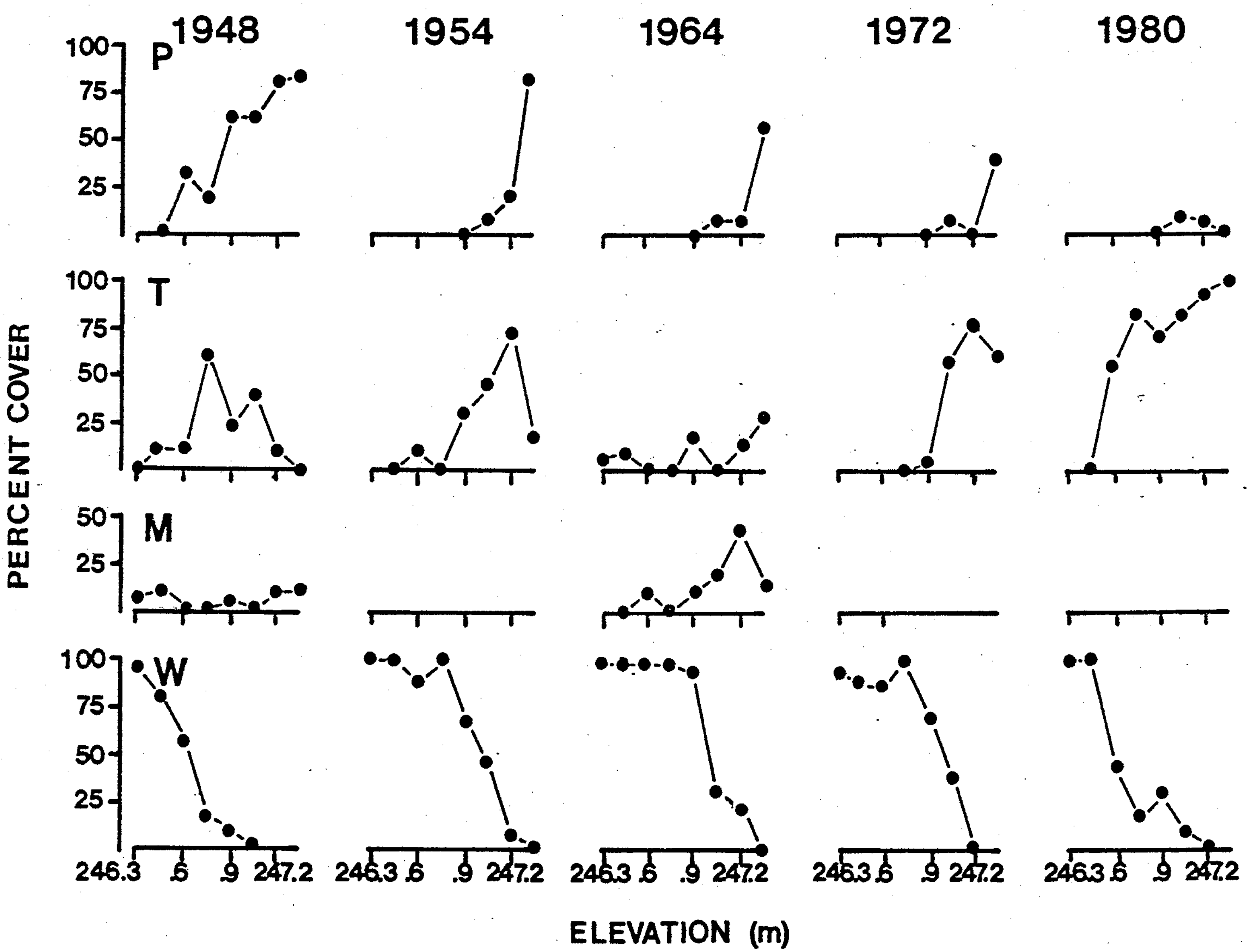
(A) Percent cover of water, mudflats, Typha and Phragmites in 1948, 1954, 1964, 1972 and 1980. (B) Lattice profiles of all cover types showing contribution to Component I: 0 = random expectation. (C) Lattice profiles of all cover types showing contribution to Component II: 0 = random expectation.


WATER
MUD
TYPHA
PHRAGMITES
A
B
C
%COVER
70
60
50
40
30
20
10
0
0
0
1948
54
64
72
80
YEAR

early 1960's exposed mudflats and residual stands of Phragmites. Between 1964 and 1980, under a relatively stable water regime, Typha increased to become the dominant emergent at the expense of Phragmites. Component II demonstrated the response of cover types to fluctuating water levels between 1954 and 1972 (Fig. 2.12C). The prevalent factor in this component was the cyclic trend shown in the profile for water. Typha and Phragmites both demonstrated a strong negative response to water because prolonged high water resulted in their dieback. Mudflats showed little deviation from random expectation.

These two major temporal trends were exemplified by the changing distribution of each cover type along the relatively steep shoreline. Contours ranged from 246.3 m to 247.35 m (Fig. 2.13). Between 1948 and 1954, inundation increased at all elevations, Typha decreased at lower elevations (246.45 m - 246.75 m), and Phragmites retreated (246.9 m - 247.35 m). But Typha increased at higher elevations (246.9 m - 247.35 m) mainly at the expense of Phragmites and, to a lesser degree, mudflats. High water levels in the mid-1950's resulted in the dieback of both Typha and Phragmites along their entire elevational range. Declining water levels in the early 1960's exposed mudflats along most of the elevational range; at higher elevations (247.05 m - 247.35 m) mudflats appeared at the expense of all vegetation, while lower elevations were associated primarily with

Figure 2.13. Chimney Marsh: Elevation profiles indicating distribution of each cover types along the coenocline in 1948, 1954, 1964, 1972 and 1980. W = water, M = mudflats, T = *Typha* and P = *Phragmites*.


1948
1954
1964
1972
1980
P
T
M
W
100
75
50
25
PERCENT COVER
246.3
.6
.9
247.2
ELEVATION (m)

Typha loss. Between 1964 and 1980, *Typha* expanded down the elevational gradient and increased at all previously occupied elevations, initially at the expense of mudflats and *Phragmites* and then at the expense of water.

2.3.1.7 Clandeboye Bay

The cover data plots indicated two types of change: cyclic changes displayed by water, mudflats and *Typha* in response to lake level fluctuations, and montonic change displayed by *Phragmites* (Fig. 2.14A). Component I showed a strong inverse relationship between *Typha* and *Phragmites* (Fig. 2.14B). This trend was similar to Component II for the pooled data. It indicated that the already dominant *Typha* moved into areas previously occupied by *Phragmites*. Component II demonstrated a response to water levels that fluctuated between 1954 and 1972 (Fig. 2.14C). *Typha* showed a strong inverse response to water, which was similar to its response in Component II for Chimney Marsh. Mudflats and *Phragmites* showed little deviation from random expectation.

The two major temporal trends identified using lattice profile analysis were dictated by the spatial dynamics of each cover type (Fig. 2.15). The relatively steep shoreline ranged in elevation from 247.05 m to 247.65 m. Between 1954 and 1964, as a result of high water levels, *Typha* retreated up the elevational gradient, but increased at all elevations within its range of 247.35 m - 247.65 m, while *Phragmites*

Figure 2.14. Clandeboye Bay.

(A) Percent cover of water, mudflats, _Typha_ and _Phragmites_ in 1948, 1954, 1964, 1972 and 1980. (B) Lattice profiles of all cover types showing contribution to Component I: 0 = random expectation. (C) Lattice profiles of all cover types showing contribution to Component II: 0 = random expectation.

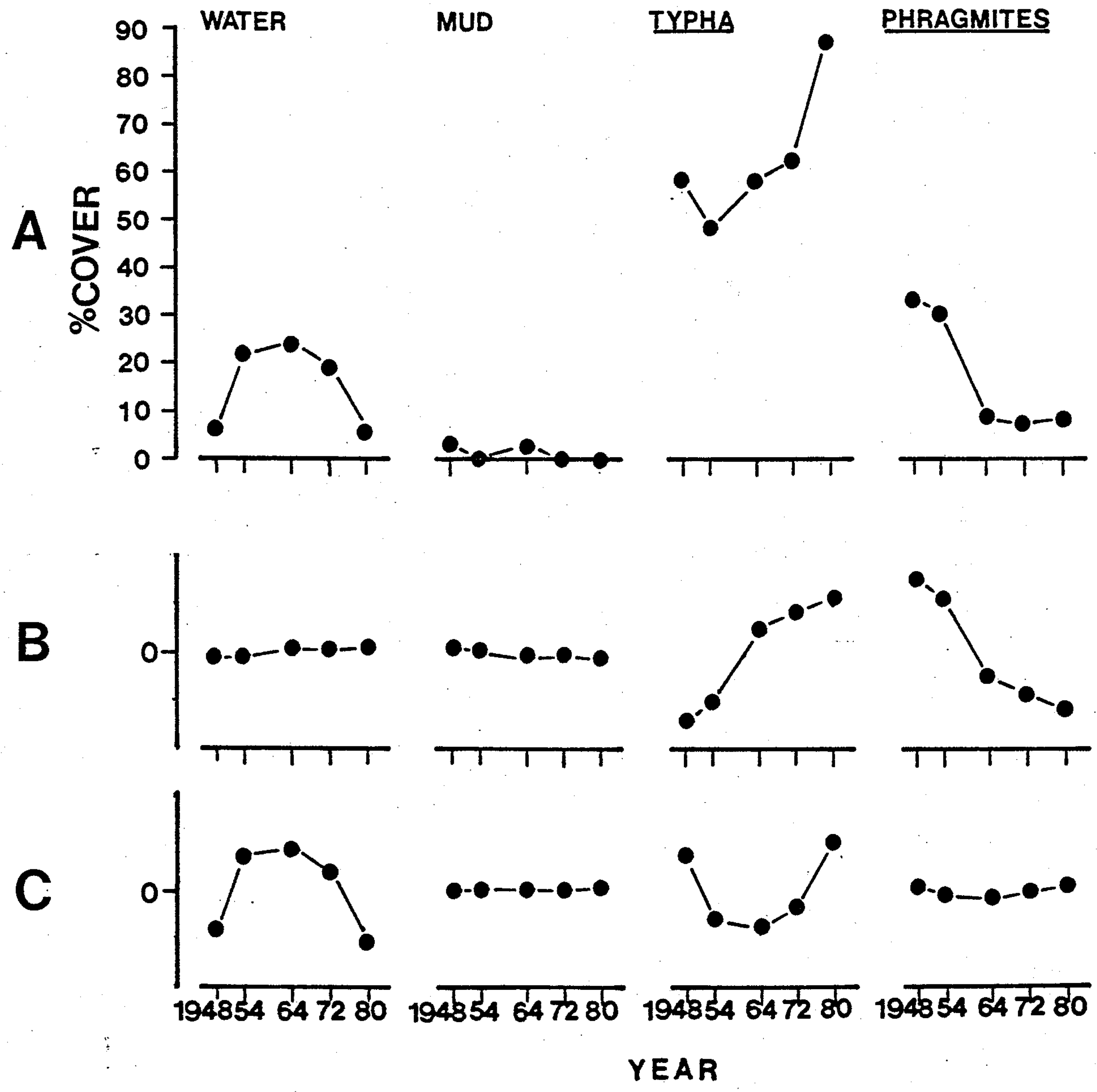
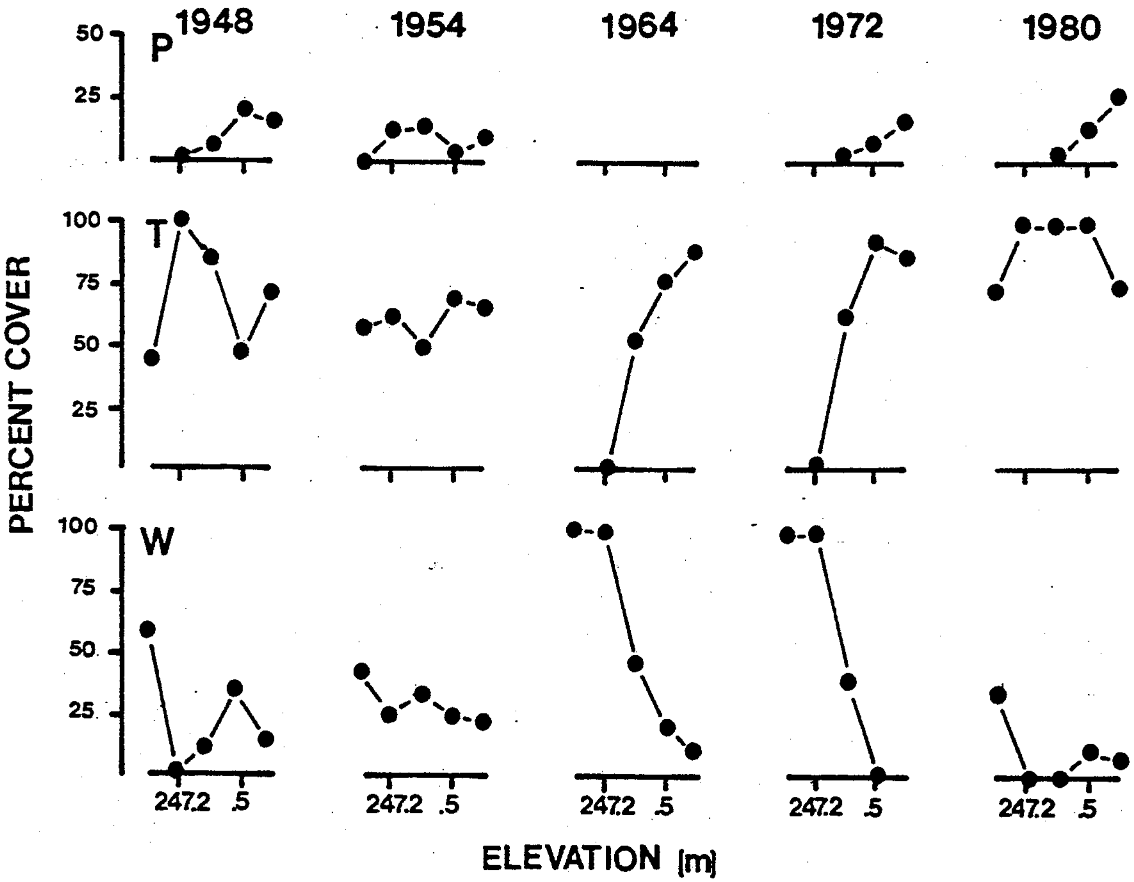

WATER
MUD
TYPHA
PHRAGMITES
90
80
70
60
50
40
30
20
10
0
%COVER
A
B
C
0
0
1948 54 64 72 80
1948 54 64 72 80
1948 54 64 72 80
1948 54 64 72 80
YEAR

Figure 2.15. Clandeboye Bay: Elevation profiles indicating distribution of each cover type along the coenocline in 1948, 1954, 1964, 1972 and 1980. W = water, M = mudflats, T = *Typha* and P = *Phragmites*.


1948
1954
1964
1972
1980
P
T
W
50
25
100
75
50
25
100
75
50
25
PERCENT COVER
247.2
.5
247.2
.5
247.2
.5
247.2
.5
247.2
.5
ELEVATION (m)

disappeared. Between 1964 and 1980, Typha increased, initially within its range determined during the 1954-64 period and later expanding down the elevational gradient to where water previously occurred.

2.4 DISCUSSION

2.4.1 Pre-regulation Period

Lattice profile analysis demonstrated that a direct response of vegetation to fluctuating water levels was the dominant trend during the pre-regulation period, although individual sites displayed some deviations from general trends. In several instances the elevation profiles showed that species did not disappear after major flooding in the mid-1950's or drawdown in the early 1960's. They retreated or advanced along the elevational gradient, and exhibited mosaic or zonal distribution patterns, depending on the microtopography.

The cover of Typha, Phragmites, Scolochloa, mudflats and water changed between successive aerial photograph years. In all sites Phragmites and Typha were the two most important emergents associated with marsh shorelines during the pre-regulation period. Scolochloa ranked third. The 1948 aerial photographs depicted conditions following a prolonged dry period. The 1954 aerial photographs corresponded with a new cycle of rapid lake level increase that began in 1953, peaked in 1955, and remained high until 1960. During this period, vegetation throughout the marsh decreased by approximately 15% (Table 2.1). Between 1954 and 1960, continuous flooding resulted in major die-offs in shoreline species. Subsequently declining water levels in the early 1960's exposed large tracts of mudflats (Table 2.1) that were colonized.

Other studies of the marsh during the pre-regulation period demonstrate partial agreement with these results. Hochbaum (1944) described Delta as a Phragmites-dominated marsh. Löve and Löve (1954), in a study at Cadham Bay and its general vicinity, also indicated that Phragmites was dominant. Their study, which included both shorelines and wet meadows, ranked Scolochloa second and described it as "present in patches throughout the Phragmites zone". The present study is concerned with shorelines, a habitat generally not associated with Scolochloa (Millar 1973). The prevalence of Typha in 1948 and 1954 did not correspond with the description given in Löve and Löve (1954). They indicated that Typha latifolia was uncommon (T. angustifolia and the hybrid T. glauca were not recognized). Where Typha was present, it was found together with Schoenoplectus (Scirpus) acutus (Muhl.) Löve & Löve in potholes in the marsh, and occasionally in deeper water along the bays.

Numerous studies have indicated that flooding during one growing season results in the partial dieback of all emergents (Harris and Marshall 1963; McDonald 1955; Millar

1973). *Typha latifolia* is especially susceptible to 60 cm or more of flooding for one growing season (Harris and Marshall 1963). Continuous flooding for three or more years, as was experienced at Delta, results in major die-offs in all emergent species (Harris and Marshall 1963; Millar 1973; Walker 1959, 1965). Dillon (1958 in: Bossenmaier *et al*. 1968, p. 15) estimated 21% of the emergent marsh vegetation was killed during the 1954-57 period.

The sequence of *Typha*, *Phragmites*, *Scolochloa*, mudflats and water, whether zonal or mosaic, did not change despite changes in the marsh level regime. The gradual elevational gradient of Forster's Bay and Centre Marsh supported a mosaic of the three species. Although complex, the slope of The Gap was also composed of a mosaic of species. In contrast, Tin Town, Chimney Marsh and Clandeboye Bay had relatively steep elevational gradients that supported zones of vegetation.

Walker (1965) reported a mosaic pattern of colonization along gradually-sloped gradients, whereas distinct zonation occurred along a steeper gradient. To date, Walker's studies (1959, 1965) provide the only detailed account of the response of vegetation at Delta under falling water conditions. The recolonization of mudflats in 20 sites throughout the marsh was monitored between 1958 and 1961. At each site, various pioneers including *Typha* and *Scolochloa* became established. There were, however, variations in frequency and cover of colonizing species, the rate of species turnover and distribution patterns.

This variability among sites was attributed to a number of factors. These factors include: initial vegetation and that which persists after flooding; the availability of seed and the conditions for its germination and establishment; the ability to propagate vegetatively and by seed; the season, depth and duration of flooding, and speed of drainage. The latter are products of basin slope and shoreline length and dictate the distribution pattern of species along the elevational gradient.

2.4.2 Post-regulation

During the post-regulation period there was a rapid expansion of *Typha*, presumably the hybrid *T. glauca*, to become the dominant macrophyte at the expense of *Phragmites*. This change is attributed to the reproductive advantage of *Typha* over *Phragmites*. Both species have extensive rhizome systems, and although *Phragmites* can produce runners (legehalme), *Typha* produces vast quantities of viable seed and has a large seed bank. It rapidly colonized mudflats that were exposed prior to 1961 (when lake regulation began) and in the interim period (1961-1967) before effective regulation was achieved. Relatively stable water levels after 1967 facilitated further recolonization and consolidation of existing stands which reversed vegetation loss. By 1980, vegetation attained cover values approximately equal to values in 1948, but now the hybrid _T. glauca_ was the dominant.

Walker (1965) described a recovery period before fringe stands and isolated clones of _Phragmites_ began the process of vegetative expansion by both rhizomes and runners. Although it produces viable seeds (Löve and Löve 1954; Walker 1965), it has few seeds in the seed bank (Pederson 1981). In contrast, both _Typha_ and _Scolochloa_ were early colonizers. _Scolochloa_ spreads by rhizomes and by seeds, and also has a large seed bank (Pederson 1981; Pederson and van der Valk 1984). It can colonize and establish readily. It can survive inundation only in the spring and was thus confined to the upper part of the gradient examined in this shoreline study. It should be noticed however that _Scolochloa_ becomes more important at elevations beyond the scope of the present investigation.

In the post-regulation study the trends described by Shay and Shay (1986) agree with the results of this study. Of the twenty sites monitored by Walker (1965), twelve were resurveyed in 1980. _Phragmites_ initially increased in presence, consolidated its position but later decreased (Shay and Shay 1986). Bossenmaier _et al_. (1968) reported _Phragmites_ was the most abundant emergent between 1964 and 1966. It covered approximately 75% of the marsh area occupied by emergent vegetation; this included both upland and shoreline areas. They also indicated _Typha_ was increasing throughout the marsh. This was corroborated at Walker's sites, where T. latifolia and the hybrid T. glauca persisted and expanded in area within the same stands over the 20-year interval (Shay and Shay 1986).

Published reports suggest that natural or human habitat disturbance is essential to natural hybridization (Lee 1975; Smith 1967). In marshes, large water level fluctuations and the activities of muskrats (Ondatra zibethica) often destroy emergent vegetation and provide habitat for colonization (van der Valk 1981; van der Valk and Davis 1980; Walker 1959, 1965). The exposed mudflats during the early 1960's presumably favoured hybridization by allowing seedling establishment of a mixture of different species at the same time (Harris and Marshall 1963).

The hybrid may have been present in the early 1950's. Löve and Löve (1954) described considerable variations in the morphology of T. latifolia but believed this was not associated with introgression after hybridization. We do not know when the hybrid appeared but the transition to a Typha-dominated marsh did not begin until after the high water of the 1950's. Although the hybrid cannot be distinguished from either of its parents on the aerial photographs, the rapid expansion of Typha during the post-regulation period implies its presence. It was the dominant Typha species during the field study in 1984.

Unlike its parents, *Typha latifolia* and *T. angustifolia*, *T. glauca* can germinate and establish in shallow water between 2-15 cm deep (Bedish 1967). This ability provides the hybrid with a competitive advantage. It can utilize habitats before they become suitable for either of its parents and other species which require wet mudflats for germination (Harris and Marshall 1963; Hotchkiss and Dozier 1949; Neckles *et al*. 1985 ; Pederson 1981; Smith 1967; Smith 1973). Once *Typha* was established, its tall growth (up to 3 m) and dense stands limited expansion of the shade-intolerant *Phragmites* (Boorman and Fuller 1981; Haslam 1971).

Under a stable water regime, expansion of the hybrid down the elevational gradient into open water is the result of two factors. Firstly, Harris and Marshall (1963) indicated it could survive and set seed during at least four years of continuous flooding with 60 cm of water. Secondly the rapid accumulation of organic matter from *Typha* (roots, rhizomes, stems, leaves, etc.) reduces water depth (Yeo 1964). This in turn creates habitat into which *Typha* can expand vegetatively or by seed.

Relatively stable water levels since 1961 have resulted in decreased diversity within the marsh, reflected in the seed bank. There has been a reduced seed input from annuals, and *Typha* has become the dominant seed source within the marsh (Pederson and van der Valk 1984).

Each study site demonstrated some deviations from the general trends, especially Tin Town and Centre Marsh. Between 1954 and 1964 vegetation at all sites decreased except Tin Town where it increased. This increase is attributed to colonization by Scolochloa which became established and persisted. Centre Marsh was unique in that there were large water level fluctuations during the post-regulation period. After completion of the Assiniboine Diversion in 1969, prolonged flooding in the spring and early summer (Jones 1978) resulted in the loss of vegetation. Drawdown in 1974 and subsequent colonization of mudflats indicated the potential productivity of this and other sites within the marsh.

There are shortcomings in any long term vegetation study based on the interpretation of aerial photographs. Central to the application of photometric methods for data extraction from aerial photographs is the concept of signature. Density slicing (using a densitometer) is an image enhancement technique to separate the continuous tonal range (density) of photographs into smaller ranges. Each plant community has a characteristic distribution of various densities rather than a discrete reading. This technique can therefore be used for quantitative analysis of such density distributions (Grainger 1981). These distributions are useful for quantification of polydominant communities. However, use of the densitometer in this study was limited by the following: (1) the equipment was not readily available; (2) the minimum mapping unit for aerial photographs with a scale of 1:16,000 would have been approximately 16 m; and (3) Typha, Phragmites and Scolochloa typically form monodominant stands and generally only exhibit mixtures in narrow transition zones (10 m). The width and composition of these transition zones would be of interest, but probably would not have been detected using density slicing.

The photographs represented major water level fluctuations, but there were no stereopairs of photographs for the intervening years. As with most long-term aerial photograph studies, there were no field data available for the years of the study photographs. Information had to be obtained from other studies at Delta, and also extrapolated from other wetlands.

The lack of information pertaining to historic water depths at known elevations and their effect on the spatial distribution of vegetation is a limiting factor in this study. Inferences drawn from the relationship between lake and marsh water levels do not provide this detailed information. In addition, the elevation on the 1980 contour maps may not represent historic elevations, because marsh basins are affected by both sedimentation and scouring. The elevation profiles were valuable, however, because they demonstrated shifts in the distribution of species, water and mudflats between successive aerial photograph years. These changes along the elevational gradient represent the major changes in the area of cover types demonstrated by Components I and II. They indicate that an elevational change of 15 cm may be biologically important. An increase in water depth of only 15 cm may exceed the threshold of a species' tolerance to flooding and increase the competitive advantage of another species. Such situations would result in the displacement of species up or down the elevational gradient. Despite these problems, several important conclusions can be drawn from this study.

2.4.3 Summary

This study demonstrates the response of emergent shoreline macrophytes to stable and to fluctuating water regimes in the Delta Marsh. The development of a signature key for Typha, Phragmites and Scolochloa enabled the accurate interpretation of aerial photographs. These photographs taken in 1948, 1954, 1964, 1972 and 1980 show substantial changes in the areal extent of these three species throughout the marsh, but shorelines were the focus of this study.

Water levels in Lake Manitoba and the marsh fluctuated synchronously with a range of greater than 2.2 m prior to 1961; thereafter they were regulated with a range of only 0.6 m. Field data from 1984 confirmed this synchrony. The change in the range of fluctuations has had a significant effect on the distribution of marsh vegetation along shorelines. Phragmites dominated emergent shorelines during the pre-regulation period and Typha ranked second. Between 1954 and 1964 the lake and the marsh experienced a period of extreme high and low water levels. Extensive flooding for more than three years (1954-57) eliminated species from the lower portion of the gradient and reduced their extent at upper elevations. Receding water levels during the early 1960's exposed extensive mudflat zones that were rapidly colonized by seeds of mudflat and emergent species from the seed bank. Lattice profile analysis, an objective procedure, revealed the presence of two major trends associated with the distribution of Typha, Phragmites and Scolochloa along the elevational gradient between 1948 and 1980. The most significant trend was the response of the three species, water and mudflats to fluctuating water levels between 1948 and 1972. The process of colonization of mudflats exposed during the early 1960's initiated the second major trend: a change during the post-regulation period from a Phragmites- to a Typha-dominated marsh. This rapid expansion implies the presence of the hybrid T. glauca, which is capable of expanding both vegetatively and from seed at a range of water depths. Under the stable water regime, the hybrid has become the dominant emergent in the marsh by invading shallow water and by encroaching upon sites formerly occupied by Phragmites. The presence of Typha thereby reduced the ability of shade-intolerant Phragmites to expand. Under the current water regime, T. glauca will probably continue to expand up and down the elevational gradient.

Each site demonstrated deviations from the general trends displayed within the marsh as a whole. This variability was the result of a combination of factors which included the relationship between lake and marsh levels, morphometry of marsh basins, and the life history characteristics of each of the species studied. Recognition and understanding of the range of vegetation response to fluctuating and stabilized water levels within the marsh is essential before effective management planning can be implemented at Delta Marsh.

REFERENCES

ANONYMOUS. 1973. Lake Manitoba Regulation. Prov. Manitoba, The Manitoba Water Commission, Winnipeg, Mb, Unpubl. 43p.

---------- 1984. Principal station data: Portage la Prairie. Envir. Canada, Atmospheric Envir. Ser., Ottawa, On.

---------- 1985. Historic water levels summary: Manitoba Dept. Envir., Inland Waters Directorate, Water Resources Branch, Water Survey, Canada. 236p.

AVERY, T.E. 1968. Interpretation of aerial photographs. Burgess Press, Minneopolis. 324p.

BEDISH, J.W. 1967. Cattail moisture requirements and their significance to marsh management. Am. Mid. Nat. 78:288-300.

BODNARUK, R.D. 1976. Delta Marsh project, Centre Unit engineering study. Dept. Mines, Res., Envir. Manage., Water Resources Div., Winnipeg, Mb.

BOSSENMAIER, E.F., J. COBER, W.G. LEITCH, G.H. MacKAY, W.R. MILLER, D.D. MOORE, J.M. WALKER, and P. WARD. 1968. The Delta Marsh: its values, problems and potentialities. Dept. Mines and Nat. Resour., Winnipeg, Mb, 75p.

BOORMAN, L.A., and R.M. FULLER. 1981. The changing status of reedswamp in The NorfolK Broads. J. Applied Ecol. 18:241-269.

BROWN, W.W. 1978. Wetland mapping in New Jersey and New York. Photogramm. Eng. and Remote Sensing, 44:303-314.

CARTER, V., D.L. MALONE, J.H. BURBANK. 1979. Wetland classification and mappping in Western Tennessee. Photogramm. Eng. and Remote Sensing, 45:273-284

CROWE, J. 1974. Lake Manitoba - the third great lake. Dept. Mines, Resour. and Envir. Manage., Res. Branch, Info. Ser. No. 5, Winnipeg, Mb, 10p.

DUCKS UNLIMITED. 1980. Contour and vegetation maps.

__________ 1981. Delta Marsh development proposal. Unpubl. 59p.

EVANS, J. 1972. Delta Marsh vegetation mapping project. Univ. Field Station, Univ. of Manitoba., Unpubl. 14p., maps.

FENTON, M.M. 1970. The Pleistocene stratigraphy and surficial geology of the Assiniboine River to Lake Manitoba area. M.Sc. thesis, University of Manitoba, Winnipeg, MB.

FEOLI, E., and L. ORLOCI. 1979. Analysis of concentration and detection of underlying factors in structured tables. Vegetatio, 40:49-54.

---------- 1985. Species dispersion profiles of anthropogenic grasslands in the Italian Eastern Pre-Alps. Vegetatio, 60:113-118.

GAMMON, P.T., and V. CARTER. 1979. Vegetation mapping with seasonal color infrared photographs. Photogramm. Eng. and Remote Sensing, 45:87-97.

GLEASON, H.A. 1926. The individualist concept of the plant association. Bull. Torrey Bot. Club, 53:7-26.

GOSSELINK, J.G., and R.E. TURNER. 1978. The role of hydrology in freshwater wetland ecosystems. In Freshwater wetlands: ecological processes and management potential. Edited by R.E. GOOD, D.F. WHIGHAM, R.L. SIMPSON. Academic Press, New York. pp.63-78.

GRAINGER, J.E. 1981. A quantitative analysis of photometric data from aerial photographs for vegetation survey. Vegetatio, 48:71-82.

GREENACRE, M.J., and L. DEGOS. 1977. Correspondence analysis of HLA gene frequency data from 124 population samples. Am. J. Hum. Genet. 29:60-75.

GREENACRE, M.J., and E.S. VRBA. 1984. Graphical display and interpretation of antelope census data on African wildlife areas, using correspondence analysis. Ecology, 65:984-997.

HARRIS, S.W., and W.H. MARSHALL. 1963. Ecology of water level manipulations on a northern marsh. Ecology, 44:331-343.

HASLAM, S.M. 1971. Community regulations in Phragmites communis Trin. II: mixed stands. J. Ecology, 59:75-88.

HATHOUT, S., and J. SIMPSON. 1982. A vegetation survey of Netley Marsh using color and color infrared imagery. J. Envir. Manage. 15:25-34.

HILL, M.O. 1974. Correspondence analysis: a neglected multivariate method. Applied Statistics, 23:340-354.

HOCHBAUM, H.A. 1944. The Canvasback on a prairie marsh. The American Wildlife Institute., 182p.

HOTCHKISS, N., and H.L. DOZIER. 1949. Taxonomy and distribution of North American Cat-tails. Am. Mid. Nat. 41:237-257.

HOWLAND, W.G. 1980. Multispectral aerial photography for wetland vegetation mapping. Photogramm. Eng. and Remote Sensing, 46:87-99.

JONES, R.E. 1978. Delta Marsh plan. Dept. N. Affairs, Renewable Resour. and Trans. Ser., Winnipeg, Mb, 66p.

KADLEC, J.A. 1962. Effects of drawdown on a waterfowl impoundment. Ecology, 43:267-281.

KIEL, W.H. Jr., A.S. HAWKINS, N.G. PERRET. 1972. Waterfowl habitat trends in the Aspen Parkland of Manitoba. CWS Rep. Ser. No. 18, Ottawa, On, 61p.

LANCASTER, H.O. 1949. The derivation and partition of chi square in certain discrete distributions. Biometrika, 36:117-129.

LAST, W.M. 1980. Sedimentology and postglacial history of Lake Manitoba. Ph.D. thesis, University of Manitoba, Winnipeg, Mb, 686p.

LEE, D.W. 1975. Population variation and introgression in North American Typha. Taxon 24:633-641.

LÖVE, A., and D. LÖVE. 1954. Vegetation of a prairie marsh. Bull. Torrey Bot. Club 81:16-34.

LOVVORN, J.R. and C.M. KIRKPATRICK. 1982. Analysis of freshwater wetland vegetation with large-scale color infrared aerial photography. J. Wildl. Manage. 46:61-70.

McDONALD, M.E. 1955. Cause and effects of a die-off of emergent vegetation. J. Wildl. Manage. 19:24-35.

MILLAR, J.B. 1969. Some characteristics of wetland basins in central and southeastern Saskatchewan. Saskatoon Wetlands Sem. CWS Rep Ser. No. 6, Ottawa, On, pp. 73-101.

__________ 1973. Vegetation changes in shallow marsh wetlands under improving moisture regime. Can. J. Bot. 51:1443-1457.

__________ 1976. Wetland classification in western Canada: A guide to marshes and shallow open water wetlands in the grasslands and parklands of the Prairie Provinces. CWS Rep. Ser. No. 37, 37p.

MUELLER-DOMBOIS, D., and H. ELLENBERG. 1974. Aims and methods of vegetation ecology. John Wiley & Sons, New York., 547p.

NECKLES, H.A., J.W. NELSON, R.L. PEDERSON. 1985. Management of Whitetop (Scolochloa festucacea) marshes for livestock and wildlife. Delta Waterfowl and Wetlands Research Station., Tech. Bull. No. 1, 11p.

NETER, J. and W. WASSERMAN. 1974. Applied linear statistical models. Richard D. Irwin, Inc., Illinois, 842p.

ORLOCI, L. 1981. Probing time series vegetation data for evidence of succession. Vegetatio 46:31-35.

ORLOCI, L., and N.C. KENKEL. 1985. Introduction to data analysis: with examples from population and community ecology. International Co-op. Pub. House, Maryland., 339p.

PEDERSON, R.L. 1981. Seed bank characteristics of the Delta Marsh, Manitoba. Selected Proceedings of the Midwestern Conf. on Wetland Values and Management. pp. 61-69.

PEDERSON, R.L., and A.G. van der VALK. 1984. Vegetation change and seed banks in marshes: ecological and management techniques. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 49:272-280.

SCOGGAN H.J. 1978. The flora of Canada: Part 2. National Museum of Natural Sciences, National Museums of Canada, Ottawa, On, pp. 93-545.

SHAY, J.M., and C.T. SHAY. 1986. Prairie marshes in western Canada, with specific reference to the ecology of five emergent macrophytes. Can. J. Bot. 64:443-454.

SMITH, A.L. 1973. Life cycle of the marsh grass, Scolochloa festucacea. Can. J. Bot. 51:1661-1668.

SMITH, S.G. 1967. Experimental and natural hybrids in North American Typha (Typhaceae). Am. Mid. Nat. 78:257-287.

SPROULE, T.A. 1972. A palaeoecological investigation into the postglacial history of Delta Marsh. M.Sc. thesis, University of Manitoba, Winnipeg, Mb, 49p.

STEELE, R.G.D., and J.H. TORRIE. 1980. Principles and procedures of statistics. McGraw-Hill Book Co., New York, 633p.

TELLER, J.T., and W.M. LAST. 1981. Late quaternary history of Lake Manitoba, Canada. Quaternary Research 16:97-116.

van der VALK, A.G. 1981. Succession in wetlands: a Gleasonian approach. Ecology 62:688-696.

van der VALK, A.G., and C.B. DAVIS. 1980. The impact of a natural drawdown on the growth of four emergent species in a prairie glacial marsh. Aqua. Bot. 9:301-322.

WALKER, B.H., and R.T. COUPLAND. 1968. An analysis of vegetation-environment relationships in Saskatchewan sloughs. Can. J. Bot. 46:509-522.

WALKER, J.M. 1959. Vegetation studies in the Delta Marsh, Delta Manitoba. M.Sc. thesis, University of Manitoba, Winnipeg, Mb, 203p.

---------- 1965. Vegetation changes with falling water levels in the Delta Marsh, Manitoba. Ph.D. thesis, University of Manitoba, Winnipeg, Mb, 259p.

WELLER, M.W. 1978. Management of freshwater marshes for wildlife. In Freshwater wetlands: ecological processes and management potential. Edited by R.E. GOOD, D.F. WHIGHAM, R.L. SIMPSON. Academic Press, New York, pp. 267-284.

YEO, R.R. 1964. Life history of the common cattail. Weeds 12:284-288.

ZOLTAI, S.C., and F.C. POLLETT. 1983. Wetlands in Canada: their classification, distribution and use. In Ecosystems of the world. 4B. Mires: Swamp, Bog, Fen and Moor. Edited by A.J.P GORE. Elsevier, Amsterdam, pp. 245-268.

APPENDIX I

COMPUTER PRINTOUTS OF CONCENTRATION ANALYSIS AND LATTICE PROFILE ANALYSIS.

```
TEXT FILE NAME:ALL/SITES/POOLED

25.96  41.43  34.74  34.28  24.52
1.17  0  43.26  0  0
28.32  27.54  27.75  34.06  54.49
47.82  34.19  22.08  29.21  22.58
3.33  2.89  9.17  6.22  6.92
```

PERCENT COVER DATA

	1948	'54	'64	'72	'80
water					
mudflats					
Typha					
Phragmites					
Scolochloa					

```
PROGRAM CONCENTRATION UNDERWAY
==============================
INPUT (OCCUPANCY COUNTS) FILE:ALL/SITES/POOLED
NUMBER OF ROWS:5
NUMBER OF COLUMNS:5
WEIGHTING OPTION: NO WEIGHTING (CONCENTRATION ANALYSIS PROPER).

ROW TOTALS
-------------------------------------------------------
160.93  44.43  172.16  155.88  28.53

COLUMN TOTALS
-------------------------------------------------------
106.6  106.05  137  103.77  108.51

GRAND TOTAL = 561.93

RELATIVE FREQUENCIES BY COLUMN
-------------------------------------------------------
COLUMN 1
.243527204  .0109756098  .265666041  .44859287  .0312382739
COLUMN 2
.390664781  0  .259688826  .322395097  .0272512966
COLUMN 3
.253576642  .315766423  .202554745  .161167883  .0669343065
COLUMN 4
.330345957  0  .328225884  .281487906  .0599402525
COLUMN 5
.225969957  0  .502165699  .20809142  .0637729241

RELATIVE FREQUENCIES BY ROW
-------------------------------------------------------
ROW 1
.161312372  .257441123  .215870254  .213011869  .152364382
ROW 2
.0263335584  0  .973666442  0  0
ROW 3
.164498141  .159967472  .161187268  .197839219  .3165079
ROW 4
.306774442  .219335386  .141647421  .187387734  .144855017
ROW 5
.116719243  .10129688  .321416053  .218016123  .2425517

SCALAR PRODUCT MATRIX
-------------------------------------------------------
.0130061835  -.0173793033  -6.29328206E-03  4.48856046E-03  -4.23440473E-03
-.0173793033  .228673409  -.0518962369  -.0580136005  .0189969277
-6.29328206E-03  -.0518962369  .0353952644  -4.73497717E-03  3.82877499E-03
4.48856046E-03  -.0580136005  -4.73497717E-03  .0366478628  -.0122955169
-4.23440473E-03  .0189969277  3.82877499E-03  -.0122955169  5.6850639E-03


CANONICAL CORRELATIONS AND LEVELS OF INFLUENCE
-------------------------------------------------------
CAN VAR 1 R(X,Y) = .508338835  LEVEL = 145.207416 OR 80.9023395%  (CUMULATIVE =.809023395)
CAN VAR 2 R(X,Y) = .213626096  LEVEL = 25.6442987 OR 14.2877259%  (CUMULATIVE =.951900654)
CAN VAR 3 R(X,Y) = .119750076  LEVEL = 8.05812159 OR 4.48958399%  (CUMULATIVE =.996796494)
```

```
TEST FOR COMPOSITIONAL HETEROGENEITY AMOUNG THE 25 BLOCKS
--------------------------------------------------------
CHI SQUARE = 178.909836
DEGREES OF FREEDOM = 16
RANK = 3

ROW CANONICAL SCORES
--------------------------------------------------------
SET 1
-.125376735  3.34308325  -.37980097  -.469456911  .357839734
SET 2
-.438068257  -.135867617  1.29094573  -1.14683606  1.15858784
SET 3
-1.50735835  .460514899  .361141589  1.02696348  -4.86156845E-03

COLUMN CANONICAL SCORES
--------------------------------------------------------
SET 1
-.578663671  -.568930273  1.76103153  -.544470787  -.578204622       CYCLIC
SET 2
-1.1397602  -.814764504  1.01582617E-03  .119991391  1.79995889      MONOTONIC
SET 3
1.62380982  -1.37062024  .0127209974  -.756803897  .452003636        CYCLIC

ROW CANONICAL SCORES STORED IN FILE ALL/SITE/ROW
COLUMN CANONICAL SCORES STORED IN FILE ALL/SITES/COL
EIGENVALUES STORED IN FILE ALL/SITES/EIG
LATTICE INFORMATION STORED IN FILE ALL/SITES/LAT
NOTE: RUN PROGRAM LATTICE TO COMPLETE CONCENTRATION ANALYSIS

PROGRAM LATTICE UNDERWAY
========================
INPUT FILES ARE ALL/SITES/LAT AND ALL/SITES/EIG
TABLE HAS 5 ROWS AND 5 COLUMNS
NUMBER OF CANONICAL VARIATES: 3

DEPARTURES FROM RANDOM EXPECTATIONS (F(HJ)-F(H.)F(.J)/F(..)):
--------------------------------------------------------------


=== LATTICE 1
1.125  1.101  -4.404  1.031  1.145
-8.289  -8.108  32.417  -7.592  -8.431
3.648  3.568  -14.271  3.341  3.711
4.083  3.994  -15.972  3.74  4.153
-.57  -.558  2.228  -.522  -.58

=== LATTICE 2
3.256  2.315  -4E-03  -.334  -5.235
.278  .198  -1E-03  -.029  -.449
-10.266  -7.301  .011  1.052  16.502
8.257  5.872  -.01  -.847  -13.274
-1.527  -1.086  1E-03  .156  2.454

=== LATTICE 3
-8.949  7.514  -.091  4.059  -2.536
.754  -.634  7E-03  -.343  .213
2.293  -1.926  .023  -1.041  .649
5.905  -4.959  .059  -2.68  1.673
-6E-03  4E-03  -1E-03  2E-03  -2E-03

=== TABLE (SUM OF LATTICES)
-4.568  10.93  -4.499  4.756  -6.626
-7.257  -8.544  32.423  -7.964  -8.667
-4.325  -5.659  -14.237  3.352  20.862
18.245  4.907  -15.923  .213  -7.448
-2.103  -1.64  2.228  -.364  1.872
```

	1948	'54	'64	'72	'80
Water					
Mudflats					
Typha					
Phragmites					
Scolochloa					

```
TEXT FILE NAME:FORSTERS/BAY

36.07  32.48  20.52  20.72  0
0  0  11.45  0  0
34.68  18.03  30.75  47.37  68.47
43.87  48.47  26.53  28.9  19.55
0  0  3.82  .17  19.55

PROGRAM CONCENTRATION UNDERWAY
==============================
INPUT (OCCUPANCY COUNTS) FILE:FORSTERS/BAY
NUMBER OF ROWS:5
NUMBER OF COLUMNS:5
WEIGHTING OPTION: NO WEIGHTING (CONCENTRATION ANALYSIS PROPER).

ROW TOTALS
-------------------------------------------------------
109.79  11.45  199.3  167.32  23.54

COLUMN TOTALS
-------------------------------------------------------
114.62  98.98  93.07  97.16  107.57

GRAND TOTAL = 511.4

RELATIVE FREQUENCIES BY COLUMN
-------------------------------------------------------
COLUMN 1
.314692026  0  .302564997  .382742977  0
COLUMN 2
.3281471  0  .182158012  .489694888  0
COLUMN 3
.220479209  .12302568  .330396476  .28505426  .0410443752
COLUMN 4
.213256484  0  .487546315  .297447509  1.74969123E-03
COLUMN 5
0  0  .636515757  .181742121  .181742121

RELATIVE FREQUENCIES BY ROW
-------------------------------------------------------
ROW 1
.328536297  .295837508  .186902268  .188723927  0
ROW 2
0  0  1  0  0
ROW 3
.174009031  .0904666332  .154290015  .237681887  .343552433
ROW 4
.262192207  .289684437  .158558451  .172722926  .116841979
ROW 5
0  0  .162276975  7.22175021E-03  .830501274

SCALAR PRODUCT MATRIX
-------------------------------------------------------
.0672354606  1.87112235E-03  -.0613499105  .0428087165  -.082128364
1.87112235E-03  .100636161  -.0142179125  -.0110199428  -3.47746724E-03
-.0613499105  -.0142179125  .0649480975  -.042740606  .067377503
.0428087165  -.0110199428  -.042740606  .0328377995  -.0479498442
-.082128364  -3.47746724E-03  .067377503  -.0479498442  .111579752

CANONICAL CORRELATIONS AND LEVELS OF INFLUENCE
-------------------------------------------------------
CAN VAR 1 R(X,Y) = .502976674  LEVEL = 129.376802 OR 67.0627093%  (CUMULATIVE =.670627093)
CAN VAR 2 R(X,Y) = .321533004  LEVEL = 52.8703081 OR 27.4054238%  (CUMULATIVE =.944681331)
CAN VAR 3 R(X,Y) = .141136248  LEVEL = 10.1868019 OR 5.28034796%  (CUMULATIVE =.99748481)
```

```
TEST FOR COMPOSITIONAL HETEROGENEITY AMOUNG THE 25 BLOCKS
-------------------------------------------------------
CHI SQUARE = 192.433912
DEGREES OF FREEDOM = 16
RANK = 3

ROW CANONICAL SCORES
-------------------------------------------------------
SET 1
1.10749168  .275422476  -.757363534  .573318116  -2.96219766
SET 2
-.0724091413  6.57903114  -.150899679  -.245498236  .160193896
SET 3
.0466318597  -.161570598  -.981336099  .703857989  3.16656912

COLUMN CANONICAL SCORES
-------------------------------------------------------
SET 1
.67359105  1.00643096  .138531082  .0641761271  -1.82162296
SET 2
-.50509983  -.533281698  2.11537564  -.503073862  -.346942346
SET 3
-.091022525  1.2840042  -.0228034721  -1.79685185  .558210551

ROW CANONICAL SCORES STORED IN FILE FORSTERS/BAY/ROW
COLUMN CANONICAL SCORES STORED IN FILE FORSTERS/BAY/COL
EIGENVALUES STORED IN FILE FORSTERS/BAY/EIG
LATTICE INFORMATION STORED IN FILE FORSTERS/BAY/LAT
NOTE: RUN PROGRAM LATTICE TO COMPLETE CONCENTRATION ANALYSIS

PROGRAM LATTICE UNDERWAY
========================
INPUT FILES ARE FORSTERS/BAY/LAT AND FORSTERS/BAY/EIG
TABLE HAS 5 ROWS AND 5 COLUMNS
NUMBER OF CANONICAL VARIATES: 3

DEPARTURES FROM RANDOM EXPECTATIONS (F(HJ)-F(H.)F(.J)/F(..)):
-------------------------------------------------------------


=== LATTICE 1
9.233  11.913  1.541  .745  -23.434
.239  .308  .039  .019  -.608
-11.462  -14.789  -1.915  -.926  29.09
7.284  9.398  1.216  .588  -18.488
-5.295  -6.832  -.885  -.428  13.438

=== LATTICE 2
.289  .263  -.985  .244  .186
-2.743  -2.5  9.324  -2.316  -1.768
1.094  .998  -3.723  .924  .705
1.495  1.363  -5.085  1.262  .963
-.138  -.126  .466  -.116  -.089

=== LATTICE 3
-.015  .179  -3E-03  -.247  .084
5E-03  -.065  1E-03  .089  -.031
.563  -6.86  .114  9.423  -3.242
-.34  4.13  -.069  -5.675  1.951
-.215  2.614  -.044  -3.592  1.235

=== TABLE (SUM OF LATTICES)
9.507  12.355  .553  .742  -23.164
-2.499  -2.257  9.364  -2.208  -2.407
-9.805  -20.651  -5.524  9.421  26.553
8.439  14.891  -3.938  -3.825  -15.574
-5.648  -4.344  -.463  -4.136  14.584
```

```
TEXT FILE NAME:CENTRE/MARSH

16.49  37.76  31.19  35.04  23.14
0  0  15.35  0  0
28.14  19.35  12.94  20.01  38.8
62.75  44.69  34.67  48.81  32.79
4.32  0  15.82  6.5  15.33

PROGRAM CONCENTRATION UNDERWAY
==============================
INPUT (OCCUPANCY COUNTS) FILE:CENTRE/MARSH
NUMBER OF ROWS:5
NUMBER OF COLUMNS:5
WEIGHTING OPTION: NO WEIGHTING (CONCENTRATION ANALYSIS PROPER).

ROW TOTALS
-------------------------------------------------------
143.62  15.35  119.24  223.71  41.97

COLUMN TOTALS
-------------------------------------------------------
111.7  101.8  109.97  110.36  110.06

GRAND TOTAL = 543.89

RELATIVE FREQUENCIES BY COLUMN
-------------------------------------------------------
COLUMN 1
.147627574  0  .251924799  .561772605  .0386750224
COLUMN 2
.370923379  0  .190078585  .438998035  0
COLUMN 3
.283622806  .139583523  .117668455  .3152678  .143857416
COLUMN 4
.317506343  0  .181315694  .442279811  .0588981515
COLUMN 5
.210248955  0  .352534981  .297928403  .139287661

RELATIVE FREQUENCIES BY ROW
-------------------------------------------------------
ROW 1
.114816878  .262916028  .217170311  .243977162  .161119621
ROW 2
0  0  1  0  0
ROW 3
.235994633  .162277759  .108520631  .167812814  .325394163
ROW 4
.280497072  .199767556  .154977426  .218184256  .146573689
ROW 5
.102930665  0  .376935907  .154872528  .365260901

SCALAR PRODUCT MATRIX
-------------------------------------------------------
.0233450726  6.39530536E-03  -.0150840847  -5.62401194E-03  -8.64336953E-03
6.39530536E-03  .111360904  -.0364414839  -.025159108  .0403322486
-.0150840847  -.0364414839  .0289722969  -1.54951927E-03  4.68500646E-03
-5.62401194E-03  -.025159108  -1.54951927E-03  .0229846968  -.0248347827
-8.64336953E-03  .0403322486  4.68500646E-03  -.0248347827  .0410375746

CANONICAL CORRELATIONS AND LEVELS OF INFLUENCE
-------------------------------------------------------
CAN VAR 1 R(X,Y) = .383604462  LEVEL = 80.0347098 OR 64.6253975%  (CUMULATIVE =.646253975)
CAN VAR 2 R(X,Y) = .233805275  LEVEL = 29.7316959 OR 24.0073672%  (CUMULATIVE =.886327647)
CAN VAR 3 R(X,Y) = .153686976  LEVEL = 12.8465113 OR 10.3731356%  (CUMULATIVE =.990059003)
```

```
TEST FOR COMPOSITIONAL HETEROGENEITY AMOUNG THE 25 BLOCKS
--------------------------------------------------------
CHI SQUARE = 122.612917
DEGREES OF FREEDOM = 16
RANK = 3

ROW CANONICAL SCORES
--------------------------------------------------------
SET 1
.118418667  5.10506002  -.543356701  -.384930805  1.32315375
SET 2
.819624368  .8672334  -1.24474488  .485622471  -2.17397444
SET 3
-1.44941835  1.566592  -.0760927749  .938626589  -.400013716

COLUMN CANONICAL SCORES
--------------------------------------------------------
SET 1
-.741580912  -.59524878  1.95832379  -.399464157  -.252962833
SET 2
-.0164754906  1.20016884  .202763744  .518731206  -1.81611829
SET 3
1.8132987  -.911147672  .240764784  -.536290147  -.700368476

ROW CANONICAL SCORES STORED IN FILE CENTRE/MARSH/ROW
COLUMN CANONICAL SCORES STORED IN FILE CENTRE/MARSH/COL
EIGENVALUES STORED IN FILE CENTRE/MARSH/EIG
LATTICE INFORMATION STORED IN FILE CENTRE/MARSH/LAT
NOTE: RUN PROGRAM LATTICE TO COMPLETE CONCENTRATION ANALYSIS

PROGRAM LATTICE UNDERWAY
========================
INPUT FILES ARE CENTRE/MARSH/LAT AND CENTRE/MARSH/EIG
TABLE HAS 5 ROWS AND 5 COLUMNS
NUMBER OF CANONICAL VARIATES: 3

DEPARTURES FROM RANDOM EXPECTATIONS (F(HJ)-F(H.)F(.J)/F(..)):
------------------------------------------------------------


=== LATTICE 1
-.994  -.727  2.583  -.529  -.334
-4.579  -3.35  11.902  -2.437  -1.539
3.785  2.769  -9.841  2.014  1.272
5.03  3.68  -13.08  2.677  1.69
-3.245  -2.374  8.434  -1.727  -1.091

=== LATTICE 2
-.094  6.182  1.128  2.896  -10.115
-.011  .699  .127  .327  -1.144
.117  -7.796  -1.423  -3.653  12.753
-.086  5.705  1.041  2.673  -9.335
.072  -4.793  -.875  -2.246  7.839

=== LATTICE 3
-11.914  5.455  -1.558  3.481  4.534
1.376  -.631  .179  -.403  -.524
-.52  .237  -.068  .151  .197
12.017  -5.504  1.57  -3.512  -4.574
-.961  .44  -.126  .28  .365

=== TABLE (SUM OF LATTICES)
-13.002  10.91  2.153  5.848  -5.915
-3.214  -3.282  12.208  -2.513  -3.207
3.382  -4.79  -11.332  -1.488  14.222
16.961  3.881  -10.469  1.838  -12.219
-4.134  -6.727  7.433  -3.693  7.113
```

```
TEXT FILE NAME:THE/GAP

13.55  29.03  18.15  23.9  10.9
0  0  14.38  0  0
35.23  46.2  58.15  48.28  65.98
51.18  25.03  10.15  27.8  16.05
0  0  0  0  9.93

PROGRAM CONCENTRATION UNDERWAY
==============================
INPUT (OCCUPANCY COUNTS) FILE:THE/GAP
NUMBER OF ROWS:5
NUMBER OF COLUMNS:5
WEIGHTING OPTION: NO WEIGHTING (CONCENTRATION ANALYSIS PROPER).

ROW TOTALS
-------------------------------------------------------
95.53  14.38  253.84  130.21  9.93

COLUMN TOTALS
-------------------------------------------------------
99.96  100.26  100.83  99.98  102.86

GRAND TOTAL = 503.89

RELATIVE FREQUENCIES BY COLUMN
-------------------------------------------------------
COLUMN 1
.135554222  0  .352440976  .512004802  0
COLUMN 2
.289547177  0  .460801915  .249650908  0
COLUMN 3
.180005951  .142616285  .57671328  .100664485  0
COLUMN 4
.239047809  0  .482896579  .278055611  0
COLUMN 5
.105969279  0  .641454404  .156037332  .096538985

RELATIVE FREQUENCIES BY ROW
-------------------------------------------------------
ROW 1
.14184026  .303883597  .189992672  .250183189  .114100283
ROW 2
0  0  1  0  0
ROW 3
.138788213  .182004412  .229081311  .19019855  .259927513
ROW 4
.393057369  .192227939  .0779510022  .213501267  .123262422
ROW 5
0  0  0  0  1

SCALAR PRODUCT MATRIX
-------------------------------------------------------
.0237273346  -3.71649248E-03  -6.23663739E-03  -2.93588222E-03  -.02695832
-3.71649248E-03  .11407831  .0173636019  -.0524219438  -.0237147378
-6.23663739E-03  .0173636019  .0197140053  -.0354744422  .0272338189
-2.93588222E-03  -.0524219438  -.0354744422  .0772732286  -.0282705766
-.02695832  -.0237147378  .0272338189  -.0282705766  .076832303


CANONICAL CORRELATIONS AND LEVELS OF INFLUENCE
-------------------------------------------------------
CAN VAR 1 R(X,Y) = .400728888  LEVEL = 80.9164913 OR 51.5310219%  (CUMULATIVE =.515310219)
CAN VAR 2 R(X,Y) = .338786886  LEVEL = 57.8347578 OR 36.8316041%  (CUMULATIVE =.883626259)
CAN VAR 3 R(X,Y) = .189057274  LEVEL = 18.0103654 OR 11.4697575%  (CUMULATIVE =.998323835)
```

```
TEST FOR COMPOSITIONAL HETEROGENEITY AMOUNG THE 25 BLOCKS
-------------------------------------------------------
CHI SQUARE = 156.761614
DEGREES OF FREEDOM = 16
RANK = 3

ROW CANONICAL SCORES
-------------------------------------------------------
SET 1
-.0864380025  4.38404688  .372773328  -1.19857805  .670382208
SET 2
-.52808634  -2.46083858  .370572907  -.498155309  5.70327521
SET 3
-1.59732403  2.44989177  -.139677486  1.05551487  1.54884819

COLUMN CANONICAL SCORES
-------------------------------------------------------
SET 1
-1.23278899  -.380504924  1.75681422  -.434017134  .268641516
SET 2
-.578644494  -.314386812  -.833699834  -.253269463  1.93219483
SET 3
1.45287506  -1.39298565  .463169863  -.824061162  .292821016

ROW CANONICAL SCORES STORED IN FILE THE/GAP/ROW
COLUMN CANONICAL SCORES STORED IN FILE THE/GAP/COL
EIGENVALUES STORED IN FILE THE/GAP/EIG
LATTICE INFORMATION STORED IN FILE THE/GAP/LAT
NOTE: RUN PROGRAM LATTICE TO COMPLETE CONCENTRATION ANALYSIS

PROGRAM LATTICE UNDERWAY
========================
INPUT FILES ARE THE/GAP/LAT AND THE/GAP/EIG
TABLE HAS 5 ROWS AND 5 COLUMNS
NUMBER OF CANONICAL VARIATES: 3

DEPARTURES FROM RANDOM EXPECTATIONS (F(HJ)-F(H.)F(.J)/F(..)):
------------------------------------------------------------

=== LATTICE 1
.809  .25  -1.164  .284  -.182
-6.179  -1.913  8.881  -2.176  1.385
-9.274  -2.871  13.33  -3.266  2.079
15.294  4.734  -21.986  5.385  -3.43
-.653  -.202  .937  -.23  .146

=== LATTICE 2
1.961  1.069  2.851  .858  -6.742
1.376  .749  2  .602  -4.729
-3.659  -1.994  -5.317  -1.602  12.569
2.522  1.374  3.666  1.104  -8.668
-2.203  -1.201  -3.201  -.965  7.567

=== LATTICE 3
-8.315  7.995  -2.674  4.716  -1.725
1.919  -1.847  .617  -1.09  .398
-1.932  1.857  -.622  1.096  -.401
7.488  -7.202  2.408  -4.249  1.553
.838  -.806  .269  -.476  .173

=== TABLE (SUM OF LATTICES)
-5.545  9.314  -.987  5.858  -8.649
-2.884  -3.011  11.498  -2.664  -2.946
-14.865  -3.008  7.391  -3.772  14.247
25.304  -1.094  -15.912  2.24  -10.545
-2.018  -2.209  -1.995  -1.671  7.886
```

```
TEXT FILE NAME:TIN/TOWN

47.09  55.88  38.77  39.72  27.94
0  0  9.87  0  0
14.28  21.9  22.92  25.25  39.58
41.92  31.06  21.55  28.41  30.35
8.34  1.1  16.75  17.05  7.01

PROGRAM CONCENTRATION UNDERWAY
==============================
INPUT (OCCUPANCY COUNTS) FILE:TIN/TOWN
NUMBER OF ROWS:5
NUMBER OF COLUMNS:5
WEIGHTING OPTION: NO WEIGHTING (CONCENTRATION ANALYSIS PROPER).

ROW TOTALS
-------------------------------------------------------
209.4  9.87  123.93  153.29  50.25

COLUMN TOTALS
-------------------------------------------------------
111.63  109.94  109.86  110.43  104.88

GRAND TOTAL = 546.74

RELATIVE FREQUENCIES BY COLUMN
-------------------------------------------------------
COLUMN 1
.421840007  0  .127922601  .375526292  .0747110991
COLUMN 2
.508277242  0  .199199563  .282517737  .0100054575
COLUMN 3
.352903696  .0898416165  .208629164  .196158747  .152466776
COLUMN 4
.359684868  0  .228651635  .257267047  .15439645
COLUMN 5
.266399695  0  .377383677  .289378337  .0668382914

RELATIVE FREQUENCIES BY ROW
-------------------------------------------------------
ROW 1
.224880611  .266857689  .185148042  .189684814  .133428844
ROW 2
0  0  1  0  0
ROW 3
.115226337  .17671266  .184943113  .203744049  .31937384
ROW 4
.273468589  .20262248  .140583208  .185334986  .197990736
ROW 5
.165970149  .0218905473  .333333333  .339303482  .139502488

SCALAR PRODUCT MATRIX
-------------------------------------------------------
.0166155148  -6.53350052E-03  -.0161088707  3.73910686E-03  -.0122554241
-6.53350052E-03  .0717891601  -5.0915095E-03  -.0213686244  .0268389019
-.0161088707  -5.0915095E-03  .0289677361  -5.44994955E-03  -8.32621987E-04
3.73910686E-03  -.0213686244  -5.44994955E-03  .0121196047  -.0107715845
-.0122554241  .0268389019  -8.32621987E-04  -.0107715845  .0332440544


CANONICAL CORRELATIONS AND LEVELS OF INFLUENCE
-------------------------------------------------------
CAN VAR 1 R(X,Y) = .307473591  LEVEL = 51.6888046 OR 58.0940712%  (CUMULATIVE =.580940712)
CAN VAR 2 R(X,Y) = .205021982  LEVEL = 22.9816763 OR 25.8295612%  (CUMULATIVE =.839236323)
CAN VAR 3 R(X,Y) = .142613007  LEVEL = 11.119855 OR 12.4978253%  (CUMULATIVE =.964214576)
CAN VAR 4 R(X,Y) = .0763123794  LEVEL = 3.18398372 OR 3.57854236%  (CUMULATIVE =1)
```

```
TEST FOR COMPOSITIONAL HETEROGENEITY AMOUNG THE 25 BLOCKS
-------------------------------------------------------
CHI SQUARE = 88.9743196
DEGREES OF FREEDOM = 16
RANK = 4

ROW CANONICAL SCORES
-------------------------------------------------------
SET 1
-.245077419  6.22226347  -.0208798061  -.531167591  1.4709609
SET 2
-.873137051  -1.6023821  1.65548357  -.21982187  .540951751
SET 3
-.271114773  -3.01745975  -.771987351  .321417588  2.64589158
SET 4
-.845605876  2.00121697  -.273235681  1.46045668  -.650615882

COLUMN CANONICAL SCORES
-------------------------------------------------------
SET 1
-.63623269  -.858848239  1.91318168  -8.01895696E-03  -.418117629
SET 2
-.969087145  -.832667766  -.328523552  .446015323  1.7788026
SET 3
.738057049  -1.22219909  -.430329002  1.52282302  -.657037952
SET 4
1.41744034  -1.02388952  .152717603  -1.19709056  .665090488

ROW CANONICAL SCORES STORED IN FILE TIN/TOWN/ROW
COLUMN CANONICAL SCORES STORED IN FILE TIN/TOWN/COL
EIGENVALUES STORED IN FILE TIN/TOWN/EIG
LATTICE INFORMATION STORED IN FILE TIN/TOWN/LAT
NOTE: RUN PROGRAM LATTICE TO COMPLETE CONCENTRATION ANALYSIS

PROGRAM LATTICE UNDERWAY
========================
INPUT FILES ARE TIN/TOWN/LAT AND TIN/TOWN/EIG
TABLE HAS 5 ROWS AND 5 COLUMNS
NUMBER OF CANONICAL VARIATES: 4

DEPARTURES FROM RANDOM EXPECTATIONS (F(HJ)-F(H.)F(.J)/F(..)):
-------------------------------------------------------------


=== LATTICE 1
2.049  2.725  -6.067  .025  1.265
-2.453  -3.262  7.259  -.031  -1.515
.103  .137  -.306  1E-03  .063
3.252  4.323  -9.625  .04  2.007
-2.953  -3.925  8.736  -.037  -1.823

=== LATTICE 2
7.416  6.276  2.474  -3.377  -12.791
.641  .542  .214  -.293  -1.107
-8.323  -7.043  -2.777  3.789  14.352
1.366  1.156  .456  -.623  -2.358
-1.103  -.934  -.368  .502  1.901

=== LATTICE 3
-1.221  1.989  .7  -2.491  1.02
-.641  1.043  .367  -1.307  .535
-2.057  3.353  1.179  -4.197  1.719
1.058  -1.727  -.608  2.161  -.886
2.857  -4.66  -1.64  5.832  -2.39

=== LATTICE 4
-3.911  2.782  -.415  3.267  -1.724
.436  -.311  .046  -.365  .192
-.748  .532  -.08  .624  -.33
4.944  -3.518  .524  -4.131  2.179
-.723  .513  -.077  .603  -.319

=== TABLE (SUM OF LATTICES)
4.333  13.772  -3.308  -2.576  -12.23
-2.017  -1.988  7.886  -1.996  -1.895
-11.025  -3.021  -1.984  .216999999  15.804
10.62  .234  -9.253  -2.553  .942
-1.922  -9.006  6.651  6.9  -2.631
```

```
TEXT FILE NAME:CHIMNEY/MARSH

33.18  54.8  64.45  65.38  30.35
7.83  0  13.83  0  0
17.2  36.98  11.8  28.93  66.4
41.8  7.55  9.93  5.7  3.03

PROGRAM CONCENTRATION UNDERWAY
===============================
INPUT (OCCUPANCY COUNTS) FILE:CHIMNEY/MARSH
NUMBER OF ROWS:4
NUMBER OF COLUMNS:5
WEIGHTING OPTION: NO WEIGHTING (CONCENTRATION ANALYSIS PROPER).

ROW TOTALS
-------------------------------------------------------
248.16  21.66  161.31  68.01

COLUMN TOTALS
-------------------------------------------------------
100.01  99.33  100.01  100.01  99.78

GRAND TOTAL = 499.14

RELATIVE FREQUENCIES BY COLUMN
-------------------------------------------------------
COLUMN 1
.331766823  .0782921708  .171982802  .417958204
COLUMN 2
.551696366  0  .372294372  .0760092621
COLUMN 3
.644435556  .138286171  .117988201  .099290071
COLUMN 4
.653734626  0  .289271073  .0569943006
COLUMN 5
.304169172  0  .665464021  .030366807

RELATIVE FREQUENCIES BY ROW
-------------------------------------------------------
ROW 1
.133704062  .220825274  .259711476  .263459059  .122300129
ROW 2
.361495845  0  .638504155  0  0
ROW 3
.106626992  .229248032  .0731510756  .17934412  .411629781
ROW 4
.614615498  .111013086  .14600794  .0838112042  .0445522717

SCALAR PRODUCT MATRIX
-------------------------------------------------------
.0458114798  .0101133536  -.036873286  -.0364286805
.0101133536  .0732039507  -.0680358161  .0441501696
-.036873286  -.0680358161  .114944737  -.0681935214
-.0364286805  .0441501696  -.0681935214  .149694065
```

```
CANONICAL CORRELATIONS AND LEVELS OF INFLUENCE
------------------------------------------------------------
CAN VAR 1 R(X,Y) = .488874167  LEVEL = 119.293437 OR 62.2951423%  (CUMULATIVE =.622951423)
CAN VAR 2 R(X,Y) = .338144191  LEVEL = 57.0724134 OR 29.8032666%  (CUMULATIVE =.920984089)
CAN VAR 3 R(X,Y) = .174111427  LEVEL = 15.1313237 OR 7.90159112%  (CUMULATIVE =1)

TEST FOR COMPOSITIONAL HETEROGENEITY AMOUNG THE 20 BLOCKS
------------------------------------------------------------
CHI SQUARE = 191.497174
DEGREES OF FREEDOM = 12
RANK = 3

ROW CANONICAL SCORES
------------------------------------------------------------
SET 1
-.0168038074  -2.05466261  1.06691291  -1.8148757
SET 2
-.854998067  -1.28005676  .806390902  1.61481302
SET 3
-.529206553  4.02295135  .552920478  -.661679622

COLUMN CANONICAL SCORES
------------------------------------------------------------
SET 1
-1.5167307  .511353896  -.714450513  .397247908  1.32911293
SET 2
1.27085224  -.144150888  -1.39740916  -.690951221  .962893349
SET 3
-.241622258  -.783440421  1.23380126  -1.28497434  1.07337739

ROW CANONICAL SCORES STORED IN FILE CHIMNEY/MARSH/ROW
COLUMN CANONICAL SCORES STORED IN FILE CHIMNEY/MARSH/COL
EIGENVALUES STORED IN FILE CHIMNEY/MARSH/EIG
LATTICE INFORMATION STORED IN FILE CHIMNEY/MARSH/LAT
NOTE: RUN PROGRAM LATTICE TO COMPLETE CONCENTRATION ANALYSIS

PROGRAM LATTICE UNDERWAY
========================
INPUT FILES ARE CHIMNEY/MARSH/LAT AND CHIMNEY/MARSH/EIG
TABLE HAS 4 ROWS AND 5 COLUMNS
NUMBER OF CANONICAL VARIATES: 3

DEPARTURES FROM RANDOM EXPECTATIONS (F(HJ)-F(H.)F(.J)/F(..)):
-----------------------------------------------------------------


=== LATTICE 1
.619  -.208  .291  -.163  -.542
6.611  -2.214  3.114  -1.732  -5.781
-25.57  8.561  -12.045  6.696  22.354
18.337  -6.141  8.637  -4.803  -16.033

=== LATTICE 2
-18.27  2.058  20.088  9.932  -13.811
-2.388  .268  2.625  1.297  -1.805
11.2  -1.262  -12.316  -6.09  8.466
9.456  -1.066  -10.398  -5.14200001  7.148
=== LATTICE 3
1.106  3.564  -5.653  5.887  -4.907
-.735  -2.366  3.75  -3.907  3.255
-.752  -2.422  3.838  -3.999  3.332
.379  1.221  -1.937  2.017  -1.682

=== TABLE (SUM OF LATTICES)
-16.545  5.414  14.726  15.656  -19.26
3.488  -4.312  9.489  -4.342  -4.331
-15.122  4.877  -20.523  -3.393  34.152
28.172  -5.986  -3.698  -7.928  -10.567
```

```
TEXT FILE NAME:CLANDEBOYE/BAY

6  21.53  23.78  18.7  5.48
3.3  0  2.45  0  0
58.53  48.33  57.9  62.18  86.7
33.8  30.15  9.33  7.63  8.3


PROGRAM CONCENTRATION UNDERWAY
==============================
INPUT (OCCUPANCY COUNTS) FILE:CLANDEBOYE/BAY
NUMBER OF ROWS:4
NUMBER OF COLUMNS:5
WEIGHTING OPTION: NO WEIGHTING (CONCENTRATION ANALYSIS PROPER).

ROW TOTALS
-------------------------------------------------------
75.49  5.75  313.64  89.21

COLUMN TOTALS
-------------------------------------------------------
101.63  100.01  93.46  88.51  100.48

GRAND TOTAL = 484.09

RELATIVE FREQUENCIES BY COLUMN
-------------------------------------------------------
COLUMN 1
.0590376857  .0324707271  .575912624  .332578963
COLUMN 2
.215278472  0  .483251675  .301469853
COLUMN 3
.254440402  .0262144233  .61951637  .0998288038
COLUMN 4
.211275562  0  .702519489  .0862049486
COLUMN 5
.0545382166  0  .86285828  .0826035032

RELATIVE FREQUENCIES BY ROW
-------------------------------------------------------
ROW 1
.0794807259  .285203338  .31500861  .247714929  .0725923963
ROW 2
.573913043  0  .426086957  0  0
ROW 3
.186615228  .154093866  .184606555  .198252774  .276431577
ROW 4
.378881291  .337966596  .104584688  .0855285282  .093038897

SCALAR PRODUCT MATRIX
-------------------------------------------------------
.0465945083  -3.76608017E-03  -.0159360172  -.0120253339
-3.76608017E-03  .0179270411  -7.23095351E-03  .0124713702
-.0159360172  -7.23095351E-03  .0262086279  -.0326468057
-.0120253339  .0124713702  -.0326468057  .069109658


CANONICAL CORRELATIONS AND LEVELS OF INFLUENCE
-------------------------------------------------------
CAN VAR 1 R(X,Y) = .299950638  LEVEL = 43.5537638 OR 56.2878363%  (CUMULATIVE =.562878363)
CAN VAR 2 R(X,Y) = .234186191  LEVEL = 26.5490312 OR 34.3113291%  (CUMULATIVE =.905991654)
CAN VAR 3 R(X,Y) = .122581722  LEVEL = 7.27407122 OR 9.40083461%  (CUMULATIVE =1)
```

```
TEST FOR COMPOSITIONAL HETEROGENEITY AMOUNG THE 20 BLOCKS
-------------------------------------------------------

CHI SQUARE = 77.3768662
DEGREES OF FREEDOM = 12
RANK = 3

ROW CANONICAL SCORES
-------------------------------------------------------
SET 1
-.240994269  1.83360336  -.551052631  2.02310935
SET 2
2.31348924  -.427316503  -.489186178  -.210288983
SET 3
.0482363137  8.92439717  -.022256448  -.537788713

COLUMN CANONICAL SCORES
-------------------------------------------------------
SET 1
1.33620697  .972588342  -.508994962  -.878942537  -1.07186904
SET 2
-.977676835  .846542655  1.08200886  .542273495  -1.33780464
SET 3
.823568489  -1.32563246  1.4581795  -.422611802  -.497600038

ROW CANONICAL SCORES STORED IN FILE CLANDEBOYE/BAY/ROW
COLUMN CANONICAL SCORES STORED IN FILE CLANDEBOYE/BAY/COL
EIGENVALUES STORED IN FILE CLANDEBOYE/BAY/EIG
LATTICE INFORMATION STORED IN FILE CLANDEBOYE/BAY/LAT
NOTE: RUN PROGRAM LATTICE TO COMPLETE CONCENTRATION ANALYSIS

PROGRAM LATTICE UNDERWAY
========================
INPUT FILES ARE CLANDEBOYE/BAY/LAT AND CLANDEBOYE/BAY/EIG
TABLE HAS 4 ROWS AND 5 COLUMNS
NUMBER OF CANONICAL VARIATES: 3

DEPARTURES FROM RANDOM EXPECTATIONS (F(HJ)-F(H.)F(.J)/F(..)):
------------------------------------------------------------


=== LATTICE 1
-1.531  -1.097  .536  .876  1.214
.887  .635  -.311  -.509  -.704
-14.543  -10.417  5.094  8.331  11.533
15.186  10.877  -5.32  -8.7  -12.045

=== LATTICE 2
-8.395  7.152  8.543  4.055  -11.358
.118  -.101  -.121  -.058  .159
7.374  -6.284  -7.506  -3.563  9.977
.901  -.769  -.918  -.436  1.219

=== LATTICE 3
.077  -.123  .125  -.035  -.047
1.087  -1.723  1.77  -.487  -.65
-.148  .234  -.241  .066  .088
-1.017  1.61  -1.656  .454  .607

=== TABLE (SUM OF LATTICES)
-9.849  5.93200001  9.204  4.896  -10.191
2.092  -1.189  1.338  -1.054  -1.195
-7.317  -16.467  -2.653  4.834  21.598
15.07  11.718  -7.894  -8.682  -10.219
```