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Limnological aspects of Upland Island: A wilderness area in East Texas

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Limnological Aspects Of Upland Island: A Wilderness Area In East Texas

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ABSTRACT--In 1980, a physico-chemical and biological investigation of the major streams and ponds in the Upland Island Area was conducted. Falls, Graham, and Cypress Creeks were found to be the most sensitive habitats with good water quality and diverse aquatic communities. All streams had low primary productivity rates and had detrital based food chains. Oxygen concentrations were marginal because of abundant leaf litter, and flow rates were critical for diverse benthic communities. Reduction of leaf litter, stream side vegetation, and formation of trails in the watersheds would probably have serious consequences on streams. Management to prevent erosion and sedimentation is recommended.

KEYWORDS: wilderness, streams, ponds, water quality, benthic macroinvertebrates, plankton, fish.

In 1980, an ecological study was conducted on the Upland Island Area (also known as the Graham Creek Area), a 3,650 ha tract of pine-hardwood forest located in the Angelina National Forest in eastern Texas. Subsequent to that investigation, the United States Congress has designated the Upland Island Area as a wilderness. That wilderness area is within the Southern Evergreen Forest formation (Tharp 1926), or region (Braun 1950), characterized by pines and hardwoods, with longleaf pine the dominant species. Also, within this region, are the floodplains of various rivers. The Neches River forms the southern boundary of the wilderness area and is part of the Bottomland Forest formation characterized by Bray (1906) as a typical mesophytic formation of the South Atlantic (Austroriparian) type. The purpose of this research was to evaluate the major aquatic ecosystems within the Upland Island Wilderness and to identify the more sensitive streams. Recommendations for preservation management are also given.

DESCRIPTION OF COLLECTION SITES

Eight collecting sites were selected within the wilderness area (Fig. 1). Station 1 was located on Oil Well Creek which flows through a beech-magnolia community. The collecting site was a pool, in water less than one meter deep. Station 2 was on Big Creek, also in a pool area less than one meter deep. Vegetation surrounding the area was predominantly beech and magnolia trees. Station 3 was in an acid bog surrounded by sweetgum trees. At the deepest point, the bog was 1.5 meters deep, and measured 60 meters long and 50 meters wide. Station 4 was a swamp area, with pine and sweetgum predominating. A dense canopy of vegetation supplied a deep layer of leaf litter on the bottom of the pond. Station 5 was located midway along Falls Creek in a pool area. Surrounding vegetation was predominantly pine and hardwood species. Station 6 was located in a pool on Graham Creek in a heavily forested, palmetto, bottomland area. Station 7 was located in a pool and a riffle area on Cypress Creek. Cypress, pine, and hardwoods dominated the canopy over the creek. Station 8 was located in a shallow pond with a sparse stand of pines along the shoreline. A few shrubs grew in the shallow area within the pond, and thick mats of sphagnum moss grew along the margin.

METHODS AND MATERIALS

Physico-Chemical Methods

All water samples for chemical analysis were collected just below the surface and stored in darkness on ice for transport to the laboratory. Stream flow rates, water temperature, dissolved oxygen, carbon dioxide, and alkalinity were determined in the field, using a Yellow Spring Oxygen and Temperature meter, model 54, and procedures reported in *Standard Methods* (APHA 1980). Calcium and sodium were analyzed using a Beckman Flame Spectrophotometer, model B, while iron, sulfate, orthophosphate, total phosphorus, nitrate, nitrite, ammonium, and color (true and apparent) were determined using colorimetric methods (APHA 1980). Optical density was

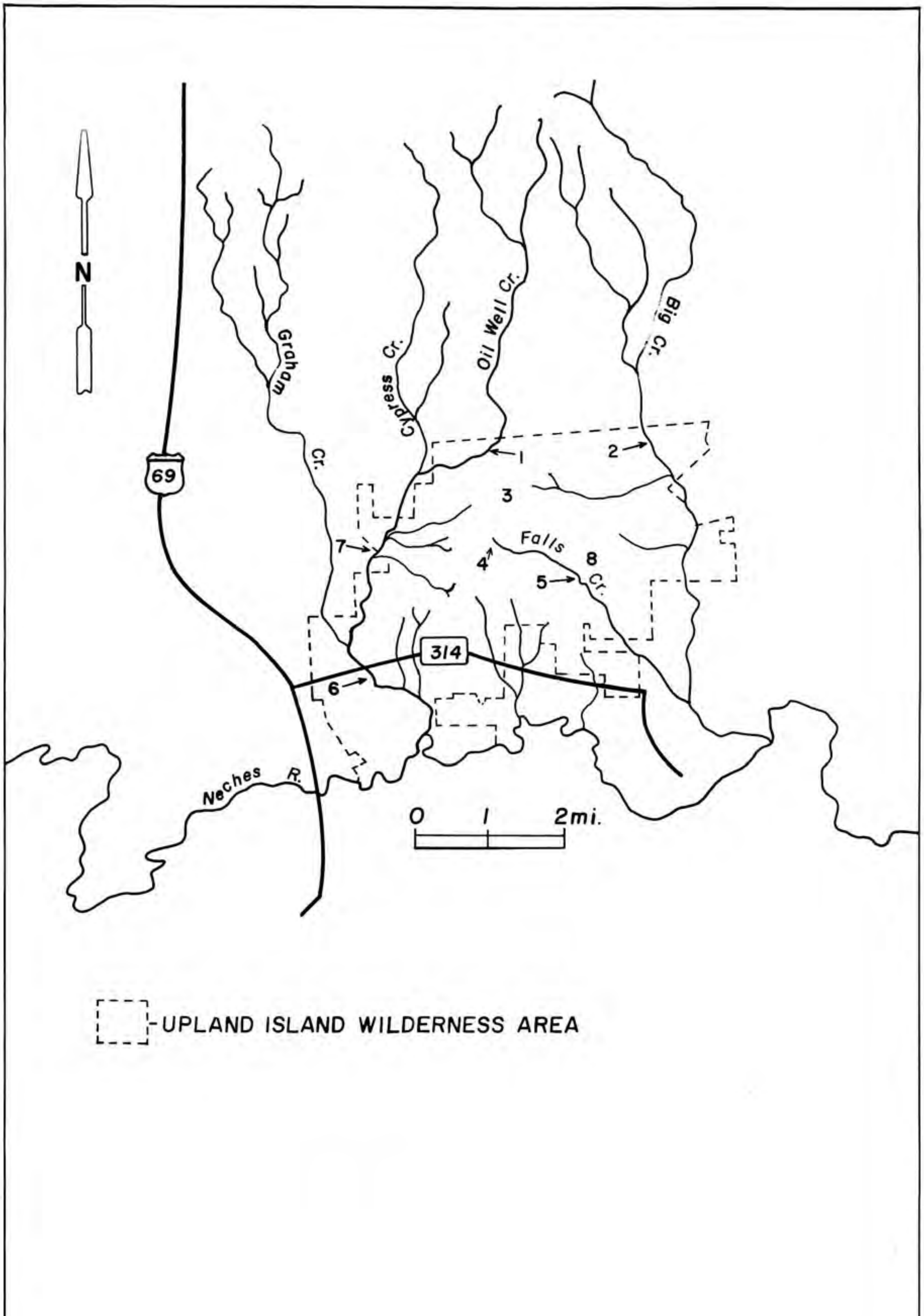

Figure 1. Upland Island Wilderness area and location of collecting sites.

determined using a Bausch and Lomb Spectrophotometer, model 70. Biochemical oxygen demand (BOD) was determined after samples were incubated five days in a Lab-Line incubator and using a Yellow Springs BOD oxygen probe and oxygen meter (APHA 1980). Turbidity was determined using a Hach Turbidimeter, model 2100A, and total suspended solids (TSS) were determined gravimetrically using a Mettler Analytical Balance, model H10. Chloride concentrations were analyzed by the mercuric nitrate method, and phytoplankton chlorophyll *a* concentrations were determined using a Turner Flourometer, model 110 (APHA 1980). Total Kjeldahl nitrogen was determined by a method reported by the EPA (1971).

Benthic Community Methods

Five grabs were collected along a transect at each site using an Ekman Dredge, and a wash bucket with a No. 30 screen bottom (0.59mm). Identifications were made using Edmondson (1959), Mason (1973), Hobbs (1976), Merritt (1978), and Pennak (1978). Species diversity was computed using Shannon's equation (Shannon and Weaver 1963). Benthic productivity was determined using a method reported by Menzie (1980).

Plankton Methods

Zooplankton were collected by pouring a known volume of water through a No. 20 plankton net. Samples were preserved and populations were estimated using methods reported by Lind (1979). Organisms were identified using Pennak (1978) and Edmondson (1959). Phytoplankton were collected by centrifuging one liter of water from each site in a Foerst Plankton Centrifuge. Population estimates were done using methods in Lind (1979), and identification of algal species were based on keys from Whitford and Schumacher (1973) and Patrick (1966). Periphyton productivity was done using an artificial substrate technique (APHA 1980).

Fish Collection and Coliform Bacteria Methods

Fish were seined from each creek and a list of taxa compiled. Identification of fish were based on keys from Eddy and Underhill (1980). Samples for coliform analysis were collected in sterilized 250 ml erlynmeyer flasks and stoppered with cotton plugs. *Standard Methods* procedures were used (APHA 1980), and values were reported in MPN/100, or the most probable number of coliform bacteria per 100 mililiters of water.

RESULTS AND DISCUSSION

The results of chemical and biological data suggest that the streams fall into two categories: Falls, Graham, and Cypress Creeks were found to be the most sensitive ecological areas, while Oil Well Creek and Big Creek were found to be more stressed habitats. The ponds were also stressed, ephemeral, bodies of water, but were none the less important in the forest ecosystem.

Streams

Table 1 reflects slightly stressful conditions in several of the streams. Dissolved oxygen values, while not anoxic, occasionally fell below 5 mg/L, which can be stressful to some aquatic organisms. Those concentrations were due to an abundance of decaying leaf litter on the stream bottom. While the benthic oxygen demand was high, the oxygen demand of organisms suspended in the water column (BOD) was relatively low. Coliform bacteria numbers (Table 2) were somewhat elevated, but those values probably originated from soils and from wildlife fecal input. Nitrogen and phosphorous concentrations were relatively high, probably because of decaying leaf litter, but shading from the heavy forest canopy greatly limited phytoplankton and periphyton density. In addition, turbidity and color

Table 1. Physicochemical Means for All Stream Stations Sampled in the Upland Island Area during the Summer of 1980.

	Station				
Parameter	1	2	5	6	7
O^2	4.5	5.4	5.9	5.4	4.2
Temp (°C)	23.7	24.5	23.5	25.1	25.3
CO_2	21.6	32.8	18.0	15.6	24.4
HCO_3 alk.	43.8	31.7	40.3	67.7	24.4
pH	6.7	6.5	6.5	6.8	6.6
Turbidity (NTU's)	21.8	20.0	16.3	23.3	28.2
Ca	0.2	0.2	trace	trace	trace
Na	17.3	22.8	11.0	26.9	17.3
Cl	15.8	24.3	11.0	29.5	17.7
Fe	2.42	1.64	2.17	1.45	2.55
SO_4	28.4	59.4	17.8	39.1	33.6
PO_4	0.36	0.12	0.14	0.25	0.25
Total phos.	0.64	0.38	0.41	0.51	0.62
NO_3-N	0.03	0.01	0.01	0.04	0.02
NO_2-N	0.06	0.03	0.04	0.05	0.05
NH_4-N	1.37	1.18	1.03	1.40	1.49
Total Kjeldahl nitrogen	3.05	3.87	3.78	3.39	5.04
Chlorophyll *a* (ug/L)	1.3	1.7	trace	1.2	0.8
BOD	1.7	1.1	1.4	1.2	1.4
Total suspended solids	55.6	22.3	12.6	34.1	92.1
Flow rate (CMS)	0.02	0.02	0.09	0.23	0.04
Conductivity (micromhos)	133	186	49	251	135
App. color (cu)	98	95	79	76	117
True color (cu)	64	61	61	64	68

Parameters are expressed in mg/L unless otherwise indicated.

Table 2. Coliform Counts (MPN) for Stream Stations Sampled in the Upland Island Area during the Summer of 1980.

	Station				
Date	1	2	5	6	7
May 28, 1980	1400	1800	5300	1400	2100
June 11, 1980	666	1246	1263	966	710

values were somewhat elevated, further restricting algal populations in the streams. The color values were partly due to dissolved organic matter from decaying vegetation, but also to relatively high iron concentrations. East Texas streams, generally, have high iron values because of the soils in this region. Generally, the streams were found to contain soft, slightly acid water with low sulfate, chloride, and sodium concentrations.

Benthic macroinvertebrates, because of their relatively low mobility, are good indicators in water quality studies. Mayflies, caddisflies, and stoneflies in high numbers, indicate good water quality, whereas the dominance of more pollution tolerant organisms, such as oligochaetes and chironomids, reflect stressful conditions. Figure 2 would suggest Oil Well creek and Big Creek were the most stressful environments. Graham and Cypress creeks were considerably less stressed, and benthic indicators in Falls Creek reflected very little stress. The mean benthic species diversity indices (Table 3) supports those observations. Oil Well and Big Creeks had the lowest benthic diversity. Dissolved oxygen values were near stressful levels in all the streams, but flow rates seemed to be the important difference between streams. Gaufin (1973) reports that flow rate is a very important factor in the survival of aquatic insects when exposed to lower oxygen concentra-

Table 3. Species Diversity and Redundancy of the Stream Benthos Sampled at the Upland Island Area during the Summer of 1980.

	Station				
Date	1	2	5	6	7
May 28	d 1.44	0.0	1.59	2.00	2.54
	r<.01	0.0	0.28	0.08	0.07
June 11	d 0.0	1.56	1.54	2.29	1.55
	r 0.0	0.69	0.40	<.01	<.01
June 25	d 1.00	0.92	1.91	1.73	2.34
	r<.01	<.01	0.21	0.49	0.14
July 9	d 0.0	1.00	—	1.76	1.58
	r 0.0	<.01	—	0.48	<.01
July 23	d 1.50	—	—	1.97	1.32
	r 0.60	—	—	<.01	0.35
Mean	d 0.79	0.87	1.68	1.95	1.87

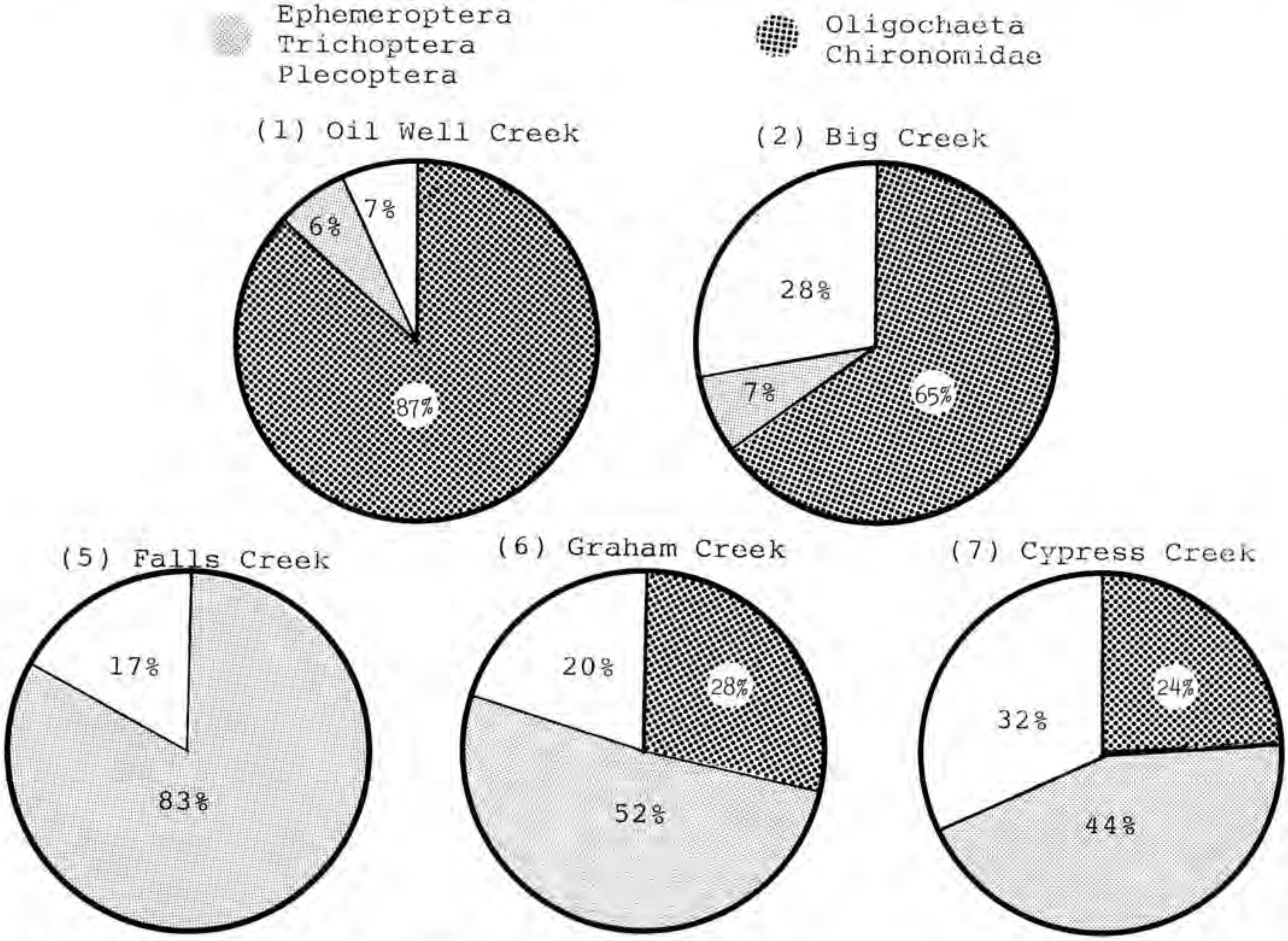

Figure 2. Relative abundance of oligochaetes and chironomids; ephemeropterans, trichopterans, and plecopterans; and other taxa collected at five streams in the Upland Island Area.

tions. Insects are able to tolerate lower oxygen levels in increased flow rates, and both Oil Well and Big Creeks had the lowest rates. Benthic standing crop and productivity were relatively low in all the streams, but Oil Well and Big Creeks had the lowest (Table 4).

Blancher (1984) reports that in the zooplankton community, cladocera and copepods generally predominate in less euthrophic habitats, while rotifers dominate in more euthropic waters. Again, Oil Well and Big Creeks had the larger numbers of rotifers (Fig. 3 and Table 5-6).

Phytoplankton populations were relatively low, as reflected by phytoplankton chlorophyll *a* values and by cell counts (Table 7). Shading, color, and turbidity were probably the limiting factors. Diatom species of *Navicula, Nitzschia, Synedra*, and *Melosira* were frequent and indicated stressful conditions. However, that impact was lessened somewhat by the presence of clean water indicators *Cyclotella, Pinnularia, Surirella, Achnanthes, Cymbella*, and *Frustulia* (Fig. 4). The periphyton community was very similar to the phytoplankton (Table 8), in fact, much of the phytoplankton probably came from the

Table 4. Organisms per m^2, mg. wet wt./m^2 (parentheses) and Productivity of the Benthic Macroinvertebrates Collected from Streams in the Upland Island Area during the Summer of 1980.

	Station				
Date	1	2	5	6	7
May 28	473	43	869	165	89
	(524)	(83)	(1686)	(243)	(186)
June 11	9	164	1376	172	22
	(18)	(229)	(2534)	(5830)	(11494)
July 9	34	18	—	86	9
	(26)	(11)	—	(479)	(11)
July 23	138	—	—	96	58
	(292)	—	—	(891)	(103)
Mean	134	63	843	126	287
	(184)	(87)	(1493)	(1535)	(2450)
Productivity	0.76	0.13	2.89	1.21	0.35

Table 6. The Occurrence of Zooplankton at Collecting Sites in the Upland Island Area during the Summer of 1980.

	Station							
Genus	1	2	3	4	5	6	7	8
Copepoda								
Canthocamptus				X	X	X		
Cyclops			X	X				X
Ectocylops	X	X		X				X
Eucyclops	X	X	X		X	X	X	
Paracyclops				X				
Cladocera								
Alona			X		X		X	
Bosmina	X	X		X		X		X
Ceriodaphnia			X					X
Chydoras			X					X
Daphnia		X		X				X
Macrothrix			X					
Scapholeberis	X	X	X	X	X	X		X
Rotifera								
Asplancha		X	X					
Brachionus	X	X	X					
Keratella	X	X	X	X	X	X	X	X
Lecane	X			X		X	X	
Manfredium			X					
Platyias				X				
Rotaria	X	X			X	X	X	X
Testudinella					X			

Table 5. Organisms per Liter and Relative Abundance (%) of Copepods, Cladocerans, and Rotifers Collected from All Stations in the Upland Island Area during the Summer of 1980.

		Station							
		1	2	3	4	5	6	7	8
May 28	Copepods	37	36	34	72	89	84	53	
	Cladocerans	27	40	48	22	8	8	20	
	Rotifers	36	24	18	6	3	8	27	
	Orgs/liter	2	2	240	500	53	42	3	
June 11	Copepods	72	62			90	53	66	
	Cladocerans	20	20			8	30	29	
	Rotifers	8	18			2	17	6	
	Orgs/liter	3	5			8	18	2	
June 25	Copepods	78	67			83	90	70	
	Cladocerans	17	20			11	4	22	
	Rotifers	5	13			6	6	8	
	Orgs/liter	2	7			18	12	2	
July 9	Copepods	61	67			82	57	60	44
	Cladocerans	17	22			5	29	30	18
	Rotifers	22	11			13	14	10	38
	Orgs/liter	18	7			26	30	4	123
July 23	Copepods	81					92	96	
	Cladocerans	7					6	1	
	Rotifers	12					2	3	
	Orgs/liter	35					16	32	

periphyton community. Periphyton primary productivity was relatively low (Table 9). Mean productivity values ranged from 54 to 186 mg Carbon/m squared/day. Wetzel (1979) suggests that values between 50 and 300 mg C/m squared/day represent very low production (Oligotrophic conditions). Since phytoplankton and periphyton production were low, the importance of the abundant leaf litter in the streams is apparent. All of the streams had detrital based food chains, rather than grazing food chains. Leaf litter input is absolutely vital in these stream ecosystems.

Table 7. Organisms per Liter of Phytoplankton Collected from All Stations at the Upland Island Area during the Summer of 1980.

	Station							
	1	2	3	4	5	6	7	8
May 28	260	400	2200	2200	480	360	280	
June 11	130	720			170	540	320	
June 25	120	1020			210	190	140	
July 9	2680	1180			420	400	500	3220
July 23	3240					850	1180	

Table 8. Relative Abundance (%) of Diatoms Collected from Periphyton Samples on June 11, 1980 in the Upland Island Area.

	Station				
Genus	1	2	5	6	7
Achnanthes	4.6	2.5	3.5		2.9
Capartogramma			0.9	0.8	
Cocconeis	0.8	0.8			1.0
Cyclotella	3.1				
Cymbella	13.0	5.8	1.7	3.0	5.7
Diploneis	2.3			3.0	
Eunotia	11.5	25.8	7.0	7.3	12.4
Frustulia	6.2	2.5	6.1	4.5	3.8
Gomphonema	1.5	4.2	0.9	5.3	2.9
Gyrosigma	0.8				1.0
Melosira	2.3	1.7	1.7	0.8	1.9
Navicula	14.6	7.5	20.0	17.2	24.8
Neidium					1.9
Nitzschia	8.5	15.8	12.2	37.1	20.0
Pinnularia	6.9	7.5	13.9	5.3	7.6
Rhopalodia	3.1		1.7	0.8	1.9
Stauroneis	6.9	1.7	2.6	2.3	1.9
Surirella	5.4	5.0	4.3	7.3	6.5
Synedra	8.5	19.2	23.5	4.5	3.8

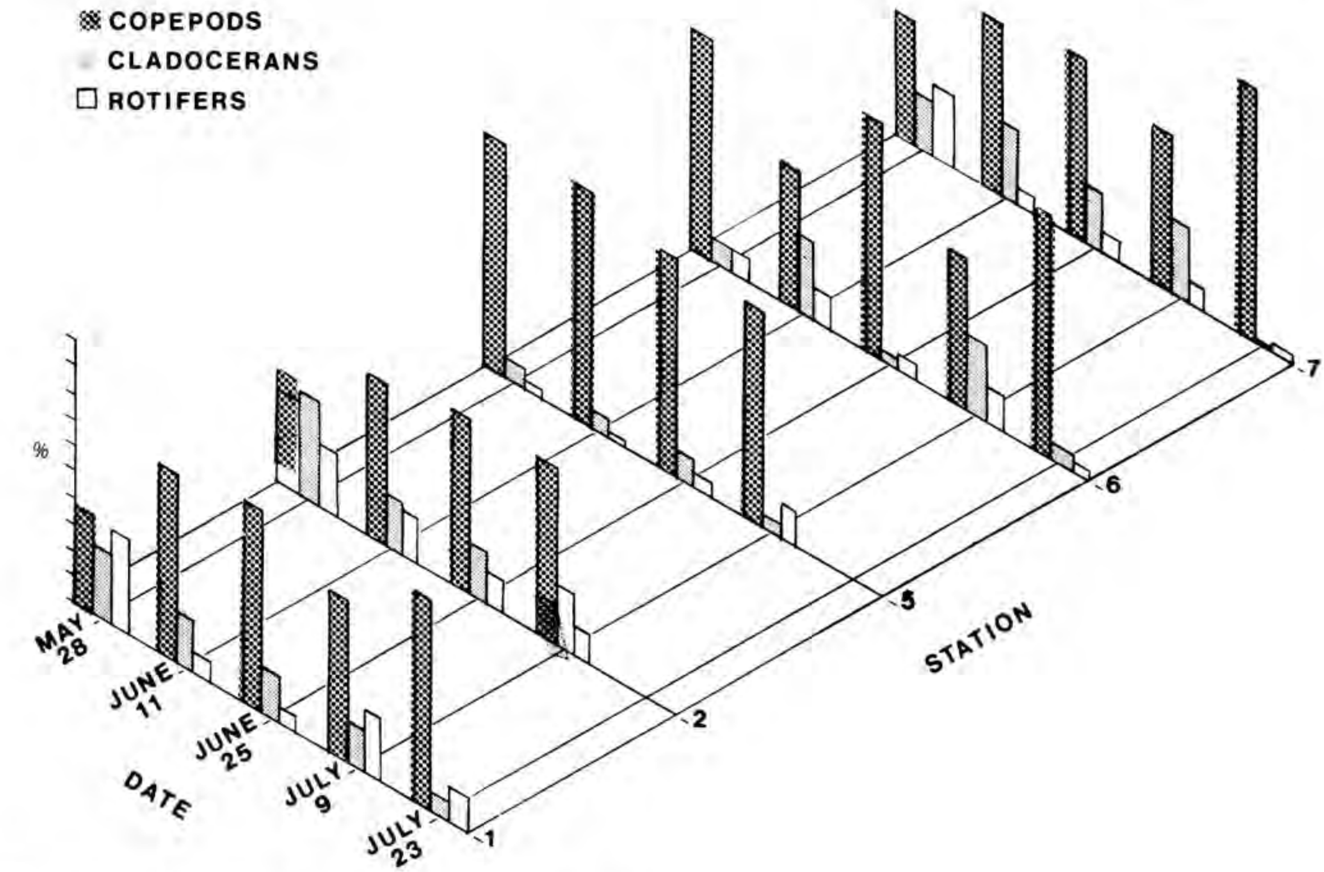

Figure 3. Relative abundance of copepods, cladocerans, and rotifers in the zooplankton of streams sampled in the Upland Island Area.

A relatively diverse fish community was found in all of the streams (Table 10). The assemblage of fish is typical of unpolluted East Texas streams, but are species that can tolerate less than 5 mg/L of dissolved oxygen for short periods of time.

Ponds

All of the ponds were found to be temporary and very environmentally stressed, aquatic habitats. Dissolved oxygen values were often less than 5 mg/L and dropped to as low as 1.1 mg/L. The pH at station 8 was 4.9, possibly because of the sphagnum moss beds. Station 4 had 95.7% oligochaetes and chironomids and station 8 had 89.4%. Zooplankton and phytoplankton populations were abundant (Table 6 and Table 7). The phytoplankton collected from the ponds were dominated by desmids *Eustrum, Desmidium* and *Xanthidium*, genera associated with acid water (Table 11). Station 3 was highly stressed (3.5 mg/L of oxygen) due to the dense mat of leaf litter, and the phytoplankton there was dominated by a small *Chlorella*-like alga, indicating organically polluted conditions. Stressful conditions at station 8 were reflected by the dominance of *Stigeoclonium*, an alga also associated with polluted water.

Management Recommendations

Falls, Graham, and Cypress Creeks were found to be sensitive aquatic habitats, and those areas would be most vulnerable to disturbance by man. Removal of vegetation from streamside on any of the streams or from any of the tributaries would be especially detrimental, since all the streams in the Upland Island Area have detrital based food chains. Falls Creek is the most environmentally sensitive of the habitats studied. It is an area of considerable aesthetic appeal, with lush, dense, vegetation along the

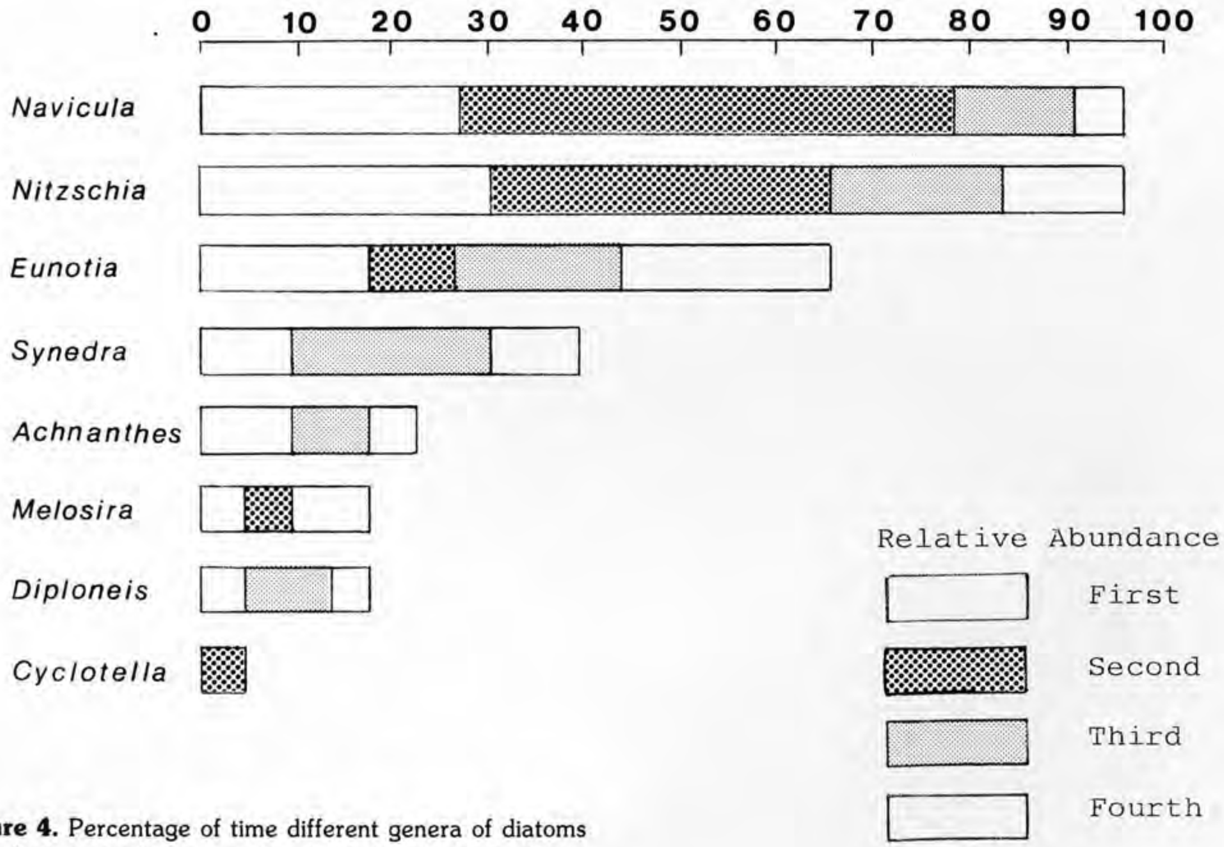

Figure 4. Percentage of time different genera of diatoms were first, second, third, or fourth in abundance in plankton samples collected from streams in the Upland Island Area. Only those genera that were first or second in abundance at least once are listed.

stream, and a thick canopy over the stream bed. The deep shading there resulted in cooler water compared with the other streams, thus higher oxygen values. Falls Creek and Cypress Creek were the only streams with populations of stoneflies (Plecoptera), which were indicators of good water quality and require high oxygen concentrations. The Falls Creek area is very remote, and the streamside vegetation provides an extensive wildlife habitat, supporting diverse avian, mammal, reptile, and amphibian communities. Certainly no seining or specimen collecting should be permitted. Human intervention should be kept at a minimum in the three sensitive areas. Trails created by the use, the cutting of trees, shrubs, or herbaceous vegetation, or the reduction in leaf litter near those streams will increase erosion and greatly disrupt biotic communities by increased sedimentation. No water removal from the streams should be permitted because of low discharge rates. Camping activity should be restricted to the higher elevations. No wastewater from man's activities should be allowed to enter any of the watersheds, because of the low discharge rates and because the streams are stressed to a degree by leaf litter.

The temporary ponds, while ephemeral and highly stressed bodies of water, are nevertheless quite important in the forest ecosystem. They support diverse amphibian and reptilian populations. In addition, a variety of birds and mammals were observed to feed on prey, in, and attracted to the ponds, and the ponds supplied a source of drinking water for them. Not only did many invertebrates complete their life cycles in those ponds, the rare Hillard's Toothpick Grasshopper (*Achurum hilliardi*) was found in the grasses and sedges which surround low wetlands in the Upland Island Area.

Because of their very shallow depth, the greatest danger to the ponds is filling in by sedimentation through erosion. Proper vegetation management and other erosion preventative measures must be practiced in the immediate vicinity of the marshes and temporary ponds.

Table 9. Primary Productivity, mg Ash-Free wt/m^2/day, Dry Weight (g/m^2), and Ash-Free wt [g/m^2] of Periphyton from Stream Stations Sampled at the Upland Island Area in the Summer of 1980.

	Station				
Date	1	2	5	6	7
June 11	238.1	182.2	309.9	213.2	98.9
	(32.7)	(28.2)	(33.6)	(33.2)	(13.0)
	[3.3]	[2.6]	[4.3]	[3.0]	[1.4]
July 9	150.8	49.2	377.7	149.2	261.9
	(44.3)	(41.1)	(36.2)	(39.6)	(28.3)
	[5.1]	[1.7]	[12.9]	[5.0]	[8.8]
July 9	351.6	66.6			300.0
	(45.3)	(65.7)	SL	SL	(29.0)
	[11.8]	[2.2]			[10.1]
Mean	246.8	99.3	343.8	181.2	220.3
	(40.8)	(45.1)	(35.0)	(36.4)	(23.4)
	[6.7]	[2.1]	[8.6]	[4.0]	[6.8]

SL—sampler lost.

Table 10. The Occurrence of Fish Species at Collection Sites in the Upland Island Area during the Summer of 1980.

	Station				
Species	1	2	5	6	7
Esox americanus redfin pickerel		X			
Phenacobius mirabilis suckermouth minnow		X	X		
Opsopoeodus emiliae pugnose minnow		X			
Notropis venustus blacktail shiner				X	
Notropis umbratilis redfin shiner	X	X			X
Erimyzon oblongus creek chubsucker	X	X			
Ictalurus melas black bullhead				X	
Fundulus notatus blackstripe topminnow	X		X		
Fundulus olivaceus blackspotted topminnow					X
Gambusia affinis mosquitofish	X	X	X	X	X
Centrarchus macropterus flier			X		
Chaenobryttus gulosus warmouth		X			
Lepomis megalotis longear sunfish	X	X	X	X	X
Lepomis macrochirus Bluegill			X		

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Table 11. Relative Abundance (%) of Non-Diatom Phytoplankters Collected in the Upland Island Area during the Summer of 1980.

	Station[1]		
Genus	3	4	8
Ankistrodesmus	10.9		
Chlorella-like		83.3	
Closterium	4.7		
Desmidium	18.8		
Dinobryon			37.4
Euastrum	38.3		
Euglena		3.7	
Oscillatoria	2.3	0.9	9.4
Pleurotaenium	3.1		
Spirogyra	3.9		
Staurastrum	0.8		
Stigeoclonium			52.3
Xanthidium	17.2		

[1] Stations 3 and 4 collected May 28, 1980, station 8 collected July 9, 1980.

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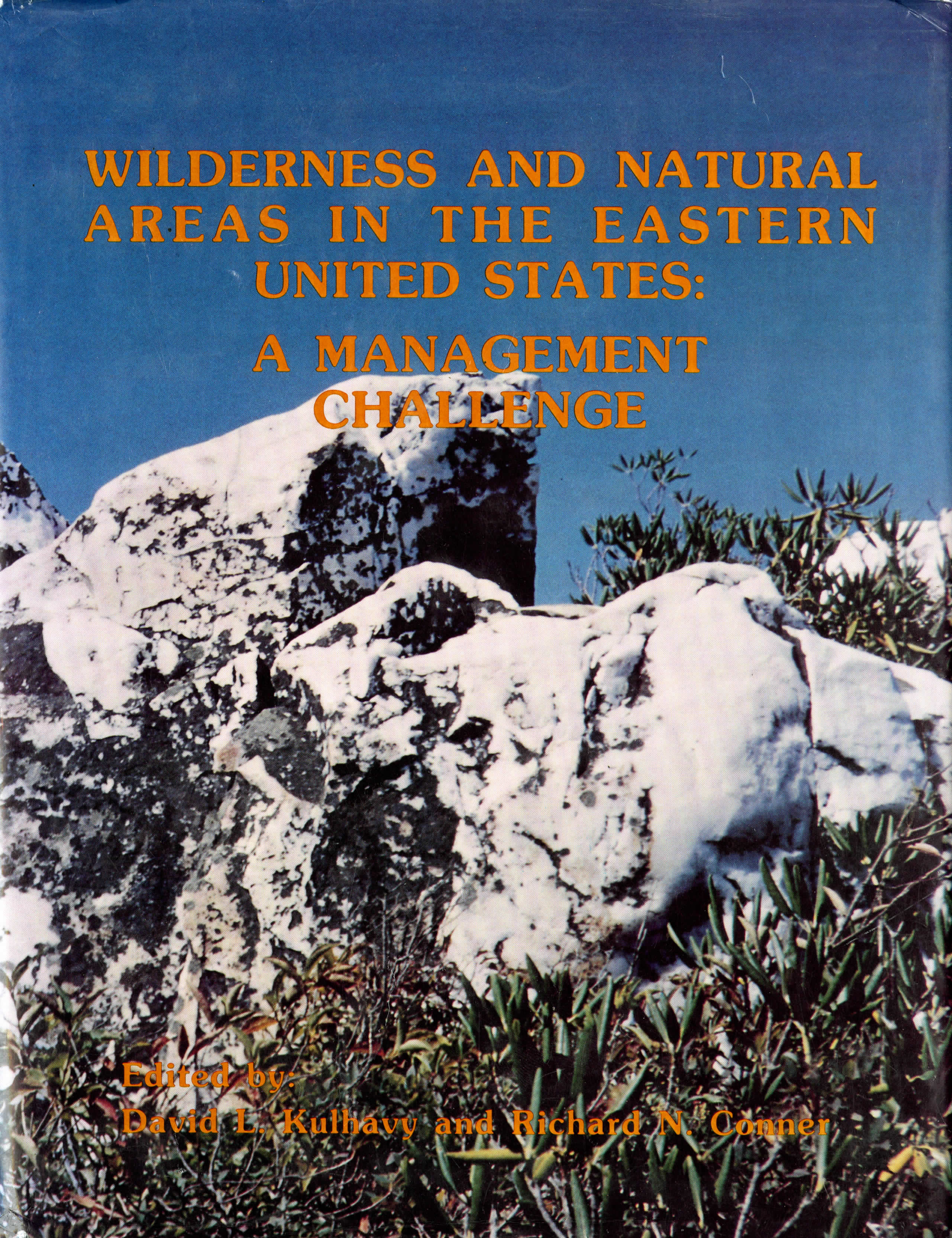
WILDERNESS AND NATURAL AREAS IN THE EASTERN UNITED STATES: A MANAGEMENT CHALLENGE



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