THE ROLE OF *POTAMOGETON CRISPUS* L. IN THE PONGOLO RIVER FLOODPLAIN ECOSYSTEM

VOLUME II

FIGURES, TABLES AND PLATES

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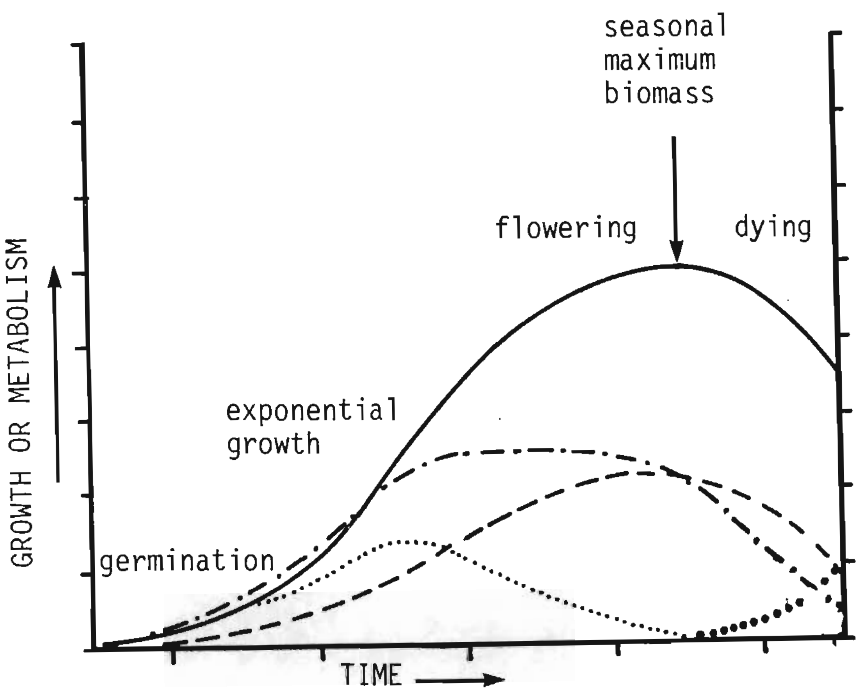


Figure 1.1 Generalized growth and metabolic patterns for a typical annual aquatic macrophyte.
—— = biomass; —•—•— = current gross productivity; .... = current net productivity; — — — = current respiration rate; • • • = death losses.
(After Westlake, 1965).

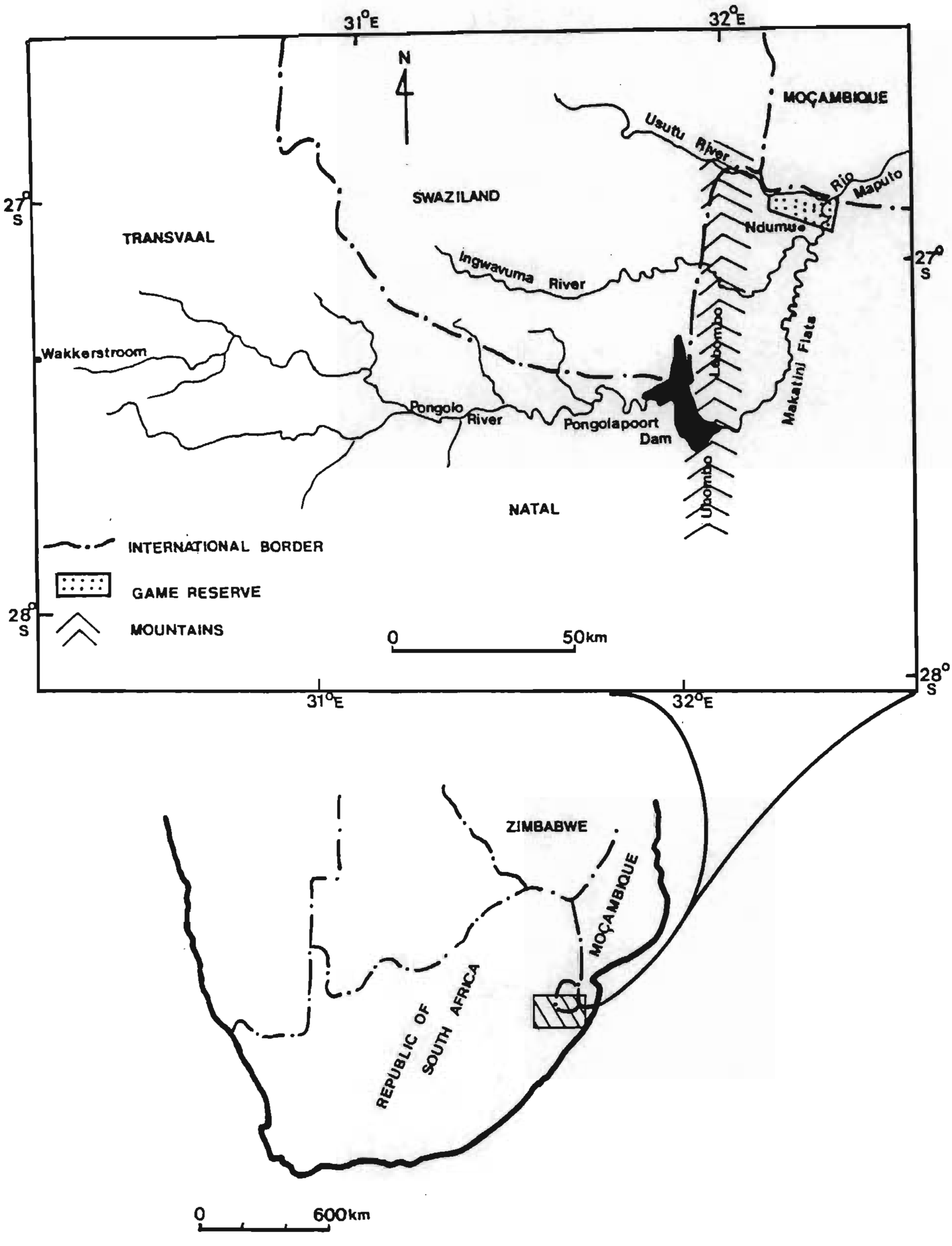


Figure 1.2 Location of the Pongolo river floodplain and its catchment. (After Furness, 1981)

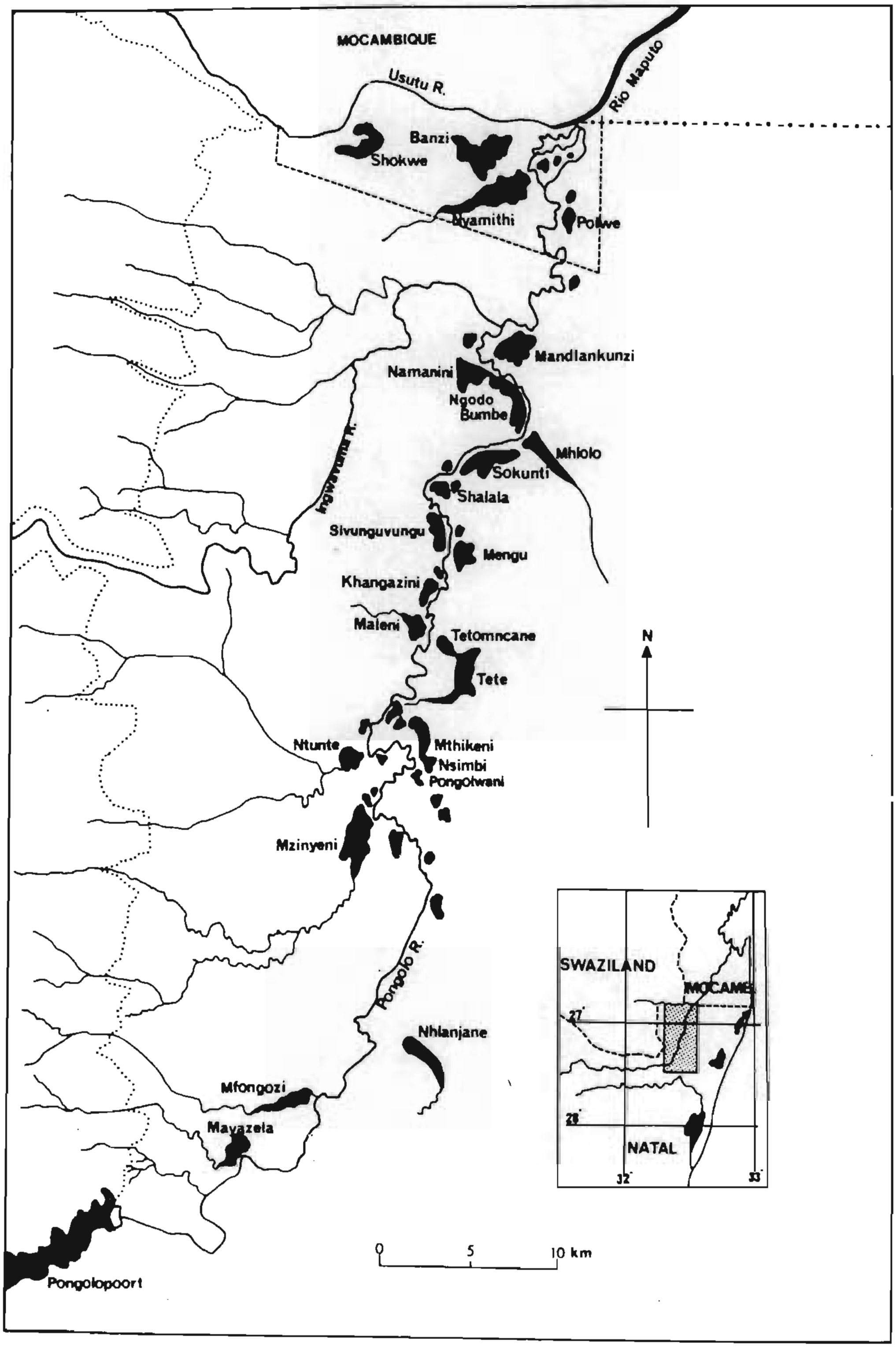


Figure 1.3 Map of the Pongolo floodplain showing the location of the major floodplain pans. (After Heeg and Breen, 1982)

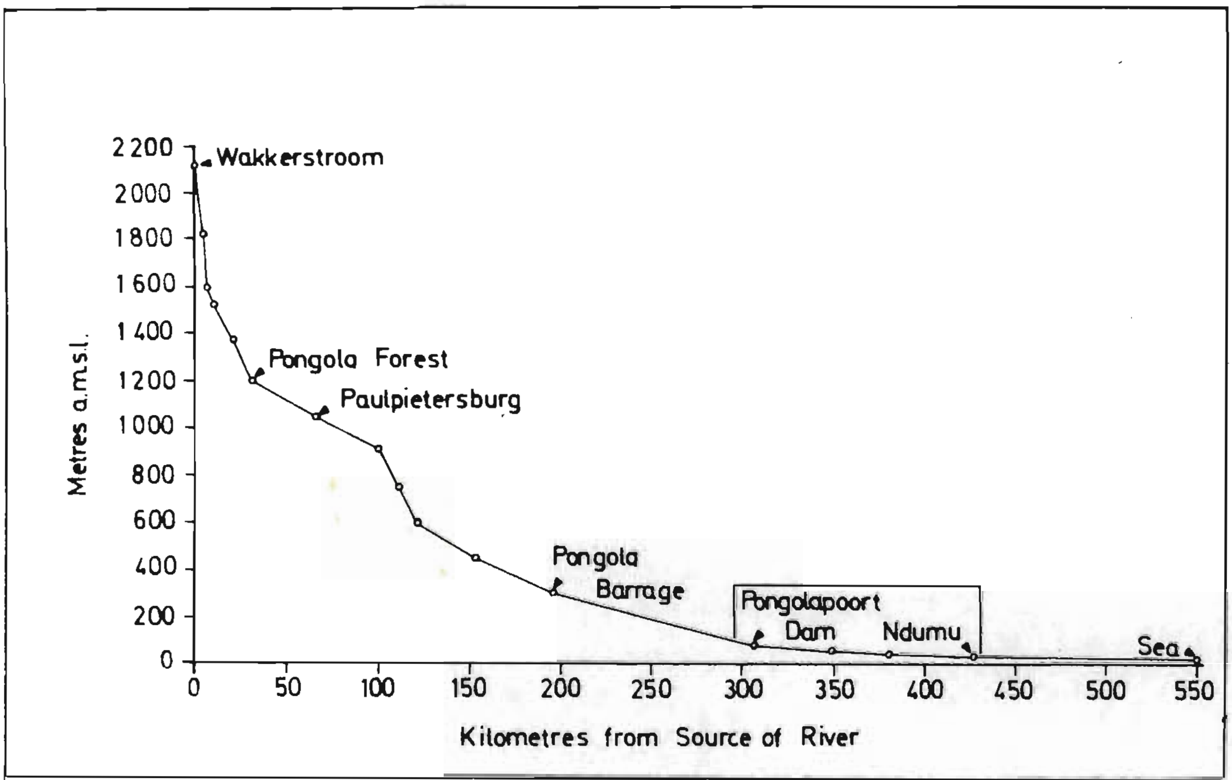


Figure 1.4 Profile of the course of the Pongolo river through its catchment. Note the marked change in gradient after the river passes through the Pongolapoort (After Heeg & Breen, 1982).

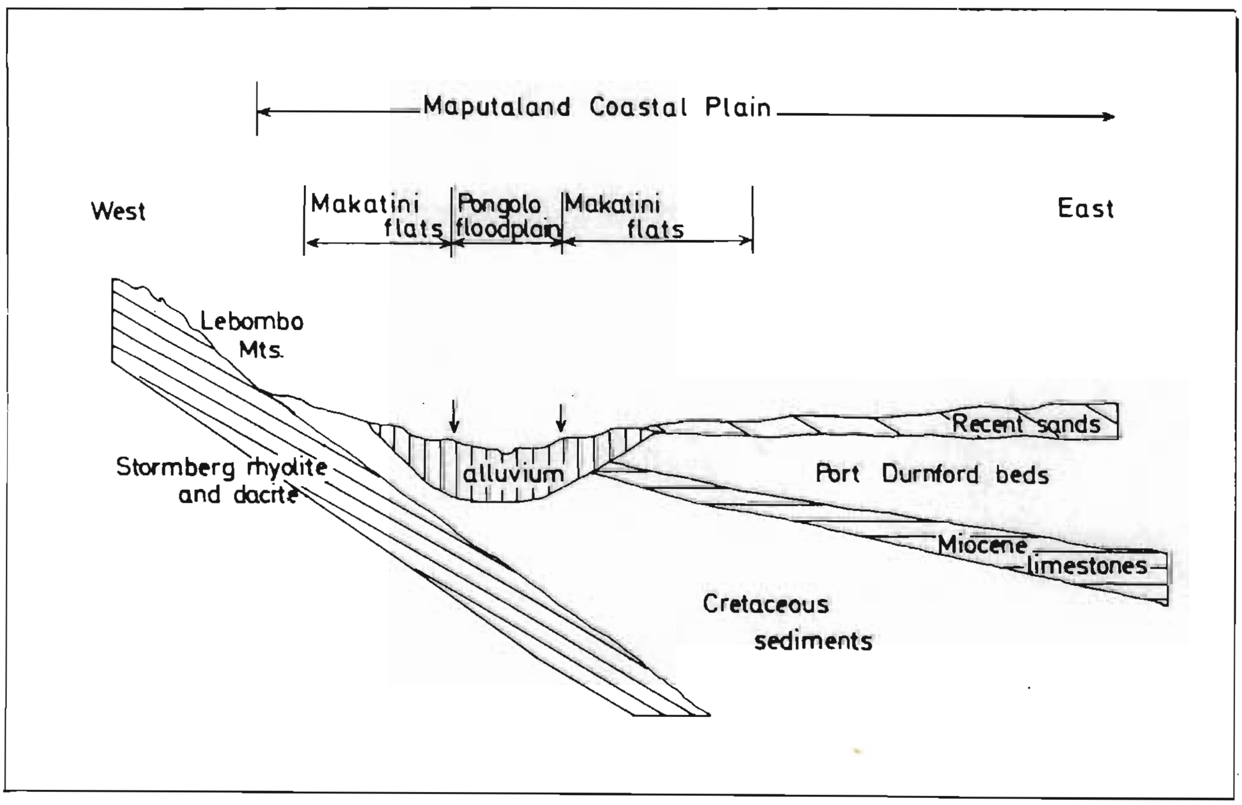


Figure 1.5 Geological section through the Pongolo floodplain and its immediate surroundings (After Heeg and Breen, 1982).

Table 1.1 Climatic data measured at the Makatini Agricultural Research Station (After Heeg and Breen, 1982)

Month	Mean Maximum Temp. (°C)	Mean Minimum Temp. (°C)	Mean Temp. (°C)	Rainfall (mm)	Wind (km day^{-1})	Relative Humidity %	
						08h00	14h00
July	25,4	8,3	16,8	12,1	149.3	86	39
Aug.	26,7	11,4	19,0	6,9	190,4	78	39
Sept.	28,2	14,5	21,3	46,9	240,8	70	40
Oct.	29,0	17,0	23,0	43,7	231,6	72	48
Nov.	29,4	18,4	23,8	64,9	238,7	71	51
Dec.	31,2	20,1	25,6	60,8	233,3	72	51
Jan.	32,5	21,3	26,8	75,9	190,2	74	51
Feb.	31,2	20,5	25,8	105,6	211,4	76	54
March	30,5	19,6	25,0	73,4	180,5	81	54
April	28,4	16,6	22,4	54,2	150,1	84	53
May	26,8	12,9	19,8	23,6	168,7	86	48
June	25,0	8,4	16,6	4,6	127,0	86	40
Year	28,7	15,8	22,1	572,6	192,7	78	47
Period from	1966	1966	1966	1966	1969	1966	1966
to	1975	1975	1975	1975	1973	1975	1975

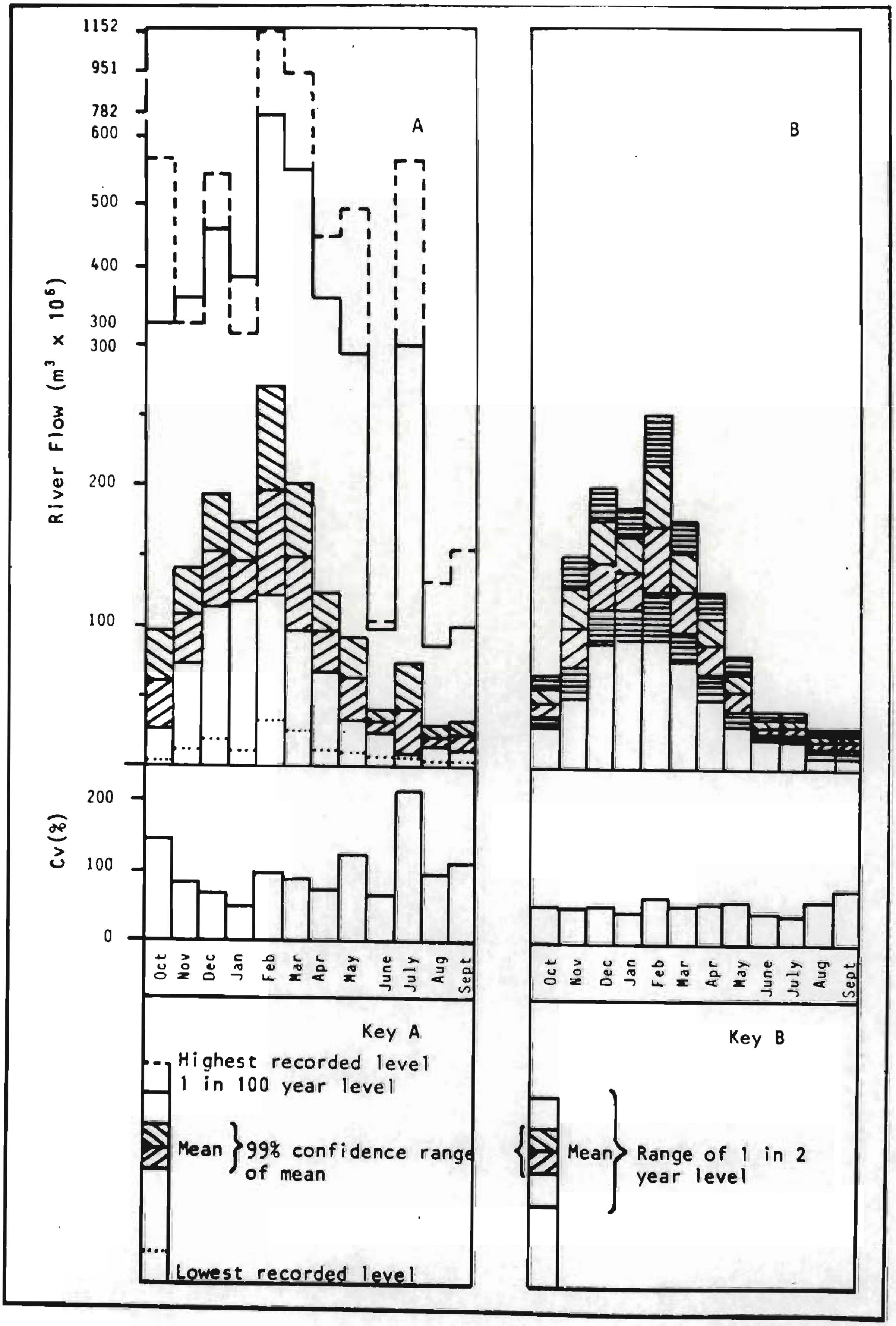


Figure 1.6 Mean monthly flow of the Pongolo river above the Pongolapoort Dam (1929-1976). (After Heeg & Breen, 1982).
(A) Mean and 99% confidence limits (uncorrected data)
(B) Data in (A) corrected to give less weighting to extremes

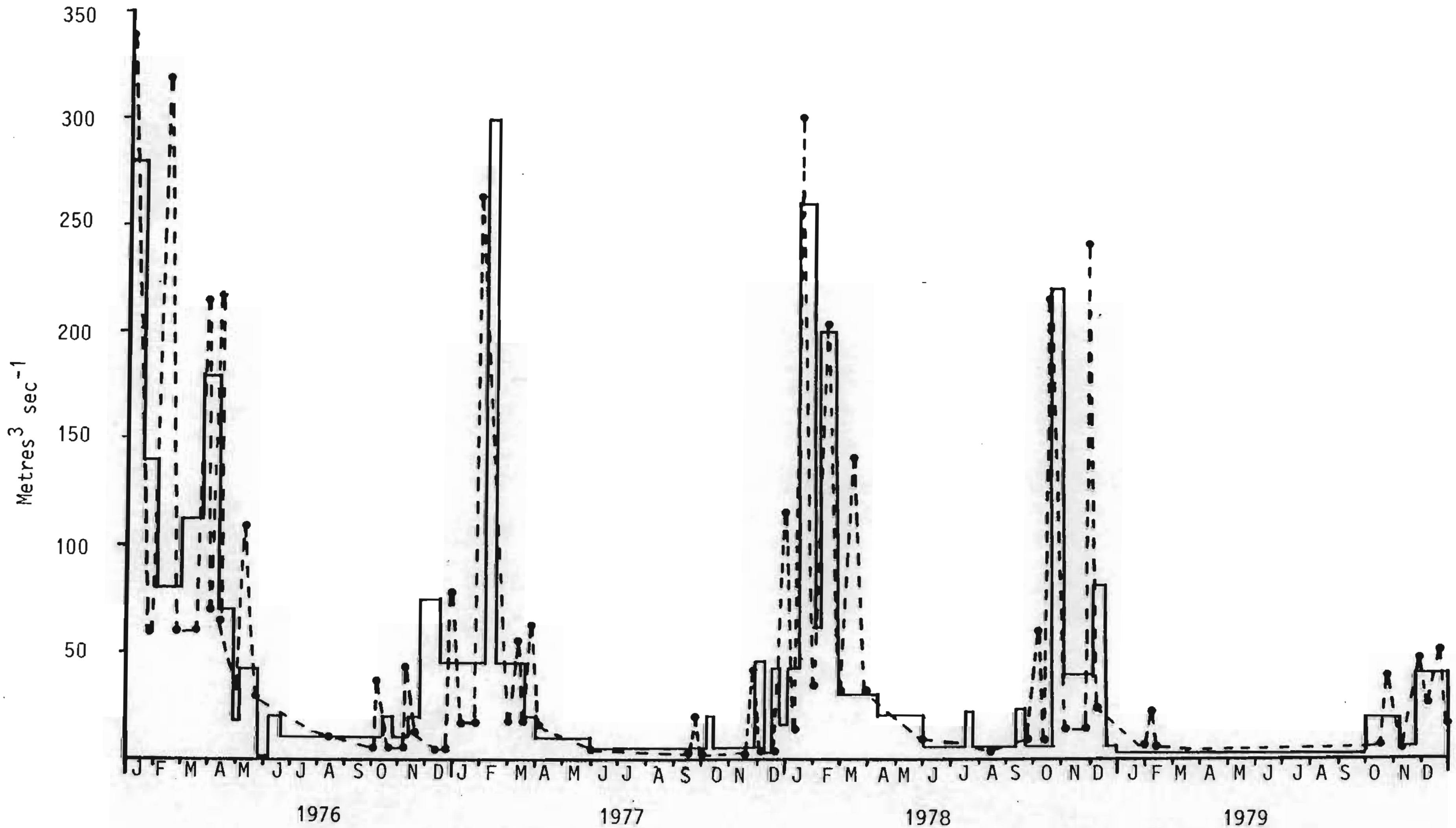


Figure 1.7 A comparison of the natural flow regime of the Pongolo River (•- - - -•) as recorded upstream of the Pongolopoort Dam and the artificial releases from the dam (histogram) during the study period.

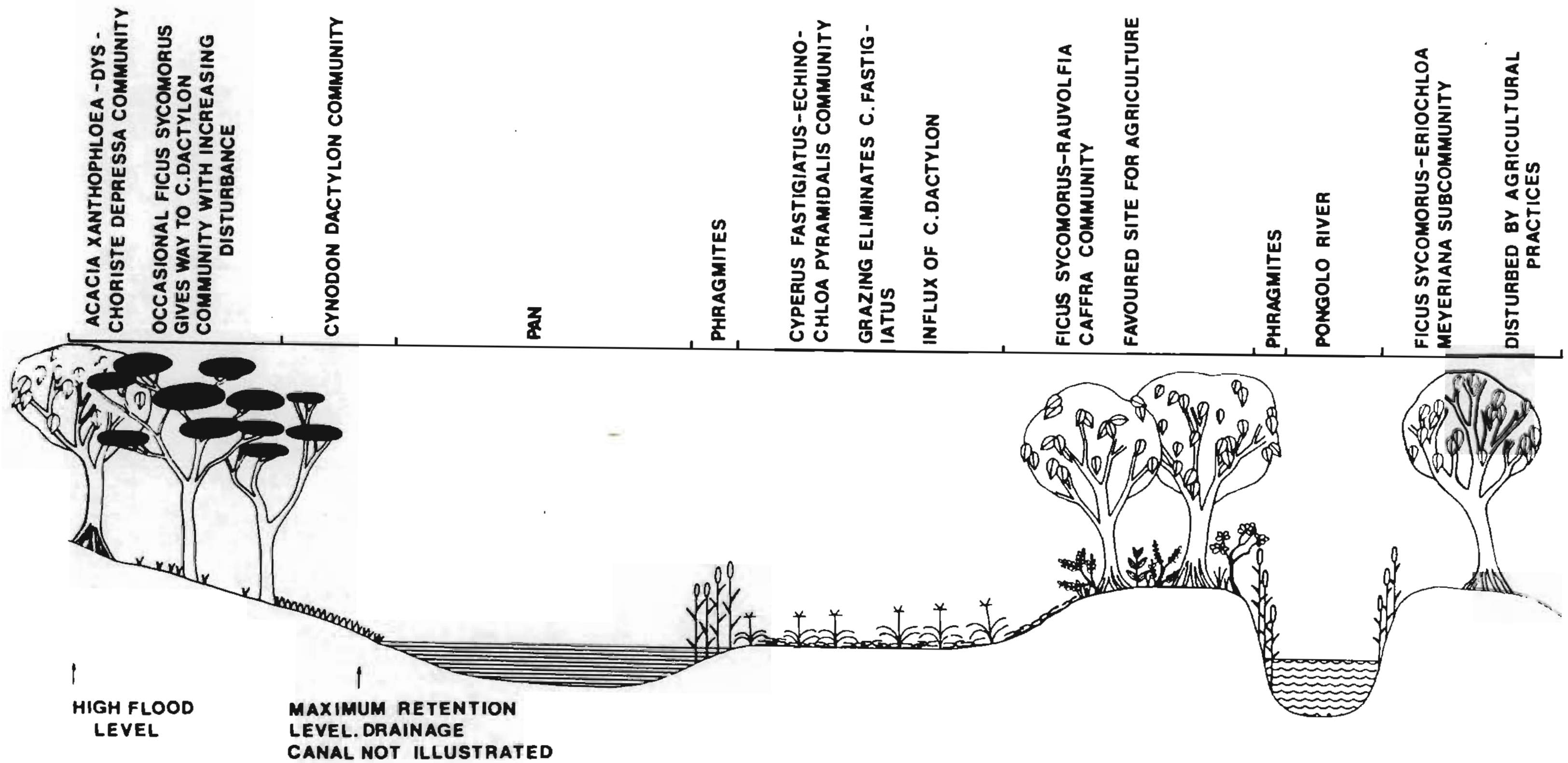


Figure 1.8 Cross-section of the Pongolo river floodplain showing the distribution of the seasonally flooded terrestrial communities (After Furness and Breen, 1980)

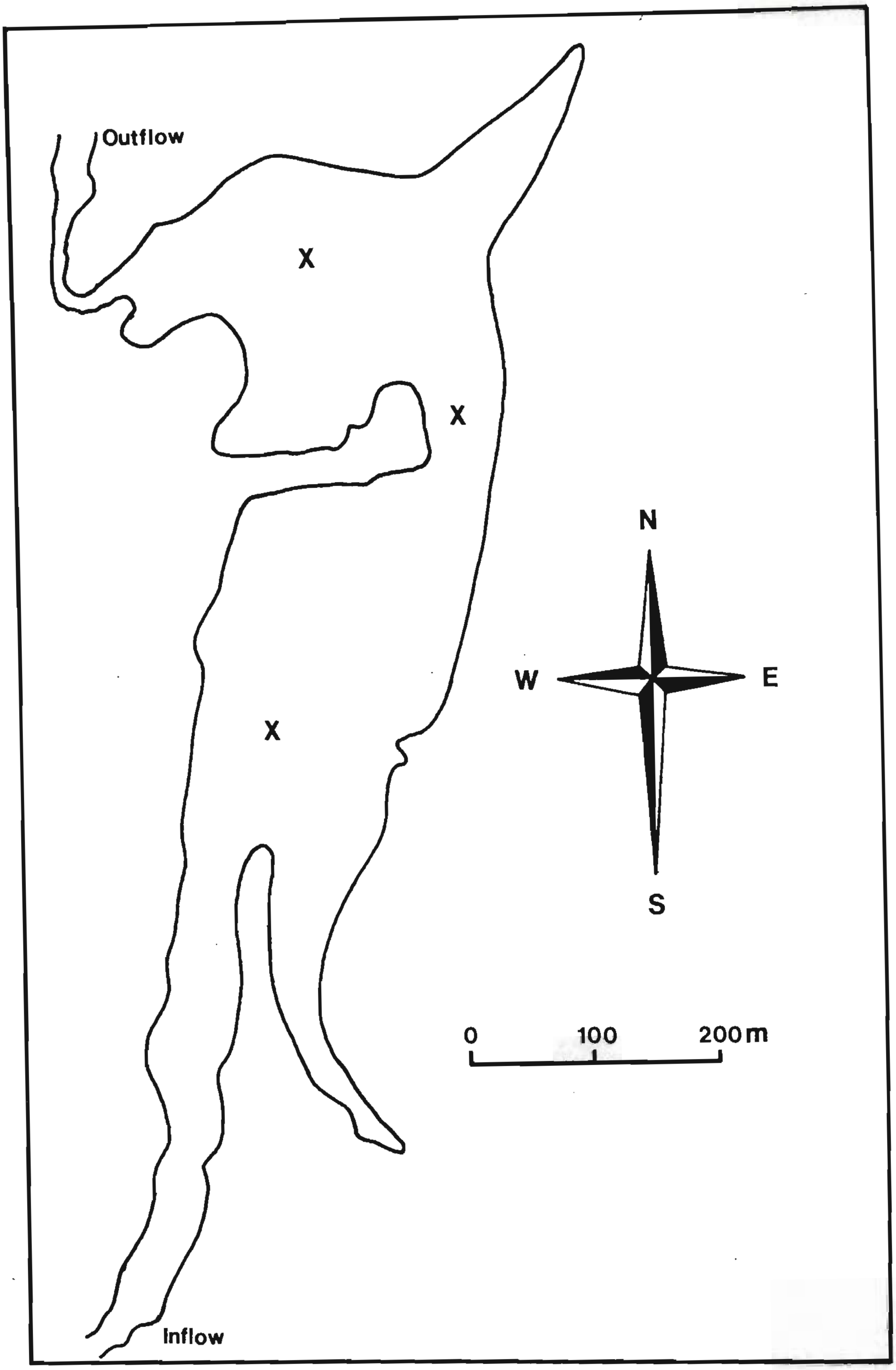


Figure 1.9 Map of Tete pan at MRL showing inflow and outflow channels, and the three sites (X) used for physico-chemical sampling of the water column.

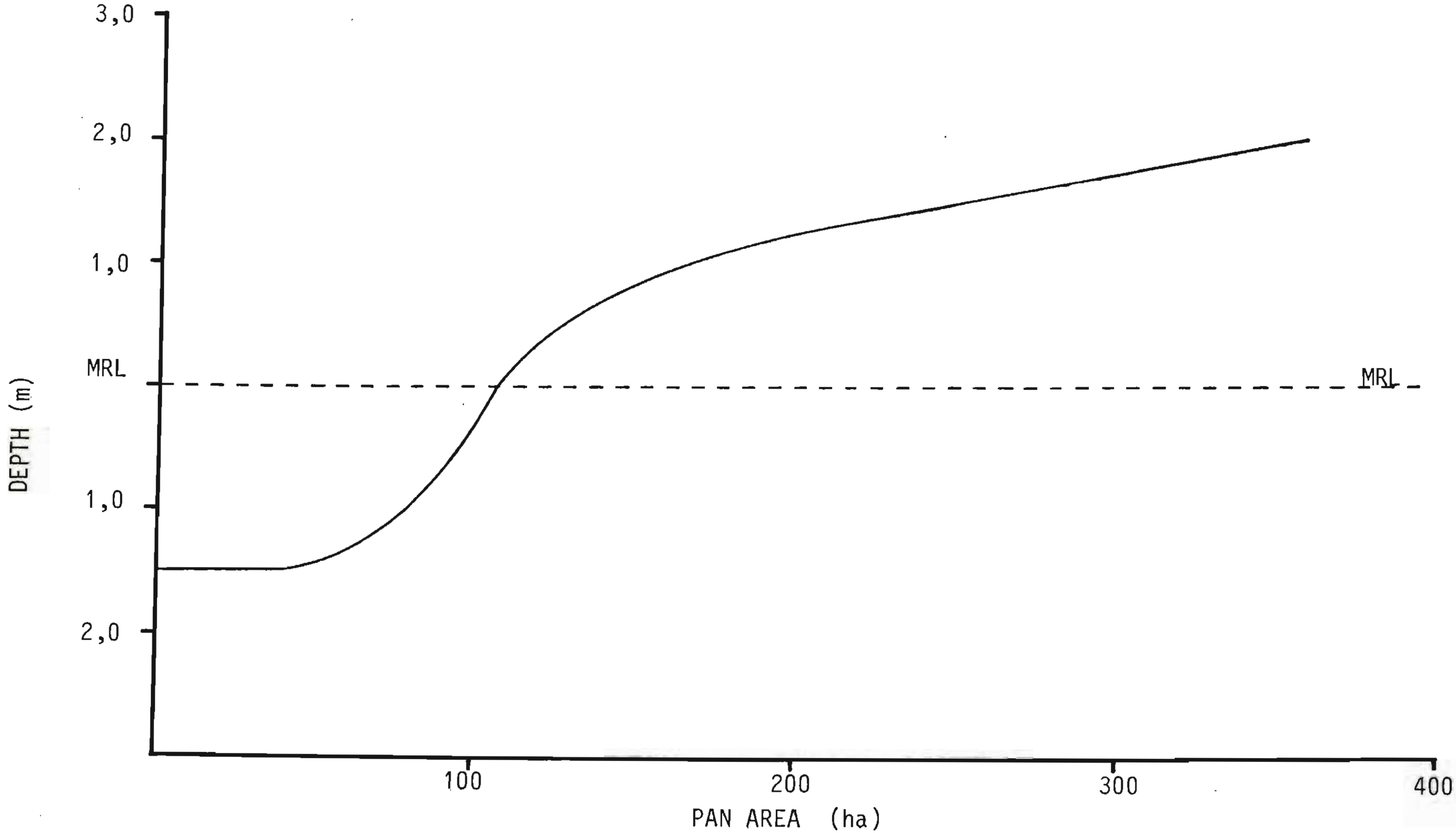


Figure 1.10 Hypsographic curve of Tete pan (modified, after Breen *et al.*,1978)

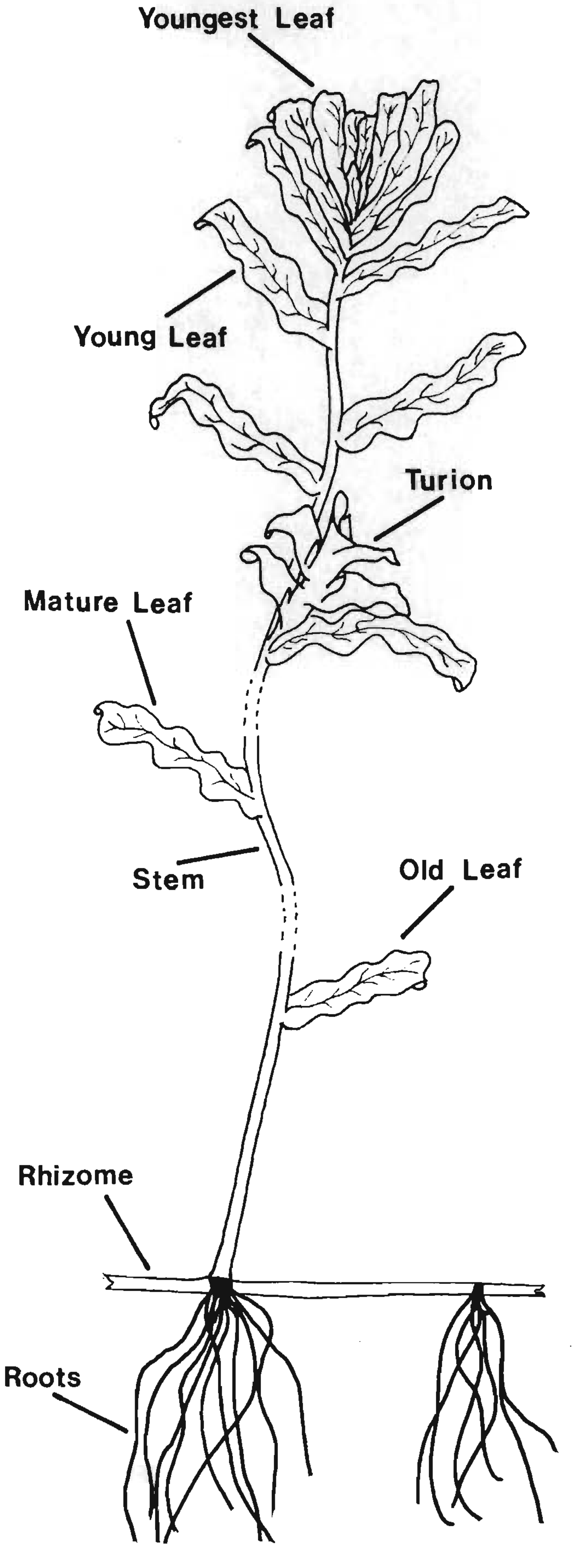


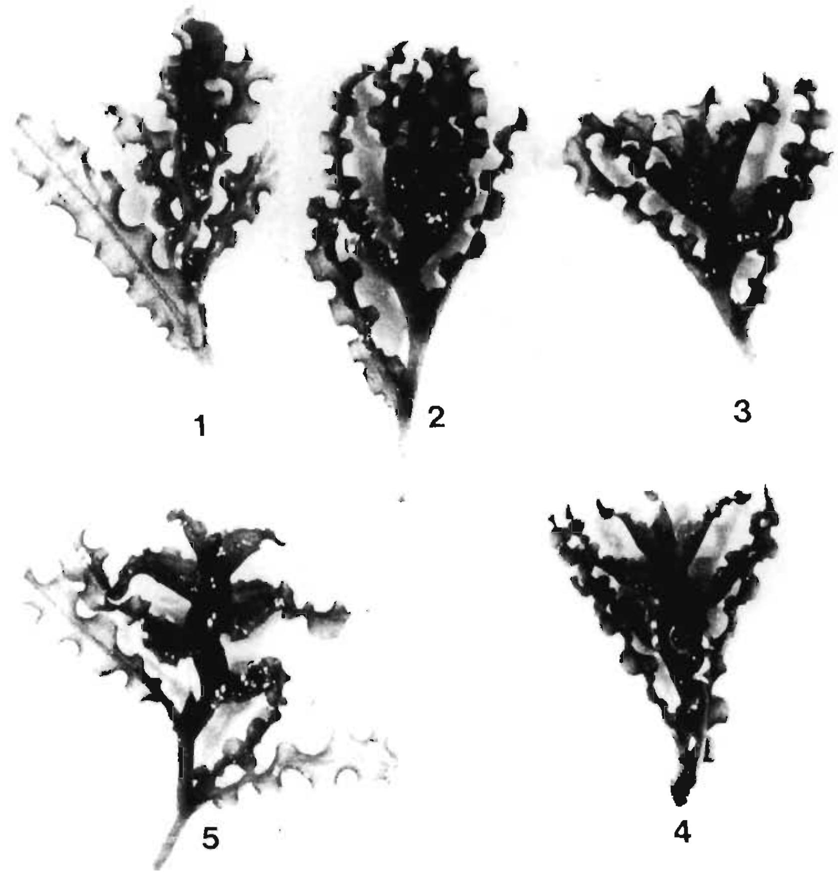
Figure 1.11 An illustration of the general morphological features of a mature *P. crispus* plant.

Plate 2.1 A comparison of "large" and "small" turions of *P. crispus*

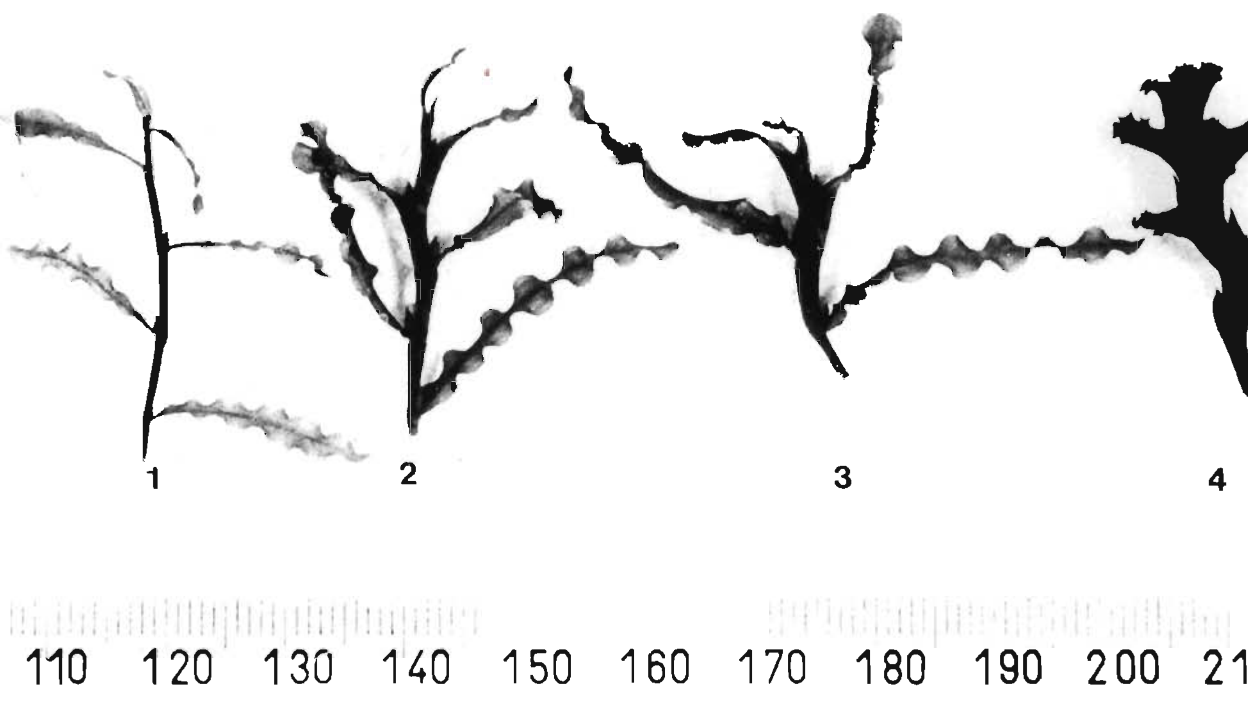
a) Large starch filled turions consisted of swollen stems with dormant buds in the axils of swollen leaf bases.
This series illustrates the maturation of a turion (1 - 5)

b) Small turions had stems which were only slightly swollen and the leaf bases were either absent (1) or so reduced that the dormant buds protruded beyond them (2 and 3)
The turions shown here were picked from senescing plants but the leaves were still intact. A large turion without attached leaves (4) illustrates the difference between these two types of turion. (Scale in cm).

(a)



(b)



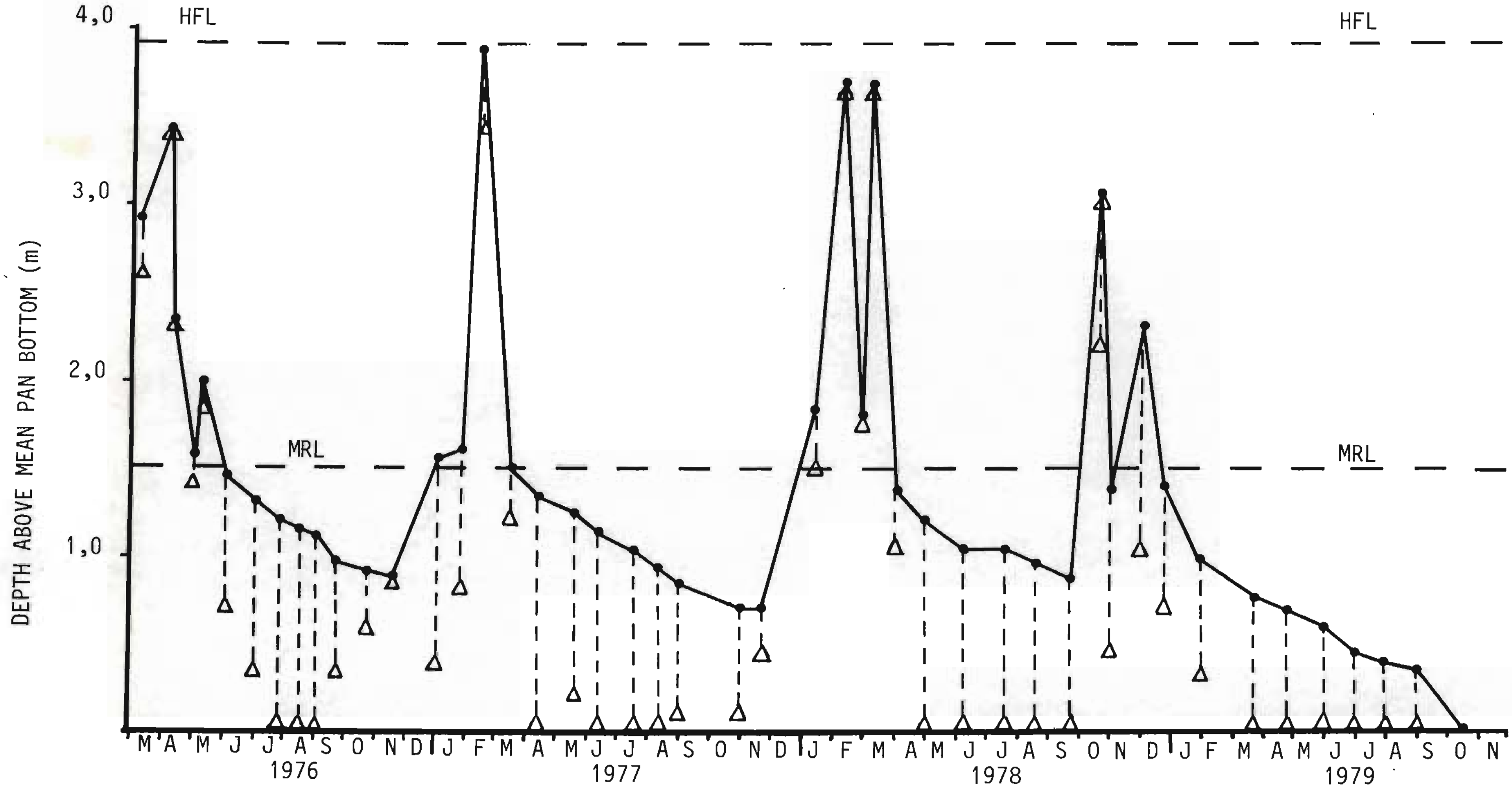


Figure 3.1 Depth of water (•——•) and Secchi disc transparency (- - - -) in Tete pan during the study period in relation to the mean retention level (MRL) and approximate high flood level (HFL).

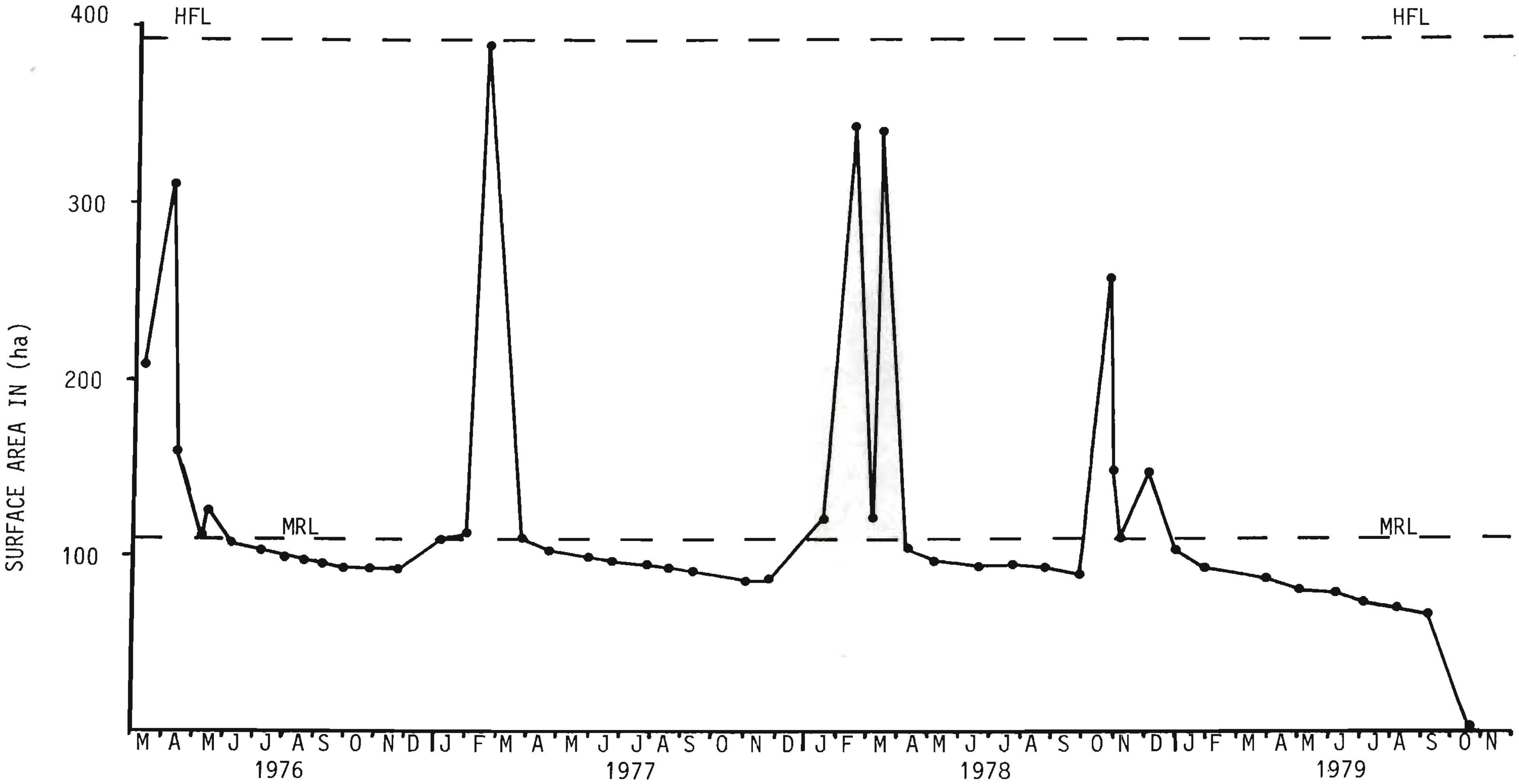


Figure 3.2 Changes in surface area of Tete pan during the study period.

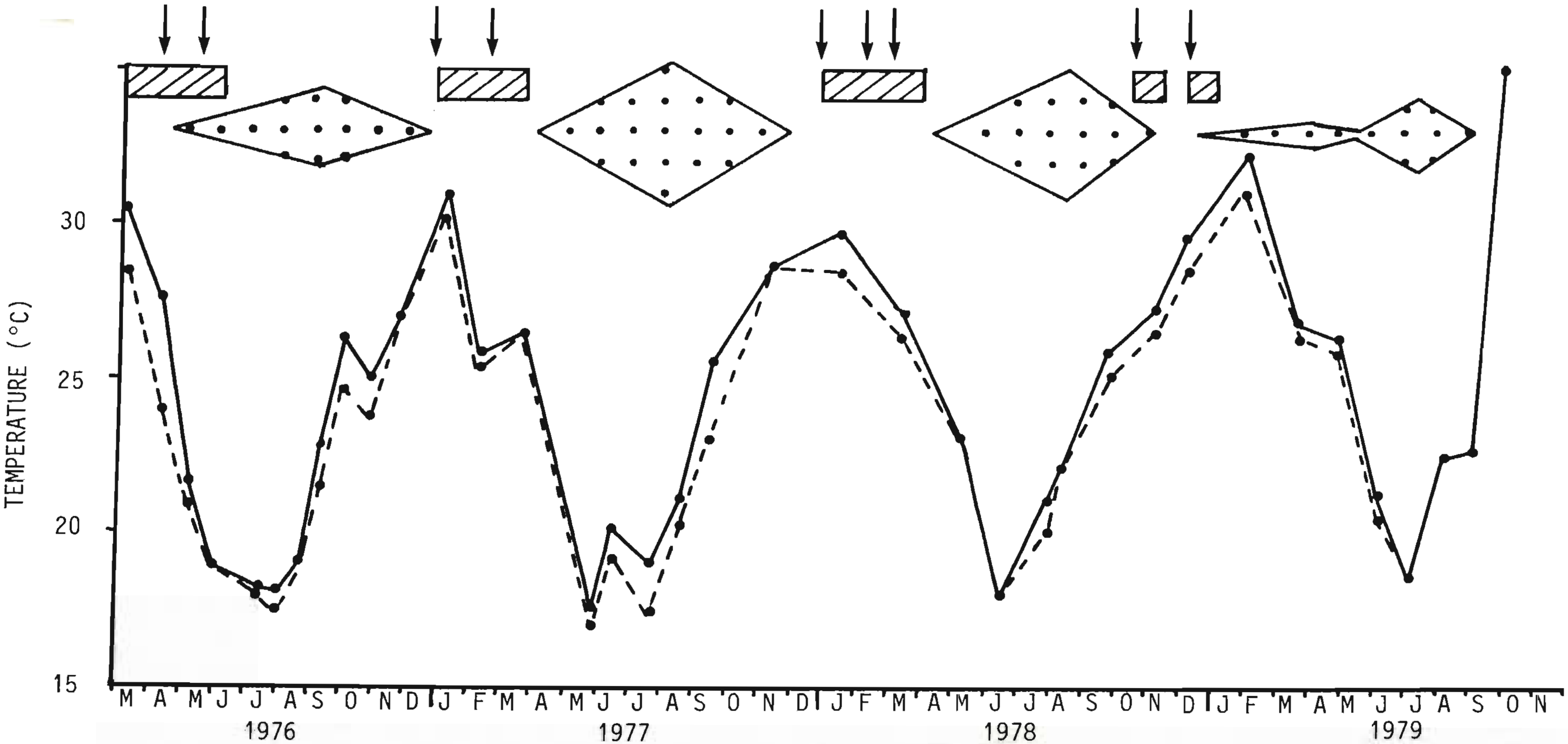


Figure 3.3 Midday water temperature in Tete pan during the study period. Stipled areas represent changes in *P. crispus* standing crop; the arrows, approximate start of recorded floods and the hatched area the period during which water level exceeded MRL. Surface temperature, •———• ; Bottom temperature, - - - - - .

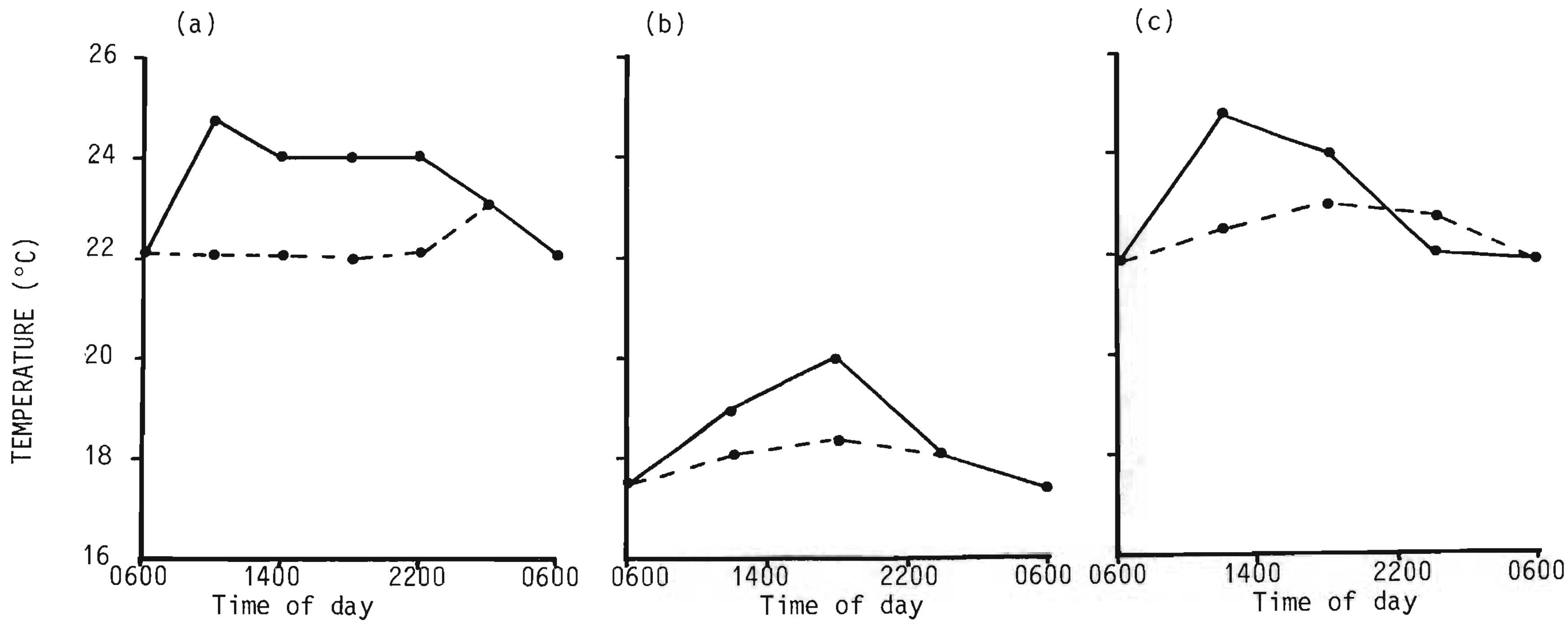


Figure 3.4 Diel variation in temperature (°C) in Tete pan during autumn (13-14/4/76), winter (17-18/8/76) and spring (27-28/10/76) of 1976. Bottom temperature, •- - -•; Surface temperature, •———•.

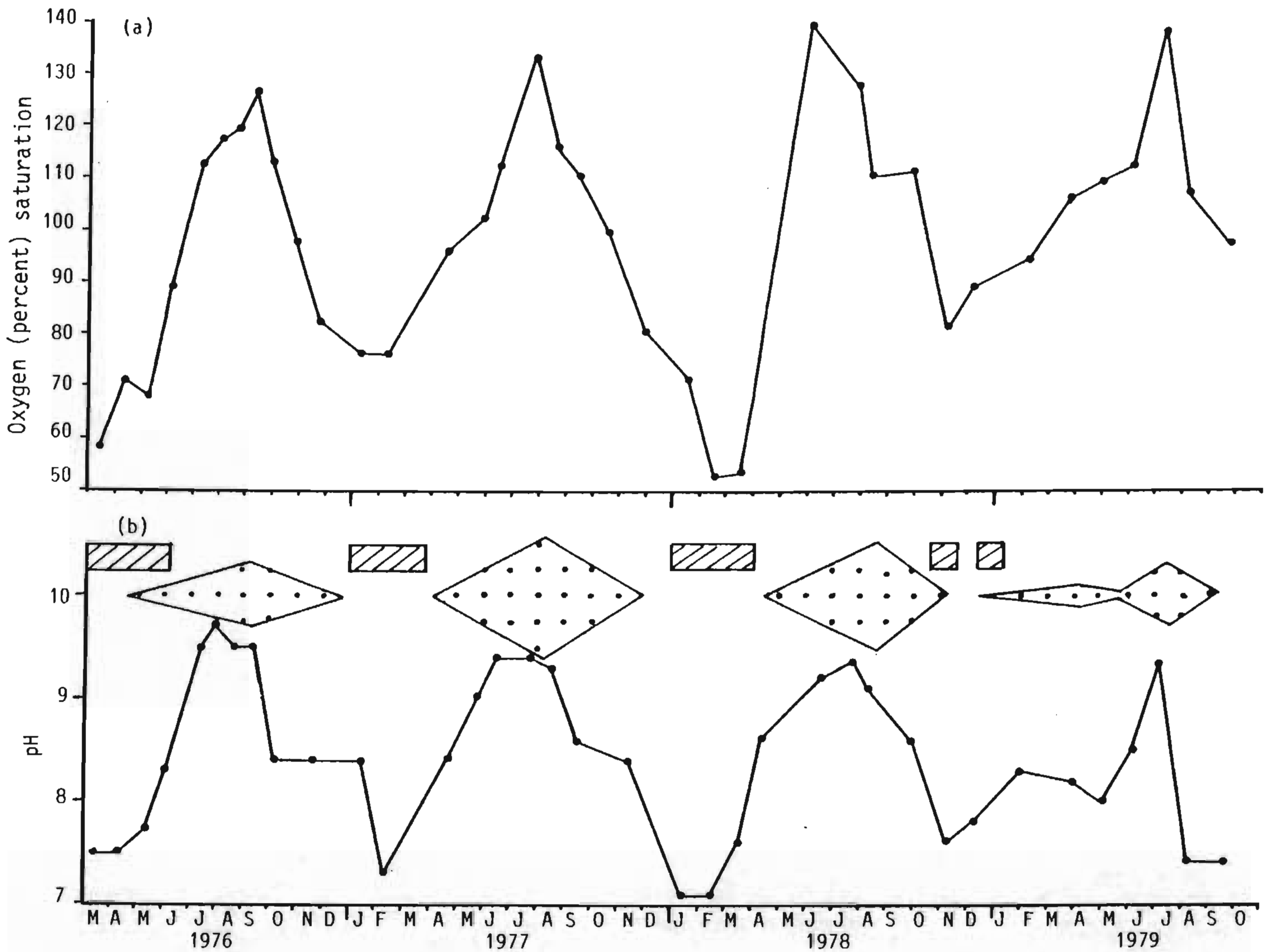


Figure 3.5 Changes in oxygen saturation (a) and pH (b) in Tete pan. Stipled areas represent changes in *P. crispus* standing crop and the hatched areas the periods during which water level exceeded MRL.

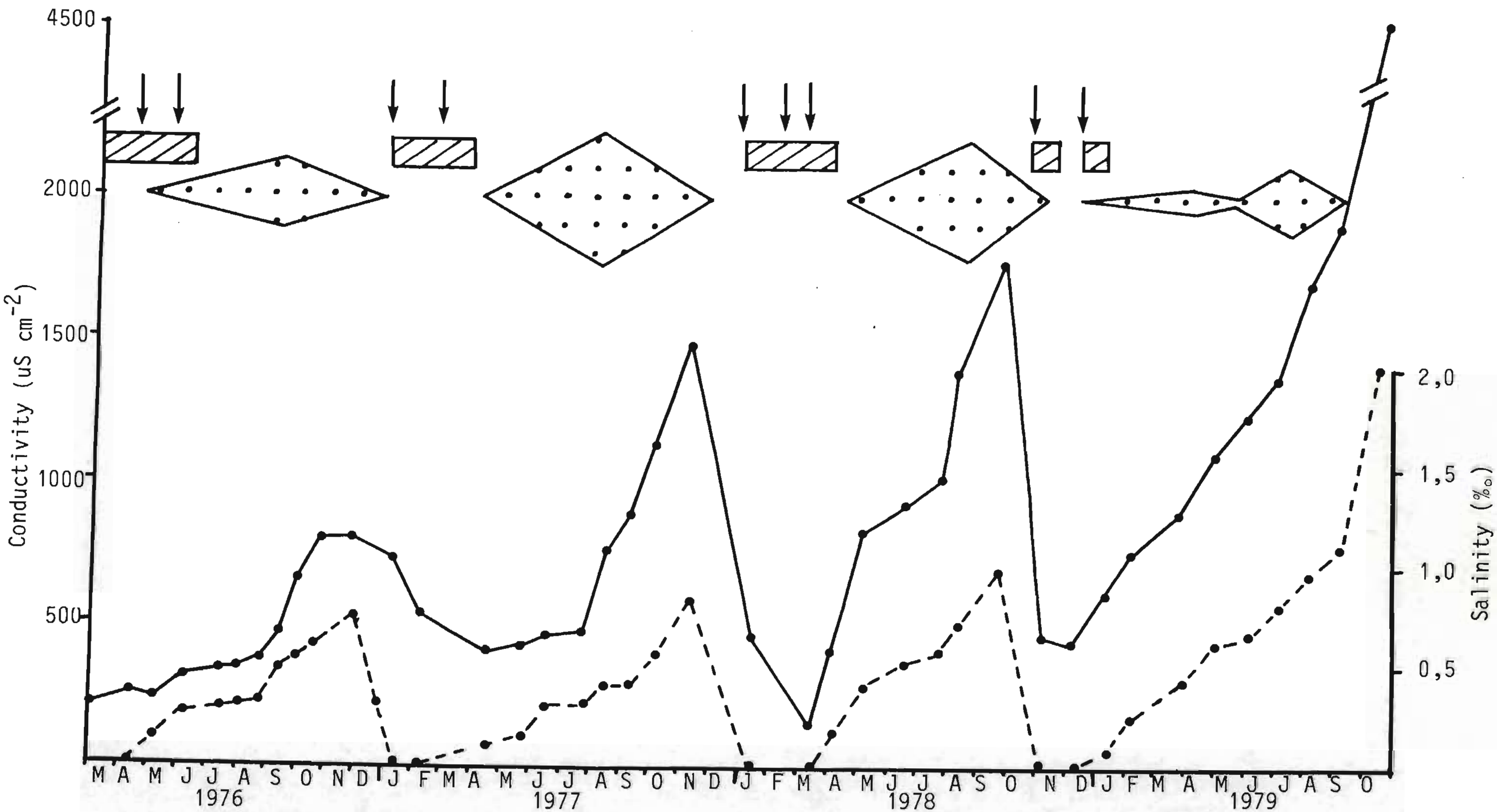


Figure 3.6 Changes in conductivity (•——•) and salinity (•- - -•) in Tete pan during the study period. Stipled areas represent changes in *P. crispus* standing crop; the arrows approximate start of recorded floods and the hatched area the period during which water level exceeded MRL.

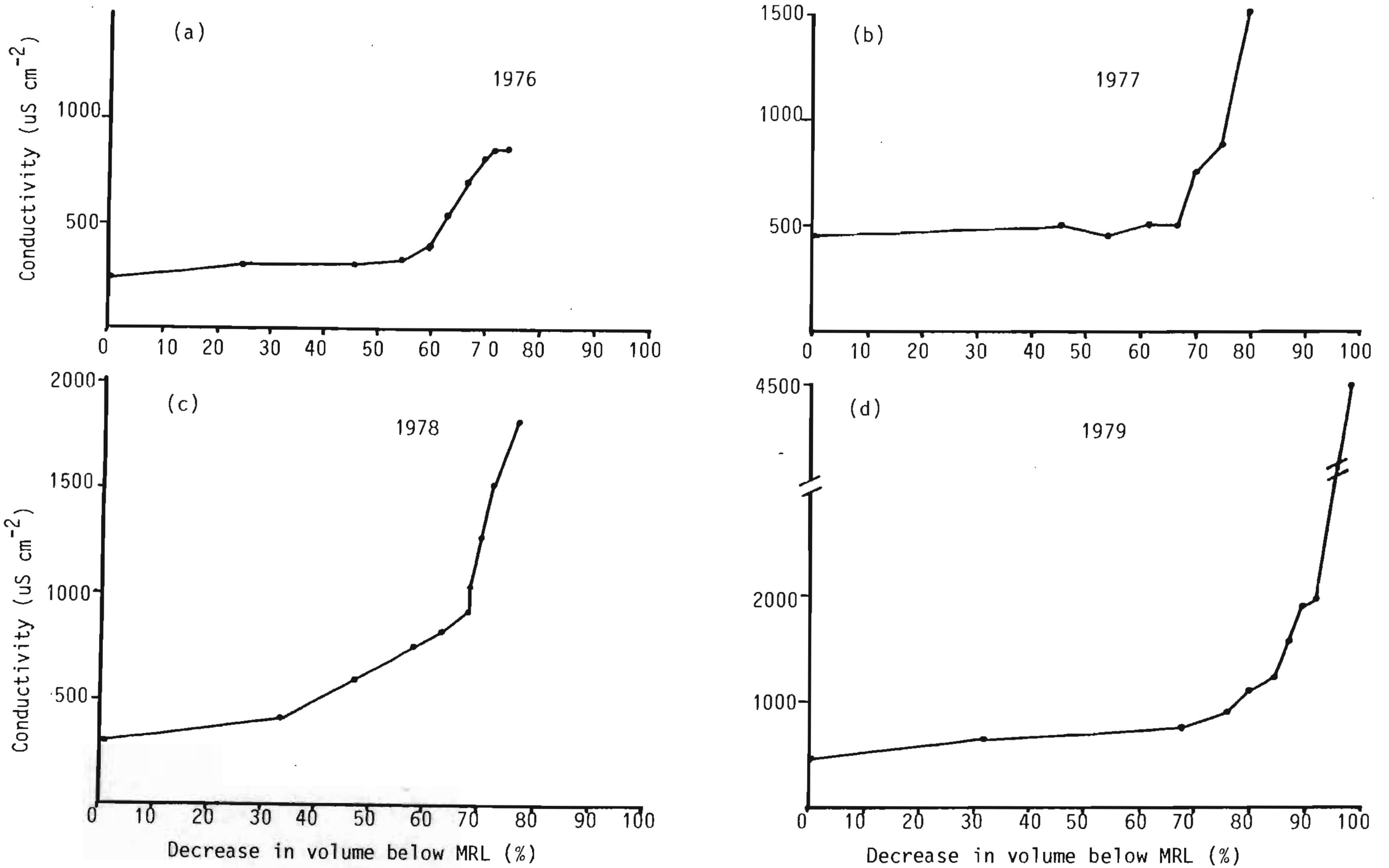


Figure 3.7 Change in conductivity as a function of volume change in Tete pan during the study period.

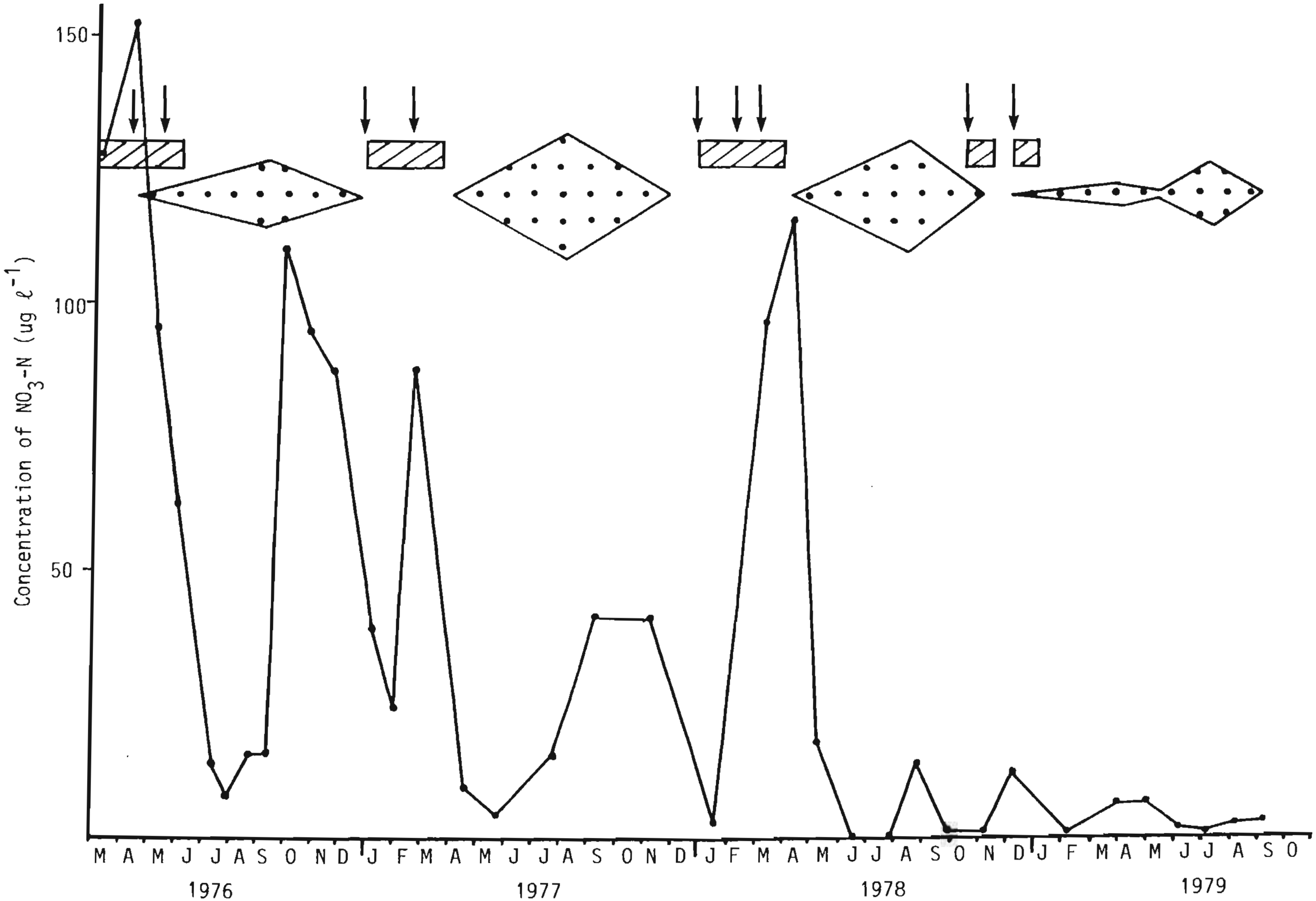


Figure 3.8 Change in the concentration of nitrate nitrogen (NO_3-N) in Tete pan. Stipled areas represent changes in *P. crispus* standing crop; the arrows, approximate start of recorded floods and the hatched areas the periods during which water level exceeded MRL.

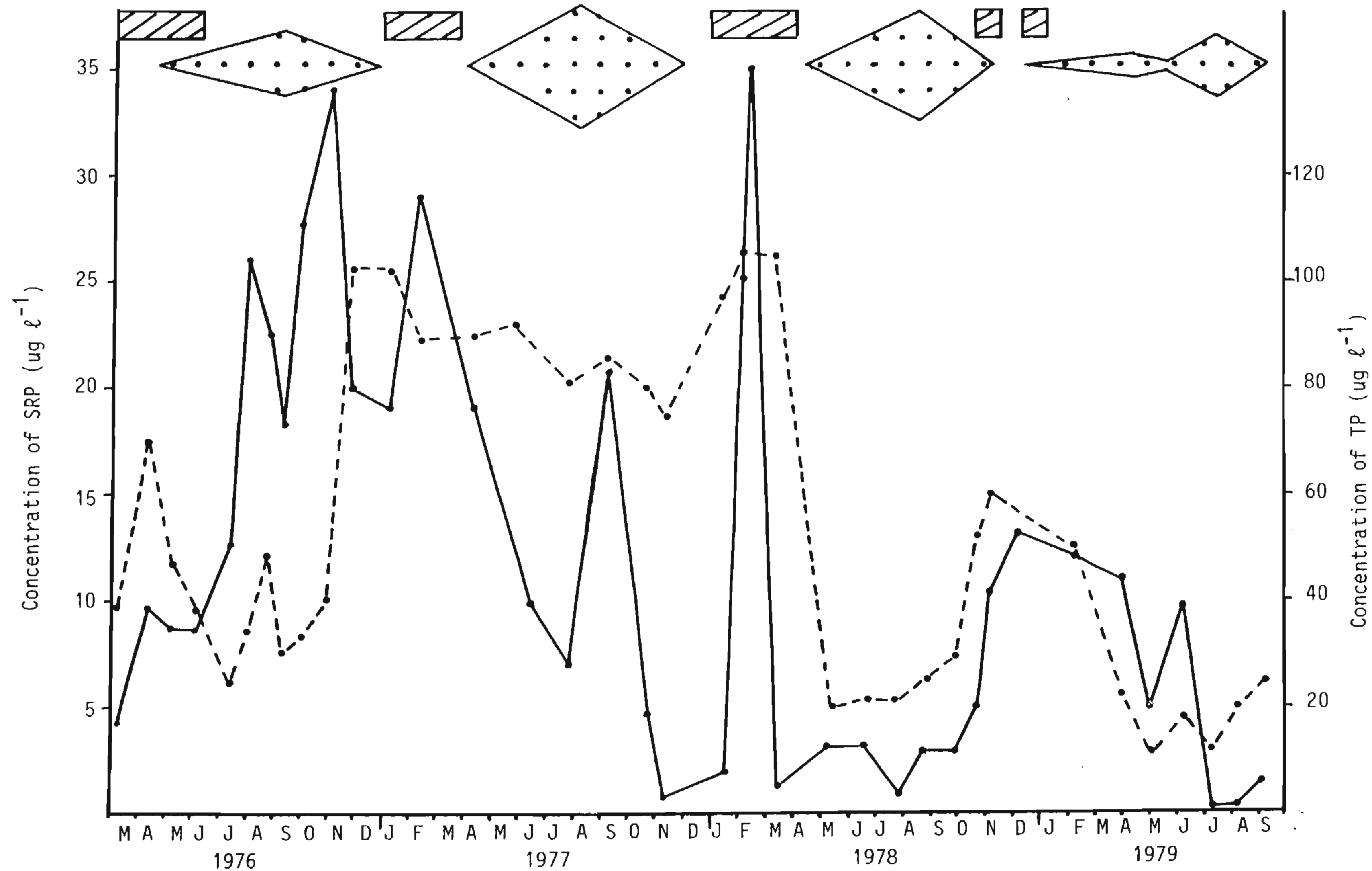


Figure 3.9 Change in concentration of soluble reactive phosphorus (SRP•——•) and total phosphorus (TP•– – –•) in Tete pan during the study period. Stipled areas represent changes in *P. crispus* standing crop and the hatched areas the periods during which water level exceeded MRL.

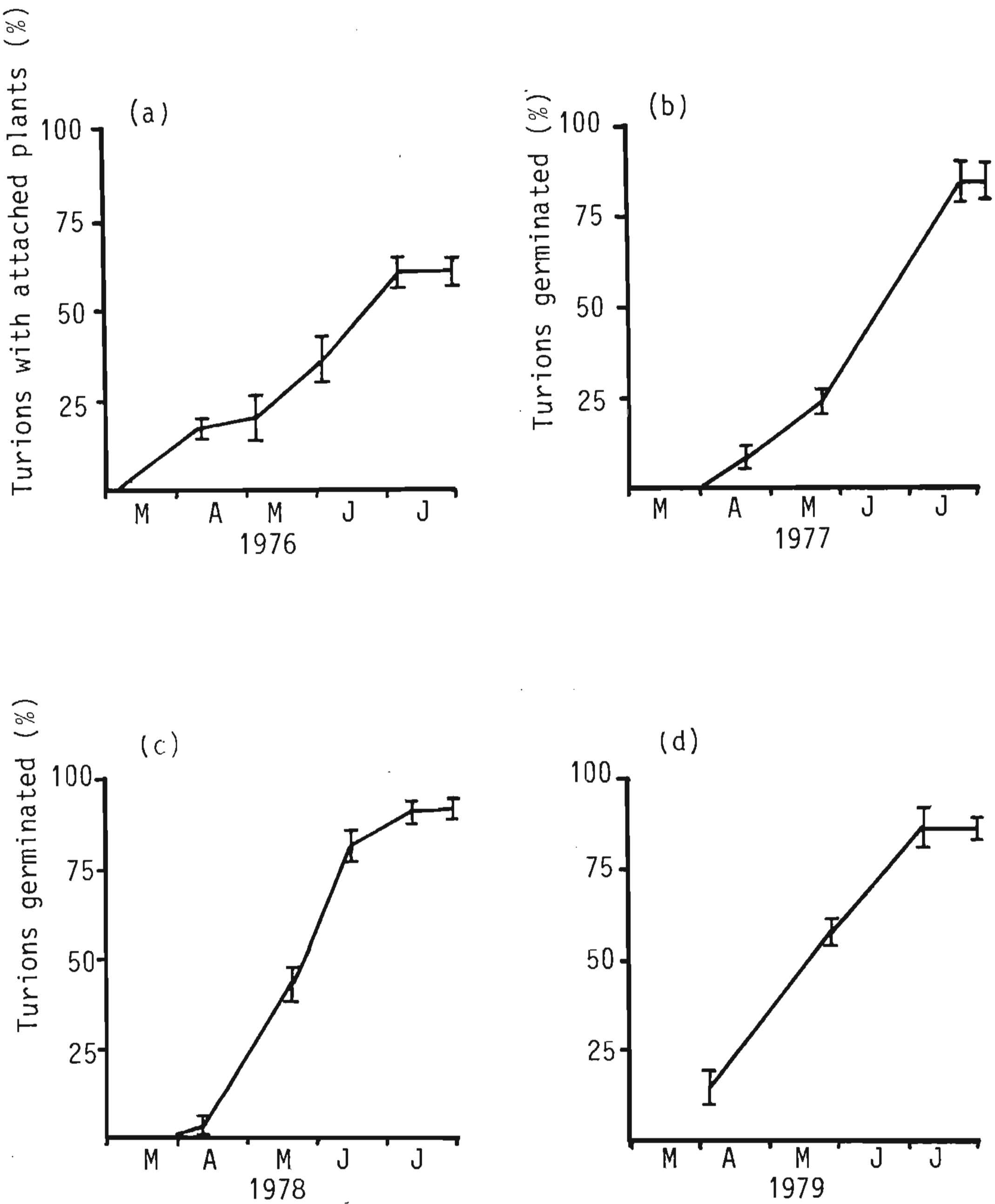


Figure 4.1 Turion germination in the field. During 1976 this was expressed as the number of turions in the sediment with attached plants but in other years as percent germination (See text pg.70 for details).
I = 1 standard error of the mean.

Table 4.1 The effects of temperature and light on germination of *Potamogeton crispus* turions. Results are expressed as mean percent germination of five replicates per treatment.

TEMP °C	% GERMINATION LIGHT	% GERMINATION DARK	
15	58.0	51.0	NS
20	41.0	33.0	NS
25	29.0	16.0	*
30	0.0	0.0	
LDS $p = 0.01$	21.88	12.08	

LSD = Least significant difference between means

* Germination significantly different in the light and dark as tested by paired t test ($p = 0.05$)

NS Not significantly affected by light conditions

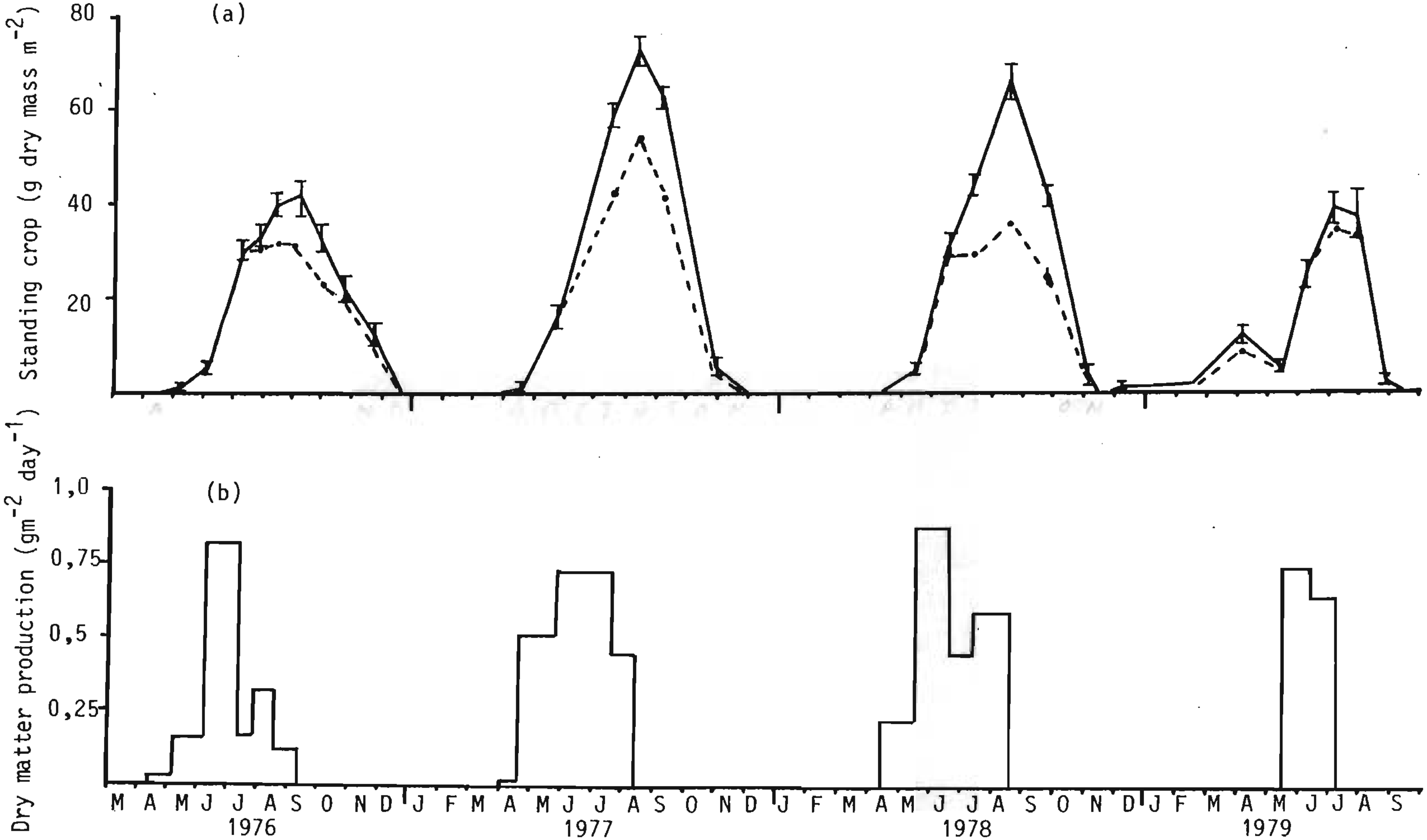


Figure 4.2 Dry matter standing crop (a) and production (b) of *P. crispus* in Tete pan during the study period. In (a) solid line (———•) = total standing crop and dotted line (•- - -•) = non-reproductive shoot material. I = ± 1 standard error of the mean.

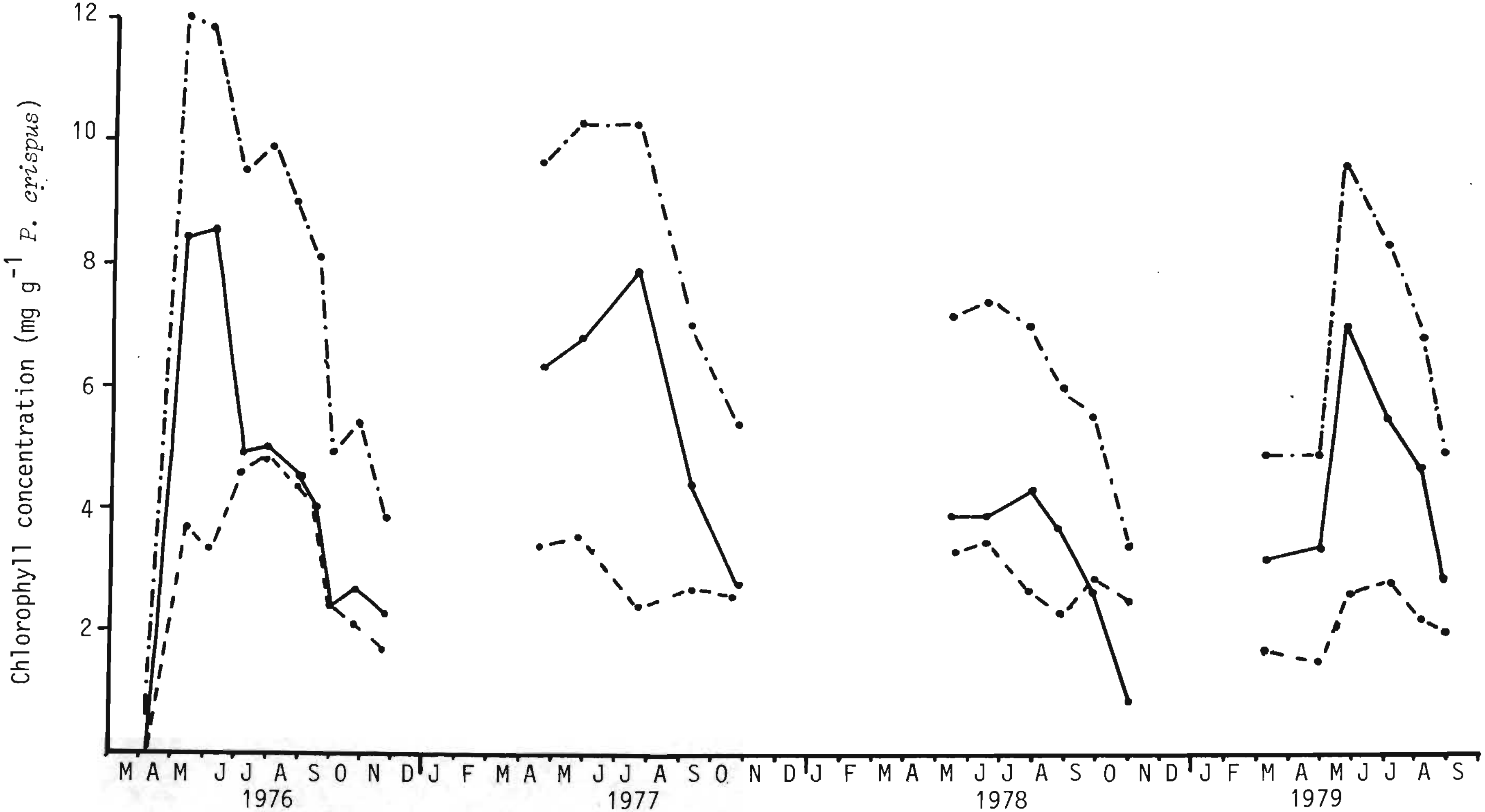


Figure 4.3 Changes in concentration of chlorophyll (chl a = ———; chl b = – – – –; chl a + b = —·—) in *P. crispus* leaves during the study period. Note that in April 1976 young plants contained no measurable chlorophyll.

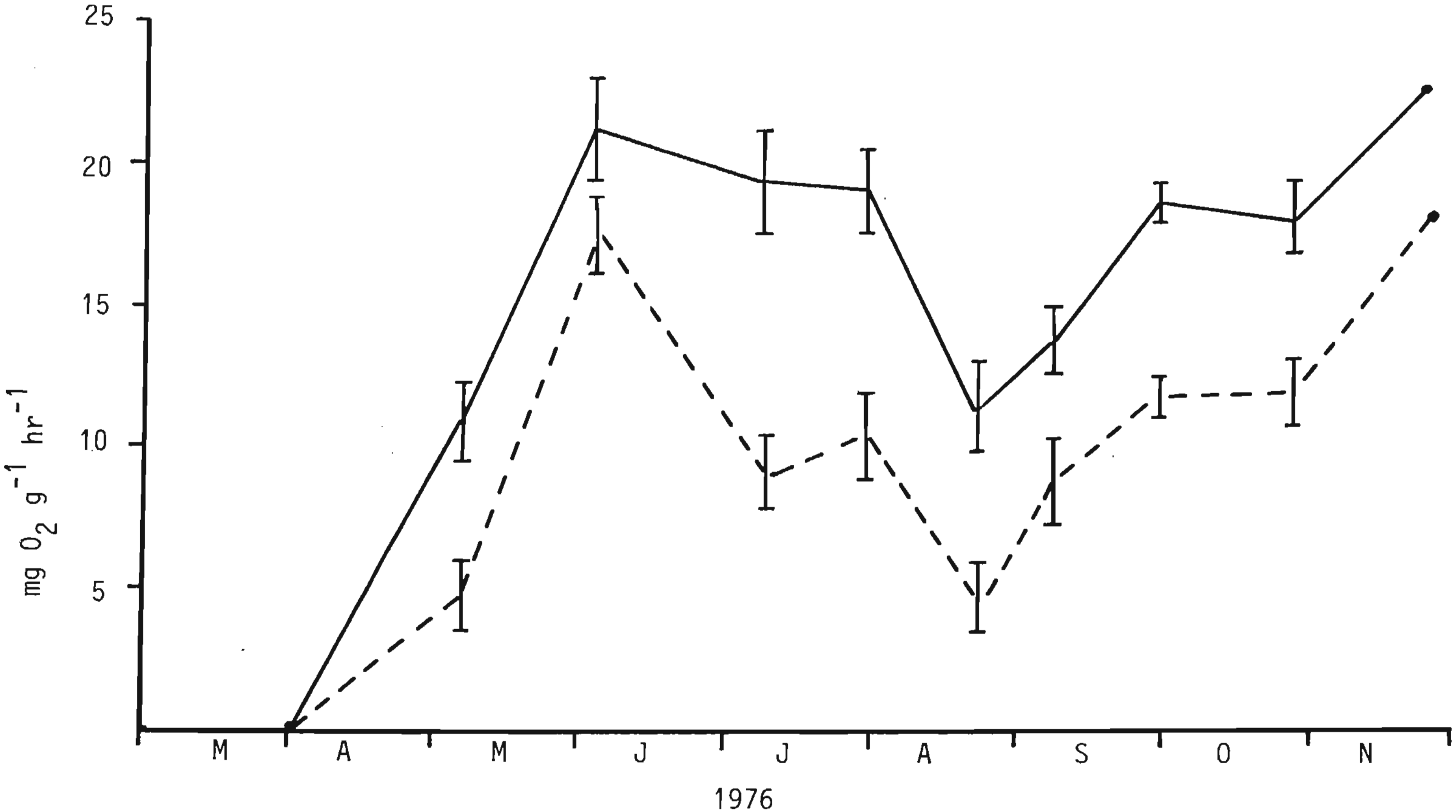


Figure 4.4 The rate of oxygen production (gross ——— ; net - - - -) per unit dry mass of *P. crispus* shoot tips incubated at their natural depth in Tete pan during 1976.
Vertical bars = 1 standard error of the mean.

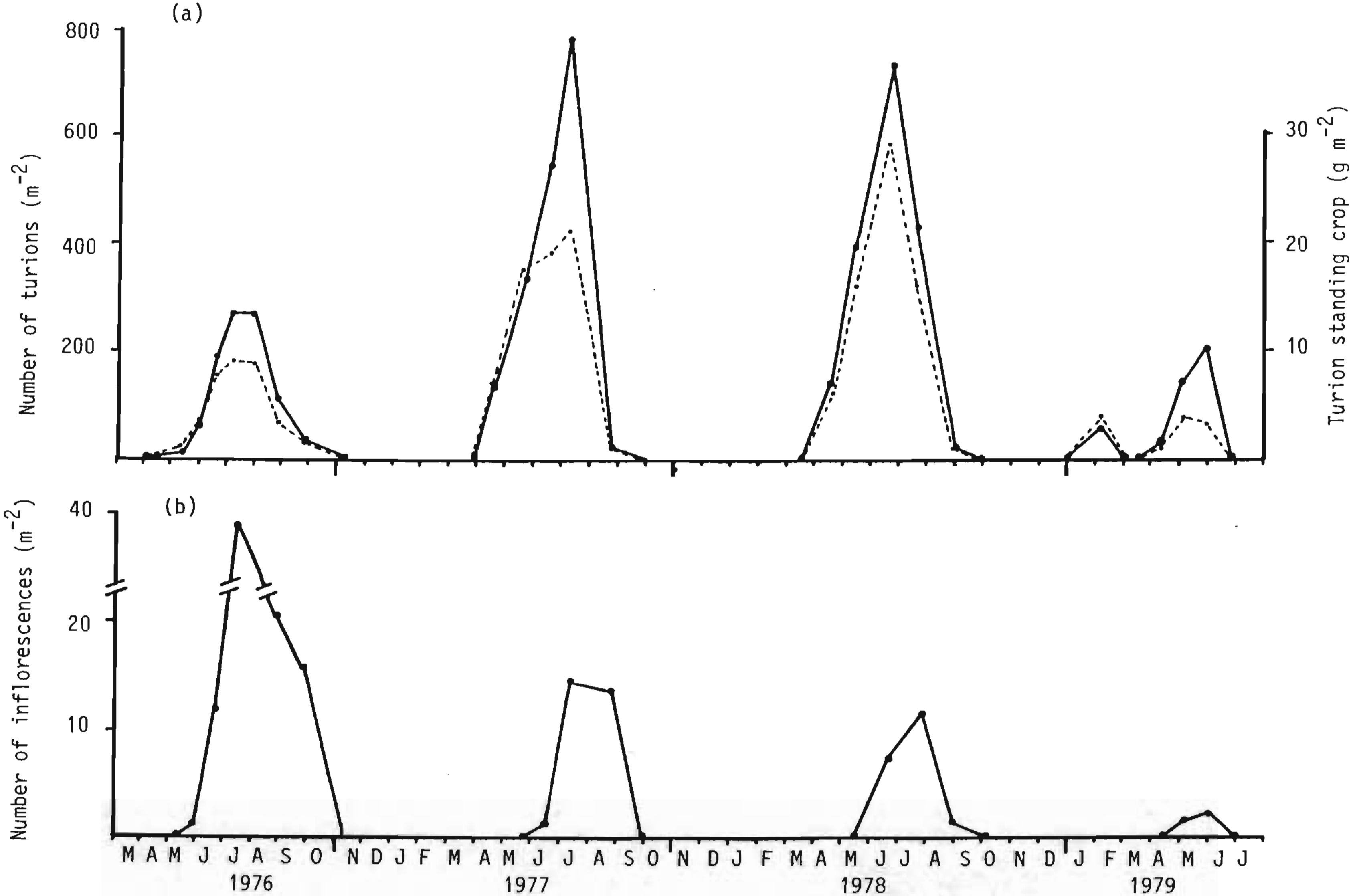


Figure 4.5 Number (•——•) and standing crop (•– – –•) of turions and number (•——•) of inflorescences on *P. crispus* in Tete pan during the study period.

Table 4.2 The numbers and mass of achenes and turions (m^{-2}) on the sediment of Tete pan at the beginning of each winter growing season (95% confidence limits in parenthesis) and the approximate achene production during that season.

YEAR	TURIONS (m^{-2})		ACHENES (m^{-2})		APPROX. ACHENE PROD. (N° m^{-2})
	Numbers	Mass (g)	Numbers	Mass (g)	
1976	1129	40.4	1445	3.9	561
	(± 195)	(± 7.0)	(± 209)	(± 0.6)	
1977	1317	36.9	1955	3.3	240
	(± 169)	(± 4.7)	(± 376)	(± 0.6)	
1978	1739	57.2	1972	3.9	180
	(± 262)	(± 8.4)	(± 380)	(± 0.7)	
1979	2100	60.0	1006	2.7	40
	(± 273)	(± 8.0)	(± 144)	(± 0.39)	

Table 4.3 Changes in concentration (% dry mass) of ash, phosphorus and nitrogen in the standing crop of *Potamogeton crispus* in Tete pan during the period 1976 - 1979

DATE	ASH	P	N	DATE	ASH	P	N
6/5/76	17.9	0.7	3.3	18/5/78	14.6	0.5	2.6
3/6/76	16.3	0.5	2.7	16/6/78	15.0	0.5	2.5
10/7/76	15.6	0.7	2.5	11/7/78	14.4	0.4	2.6
28/7/76	16.5	0.9	2.6	22/8/78	13.2	0.3	2.0
19/8/76	15.1	0.6	2.9	23/9/78	12.1	0.2	1.9
8/9/76	12.9	0.5	2.4	30/10/78	12.0	0.2	1.5
29/9/76	12.1	0.4	1.8				
26/10/76	13.3	0.3	1.6				
24/11/76	12.0	0.3	1.4				
20/4/77	16.9	0.4	2.5	18/5/79	15.1	0.13	1.4
22/5/77	16.4	0.4	2.5	12/6/79	9.5	0.08	1.4
20/7/77	17.0	0.4	2.1	3/7/79	14.1	0.11	1.5
15/8/77	15.5	0.3	1.9	31/7/79	12.4	0.11	1.5
3/9/77	14.9	0.2	1.5	28/8/79	12.2	0.11	1.4
15/10/77	13.6	0.3	1.7				

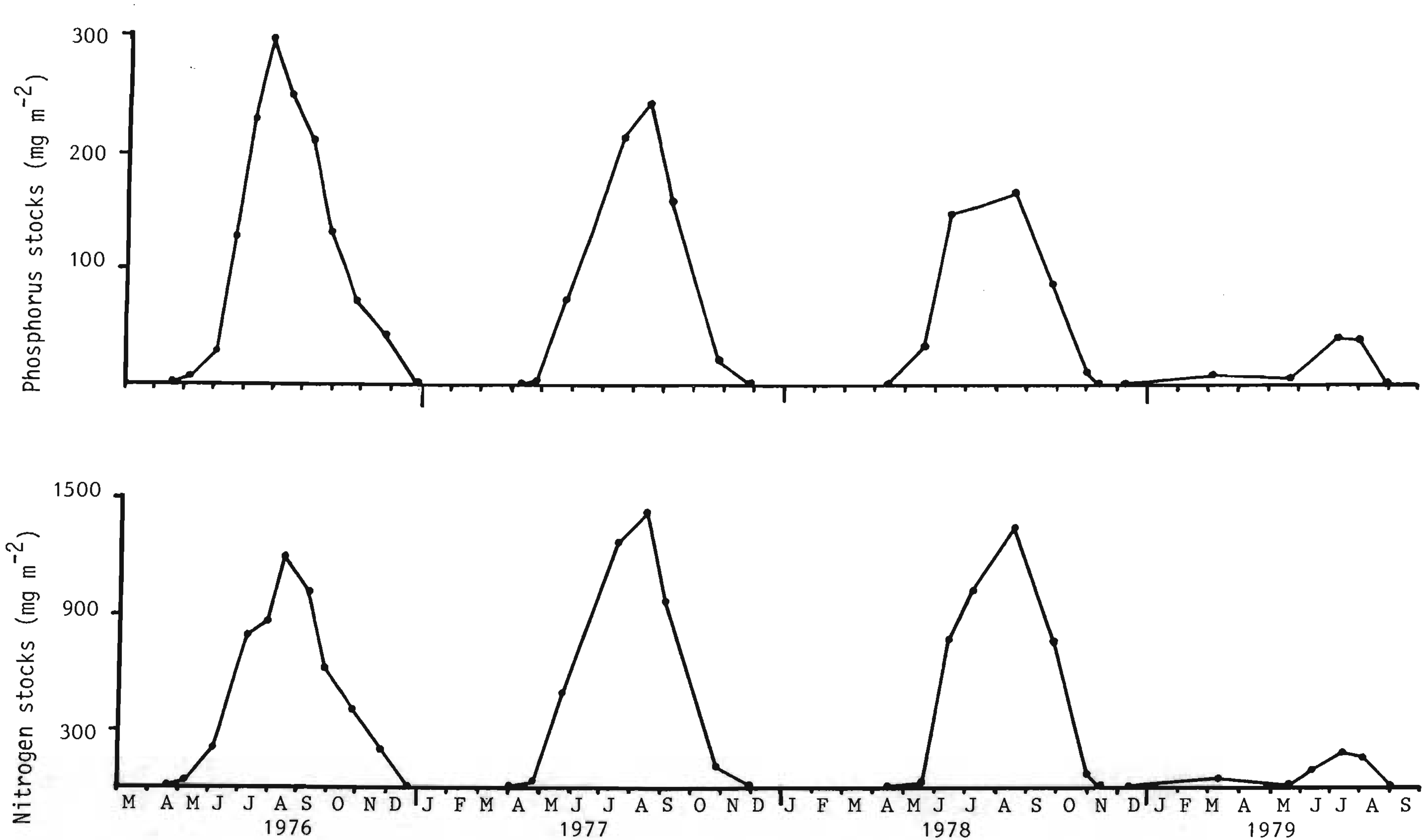


Figure 4.6 Standing stocks of phosphorus and nitrogen in *P. crispus* from Tete pan during the study period.

Table 4.4 A preliminary mass balance of phosphorus (as Total P, kg) and nitrogen (as $NO_3^=$ -N in the water and Total N in plants, kg) in the plants and water of Tete pan during periods between summer floods. The difference between mass of nutrients in the water at MRL (when the pan and river lost contact) and the next flood represents that transferred to other components of the system.

							NON-REPRODUCTIVE *P. CRISPUS*			
	WATER AT MRL		WATER AT FLOOD		TRANSFERRED		AT MAX. ST. CROP		AT FLOODS	
	TP	$NO_3^=$ -N	TP	$NO_3^=$ -N	TP	$NO_3^=$ -N	TP	TN	TP	TN
1976	42	82	35	21	7	61	152	730	0	0
1977	99	17	19	13	80	5	158	905	0	0
1978	88	127	18	1	80	126	81	647	44	400
1979	58	10	-	-	-	-	33	145	0	0

Table 4.5 Estimates of annual net production and production:biomass (P/B) ratio of *P. crispus* in Tete pan from 1976 to 1978

YEAR	NET PRODUCTION $g\ m^{-2}\ a^{-1}$					MAX. ST. CROP $g\ m^{-2}$	P/B
	Non-Repro.	Root	Turion	Achene	Total		
1976	68	3	48	1.1	120.1	43	2.8
1977	107	5	75	0.5	187.5	72	2.6
1978	74	4	81	0.4	159.4	64	2.5

Table 4.6 Comparisons of estimates for seasonal maximum standing crop, annual net production and production:biomass ratio (P/B) of different submerged macrophyte communities

Locality	Species	Max. St. crop g m^{-2}	Net Prod. g m^{-2} yr^{-1}	P/B	Source
Lawrence Lake Michigan	*Scirpus*	338	565	1.7	Rich, Wetzel and Thuy (1971)
	Chara	110	155	1.4	
	Annuals	130	199	1.5	
Borax Lake California	*Ruppia*	60	64	1.1	Wetzel (1964)
Swartvlei S.E. Cape	*P. pectinatus*	1952	2506	1.2	Howard-Williams (1978)

Table 5.1 General characteristics of the eleven floodplain pans during winter and spring when duck populations are largest. Information from Colvin (1971), Musil (1972) and Rogers and Breen (1981b)

PAN	*P. crispus* coverage	Depth at MRL	Area	Turbidity	Conduct.	‰ Salinity	Susceptibility to drought	Other aquatic vegetation coverage
Tete	Abundant	1.5	100 ha	Clear	900	1‰	Med	2%
Mtikheni	Abundant	1.5	25	Clear	$<$500	$<$1	Med	5%
Mhlolo	Abundant	2.5	60	Clear	2100	2.5‰	Low	20%*
Sivunguvungu	Abundant	2.5	40	Clear	235	$<$1	Med	5%
Bumbe	Abundant	2.0	60	Clear	$<$500	$<$1	Med	5%
Ntujanene	Abundant	1.2	15	Clear	$<$500	$<$1	High	25%*
		TOTAL	300 ha					
Mzinyeni	Sparse	1.8	80	V. Turbid	215	$<$1	Low	20%
Mandlankunzi	Sparse	2.5	250	Turbid	260	$<$1	Low	15%
Kangazini	Sparse	0.5	50	Variable	400	$<$1	High	0
		TOTAL	380 ha					
Namanini	None	1 m	65 ha	Turbid	$<$500	$<$1	High	0
Sokunti	None	4.5	120	V. Turbid	290	$<$1	Low	$<$1%
		TOTAL	185 ha					

Susceptibility to drought

Low = unlikely to dry out even during exceptional drought
Med. = will dry out only during protracted drought
High = usually becomes very shallow each year and frequently dries out

* Includes areas where *P. crispus* and floating leaved plants occur together

Table 5.2 Species composition (proportion of sightings) and abundance of waterfowl on 11 different pans of the Pongolo flood-plain, 1978. Pans were grouped according to the abundance of *P. crispus* during winter and spring as in Table 5.1.
P = < 0.1% or 0.1 birds ha^{-1}. Waterfowl nomenclature follows Mclachlan and Liversidge (1978)

Species	Number of sightings	% Total sightings	Number of birds per ha. *P. crispus* at Max. st. crop		
			Abundant	Sparse	None
White-faced Whistling Duck (*Dendrocygna viduata (L.)*)	18504	73.5	48.6	8.9	2.8
Spur-wing Goose (*Plectropterus gambensis (L.)*)	2363	9.4	3.8	4.0	0.1
Yellow Billed Duck (*Anas undulata, Dubois*)	1097	4.4	2.5	0.7	0.7
Knob-billed Duck (*Sarkidornis melanotos (Pennant)*)	1010	4.0	3.0	0.4	P
Pygmy Goose (*Nettopus auritus (Boddaert)*)	619	2.6	1.3	0.8	0
Red-billed Teal (*Anas erythrorhyncha, Gmelin)*)	525	2. 2	0.8	0.4	0.9
Egyptian Goose (*Alopchen aegyptiacus (L.)*)	347	1.4	0.6	0.2	0.2
Fulvous Whistling Duck (*Dendrocygna bicolor (Viellot)*)	312	1.3	P	0.8	0
Hottentot Teal (*Anas hottentota, Eyton*)	216	0.9	0.5	0.1	0.2
Red-eyed Pochard (*Netta erythrophthalma (Weid)*)	29	0.1	0.1	P	0
Cape Teal (*Anas capensis, Gmelin*)	1	P	0	0	P
White-backed Duck (*Thalassornis leuconatus, Eyton*)	1	P	P	0	0
TOTALS	25209	99.8%	71.2 ha^{-1}	16.1 ha^{-1}	4.9ha^{-1}

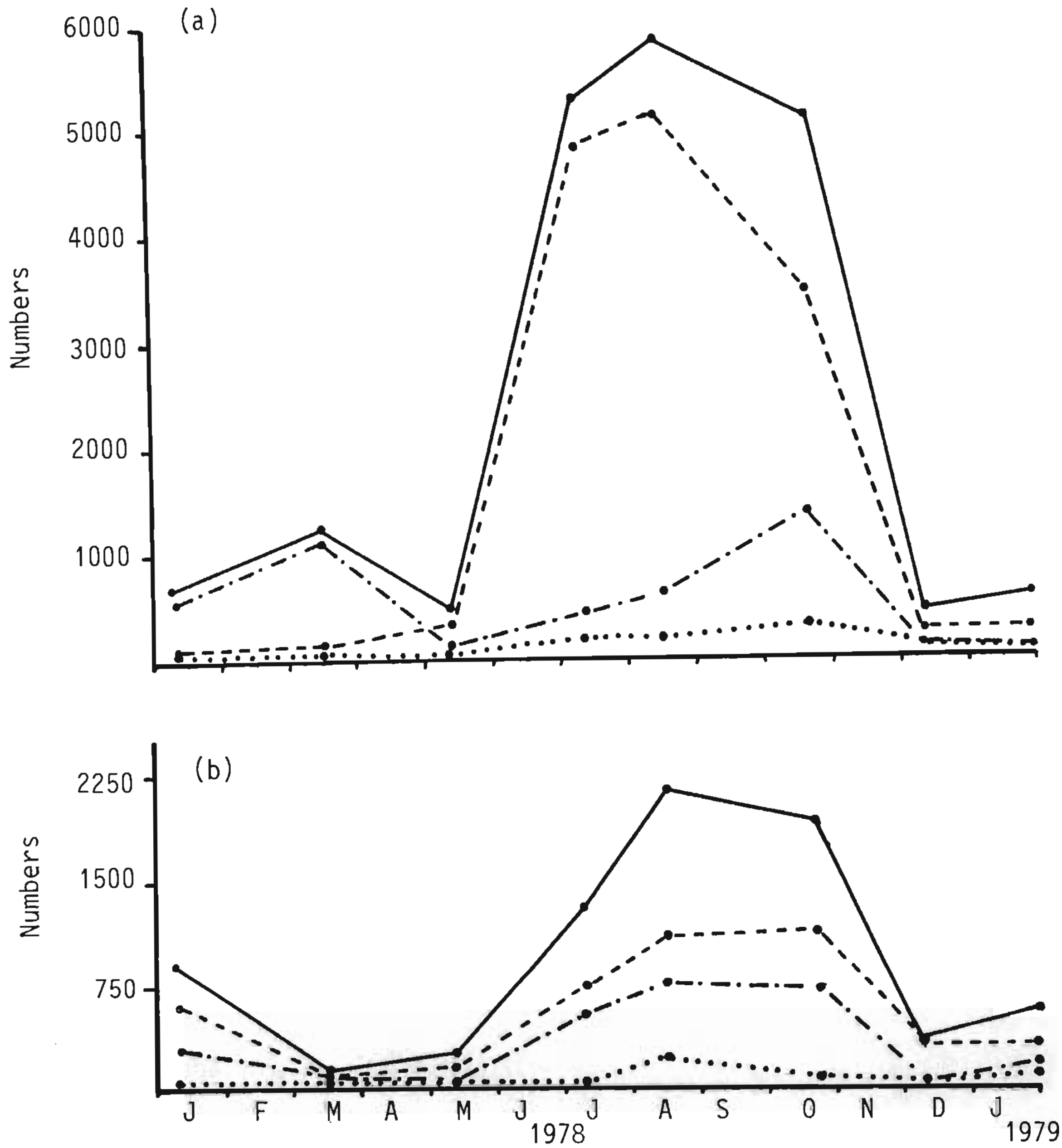


Figure 5.1 The numbers of White-faced Duck (a) and total numbers of birds of other waterfowl species (b) on 11 different pans of the Pongolo floodplain during the period January 1978 through January 1979. Number of birds on pans with : Abundant *P. crispus* = ; sparse *P. crispus* = ; no *P. crispus* = . Total on all 11 pans = .

Table 5.3 Species composition of waterfowl populations at Tete Pan during the period 1976 - 1978 expressed as a percentage of the total sightings for each year.
P = $< 0.1\%$

DUCK SPECIES	1976	1977	1978	1979
White-faced Duck	80.9	91.1	88.2	42.9
Spur-wing Goose	0.1	1.3	2.7	11.3
Yellow-billed Duck	0.3	1.0	1.4	20.9
Knob-billed Duck	14.9	4.4	4.5	2.2
Pygmy Goose	2.8	0.5	0.9	0
Red-billed Teal	0.3	0.4	0.7	13.2
Egyptian Goose	0.7	1.1	1.0	8.8
Fulvous Whistling Duck	P	0.3	P	0.1
Hottentot Teal	P	P	0.9	P
Red-eyed Pochard	-	-	P	0.1
Cape Shoveler	-	-	-	0.7

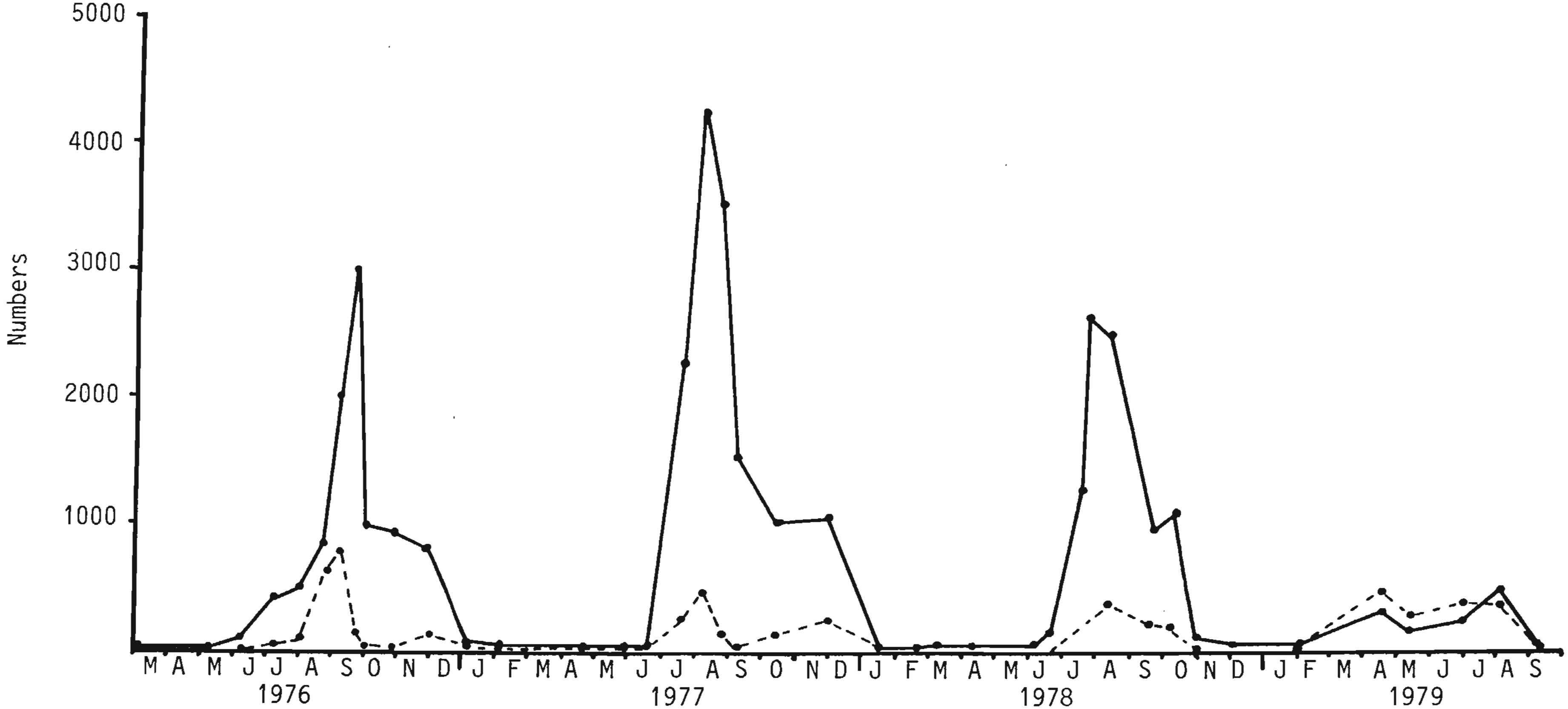


Figure 5.2 Numbers of White-faced Duck (•——•) and total number of birds of other waterfowl species (•- - - -•) on Tete pan during the study period.

Table 5.4 Composition (Aggregate %) and frequency of occurence of food of 56 White-faced Duck shot on 11 different pans on the Pongolo floodplain between January 1978 and April 1979 inclusive.

Food Species	Organ	Winter/spring		Summer/Autumn	
		Agg.%	Freq.%	Agg.%	Freq.%
Potamogeton crispus	Turion	63.5	83	8.0	9
Potamogeton crispus	Achene	3.6	17	P	1
Aquatic Insect Larvae	-	0.4	29	3.4	6
Melanoides tuberculata Müller (Mollusca)	-	P	4	4.1	6
Terrestrial Insects	-	0	0	7.8	16
Heliotropium indicum L.	Nutlet	0	0	42.0	47
Polygonum salicifolium Willd.	Achene	0	0	6.4	16
Polygonum senegalense Meisn.	Achene	0	0	9.4	13
Cyperus spp.	Achene	14.1	17	5.3	9
Ceratophyllum demersum L.	Achene	0	0	0.5	3
Echinochloa pyramidalis (Lam.) Hitch. and Chase	Caryopsis	8.2	13	6.3	6
Nymphaea spp.	Seed	2.5	4	1.1	3
Nymphaea spp.	Tuber	7.0	13	3.1	3
Legume sp.	Legume	P	4	P	3
Sp. D.	Seed	0	0	3.2	9
Eriochloa sp.	Caryopsis	0	0	P	6
TOTAL		99.5		100.6	
N =		24		32	

Table 5.5 Composition (Aggregate %), frequency of occurence and mass of food of White-faced Duck shot on Tete pan between April 1976 and February 1977 inclusive.

CROP CONTENTS		MONTH											TOTAL	TOTAL
SPECIES	ORGAN	A	M	J	J_5	J_{29}	A	S	O	N	J	F	OCC*	MASS (g)
Nymphaea sp.	Tubers				1.0								1	0.17
Nymphaea sp	Seed	P	22.8	14.5	15.4								5	5.71
Echinochloa pyramidalis	Caryopsis	74.5	1.3	15.1	5.0	2.8							9	7.68
Polygonum senegalense	Achène	25.4	74.9	63.1	20.1	0.4	2.0				0.2	16.6	20	0.07
Potamogeton crispus	Turion			0.3	38.8	83.3	96.2	97.8	99.6	80.0	47.3	53.1	36	7.27
Aquatic Insect Larvae	-		0.3	0.7	0.2	13.2	0.1	0.4	0.1	P	0.8	8.1	14	0.4
Potamogeton crispus	Achene		0.6	6.3	18.6		0.2	1.8	0.3	19.7			13	0.2
Cyperus spp.	Achene	0.1			0.9	0.1					5.0	0.2	7	0.4
Heliotropium indicum	Nutlet										42.8	14.0	2	2.73
Sp. F	Achene										0.7	0.3	2	0.05
Legume	Legume											7.7	1	0.11
Najas pectinata	Leaf Stem									P	1.6		2	0.02
Chara sp.	Filaments									0.2	1.5		2	0.02
Sp. D						0.1	1.5						2	0.09
NO OF BIRDS		5	7	5	6	5	6	4	8	5	2	4		
MEAN CROP MASS (g)		0.95	0.18	1.01	0.47	1.46	3.27	4.37	3.15	2.49	1.72	0.58		

P = Present at < 0.1% of the total composition * No of occurrences in 57 birds

Table 5.6 The winter diet (Aggregate %) of some important waterfowl species on Tete pan during 1978. Three birds of each species were shot and the data presented as the aggregate percentage composition.

Duck Species	Food Items %					
	P. crispus Turions	*P. crispus* Achenes	Aquatic Insects	*Bulinus natalensis*	Ostracods	*C. dactylon* leaves
Knob-billed Duck	99.9	-	0.1	-	-	-
Spur-winged Goose	89.1	10.7	-	-	-	0.2
Egyptian Goose	95.0	-	0.6	-	-	4.4
Fulvous Whistling Duck	98.8	-	1.2	-	-	-
Hottentot Teal	2.3	-	0.4	94.6	2.3	-

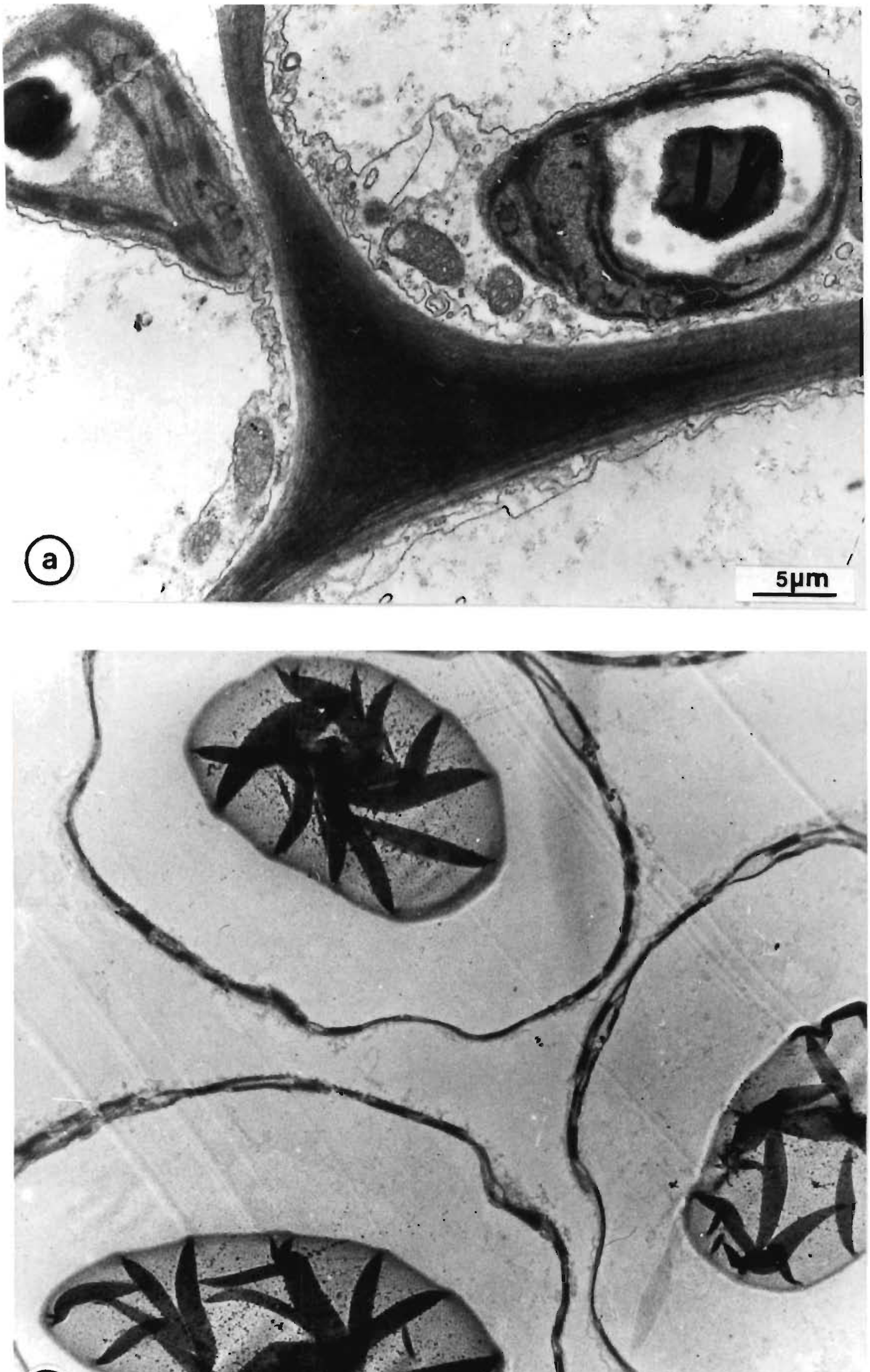
Table 5.7 The nutritional quality of *P. crispus* turions and achenes. Carbohydrate = Total available (non-structural) carbohydrate; Lipids = Ether extraction and A.M.E. = Apparent Metabolizable Energy.

		Turions	Achenes
Total Phosphorus	(%)	0.16	0.20
Total Potassium	(%)	0.95	1.8
Total Calcium	(%)	0.27	0.34
Total Nitrogen	(%)	0.60	0.94
Protein	(%)	3.7	5.9
Carbohydrate	(%)	50.0	18.8
Lipids	(%)	1.5	15.6
Gross Energy	(kj g^{-1})	16.4	18.9
A.M.E.	(kj g^{-1})	12.4	12.3
A.M.E. as % Gross E.		75.5	65.1

Plate 5.1 T/S of turion parenchyma cells showing starch accumulation.

a: Developing turion with a few starch granules in the chloroplasts of each cell

b: In mature turions most of the cell volume was taken up by large starch granules.


a
5µm
b
5µm

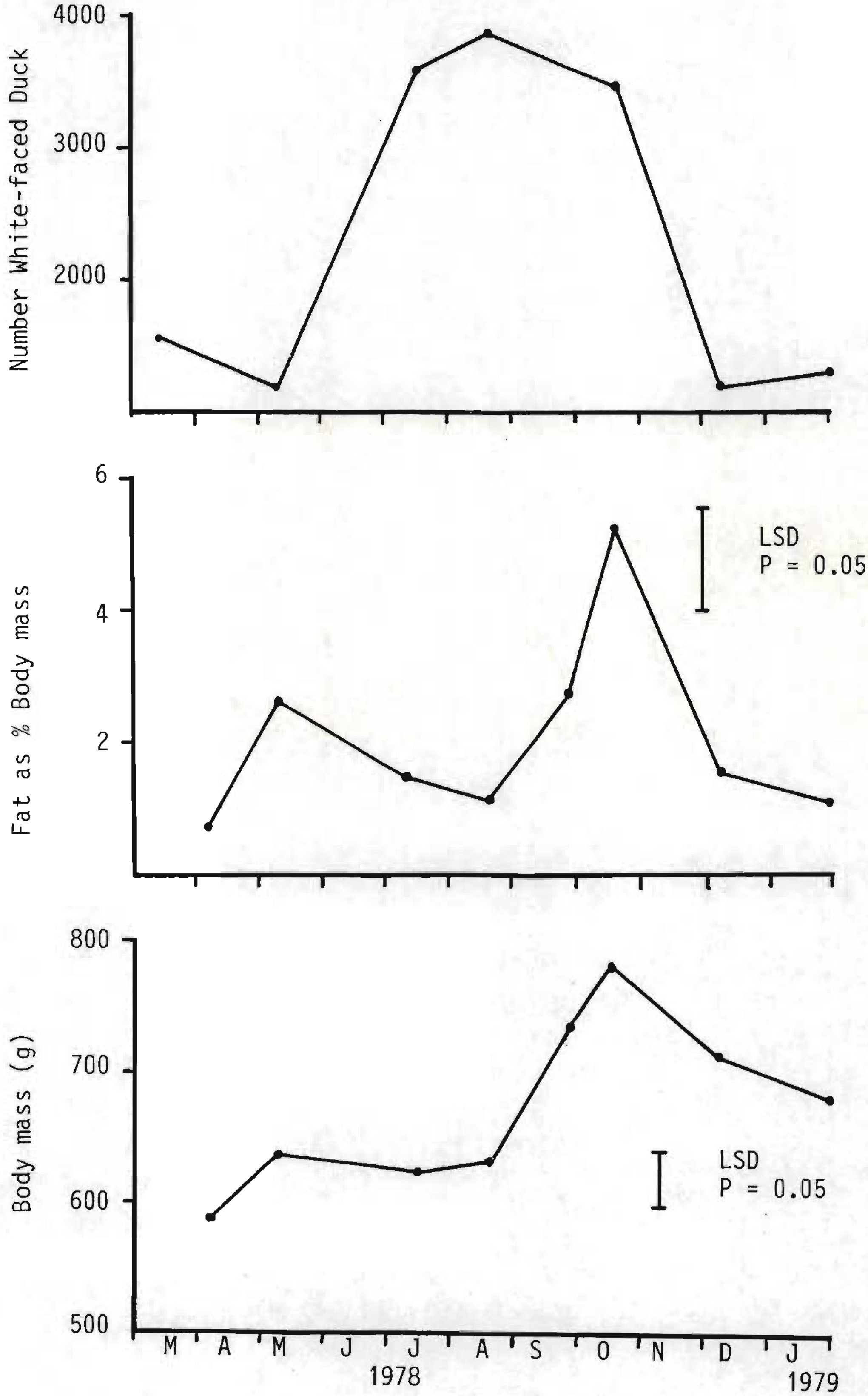


Figure 5.3 Changes in body mass (g) and condition (fat as percent total body mass) of White-faced Duck on the Pongolo floodplain in relation to seasonal change in population size during the period March 1978 to January 1979.

Table 5.8 Numbers and mass (m^{-2}) of turions and achenes inside and outside exclosures in Tete pan after the 1976 *P. crispus* growing season. The significance of differences was tested by the t test of differences between two means (Parker, 1973).

		EXCLOSURE	PAN	SIGNIFICANCE OF DIFFERENCES
Turions (m^{-2})	N°	890	1317	S ($P < 0.001$)
	Mass	30	38	NS ($P > 0.05$)
Achenes (m^{-2})	N°	1543	1955	NS ($P > 0.05$)
	Mass	2.7	3.5	NS ($P > 0.05$)

Table 5.9 Turion consumption by waterfowl on Tete pan (calculated by means of the Wiens-Innis model) in relation to total turion production.

YEAR	Mass turions consumed (g m^{-2})		Turions on sediment (g m^{-2})	Total turion production (g m^{-2})	Percent Turion Production consumed		
	White-faced	Other spp.			White-faced	Other spp.	All spp.
1976	7.9	3.4	36.9	48.2	16.4	7.1	23.5
1977	14.2	4.1	57.2	75.5	18.8	5.4	24.2
1978	10.0	2.1	68.9	81.5	12.3	2.6	14.9
1979	1.8	3.5	-	-	-	-	-

Table 5.10 The change in mean mass (g) of individual turions, calculated as the standing crop divided by the total number per square metre, in Tete pan 1976 -1979.
* indicates the sudden drop in mass discussed in the text.

1976		1977		1978	
Date	$\bar{x}$ Mass	Date	$\bar{x}$ Mass	Date	$\bar{x}$ Mass
4/7	0.051	18/6	0.050	16/6	0.046
29/7	0.050	20/7	0.050	13/7	0.040*
19/8	0.040*	16/8	0.034*	20/8	0.040
10/9	0.032	3/9	0.024	23/9	0.039
30/9	0.030	15/10	0.062	30/10	0.030
26/10	0.028	-	-	-	-
23/11	0.040	-	-	-	-

Table 5.11 Turion and achene numbers and mass per unit area in Tete pan and exclosures after the 1978 growing season.

	Achenes (m^{-2})		Large Turions(m^{-2})		Small Turions(m^{-2})		Total Turions(m^{-2})	
	Numbers	Mass (g)	Numbers	Mass (g)	Numbers	Mass (g)	Numbers	Mass (g)
Exclosure	803	1.6	1568	88	950	7	2518	94
Pan	778	1.5	851	55	1570	14	2421	69
Significant $P <$			*0.001	*0.001	*0.01	*0.001		*0.001
Not significant $P >$	*0.1	*0.1					*0.1	

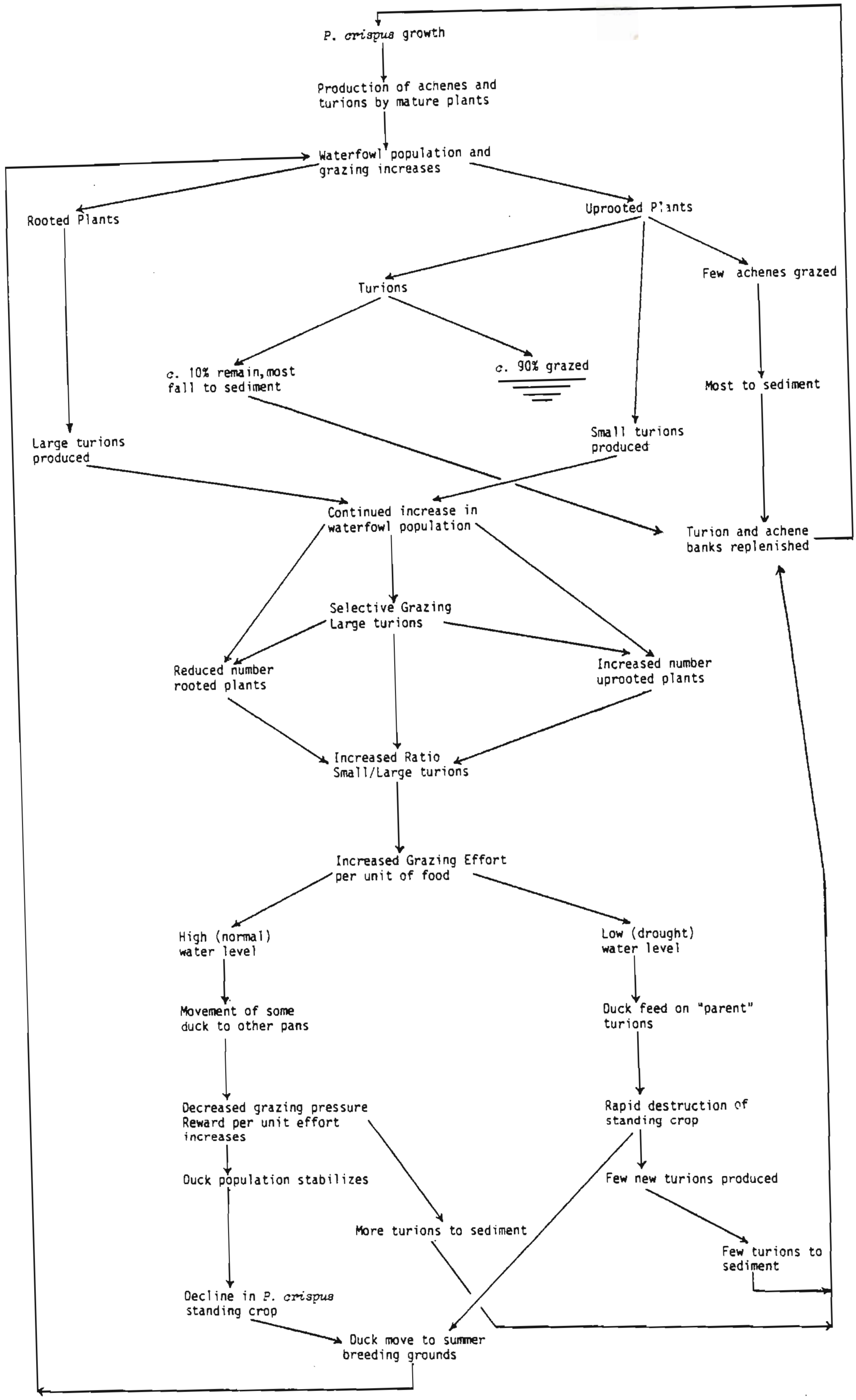


Figure 5.4 A conceptual model (hypothesis) of interactions between waterfowl and *Potamogeton crispus* which maintain the stability of the grazing system in Tete pan.

Plate 6.1 (a - j) Scanning electron micrographs of the epiphyton on *P. crispus* leaves of different ages.

a & b : The youngest leaves are devoid of epiphyton.

c & d : A young leaf colonized by a few diatoms *Cocconeis placentula* (Cp) and short stout bacteria (SB) (d inset).

e & f : Mature leaves colonized by *C. placentula* (Cp); *Gomphonema* spp. (G); filamentous cyanobacteria (Cb); short stout bacteria (SB) and prostrate rods (PB).

g & h : The oldest leaves colonized by *C. placentula* (Cp); *Navicula* spp. (N); cyanobacteria (Cb); short stout bacteria (SB) and filamentous bacteria (FB).

i & j : A dead leaf densely covered with *C. placentula* (Cp); short stout bacteria (SB) and filamentous bacteria (FB).

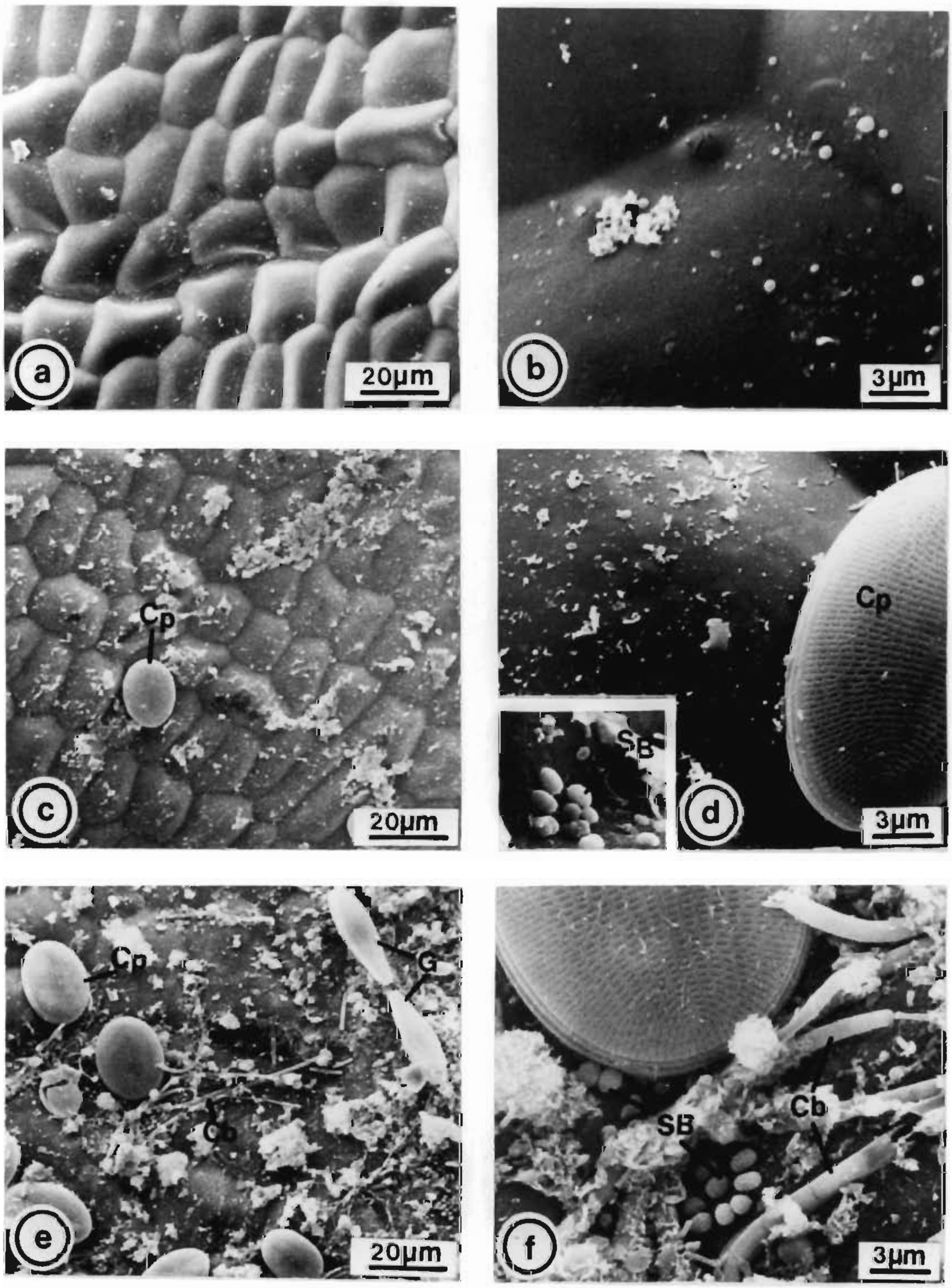

a
20µm
b
3µm
Cp
c
20µm
Cp
SB
d
3µm
Cp
G
e
20µm
SB
Cb
f
3µm

Plate 6.1	(a - j)	Scanning electron micrographs of the epiphyton on *P. crispus* leaves of different ages.
	a & b :	The youngest leaves are devoid of epiphyton.
	c & d :	A young leaf colonized by a few diatoms *Cocconeis placentula* (Cp) and short stout bacteria (SB) (d inset).
	e & f :	Mature leaves colonized by *C. placentula* (Cp); *Gomphonema* spp. (G); filamentous cyanobacteria (Cb); short stout bacteria (SB) and prostrate rods (PB).
	g & h :	The oldest leaves colonized by *C. placentula* (Cp); *Navicula* spp. (N); cyanobacteria (Cb); short stout bacteria (SB) and filamentous bacteria (FB).
	i & j :	A dead leaf densely covered with *C. placentula* (Cp); short stout bacteria (SB) and filamentous bacteria (FB).

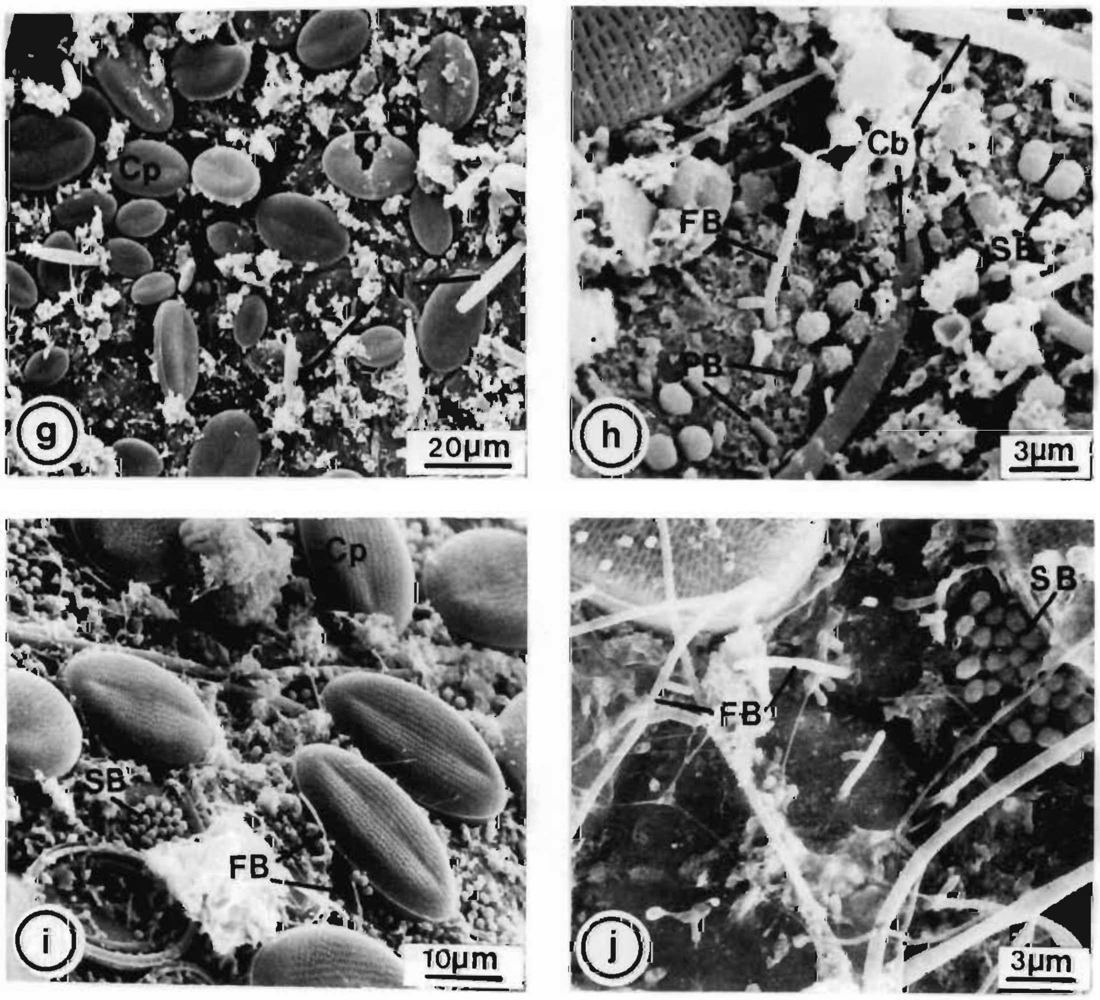

g
Cp
20µm
h
Cb
FB
SB
PB
3µm
i
Cp
SB
FB
10µm
j
SB
FB
3µm

Plate 6.2 (a - c) Bacteria seen on *P. crispus* leaves of different ages.

a : Short stout bacteria (SB) covered by fimbriate webs which may be used for attachment.

b : Upright rods (UB) and short stout bacteria (SB), the latter seen both from the side and above.

c : A diverse community on the oldest leaves; short stout bacteria (SB); prostrate rods (PB); upright rods (UB). Filamentous cyanobacteria are also visible (CB).

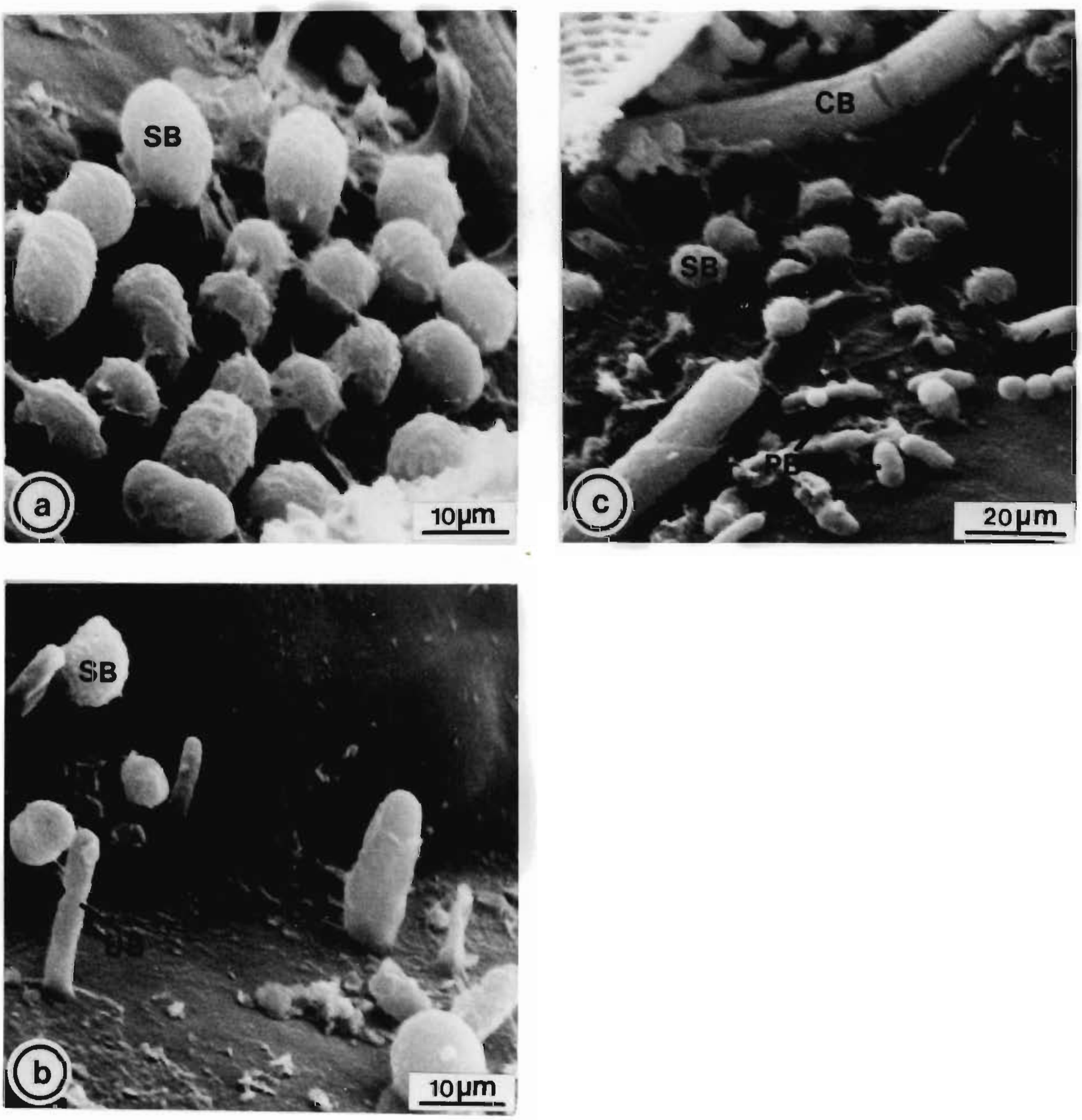
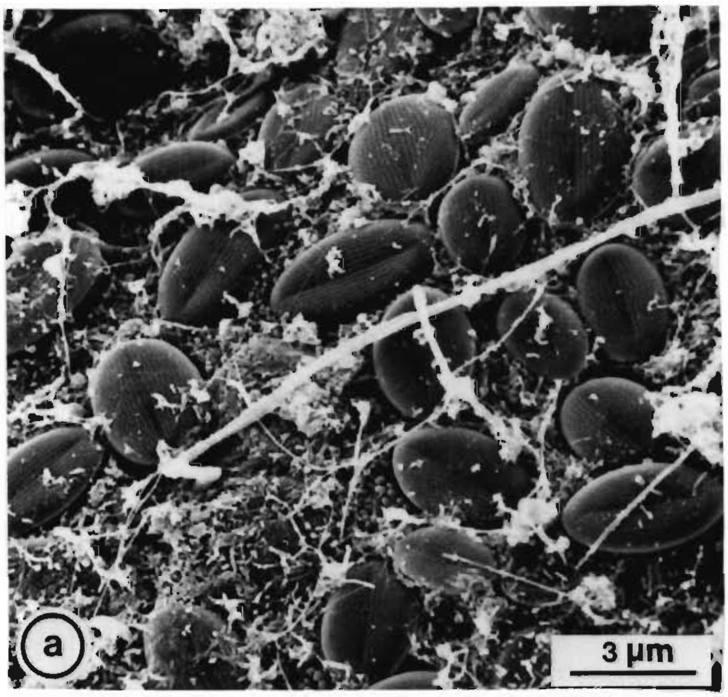

SB
a
10µm
CB
SB
PB
c
20µm
SB
b
10µm

Plate 6.3 a - b : Scanning electron micrographs of the epiphyton on basal sections of *P. crispus* stems after 12 days incubation in unfiltered pan water. The diatom and bacterial communities are similar to but more dense than, those on leaves incubated for the same period.


a
3 µm

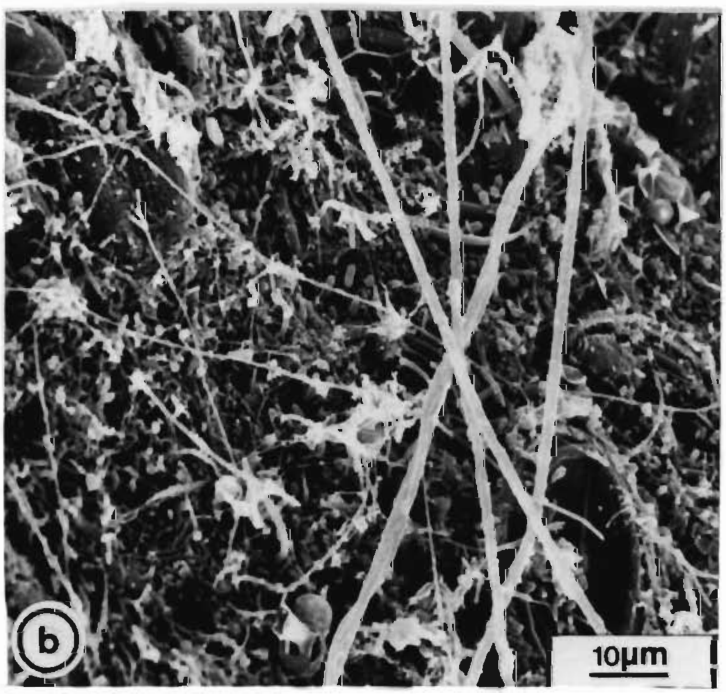

b
10µm

Plate 6.4 (a - c) T/S through *P. crispus* leaf epidermidi.

a : The youngest leaves have a thin cuticle (C); layered cell wall (W) and a dense cytoplasm including mitochondria (M), dictyosomes (D) and chloroplasts (Ch).

b : A young leaf showing attached bacterial epiphytes (B) and debris; the layered cell wall (W); a broad electron translucent band on the interior of the cell wall (SW); a narrow band of cytoplasm with densely packed chloroplasts (Ch) and mitochondria (M) and a large central vacuole (V).

c : A higher magnification of the cell wall showing the electron translucent band to represent a swelling of the wall (SW) consisting of loosely arranged microfibrils. Note the narrow band of cytoplasm (Cy) and central vacuole (V).

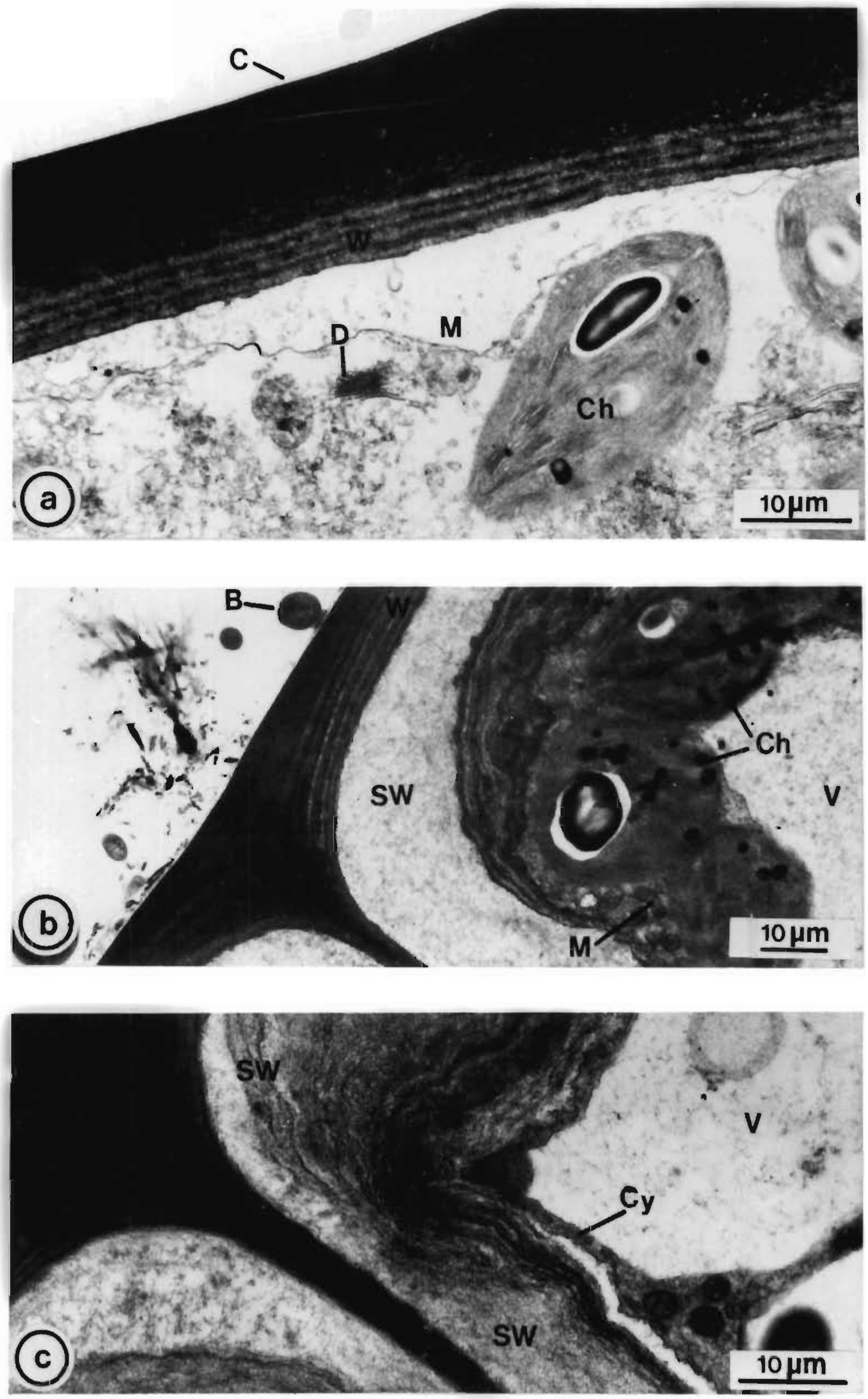

C
W
D
M
Ch
a
10 μm
B
W
Ch
SW
V
M
b
10 μm
SW
V
Cy
SW
c
10 μm

Plate 6.5 (a - d) T/S of mature *P. crispus* leaves.

a : Bacteria (B) both inside and outside the cell wall. Those inside being surrounded by an electron translucent (Et) area resembling hydrolysis of the wall material.

b : Note the absence of a cuticle; the digestion of the electron translucent cell wall (Et) and bacteria (B) inside and outside the cell wall.

c : An epidermal and adjacent mesophyll cell illustrating the electron translucent area (Et) surrounding bacteria (B) which have invaded the epidermal wall; the swollen epidermal walls (SW) and the early stages of such swelling in the mesophyll cell (SW).

d : Cross sections of bacteria within an epidermal cell wall showing the well defined cell walls (W); fibrous nuclear material (Fn) within an electron translucent area of cytoplasm. Note the sparse disorganised microfibrils of the surrounding plant cell wall.

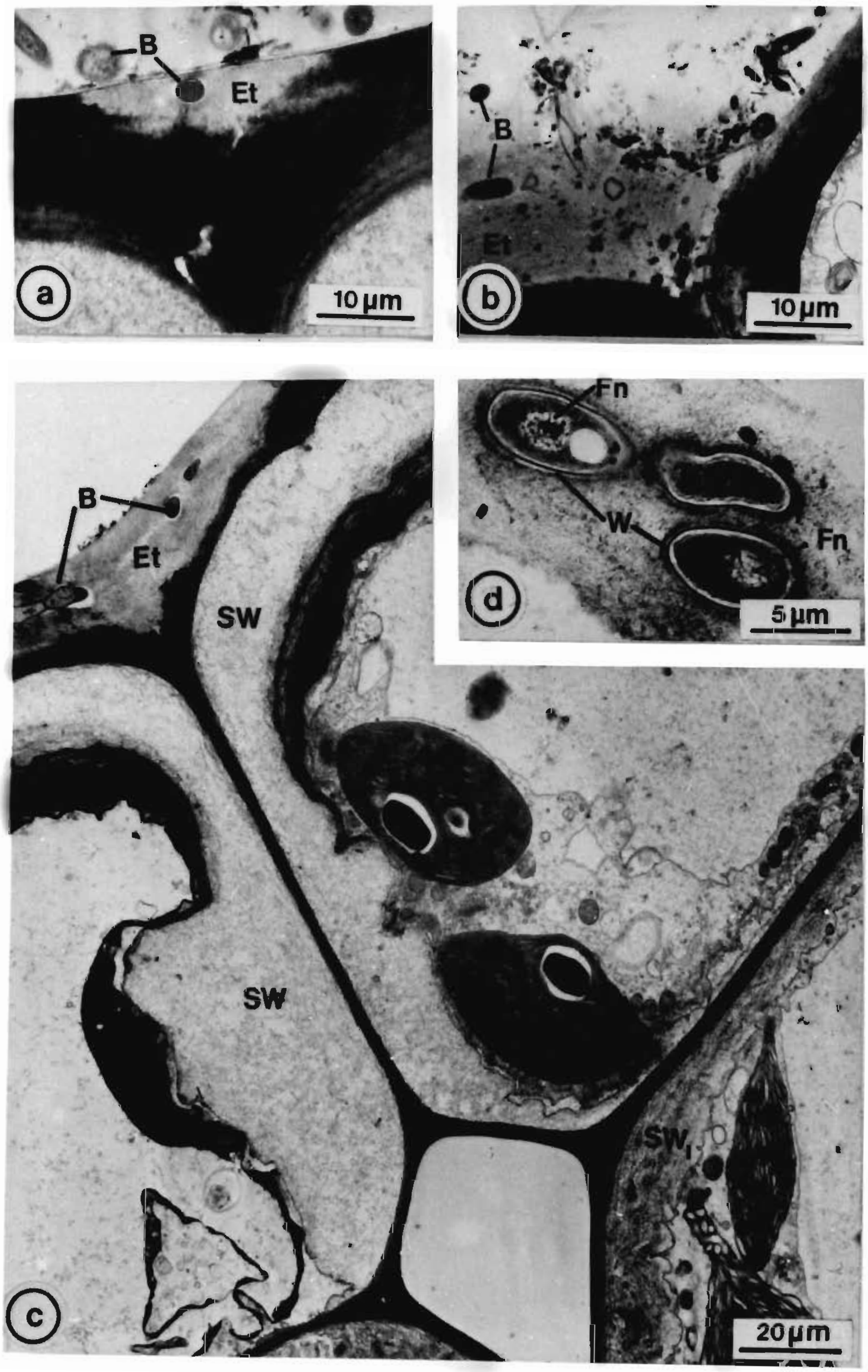

B
Et
a
10 µm
B
Et
b
10 µm
B
Et
SW
SW
SW_1
c
20 µm
Fn
W
Fn
d
5 µm

Plate 6.6 (a - b) T/S of the oldest *P. crispus* leaves.

a : Note the absence of a cuticle and extensive damage to the epidermal wall (W) which is almost entirely electron translucent; the swollen cell walls (SW); a narrow band of cytoplasm enclosing a few swollen chloroplasts (Ch) with ill defined grana stacks and an ill defined tonoplast (T).

b : A mesophyll cell showing the swollen cell walls (SW) (at higher magnification in inset); large vacuole (V); chloroplasts (Ch); well defined tonoplast (T) and highly invaginated plasmalemma (P).

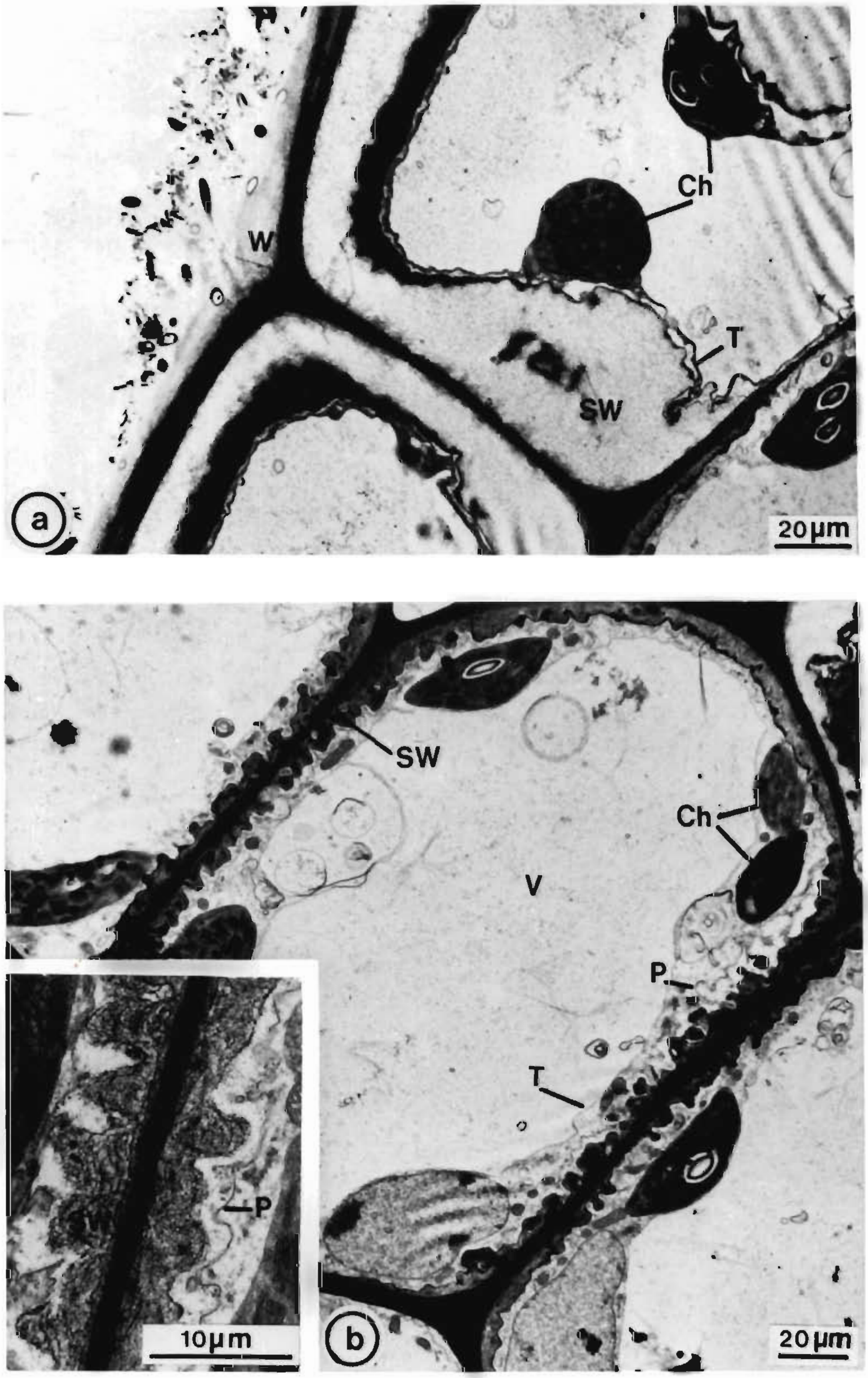

W
Ch
T
SW
a
20µm
SW
Ch
V
P
T
P
10µm
b
20µm

Plate 6.7 (a - b) T/S of the oldest *P. crispus* leaves after 12 days incubation in pan water.

a : The epidermal cell wall (W) containing numerous bacteria (B) is almost entirely electron translucent. Note the bacteria (B) within the swollen cell wall area (SW) which contains only very sparse microfibrils.

b : Bacteria, with well defined cell wall (BW) and fibrous nuclear material (Fn), within the swollen area of the mesophyll cell wall (SW). Note the swollen, ill defined plasmalemma (P) and lack of cytoplasm; the degraded cell wall (DW) and very sparse microfibrils of the swollen area.

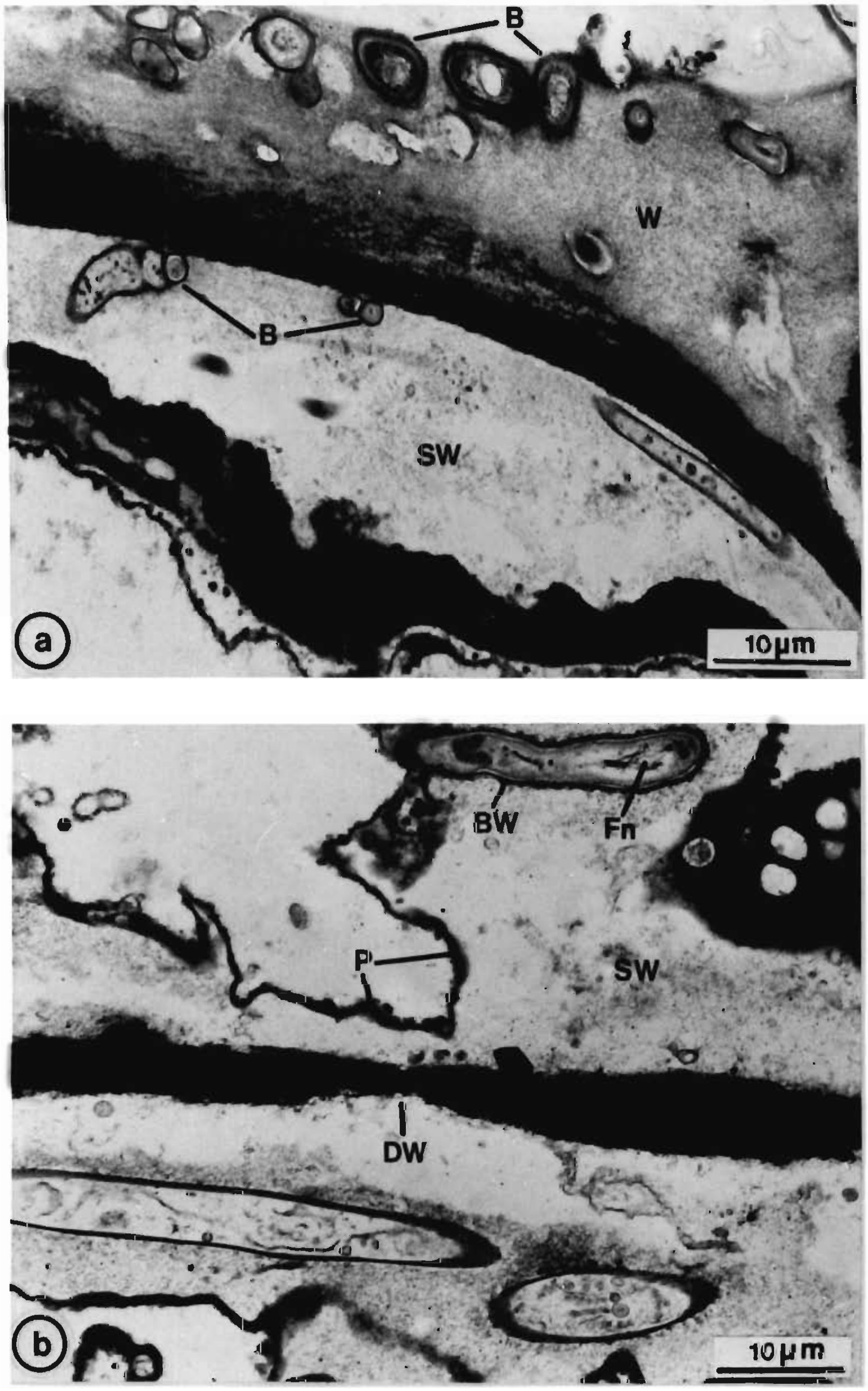

B
B
W
SW
a
10µm
BW
Fn
P
SW
DW
b
10µm

Plate 6.8 (a - c) T/S of stems of mature *P. crispus* plants.

a : Mid-way down the stem occasional bacteria were evident within the outer epidermal wall.

b : Epidermal cells of basal stem sections showed swelling typical of that in leaf cells.

c : After 12 days incubation in pan water intercellular spaces of the cortex had been invaded by bacteria.

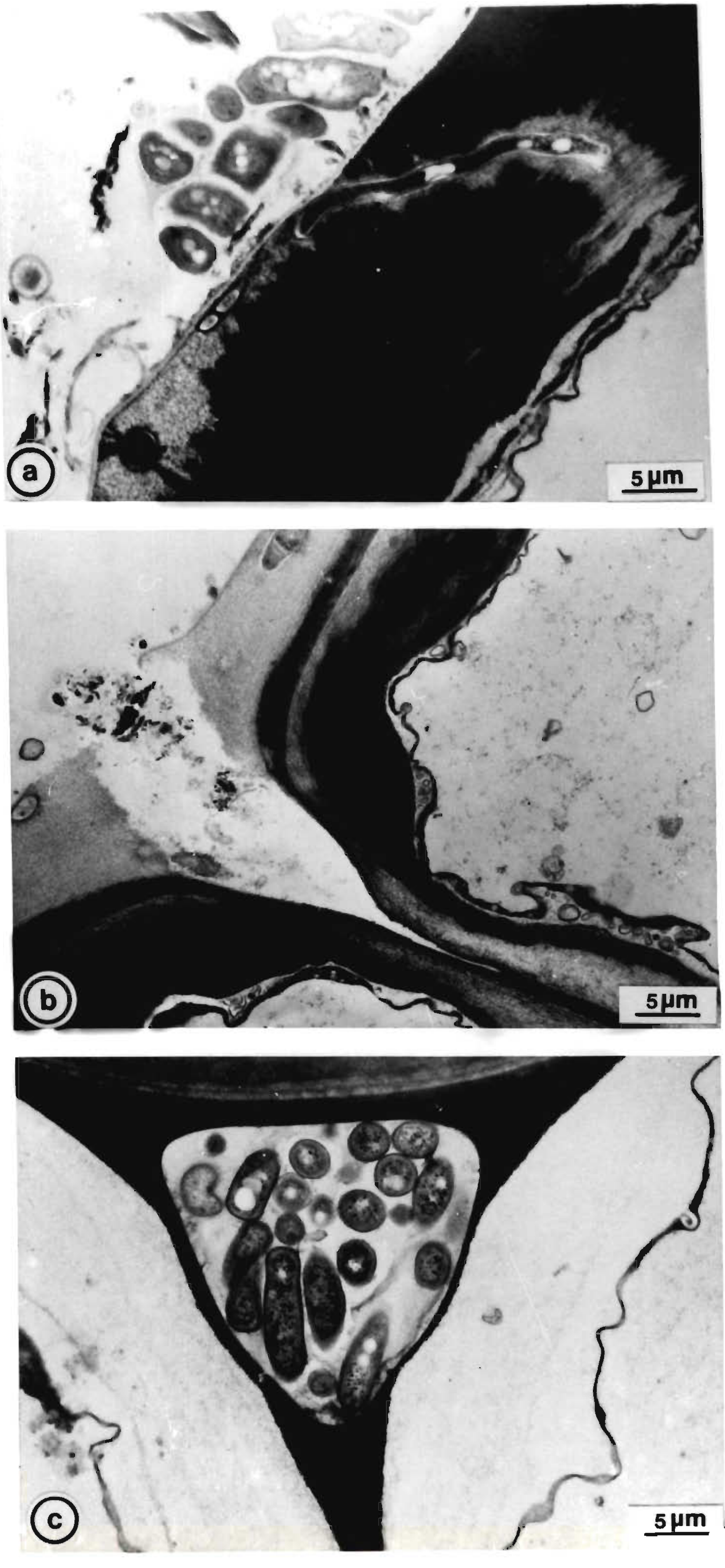

a
5 µm
b
5 µm
c
5 µm

Plate 6. 9 (a - f) The effects of snail grazing for 24 hours on the epiphyton and surface structure of *P. crispus* leaves of different ages.

a & b : Young leaves were not damaged despite removal of most of the epiphyton.

c & d : Mature leaves; the outer walls of groups of epidermal cells had been removed (c) and numerous "canals" probably resulting from the action of necrotrophic bacteria can be seen (d).

e & f : Senescent leaves were extensively damaged by snail grazing.

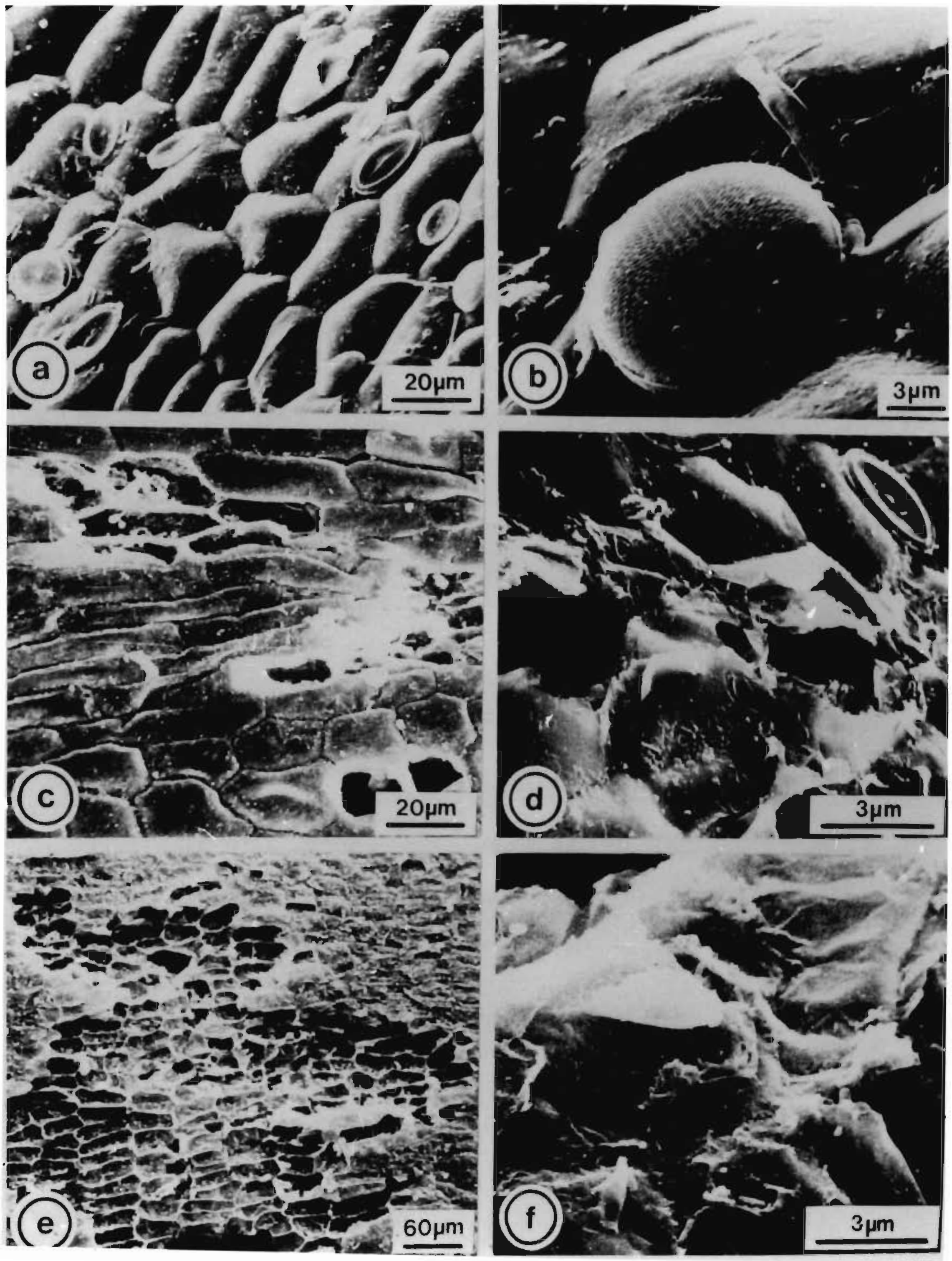
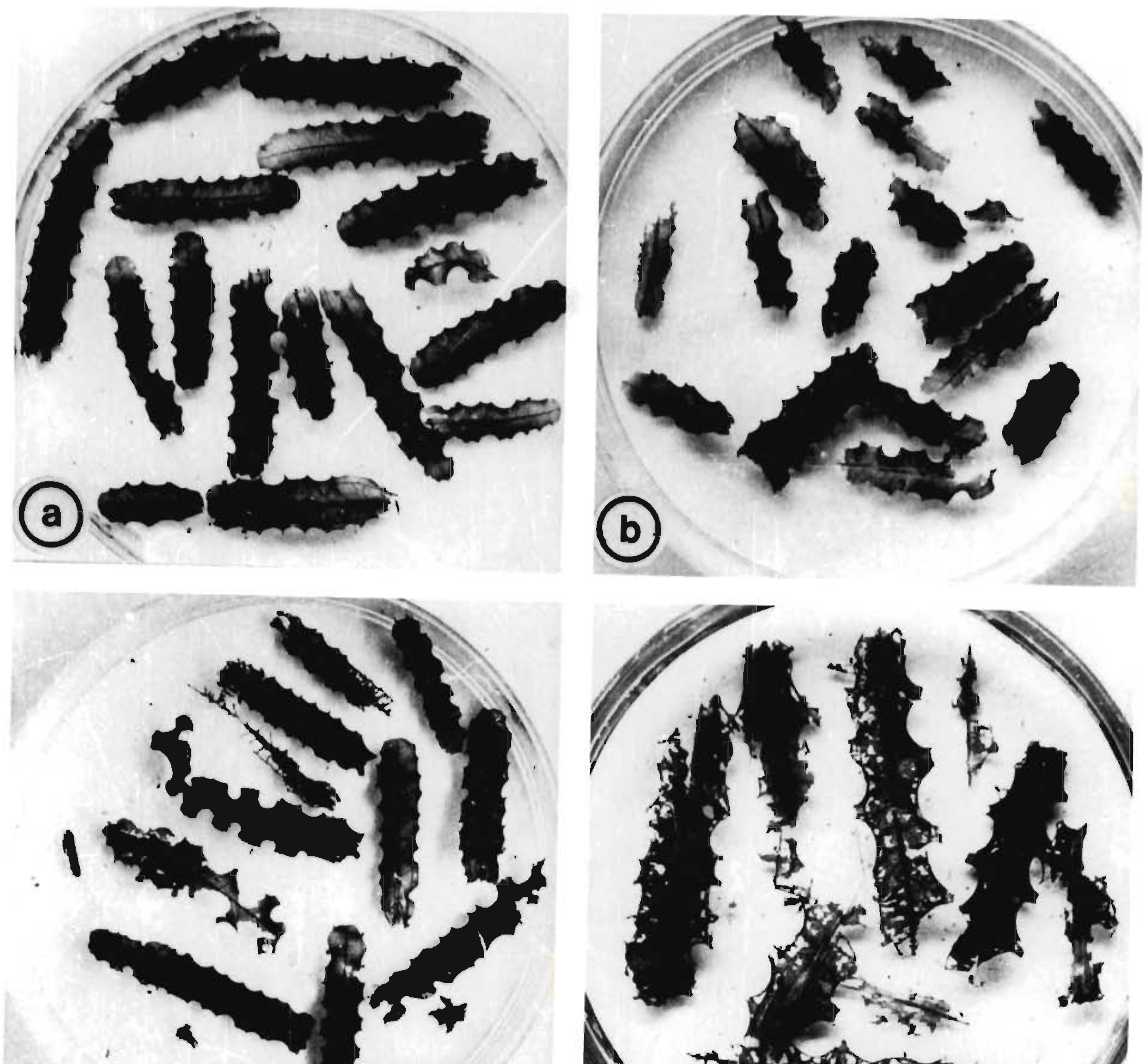

a
20μm
b
3μm
c
20μm
d
3μm
e
60μm
f
3μm

Plate 6. 10 (a - d) The effects of snail grazing on *P. crispus* leaves of different ages 6 days after the introduction of snails.

a & b : The youngest (a) and most young (b) leaves remained intact and showed no macroscopic evidence of damage. (x 0.9)

c & d : Most mature (c) leaves had been damaged and the few senescent (d) leaves remaining were extensively damaged. (x 0.9)


a
b
c
d

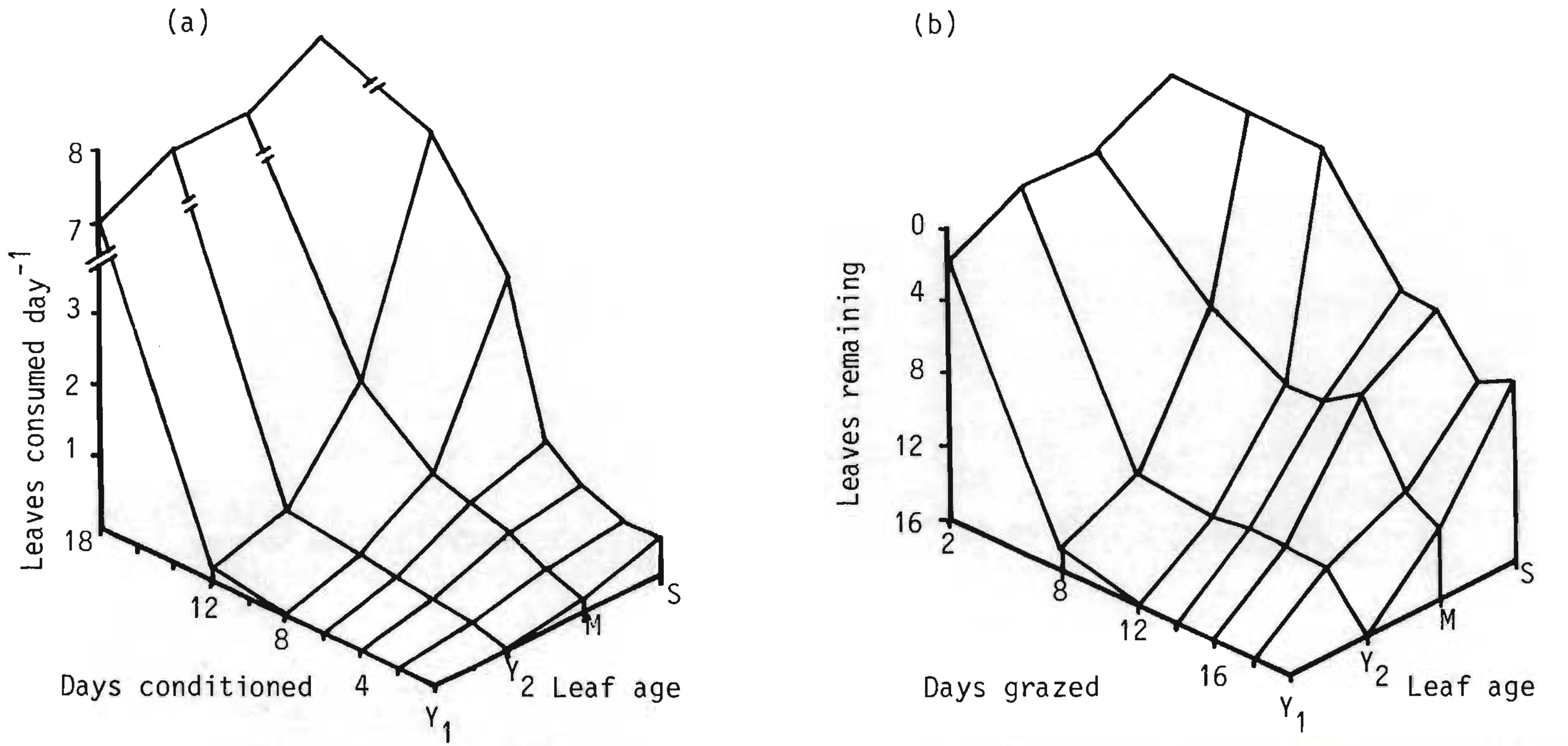


Figure 6.1 The relationship between leaf age, conditioning and grazers in *P. crispus*.
(a):The effects of leaf age and time allowed for conditioning in the absence of grazers, on leaf edibility (leaves consumed day^{-1}). (b): The effects of leaf age on time permitted for grazing, after conditioning, on the number of leaves remaining at the end of the experiment (20 days).
(Y_1 = youngest leaves; Y_2 = young leaves; M = mature leaves; S = senescent leaves).

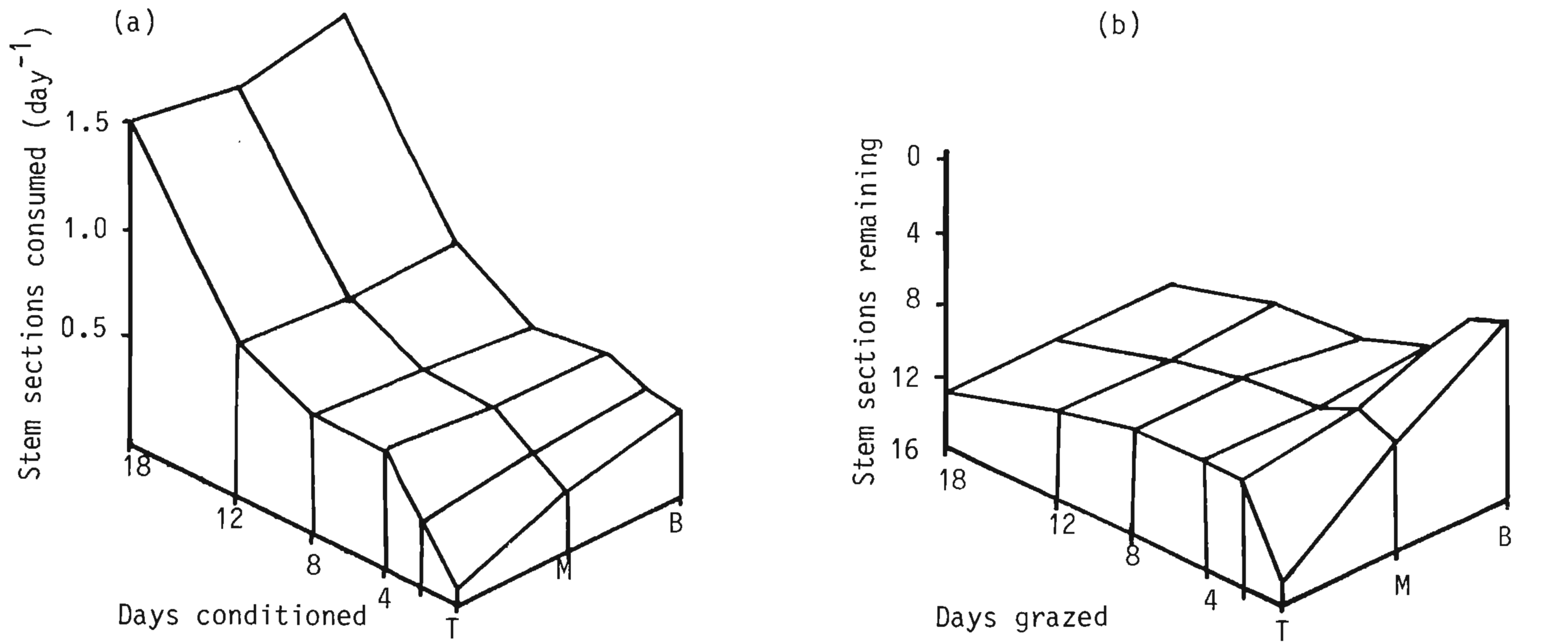


Figure 6.2 The relationship between stem position, conditioning and grazers in *P. crispus*.
(a) The effects of stem position and time allowed for conditioning in the absence of grazers, on stem edibility (stems consumed day-1) (b) The effects of stem position and time permitted for grazing, after conditioning, on the number of stem sections remaining at the end of the experiment (20 days).
(T = stem section from tip of plants; M = sections from middle of the stem; B = basal stem sections).

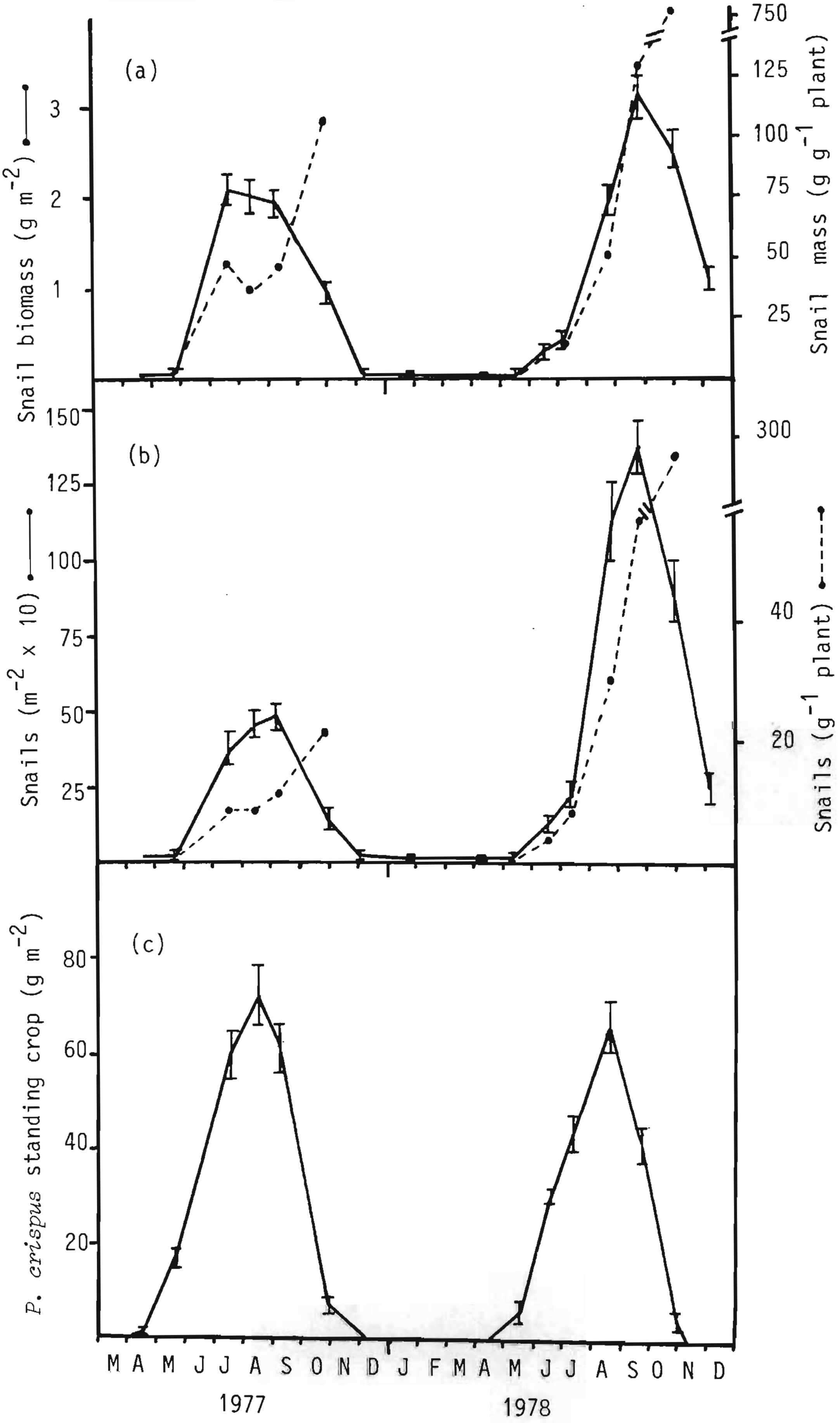


Figure 6.3 Changes in (a) snail biomass and (b) numbers in relation to (c) changes in *P. crispus* standing crop in Tete pan during 1977 and 1978.

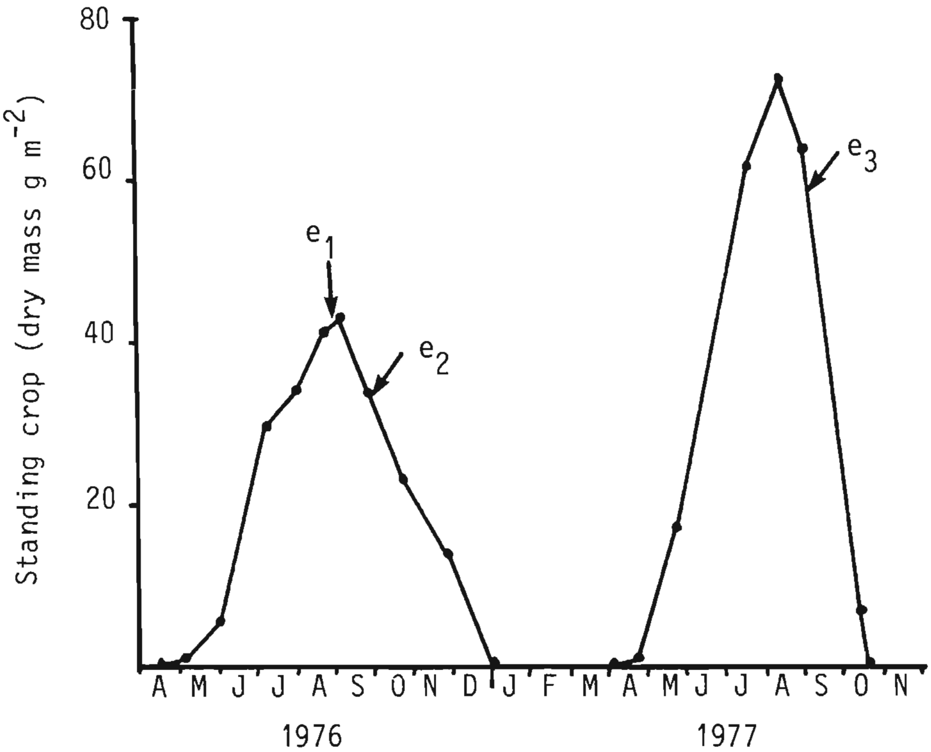


Figure 7.1 The growth cycle of *P. crispus* population in Tete pan as determined by sequential estimates of standing crops. Arrows e_1, e_2 and e_3 indicate the times at which decomposition experiments were initiated.

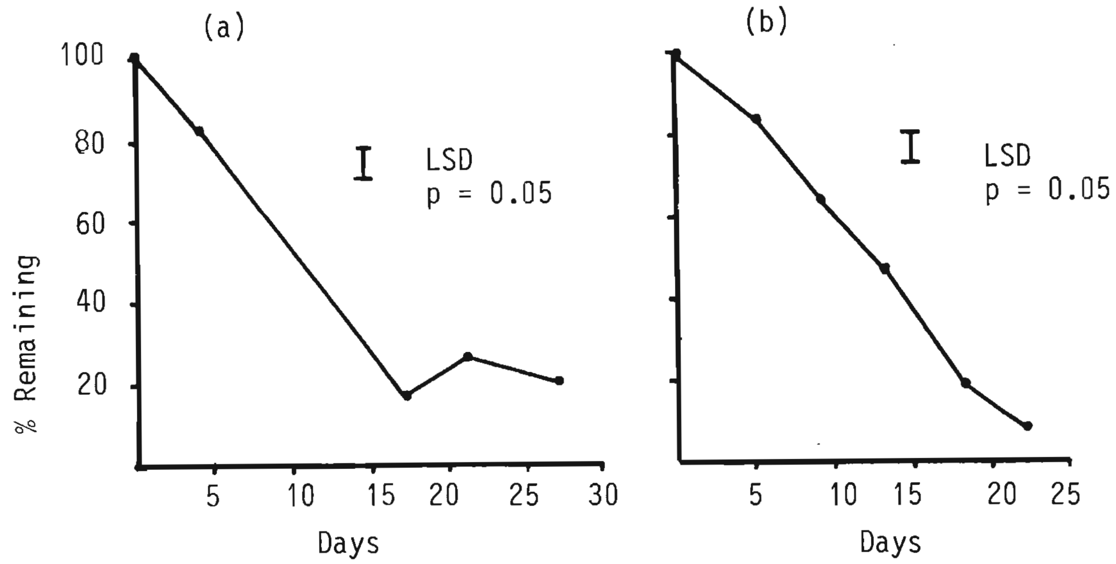


Figure 7.2 Loss of dry mass during decomposition of *P. crispus* shoots expressed as percent mass remaining in decomposition bags with time. (a) Experiment initiated at maximum standing crop (e_1 Fig. 7.1). (b) Experiment initiated 30 days after maximum standing crop (e_2 Fig. 7.1).

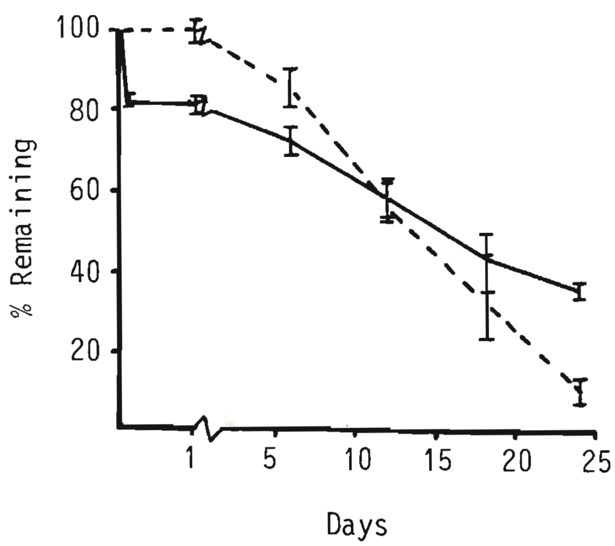


Figure 7.3 Loss of dry mass of senescent *P. crispus* shoots (----) and dried shoots (———) expressed as percent remaining in litter bags with time. (Vertical bars = 1 standard deviation from the mean).

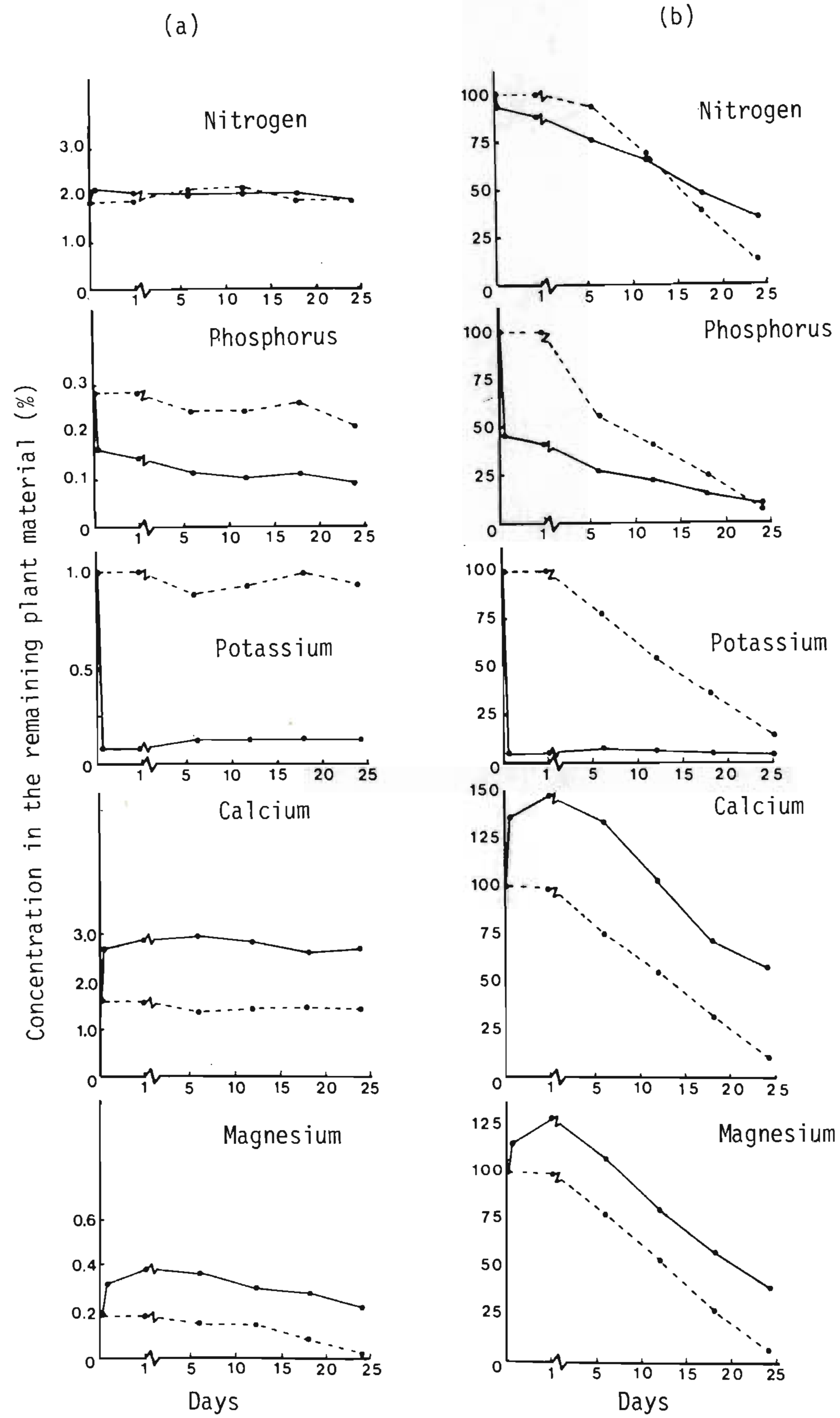


Figure 7.4 Changes in the concentration (a) and stocks (b) of selected nutrients in senescent (•----•) and dried (•——•) *P. crispus* remaining in decomposition bags

Table 7.1 Mean number and mass of snails *(Bulinus natalensis)* found in small mesh decomposition bags containing (1) senescent plants and (2) dried plants and in (3) large mesh bags containing senescent plants. LSD = least significant difference between the means.

TIME	SENESCENT		DRIED		LARGE MESH	
(days)	No	Mass (mg)	No	Mass(mg)	No	Mass (mg)
6	48	17	131	34	144	330
12	158	70	177	84	144	570
18	487	453	195	181	174	640
24	325	455	135	202	120	660
LSD $p = 0.05$	77	101	121	73	57	186

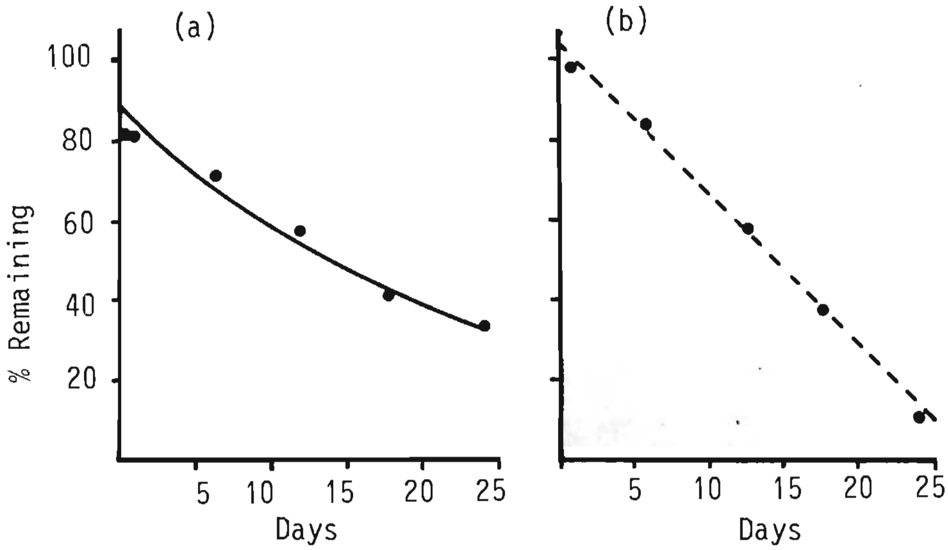


Figure 7.5 Mathematical functions of mass of plant material remaining against time in relation to actual data points for the 1977 experiment. (a) Loss of dried plant material from decomposition bags as described by a simple exponential function where $y = ae^{-bk}$.
(b) Loss of senescent plant material as described by a linear function where $y = a_0 - a_1x$.

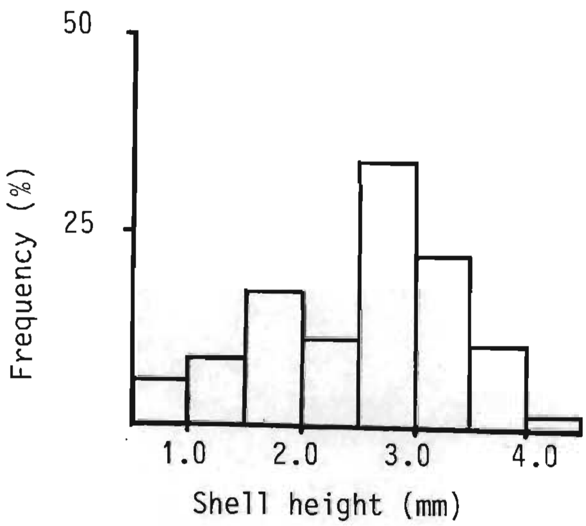


Figure 7.6 Size frequency distribution of the *Bulinus natalensis* population in Tete pan in September 1977.

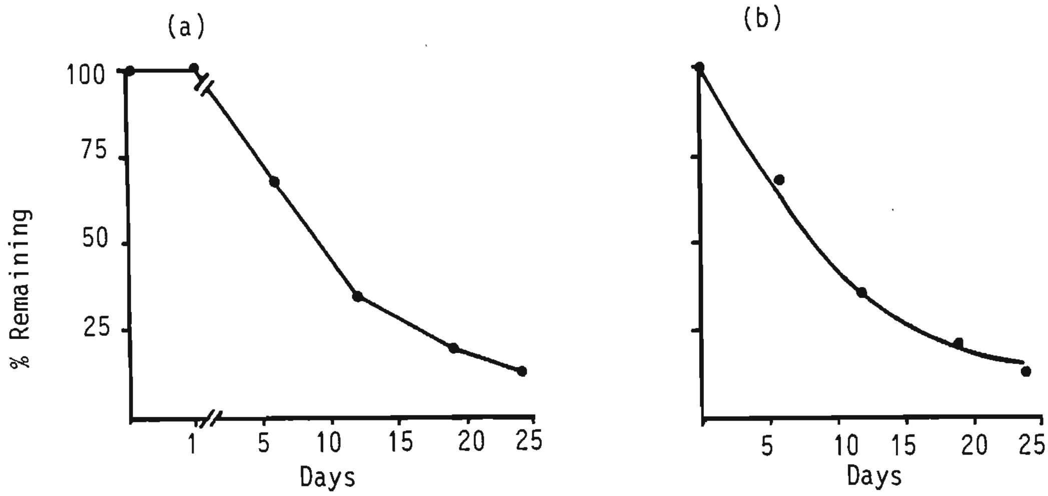


Figure 7.7 Loss of mass of senescent *P. crispus* from coarse mesh gauze bags expressed as the percent original mass remaining. (a) Actual data points. (b) Described by simple exponential function where $y = ae^{-bk}$.

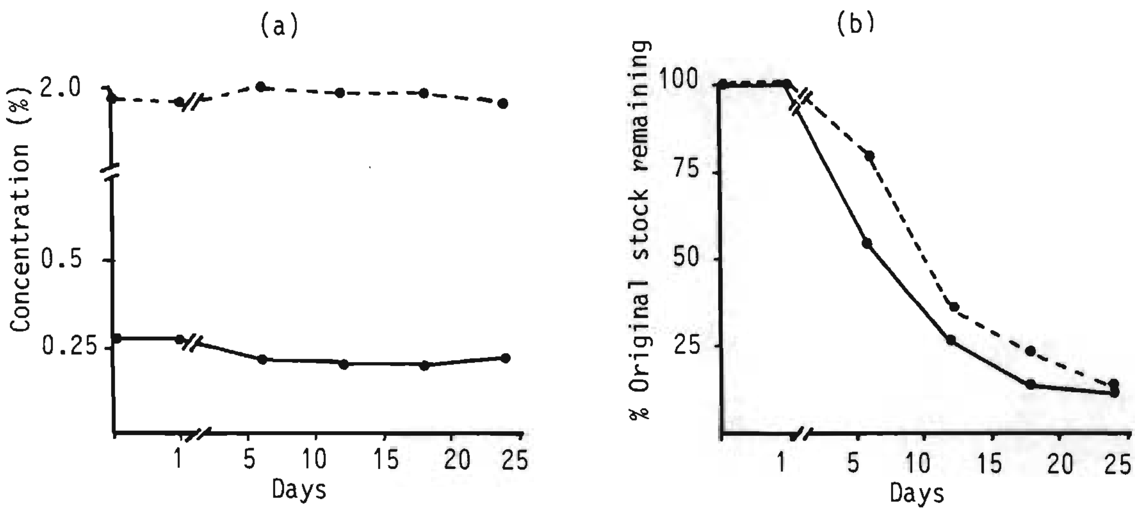


Figure 7.8 The changes in (a) concentration and (b) original stock of nitrogen (•- - -•) and phosphorus (•——•) in senescing *P. crispus* incubated in coarse mesh gauze bags.

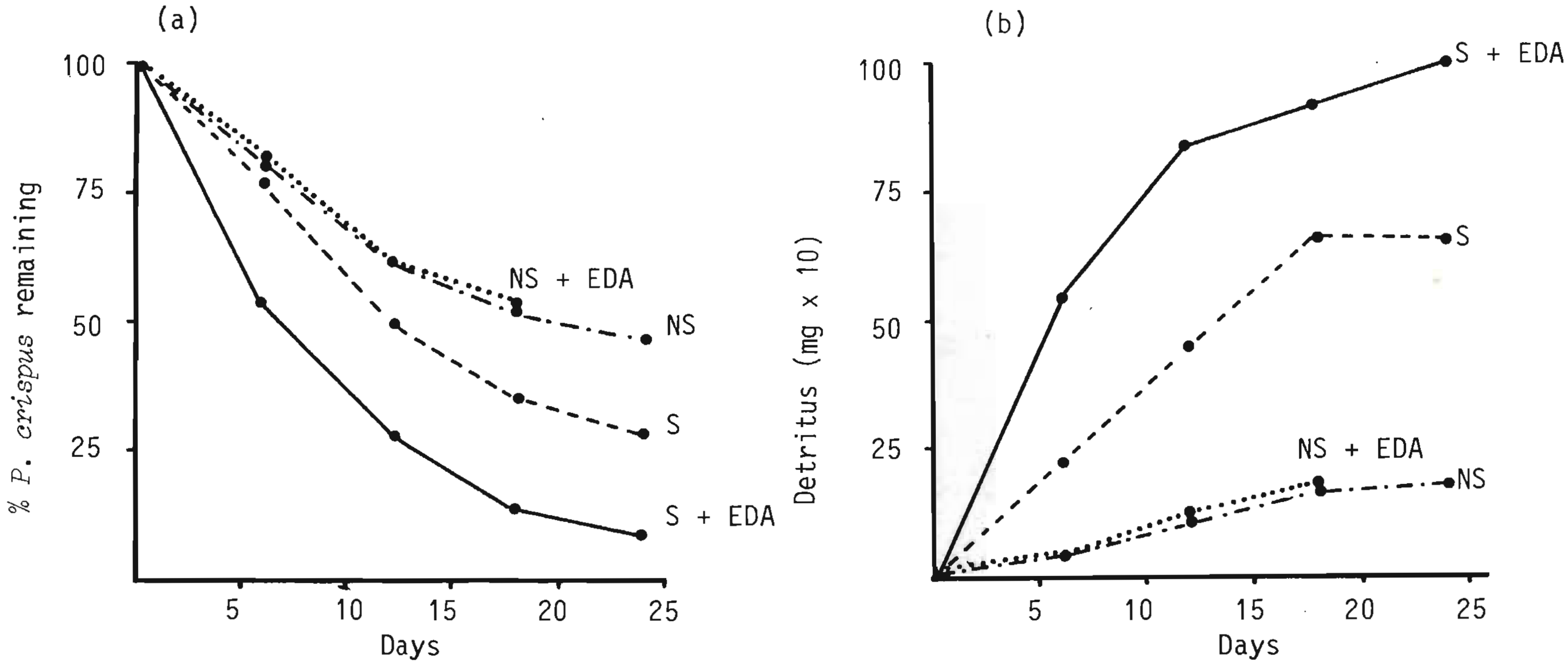


Figure 7.9 Effects of snails and epiphytic detrital aggregate (EDA) on; (a) loss of mass and (b) detritus accumulation from senescent *P. crispus* plants incubated in the laboratory.
(NS = no snails; S = snails).

Table 7.2 The effects of snails and epiphytic detrital aggregate (EDA) on mass loss of uprooted *P. crispus* plants. Described by a simple exponential function ($y = ae^{-kt}$) where r^2 = coefficient of determination, k = rate constant, $t_{½}$ = time taken for 50% mass loss.
Significance between regresssions (Sokal and Rohlf, 1969); NS = not significant; * = p 0.05; ** = $p < 0.01$.

TREATMENT	r^2	k	$t_{½}$	SIGNIFICANCE			
NO SNAILS	0.981	- 0.033	22	NS	*	**	
NO SNAILS & EDA	0.877	- 0.034	20	NS			
SNAILS	0.987	- 0.056	13		*		**
SNAILS & EDA	0.999	- 0.091	6			**	**

Table 7.3 The precentage distribution of total nitrogen and phosphorus between the dissolved phase, fine particulate matter (FPOM) and remaining plant material during *in vitro* decomposition of *P. crispus* in the presence and absence of snails.

	PHOSPHORUS (%)					NITROGEN (%)				
DAYS	0	6	12	18	24	0	6	12	18	24
Snails + EDA										
Plants	99.8	62	35	19	9	99.2	55	33	19	10
Dissolved	0.2	9	24	29	29	0.8	3	4	6	11
FPOM	-	28	43	53	63	-	55	119	131	146
Total	100	99	102	101	101	100	113	156	156	167
No Snails										
Plants	99.8	78	60	51	49	99.2	94	79	68	60
Dissolved	0.2	7	16	22	27	0.8	2	3	4	3
FPOM	-	2	4	6	7	-	4	11	16	19
Total	100	87	80	79	83	100	100	93	88	82

Table 7.4 The concentration of N, P and ash free dry mass (expressed as a percentage) in senescent *P. crispus* plants (day 0) and in the fine particulate organic matter (FPOM; days 6 - 24) during *in vitro* decomposition in the presence and absence of snails and epiphytic detrital aggregate (EDA)

Time Days	Snails + EDA			No Snails		
	P %	N %	Ash free %	P %	N %	Ash free %
Plants						
0	0.31	1.6	85	0.31	1.6	85
FPOM						
6	0.30	5.0	70	0.32	4.8	56
12	0.30	6.9	75	0.32	5.5	67
18	0.31	7.0	79	0.32	5.0	68
24	0.32	7.2	77	0.31	5.2	69

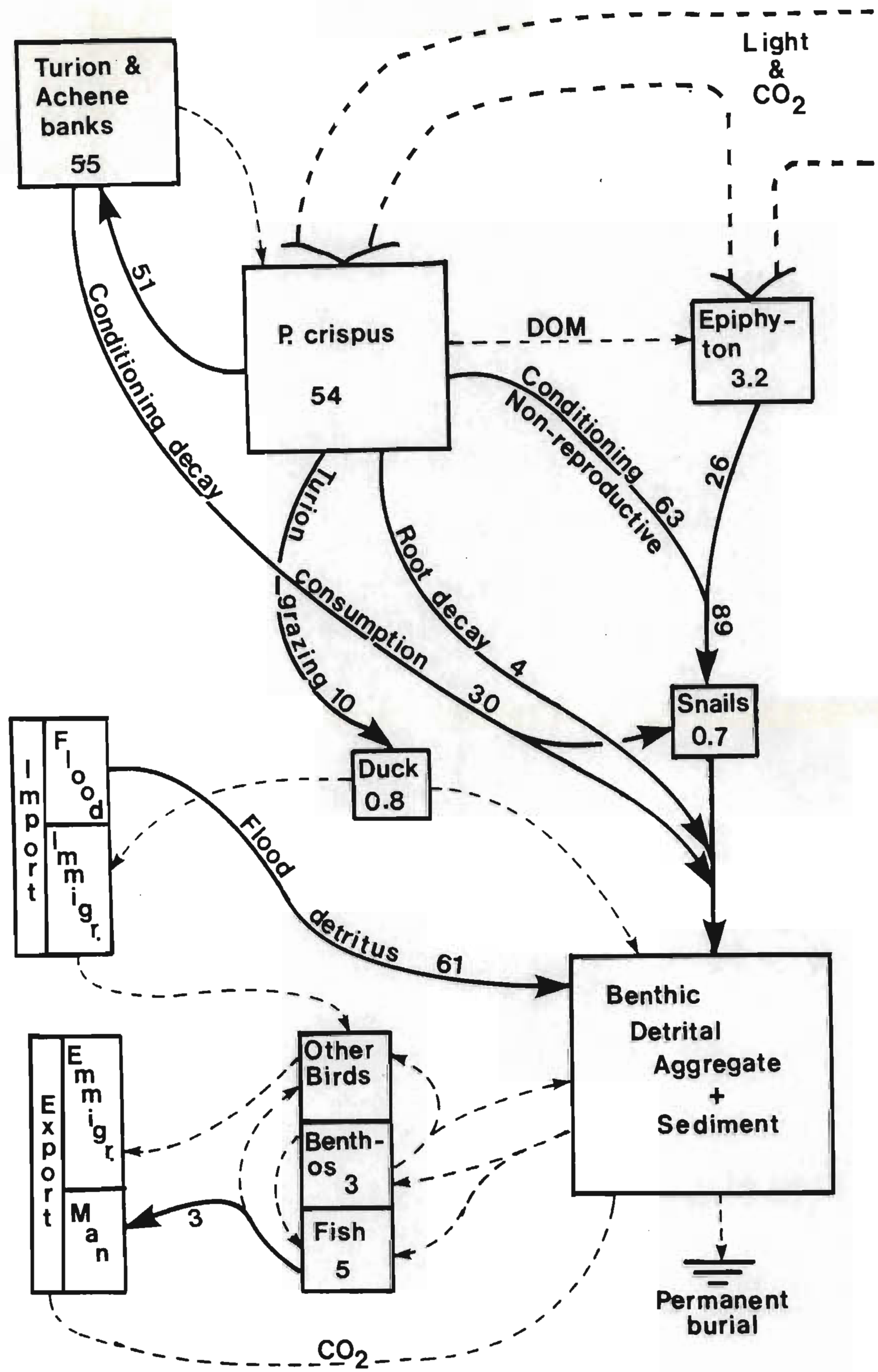


Figure 8.1 A conceptual, semi-quantitative, model of the major organic matter (tonnes ash free dry mass p.a.) pools and transfers in the conservative network of Tete pan ecosystem. Dotted lines represent known but not as yet quantified, pathways of transfer.

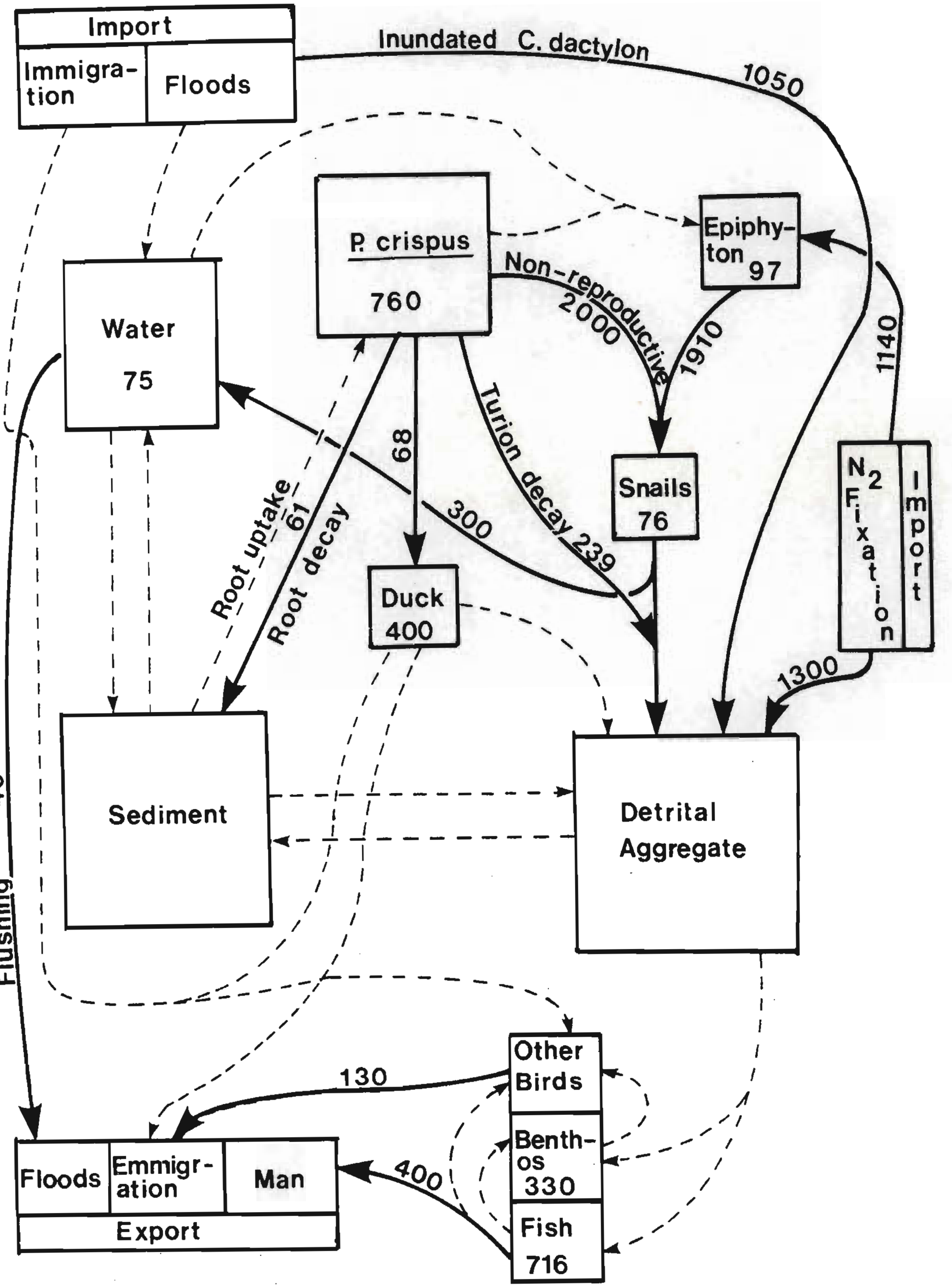


Figure 8.2 A conceptual, semi-quantitative, model of pools and transfers of nitrogen (kg p.a.) in the conservative network of Tete pan ecosystem. Dotted lines represent known but not as yet quantified, pathways of transfer.

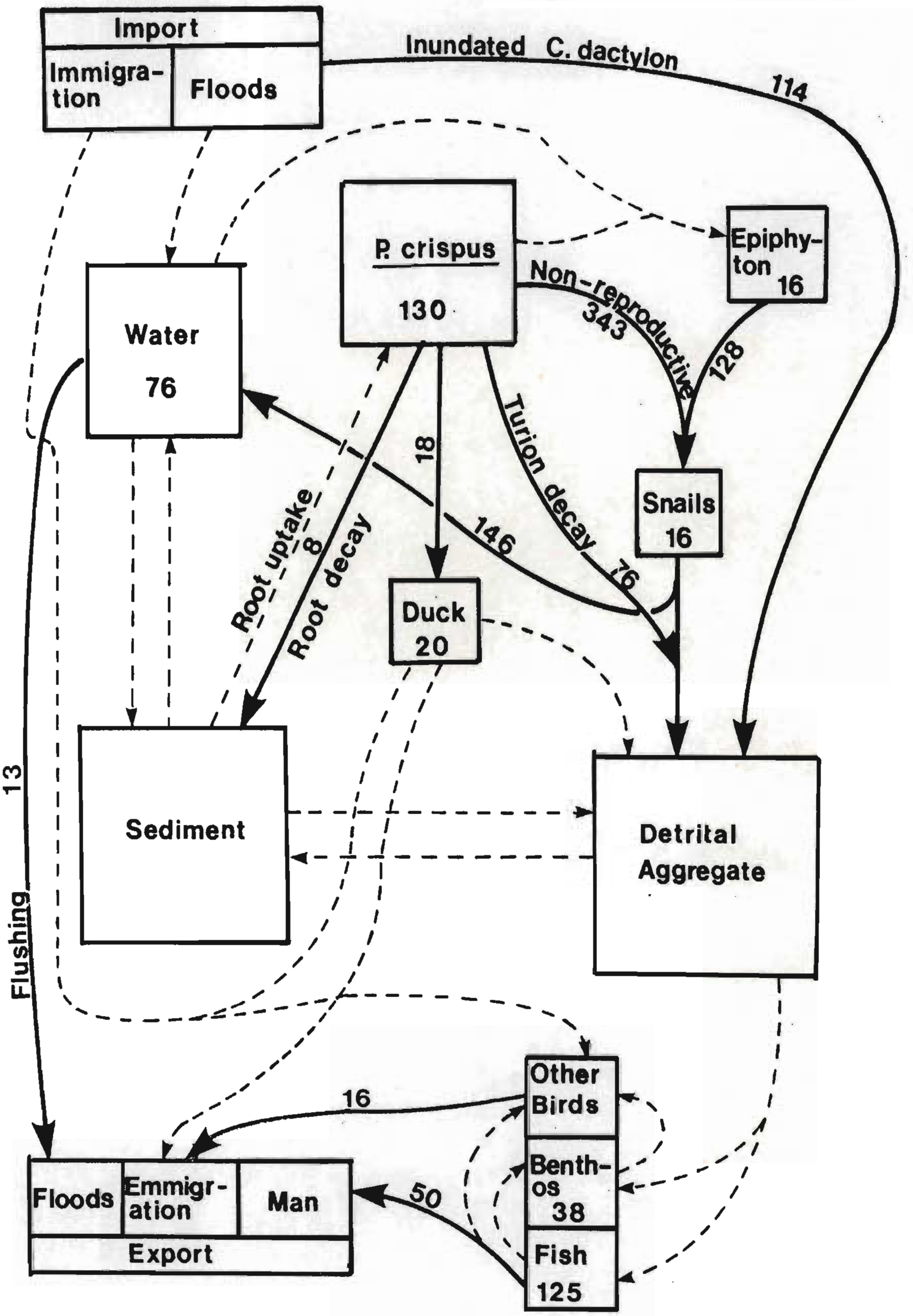


Figure 8.3 A conceptual, semi-quantitative, model of pools and transfers of phosphorus (kg p.a.) in the conservative network of Tete pan ecosystem. Dotted lines represent known but not as yet quantified, pathways of transfer.

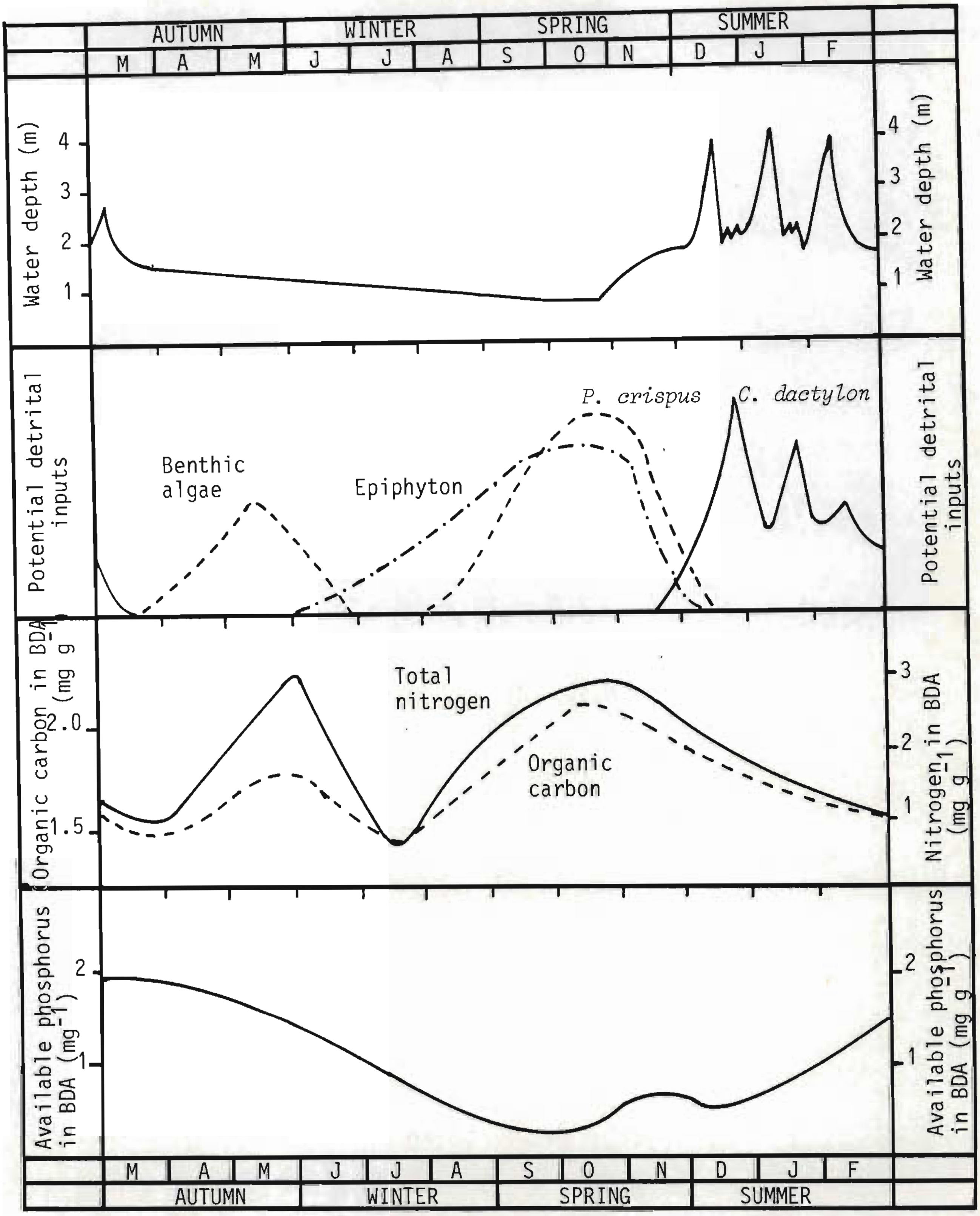


Figure 8.4 Seasonal fluctuations in the chemical composition of the benthic detrital aggregate (BDA) in Tete pan in relation to potential detrital inputs and flooding.
(Data from Everson, 1980; Rogers, 1981; Heeg and Breen, 1982 and this study).

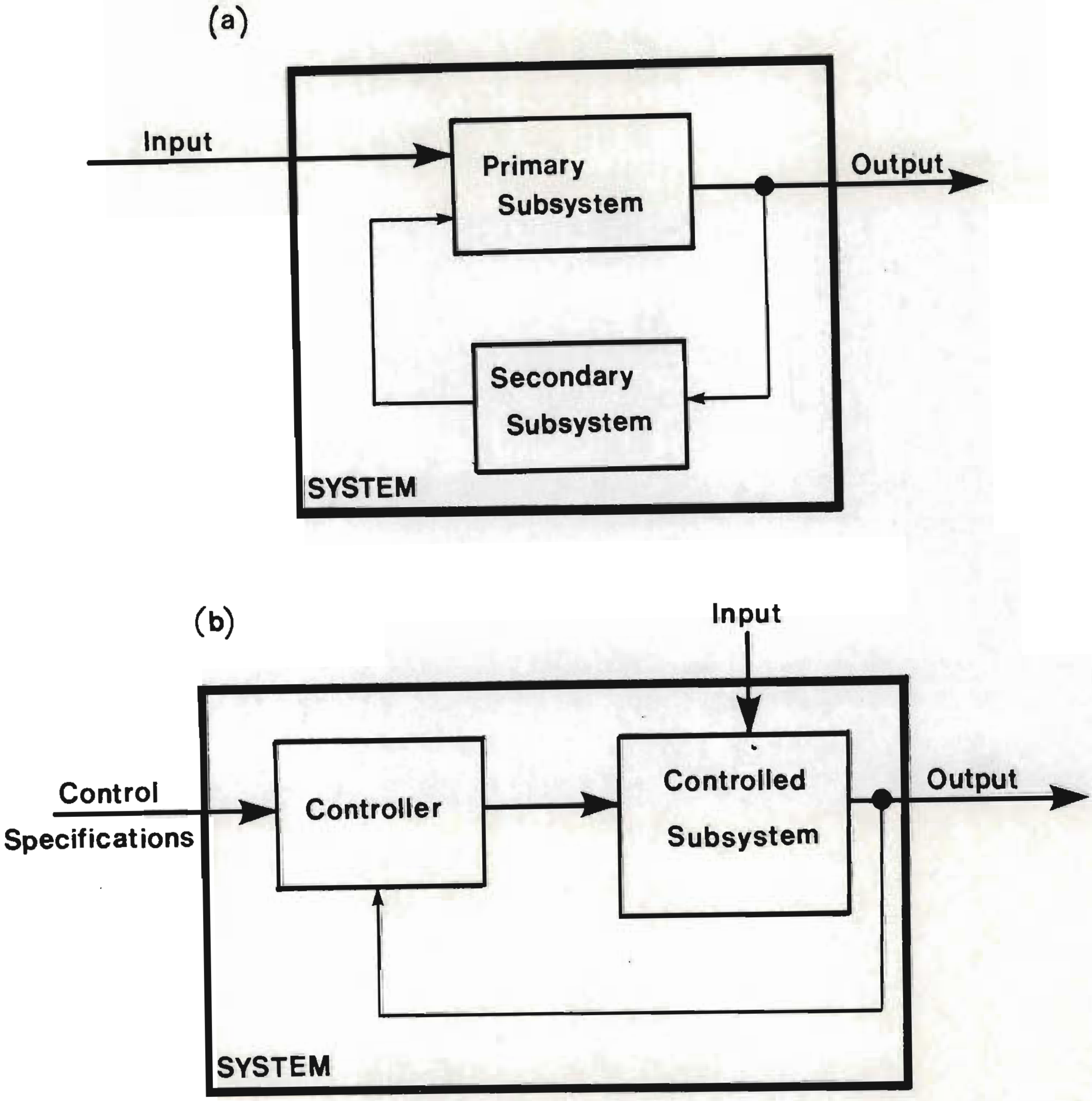


Figure 9.1 A diagramatic comparison of two cybernetic systems. (a) A nonteleological, deterministic system such as an ecosystem and (b) a teleological (goal seeking) system typical of man-made automatic control systems. (After Patten and Odum, 1981).

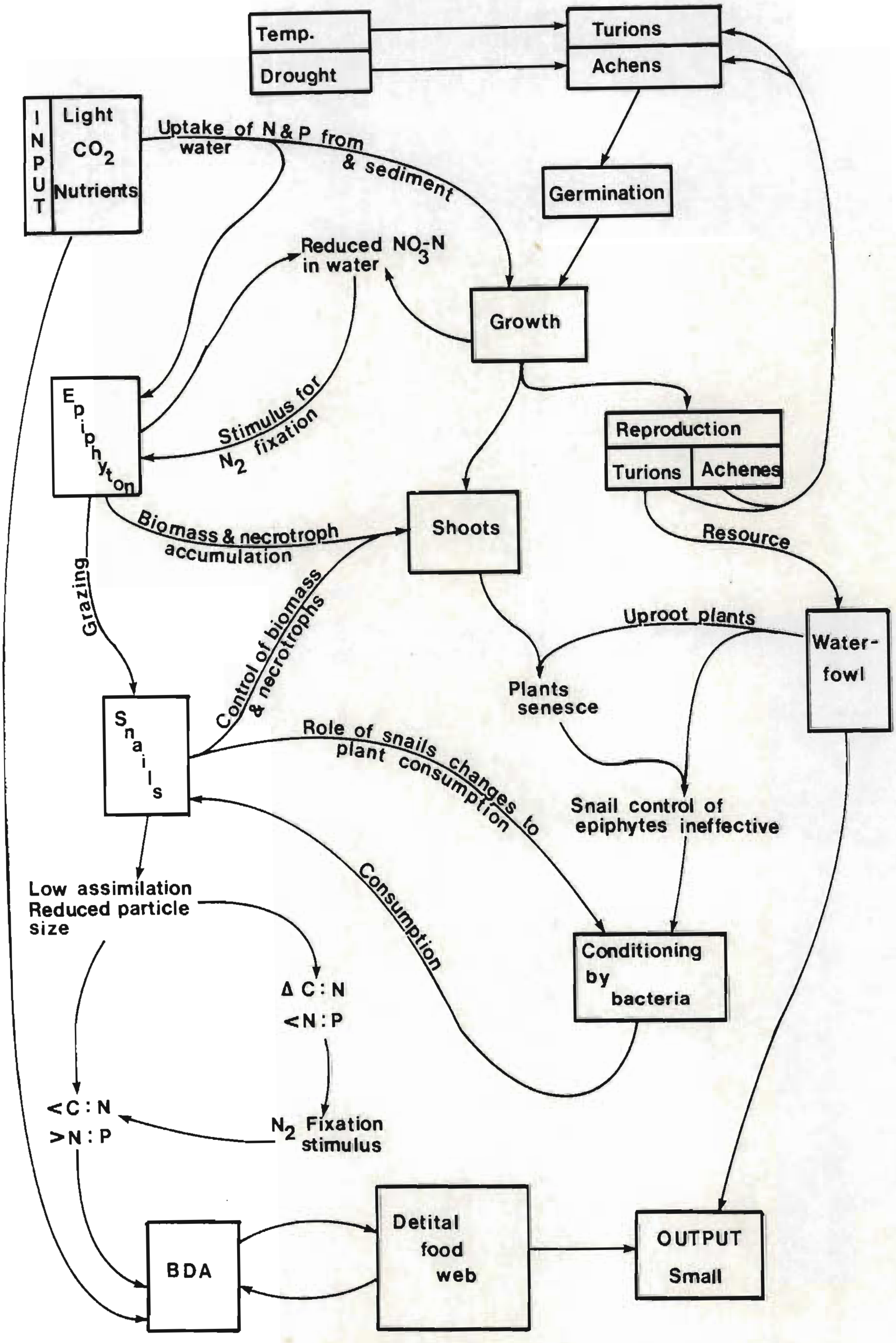


Figure 9.2 A conceptual model which summarises the conservative and informational processes which regulate the role of *P. crispus* in Tete pan ecosystem.