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CESIUM-137 DYNAMICS WITHIN A REACTOR EFFLUENT STREAM IN SOUTH CAROLINA

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MASTER

ABSTRACT

Radiocesium dynamics are being studied in a blackwater creek which had received production reactor releases from the Savannah River Plant in South Carolina. Most ^{137}Cs in the water column is dissolved or in colloidal form and is believed to originate primarily through outflow from an upstream "contaminated" reservoir. All ecosystem components in the stream have high ^{137}Cs concentration factors. Radiocesium concentrations are highest in filamentous algae (332 pCi/g-dry) and suspended particulate matter (100-200 pCi/g). Other food chain bases had much lower ^{137}Cs levels. Most consumer populations averaged 10-50 pCi/g. Radiocesium concentrations decreased in transfers between food chain bases and primary consumers or filter feeders. Omnivores and small predators have similar ^{137}Cs concentrations with bioaccumulation occurring by top-carnivores. Radiocesium levels are around 100 pCi/g in largemouth bass and water snakes. Foodweb components in the stream have reached a dynamic equilibrium in ^{137}Cs concentrations despite a 10 year absence of reactor operations. Radiocesium levels are apparently being maintained through long-term ^{137}Cs cycling in the upstream reservoir and surrounding flood plain forest systems. Rainfall and other physical processes influence the seasonal ^{137}Cs fluctuations in stream components.

Key words: radiocesium, food chains, trophic levels, consumers, concentration factors, freshwater stream, allochthonous material, suspended particulate matter.

INTRODUCTION

Considerable information has accumulated over the past two decades concerning the fate of radiocesium and other fission materials in natural systems. Some studies have dealt primarily with temporal fluctuations of major radionuclides in selected species while other research has focused on causal mechanisms for radionuclide transfer processes. A few opportunities have existed to follow the cycling of key radionuclides in natural systems which have received past releases from reactor operations. Available studies include research at the Hanford site (Watson, Cushing, Coutant and Templeton 1969), Perch Lake in Canada (Ophel 1963, Ophel and Fraser 1969), White Oak Lake in Tennessee (Crossley 1963, Shanks and DeSelm 1963), Hudson River estuary (Wrenn, Lentsch, Eisenbud, Lauer and Howells 1973) and effluent streams on the Savannah River Plant in South Carolina (Sharitz, Scott, Pinder and Woods 1975; Ragsdale and Shure 1973). However, the projected increase in nuclear facilities warrants further research on the fate of radionuclide releases to effluent systems.

Freshwater systems either serve as direct recipients of radionuclide releases or accumulate materials through airborne fallout and subsequent watershed transfer processes (Ritchie, McHenry and Gill, 1974). Models have recently been developed to explain the functional relationships within stream ecosystems (Fisher and Likens 1973, Cummins 1974) and the dynamic interactions and material transfers between aquatic and terrestrial systems (Likens and Bormann 1974). These models should prove quite valuable in clarifying the pathways of radionuclide movements through stream systems in the event of future releases. This is particularly true of the Southeastern United States where nuclear facilities are concentrated and strong interactions exist between slow-moving Coastal Plain streams and surrounding flood plain forests. Ragsdale and Shure (1973) have documented the importance of lateral redistribution in radionuclide exchanges across swampy flood plains and the long-term consequences of this process. Evidence is also accumulating (Ragsdale and Shure 1973, Sharitz et al. 1975, Jenkins and Fendley 1973) on the high degree of radiocesium cycling in Coastal Plain systems. The need for further studies on the mechanisms for this active radiocesium cycling is readily apparent.

Research is currently underway on different aspects of radiocesium dynamics within Coastal Plain streams which have received radiocesium releases from production reactor operations on the Savannah River Plant in South Carolina. Anderson, Gentry, and Smith (1973), Beyers, Dapson, Geiger, Gentry, Gibbons, Smith and Woods (1974) and Sharitz et al. (1975) have studied the high levels and probable transfer mechanism of ^{137}Cs among sediments, vegetation and terrestrial arthropods in a swamp where Steel Creek enters the flood plain of the Savannah River. Additional studies are in progress on Lower Three Runs Creek (LTRC - Fig. 1), another reactor effluent stream which drains into the Savannah River. Research at LTRC is focusing on radiocesium cycling within the blackwater creek and contiguous flood plain forest complex at locations upstream from the Savannah River swamp forest.

Lower Three Runs Creek is a 43.5 km blackwater creek (10m - 100m wide) which drains about 466 km^2 of watershed before entering the Savannah River. Production reactor operations were initiated in 1954 and LTRC received thermal and radionuclide releases as well as increased flow through reactor pumpage of Savannah River water. Par Pond, a 1200 ha impoundment, was constructed at the upper stretch of LTRC in 1958. Pond construction reduced the water flow and prevented further thermal inputs to LTRC. However, radiocesium releases continued until the reactor facilities were shut down in 1964. Present radiocesium additions to LTRC consist only of overflow from Par Pond which contains ^{137}Cs that has been cycling within the reservoir. Lower Three Runs Creek will also receive direct effluents and overland flow from the Barnwell Nuclear Fuel Reprocessing Plant which is projected to begin operations in 1976.

The past and projected utilization of LTRC thus emphasizes the need for a thorough understanding of the pathways of radionuclide exchanges within this system. The objectives of the present study were to determine the existing ^{137}Cs concentrations within major ecosystem components of LTRC and to follow the temporal fluctuations in radiocesium levels over a several-year period.

METHODS AND MATERIALS

Detailed studies were undertaken in April 1971 and April 1972 to determine the ^{137}Cs concentrations in major ecosystem components at six locations on LTRC (Fig. 1). Sample locations included access points along the stream between Par Pond and the Savannah River swamp forest. Suspended particulate matter, sediment, vegetation and animal samples were collected at each station. Sampling has since been conducted at Donora Station in October 1972 and at 10 intervals since February 1973. Collections at Patterson Mill have continued each April since 1971 to provide yearly comparisons of ^{137}Cs concentrations at replicate locations along LTRC. A control station was also established at Upper Three Runs Creek (UTRC), a similar blackwater creek on the Savannah River Plant (Fig. 1) which has remained free of reactor effluents. Upper Three Runs Creek receives low levels of ^{137}Cs through airborne fallout and watershed transfer processes. Samples were obtained from Upper Three Runs Creek in April 1972 and 1974 to enable radiocesium comparisons at a "non-contaminated" location.

All collections consisted of obtaining representative samples of major abiotic and biotic components from a 100-300 m segment of the stream at each sample location. A plankton net (80μm) was used to sample suspended particulate matter from the mid-stream water column. Large volume water samples (100-300 liters) were filtered. The specific volume sampled depended on suspended particulate matter load in the water column. Single samples were obtained initially. However, six replicate samples have been obtained on each sample date since July 1973. Two 20-25 liter water samples were also collected in polyethylene containers at Donora Station on each sample date since April 1973. Each 20-25 liter sample was filtered at 5μm and then 0.22μm using pre-weighed millipore filters. After filtration, each water sample was passed through an ion exchange column (Dowex 50W-X2) to remove ^{137}Cs dissolved in the water or sorbed to particles less than 0.22μm. Plankton net samples were also filtered. The filters and suspended particulate matter fractions were oven-dried at 70C, weighed, and radioassayed for ^{137}Cs content. Quantitative analyses were thus possible on relative weights and ^{137}Cs content of the > 80μm, > 5μm, 0.22-5μm, and dissolved or colloidal fractions of LTRC water on a seasonal basis.

Organic detritus and major submergent and emergent vegetation species were randomly sampled for radiocesium analysis of food-chain bases. Detrital samples were collected within the emergent vegetation beds. Triplicate samples were obtained prior to July 1973 and ten samples thereafter. Plant species sampled included the two major emergent vegetation bed species (Polygonum densiflorum, P. punctatum), a submergent species (Potomogeton pectinatus) and a filamentous algae (Oedogonium sp.). Eight plants of each Polygonum species and four composite Potomogeton samples were generally obtained on each sample date after July 1973. However, Polygonum species were often undistinguishable during the non-growing season. All detritus and vegetation samples were oven-dried at 100C for 24 hrs, ground in a Wiley Mill, weighed, and analyzed for ^{137}Cs content.

The larger invertebrate and vertebrate species at each sample location were obtained using dip nets, seines, fish traps or rod and reel. Efforts were made to select species representative of each trophic level and feeding habit (Table 1). The number of each species sampled was determined by considering biomass requirements for radioassays and the possible effects of destructive sampling. Animal samples were frozen after collection and stored until thawed for radiocesium analysis. Wet and dry weights were obtained and animal samples were oven-dried at 100C for 48 hours. Most invertebrates were pooled as composite species groups to insure sufficient biomass for statistical counting purposes. Only the larger vertebrates, clams and crayfish were analyzed individually. However, larger numbers of certain species were collected near the end of the study to obtain variance estimates.

All samples were placed in counting vials and analyzed for ^{137}Cs content using a Nuclear-Chicago automatic gamma counting system with a 3-in (7.7cm) NaI(Tl) well-type scintillation crystal. Samples were run until 4000 counts were accumulated (20 cpm bkg.) and counting rates were corrected for background, counting efficiency, sample geometry and sample weight. Ion exchange resins used in creek water analysis were counted on a Ge(Li)-NaI(Tl) gamma ray spectrometer system in the Physics Department of Emory University.

RESULTS AND DISCUSSION

Suspended particulate matter at Donora Station consists primarily of organic detritus and clay particles between 5-80μm (Fig. 2). Radiocesium concentrations were highest in this 5-80μm component. Cesium-137 levels remained slightly lower in larger particulate matter (> 80μm) and were undetectable in fine particles because of low mass. Very low and relatively stable ^{137}Cs concentrations (pCi/g or ml) are dissolved in the water or sorbed on colloidal particles (< 0.22μm). However, approximately 80-90% of the total ^{137}Cs in the water column occurs in this dissolved-colloidal fraction when considered on a pCi/liter basis (Fig. 2). The low mass of suspended particulate matter at Donora Station produces a small ^{137}Cs load despite the high ^{137}Cs concentration per g of this material.

Radiocesium levels varied in different food-chain bases at Donora Station (Fig. 3). Highest ^{137}Cs levels (331.8 pCi/g -April 1974) occurred in the widely-scattered growths of filamentous algae. Suspended particulate matter also contained relatively high ^{137}Cs levels over most of the study. Other food-chain bases including the two Polygonum species, streambottom detritus and Potomogeton had much lower ^{137}Cs concentrations.

Radiocesium concentrations in consumer species are strongly dependent on trophic levels (Figs. 4 and 5). Snails (Campeloma sp.) and clams (Elliptio complanata) are abundant in LTRC and are expected to feed mainly as primary consumers or detritivores (Pennak 1953). These species contained low ^{137}Cs levels throughout the study (Fig. 4). The shells of both species consistently ranged between 1-2 pCi/g. Freshwater shrimp (Palaemonetes paludosus) and crayfish (Procambarus hirsutus) are considered omnivores and often utilize fine or coarse detritus as major food sources in stream systems (Pennak 1953, Minshall 1967 and Harvey 1973). Shrimp and crayfish had higher ^{137}Cs contents than molluscs and both decapod species exhibited similar radiocesium fluctuations over time at Donora Station (Fig. 4). Whirligig beetles (Dineutes sp.) are also considered omnivores (Pennak 1953) and they had consistently low ^{137}Cs levels.

Invertebrates and small vertebrate predators had similar or slightly higher radiocesium concentrations than consumers at lower trophic levels (Fig. 5). Dragonfly nymphs (Libellulidae) and mosquitofish (Gambusia affinis) generally maintained ^{137}Cs concentrations around 25-30 pCi/g. Other small fish including young pirate perch (Aphredoderus sayanus - 25.2 $\pm$ 1.5 pCi/g), immature pickerel (Esox spp. - 32.1 $\pm$ 3.4 pCi/g) and dollar sunfish (Lepomis marginatus - 23.2 $\pm$ 3.4 pCi/g) had similar ^{137}Cs levels. Coastal shiners (Notropis petersoni) were very abundant at Donora Station and contained slightly higher ^{137}Cs levels than most other small consumers. Fishing spiders (Dolomedes sexpunctatus) exceeded 110 pCi/g in April 1971, but had lower and variable ^{137}Cs concentrations thereafter. Fishing spiders may occupy a fairly high trophic level in LTRC, since small fish are included as prey species (Borror and DeLong 1964).

The larger vertebrates at Donora Station had relatively high ^{137}Cs concentrations. Redbreast sunfish (Lepomis auritus) were abundant at Donora Station and these large sunfish contained fairly high ^{137}Cs levels (47.3 $\pm$ 13.4 pCi/g). Largemouth bass (Micropterus salmoides - 99.4 $\pm$ 1.9 pCi/g) and banded water snakes (Natrix sipedon - 92.0 pCi/g) are top-level carnivores and they had the highest mean ^{137}Cs concentrations among animals sampled at Donora Station.

Seasonal ^{137}Cs fluctuations in LTRC components appear related to an interacting complex of physical, metabolic and phenological processes. Very heavy rainfall and abnormally high stream flow during the first six months of 1973 (Gladden and Shure, this volume) produced a higher ^{137}Cs load in suspended particulate matter until late summer (Figs. 2 and 3). Radiocesium concentrations in suspended particulate matter decreased significantly in late 1973 as high waters receded during the normal fall dry period. Much less rainfall occurred during 1974 and ^{137}Cs levels in suspended particulate matter remained relatively low during this period. Cesium-137 levels increased again in fall 1974 when a large amount of ^{137}Cs is added annually to the stream through allochthonous leaffall, leaching by throughfall, and cesium losses from aquatic vegetation at the end of the growing season (Gladden and Shure, this volume).

Most producer and consumer species increased in ^{137}Cs content during the warmer growing season (Figs. 3-5). Radiocesium levels dropped during colder months when species are either dormant or less-active metabolically. However, the relatively high ^{137}Cs concentrations in many species in March or April 1974 may represent a rapid uptake and utilization of ^{137}Cs which was added to the system during the heavy flooding in 1973. A few consumers such as snails and dragonfly nymphs showed no clearcut seasonal pattern in ^{137}Cs concentrations.

The downstream patterns of ^{137}Cs concentrations along LTRC have been summarized elsewhere (Mayer, Palms, Platt, Ragsdale and Shure 1973). Consumer species were the only ecosystem components with a definite downstream reduction in ^{137}Cs content. Other components either had similar radiocesium levels along the stream or the concentrations were dependent on complex factors. Radiocesium dynamics are apparently similar at Patterson Mill and Donora Station

(Fig. 3-6). Producer (<u>Polygonum</u>) and consumer populations which were present at both locations had nearly equal ^{137}Cs concentrations. However, allochthonous materials such as suspended particulate matter ($t = 12.1$, $p < .01$) and streambottom detritus ($t = 2.17$, $p = .05$)contained significantly higher ^{137}Cs concentrations at Patterson Mill in April 1974 (Fig. 3).

Radiocesium concentrations within LTRC are considerably higher than levels observed in Upper Three Runs Creek or reported from other non-contaminated freshwater (Ritchie et al. 1974; Minckley, Craddock and Krumholz 1963; Rickard and Eberhardt 1973; Gustafson 1969) or estuarine systems (Wrenn et al. 1973). Food-chain bases from Donora Station had significantly ($p < .01$, t tests) higher ^{137}Cs levels than suspended particulate matter (16.7 ± 4.3 pCi/g, $t = 11.91$) organic detritus (8.7 ± 1.1 pCi/g, $t = 5.95$) and submergent vegetation (9.05 ± 1.1 pCi/g, $t = 4.74$) samples from Upper Three Runs Creek in April 1974. Consumer populations at Upper Three Runs Creek usually contained two to ten times less ^{137}Cs than LTRC populations (Fig. 4-6). However, the similar ^{137}Cs levels in freshwater shrimp at Upper Three Runs and LTRC is surprising and may be related to the active sorption process of this species (Harvey 1973). Cesium-137 levels in LTRC are only slightly lower than levels in nearby Steel Creek (Sharitz et al. 1973) or in sediments from White Oak Lake in Tennessee (Crossley 1963). The radiocesium in LTRC thus represents one of the largest accumulations of this long-lived isotope and offers an excellent opportunity to study radiocesium dynamics in a freshwater habitat.

Cesium-137 was highly concentrated by all biotic components of LTRC (Table 1), which follows the general pattern expected for freshwater systems (Polikarpov 1966). Filamentous algae and suspended particulate matter had the highest mean concentration factors among LTRC food-web components. Williams and Swanson (1958) have also documented the ability of algae to accumulate ^{137}Cs and Pendleton and Hanson (1958) reported that algal species had the highest concentration factors in experimental and effluent ponds at the Hanford site in Washington. Plant species from Hanford generally had concentration factors similar to aquatic vegetation from LTRC.

Many factors influence the relative concentration of ^{137}Cs in aquatic animal species (Reichle, Dunaway and Nelson 1970; Davis and Foster 1958). Reichle et al. (1970) concluded that radiocesium concentrations in aquatic animals are considerably higher than water, but show little or no increase from plant to herbivore to predator. Minckley et al. (1963) found various accumulations or discriminations of ^{137}Cs at higher trophic levels, whereas Pendleton and Hanson (1958) reported a definite increase in concentration factors for vertebrate predators. Radiocesium concentration factors in LTRC generally decreased in transfers between food-chain bases and primary consumers such as molluscs (Table 1). Omnivores and most small predator species had similar concentration factors and the levels were generally comparable to many food-chain bases. Concentration factors increased slightly in a few small predators and reached much higher levels by top carnivores. Results from LTRC and Hanford thus indicate a tendency in freshwater systems for greater ^{137}Cs accumulations at higher consumer trophic levels. Vertebrate food chains show a similar relationship in terrestrial systems (Pendleton, Mays, Lloyd and Church 1965; Jenkins, Monroe and Golley 1969), although radiocesium concentrations generally decrease along terrestrial arthropod food chains (Crossley 1963, Reichle et al. 1970).

Allochthonous detritus from surrounding systems is considered the major food source for consumer species in woodland stream ecosystems (Cummins 1974, Minshall 1967, Nelson and Scott 1962, Fisher and Likens 1973). Food chains are thus strongly detrital-based in heterotrophic systems such as LTRC and the cycling of materials including radiocesium is governed by import-export processes. Allochthonous particulate matter and its ^{137}Cs is added to LTRC primarily as litterfall or by material transport during annual flooding and heavy rainfall (Gladden and Shure, this volume). Some of this allochthonous material is trapped and accumulates within the emergent vegetation beds and is believed to serve as a major food source for consumer populations. The large amount of dissolved or colloidal ^{137}Cs in LTRC is added primarily through Par Pond outflow (John Gladden - unpublished data) and to some extent through leaching and decomposition processes within the blackwater creek-flood plain forest complex (Gladden and Shure, this volume). This dissolved or colloidal ^{137}Cs is available throughout the year for sorption on suspended particulate matter or direct uptake by food-chain components. Radiocesium incorporation by LTRC components is thus dependent on those annual processes governing allochthonous particulate and dissolved or colloidal inputs to the system. Stochastic events such as the heavy rainfall and subsequent flooding in 1973 may produce temporary or long-time shifts in ^{137}Cs concentrations of biotic populations.

Ecosystem components in LTRC appear to have reached a dynamic equilibrium in ^{137}Cs concentrations despite a 10 year absence of reactor inputs. This hypothesis is supported by the lack of a definite decline in ^{137}Cs levels over a nearly four-year period. The presence of approximate steady state or equilibrium ^{137}Cs levels in LTRC components suggests the importance of material cycling within Par Pond and the "contaminated" LTRC floodplain (Ragsdale and Shure 1973) as causal mechanisms. A slow annual input of ^{137}Cs from the reservoir and surrounding flood plain could maintain equilibrium levels in LTRC over an extended period. Cesium-137 is highly mobile in these blackwater creek systems (Sharitz et al. 1975). Therefore, radiocesium concentrations may remain relatively high in LTRC depending on the compartmental mass of ^{137}Cs within the reservoir-stream complex, and the rate of ^{137}Cs lost as net export to the Savannah River. Hydrological and radiocesium cycling studies are currently in progress to provide these data. However, the implications of this long-term phenomenon should be understood in future decisions concerning nuclear facility citing, particularly in non-confined aquatic systems such as those in the Southeastern Coastal Plain areas.

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Table 1. Mean concentration factors (wet weight) and major trophic level of important ecosystem components from Donora Station.

Component	Number[a] Sampled	Trophic[b] Level	Conc. Factor	Component	Number Sampled	Trophic Level	Conc. Factor
Sus.part. > 80μm	--	--	2246	Dineutes	494	O	480
matter > 5μm	--	--	4243	Aphredoderus	33	O-C	720
Detritus	--	P	938	L. marginatus	5	O-C	691
P. densiflorum	78	P	734	Anisoptera	118	C	648
P. punctatum	72	P	716	Dolomedes	78	C	1282
Potomogeton	--	P	295	Gambusia	223	C	891
Oedogonium	--	P	4496	Notropis	195	C	1092
Campeloma	397	H	260	Esox	6	C	908
Elliptio	91	FF	300	L. auritus	3	TC	1334
Palaemonetes	505	O	867	Micropterus	4	TC	2803
Procambarus	89	O	997	Natrix	2	TC	2595

[a]Indicates total number of individuals collected and used for radioassays.

[b]Abbreviations represent producers (P), filter feeders (FF), omnivores (O), carnivores (C) and top carnivores (TC).

FIGURE HEADINGS

Fig. 1 Map of Savannah River Plant (SRP) indicating sampling stations on Upper Three Runs Creek (UTRC) and Lower Three Runs Creek (LTRC). Sampling stations include Route B (Rt. B), Donora Station (Don.), Patterson Mill (PM), Boiling Springs (BS), Tabernacle Church Road (TCR) and Martin-Millette. The Barnwell Nuclear Fuel Reprocessing Plant (BNFP) site is also indicated.

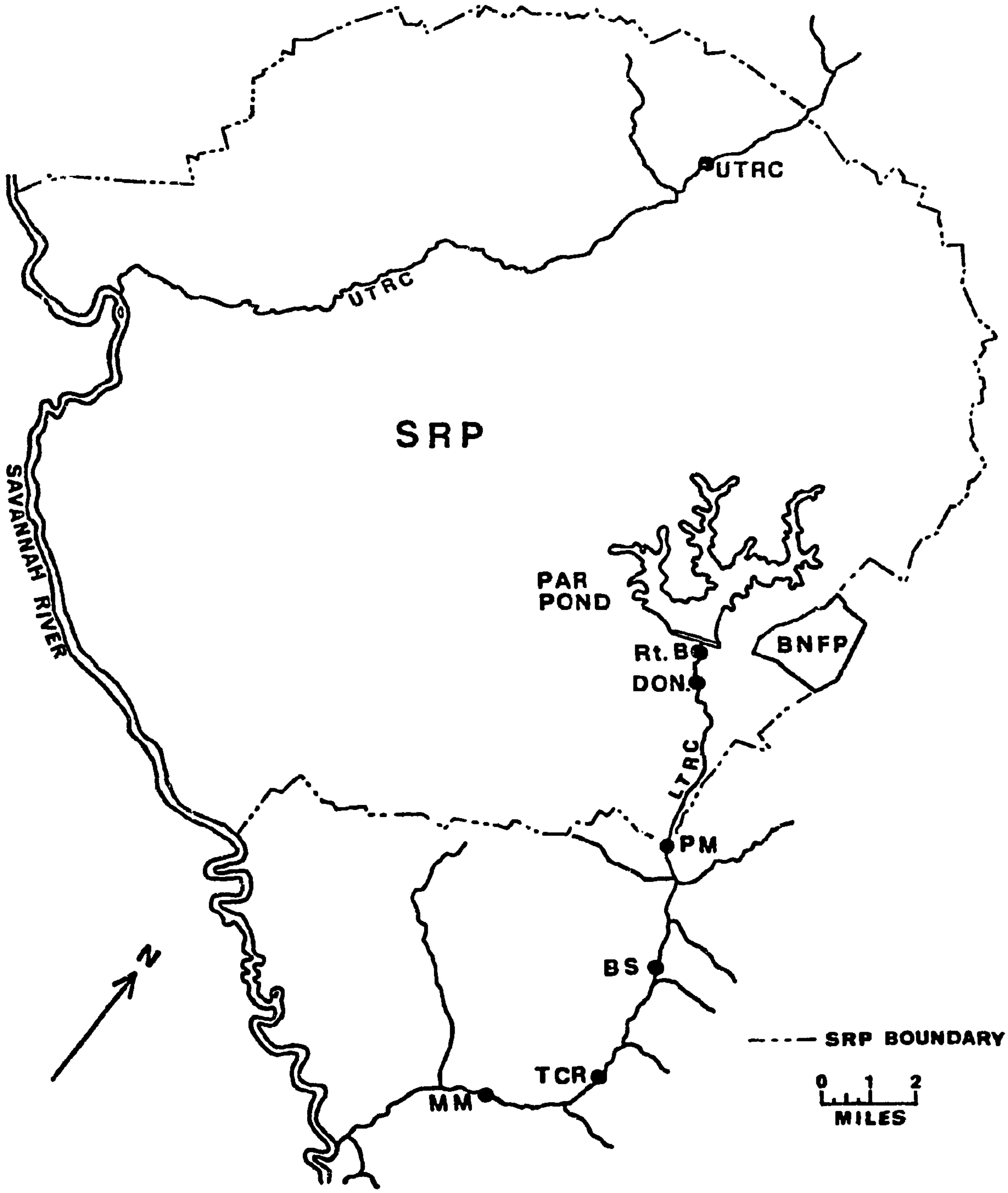
Fig. 2 Particulate load, ^{137}Cs levels and total amount of ^{137}Cs in different components of the LTRC water column at Donora Station. Cesium-137 levels represent dry weights with the scale for dissolved-colloidal fraction (Dis.) shown on right and indicating pCi/g or ml. Intervals shown in April 1973 are $\pm$ 1SE (N = 3). Means of two (25μm, 0.22 - 5μm and dissolved-colloidal) or six samples (80 μm) are shown thereafter. (μ = μm)

Fig. 3 Cesium-137 activity densities (pCi/g dry wt.) over time in major food-chain bases at Donora Station and Patterson Mill. Intervals shown for each component indicate graphical extensions of the least significant difference ($\pm \frac{LSD}{2}$, Steel and Torrie 1960) as determined (.05 level) from a one-way analysis of variance. Missing data (N) represent no sample on particular dates.

Fig. 4 Cesium-137 activity densities (pCi/g dry wt.) over time in major consumer species at Donora Station. Confidence intervals (95% level) are shown for particular species. Missing data represent no sample collected (N) or undetectable (U) levels of ^{137}Cs.

Fig. 5 Cesium-137 activity densities (pCi/g dry wt.) over time in important predator species at Donora Station. Confidence intervals (95% level) are shown for *Notropis*. Missing data represent no sample collected (N) or undetectable (U) levels of ^{137}Cs.

Fig. 6 Cesium-137 activity densities (pCi/g dry wt.) over time in major consumer species at Patterson Mill (PM) and Upper Three Runs Creek (UTRC) stations. Missing data represent no sample collected (N) or undetectable (U) levels of ^{137}Cs.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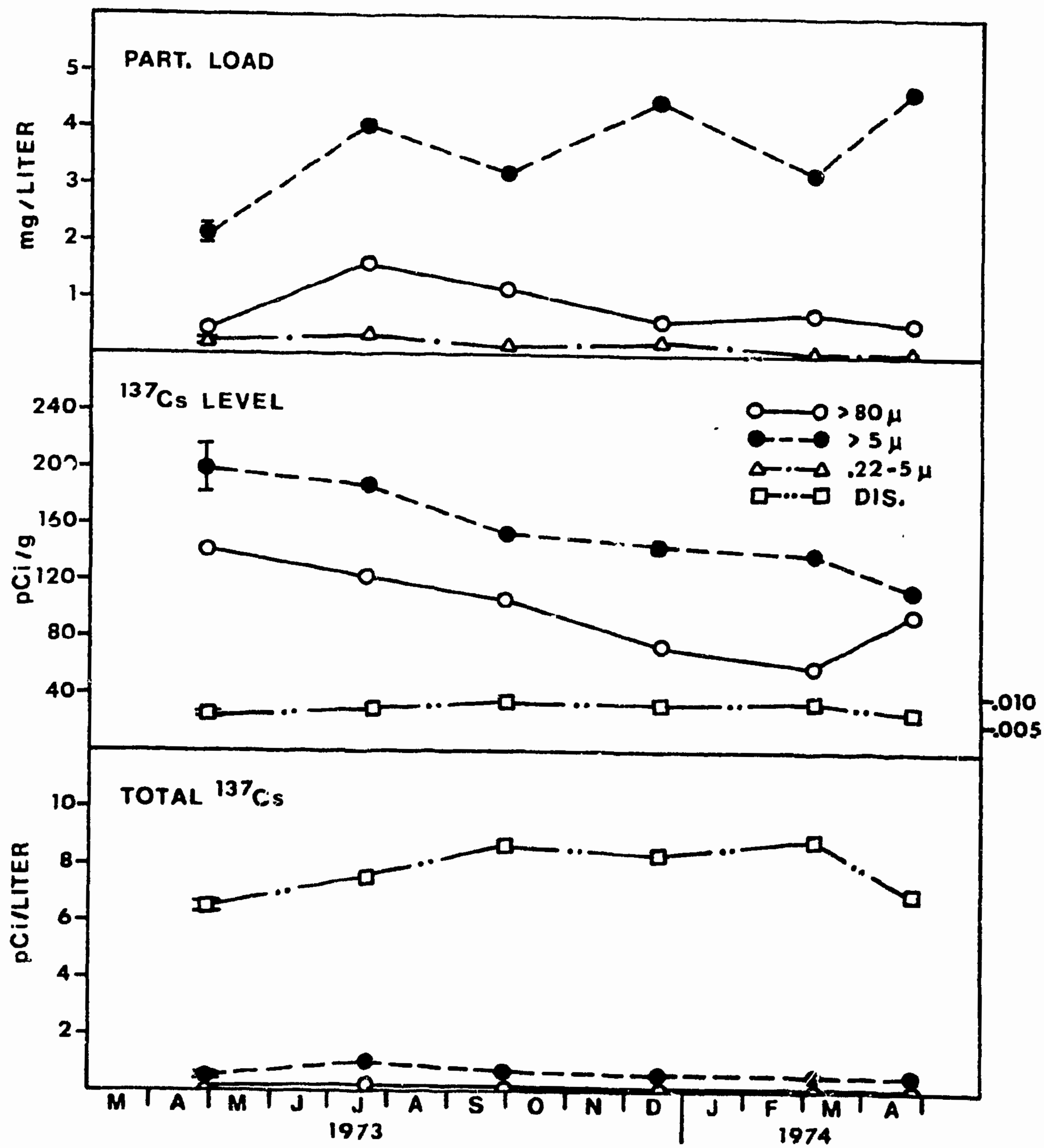
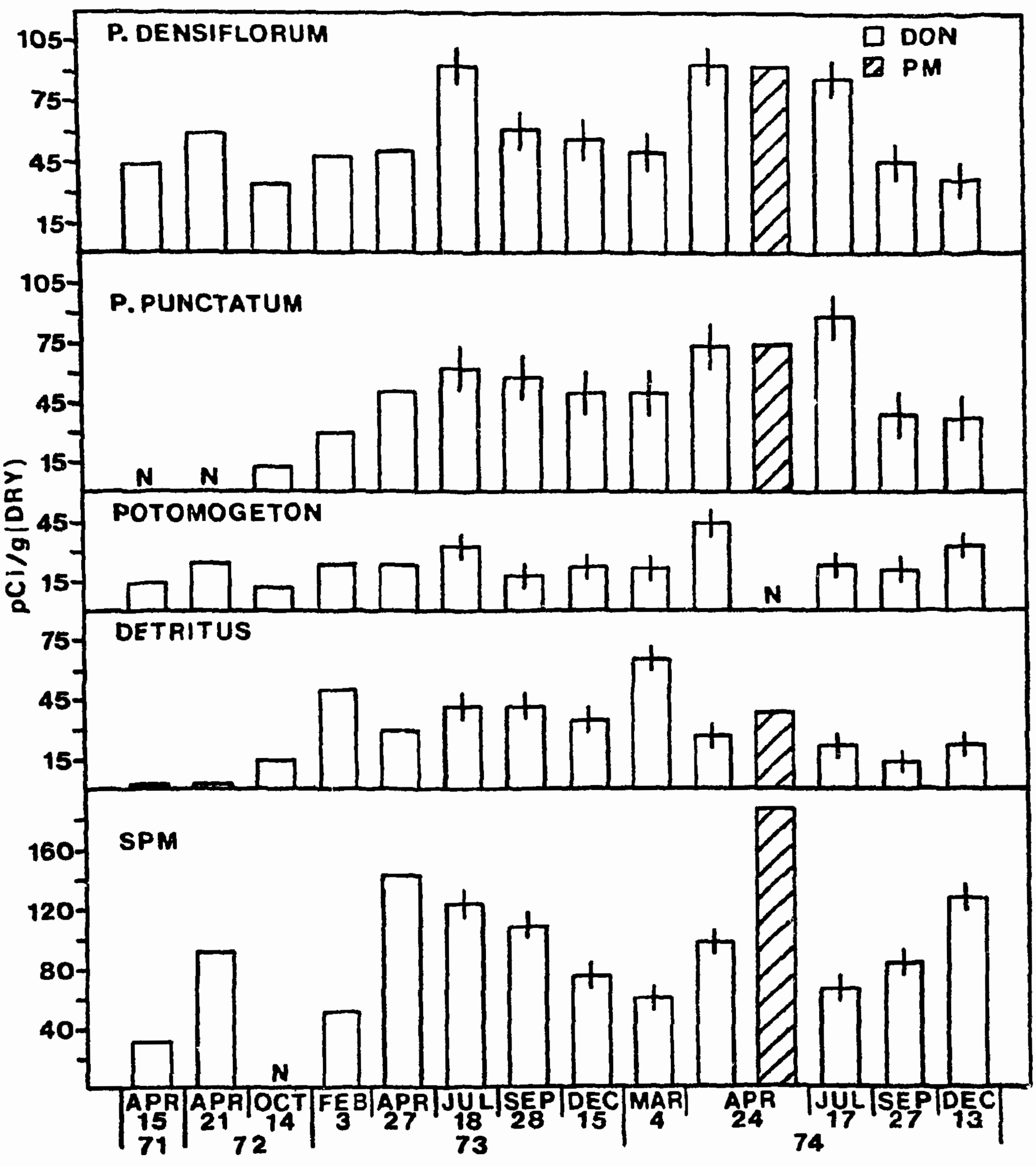
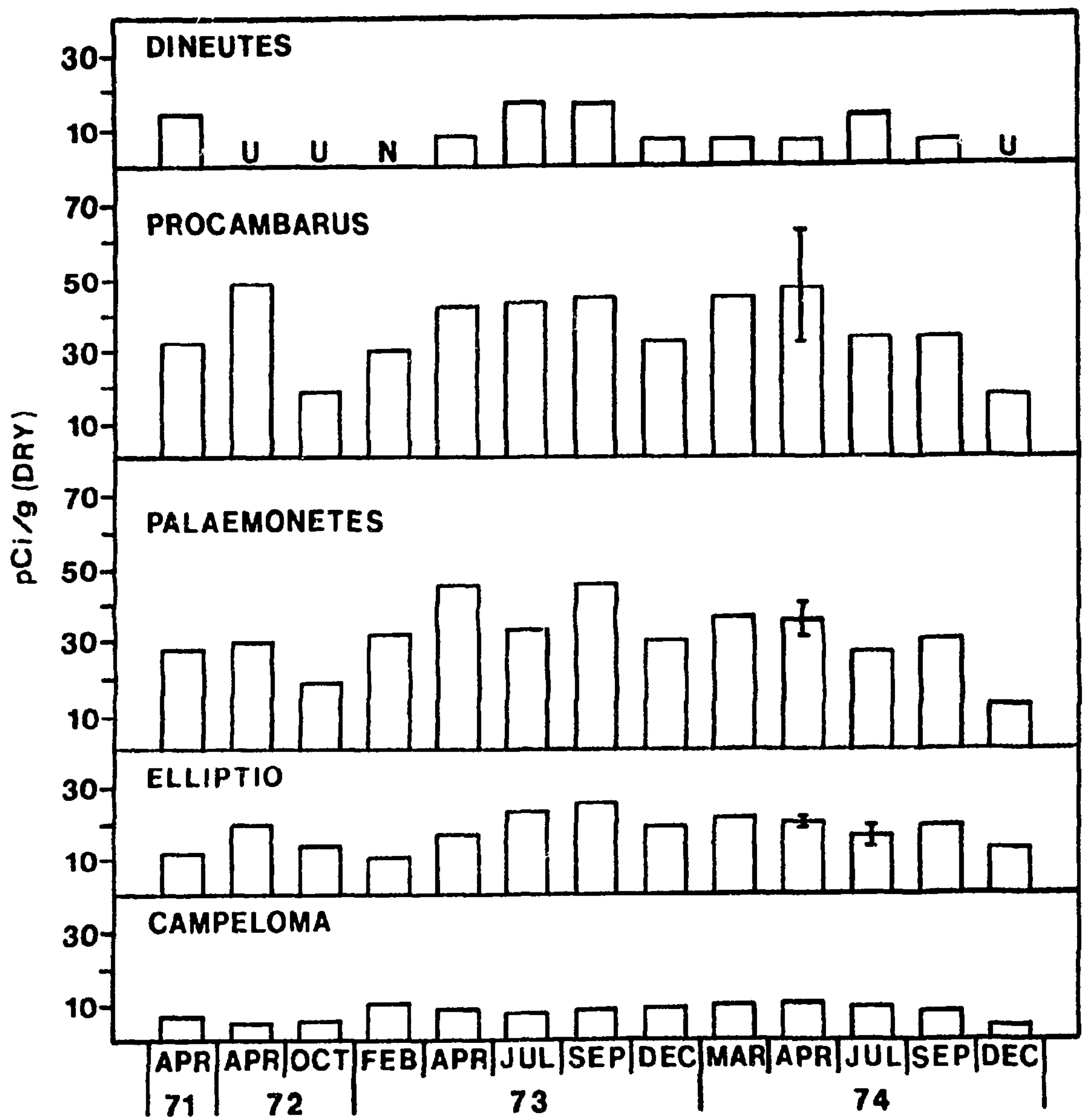
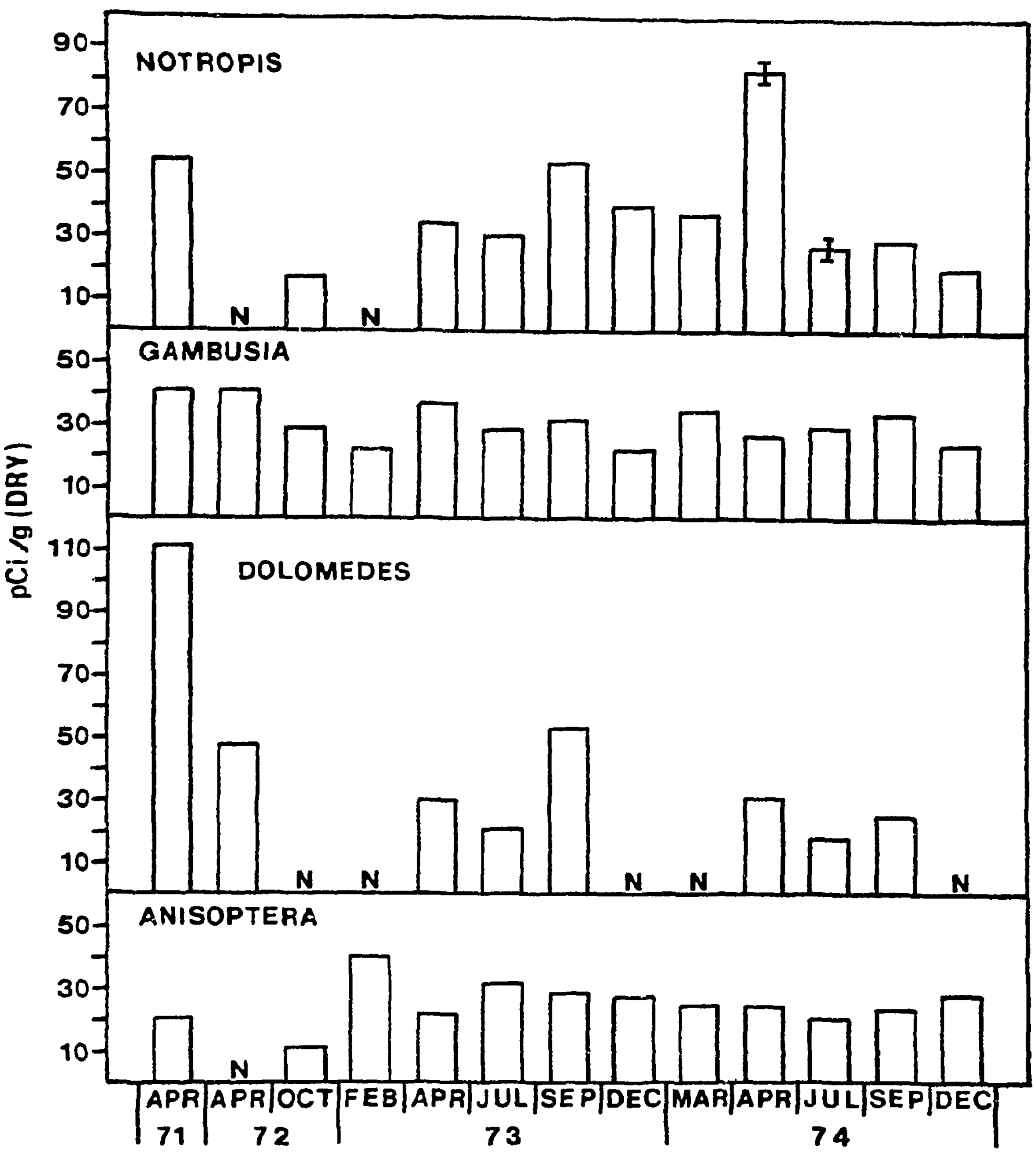
0 1 2
MILES



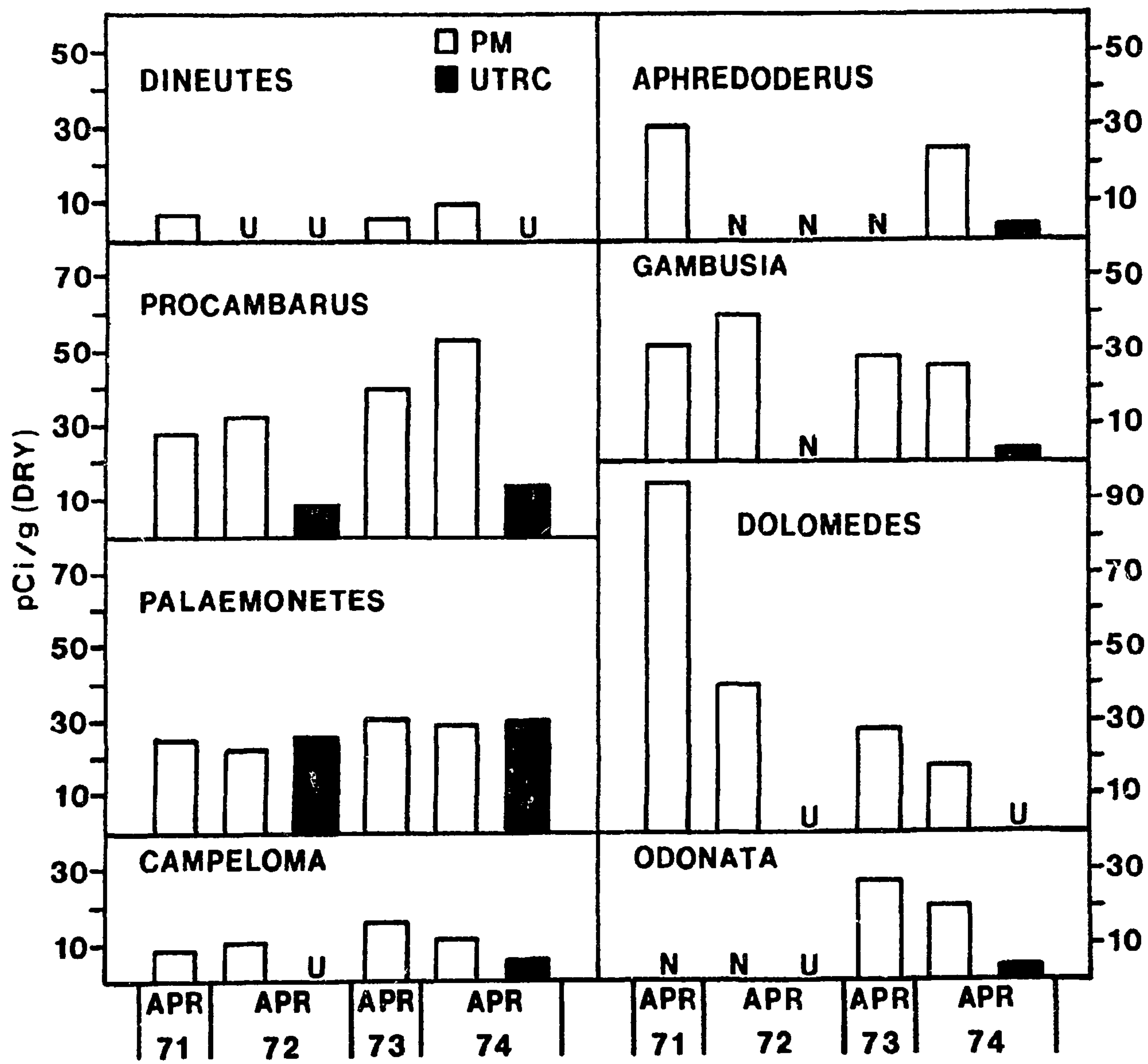
PART. LOAD
mg/LITER
5
4
3
2
1
137Cs LEVEL
>80 μ
>5 μ
.22-5 μ
DIS.
240
200
160
120
80
40
pCi/g
.010
.005
TOTAL 137Cs
10
8
6
4
2
pCi/LITER
M
A
M
J
J
A
S
O
N
D
J
F
M
A
1973
1974


P. DENSIFLORUM
DON
PM
P. PUNCTATUM
POTOMOGETON
DETRITUS
SPM
pCi/g (DRY)
105
75
45
15
160
120
80
40
N
APR 15
APR 21
OCT 14
FEB 3
APR 27
JUL 18
SEP 28
DEC 15
MAR 4
APR 24
JUL 17
SEP 27
DEC 13
71
72
73
74


pCi/g (DRY)
DINEUTES
30
10
U
U
N
U
PROCAMBARUS
70
50
30
10
PALAEMONETES
70
50
30
10
ELLIPTIO
30
10
CAMPELOMA
30
10
APR
APR
OCT
FEB
APR
JUL
SEP
DEC
MAR
APR
JUL
SEP
DEC
71
72
73
74



NOTROPIS
GAMBUSIA
DOLOMEDES
ANISOPTERA
pCi/g (DRY)
90
70
50
30
10
110
N
APR
OCT
FEB
JUL
SEP
DEC
MAR
71
72
73
74



PM
UTRC
DINEUTES
APHREDODERUS
PROCAMBARUS
GAMBUSIA
PALAEMONETES
DOLOMEDES
CAMPELOMA
ODONATA
pCi/g (DRY)
U
N
APR 71
APR 72
APR 73
APR 74