

# Land Use, Organochlorine Compound Concentrations, and Trends in Benthic-Invertebrate Communities in Selected Stream Basins in Chester County, Pennsylvania

By Mark A. Hardy, Kim L. Wetzel, and Craig R. Moore

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CHESTER COUNTY WATER RESOURCES AUTHORITY

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**U.S. DEPARTMENT OF THE INTERIOR**

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CONVERSION FACTORS AND ABBREVIATED WATER-QUALITY UNITS

<u>Multiply</u>	<u>By</u>	<u>To obtain</u>
inch (in.)	2.54	centimeter
square mile (mi <sup>2</sup> )	2.590	square kilometer
cubic foot per second (ft <sup>3</sup> /s)	0.02832	cubic meter per second

Abbreviated water-quality units used in this report

- micrometer (μm)
- micrograms per kilogram (μg/kg)
- picocurie per gram (pCi/g)
- grams per kilogram (g/kg)

# LAND USE, ORGANOCHLORINE COMPOUND CONCENTRATIONS, AND TRENDS IN BENTHIC-INVERTEBRATE COMMUNITIES IN SELECTED STREAM BASINS IN CHESTER COUNTY, PENNSYLVANIA

*By Mark A. Hardy, Kim L. Wetzel, and Craig R. Moore*

## ABSTRACT

Land use was analyzed for the drainage areas of 26 stream sites in Chester County, Pa., that cover a total area of 227 square miles or about 30 percent of the county. The most significant land-use changes during 1967-87 were decreased agricultural land use, increased residential land use, and increased commercial and industrial land use.

Bulk samples of stream-bottom materials were collected at 42 sites in the study area from October 1985 through November 1987 and analyzed for content of organochlorine pesticides and polychlorinated biphenyls (PCB's). Organochlorine compounds and (or) PCB's were detected in streambed materials collected at 40 of the 42 sites sampled. The most enriched compounds (greater than 15 micrograms per kilogram) were PCB's, chlordane, and DDT plus its breakdown products. Data suggest that chlordane residues are closely associated with residential land use. PCB residues are closely associated with industrial and commercial land use.

Cores of lakebed sediments from the site of Icedale Lake, a drained reservoir on the West Branch Brandywine Creek, indicate that DDT was the first organochlorine pesticide to enter the Brandywine Creek; concentrations peaked in the late 1940's and early 1950's. As DDT influx subsequently decreased, influxes of chlordane and dieldrin increased and peaked in the mid-1960's, before the Chester County biological monitoring program. Influx of all pesticides appears to have decreased significantly since the 1960's.

Upward trends in Brillouin's diversity index for benthic-invertebrate communities were found at 45 of 46 stream sites in Chester County. The upward trends were statistically significant at the 99-percent confidence level at 30 sites. Trends at only four sites were not statistically significant at the 90-percent confidence level.

Contingency analyses showed that the relation between the Kendall slope estimator for trend and the increases in residential land use of 12 percent or greater were significant at the 95-percent confidence level. The contingency tables also showed that the relation between diversity indices of less than 2.25 and organochlorine-compound concentrations greater than 45 micrograms per kilogram was significant at the 95-percent confidence level.

## INTRODUCTION

Chester County, in southeastern Pennsylvania, is being rapidly urbanized. Former agricultural land is being converted to residential developments, commercial areas, and industrial and corporate parks. This urban growth is affecting the quality of streams in Chester County. A study by Moore (1987) showed that the diversity of benthic-invertebrate communities increased at 44 of 46 sites and decreased at 2 sites from 1970-80. Subsequent sampling of stream-bottom sediments at one of the two sites where the diversity decreased revealed elevated concentrations of pesticides and other organic compounds. A study by Sloto (1987) showed that the more rapidly a basin in eastern Chester County changed from rural to suburban, the faster the diversity index increased. Both studies suggest that changes in diversity may be related to organochlorine compounds in stream-bottom sediment, and that this relation also can be affected by land use.

Information is needed to improve the understanding of the relations among land use and changes in land use, organochlorine-compound concentrations, and benthic-invertebrate diversity indexes so that Chester County planners and developers can maintain improvements in diversity index already observed (Moore, 1987). In 1988, a study to obtain such information was begun by the U.S. Geological Survey (USGS) in cooperation with the Chester County Water Resources Authority (CCWRA).

### Purpose and Scope

This report describes (1) land-use changes in relation to the trends in diversity indexes of benthic-macroinvertebrate communities, (2) the detection and concentrations of organochlorine compounds in stream-bottom sediments in relation to diversity indexes, and (3) the distribution of organochlorine compounds in stream-bottom sediments at 42 stream sites in the study area.

The information in this report is based on data collected at 51 sites on 16 major streams in Chester County. The data record for 39 of these sites is continuous for 1970-88. Stream-bottom sediments were analyzed for organochlorine compounds during 1985-87 at 42 sites. Changes in land use from 26 drainage areas during 1967-87, obtained from the Chester County Planning Commission (CCPC), were quantified and compared to diversity trends at 26 stream sites in the county. Concentrations of organochlorine compounds were compared to diversity indexes of benthic-invertebrate samples collected at 42 stream sites in the county.

### Network Description and Previous Investigations

In 1969, a limnological monitoring program began to evaluate water quality of selected Chester County streams by use of physical, chemical, and (beginning in 1970) benthic-invertebrate data. The program is a cooperative effort of the USGS, the CCWRA, and the Chester County Board of Commissioners. The project was conceived by Luna B. Leopold, former Chief Hydrologist, USGS, and Robert G. Struble, former Executive Director of the CCWRA. The major goal of the program is to further the understanding of stream changes in response to urbanization (Lium, 1977, p.6). Some changes have occurred since the creation of the network. Early analysis of the data resulted in discontinuance of nine sites (sites 7, 8, 9, 11, 18, 25, 35, 41, and 43). At two sites (sites 16 and 39), quantitative data collection replaced qualitative collections after 1979. One new site (site 51) was added in 1983. The locations of the 51 sampling sites are shown in figure 1, and drainage areas are listed in table 1. This network of sampling sites and the biological, physical, and chemical data collected for this program are the basis for this investigation.



**Table 1. Drainage areas of sampling sites for major streams in Chester County, Pennsylvania**

[--, land-use data not available]

Site number	Drainage area (square miles)	Land-use data available	Site number	Drainage area (square miles)	Land-use data available
	<u>Pickering Creek</u>			<u>Red Clay Creek</u>	
1	3.09	Yes	26	10.2	--
2	5.98	Yes	27	9.79	Yes
3	21.2	Yes		<u>White Clay Creek</u>	
4	27.5	Yes	28	11.3	Yes
5	31.4	Yes	29	9.94	--
	<u>Stony Run</u>		30	9.92	--
6	2.00	Yes		<u>Elk Creek</u>	
7	4.07	--	31	11.1	--
	<u>Pigeon Creek</u>		32	10.0	--
8	4.20	--		<u>Octoraro Creek</u>	
9	6.97	--	33	11.8	--
10	12.0	Yes	34	10.5	Yes
	<u>French Creek</u>		35	32.9	--
41	5.06	--		<u>West Branch Brandywine Creek</u>	
11	11.7	--	37	37.3	--
12	12.4	Yes	38	134.	--
13	19.9	Yes	45	11.8	Yes
14	46.1	Yes	46	22.6	--
15	59.1	Yes		<u>East Branch Brandywine Creek</u>	
16	70.7	--	36	60.6	--
	<u>Darby Creek</u>		39	123.	--
17	5.15	Yes	42	16.5	--
	<u>Crum Creek</u>		43	4.36	--
18	6.16	--	44	16.1	Yes
19	10.1	Yes	47	4.26	Yes
	<u>Ridley Creek</u>		48	5.98	--
20	4.22	Yes		<u>Brandywine Creek</u>	
21	9.71	Yes	40	291	--
	<u>Chester Creek</u>			<u>Valley Creek</u>	
22	.63	Yes	49	6.45	Yes
23	5.77	Yes	50	12.7	Yes
24	10.4	Yes			
25	4.28	--			
51	19.2	--			

A report by Moore (1989) contains the physical, chemical, and biological data for this investigation for 1969-80. This superceded an earlier report by Lium (1976) that contained much of the same data for 1969-74. The physical and chemical data for the 1974-88 water years<sup>1</sup> also have been published in the USGS annual water resources data reports for Pennsylvania (U.S. Geological Survey, 1975-89) and are available in USGS computer files.

Lium (1977) developed a biotic index that uses a 10-point rating scale to determine the environmental condition of streams at the 50 sites from his previous (1976) report. Most streams studied had ratings indicating they were experiencing variable degrees of nutrient enrichment and (or) sediment deposition. Large changes in the numerical rating of a stream were related to changes in land-use patterns.

<sup>1</sup>Water year is the 12-month period October 1 through September 30 and is designated by the calendar year in which it ends.

In 1967-68, a study was conducted in the Pickering Creek and East Branch Brandywine Creek Basins by Miller and others (1971). Their study examined and documented existing hydrologic conditions in these two small basins so that the effects of future urbanization in the basins could be studied by comparison with their data. These two basins are among the areas studied in this investigation.

Moore (1987) evaluated the biological monitoring of stream-water quality in Chester County. This study showed statistically valid upward trends in Brillouin's diversity index during 1970-80 at 27 sites studied where improved environmental quality was indicated. However, few trends were detected in the physical and chemical data because of a high degree of variability in the data. Both Lium (1977) and Moore (1987) observed that total dissolved solids correlated significantly with biotic index and diversity index.

An investigation by Sloto (1987) described the effects of urbanization on water quality in eastern Chester County. Sloto observed that basins that had a greater change in land use, from undeveloped to developed, surprisingly had a greater increase in diversity index. Sloto postulated that the increase may be caused by the banning of certain pesticides, a decreasing use of pesticides in urbanizing basins, (and) or flushing or burial of older pesticide-contaminated sediments.

### Description of Study Area

The study area is in the southeastern corner of Pennsylvania near Philadelphia (fig. 1) in the Piedmont Physiographic Province. General topography of the area is broad, gently rolling hills having low to moderate relief. Nearly 95 percent of Chester County (720 mi<sup>2</sup>) is drained by the streams included in the study (fig 1). All streams sampled originate within the boundaries of the county, except for short reaches in the headwaters of the West Branch Brandywine, French, and Octoraro Creeks. Octoraro Creek forms part of the western boundary of the county, and its headwaters lie in both Chester and Lancaster Counties (fig. 1).

The population of Chester County doubled between 1950 and 1980 (Sloto, 1987) and increased another 10 percent from 1980 to 1987 to 348,484 persons. Population projections by the CCPC indicate that by the year 2010, the county will have more than 418,000 persons (Chester County Planning Commission, written commun., 1988).

Some areas, particularly in the eastern half of the county, have undergone more rapid growth. Several townships in the county have population increases ranging from 53 to 145 percent from 1970 to 1980. These townships, along with six others in the county, are expected to increase 50 percent or more over their 1980 populations by the year 2010 (Chester County Planning Commission, written commun., 1988).

### Acknowledgments

The cooperation of the Chester County Board of Commissioners, the Chester County Water Resources Authority, Chester County Planning Commission, and the Chester County Health Department is gratefully acknowledged. The authors are particularly indebted to Robert E. Walker and the staff of the Chester County Planning Commission for graciously allowing us to use their resources and facilities during the course of the study. Special thanks are extended to David C. Yaeck, former Executive Director of the Chester County Resources Authority, and Dr. Robin Vannote, Stroud Water Research Center, for their particular interest throughout the study. The authors also would like to thank all the individuals who provided assistance and information essential to the successful completion of this study.

## LAND USE

Drainage basins of 26 sites were selected for land-use analysis (table 1). These basins were selected to provide good areal coverage of Chester County and to represent the widest possible range of dominant land-use categories. Basins selected on French, Pickering, Ridley, and East Branch Chester Creeks comprise series of concatenated drainage areas representing progressively larger parts of the stream basin. These are referred to as "nested systems" in this report and allow observations of changing land use within individual watersheds. Land-use analyses were not performed for sites in the lower reaches of the Brandywine Creek Basin. These basins are quite large and heterogeneous, thus making it more difficult to separate the effects of differing land use. In addition, the lower Brandywine Creek Basin also contains many major point-source discharges that can mask the effects of land use in the basin.

### Categories

Land-use classifications are from land-use maps prepared by the CCPC (1972; 1987). The seven land-use classifications used in this report are combinations with slight modifications of the 15 categories used by the CCPC.

Residential land use combines CCPC's Medium Density (single-family detached homes on lots less than 1 acre) and High Density (two-family dwellings, townhouses, apartments, and mobile homes) categories. For the purpose of this study, homes included in CCPC's Low Density residential category were placed in either the Open Space or Agricultural categories on the basis of the surrounding land use.

Commercial land use combines CCPC's Commercial, General (retail and wholesale trade, and professional, personal, and business services); Commercial, Office Park (office and corporate park development); and Institutional (health, educational, governmental, and religious facilities, excluding cemeteries, which were placed in the Open Space category).

Industrial land use combines CCPC's Industrial, Limited (light assembly, warehouse, and research and developmental facilities); Industrial, Manufacturing (processing, fabrication, or assembly of raw materials or component parts); Transportation/Communications/Utilities (rail, air, and highway transportation; communication facilities; and utility facilities); and Mining/Quarry (mining, quarrying, and other extractive operations).

Open space combines CCPC's Recreational Lands (parks, playgrounds, and related facilities, but excluding golf courses), Woodlands (tree masses in excess of 10 acres), Water Bodies (lakes and reservoirs in excess of 50 acres), Other Land (floodplain land, land which is awaiting development, vacant, unused, or otherwise undefined), and cemeteries. The woodlands are primarily composed of deciduous hardwoods such as red and black oak, tulip poplar, beech, sugar maple, and chestnut oak; and are situated on steep, less productive soils (Lium, 1977).

Agricultural lands were divided into three categories in CCPC's 1967 classification system: Agriculture (row crops), Pasture (pasture or meadow lands), and Specialized Agriculture (orchards, nurseries, tree farms, and mushroom farms). For the purpose of this study, the same categories for agricultural lands were used with one modification. Golf courses were included in the Specialized Agriculture category as opposed to Open Space (recreation land). Because of the heavy applications of fertilizers, insecticides, and herbicides, golf courses more closely approximate a specialized form of agriculture. Major crops are hay, winter wheat, corn, garden crops, and mushrooms. Livestock raised primarily include dairy and beef cattle, and horses.

## Summary of Changes

Land use was analyzed for the 26 drainage areas covering a total area of 227 mi<sup>2</sup> or about 30 percent of the county (table 2). Overall, the most significant land-use changes for these basins during 1967-87 were (1) decreased agricultural land use (ranging from 2.5 to 52.6 percent; median 14.2 percent); (2) increased residential land use (ranging from 4.0 to 42.9 percent; median 20.8 percent); and (3) increased commercial and industrial land use (ranging from 0 to 20.0 percent; median 3.0 percent). These changes were greatest in the northeastern half of the study area, including East Branch Brandywine Creek but excluding French and Darby Creeks.

Pasture and open space decreased in some basins and increased in others. Decreases for both categories generally were the result of residential, industrial, or commercial development. Increases in pasture seem to be a result of converted agricultural land use. Increases in open space seem to be a result of converted pasture and (or) agricultural land use.

The nested systems represented increases in residential land use ranging from 10.3 to 42.9 percent; and decreases in residential land use ranging from 5.0 to 34.8 percent. In the Pickering Creek and East Branch Chester Creek nested systems, land-use changes were not uniform. In Pickering Creek, the increase in residential land use was about 15 percent less for the site 1 drainage area than the other four downstream drainage areas. Agricultural land use progressively decreased by about 6 percent from the site 1 to the site 3 drainage areas. In East Branch Chester Creek, the increase in residential land use was about 13 percent greater for the site 24 drainage area (the most downstream site) than for the other two sites. The decrease in agricultural land use was about 11 percent less for the site 22 drainage area than for the other two downstream sites. In addition, open space increased 17 percent within this drainage area but decreased for the two downstream sites.

**Table 2.** Changes in land use within drainage areas of selected stream sites in Chester County, Pa., 1967-87

[Rounding may account for differences.]

Land-use category	1967		1987		Change	
	Square miles	Percentage of drainage area	Square miles	Percentage of drainage area	Square miles	Percentage of drainage area
<b>Site 1</b>						
Open space	0.80	25.8	0.67	21.7	-0.13	-4.2
Agricultural	1.57	50.8	1.07	34.6	-.50	-16.2
Pasture	.58	18.8	.67	21.7	.09	2.9
Residential	.14	4.6	.46	14.9	.32	10.4
Commercial	.00	.0	.22	7.1	.22	7.1
<b>Site 2</b>						
Open space	1.50	25.1	1.23	20.6	-.27	-4.5
Agricultural	2.82	47.2	1.64	27.4	-1.18	-19.7
Pasture	1.30	21.8	1.00	16.7	-.30	-5.0
Residential	.36	5.9	1.88	31.4	1.52	25.4
Commercial	.00	.0	.23	3.8	.23	3.8
<b>Site 3</b>						
Open space	6.09	28.7	4.99	23.5	-1.10	-5.2
Agricultural	9.47	44.7	4.78	22.6	-4.69	-22.1
Pasture	4.83	22.8	4.10	19.3	-.73	-3.4
Specialized agriculture	.09	.4	.06	.3	-.03	-.1
Residential	.60	2.8	6.23	29.4	5.63	26.6
Commercial	.00	.0	.23	1.1	.23	1.1
Industrial	.12	.6	.81	3.8	.69	3.3

**Table 2.** Changes in land use within drainage areas of selected stream sites in Chester County, Pa., 1967-87—Continued

[Rounding may account for differences.]

Land-use category	1967		1987		Change	
	Square miles	Percentage of drainage area	Square miles	Percentage of drainage area	Square miles	Percentage of drainage area
		<u>Site 4</u>				
Open space	8.01	29.1	6.87	25.0	-1.14	-4.2
Agricultural	12.29	44.7	6.66	24.2	-5.63	-20.5
Pasture	6.09	22.1	5.38	19.6	-.71	-2.6
Specialized agriculture	.11	.4	.06	.2	-.05	-.2
Residential	.86	3.1	7.47	27.2	6.61	24.0
Commercial	.00	.0	.23	.8	.23	.8
Industrial	.14	.5	.83	3.0	.69	2.5
		<u>Site 5</u>				
Open space	9.62	30.6	8.03	25.6	-1.59	-5.1
Agricultural	13.60	43.3	6.97	22.2	-6.63	-21.1
Pasture	6.76	21.5	6.22	19.8	-.54	-1.7
Specialized agriculture	.11	.3	.06	.2	-.05	-.2
Residential	1.10	3.5	8.92	28.4	7.82	24.9
Commercial	.00	.0	.23	.7	.23	.7
Industrial	.21	.7	.97	3.1	.76	2.4
		<u>Site 6</u>				
Open space	.23	11.6	.23	11.5	.00	.0
Agricultural	1.34	67.2	.87	43.5	-1.05	-52.6
Pasture	.40	19.8	.32	16.0	.08	-4.0
Specialized agriculture	.03	1.4	.02	1.0	-.01	-.5
Residential	.00	.0	.56	28.0	.56	28.0
		<u>Site 10</u>				
Open space	3.69	30.8	3.27	27.2	-.42	-3.5
Agricultural	4.82	40.2	3.62	30.2	-1.20	-10.0
Pasture	2.59	21.6	.63	5.2	-1.96	-16.3
Specialized agriculture	.20	1.7	.16	1.3	-.04	-.3
Residential	.64	5.3	4.16	34.7	3.52	29.3
Commercial	.06	.5	.16	1.3	.10	.8
		<u>Site 12</u>				
Open space	4.54	36.6	4.58	36.9	.04	.3
Agricultural	3.94	31.8	3.21	25.9	-.73	-5.9
Pasture	3.63	29.3	2.90	23.4	-.73	-5.9
Specialized agriculture	.05	.4	.03	.2	-.02	-.2
Residential	.24	1.9	1.56	12.6	1.32	10.6
Commercial	.00	.0	.00	.0	.00	.0
Industrial	.00	.0	.12	1.0	.12	1.0
		<u>Site 13</u>				
Open space	15.54	66.9	15.03	64.7	-.51	-2.2
Agricultural	4.22	18.2	3.07	13.2	-1.15	-5.0
Pasture	3.19	13.7	2.33	10.0	-.86	-3.7
Residential	.29	1.2	2.69	11.6	2.40	10.3
Commercial	.00	.0	.12	.5	.12	.5
		<u>Site 14</u>				
Open space	24.99	53.5	24.14	52.4	.85	-1.8
Agricultural	11.66	25.3	9.10	19.7	-2.56	-5.6
Pasture	8.76	19.0	5.99	13.0	-2.77	-6.0
Specialized agriculture	.11	.2	.03	.1	-.08	-.2
Residential	.87	1.9	6.34	13.8	5.47	11.9
Commercial	.03	.1	.38	.8	.35	.8
Industrial	.00	.0	.12	.3	.12	.3

**Table 2.** Changes in land use within drainage areas of selected stream sites in Chester County, Pa., 1967-87—Continued

[Rounding may account for differences.]

Land-use category	1967		1987		Change	
	Square miles	Percentage of drainage area	Square miles	Percentage of drainage area	Square miles	Percentage of drainage area
<u>Site 15</u>						
Open space	27.36	49.2	27.61	48.3	0.24	-0.9
Agricultural	15.20	27.3	12.29	21.5	-2.92	-5.8
Pasture	11.80	21.2	7.38	12.9	-4.41	-8.3
Specialized agriculture	.13	.2	.03	.0	-.10	-.2
Residential	1.14	2.0	9.32	16.3	8.18	14.3
Commercial	.03	.1	.40	.7	.38	.7
Industrial	.00	.0	.12	.2	.12	.2
<u>Site 17</u>						
Open space	.97	18.8	.70	13.6	-.27	-5.2
Agricultural	.31	6.0	.01	.2	-.30	-5.8
Pasture	.78	15.2	.15	2.9	-.63	-12.2
Residential	2.85	55.3	3.89	75.5	1.04	20.2
Industrial	.00	.0	.02	.4	-.02	.4
Commercial	.24	4.7	.38	7.34	.14	2.7
<u>Site 19</u>						
Open space	2.63	26.1	1.97	19.5	-.66	-6.5
Agricultural	1.24	12.2	.65	6.4	-.59	-5.8
Pasture	1.97	19.5	.32	3.2	-1.65	-16.3
Specialized agriculture	.51	5.3	.54	5.4	.03	.3
Residential	3.21	31.8	6.01	59.5	2.80	27.7
Commercial	.54	5.1	.61	6.0	.07	.7
<u>Site 20</u>						
Open space	1.10	26.0	.94	22.3	-.16	-3.8
Agricultural	1.58	37.4	.11	2.6	-1.47	-34.8
Pasture	.63	15.1	.33	7.8	-.30	-7.1
Specialized agriculture	.18	4.2	.17	4.0	-.01	-.2
Residential	.61	14.4	2.42	57.4	1.81	42.9
Commercial	.12	2.9	.16	3.8	.04	1.0
Industrial	.00	.0	.09	2.0	.09	2.1
<u>Site 21</u>						
Open space	2.17	22.4	1.63	16.8	-.54	-5.6
Agricultural	4.09	42.1	.92	9.4	-3.17	-32.6
Pasture	1.60	16.5	1.23	12.6	-.37	-3.8
Specialized agriculture	.21	2.1	.18	1.8	-.03	-.3
Residential	1.46	15.1	5.29	54.5	3.83	39.4
Commercial	.18	1.8	.27	2.8	.09	.9
Industrial	.00	.0	.19	2.0	.19	2.0
<u>Site 22</u>						
Open space	.02	1.9	.20	18.9	.18	17.0
Agricultural	.12	11.3	.00	.0	-.12	-11.3
Pasture	.36	34.0	.05	4.7	-.31	-29.2
Residential	.56	52.8	.78	73.6	.22	20.8
Commercial	.00	.0	.03	2.8	.03	2.8
<u>Site 23</u>						
Open space	1.14	19.8	.76	13.2	-.38	-6.6
Agricultural	1.56	27.0	.24	4.2	-1.32	-22.9
Pasture	1.21	21.0	.66	11.4	-.55	-9.5
Residential	1.86	32.2	3.06	53.0	1.20	20.8
Commercial	.00	.0	.16	2.8	.16	2.8
Industrial	.00	.0	.89	15.4	.89	15.4

**Table 2.** Changes in land use within drainage areas of selected stream sites in Chester County, Pa., 1967-87—Continued

[Rounding may account for differences.]

Land-use category	1967		1987		Change	
	Square miles	Percentage of drainage area	Square miles	Percentage of drainage area	Square miles	Percentage of drainage area
<b>Site 24</b>						
Open space	2.01	19.3	1.14	11.0	-0.87	-8.4
Agricultural	2.53	24.3	.28	2.7	-2.25	-21.6
Pasture	2.58	24.8	.92	8.8	-1.66	-16.0
Specialized agriculture	.24	2.3	.12	1.2	-.12	-1.2
Residential	2.96	28.5	6.52	62.7	3.56	34.2
Commercial	.08	.8	.51	4.9	.43	4.1
Industrial	.00	.0	.91	8.8	.91	8.8
<b>Site 27</b>						
Open space	1.69	17.3	1.70	17.4	.01	.1
Agricultural	2.61	26.7	2.20	22.5	-.41	-4.2
Pasture	3.81	38.9	2.83	28.9	-.98	-10.0
Specialized agriculture	.31	3.2	.34	3.5	.03	.3
Residential	1.24	12.7	2.34	23.9	1.10	11.2
Commercial	.09	.9	.19	1.9	.10	1.0
Industrial	.04	.4	.19	1.9	.15	1.5
<b>Site 28</b>						
Open space	2.32	20.5	2.64	23.4	.32	2.8
Agricultural	4.47	39.5	4.19	37.1	-.28	-2.5
Pasture	3.91	34.6	2.96	26.2	-.95	-8.4
Specialized agriculture	.33	2.9	.32	2.8	-.01	-.1
Residential	.24	2.1	.85	7.5	.61	5.4
Commercial	.00	.0	.24	2.1	.24	2.1
Industrial	.04	.4	.10	.9	.06	.5
<b>Site 34</b>						
Open space	2.22	21.1	2.09	19.9	-.13	-1.2
Agricultural	5.86	55.8	4.84	46.1	-1.02	-9.7
Pasture	1.84	17.5	1.02	9.7	-.82	-7.8
Specialized agriculture	.12	1.1	.09	.9	-.03	-.3
Residential	.37	3.5	1.97	18.8	1.60	15.2
Commercial	.06	.6	.42	4.0	.36	3.4
Industrial	.03	.3	.07	.7	.04	.4
<b>Site 44</b>						
Open space	6.47	31.9	4.76	23.4	-1.71	-10.6
Agricultural	6.09	30.0	1.88	9.3	-4.21	-26.2
Pasture	3.73	18.4	2.29	11.3	-1.44	-8.9
Specialized agriculture	.36	1.8	.26	1.3	-.10	-.6
Residential	2.65	13.1	8.19	40.3	5.54	34.4
Commercial	.62	3.1	1.56	7.7	.94	5.8
Industrial	.38	1.9	1.36	6.6	.98	6.1
<b>Site 45</b>						
Open space	2.38	20.2	2.30	19.5	-.08	-.7
Agricultural	5.59	47.4	5.09	43.1	-.50	-4.2
Pasture	3.57	30.2	3.28	27.8	-.29	-2.5
Specialized agriculture	.08	.7	.00	.0	-.08	-.7
Residential	.18	1.5	1.13	9.6	.95	8.0
<b>Site 47</b>						
Open space	2.06	48.4	1.60	37.6	-.46	-10.8
Agricultural	1.71	40.1	.22	5.2	-1.49	-35.0
Pasture	.39	9.2	1.33	31.2	.94	22.1
Residential	.05	1.2	1.08	25.4	1.03	24.1
Industrial	.05	1.2	.03	.7	-.02	-.5

**Table 2.** Changes in land use within drainage areas of selected stream sites in Chester County, Pa., 1967-87—Continued

[Rounding may account for differences.]

Land-use category	1967		1987		Change	
	Square miles	Percentage of drainage area	Square miles	Percentage of drainage area	Square miles	Percentage of drainage area
	<u>Site 49</u>					
Open space	1.35	20.9	1.37	21.2	0.02	0.3
Agricultural	.98	15.2	.19	3.0	-.79	-12.2
Pasture	1.04	16.1	.62	9.6	-.42	-6.5
Residential	2.36	36.6	2.62	40.6	.26	4.0
Commercial	.18	2.8	.40	6.2	.22	3.4
Industrial	.54	8.4	1.25	19.4	.71	11.0
	<u>Site 50</u>					
Open space	3.07	24.1	3.33	26.2	.26	2.0
Agricultural	4.01	31.5	.35	2.8	-3.66	-28.8
Pasture	1.73	13.6	.60	4.7	-1.13	-8.9
Specialized agriculture	.44	3.5	.52	4.1	.08	.6
Residential	2.74	21.5	4.62	36.4	1.88	14.8
Commercial	.26	2.0	.62	4.9	.36	2.8
Industrial	.47	3.7	2.66	21.0	2.19	17.2

## ORGANOCHLORINE COMPOUNDS

### Icedale Lake Sediment Cores

Accumulated sediments at the site of Icedale Lake, a drained reservoir on West Branch Brandywine Creek (fig. 1), provided an opportunity to examine relative influx of organochlorine compounds to the stream over time. The lake was a small reservoir built in 1913 to allow wintertime ice production. In 1984, a breach in the dam drained the reservoir, leaving a large amount of accumulated sediment. Like most basins in the study area, the Icedale Lake Basin has experienced increased residential development and subsequent decreases in agricultural land use, pasture, and open space (table 3).

Three cores of accumulated sediments were collected by driving 6-in. diameter PVC pipe into the old lake bed. Resistance to driving by rock or gravel was considered to be the bottom of the accumulated sediment. The cores were extruded from the pipes in 2-cm segments. The outermost part of each extruded core segment was removed to minimize smearing problems, and the central part was analyzed for lead-210 and cesium-137 activities, silt and clay content, and concentrations of selected organochlorine compounds and organic carbon. The radioactive elements were analyzed at a contract laboratory according to the methods of the National Council on Radiation Protection and Measurements (1985) and the American Society for Testing and Materials (1987). The silt and clay contents were determined at the USGS Pennsylvania District Sediment Laboratory by sieving technique. Analyses of organic carbon and organochlorine compounds were performed by the USGS National Water-Quality Laboratory according to the methods of Wershaw and others (1987, p. 17-22 and 31-35). Compaction errors for the three cores were small and ranged from 0 to 4 percent of the core depths. Therefore, data from same depth segments in each core were considered comparable.

**Table 3.** Change in land use for Icedale Lake Basin, Chester County, Pa., 1967-87

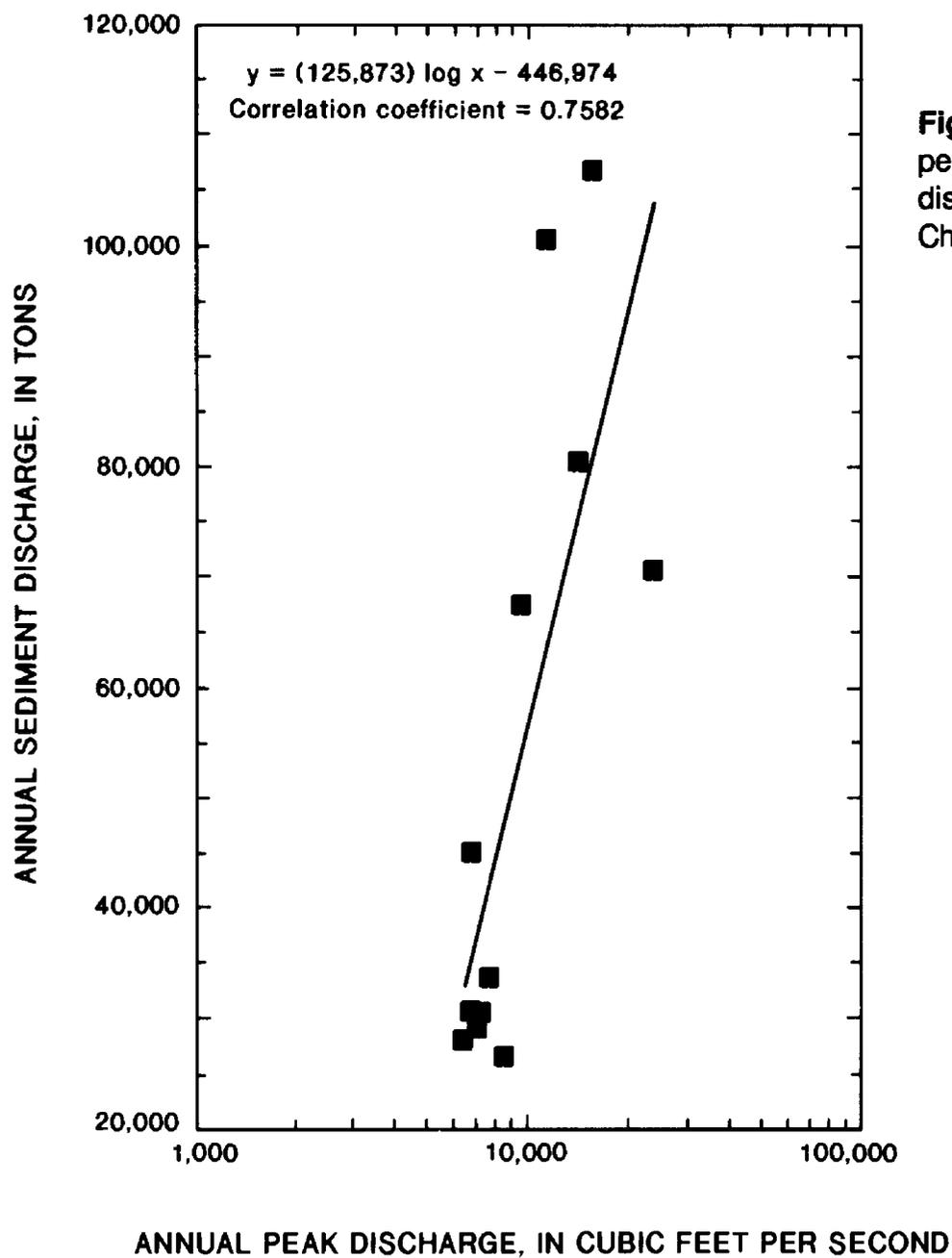
Land-use category	1967		1987		Change	
	Square miles	Percentage of drainage area	Square miles	Percentage of drainage area	Square miles	Percentage of drainage area
Open space	6.38	32.4	5.46	27.6	-0.92	-4.8
Cropland	9.98	50.7	8.89	44.9	-1.09	-5.8
Pasture	2.45	12.5	1.99	10.1	-.46	-2.4
Residential	.80	4.1	3.14	15.8	2.34	11.8
Commercial	.00	.0	.07	.3	.07	.3
Industrial	.08	.4	.26	.3	.18	.9

## Core Dating

Estimates of the times of deposition for core segments were made by estimating the amount of annual sediment loads for the Brandywine Creek at Chadds Ford. Because the accuracy of these estimates could be affected by unknown changes in sediment transport caused by land-use changes (table 3), the estimates were compared to cesium-137 activities in the core segments. Although lead-210 data also were collected for dating purposes, activities were less than 1.25 pCi/g in all core segments and were considered too small and variable for dating purposes.

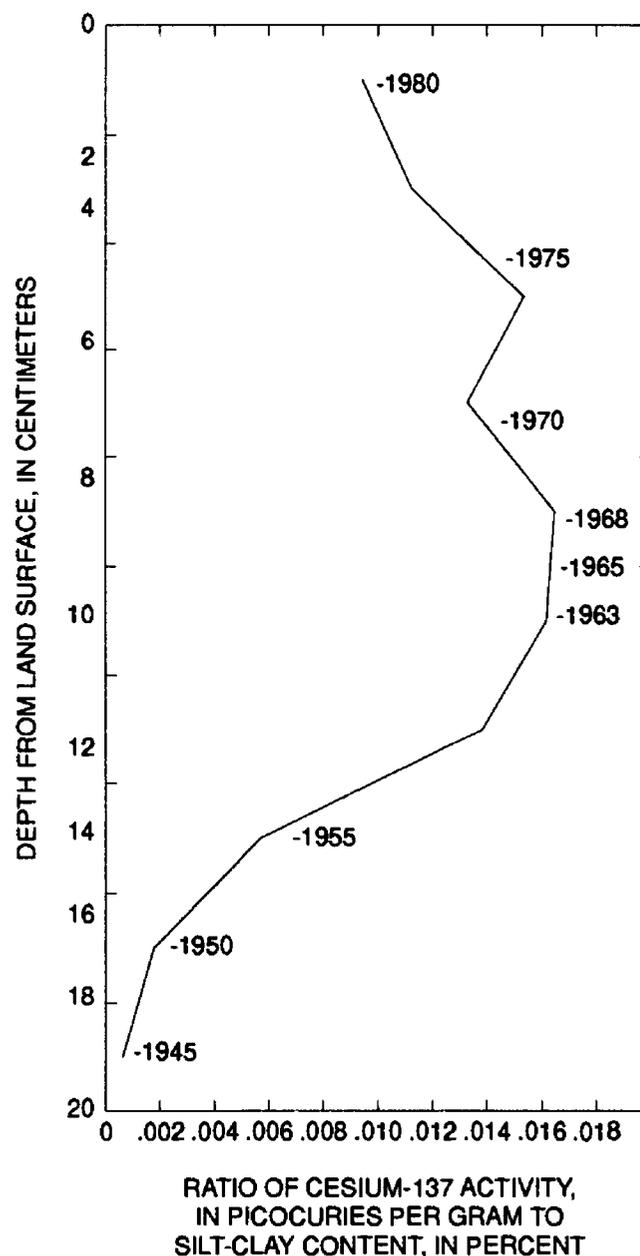
The USGS streamflow-gaging station at Chadds Ford (fig. 1) has streamflow data from 1912 to 1955 and continuously since 1963. Suspended-sediment data were collected from 1964 to 1978. Assuming that peak-flow events transported most sediment to the lake, annual sediment loads for the period of record (1964-78) were correlated ( $r=0.76$ ,  $p<0.05$ ) with the annual peak discharges exceeding 6,000 ft<sup>3</sup>/s (fig. 2). By use of this relation, annual sediment loads were calculated for all years that the lake existed except for 1956-63, when discharge data were not collected. About 10 percent of the sediment discharged to the lake during the period of missing record. The amount of sediment discharged for individual years was divided by the total sediment discharged from 1913 to 1984 and multiplied by the core depth to assign approximate deposition years to the core. The depth of the shallowest core (32 cm) was used as total depth because the deeper cores (40 and 50 cm) are thought to represent low-elevation areas of the lakebed that might have accumulated disproportionately large amounts of sediment in the early period of the reservoir's existence.

Cesium-137 fallout is a product of atmospheric nuclear detonations. Activities in the core segments (table 4) were used to determine the reasonability of the calculated deposition years. Because metals like cesium (which has a high affinity for sediment attachment) have disproportionately higher concentrations on fine particles compared to coarse particles, the core-segment activities were normalized for silt and clay content according to methods used by Horowitz (1991, p. 84) and compared to the calculated deposition periods in figure 3. The largest cesium-137 peak on figure 3 (at 9-13 cm) is considered representative of cesium-137 deposition to the basin during the highest fallout period from 1959 to 1966 (Ritchie and others, 1973). This suggests a lag time of about 2 or 3 years for transport to the reservoir and is considered reasonable for this analysis. The sharp decrease (at 7 cm) and secondary peak (at 5 cm) also correlate on a 2- to 3-year lag time with the low fallout rate in 1967 and subsequent increase reported by Ritchie and others (1973).



**Figure 2.** Relation between annual peak flows and annual sediment discharge at Brandywine Creek at Chadds Ford, 1964-78

**Figure 3.** Depth profile of ratio of cesium-137 and silt-clay fraction in bottom materials of Icedale Lake, Chester County, Pa.



**Table 4.** Concentrations of carbon and organochlorine compounds, Cesium-137 activities, and silt and clay sized particles in bottom materials at selected depths from Icedale Lake, Chester County, Pa., September 1988

[cm, centimeter;  $\mu\text{g}/\text{kg}$ , microgram per kilogram; g/kg, gram per kilogram; <, less than; pCi/g, picoCurie per gram;  $\mu\text{m}$ , micrometer]

Depth (cm)	Aldrin, total ( $\mu\text{g}/\text{kg}$ )	Chlordane, total ( $\mu\text{g}/\text{kg}$ )	DDD, total ( $\mu\text{g}/\text{kg}$ )	DDE, total ( $\mu\text{g}/\text{kg}$ )	DDT, total ( $\mu\text{g}/\text{kg}$ )	Dieldrin, total ( $\mu\text{g}/\text{kg}$ )	Endosulfan, total ( $\mu\text{g}/\text{kg}$ )	Endrin, total ( $\mu\text{g}/\text{kg}$ )	PCB, total ( $\mu\text{g}/\text{kg}$ )	PCN, total ( $\mu\text{g}/\text{kg}$ )	Heptachlor, total ( $\mu\text{g}/\text{kg}$ )
0-2	<0.1	4.0	0.8	1.9	<10	0.4	<0.1	<0.1	5	<1.0	<0.1
2-4	<.1	3.0	.6	2.1	<10	.4	<.1	<.1	6	<1.0	<.1
4-6	<.1	3.0	.6	2.1	<10	.3	<.1	<.1	5	<1.0	<.1
6-8	<.1	3.0	.6	2.1	<10	.3	<.1	<.1	5	<1.0	<.1
8-10	<.1	4.0	.8	2.5	<10	.4	<.1	<.1	7	<1.0	<.1
10-12	<.1	4.0	1.2	2.9	<10	.4	<.1	<.1	3	<1.0	<.1
12-14	<.1	3.0	1.8	3.4	<10	.3	<.1	<.1	7	<1.0	<.1
14-16	<.1	2.0	2.9	3.6	<10	.2	<.1	<.1	6	<1.0	<.1
16-18	<.1	2.0	3.4	4.1	<10	.1	<.1	<.1	7	<1.0	<.1
18-20	<.1	2.0	2.5	2.9	<10	<.1	<.1	<.1	4	<1.0	<.1
20-22	<.1	1.0	1.0	1.4	<10	<.1	<.1	<.1	3	<1.0	<.1
22-24	<.1	<1.0	.3	.5	<10	<.1	<.1	<.1	3	<1.0	<.1
24-26	<.1	<1.0	<.1	.1	<.1	<.1	<.1	<.1	<1	<1.0	<.1
26-28	<.1	<1.0	<.1	.1	<.1	<.1	<.1	<.1	<1	<1.0	<.1
28-30	<.1	<1.0	<.1	.1	<.1	<.1	<.1	<.1	<1	<1.0	<.1

Depth (cm)	Heptachlor epoxide, total ( $\mu\text{g}/\text{kg}$ )	Lindane, total ( $\mu\text{g}/\text{kg}$ )	Methoxychlor, total ( $\mu\text{g}/\text{kg}$ )	Mirex, total ( $\mu\text{g}/\text{kg}$ )	Perthane, total ( $\mu\text{g}/\text{kg}$ )	Toxaphene, total ( $\mu\text{g}/\text{kg}$ )	Carbon, inorganic total (g/kg as C)	Carbon, inorg. + organic, total (g/kg as C)	Cesium 137, total (pCi/g)	Grain size <63 $\mu\text{m}$ percent of total
0-2	<0.1	<0.1	<0.1	<0.1	<1.00	<10	<0.1	31	0.236	25
2-4	<.1	<.1	<.1	<.1	1.00	<10	<.1	27	.315	28
4-6	<.1	<.1	<.1	<.1	<1.00	<10	<.1	24	.415	27
6-8	<.1	<.1	<.1	<.1	<1.00	<10	<.1	23	.386	29
8-10	<.1	<.1	<.1	<.1	<1.00	<10	<.1	21	.528	32
10-12	<.1	<.1	<.1	<.1	<1.00	<10	<.1	23	.550	34
12-14	<.1	<.1	<.1	<.1	<1.00	<10	<.1	25	.526	38
14-16	<.1	<.1	<.1	<.1	<1.00	<10	<.1	25	.194	34
16-18	<.1	<.1	<.1	<.1	<1.00	<10	<.1	25	.046	26
18-20	<.1	<.1	<.1	<.1	<1.00	<10	<.1	24	<.020	32
20-22	<.1	<.1	<.1	<.1	<1.00	<10	<.1	22	--	30
22-24	<.1	<.1	<.1	<.1	<1.00	<10	<.1	24	--	27
24-26	<.1	<.1	<.1	<.1	<1.00	<10	<.1	28	--	30
26-28	<.1	<.1	<.1	<.1	<1.00	<10	<.1	32	--	31
28-30	<.1	<.1	<.1	<.1	<1.00	<10	<.1	29	--	31

## Compounds in Core Segments

Five organochlorine compounds—chlordane, dieldrin (a commercial insecticide and biodegradation product of aldrin), PCB's, DDD, and DDE—were detected in the Icedale Lake core and represent primary-use compounds or degradation products that are resistant to further decomposition in the natural environment (Callahan and others, 1979). DDD and DDE typically reflect biodegradation of DDT (Johnsen, 1976). Because these nonionic organic compounds have a strong tendency to partition into organic material in the presence of water (Smith and others, 1988, p. 27-28), ratios of their concentrations and concentrations of organic carbon were used to normalize the data for more meaningful comparisons. The highest ratios suggest the periods of greatest influx of organochlorine compounds to the lake. Figure 3 compares these ratios for the detected compounds. Generally, data suggest the influx of the detected compounds was smaller in recent years than in the past, although only DDD, the compound most likely to be biodegraded (Johnsen, 1976), had recent ratios nearly as low as the oldest ones. Although DDT was not detected, the ratios of DDE and DDD suggest that the greatest effects of this pesticide were in the late 1940's to early 1950's, shortly after commercial production began in the United States. Influxes of chlordane and dieldrin seem to increase after 1950, while those of DDE and DDD decrease, suggesting that DDT use was gradually replaced by chlordane and dieldrin. The influx of chlordane and dieldrin appears to be greatest in the mid 1960's, corresponding closely with the peak farm use of aldrin and dieldrin (1966) and chlordane (1971) reported by Gilliom and others (1985, p. 7). This usage peaked just before the biological monitoring program began in Chester County.

Two peaks are present for PCB's, one in the late 1950's and the other in the late 1960's. It is not known if this is related to use of PCB's as a pesticide extender (National Research Council, 1979, p. 3-4) or any of the many other wide-ranging historical uses for these compounds. Although greatest regional concentrations are commonly in industrial areas, atmospheric discharges (volatilization, incineration, etc.) contribute to their very widespread distribution (Smith and others, 1988, p. 30-32).

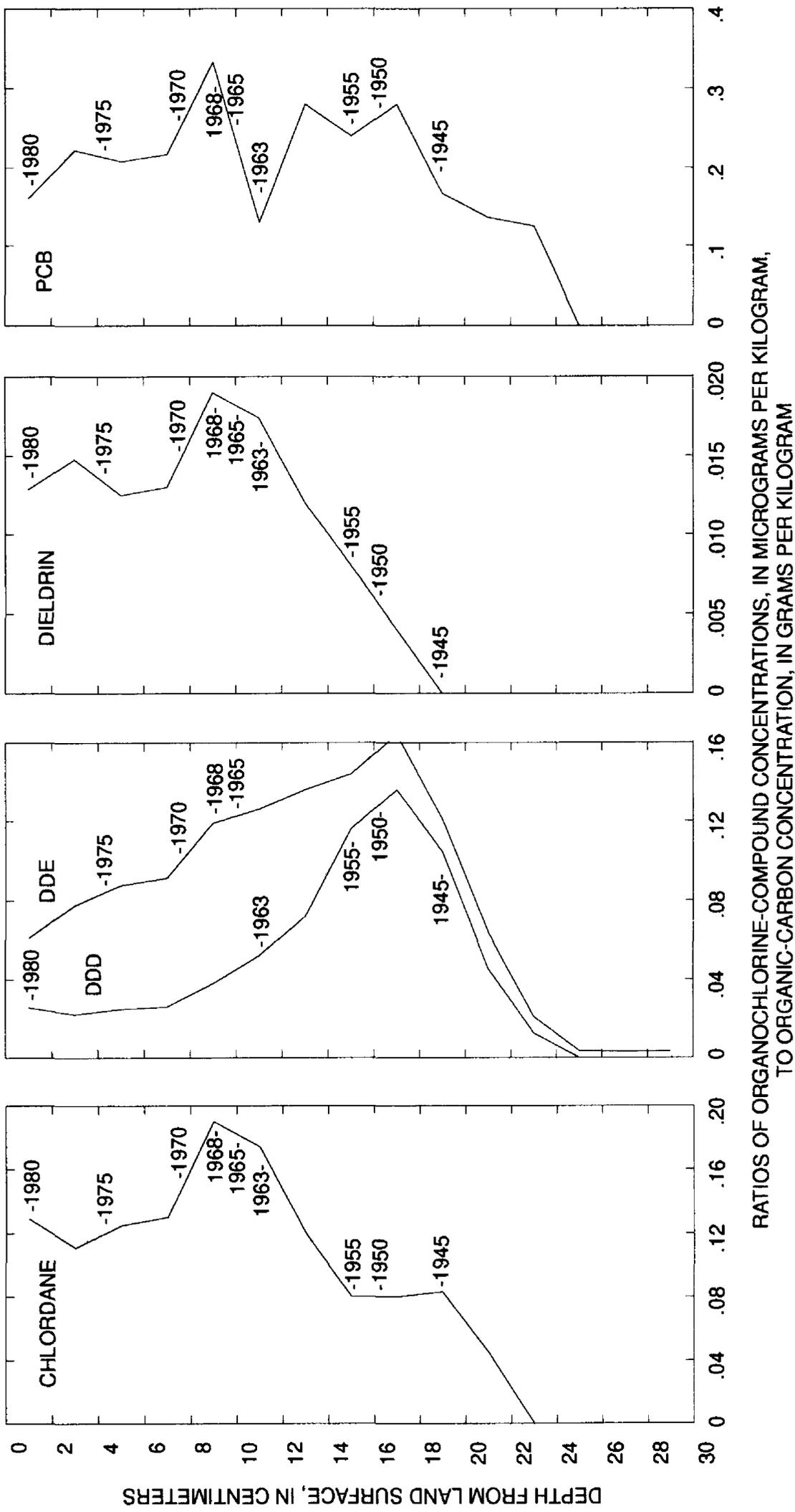
## Stream-Bottom Materials

Bulk samples of stream-bottom materials were collected at 42 sites in the study area from October 1985 through November 1987 and analyzed for content of organochlorine pesticides and PCB's (table 5). The samples were collected from the top 2 cm of the stream bottom in depositional areas of the stream by use of stainless-steel scoops according to the methods of Wershaw and others (1987, p. 7-8). Analyses were performed by the USGS National Water-Quality Laboratory according to the methods of Wershaw and others (1987, p. 31-35).

The most frequently detected compounds were PCB's, chlordane, DDT, DDD, DDE, dieldrin, heptachlor epoxide, methoxychlor, and lindane (table 5). In a few instances, the minimum reporting levels<sup>1</sup> exceeded those typically reported or no values are reported for some compounds. This is a result of interference caused by high concentrations of other target or nontarget compounds and the resulting subsample dilutions that sometimes must be made during analysis. Organochlorine compounds were detected at every site except one (site 46) located in the northwestern part of the study area. Methoxychlor was detected at only three sites (sites 1, 39, and 49). Land-use analysis was done for the drainage areas of two of these three sites (sites 1 and 49). The data show that drainage areas for these sites were among the four areas having the greatest commercial land use in 1987 (greater than 6 percent). Methoxychlor is usually associated only with agricultural activities, has a short half-life compared to other organochlorine pesticides, and is rarely detected in the stream-bottom materials in stream basins where this pesticide is used (Gilliom and others, 1985, p. 9). Detection of methoxychlor at these sites might be a result of commercial construction activities on former agricultural lands.

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<sup>1</sup>The smallest measured concentration of a constituent that may be reliably reported using a given analytical method.



**Figure 3.** Depth profiles of ratios of selected organochlorine compounds and organic carbon in bottom materials of Icedale Lake, Chester County, Pennsylvania

**Table 5. Concentrations of organochlorine compounds on unsorted streambed materials of streams in Chester County, Pennsylvania, October 1985 through November 1987**

[All values are in micrograms per kilogram; <, less than]

Site number	Date	Aldrin, total	Chlordane, total	DDD, total	DDE, total	DDT, total	Dieldrin, total	Endosulfan, total	Endrin, total	PCB, total
1	10-09-87	<0.1	2.0	0.3	0.2	<1.0	<0.1	<0.1	<0.1	3
2	10-07-86	<.1	<1.0	<.2	.5	<.1	<.1	<.2	<.1	<5
3	10-08-86	<.1	<1.0	.3	.4	-	<.1	.1	<.1	<1
4	10-07-85	<.1	<1.0	<.1	-	<.1	.1	<.1	<.1	9
5	10-06-86	<.1	<1.0	<.1	.4	.3	<.1	.3	<.1	<1
6	10-11-85	<.1	6.0	.4	1.0	<.1	.3	<.1	<.1	3
10	10-11-85	<.1	<1.0	<.1	.1	<.1	<.1	<.1	<.1	<1
12	10-10-85	<.1	<1.0	.3	.4	.4	4.8	<.1	.1	<1
13	10-22-86	<.1	<1.0	1.2	1.1	<.1	.3	<.1	<.1	<1
14	10-11-85	<.1	6.0	<.1	.6	<.1	.1	<.1	<.1	12
15	12-05-86	<.1	1.0	<.1	.2	<.1	.1	<.1	<.1	3
16	10-09-85	<.1	5.0	<.1	<.1	<.1	.2	<.1	<.1	5
17	11-14-86	<.1	<1.0	.8	1.7	1.0	2.7	<.1	<.1	95
19	10-09-86	<.1	7.0	.1	.3	2.2	.1	<.1	<.1	7
20	10-15-85	<.1	7.0	.6	.6	<.1	.3	<.1	<.1	5
21	10-09-86	<.1	<1.0	.1	.1	<.1	<.1	<.1	<.1	<1
22	10-15-86	<.1	30	.8	1.6	1.3	.5	<.1	<.1	8
23	10-15-86	<.1	<1.0	.3	.6	<.1	.4	<.1	<.1	4
24	10-16-85	<.1	7.0	<.1	.3	<.1	.1	<.1	<.1	2
26	10-18-85	<.1	5.0	36	22	61	<.1	<.1	<.1	38
27	11-18-86	<.1	-	-	-	-	-	<.1	<.1	1,400
28	10-25-85	<.1	<1.0	6.3	2.8	.4	.1	<.1	<.1	<1
29	12-02-86	<.1	<1.0	1.1	1.2	1.3	.1	<.1	<.1	3
30	10-25-85	<.1	<1.0	-	.4	<.1	<.1	<.1	<.1	<1
31	10-28-86	<.1	29	3.2	7.4	.8	.9	<.1	<.1	<1
32	10-17-85	<.1	1.0	.8	1.0	3.1	<.1	<.1	<.1	<1
33	11-20-86	<.1	4.0	3.1	4.8	3.8	1.2	<.1	.3	3
34	10-24-85	<.1	<1.0	.1	<.1	.2	<.1	<.1	<.1	<1
36	10-21-85	<.1	<1.0	.1	.2	<.1	<.1	<.1	<.1	<1
37	11-17-86	<.1	<1.0	.2	.3	<.1	.6	<.1	<.1	6
38	10-22-85	<.1	3.0	.6	.2	<.1	.1	<.1	<.1	11
39	11-03-86	<.1	32	4.4	4.1	1.3	3.2	.2	<.1	14
40	10-30-85	<.1	3.0	3.6	2.5	<.1	<.1	<.1	<.1	6
42	10-23-85	<.1	<1.0	<.1	.2	<.1	<.1	<.1	<.1	<1
44	10-31-85	<.1	4.0	.4	<.1	<.1	.3	<.1	<.1	40
45	10-30-86	<.1	4.0	.6	2.1	<.1	.7	<.1	<.1	<1
46	10-29-85	<.1	<1.0	<.1	<.1	<.1	<.1	<.1	<.1	<1
47	10-29-86	<.1	<1.0	.4	-	<.1	.4	<.1	<.1	3
48	10-29-86	.1	1.0	.3	1.8	<.1	.4	<.1	<.1	<1
49	11-16-87	<10	13	.3	<10	<10	.8	<.1	<.1	540
50	10-09-85	<.1	5.0	1.7	1.7	3.2	.1	<.1	<.1	18
51	10-16-86	<.1	110	5.0	2.1	1.2	.6	<.1	<.1	73

**Table 5. Concentrations of organochlorine compounds on unsorted streambed materials of streams in Chester County, Pennsylvania, October 1985 through November 1987—Continued**

[All values are in micrograms per kilogram; <, less than]

Site number	Date	PCN, total	Heptachlor, total	Heptachlor epoxide, total	Lindane, total	Methoxychlor, total	Mirex, total	Perthane, total	Toxaphene, total
1	10-09-87	<1.0	<0.1	<0.1	<0.1	2.4	<0.1	<1.00	<10
2	10-07-86	<1.0	<.1	<.1	<.1	<.1	<.1	<1.00	<10
3	10-08-86	<1.0	<.1	3.8	<.1	<.1	<.1	<1.00	<10
4	10-07-85	<1.0	<.1	<.1	<.1	<.1	<.1	<1.00	<10
5	10-06-86	<1.0	<.1	<.1	<.1	<.1	.2	<1.00	<10
6	10-11-85	<1.0	<.1	.2	<.1	<.1	<.1	<1.00	<10
10	10-11-85	<1.0	<.1	<.1	<.1	<.1	<.1	<1.00	<10
12	10-10-85	<1.0	<.1	.4	<.1	<.1	<.1	<1.00	<10
13	10-22-86	<1.0	<.1	<.1	.1	<.1	<.1	<1.00	<10
14	10-11-85	<1.0	<.1	.1	<.1	<.1	<.1	<1.00	<10
15	12-05-86	<1.0	<.1	<.1	<.1	<.1	<.1	<1.00	<10
16	10-09-85	<1.0	<.1	.1	<.1	<.1	<.1	<1.00	<10
17	11-14-86	<1.0	<.1	<.1	<.1	<.1	<.1	<1.00	<10
19	10-09-86	<1.0	<.1	<.1	<.1	<.1	.7	<1.00	<10
20	10-15-85	<1.0	<.1	.4	.1	<.1	<.1	<1.00	<10
21	10-09-86	<1.0	<.1	<.1	<.1	<.1	<.1	<1.00	<10
22	10-15-86	<1.0	<.1	.1	.1	<.1	<.1	<1.00	<10
23	10-15-86	<1.0	<.1	.2	<.1	<.1	<.1	<1.00	<10
24	10-16-85	<1.0	<.1	.1	.4	<.1	<.1	<1.00	<10
26	10-18-85	1.0	<.1	<.1	.3	<.1	<.1	<1.00	<10
27	11-18-86	<1.0	<.1	<.1	<.1	<.1	<.1	-	<10
28	10-25-85	<1.0	<.1	<.1	<.1	<.1	<.1	<1.00	<10
29	12-02-86	<1.0	<.1	<.1	<.1	<.1	<.1	<1.00	<10
30	10-25-85	<1.0	<.1	<.1	<.1	<.1	<.1	<1.00	<10
31	10-28-86	<1.0	.5	<.1	<.1	<.1	<.1	<1.00	<10
32	10-17-85	<1.0	<.1	.1	<.1	<.1	<.1	<1.00	<10
33	11-20-86	<1.0	<.1	.1	<.1	<.1	<.1	<1.00	<10
34	10-24-85	<1.0	<.1	<.1	<.1	<.1	<.1	<1.00	<10
36	10-21-85	<1.0	<.1	<.1	<.1	<.1	<.1	<1.00	<10
37	11-17-86	<1.0	<.1	<.1	<.1	<.1	<.1	<1.00	<10
38	10-22-85	<1.0	<.1	.1	<.1	<.1	<.1	<1.00	<10
39	11-03-86	<1.0	<.1	<.1	.2	.2	<.1	<1.00	<10
40	10-30-85	<1.0	<.1	<.1	<.1	<.1	<.1	<1.00	<10
42	10-23-85	<1.0	<.1	<.1	<.1	<.1	<.1	<1.00	<10
44	10-31-85	<1.0	<.1	<.1	<.1	<.1	<.1	<1.00	<10
45	10-30-86	<1.0	<.1	.1	<.1	<.1	<.1	<1.00	<10
46	10-29-85	<1.0	<.1	<.1	<.1	<.1	<.1	<1.00	<10
47	10-29-86	<1.0	<.1	<.1	<.1	<.1	<.1	<1.00	<10
48	10-29-86	<1.0	<.1	<.1	<.1	<.1	<.1	<1.00	<10
49	11-16-87	<1.0	<10	<.1	<.1	13	<10	<1.00	<10
50	10-09-85	<1.0	.1	.1	<.1	<.1	<.1	<1.00	<10
51	10-16-86	<1.0	.1	.1	1.0	<.1	<.1	<1.00	<10

Because compound concentrations in these bulk stream-bottom samples can be expected to be complicated by variation in sample organic-carbon concentrations, only concentrations equal to or greater than 15 µg/kg were considered enriched for this study. Comparison of all compound concentrations by use of probability plots according to the methods of Velz (1970) also suggests that concentrations greater than about 15 to 20 µg/kg can be considered enriched over background. Table 6 summarizes results for compounds detected at greater than 15 µg/kg.

Only one site (site 22) had both a bottom-material sample with the concentration of chlordane exceeding 15 µg/kg and an analysis of drainage-area land use. This drainage area had the second highest residential land use (greater than 74 percent) and low agricultural land use (0 percent), suggesting that residential land use is, or has been, the most significant source of chlordane, possibly for termite control. Moore (1987, p. 28) reports that chlordane also was used by the mushroom industry in Chester County.

Site 26 (East Branch Red Clay Creek) was the only site having combined DDT, DDD, and DDE concentrations in bottom materials exceeding 15 µg/kg. Although no land-use data were available, the high concentrations at this site are consistent with other data suggesting heavy past or current use of DDT throughout the Red Clay Creek Basin (Cindy Rice, U.S. Fish and Wildlife Service, written commun., 1992). Unfortunately, comparisons could not be made to site 27 (West Branch Red Clay Creek) because elevated concentrations of PCB (1,400 µg/hg) at this site interfered with pesticide determinations.

Bottom-material samples from seven sites had PCB concentrations exceeding 15 µg/kg, but only five sites had analyses of drainage-area land use. The drainage area of four of these sites (sites 17, 44, 49, and 50) were among the six having the highest combined industrial and commercial land uses in 1987 (ranging from 7 to 26 percent). Although the drainage area of site 27 did not have high industrial and commercial land use, the extremely high PCB concentrations may have been caused by reported industrial contamination to the West Branch Red Clay Creek at Kennett Square, Pa. (Roy F. Weston, Inc., 1988, P. 3-33 to 3-36).

Three bottom-material samples from sites with drainage area land-use data (sites 5, 21, and 23) had lower concentrations of organochlorine compounds than the samples from upstream sites (see table 7). The drainage areas for the downstream sites all experienced greater than 20 percent residential growth between 1967-87, suggesting that construction activities between each pair of sites may contribute sediments that have lower pesticide concentration than do the older sediments of the streams.

**Table 6.** Concentrations of organochlorine compounds exceeding or equalling 15 micrograms per kilogram on unsorted streambed materials in Chester County, Pa., October 1985 through November 1987

[--, concentration did not equal or exceed 15 micrograms per kilogram]

Site number	Chlordane	DDT, DDD, and DDE	PCB
<sup>1</sup> 17	--	--	95
<sup>1</sup> 22	30	--	--
26	--	119	38
<sup>1</sup> 27	--	--	1,400
31	29	--	--
39	32	--	--
<sup>1</sup> 44	--	--	40
<sup>1</sup> 49	--	--	540
<sup>1</sup> 50	--	--	18
51	110	--	73

<sup>1</sup>1967 and 1987 land-use data available for the drainage area of this site.

**Table 7.** Comparison of pesticide concentrations at paired sites with increasing residential land use

[Concentrations are in micrograms per kilogram; <, less than]

Sample location	Chlordane	Combined DDT, DDD, and DDE	PCB	Heptachlor epoxide	Methoxychlor
<b>Pickering Creek</b>					
Upstream from site 5	2	0.5	9	3.8	2.4
Site 5	<1	.7	<1	<.1	<.1
<b>Ridley Creek</b>					
Upstream from site 21	7	1.2	5	.4	<.1
Site 21	<1	.2	<1	<.1	<.1
<b>East Branch Chester Creek</b>					
Upstream from site 23	30	2.9	8	.1	<.1
Site 23	<1	<.1	4	.2	<.1

## BENTHIC-INVERTEBRATE COMMUNITIES

Benthic-invertebrate communities were sampled annually in autumn. Samples were collected in riffles at each site by collecting 10 rocks between 45 and 90 mm in diameter. A Lium Sampler (Britton and Greeson, 1988, pp. 280-281) having a 210  $\mu\text{m}$  mesh screen was used to collect the samples. Moore (1987) discusses this sampling method and its comparability to other techniques in greater detail.

Diversities of the invertebrate communities were determined for each sample by calculating Brillouin's diversity index (Brillouin, 1962). This index is commonly used by aquatic ecologists and, when samples are only a representative part of a larger, undefined community, this index most appropriately represents community diversity (Pielou, 1969; Kaesler and Herricks, 1976; and Zand, 1976). All organisms were identified to the genus level for the entire study period except for midges (Chironomidae), which were identified to only family level for the 1970-74 and 1981-88 periods. In order to ensure comparability for this study, all diversity indexes were calculated on the basis of midge identification to family level. Brillouin's diversity indexes for each sample for 1970-88 are given in the appendix. Diversity indexes as a function of time also are given in graphic form for each site. The 1978 data were omitted from the tables, time plots, and trend analyses because variations in the sampling procedures made comparisons to the other data inappropriate. Supplementary information also given in the appendix includes numbers of organisms and taxa and calculations of minimum diversity, maximum diversity, and evenness. Moore (1987, p. 11) gives detailed descriptions of these calculations. Generally, higher diversities were directly related to higher numbers of organisms and higher numbers of taxa at the genus and family levels, but not at the order level.

A nonparametric, distribution-free statistical test for monotonic trend with time was used to detect trends in the diversities at each of 46 sites. Magnitude of trend in the data was determined by the Kendall slope estimator (Hirsch and others, 1982). Sites previously dropped from the network because habitat differences resulted in data that could not be compared to other network sites (sites 25 and 41) and sites having only recent diversity data (sites 16, 39, and 51) were not included in the analysis. Trend tests and estimates of the slope of the linear trends are presented in table 8. The diversity of benthic-invertebrate communities increased at 45 of 46 sites. The upward trends were significant at the 99-percent confidence level at 30 sites, 95- to 98-percent confidence level at 9 sites, and 90- to 94-percent confidence level at 3 sites (table 8). The trends in diversity indexes at sites 7, 28, 31, and 47 were not statistically significant. Sites 3 and 26, which exhibited downward diversity-index trends prior to 1981 (Moore, 1987), show statistically significant upward trends.

**Table 8.** Values of slope, tau, p, and level of confidence from seasonal Kendall test of diversity index

[--, trend not statistically significant at the 90-percent confidence level; Tau, measures the degree of correlation—the lower the tau value, the lower the correlation; p, measures the significance of the trend—the higher the p value, the higher the probability of error]

Site number	Kendall slope estimator	Tau	p	Level of confidence of significant trends (percent)
1	0.08	0.72	0.00	99
2	.08	.43	.02	98
3	.06	.42	.03	97
4	.10	.67	.001	99
5	.09	.55	.01	99
6	.16	.78	.00	99
7	.14	.33	.18	--
8	.08	.44	.09	91
9	.11	.64	.01	99
10	.09	.64	.00	99
11	.13	.72	.01	99
12	.08	.68	.00	99
13	.06	.32	.09	91
14	.06	.37	.05	95
15	.07	.43	.02	98
17	.13	.85	.00	99
18	.13	.56	.03	97
19	.09	.50	.01	99
20	.11	.66	.00	99
21	.09	.56	.00	99
22	.09	.57	.00	99
23	.15	.70	.00	99
24	.12	.67	.00	99
26	.08	.39	.05	95
27	.01	.58	.00	99
28	.00	.01	1.00	--
29	.12	.66	.00	99
30	.10	.70	.00	99
31	.08	.31	.11	--
32	.07	.47	.02	98
33	.10	.68	.00	99
34	.12	.59	.00	99
35	.10	.41	.07	93
36	.08	.54	.00	99
37	.09	.47	.01	99
38	.14	.71	.00	99
40	.15	.78	.00	99
42	.12	.62	.00	99
43	.21	.71	.02	98
44	.08	.55	.01	99
45	.07	.47	.02	99
46	.12	.65	.00	99
47	.04	.35	.11	--
48	.07	.46	.02	98
49	.10	.69	.00	99
50	.13	.88	.00	99

## RELATIONS AMONG LAND USE, BENTHIC-INVERTEBRATE COMMUNITIES, AND ORGANOCHLORINE COMPOUNDS

Streamflow data were examined to determine if extreme hydrologic conditions would have significantly affected invertebrate communities for any sampling periods. Available discharge records from Brandywine, Darby, and French Creeks were examined for streamflows less than the 7-day, 10-year low flow and the two highest peak flows occurring up to 3 months prior to or during sampling. These extreme flows were compared to invertebrate-community diversities and numbers of organisms. The comparisons showed no consistent effects that could be expected to overwhelm other factors, such as land use, for any sampling periods.

The trends in community diversities and changes in land use were compared. The 1988 land-use data for 26 drainage areas primarily show increases in residential land use and decreases in agricultural land use since 1967. Biological data collected from sites in these drainage areas show positive trends in the diversity indices for the period 1970-88. These data were analyzed by use of contingency tables to measure any possible relation between the biological trends and land-use changes. The contingency analyses were based on the frequency with which a large percentage change in land use and a high Kendall slope estimator occurred together in a basin.

The contingency analyses showed that the relation between the Kendall slope estimator and the increases in residential land use of 12 percent or greater was significant at the 95-percent confidence level. The phi-coefficient (the correlation coefficient calculated on the observations in the contingency table) was 0.43, which shows a moderate dependence. Increases in residential land use greater than or equal to 12 percent occurred in 18 of the 26 drainage areas with land-use data in Chester County.

The contingency analyses also showed that the relation between the Kendall slope estimators and decreases in agricultural land use of 5 percent or greater was significant at the 95-percent confidence level. The phi-coefficient was 0.39, which again shows a moderate dependence. Decreases in cropland greater than or equal to 5 percent occurred in 23 of the 26 drainage areas.

Data from the nested systems (French, Pickering, Ridley, and East Branch Chester Creeks) suggest no refinements to conclusions drawn from the entire data base. All sites showed similar degrees of improvement in the diversity of benthic communities.

The relation between community diversities and concentrations of organochlorine compounds in bottom sediments also was analyzed by use of contingency tables. Concentrations of chlordane, PCB's, and DDT plus its breakdown products were totaled for use in the analyses and compared to those diversities for biological samples collected in the same year. The contingency tables showed that the relation between diversity indexes of less than 2.25 and concentrations of organochlorine compounds greater than 45  $\mu\text{g}/\text{kg}$  was significant at the 95-percent confidence level. The phi-coefficient was 0.37, which showed a moderate dependence. Concentrations of organochlorine compounds were greater than 45  $\mu\text{g}/\text{kg}$  at 5 of the 42 sites (sites 17, 26, 27, 49, and 51).

Comparisons of the magnitude of organochlorine-compound concentrations to the ranking of the diversities suggest that pesticide residues could influence the benthic communities more than PCB residues influence them. The maximum concentrations of DDT plus its breakdown products and chlordane (119 and 110  $\mu\text{g}/\text{kg}$ , respectively) were at sites 26 and 51. The concentration of PCB residues at site 27 (1,400  $\mu\text{g}/\text{kg}$ ) was so high that it interfered with the detection of other pesticides. The diversities associated with these high concentrations were in the lowest quartile of all diversities (less than 2.39). In contrast, concentrations of PCB at sites 17 and 49 (95 and 540  $\mu\text{g}/\text{kg}$ , respectively) were associated with diversities greater than 3.0 (median diversity).

Overall, the contingency-table analyses show relations that support several possible factors or combination of factors affecting the invertebrate communities. Sediment produced by new residential development might be less than that produced by the replaced agricultural activities, causing less stress on the communities. Decreases in agricultural land use and (or) changing pesticide use might translate into less pesticide influx to streams, also causing less stress on communities. Finally, sediment from new residential development might have lower pesticide concentrations associated with it than sediment from agricultural land does, resulting in dilution of pesticides in the streambed materials where the benthic communities reside. However, the moderate degree of dependence for these relations indicates that land-use changes and organochlorine compounds are probably only two of several factors that might cause the improvements in benthic-invertebrate communities observed in the streams studied. Site-specific studies would be required to verify the cause and effect relations suggested by this study or to identify other significant factors affecting the communities.

## SUMMARY AND CONCLUSIONS

Land use was analyzed for the drainage areas of 26 stream sites that cover about 30 percent of Chester County. The most significant land-use changes during 1967-87 were decreased agricultural land use and increased residential, commercial, and industrial land use.

Cores of lakebed sediments at the site of Icedale Lake (a drained reservoir on West Branch Brandywine Creek) were collected to evaluate past influx of organochlorine pesticides and PCB's. Residues of DDD and DDE indicate that DDT was the first organochlorine insecticide entering the stream; concentrations peaked in the late 1940's and early 1950's. After this time, the influx of DDT decreased and those of chlordane and dieldrin increased. The influxes of these two insecticides peaked near the late-1960's, corresponding with reported national peak farm usage. Influx of PCB's seemed to be somewhat erratic; concentrations peaked from the late 1940's through the late 1960's. It is not known if any of the PCB influxes were associated with pesticide use. The core data suggest that influx of chlordane, dieldrin, and PCB's were greatest before the start of the biological monitoring program and decreased through the early 1980's, supporting the hypothesis of decreased pesticide use suggested by Sloto (1987).

Samples of stream-bottom material were collected at 42 sites in the study area from October 1985 through November 1987 and analyzed for organochlorine pesticides and PCB's. Organochlorine compounds were detected in streambed materials at 41 of the 42 sites sampled. The most enriched compounds (greater than 15  $\mu\text{g}/\text{kg}$ ) were PCB's, chlordane, and DDT plus its breakdown products. Methoxychlor was detected only in drainage areas with commercial land use greater than 6 percent. Chlordane concentrations exceeding 15  $\mu\text{g}/\text{kg}$  were detected at four sites, and the only site of these four with drainage area land-use data had high residential land use (74 percent) and low (0 percent) agricultural land use. Four of the five highest PCB concentrations were within the six drainage areas with the highest combined industrial and commercial land use. Although the drainage area of the site with the highest PCB concentration included less than 4 percent total industrial and commercial land use, the site is located downstream of an industrial-contamination site. In the nested systems, pesticide and (or) PCB concentrations were lower at three downstream sites than they were at the upstream sites. The drainage areas of all of these sites experienced greater than 20 percent residential growth between 1967 and 1987.

Brillouin's diversity index was calculated for all biological samples for each site in Chester County. Diversity index was plotted as a function of time at each site and tested for trend by use of the seasonal Kendall test. Upward trends in Brillouin's diversity index were found at 45 of the 46 stream sites. The upward trends were significant at the 99-percent confidence level at 30 sites, were significant at the 95- to 98-percent confidence level at 9 sites, and were significant at the 90- to 94-percent confidence level at 3 sites. Trends at only four sites were not statistically significant at the 90-percent confidence level.

Contingency-table analyses showed that upward trends in invertebrate-community diversities were associated with increases in residential land use of 12 percent or greater; and decreases in agricultural land use of 5 percent or greater. Contingency-table analyses also showed that concentrations of organochlorine compounds exceeding 45  $\mu\text{g}/\text{kg}$  in stream-bottom material were associated with community diversities less than 2.25. However, the moderate degree of dependence demonstrated by the contingency analyses suggests that additional factors also affect the communities.

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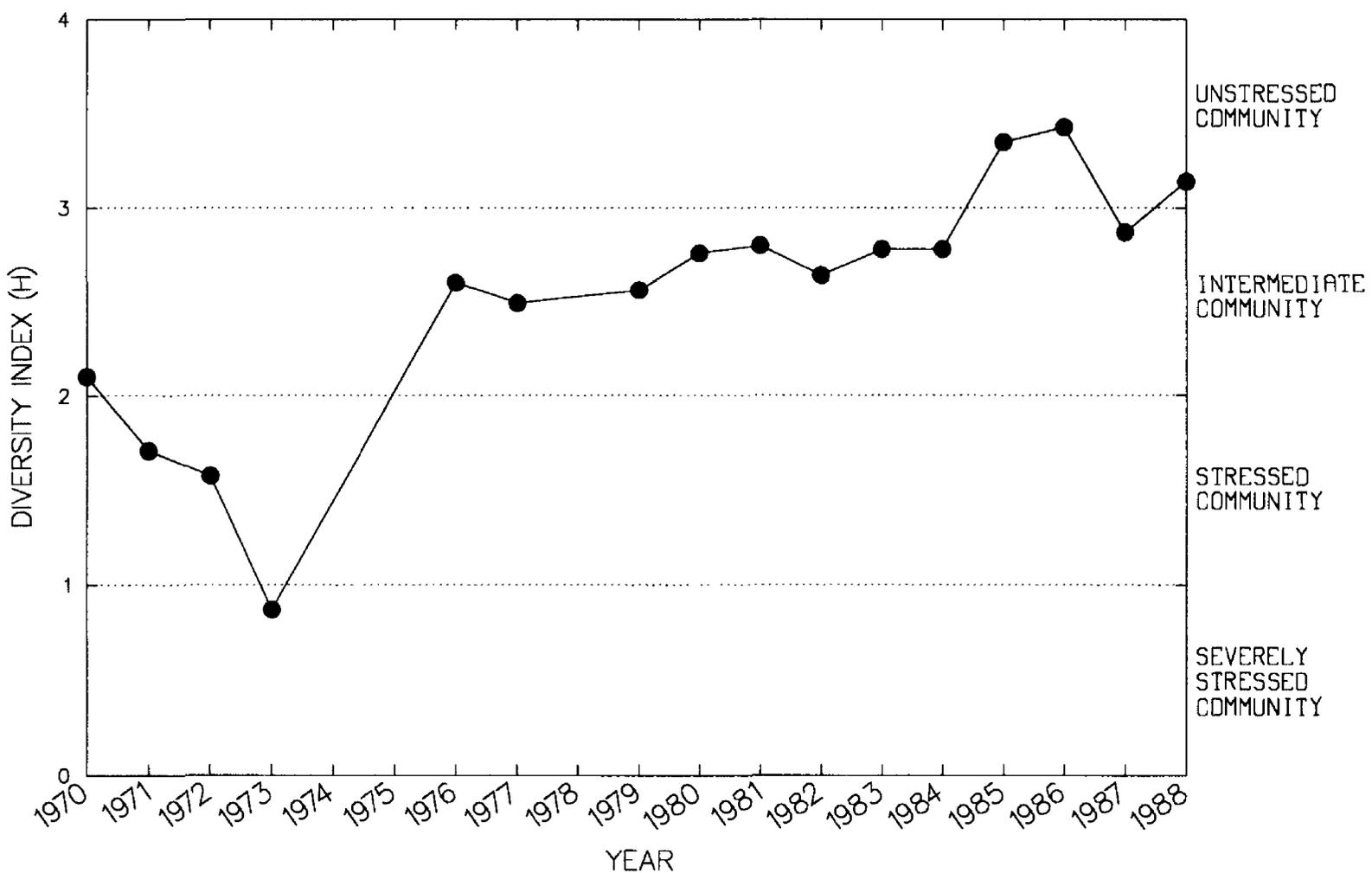
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**Appendix.—Brillouin's diversity index, maximum diversity, minimum diversity,  
and relative evenness, by site**

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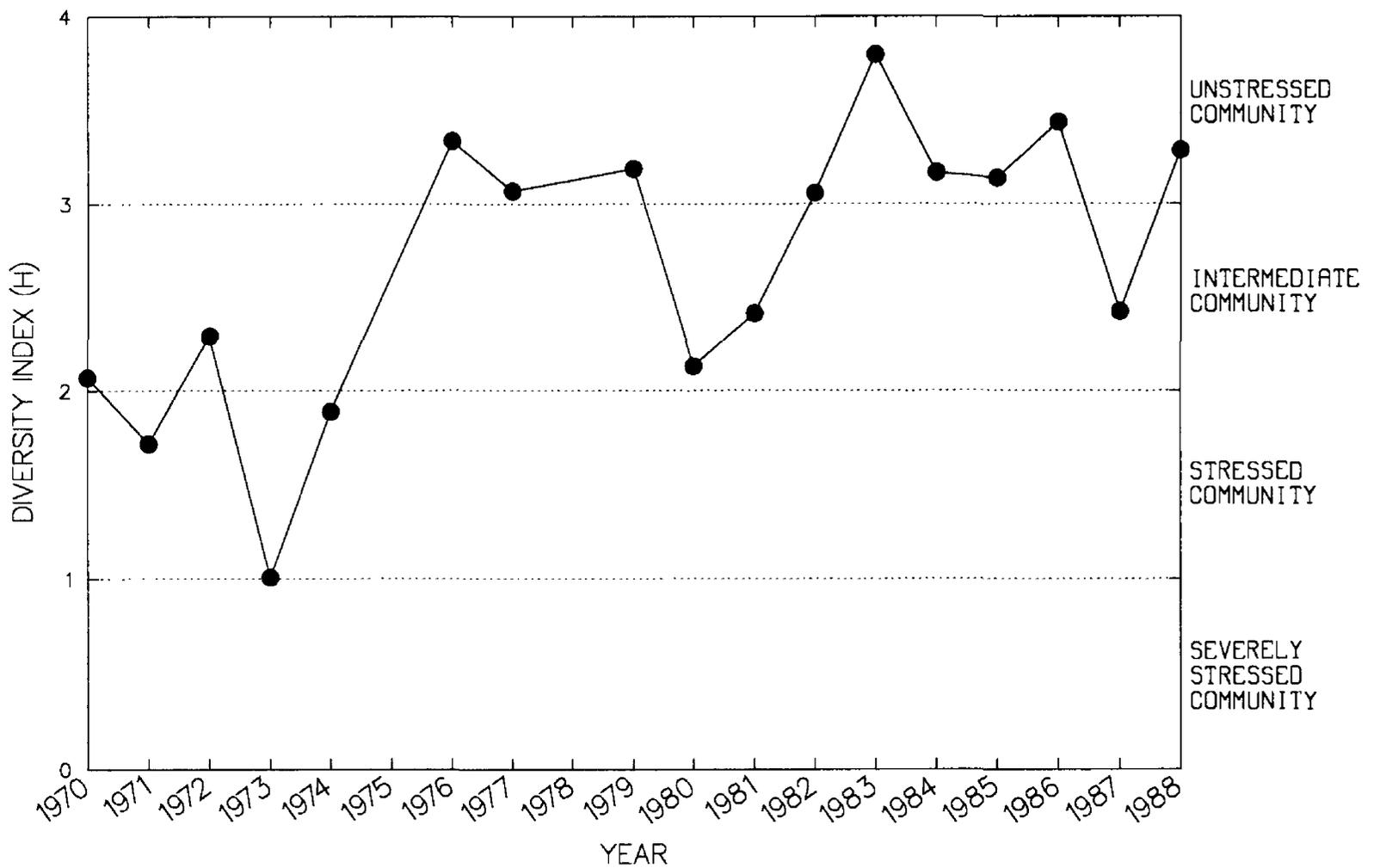
Site 1

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	161	5	2.10	2.27	0.18	0.92
1971	37	4	1.71	1.88	.42	.89
1972	743	14	1.58	3.74	.17	.40
1973	173	6	.87	2.62	.21	.27
1974	--	--	--	--	--	--
1975	--	--	--	--	--	--
1976	820	23	2.60	4.52	.26	.55
1977	1,121	22	2.49	4.49	.19	.54
1979	94	11	2.56	3.37	.69	.70
1980	242	16	2.76	3.84	.49	.68
1981	1,307	23	2.80	4.54	.17	.60
1982	2,651	22	2.64	4.45	.09	.58
1983	2,711	31	2.78	4.94	.13	.55
1984	1,539	23	2.78	4.55	.15	.60
1985	760	31	3.35	4.91	.38	.66
1986	1,096	32	3.43	4.93	.29	.68
1987	1,438	25	2.87	4.63	.17	.61
1988	2,731	29	3.14	4.82	.12	.64



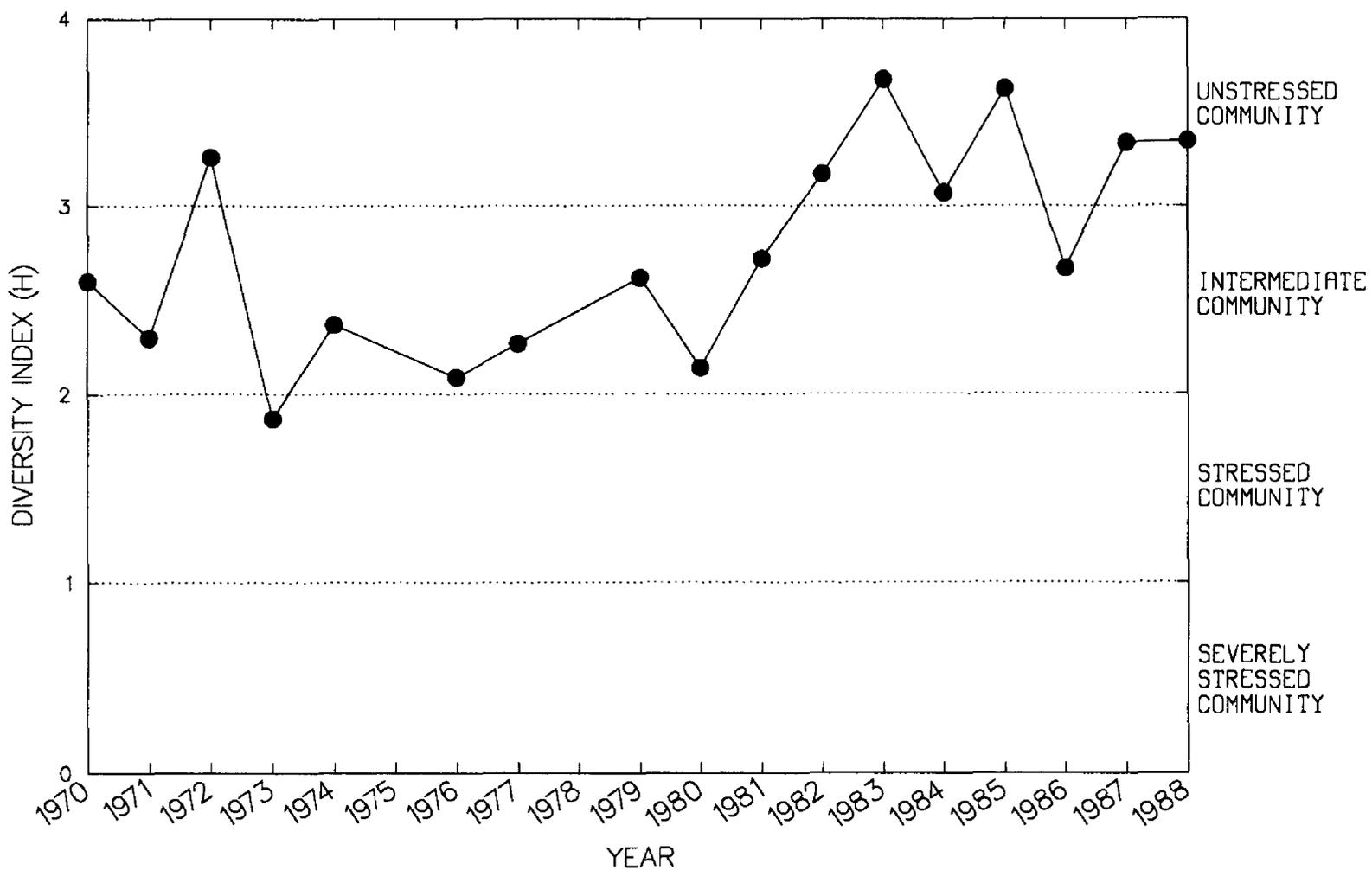
**Site 2**

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	84	7	2.07	2.60	0.45	0.75
1971	29	4	1.72	1.85	.50	.90
1972	413	17	2.29	4.01	.34	.53
1973	629	20	1.01	4.28	.28	.18
1974	173	13	1.89	3.58	.51	.45
1975	--	--	--	--	--	--
1976	531	35	3.34	4.97	.58	.63
1977	190	17	3.07	3.89	.63	.75
1979	837	19	3.19	3.94	1.35	.71
1980	132	7	2.13	2.85	.32	.72
1981	745	20	2.41	4.26	.24	.54
1982	1,088	26	3.06	4.72	.23	.63
1983	526	24	3.80	4.62	.39	.80
1984	1,351	21	3.17	4.36	.15	.72
1985	598	28	3.14	4.73	.42	.63
1986	485	30	3.44	4.75	.53	.69
1987	170	18	2.42	4.04	.73	.51
1988	1,341	24	3.29	4.60	.18	.70



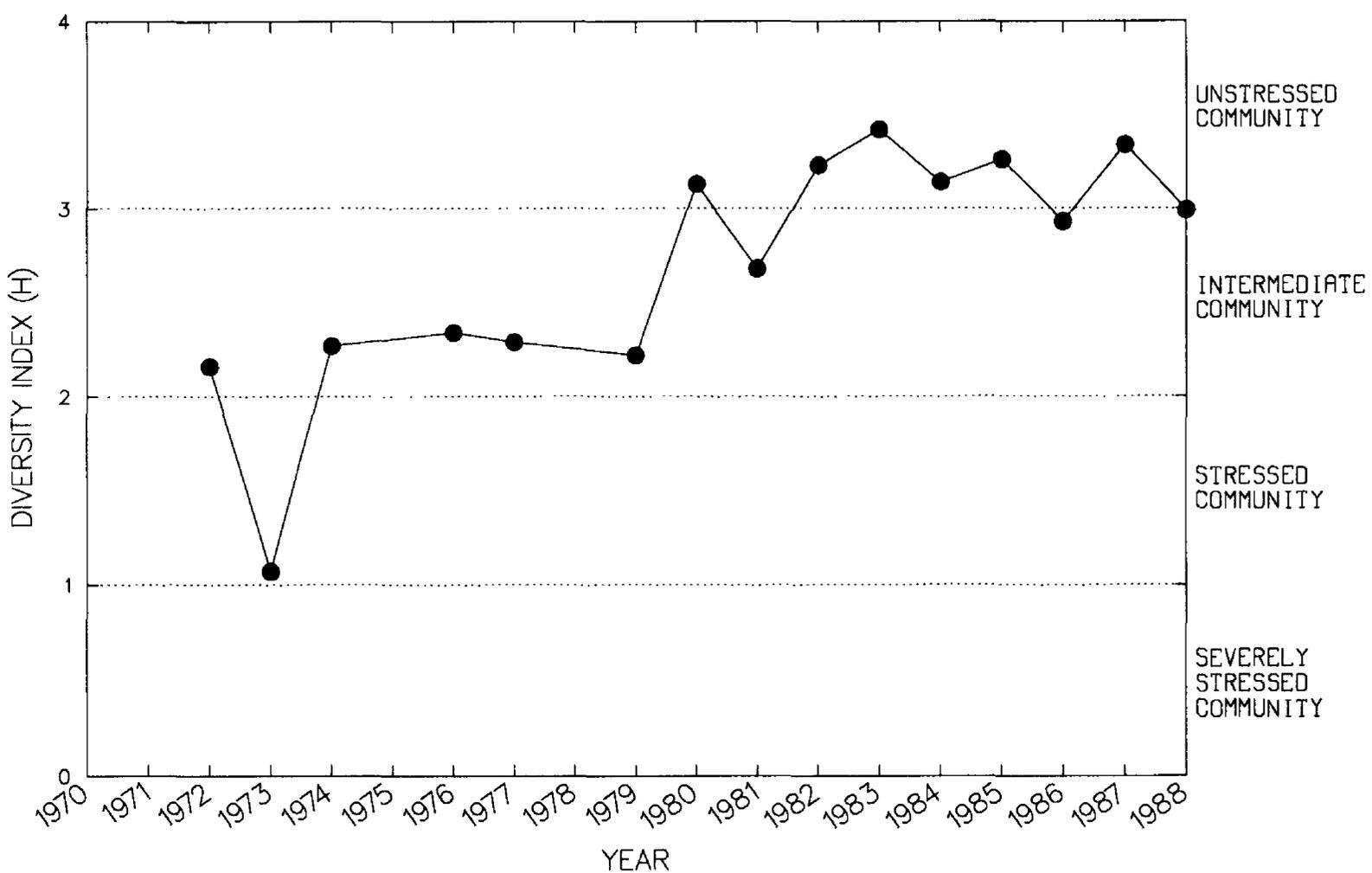
Site 3

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	79	10	2.60	3.36	0.71	0.71
1971	71	7	2.30	2.62	.52	.85
1972	119	24	3.26	4.57	1.31	.60
1973	560	21	1.87	4.38	.33	.38
1974	128	14	2.37	3.57	.70	.58
1975	--	--	--	--	--	--
1976	1,660	27	2.09	4.74	.17	.42
1977	547	23	2.27	4.53	.36	.46
1979	47	13	2.62	3.48	1.37	.59
1980	1,334	28	2.14	4.80	.21	.42
1981	1,757	27	2.72	4.70	.16	.56
1982	2,118	30	3.17	4.90	.15	.63
1983	931	25	3.68	4.58	.25	.79
1984	1,394	24	3.07	4.52	.17	.66
1985	916	40	3.63	5.35	.42	.65
1986	1,052	36	2.67	5.08	.33	.49
1987	1,394	38	3.34	5.24	.28	.62
1988	1,044	24	3.35	4.56	.22	.72



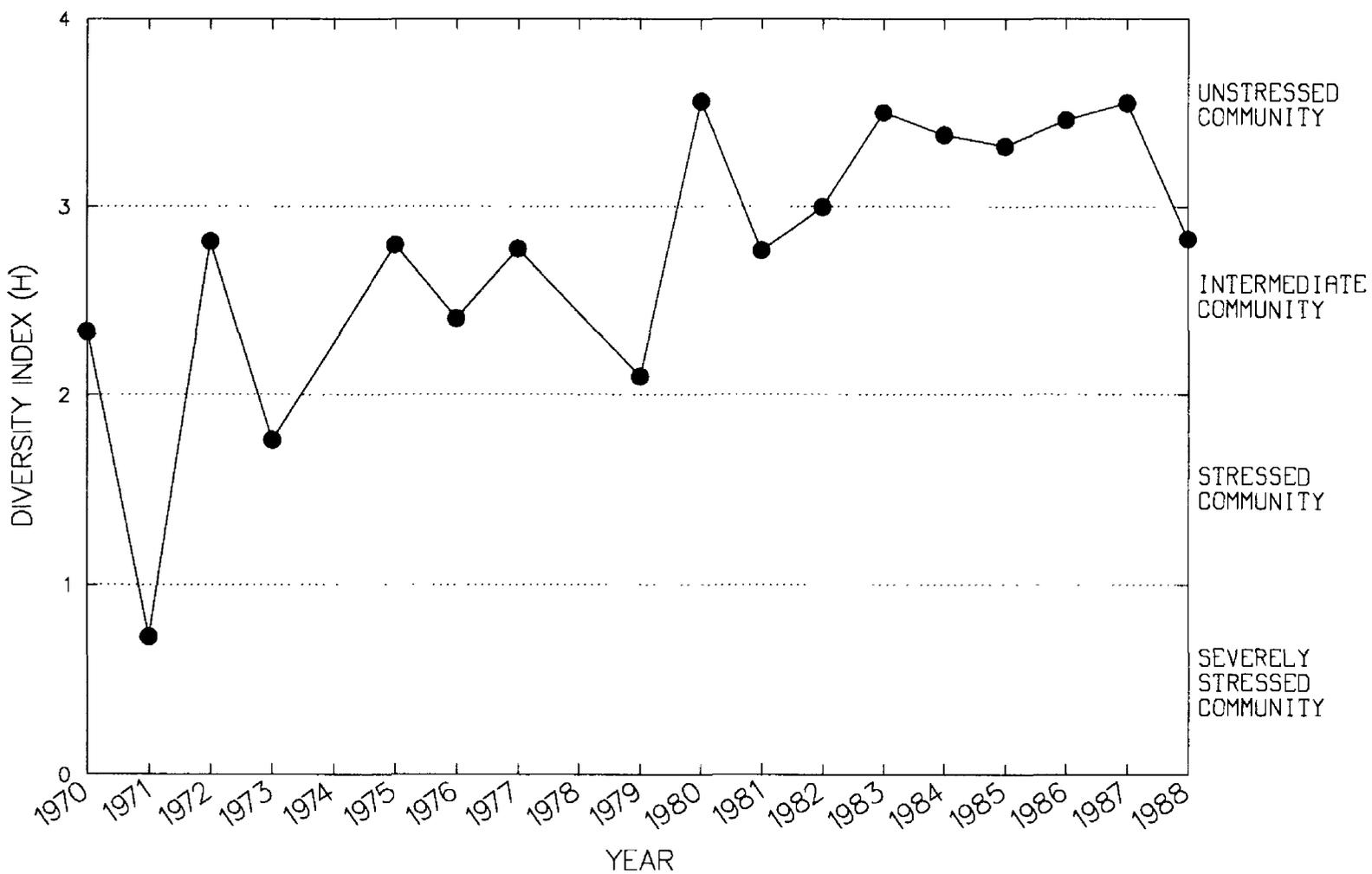
**Site 4**

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	--	--	--	--	--	--
1971	--	--	--	--	--	--
1972	483	16	2.16	3.92	0.28	0.52
1973	103	9	1.07	3.08	.52	.21
1974	415	17	2.27	4.03	.33	.52
1975	--	--	--	--	--	--
1976	740	26	2.34	4.66	.32	.47
1977	862	22	2.29	4.39	.24	.49
1979	232	19	2.22	4.08	.61	.47
1980	2,864	22	3.13	4.43	.08	.70
1981	3,650	32	2.68	4.96	.10	.53
1982	1,885	31	3.23	4.97	.17	.64
1983	1,306	27	3.42	4.72	.21	.71
1984	1,947	26	3.14	4.72	.14	.66
1985	556	27	3.26	4.72	.42	.66
1986	2,610	38	2.93	5.25	.15	.54
1987	2,326	36	3.34	5.16	.17	.64
1988	4,126	36	2.99	5.17	.10	.57



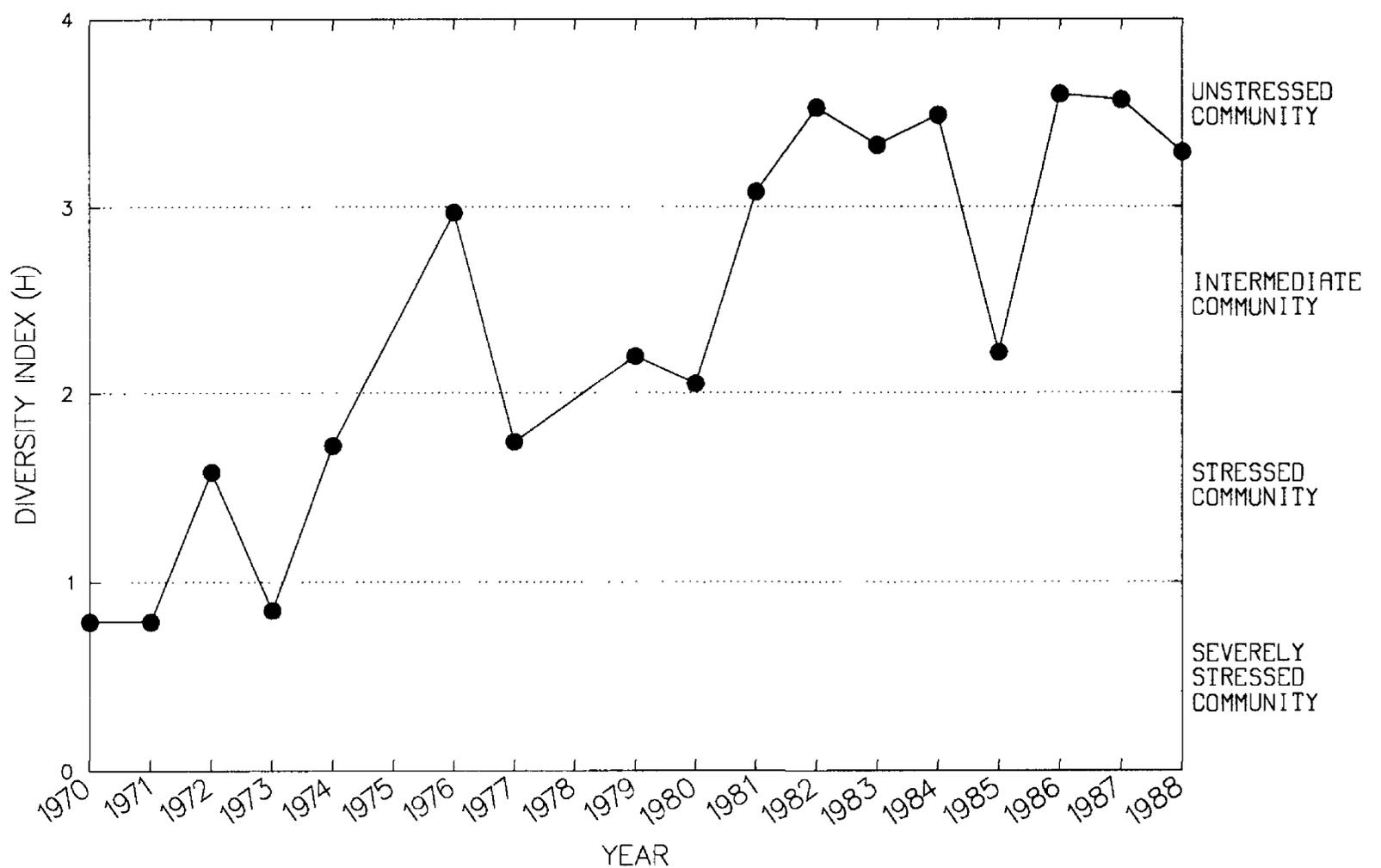
Site 5

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	127	10	2.34	3.31	0.49	0.65
1971	7	2	.73	1.02	.40	.54
1972	241	17	2.82	3.93	.52	.68
1973	156	11	1.76	3.31	.46	.46
1974	--	--	--	--	--	--
1975	375	17	2.80	3.95	.36	.68
1976	906	29	2.41	4.78	.30	.47
1977	316	23	2.78	4.51	.57	.56
1979	85	12	2.10	3.28	.82	.52
1980	520	20	3.56	4.19	.33	.84
1981	2,062	32	2.77	4.98	.17	.54
1982	3,230	39	3.00	5.30	.14	.56
1983	2,167	38	3.50	5.18	.19	.66
1984	1,506	32	3.38	4.92	.22	.67
1985	433	30	3.32	4.81	.58	.65
1986	1,154	40	3.46	5.34	.34	.62
1987	2,020	39	3.55	5.30	.21	.66
1988	2,653	28	2.83	4.81	.12	.58



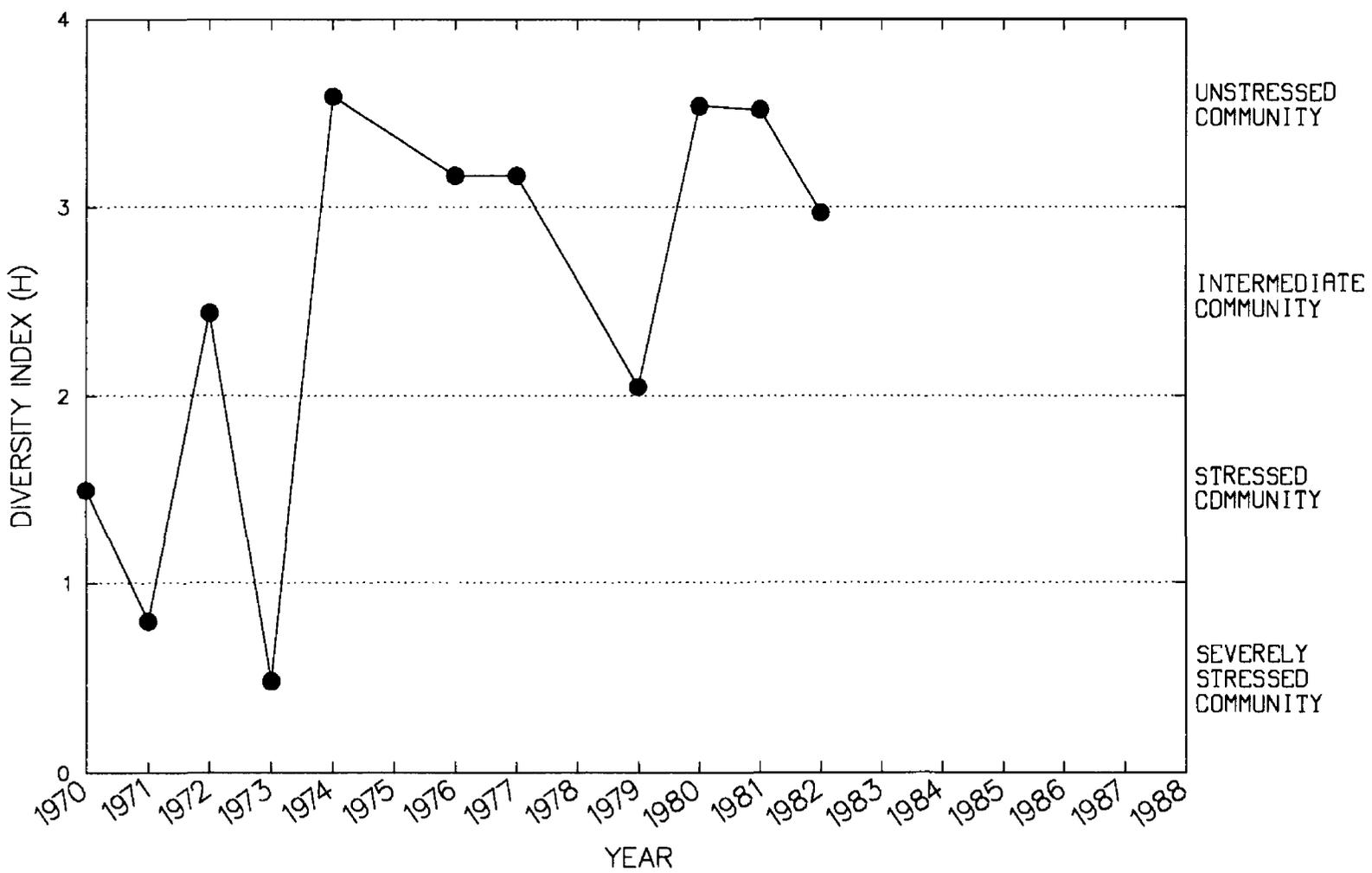
**Site 6**

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	124	2	0.79	0.97	0.06	0.81
1971	30	2	.79	.91	.16	.85
1972	508	12	1.58	3.54	.19	.41
1973	391	6	.85	2.55	.11	.31
1974	177	8	1.72	2.89	.29	.55
1975	--	--	--	--	--	--
1976	285	23	2.97	4.40	.63	.62
1977	34	8	1.74	2.68	1.02	.43
1979	132	11	2.20	3.24	.53	.62
1980	272	15	2.05	3.77	.41	.49
1981	2,754	32	3.08	4.95	.13	.61
1982	1,261	27	3.53	4.76	.21	.73
1983	2,081	37	3.33	5.16	.19	.63
1984	998	26	3.49	4.66	.25	.74
1985	546	26	2.22	4.54	.41	.44
1986	650	38	3.60	5.08	.53	.67
1987	1,471	34	3.57	5.03	.24	.70
1988	820	24	3.29	4.50	.27	.71



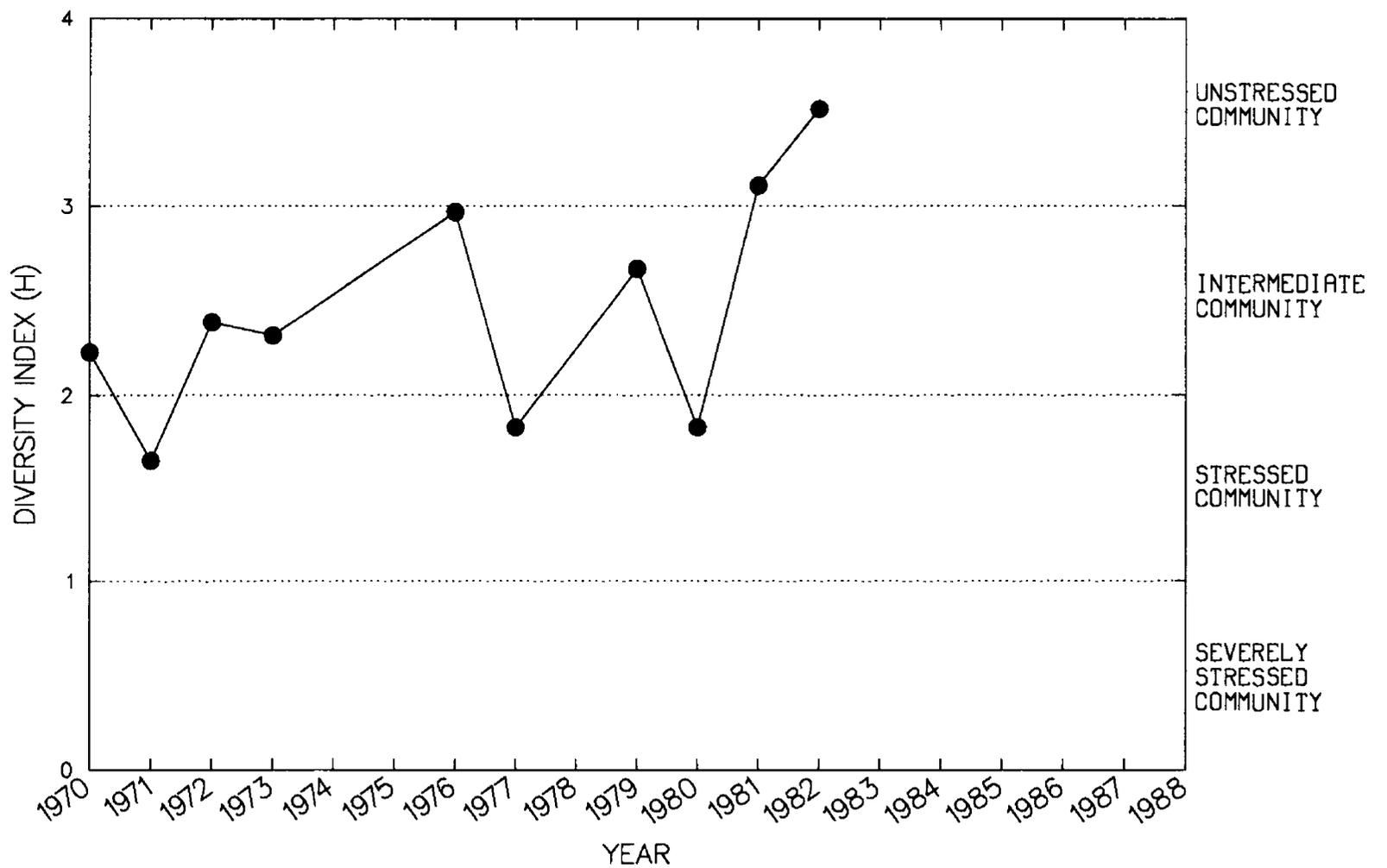
Site 7

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	93	6	1.50	2.55	0.35	0.52
1971	47	3	.80	1.63	.24	.41
1972	109	11	2.44	3.50	.62	.63
1973	13	2	.48	1.04	.28	.26
1974	146	19	3.59	4.18	.88	.82
1975	--	--	--	--	--	--
1976	495	21	3.17	4.36	.36	.70
1977	200	24	3.17	4.39	.87	.65
1979	124	14	2.05	3.31	.56	.54
1980	850	29	3.54	4.79	.32	.72
1981	1,512	32	3.52	4.95	.22	.70
1982	1,785	27	2.97	4.70	.16	.62



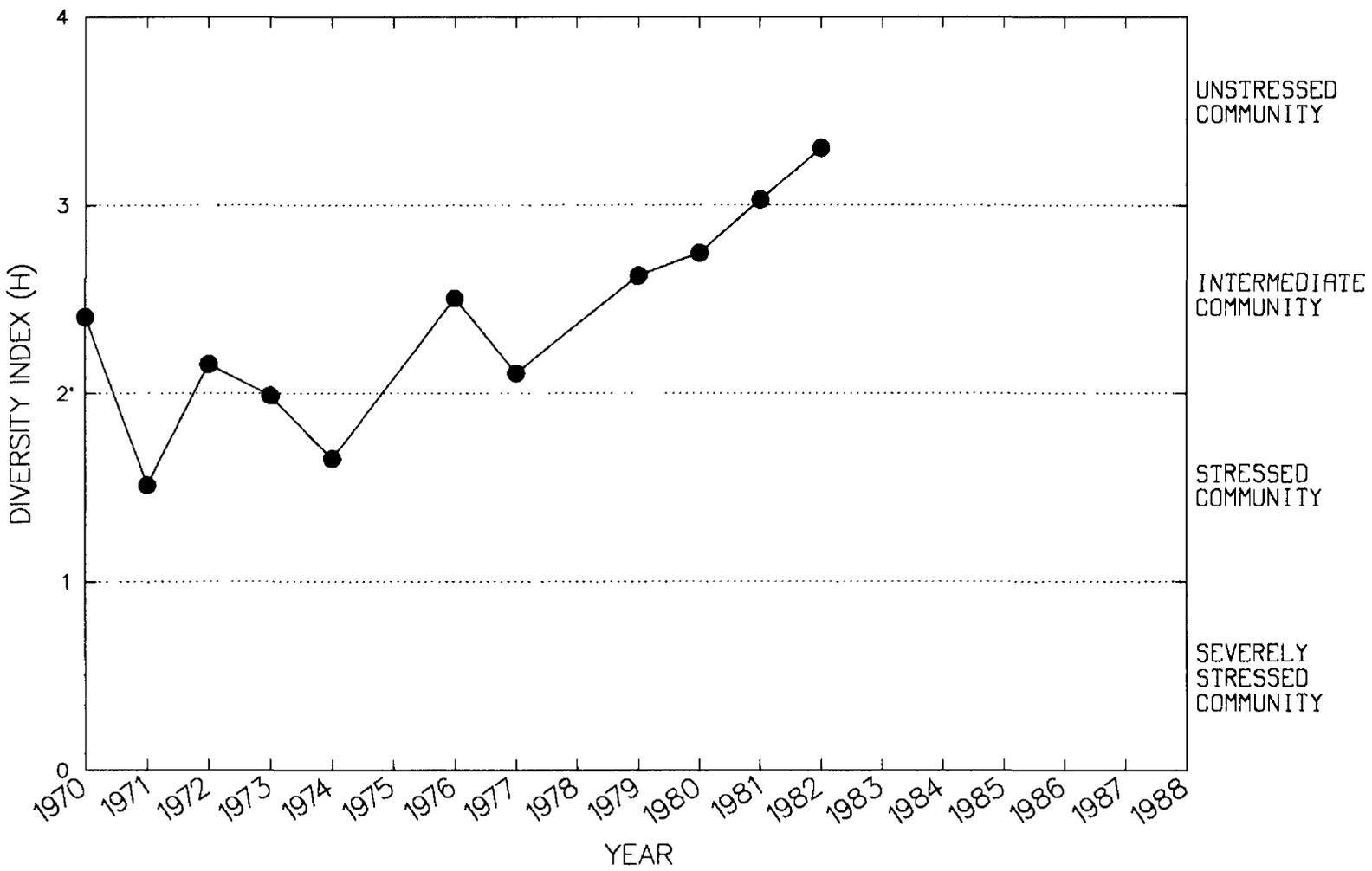
**Site 8**

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	94	6	2.23	2.59	0.35	0.84
1971	26	4	1.65	1.94	.54	.79
1972	288	15	2.39	3.79	.40	.59
1973	486	20	2.32	4.24	.35	.51
1974	--	--	--	--	--	--
1975	--	--	--	--	--	--
1976	554	21	2.97	4.33	.33	.66
1977	125	12	1.83	3.47	1.61	.43
1979	117	14	2.67	3.64	.75	.66
1980	440	9	1.83	3.20	.16	.55
1981	826	28	3.11	4.77	.32	.63
1982	979	31	3.52	4.92	.30	.70



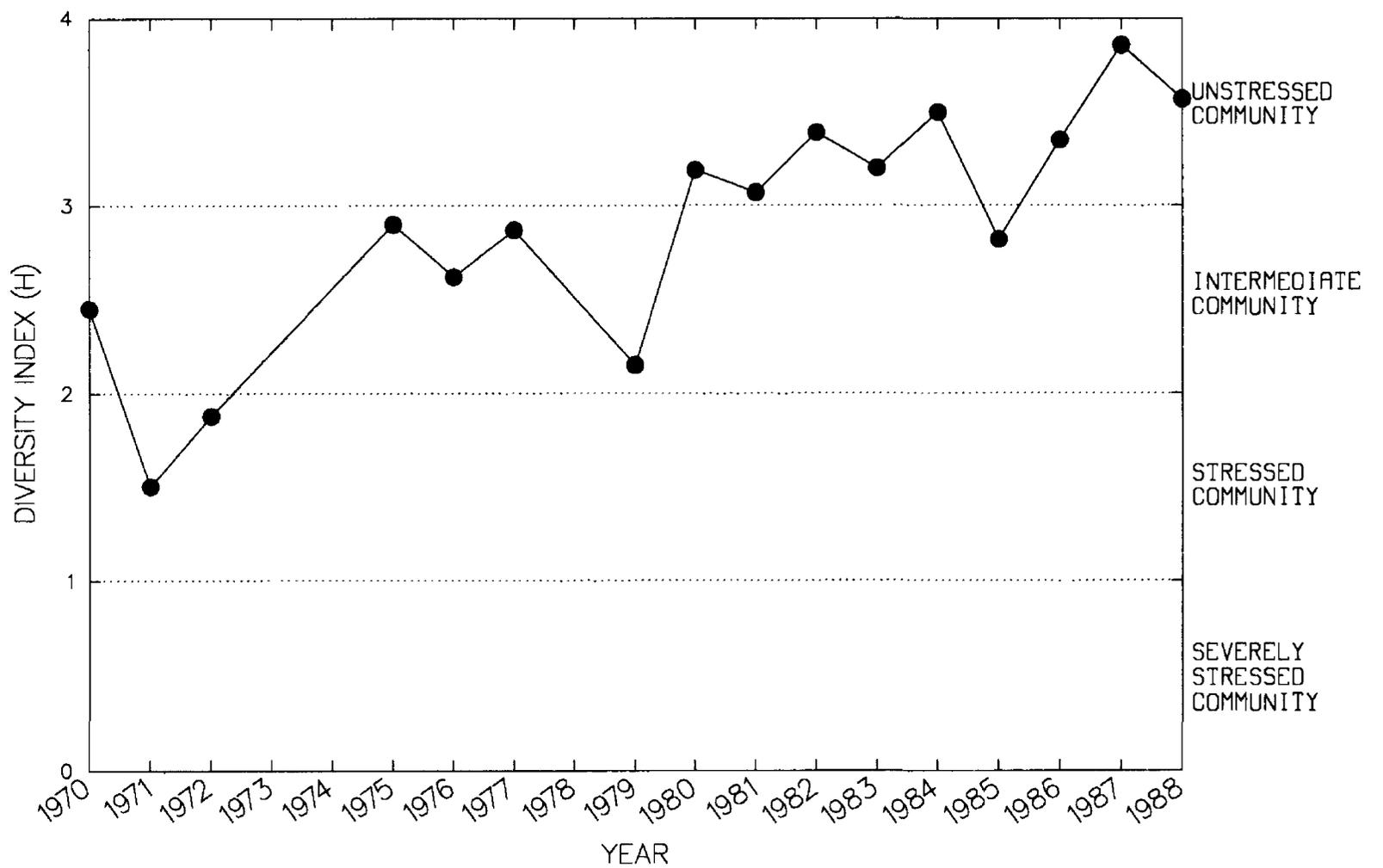
Site 9

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	132	7	2.41	2.85	0.32	0.83
1971	37	4	1.51	1.88	.42	.75
1972	125	9	2.16	3.22	.44	.62
1973	361	15	1.99	3.78	.33	.48
1974	131	11	1.65	3.51	.53	.38
1975	--	--	--	--	--	--
1976	579	21	2.51	4.37	.32	.54
1977	42	7	2.11	2.46	.76	.79
1979	290	21	2.63	4.40	.56	.54
1980	254	11	2.75	3.34	.31	.80
1981	482	23	3.03	4.57	.41	.63
1982	914	24	3.30	4.50	.25	.72



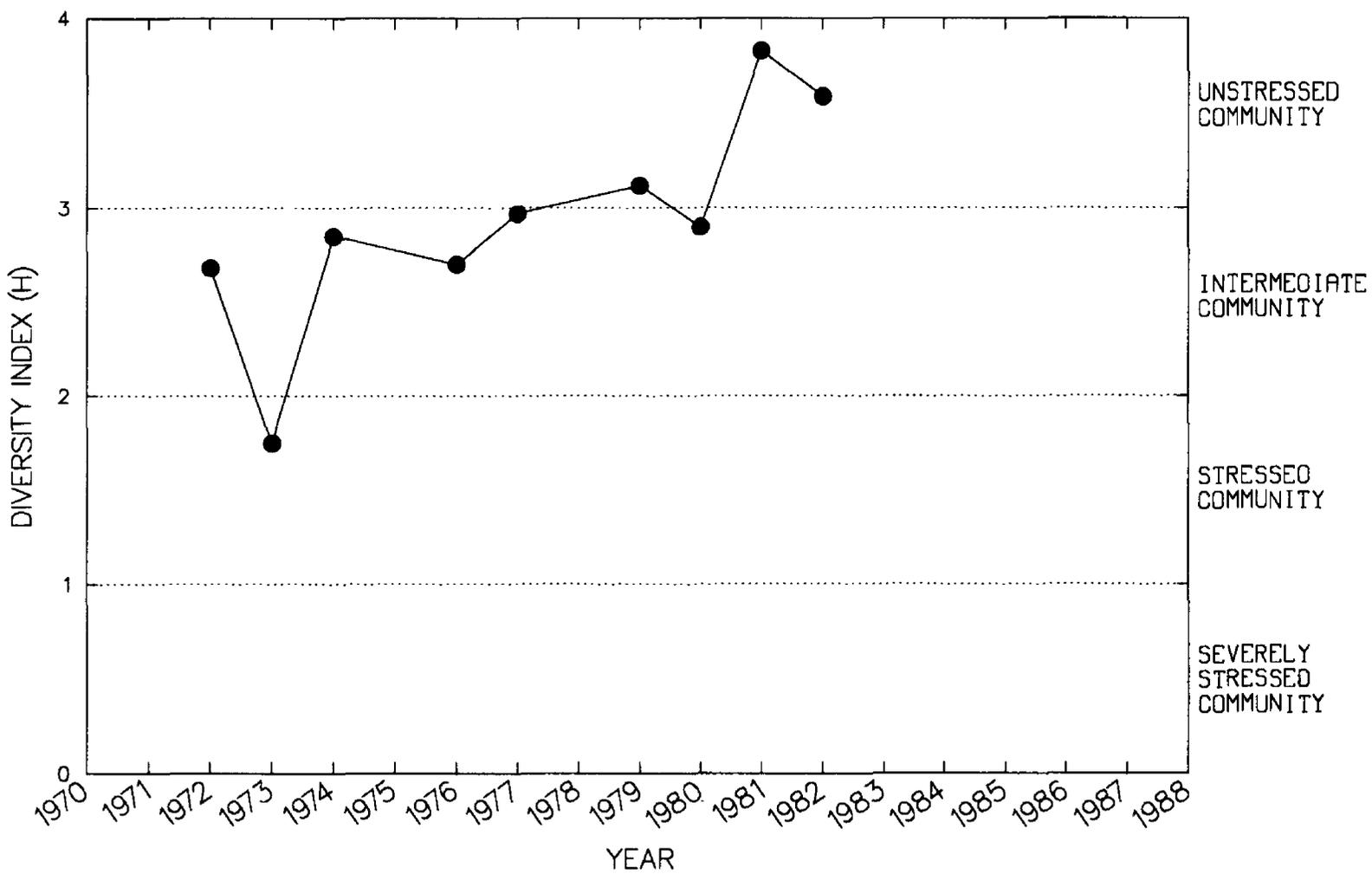
**Site 10**

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	104	8	2.45	2.80	0.45	0.85
1971	24	4	1.50	1.71	.57	.81
1972	548	15	1.88	3.89	.23	.45
1973	--	--	--	--	--	--
1974	--	--	--	--	--	--
1975	767	19	2.90	4.21	.22	.67
1976	880	26	2.62	4.72	.28	.53
1977	344	27	2.87	4.74	.63	.55
1979	32	10	2.15	2.87	1.35	.53
1980	620	19	3.19	4.24	.27	.74
1981	2,787	33	3.07	5.03	.13	.60
1982	1,686	30	3.39	4.86	.18	.69
1983	972	24	3.20	4.56	.23	.69
1984	1,492	29	3.50	4.83	.20	.71
1985	1,031	21	2.82	4.33	.19	.63
1986	1,121	24	3.35	4.59	.21	.72
1987	2,097	39	3.86	5.29	.20	.72
1988	2,400	31	3.57	4.93	.14	.71



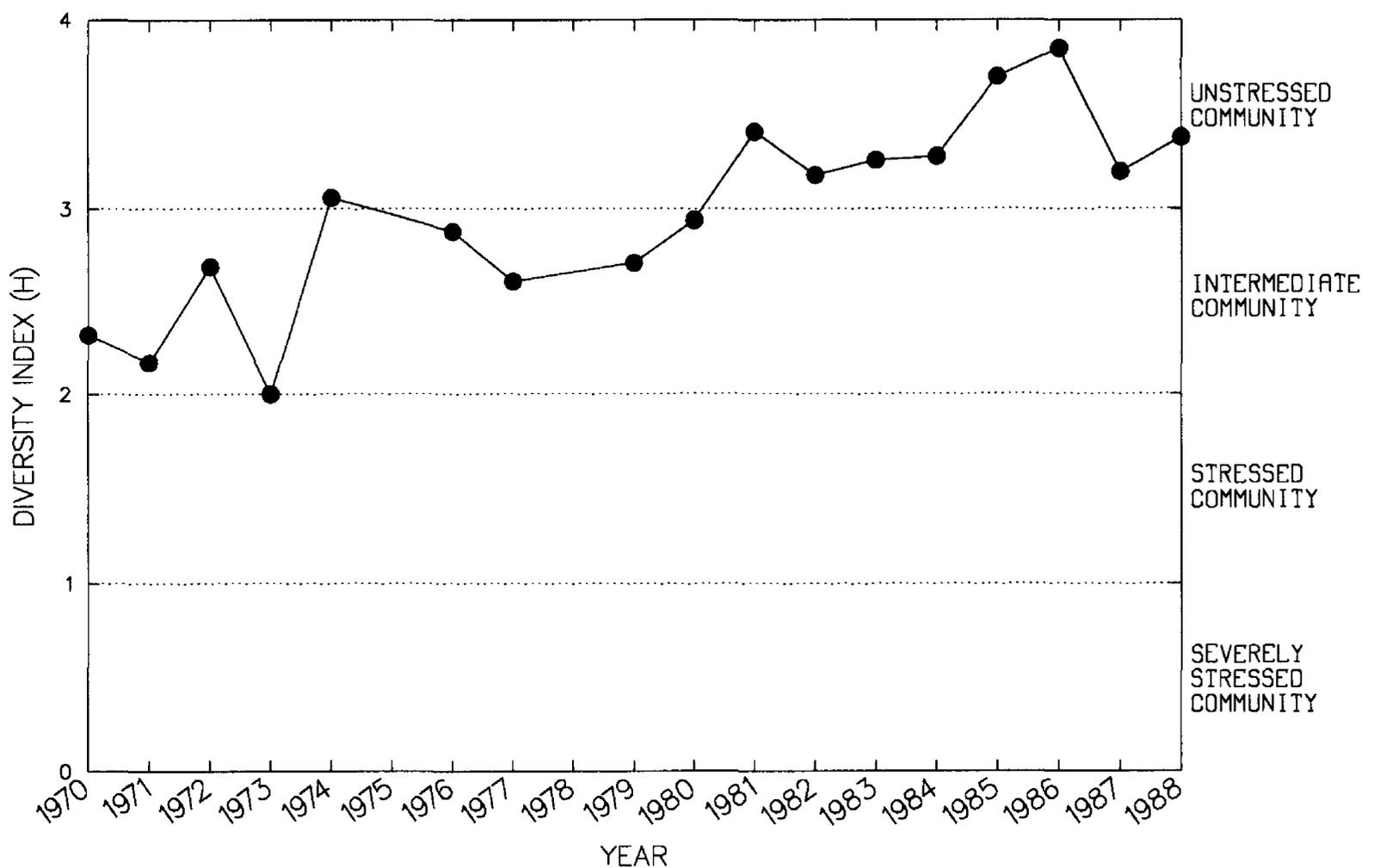
Site 11

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	--	--	--	--	--	--
1971	--	--	--	--	--	--
1972	64	11	2.68	3.44	0.92	0.70
1973	343	16	1.75	3.94	.37	.39
1974	166	18	2.85	3.96	.75	.65
1975	--	--	--	--	--	--
1976	136	15	2.70	3.64	.72	.68
1977	491	27	2.97	4.62	.47	.60
1979	151	18	3.12	4.00	.81	.72
1980	1,088	21	2.90	4.41	.19	.64
1981	1,076	36	3.83	5.20	.33	.72
1982	2,169	40	3.59	5.27	.20	.67



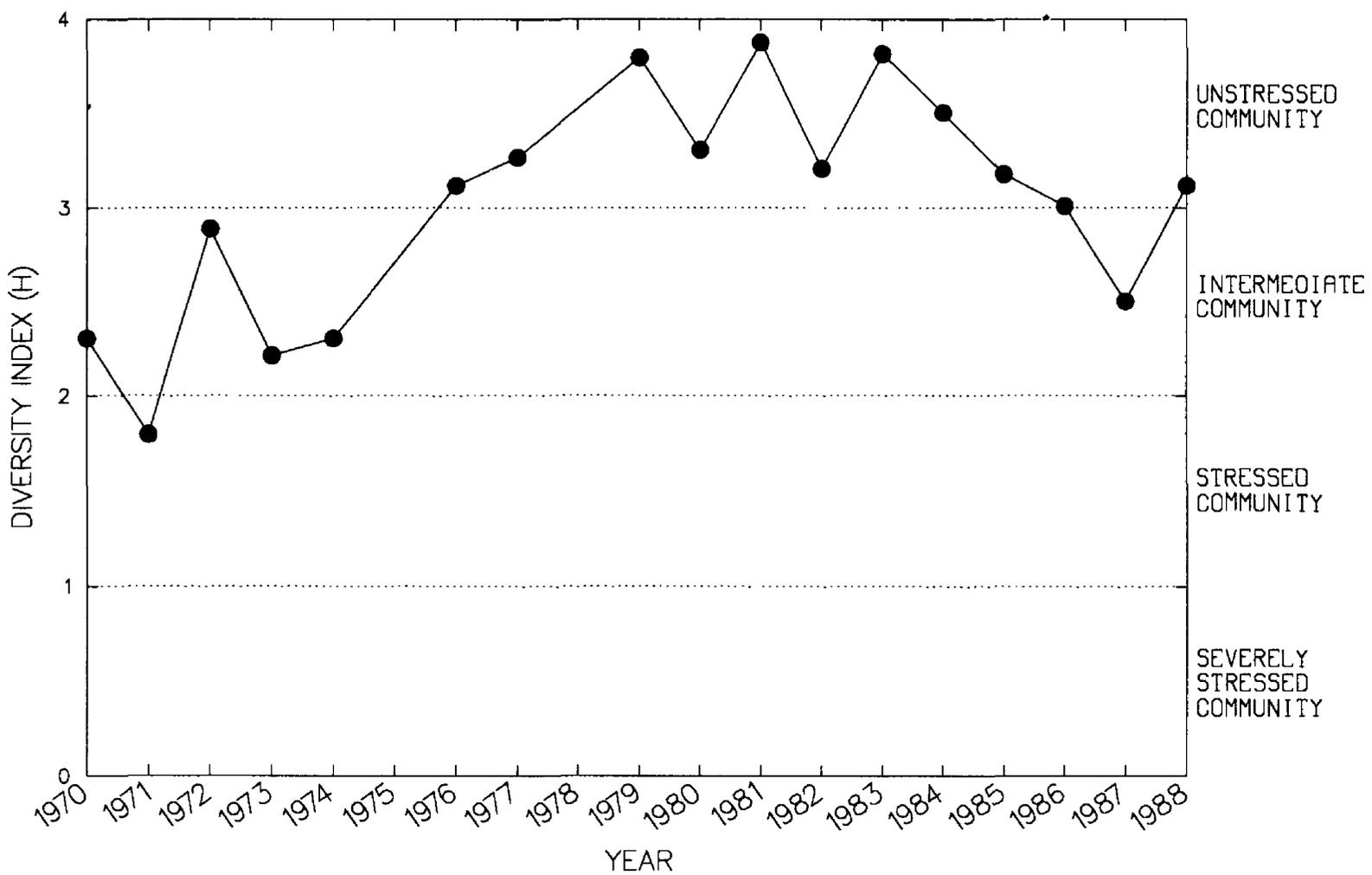
**Site 12**

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	118	7	2.32	2.86	0.35	0.79
1971	36	7	2.17	2.49	.84	.81
1972	1,053	19	2.69	4.22	.17	.62
1973	288	20	2.00	4.22	.54	.40
1974	271	20	3.06	4.26	.56	.68
1975	--	--	--	--	--	--
1976	972	28	2.88	4.81	.28	.57
1977	942	22	2.61	4.48	.22	.56
1979	137	16	2.71	3.90	.77	.62
1980	1,499	27	2.94	4.74	.18	.61
1981	1,186	32	3.41	4.91	.27	.68
1982	2,680	33	3.18	5.01	.14	.63
1983	1,683	31	3.26	4.91	.19	.65
1984	1,560	26	3.28	4.63	.17	.70
1985	771	32	3.70	4.88	.38	.74
1986	1,303	39	3.85	5.24	.30	.72
1987	2,017	40	3.20	5.29	.21	.59
1988	2,168	27	3.38	4.73	.13	.71



Site 13

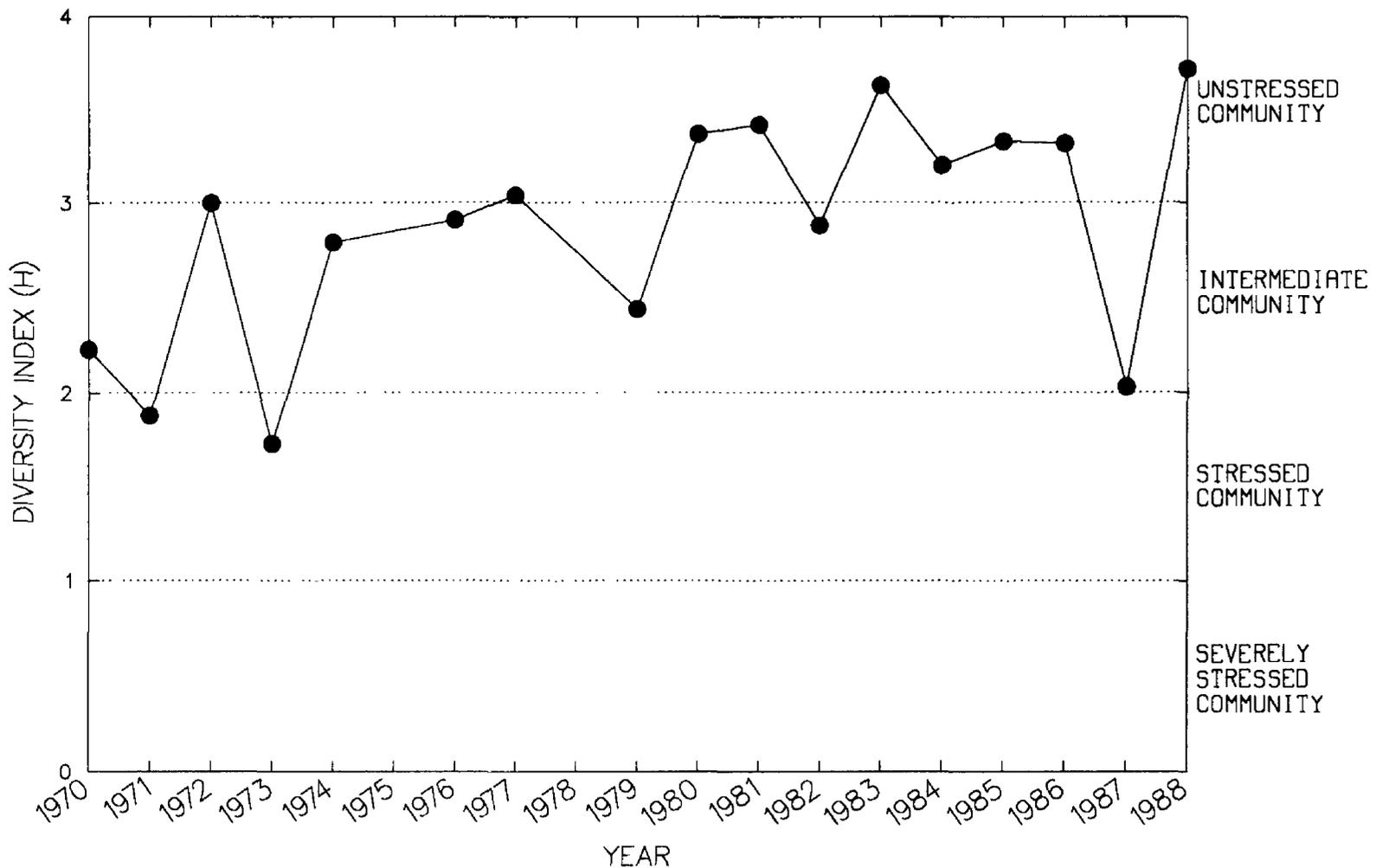
Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	58	8	2.30	2.79	0.70	0.77
1971	23	5	1.80	2.24	.77	.70
1972	272	23	2.89	4.53	.65	.58
1973	101	14	2.21	3.56	.85	.50
1974	31	8	2.30	2.97	1.08	.64
1975	--	--	--	--	--	--
1976	160	18	3.12	4.19	.77	.69
1977	380	22	3.27	4.34	.47	.72
1979	163	29	3.80	4.71	1.24	.74
1980	694	21	3.31	4.29	.27	.76
1981	1,541	43	3.88	5.44	.29	.70
1982	2,429	35	3.21	5.10	.16	.62
1983	1,607	38	3.82	5.119	.24	.72
1984	1,291	27	3.51	4.77	.21	.72
1985	539	36	3.18	5.21	.59	.56
1986	1,396	31	3.01	4.87	.22	.60
1987	1,338	31	2.50	4.89	.23	.49
1988	1,846	31	3.12	4.94	.18	.62



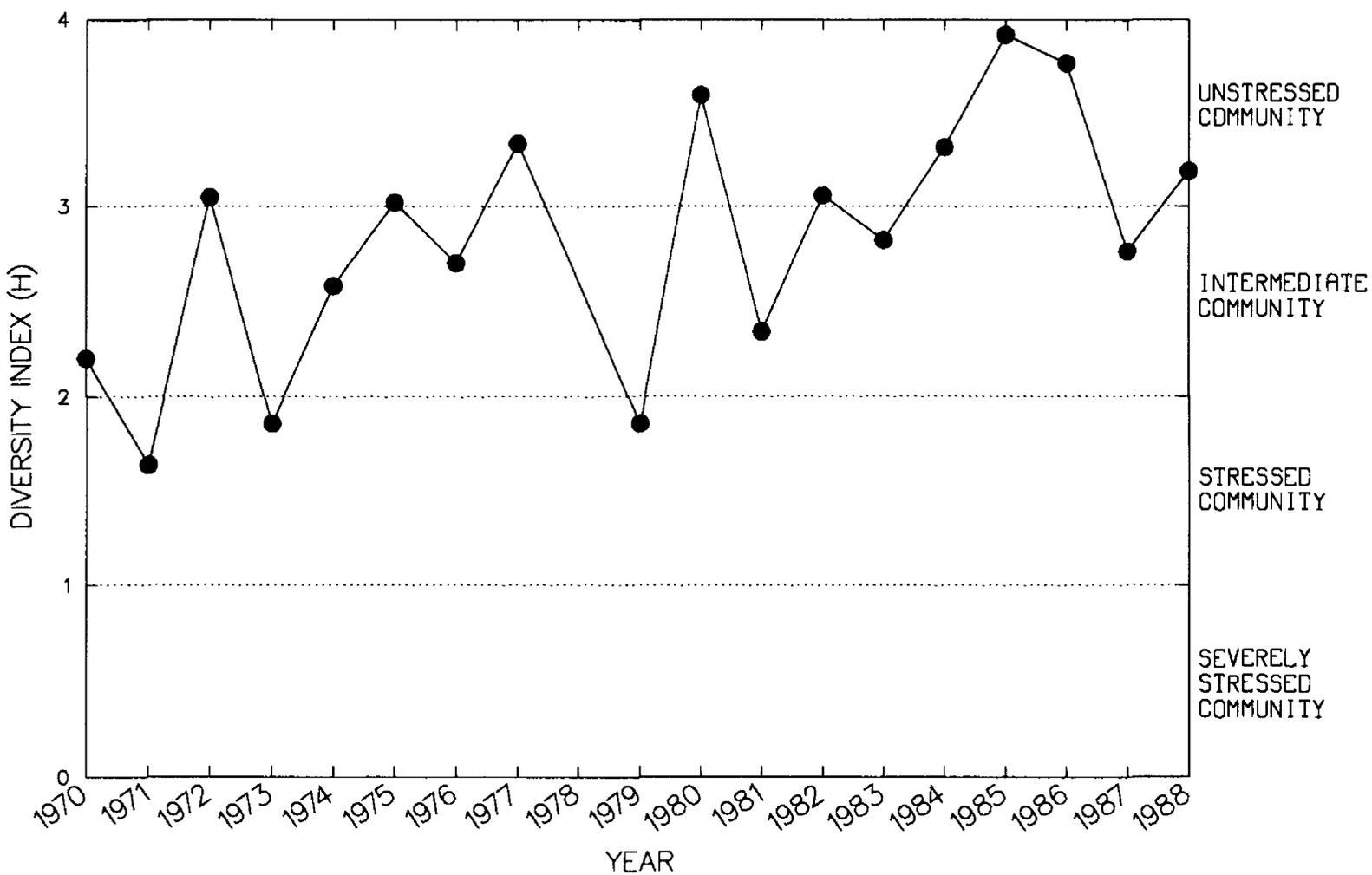
**Site 14**

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	58	8	2.23	2.79	0.70	0.73
1971	34	6	1.88	2.54	.74	.63
1972	643	27	3.00	4.77	.38	.60
1973	225	15	1.73	3.71	.48	.39
1974	189	16	2.79	4.01	.60	.64
1975	--	--	--	--	--	--
1976	362	27	2.91	4.65	.61	.57
1977	747	27	3.04	4.74	.33	.61
1979	96	16	2.44	3.61	1.01	.55
1980	615	26	3.37	4.68	.38	.70
1981	1,763	35	3.42	5.09	.21	.66
1982	1,543	29	2.88	4.81	.19	.58
1983	1,427	40	3.63	5.31	.29	.66
1984	1,719	31	3.20	4.93	.19	.64
1985	421	24	3.33	4.53	.47	.70
1986	1,419	32	3.32	4.96	.23	.65
1987	1,328	31	2.03	4.97	.23	.38
1988 <sup>1</sup>	2,589	33	3.72	5.03	.14	.73

<sup>1</sup> Sampled upstream riffle because of bridge construction.

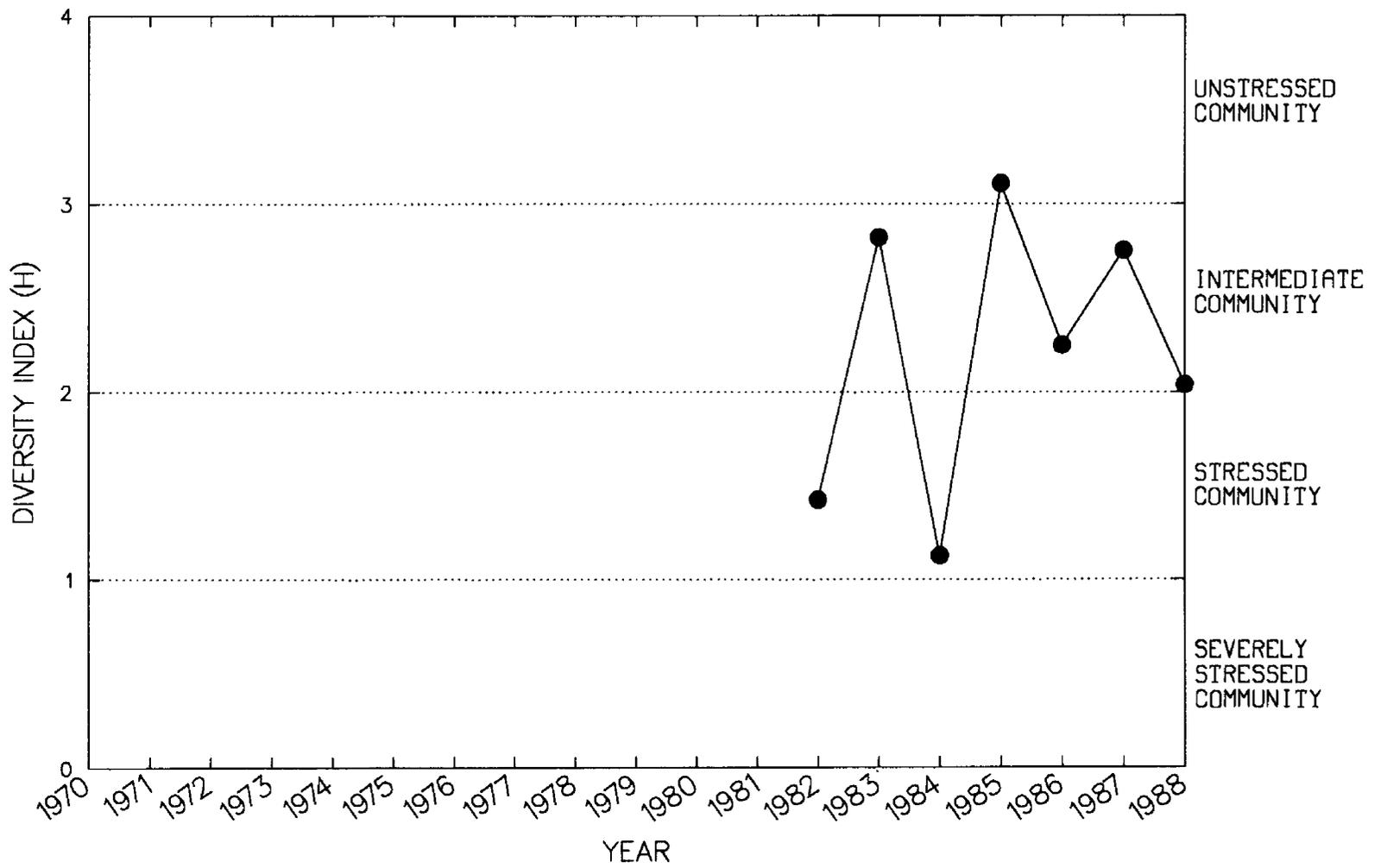


Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	56	7	2.20	2.53	0.62	0.83
1971	24	6	1.64	2.15	.93	.58
1972	324	19	3.05	4.08	.46	.72
1973	96	11	1.86	3.44	.68	.43
1974	85	14	2.58	3.46	.96	.65
1975	232	21	3.02	4.15	.67	.67
1976	277	22	2.70	4.40	.61	.55
1977	645	31	3.34	4.96	.43	.64
1979	174	10	1.86	3.25	.38	.51
1980	629	27	3.60	4.67	.38	.75
1981	3,444	32	2.34	5.00	.11	.46
1982	546	22	3.06	4.48	.35	.66
1983	1,138	28	2.82	4.80	.24	.57
1984	820	29	3.32	4.78	.33	.67
1985	226	30	3.92	4.77	.99	.77
1986	719	36	3.77	5.21	.46	.70
1987	602	35	2.76	4.99	.52	.50
1988	2,493	41	3.19	5.37	.18	.58



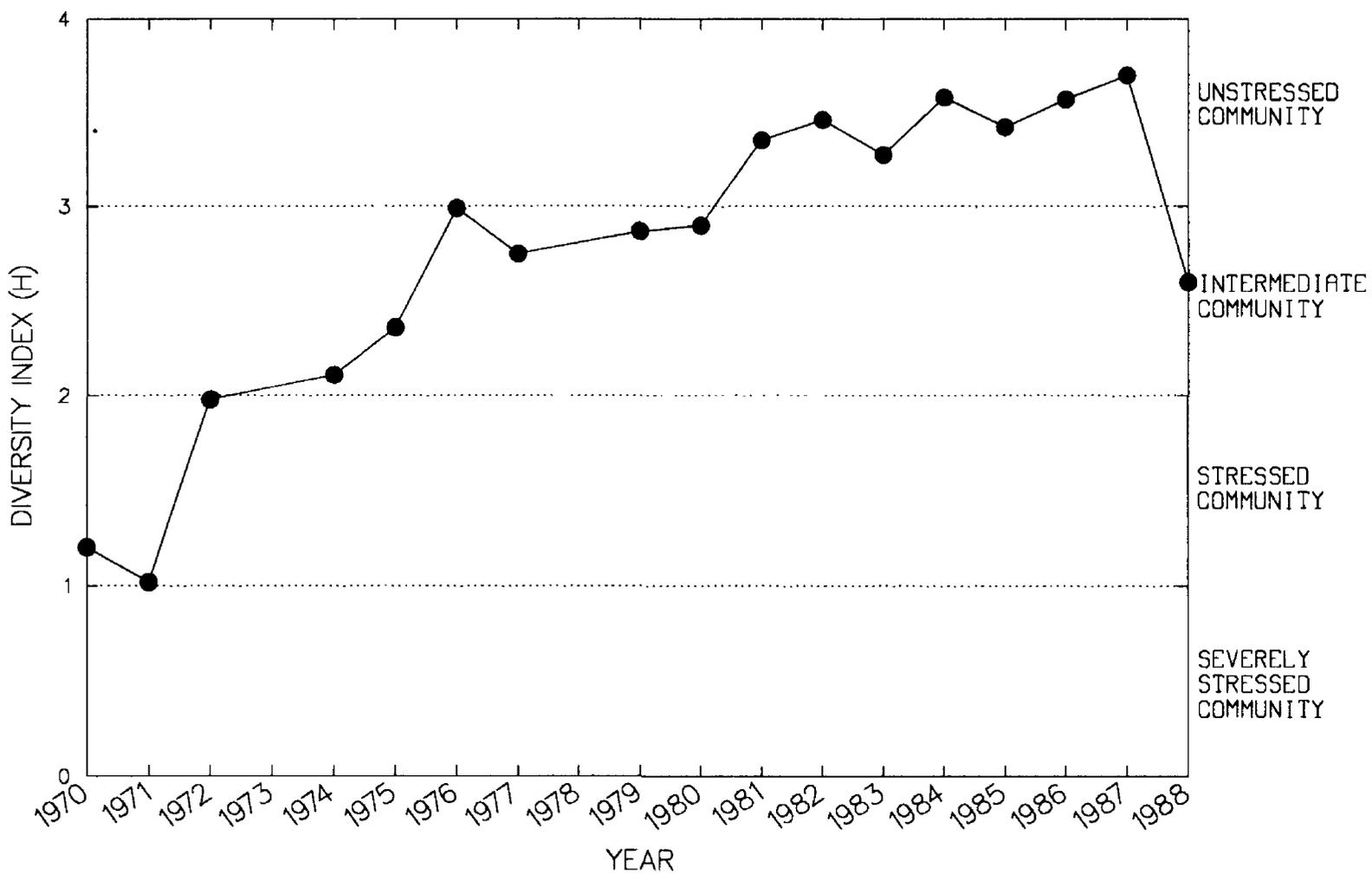
**Site 16**

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1981	243	8	0.53	2.96	0.23	0.11
1982	620	20	1.43	4.21	.28	.29
1983	342	24	2.82	4.44	.56	.58
1984	2,246	18	1.13	4.18	.08	.26
1985	72	21	3.11	4.03	1.66	.61
1986	599	21	2.25	4.36	.31	.48
1987	490	25	2.75	4.61	.44	.55
1988	1,337	20	2.04	4.34	.15	.45



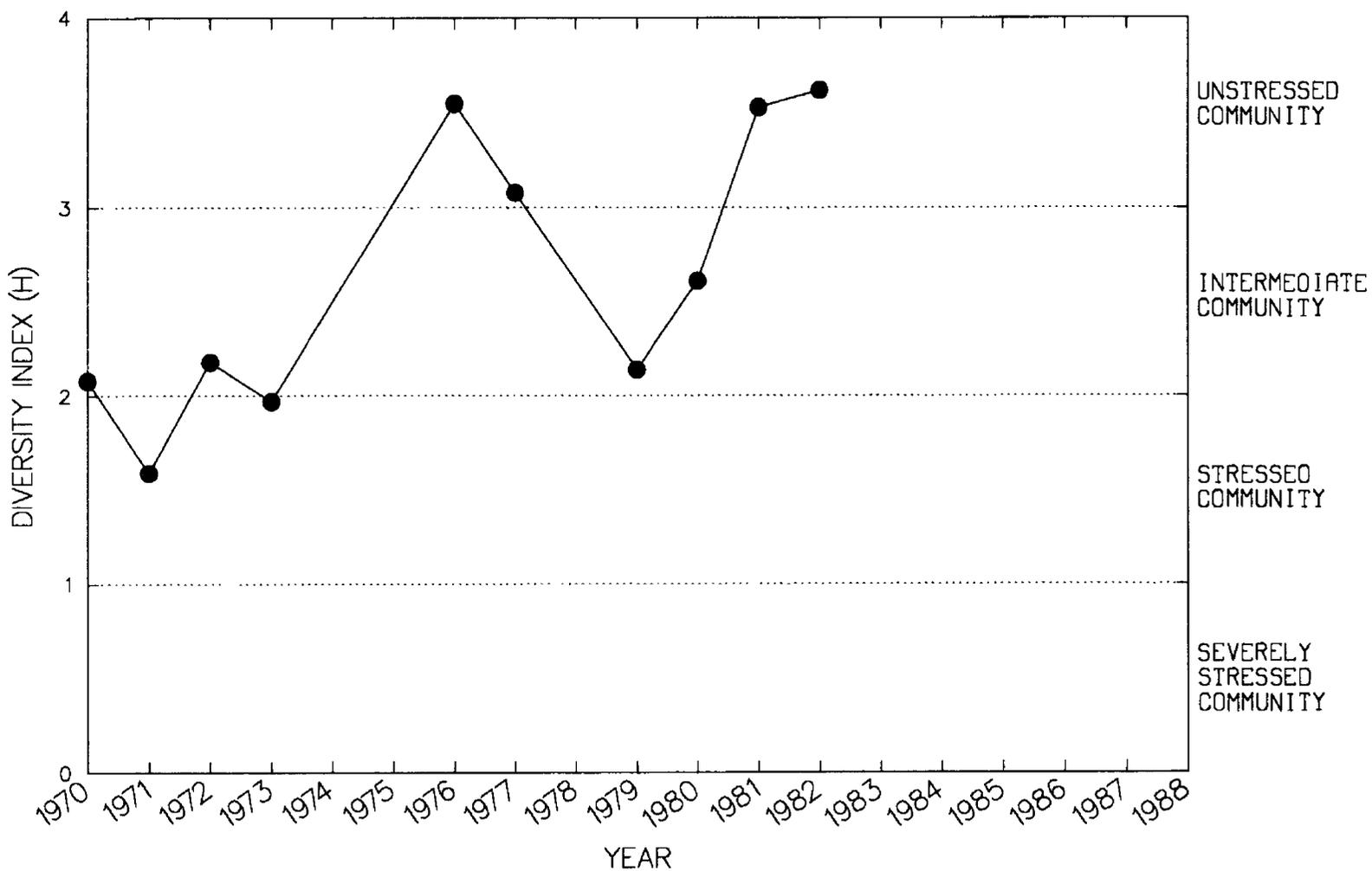
Site 17

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	46	3	1.20	1.54	0.24	0.74
1971	8	3	1.02	1.54	.73	.36
1972	155	10	1.98	3.27	.42	.55
1973	--	--	--	--	--	--
1974	239	11	2.11	3.47	.33	.57
1975	690	15	2.36	3.83	.19	.60
1976	473	21	2.99	4.35	.37	.66
1977	555	18	2.75	4.19	.28	.63
1979	362	18	2.87	4.04	.40	.68
1980	468	15	2.90	3.83	.26	.74
1981	528	23	3.35	4.57	.38	.71
1982	215	20	3.44	4.30	.68	.76
1983	404	28	3.26	4.71	.58	.65
1984	1,188	28	3.58	4.77	.23	.74
1985	965	26	3.42	4.62	.26	.73
1986	709	26	3.57	4.62	.33	.76
1987	1,114	27	3.70	4.70	.24	.78
1988	2,032	24	2.60	4.59	.12	.56



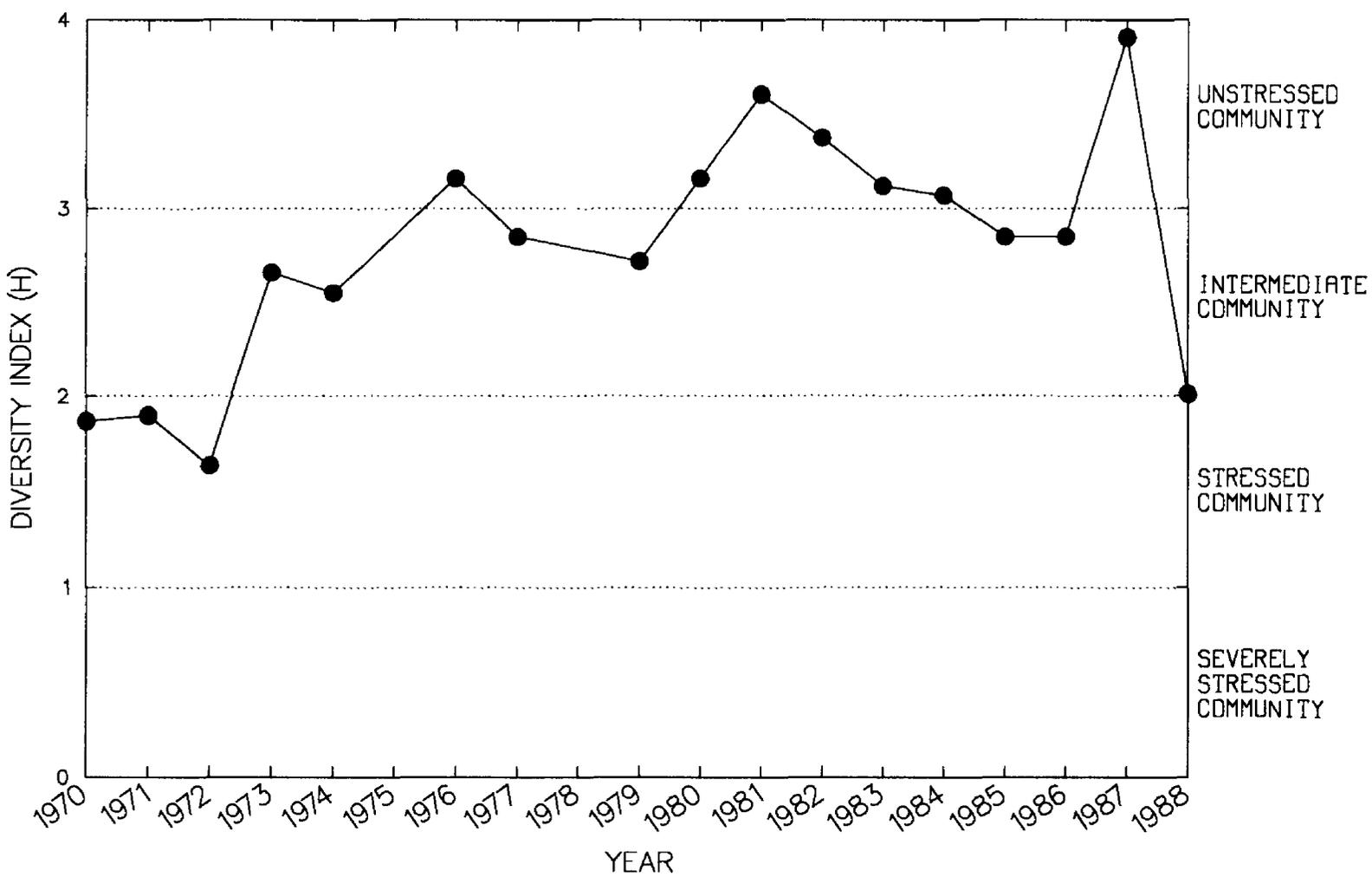
**Site 18**

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	125	8	2.08	2.99	0.39	0.65
1971	28	4	1.59	1.74	.51	.87
1972	129	11	2.18	3.45	.54	.56
1973	132	12	1.97	3.34	.58	.50
1974	--	--	--	--	--	--
1975	--	--	--	--	--	.78
1976	212	23	3.55	4.31	.79	.59
1977	221	25	3.08	4.64	.84	.49
1979	22	9	2.14	2.77	1.53	.59
1980	46	13	2.61	3.44	1.39	
1981	1,134	29	3.53	4.78	.25	.73
1982	578	27	3.62	4.68	.41	.75



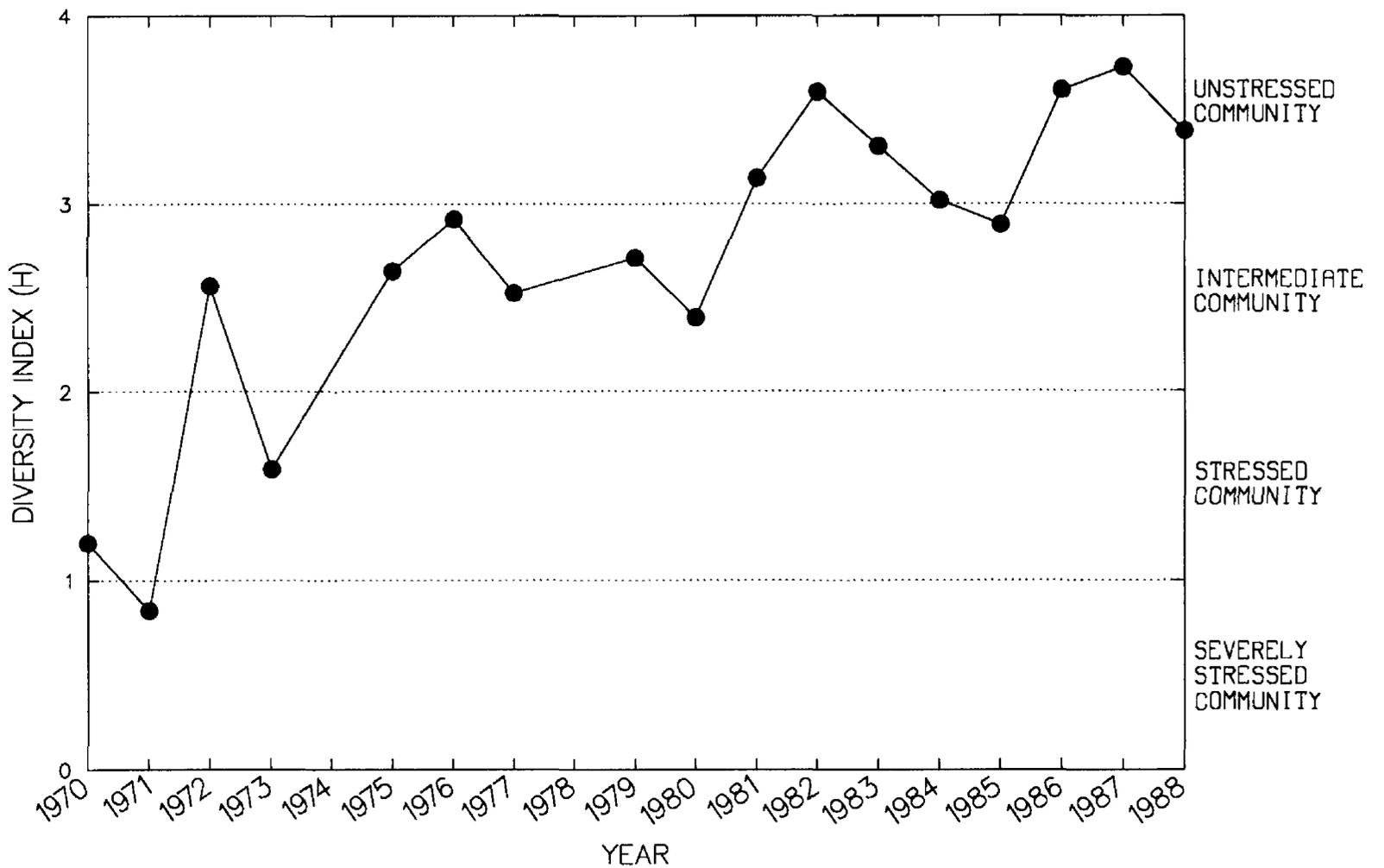
Site 19

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	88	9	1.87	3.18	0.58	0.50
1971	45	6	1.90	2.50	.60	.68
1972	219	8	1.64	2.95	.25	.51
1973	120	17	2.66	3.76	.91	.61
1974	67	14	2.55	3.73	1.15	.54
1975	--	--	--	--	--	--
1976	363	25	3.16	4.57	.56	.65
1977	835	27	2.85	4.79	.30	.57
1979	131	12	2.72	3.63	.59	.70
1980	417	16	3.16	3.88	.31	.80
1981	994	38	3.61	5.14	.37	.68
1982	1,628	35	3.38	5.11	.22	.65
1983	526	30	3.12	4.85	.50	.60
1984	1,220	26	3.07	4.73	.21	.63
1985	571	28	2.85	4.73	.43	.56
1986	912	28	2.85	4.78	.29	.57
1987	1,286	33	3.91	5.08	.26	.76
1988	1,987	24	2.01	4.59	.13	.42



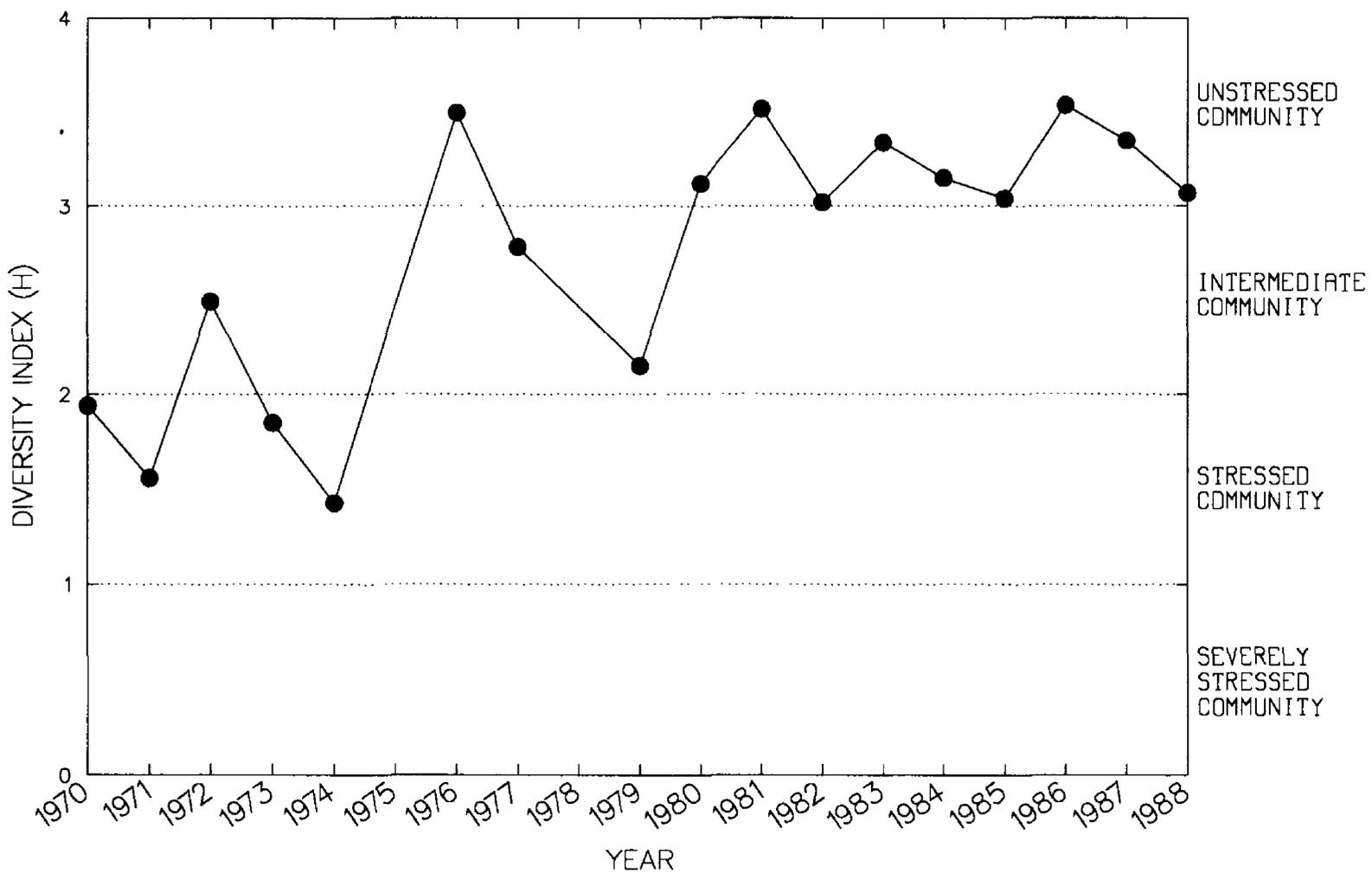
Site 20

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	116	5	1.20	2.25	0.24	0.48
1971	15	2	.84	1.04	.26	.74
1972	158	14	2.56	3.66	.60	.64
1973	246	13	1.59	3.75	.39	.36
1974	--	--	--	--	--	--
1975	788	20	2.64	4.28	.23	.59
1976	420	17	2.92	4.09	.33	.69
1977	349	15	2.52	3.82	.34	.63
1979	84	14	2.71	3.42	.97	.71
1980	202	18	2.39	3.99	.64	.52
1981	241	27	3.14	4.78	.85	.58
1982	1,342	29	3.60	4.81	.22	.74
1983	850	22	3.31	4.45	.24	.73
1984	1,700	21	3.02	4.42	.13	.67
1985	719	19	2.89	4.27	.24	.66
1986	977	26	3.61	4.68	.25	.76
1987	1,878	30	3.73	4.90	.17	.75
1988	1,643	26	3.39	4.65	.16	.72



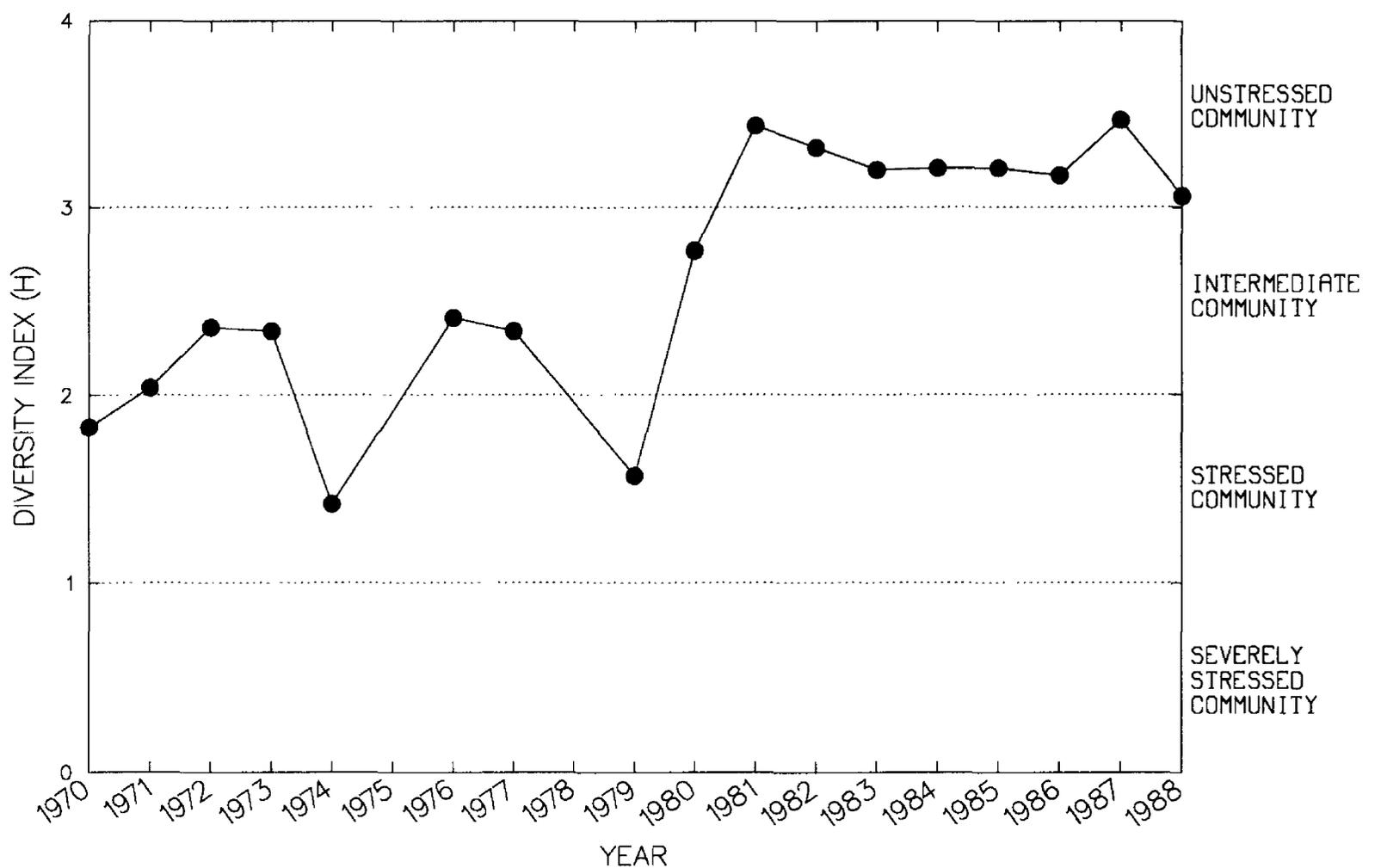
Site 21

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	172	9	1.94	3.04	0.34	0.59
1971	32	5	1.56	2.19	.62	.60
1972	189	12	2.49	3.59	.44	.65
1973	63	8	1.85	3.04	.66	.50
1974	165	8	1.43	2.99	.31	.42
1975	--	--	--	--	--	--
1976	470	25	3.50	4.65	.45	.72
1977	105	17	2.78	3.78	1.01	.64
1979	236	15	2.15	3.90	.47	.49
1980	1,144	21	3.12	4.37	.18	.70
1981	1,402	33	3.52	5.02	.24	.69
1982	1,585	27	3.02	4.76	.17	.62
1983	1,692	32	3.34	5.02	.20	.65
1984	3,854	26	3.15	4.68	.08	.67
1985	1,616	27	3.04	4.77	.17	.62
1986	1,632	30	3.54	4.88	.19	.71
1987	1,196	27	3.35	4.71	.22	.70
1988	2,449	25	3.07	4.66	.11	.65

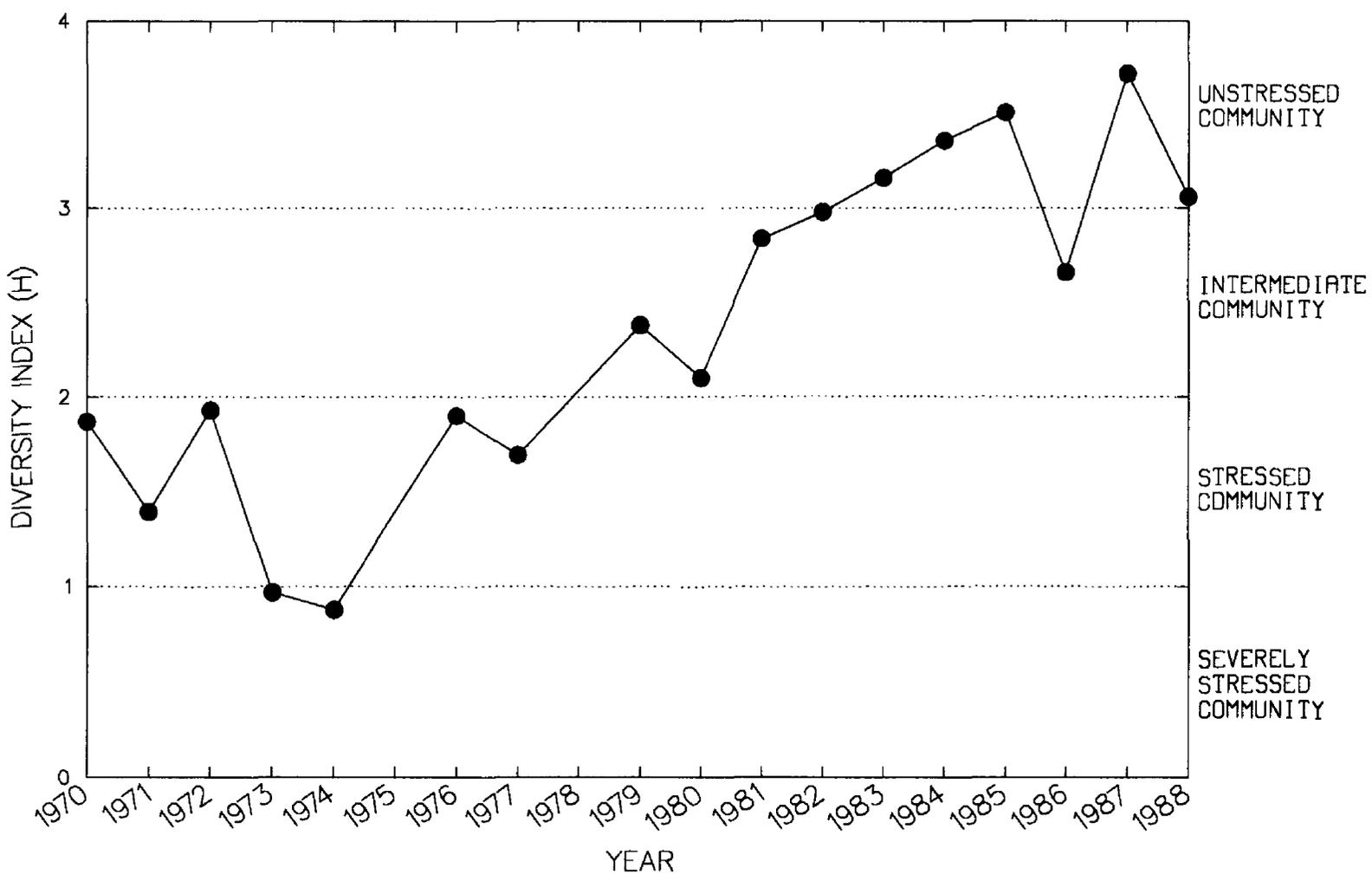


Site 22

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	59	5	1.83	2.37	0.40	0.73
1971	43	7	2.04	2.53	.74	.73
1972	520	17	2.36	4.07	.28	.55
1973	144	11	2.34	3.28	.49	.66
1974	13	4	1.42	1.71	.83	.67
1975	--	--	--	--	--	--
1976	703	21	2.41	4.36	.27	.52
1977	162	12	2.34	3.52	.50	.61
1979	179	10	1.57	3.37	.37	.40
1980	247	16	2.77	3.92	.48	.67
1981	323	25	3.44	4.68	.62	.70
1982	465	20	3.32	4.23	.36	.77
1983	319	22	3.20	4.39	.54	.69
1984	516	21	3.21	4.36	.35	.71
1985	247	13	3.21	3.54	.38	.89
1986	340	21	3.17	4.25	.49	.71
1987	1,307	33	3.47	5.03	.25	.57
1988	1,027	19	3.06	4.18	.18	.72

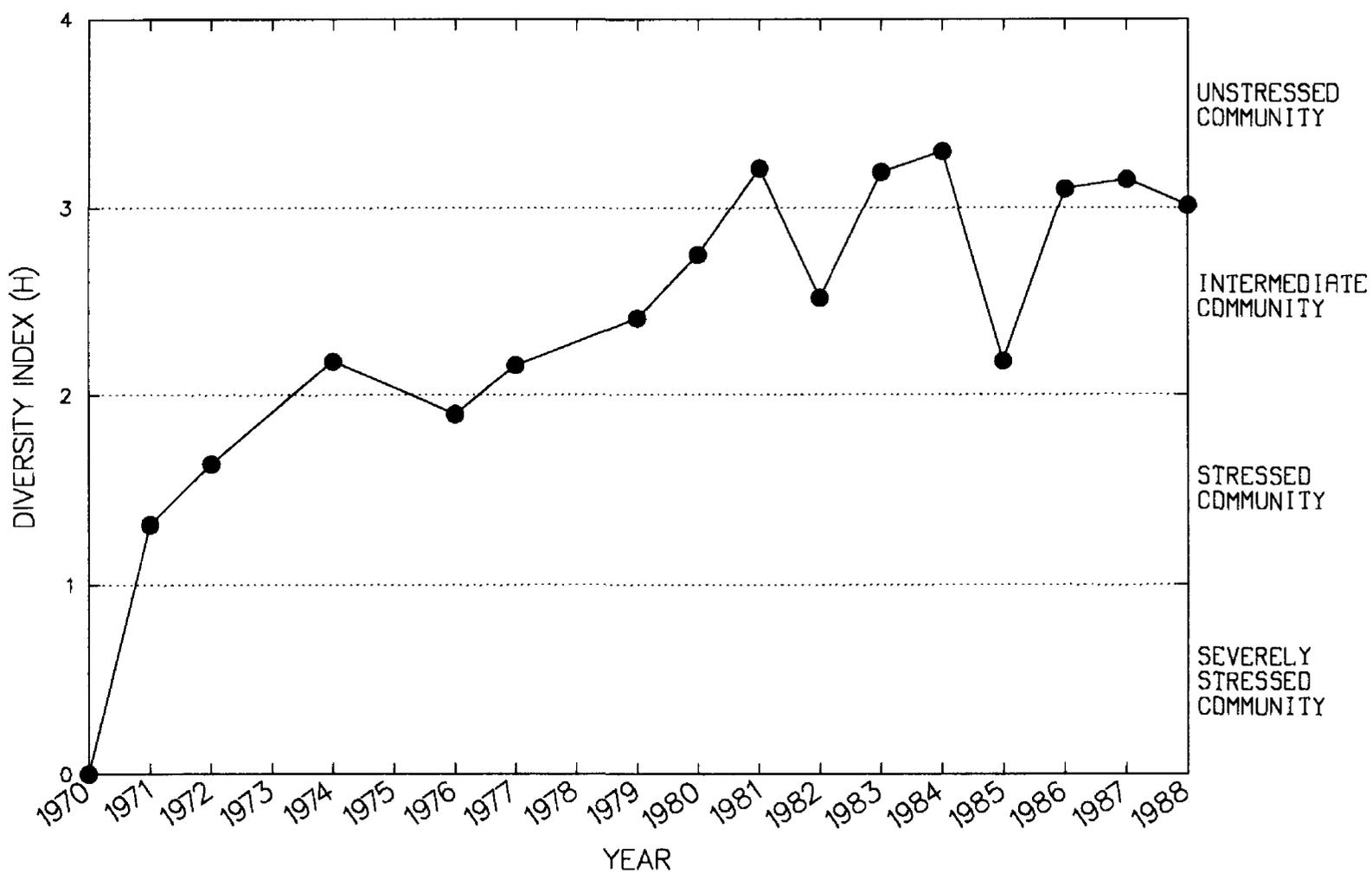


Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	83	4	1.87	2.04	0.23	0.90
1971	24	4	1.39	1.71	.57	.72
1972	299	10	1.93	3.36	.25	.54
1973	234	5	.97	2.35	.13	.38
1974	73	6	.88	2.44	.42	.23
1975	--	--	--	--	--	--
1976	244	19	1.90	4.26	.58	.36
1977	338	14	1.69	3.70	.32	.40
1979	490	19	2.38	4.26	.33	.52
1980	102	8	2.10	3.01	.45	.64
1981	1,373	28	2.84	4.73	.20	.58
1982	1,704	27	2.98	4.70	.16	.62
1983	1,249	31	3.16	4.90	.25	.63
1984	1,086	29	3.36	4.82	.26	.68
1985	1,000	25	3.61	4.55	.24	.76
1986	513	19	2.66	4.12	.32	.62
1987	2,241	31	3.72	4.92	.15	.75
1988	2,471	24	3.06	4.60	.10	.66

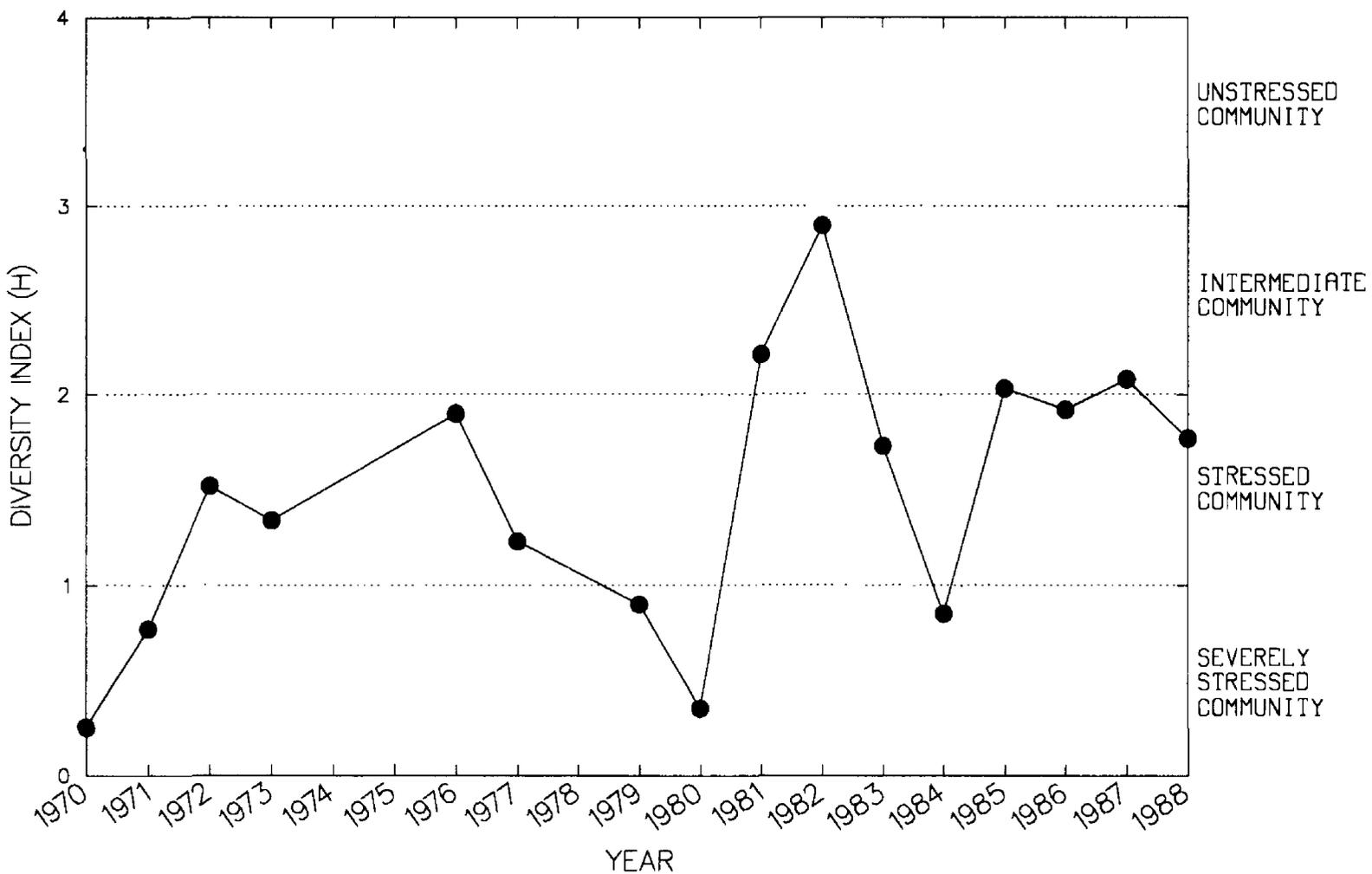


Site 24

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	55	1	0	0	0	0
1971	156	5	1.32	2.26	.19	.54
1972	901	11	1.64	3.48	.11	.45
1973	--	--	--	--	--	--
1974	1,333	13	2.18	3.69	.09	.58
1975	--	--	--	--	--	--
1976	860	18	1.90	4.18	.19	.43
1977	1,094	21	2.16	4.33	.18	.48
1979	49	10	2.41	3.32	1.01	.61
1980	2,721	19	2.75	4.23	.08	.64
1981	1,790	28	3.21	4.83	.16	.50
1982	3,571	22	2.52	4.45	.07	.56
1983	2,251	30	3.19	4.85	.14	.65
1984	2,431	30	3.30	4.86	.13	.67
1985	1,357	25	2.18	4.60	.18	.45
1986	1,024	19	3.10	4.27	.18	.71
1987	2,576	29	3.15	4.87	.12	.64
1988	1,667	22	3.01	4.47	.13	.66

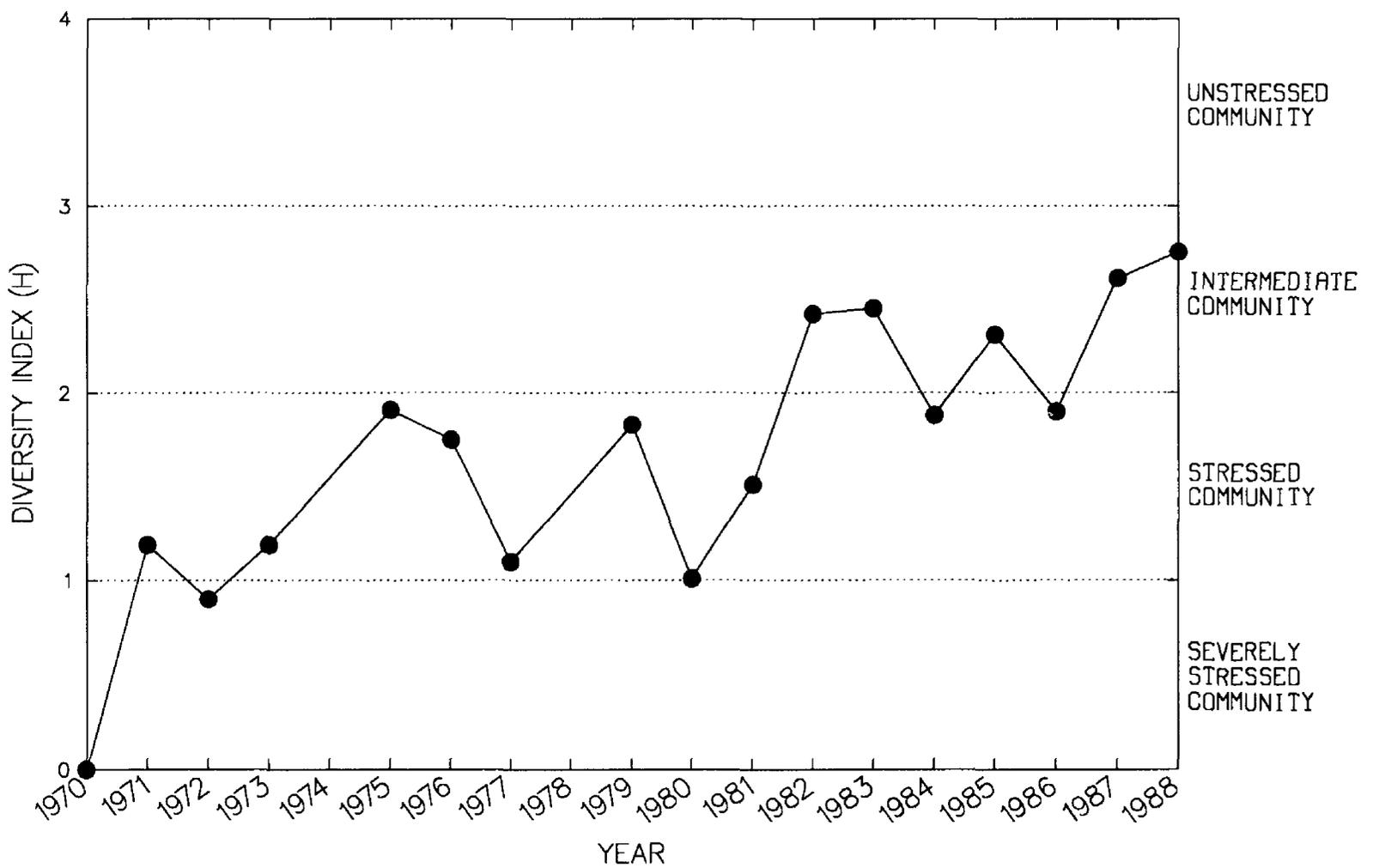


Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	61	2	0.25	1.03	0.10	0.16
1971	7	3	.77	1.33	.77	0
1972	181	5	1.52	2.27	.17	.64
1973	473	12	1.34	3.55	.21	.34
1974	--	--	--	--	--	--
1975	--	--	--	--	--	--
1976	826	12	1.90	3.60	.13	.51
1977	1,463	13	1.23	3.70	.09	.32
1979	239	4	.90	2.02	.10	.41
1980	468	4	.35	1.97	.06	.15
1981	1,047	14	2.21	3.82	.12	.56
1982	281	16	2.90	3.96	.43	.70
1983	578	17	1.73	3.98	.25	.39
1984	2,397	12	.85	3.59	.05	.23
1985	625	16	2.03	3.92	.22	.49
1986	34	10	1.92	3.00	1.30	.37
1987	575	17	2.08	4.11	.25	.47
1988	919	11	1.77	3.45	.11	.50

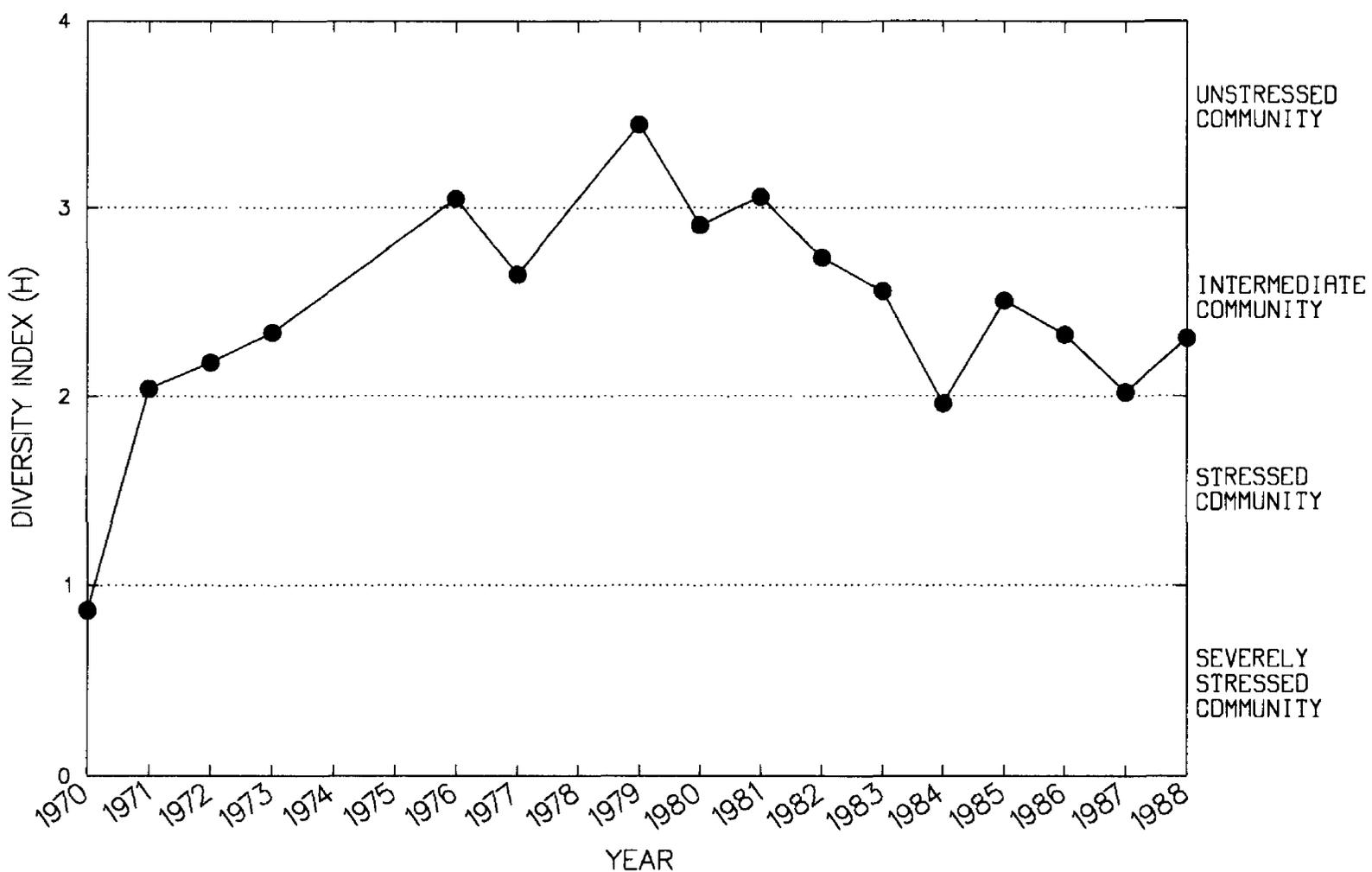


**Site 27**

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	182	1	0	0	0	0
1971	30	4	1.19	1.95	.49	.48
1972	177	5	.90	2.30	.17	.35
1973	108	6	1.19	2.44	.31	.41
1974	--	--	--	--	--	--
1975	60	9	1.91	3.11	.78	.48
1976	172	12	1.75	3.48	.47	.43
1977	70	5	1.10	2.15	.35	.41
1979	29	8	1.83	2.83	1.13	.41
1980	556	3	1.01	1.58	.03	.63
1981	210	11	1.51	3.32	.37	.39
1982	776	13	2.42	3.71	.15	.64
1983	84	11	2.45	3.39	.75	.64
1984	459	10	1.88	3.35	.17	.54
1985	327	18	2.31	4.04	.43	.52
1986	107	10	1.90	3.31	.56	.49
1987	267	15	2.61	3.92	.42	.63
1988	543	17	2.75	4.13	.27	.64

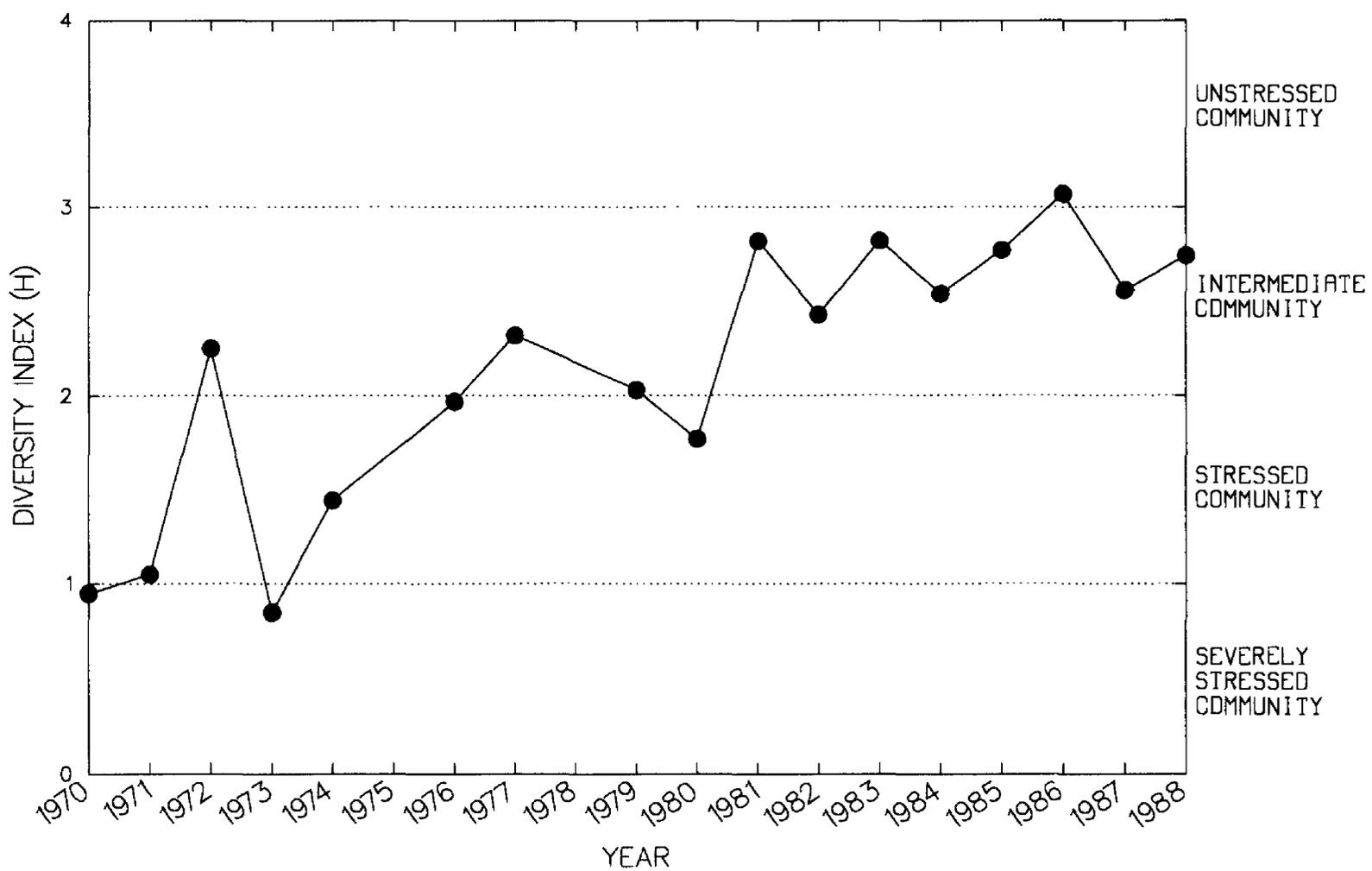


Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	76	4	0.87	1.88	0.25	0.38
1971	26	6	2.04	2.34	.88	.79
1972	202	10	2.18	3.22	.34	.64
1973	293	10	2.34	3.26	.25	.70
1974	--	--	--	--	--	--
1975	--	--	--	--	--	--
1976	820	18	3.05	4.16	.20	.72
1977	935	23	2.65	4.52	.23	.56
1979	855	27	3.45	4.75	.30	.71
1980	1,188	17	2.91	4.11	.14	.70
1981	836	18	3.06	4.14	.20	.73
1982	1,298	23	2.74	4.50	.18	.59
1983	1,358	18	2.56	4.15	.13	.60
1984	928	16	1.96	3.93	.16	.48
1985	1,007	21	2.51	4.42	.20	.55
1986	1,026	19	2.33	4.18	.18	.54
1987	4,216	19	2.02	4.26	.05	.47
1988	2,599	19	2.31	4.26	.08	.53

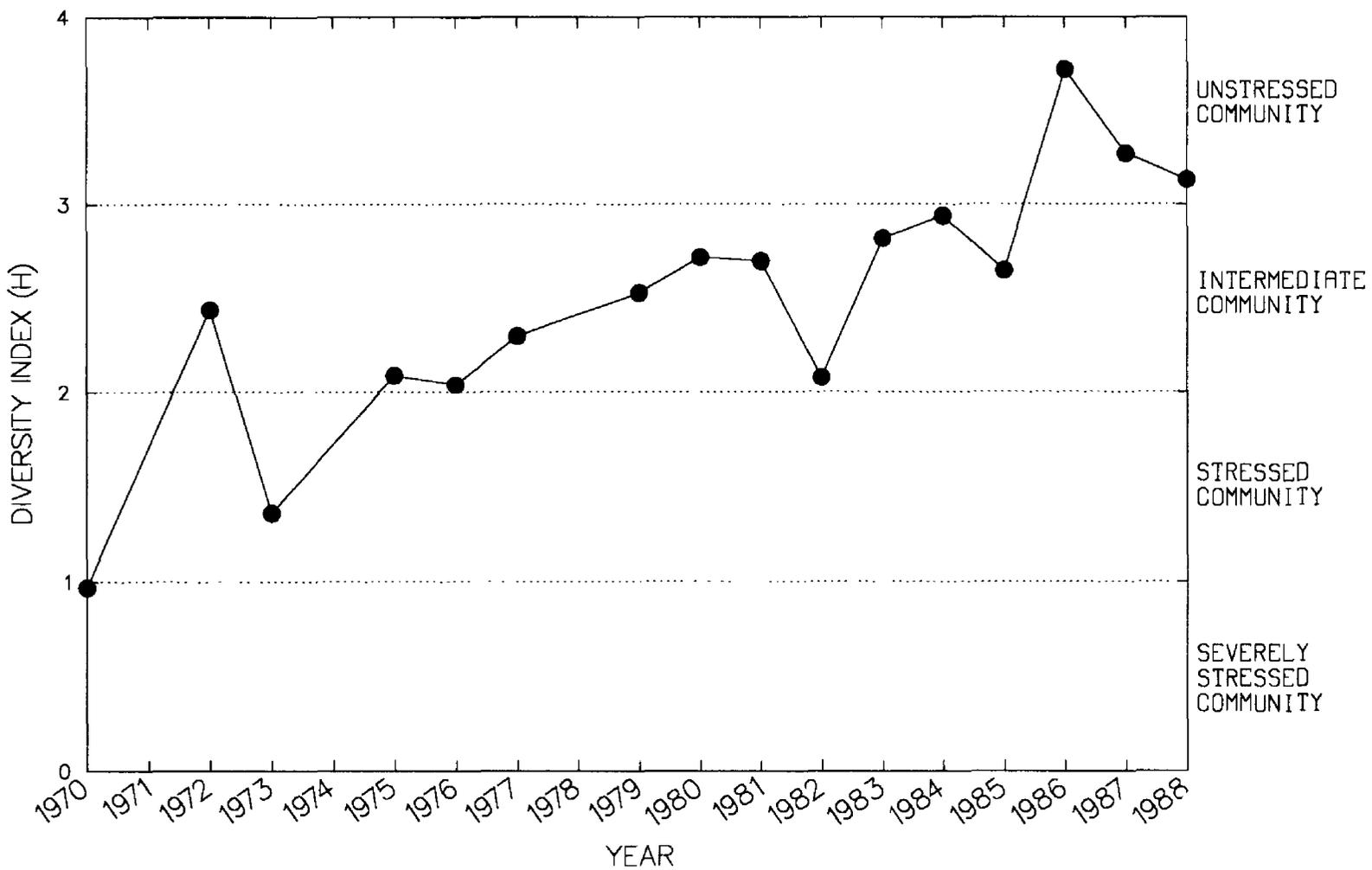


**Site 29**

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	61	6	0.95	2.42	0.48	0.24
1971	13	3	1.05	1.44	.56	.55
1972	677	15	2.25	3.84	.19	.56
1973	290	6	.85	2.56	.14	.29
1974	156	6	1.44	2.48	.23	.54
1975	--	--	--	--	--	--
1976	174	12	1.97	3.52	.47	.49
1977	283	12	2.32	3.56	.32	.62
1979	84	13	2.03	3.53	.90	.43
1980	1,376	14	1.77	3.78	.10	.45
1981	778	16	2.82	4.00	.18	.69
1982	1,698	19	2.43	4.23	.11	.56
1983	832	17	2.82	4.12	.19	.67
1984	1,742	19	2.54	4.25	.11	.59
1985	1,276	25	2.77	4.57	.19	.59
1986	905	24	3.07	4.59	.25	.65
1987	1,317	23	2.56	4.48	.17	.55
1988	3,469	21	2.74	4.37	.07	.62

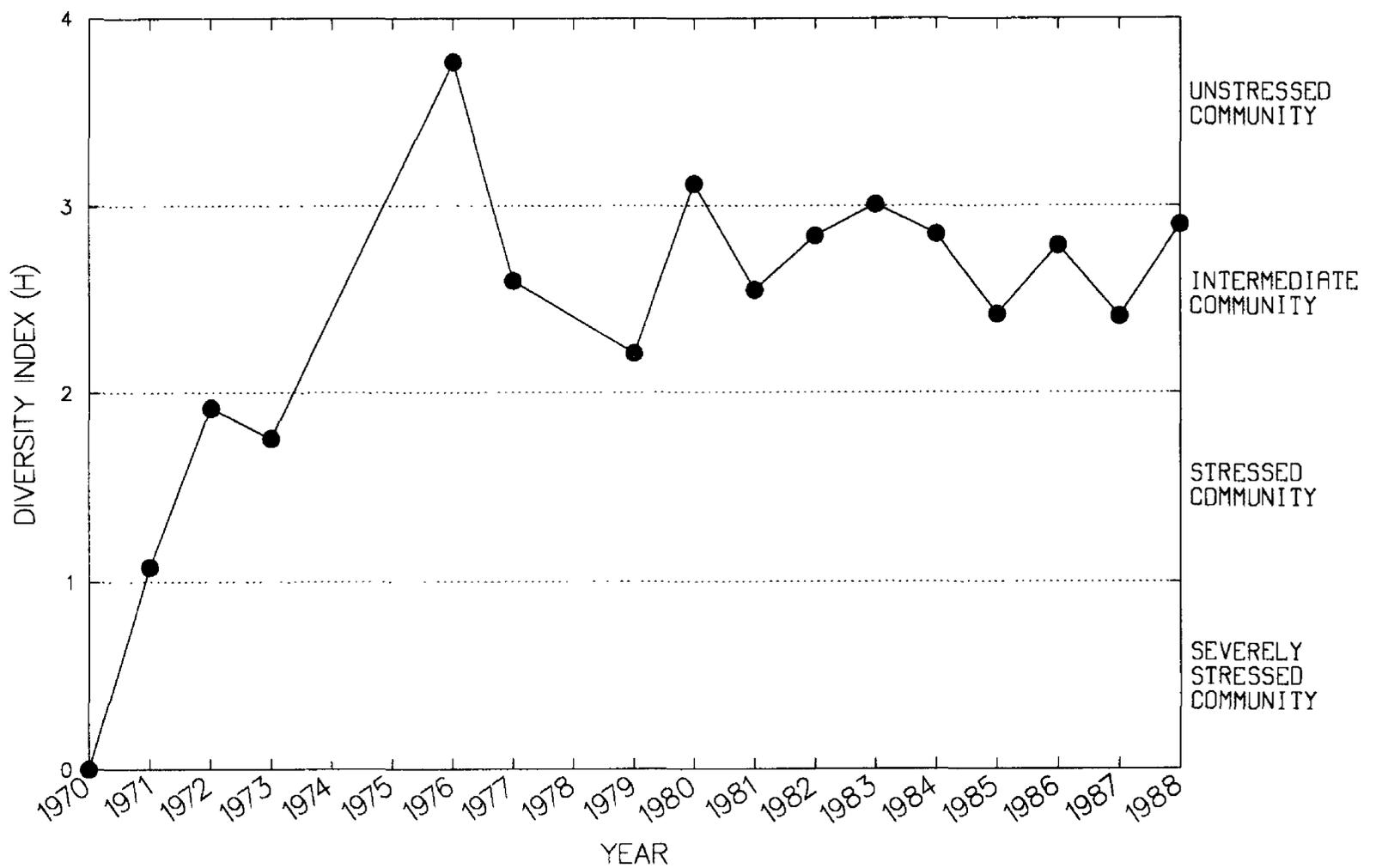


Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	42	4	0.97	1.97	0.38	0.37
1971	--	--	--	--	--	--
1972	367	15	2.44	3.86	.32	.60
1973	259	7	1.36	2.72	.19	.46
1974	--	--	--	--	--	--
1975	669	14	2.09	3.82	.18	.52
1976	391	19	2.04	4.21	.39	.43
1977	823	17	2.30	4.06	.19	.55
1979	80	10	2.53	3.02	.70	.79
1980	908	14	2.72	3.83	.14	.70
1981	1,217	22	2.70	4.42	.18	.59
1982	2,238	23	2.08	4.50	.11	.45
1983	795	23	2.82	4.50	.27	.60
1984	1,242	23	2.94	4.45	.18	.65
1985	830	29	2.65	4.84	.33	.52
1986	1,092	24	3.22	4.56	.21	.69
1987	1,647	24	3.27	4.58	.15	.71
1988	2,071	23	3.13	4.48	.12	.69

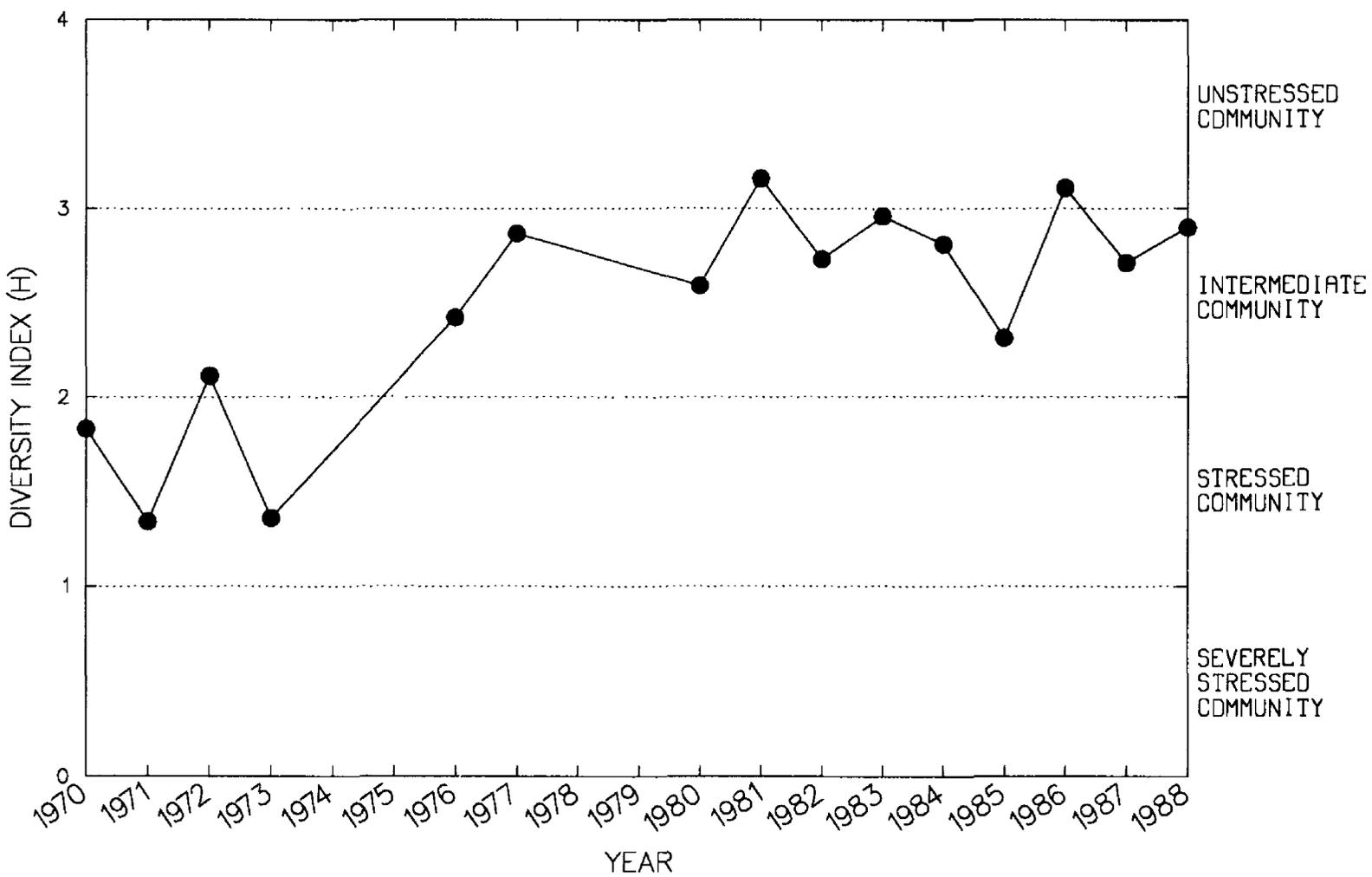


**Site 31**

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	69	1	0	0	0	0
1971	6	3	1.08	1.08	.82	1.0
1972	325	14	3.71	1.92	.33	.47
1973	43	6	2.36	1.76	.62	.65
1974	--	--	--	--	--	--
1975	--	--	--	--	--	--
1976	199	19	4.14	3.77	.68	.89
1977	1,005	20	4.27	2.60	.19	.59
1979	37	9	2.76	2.21	1.09	.67
1980	972	18	4.10	3.12	.17	.75
1981	847	25	2.55	4.67	.28	.52
1982	1,413	26	2.84	4.66	.18	.59
1983	1,174	23	3.01	4.45	.19	.66
1984	1,215	25	2.85	4.63	.26	.60
1985	549	22	2.42	4.50	.35	.50
1986	846	20	2.79	4.27	.22	.63
1987	1,640	21	2.41	4.35	.13	.54
1988	1,351	26	2.90	4.73	.19	.60

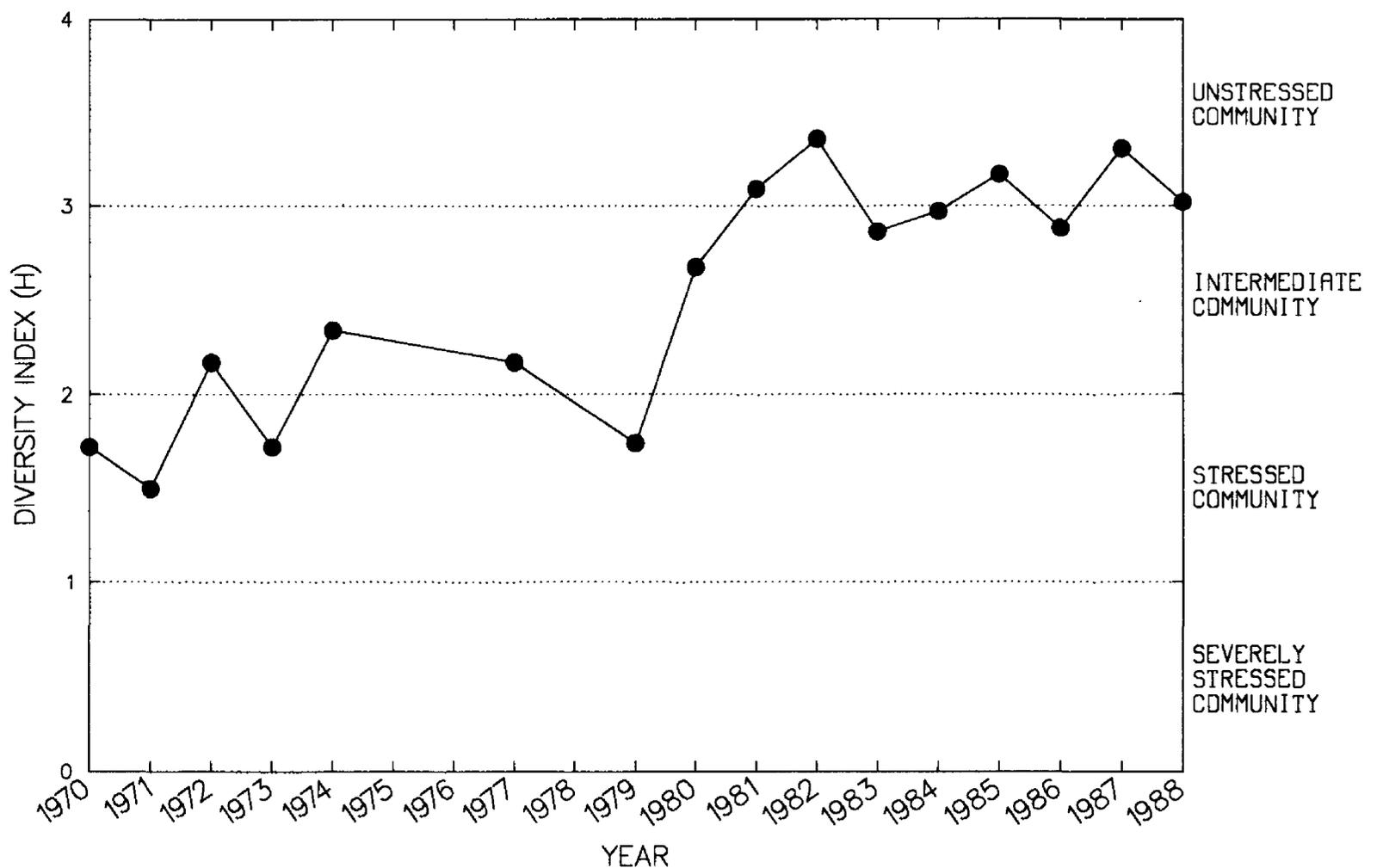


Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	104	4	1.83	1.90	0.19	0.96
1971	15	4	1.34	1.99	.76	.47
1972	921	17	2.11	4.04	.17	.50
1973	441	11	1.36	3.38	.20	.37
1974	--	--	--	--	--	--
1975	--	--	--	--	--	--
1976	256	20	2.42	4.33	.59	.49
1977	758	22	2.87	4.42	.26	.63
1979	--	--	--	--	--	--
1980	1,304	15	2.59	3.93	.11	.65
1981	1,503	30	3.16	4.84	.20	.64
1982	2,456	26	2.73	4.69	.11	.57
1983	1,194	28	2.96	4.80	.23	.60
1984	1,867	23	2.81	4.49	.13	.62
1985	1,113	21	2.31	4.32	.18	.52
1986	1,399	24	3.11	4.55	.17	.67
1987	1,307	22	2.71	4.43	.17	.60
1988	2,241	20	2.90	4.29	.09	.67

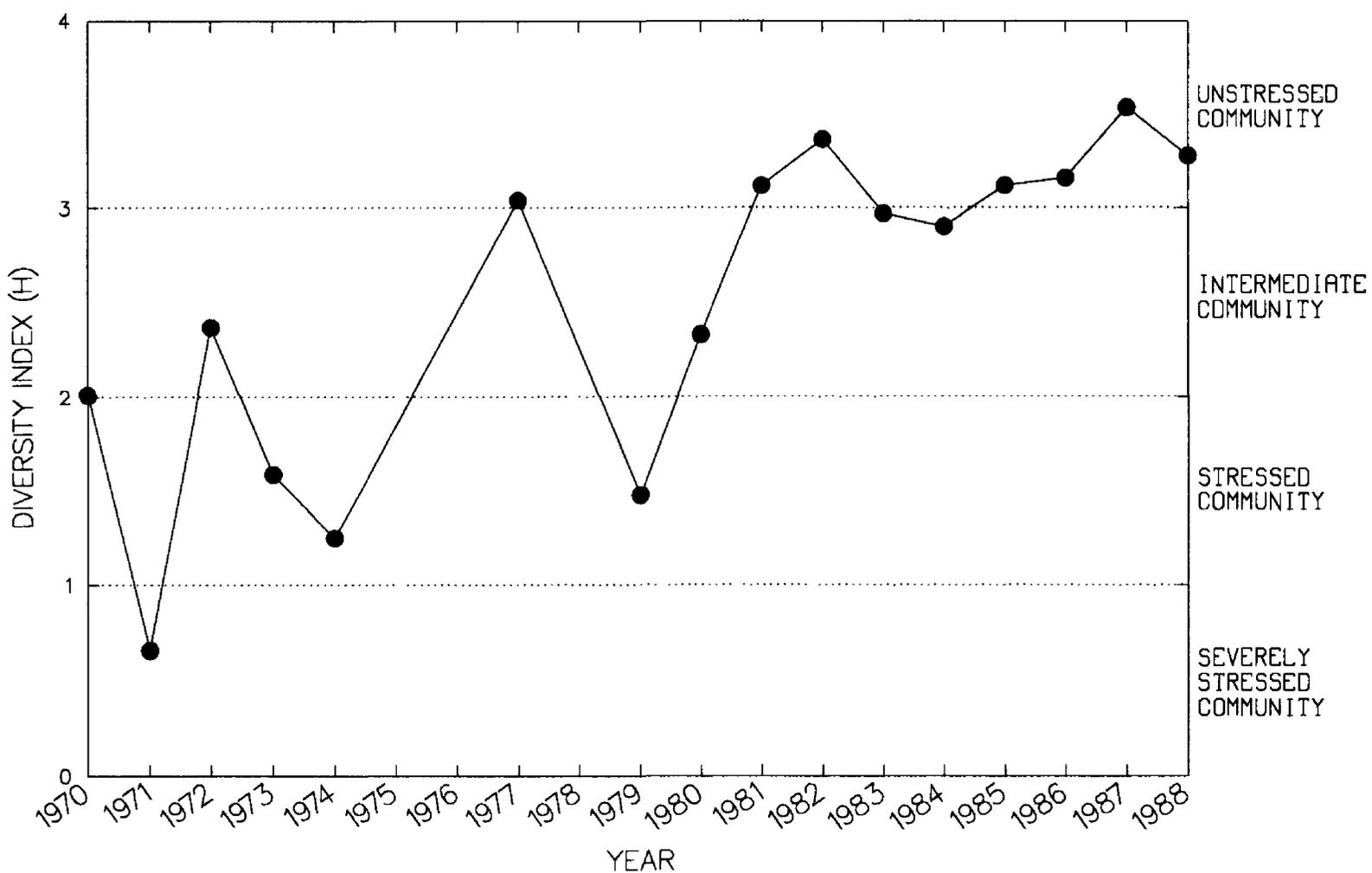


Site 33

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	76	4	1.72	1.88	0.25	0.91
1971	63	5	1.50	2.31	.38	.58
1972	705	13	2.17	3.66	.16	.57
1973	385	12	1.72	3.49	.24	.45
1974	172	11	2.34	3.44	.43	.63
1975	--	--	--	--	--	--
1976	--	--	--	--	--	--
1977	1,125	23	2.17	4.55	.20	.45
1978	--	--	--	--	--	--
1979	141	7	1.74	2.70	.30	.60
1980	476	11	2.67	3.41	.19	.77
1981	975	18	3.09	4.12	.17	.74
1982	1,672	24	3.36	4.58	.15	.72
1983	851	25	2.86	4.54	.27	.61
1984	1,509	21	2.97	4.41	.14	.66
1985	593	25	3.17	4.64	.37	.65
1986	1,105	27	2.88	4.78	.24	.58
1987	1,410	27	3.31	4.70	.19	.69
1988	1,955	20	3.02	4.33	.11	.69

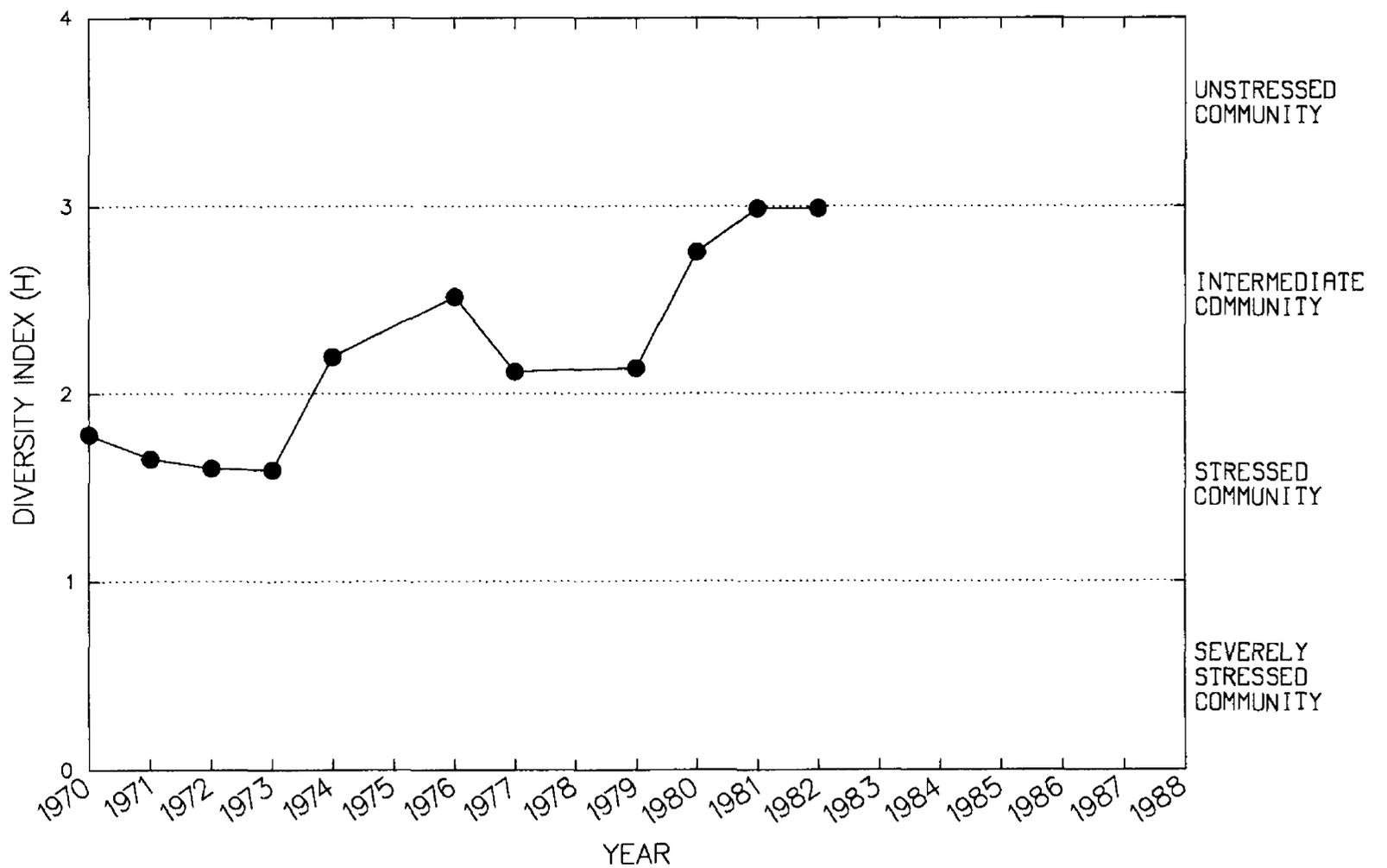


Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	77	5	2.01	2.27	0.32	0.87
1971	5	2	.66	.98	.46	.39
1972	334	14	2.37	3.84	.33	.58
1973	136	7	1.59	2.76	.31	.52
1974	130	7	1.25	2.79	.32	.38
1975	--	--	--	--	--	--
1976	--	--	--	--	--	--
1977	768	19	3.04	4.21	.22	.71
1979	13	6	1.48	2.04	1.33	.22
1980	1,288	12	2.33	3.57	.09	.64
1981	2,184	21	3.12	4.35	.10	.71
1982	2,495	32	3.37	5.02	.14	.66
1983	937	23	2.97	4.53	.23	.64
1984	2,250	30	2.90	4.85	.14	.59
1985	965	28	3.12	4.77	.28	.63
1986	776	23	3.16	4.53	.27	.68
1987	2,309	31	3.54	4.94	.15	.71
1988	2,901	24	3.28	4.60	.09	.71

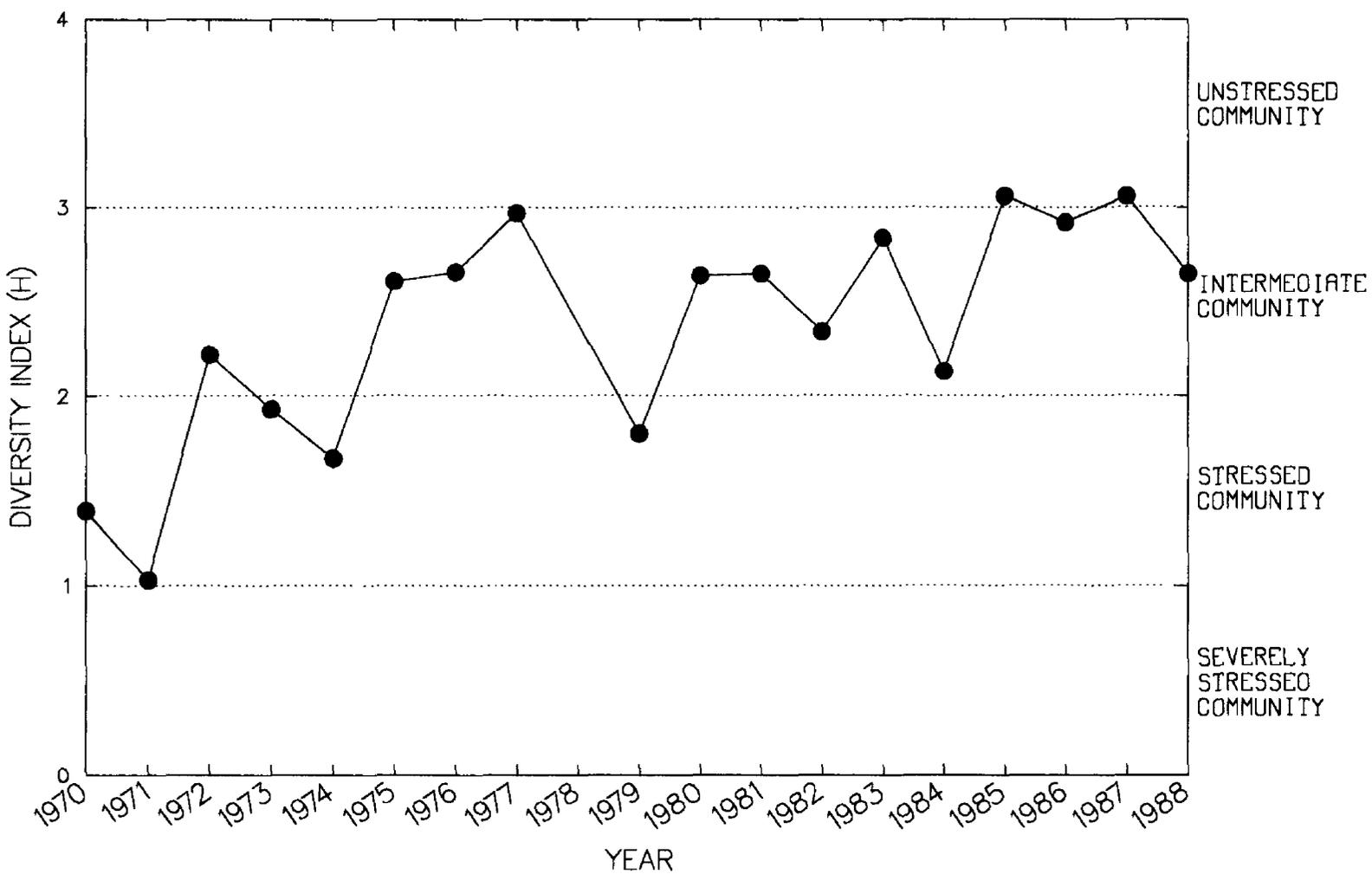


**Site 35**

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	102	5	1.78	2.28	0.26	0.75
1971	43	4	1.65	2.05	.38	.76
1972	858	14	1.60	3.77	.15	.40
1973	138	6	1.59	2.46	.26	.60
1974	140	12	2.20	3.56	.56	.55
1975	--	--	--	--	--	--
1976	182	13	2.52	3.50	.49	.67
1977	1,174	17	2.12	4.03	.14	.51
1979	79	10	2.14	3.36	.71	.54
1980	1,048	11	2.76	3.44	.10	.80
1981	1,043	27	2.99	4.74	.25	.61
1982	1,780	25	2.99	4.60	.15	.64

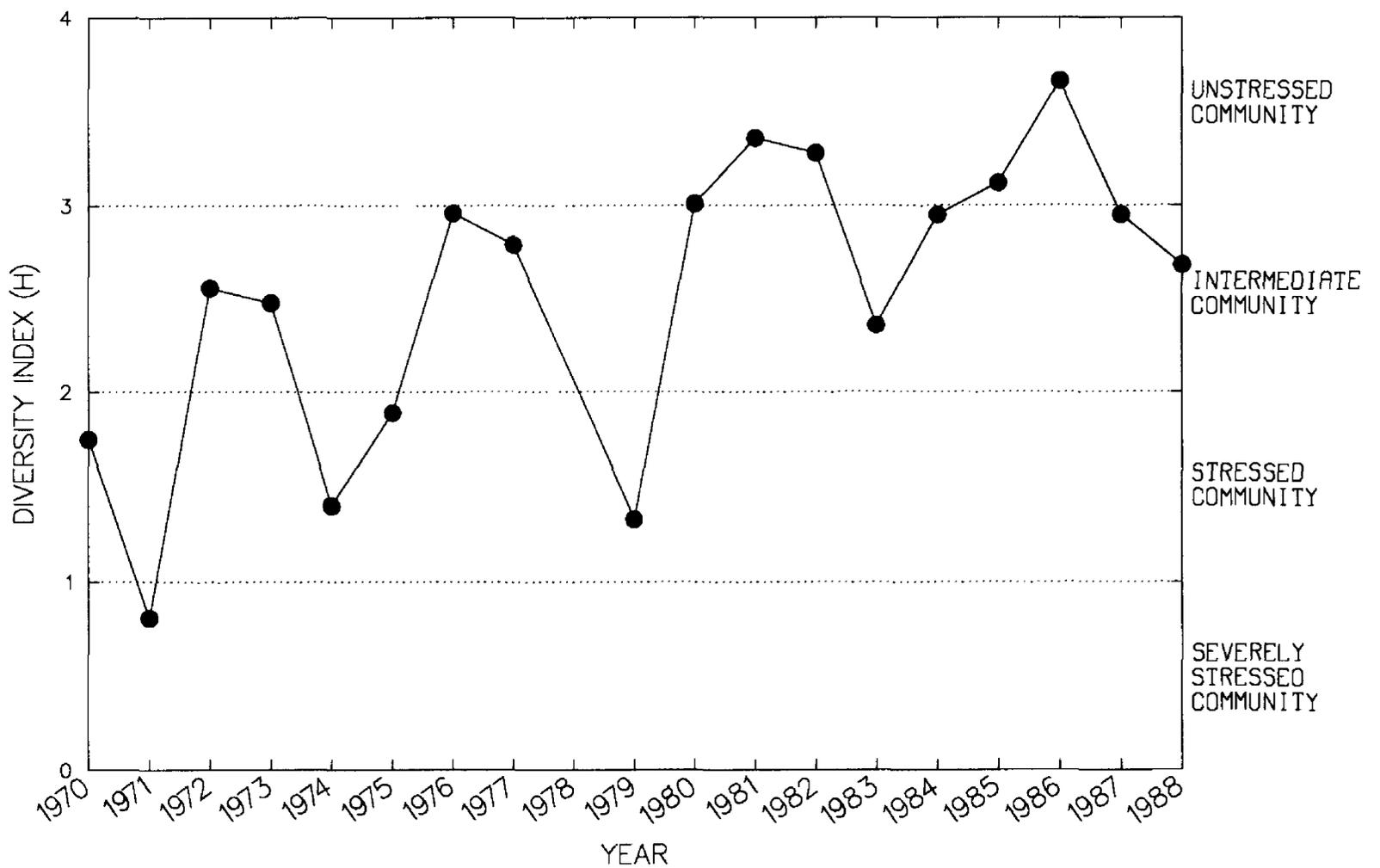


Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	86	7	1.39	2.69	0.45	0.42
1971	38	5	1.03	2.29	.55	.28
1972	127	14	2.22	3.55	.71	.53
1973	201	13	1.93	3.63	.45	.46
1974	147	14	1.67	3.72	.63	.34
1975	357	21	2.61	4.21	.47	.57
1976	685	29	2.66	4.83	.38	.51
1977	325	24	2.97	4.52	.59	.61
1979	55	10	1.80	3.16	.93	.39
1980	3,840	14	2.64	3.80	.04	.69
1981	2,454	28	2.65	4.81	.12	.54
1982	1,798	22	2.34	4.46	.13	.51
1983	2,839	31	2.84	4.95	.12	.56
1984	5,952	33	2.13	5.03	.07	.42
1985	1,852	30	3.06	4.91	.17	.61
1986	2,233	31	2.92	4.90	.15	.58
1987	2,184	31	3.06	4.93	.15	.61
1988	1,498	24	2.65	4.56	.16	.57



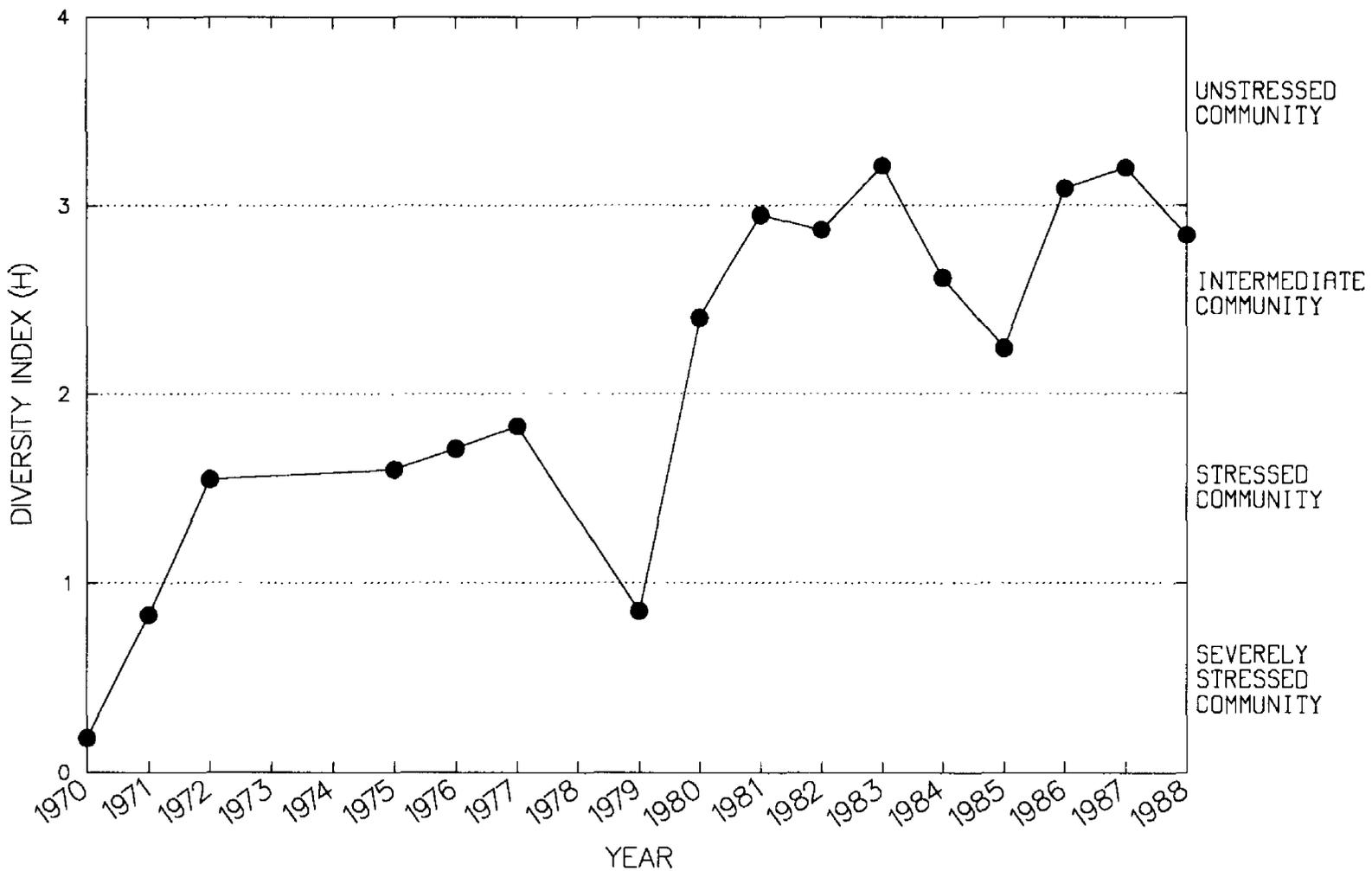
Site 37

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	66	7	1.75	2.71	0.54	0.55
1971	20	2	.81	.87	.22	.90
1972	128	14	2.56	3.57	.70	.65
1973	117	16	2.48	3.79	.87	.55
1974	113	7	1.40	2.68	.36	.45
1975	40	7	1.89	2.77	.78	.56
1976	266	20	2.96	4.19	.57	.66
1977	221	15	2.79	3.90	.49	.67
1979	77	9	1.33	3.09	.64	.28
1980	468	19	3.01	4.23	.34	.68
1981	559	29	3.36	4.75	.46	.68
1982	1,074	31	3.28	4.94	.28	.64
1983	1,242	31	2.36	4.87	.25	.46
1984	1,051	30	2.95	4.81	.28	.59
1985	1,704	32	3.20	4.95	.20	.63
1986	647	34	3.66	4.92	.47	.72
1987	1,278	36	2.95	5.14	.28	.55
1988	1,190	28	2.68	4.78	.23	.54



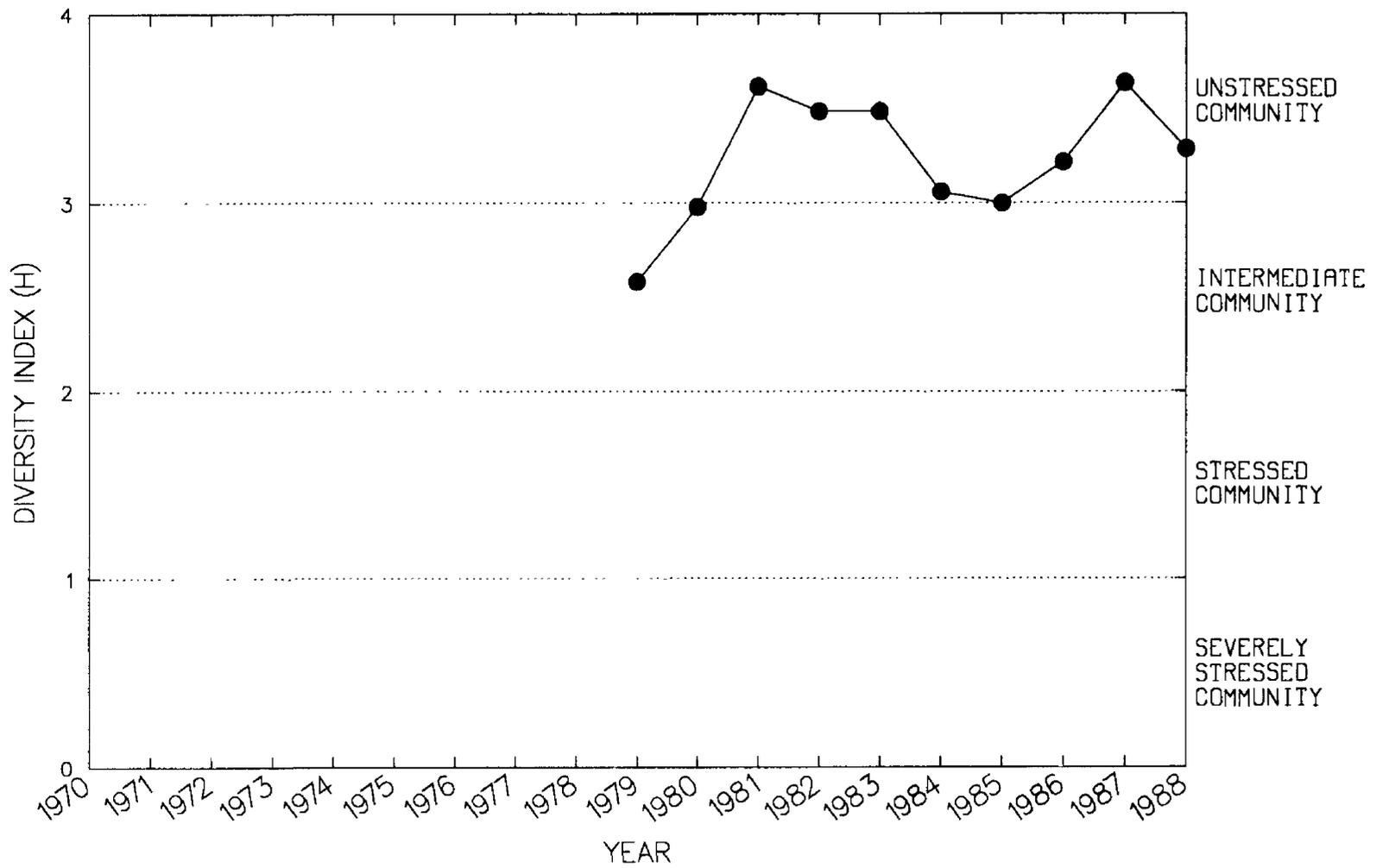
Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	58	2	0.18	0.94	0.10	0.10
1971	26	2	.83	.90	.18	.91
1972	507	11	1.55	3.39	.18	.43
1973	--	--	--	--	--	--
1974	--	--	--	--	--	--
1975	277	11	1.60	3.37	.29	.42
1976	196	10	1.71	3.30	.35	.46
1977	52	10	1.83	3.01	.97	.42
1979	52	4	.85	1.84	.33	.35
1980	464	13	2.40	3.70	.23	.63
1981	605	31	2.95	4.90	.46	.56
1982	1,653	21	2.87	4.40	.13	.64
1983	1,104	27	3.21	4.78	.24	.66
1984	1,406	22	2.61	4.48	.16	.57
1985	1,079	24	2.24	4.62	.21	.46
1986	775	24	3.09	4.52	.28	.66
1987 <sup>1</sup>	402	23	3.20	4.46	.47	.69
1988	1,941	22	2.84	4.43	.12	.63

<sup>1</sup> Sampled upstream riffle because of bridge construction.

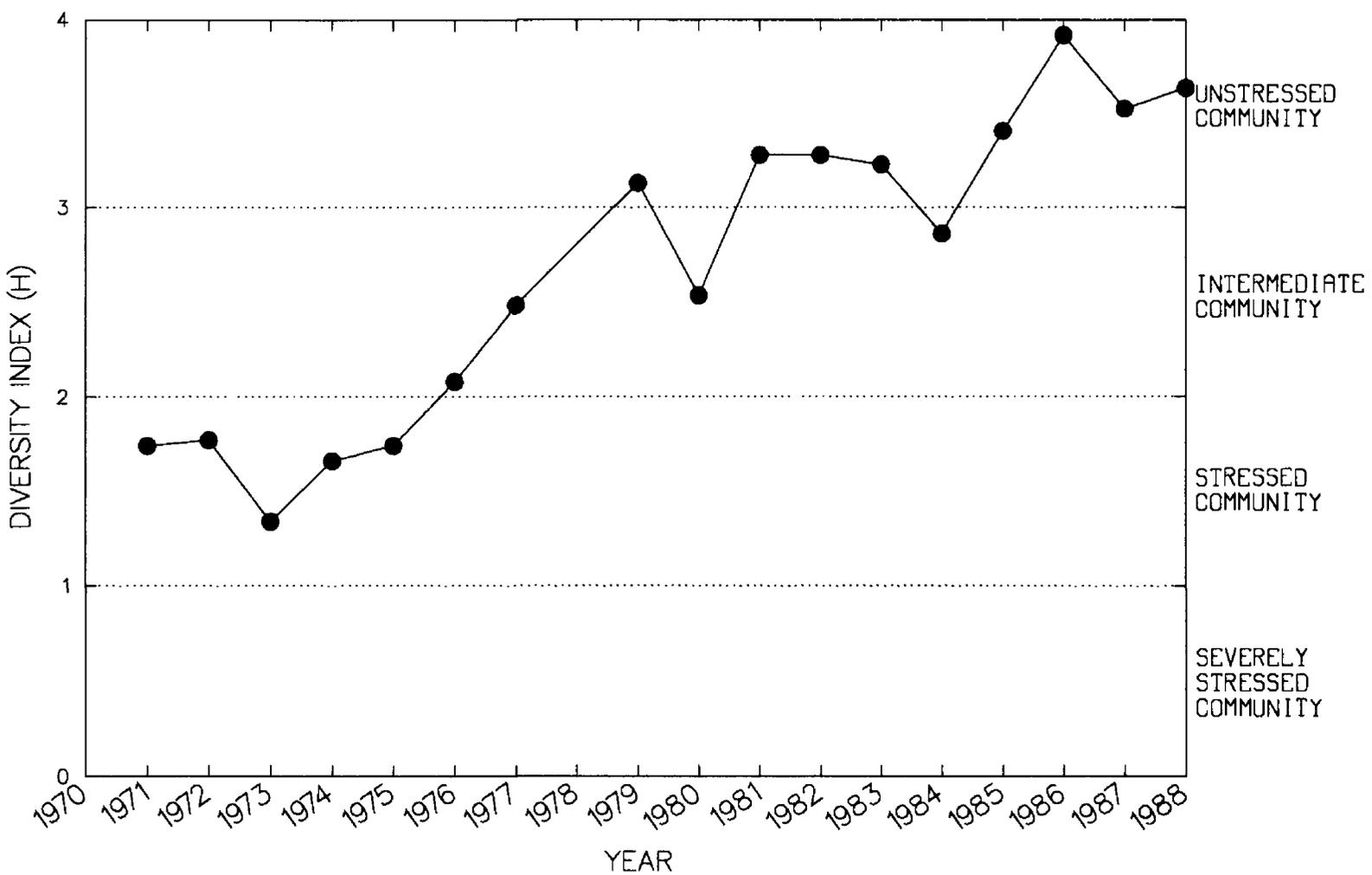


**Site 39**

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1979	1,455	18	2.58	4.18	0.12	0.60
1980	238	16	2.98	4.03	.49	.70
1981	639	30	3.62	4.81	.42	.73
1982	2,814	36	3.49	5.13	.14	.67
1983	766	36	3.49	5.07	.44	.66
1984	3,044	42	3.06	5.37	.16	.56
1985	701	27	3.00	4.80	.35	.60
1986	2,581	44	3.22	5.46	.19	.57
1987	1,110	40	3.64	5.32	.35	.66
1988	1,354	28	3.29	4.77	.21	.68

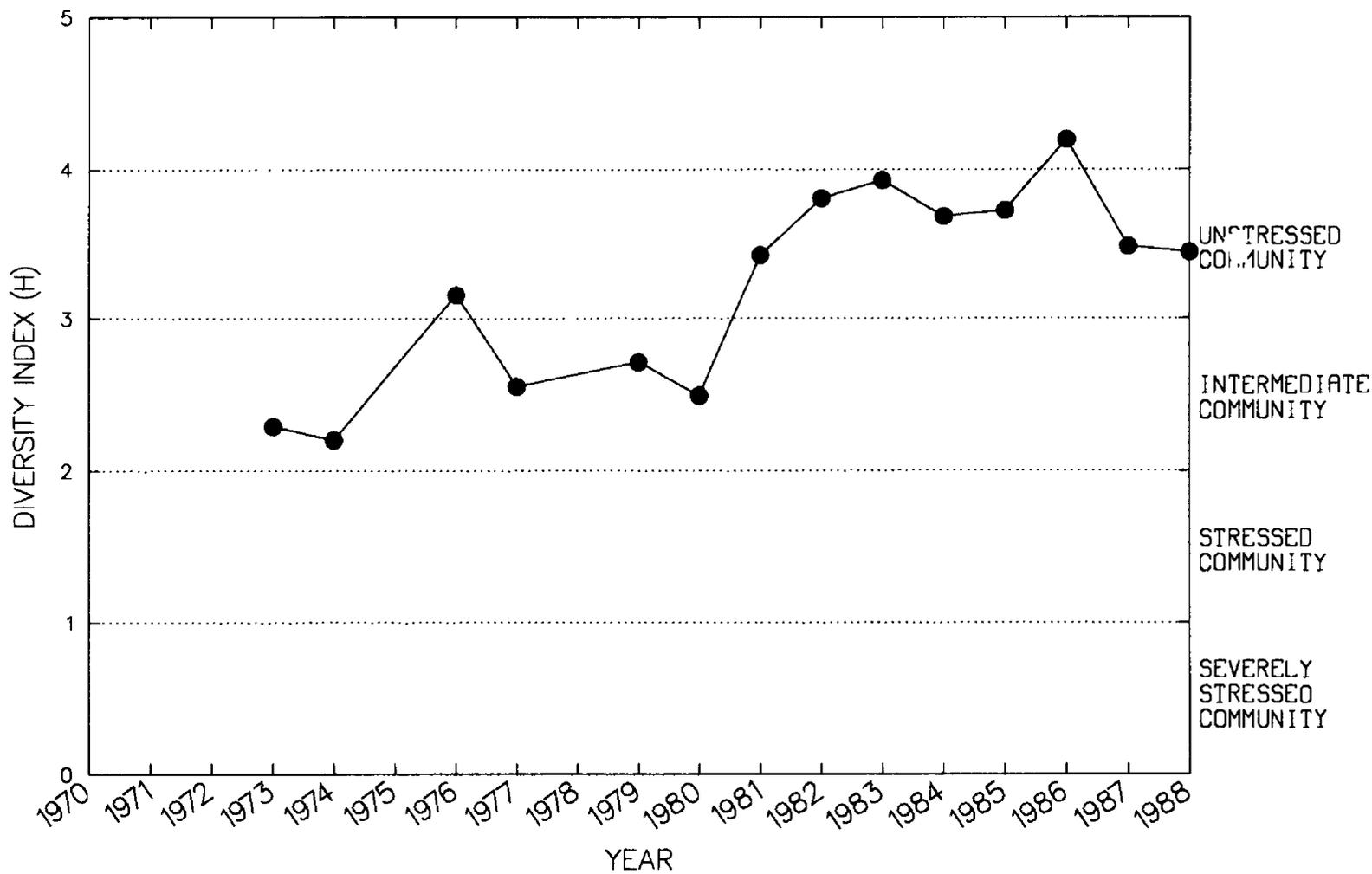


Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1970	--	--	--	--	--	--
1971	--	--	--	--	--	--
1972	133	8	1.77	2.99	0.37	0.53
1973	653	11	1.34	3.43	.14	.36
1974	246	10	1.66	3.31	.29	.46
1975	717	16	1.74	4.02	.20	.40
1976	460	13	2.08	3.66	.23	.54
1977	103	15	2.48	3.91	.90	.53
1979	132	18	3.13	3.96	.90	.73
1980	549	10	2.53	3.35	.15	.74
1981	650	23	3.28	4.45	.32	.72
1982	1,663	30	3.28	4.88	.19	.66
1983	1,016	32	3.23	5.00	.30	.62
1984	1,441	24	2.86	4.52	.17	.62
1985	999	25	3.41	4.68	.24	.72
1986	428	36	3.92	5.19	.71	.72
1987	1,049	37	3.53	5.14	.34	.66
1988	1,819	25	3.64	4.65	.14	.78



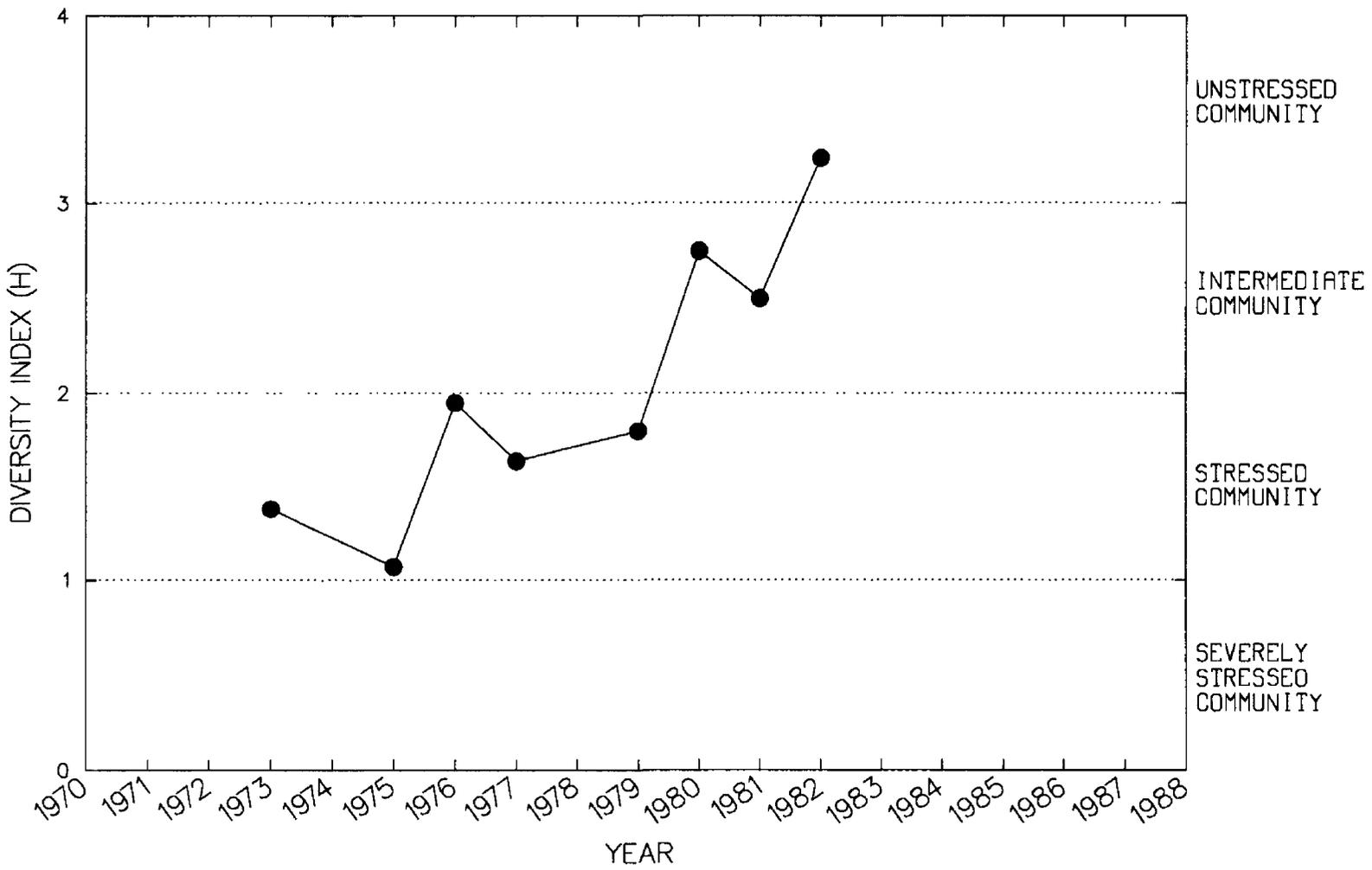
Site 42

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1973	134	14	2.29	3.73	0.68	0.53
1974	113	17	2.20	3.99	.95	.41
1975	--	--	--	--	--	--
1976	424	24	3.16	4.56	.47	.66
1977	120	16	2.55	3.80	.85	.56
1979	305	14	2.71	3.82	.35	.68
1980	444	18	2.49	4.16	.34	.56
1981	749	36	3.43	5.18	.44	.63
1982	1,691	48	3.81	5.51	.30	.67
1983	1,341	45	3.93	5.50	.34	.70
1984	1,005	36	3.69	5.20	.35	.69
1985	1,361	43	3.73	5.41	.32	.67
1986	719	48	4.20	5.63	.62	.72
1987	1,438	36	3.49	5.20	.25	.65
1988	1,662	33	3.45	5.01	.21	.68



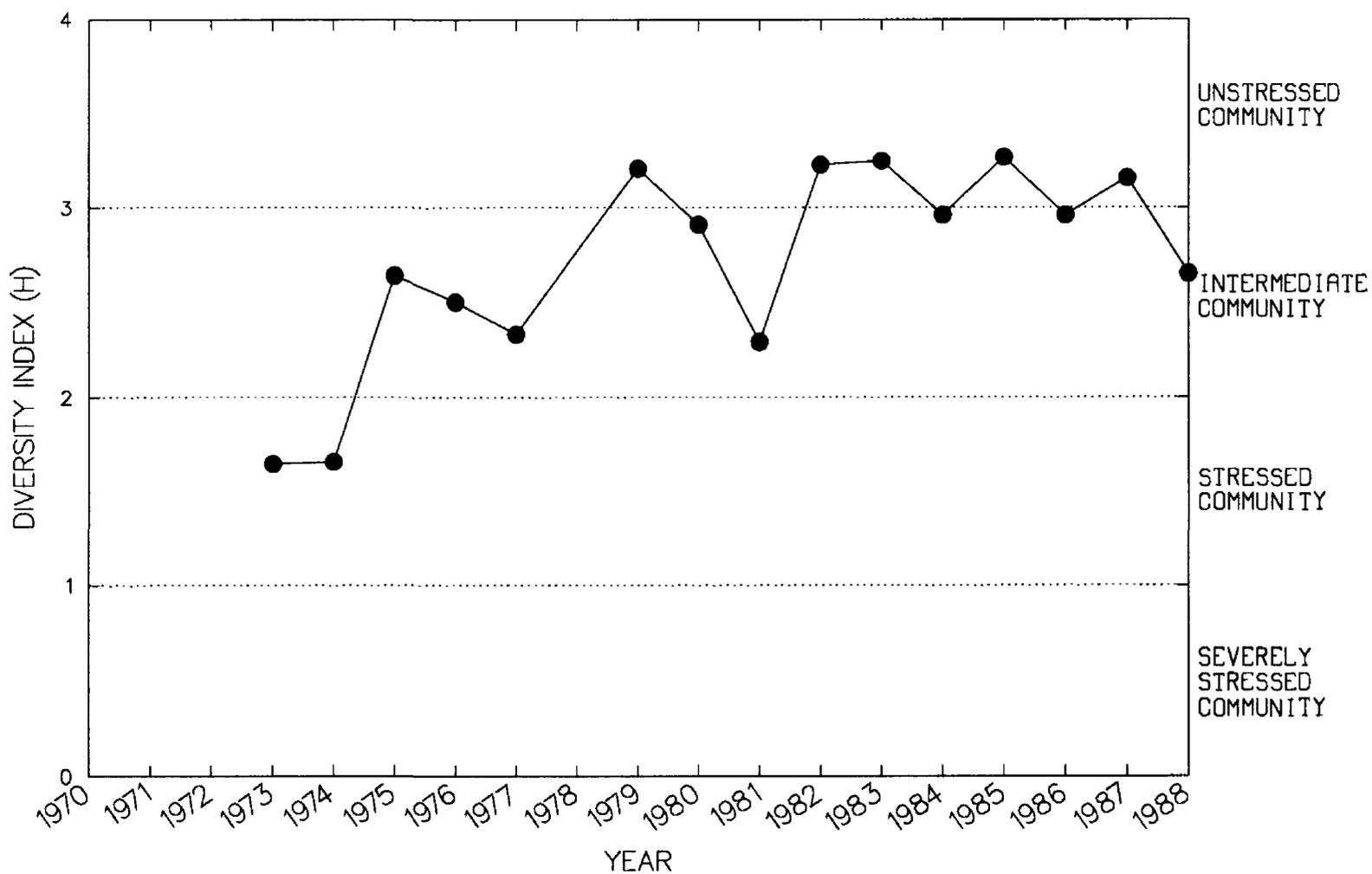
**Site 43**

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1973	191	8	1.38	3.04	0.28	0.40
1974	--	--	--	--	--	--
1975	228	8	1.07	2.98	.24	.30
1976	295	15	1.95	3.89	.39	.44
1977	12	6	1.64	1.90	1.38	.50
1979	130	10	1.80	3.11	.48	.50
1980	188	19	2.75	4.27	.72	.57
1981	298	22	2.50	4.39	.58	.50
1982	572	25	3.24	4.67	.38	.67

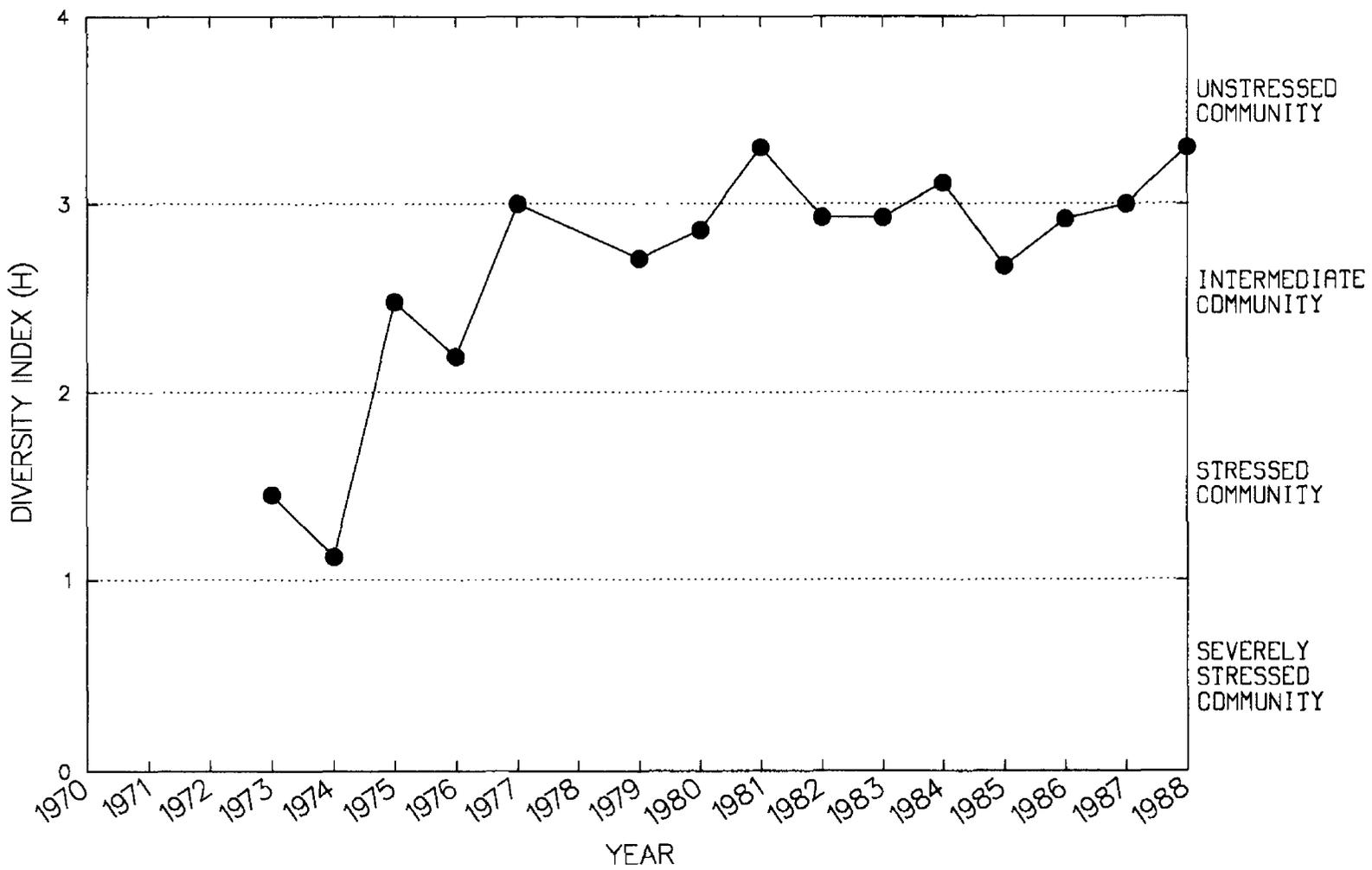


**Site 44**

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1973	770	16	1.65	3.94	0.19	0.39
1974	949	16	1.66	3.97	.16	.39
1975	997	18	2.64	4.14	.17	.62
1976	630	20	2.50	4.29	.28	.55
1977	433	18	2.33	4.04	.34	.54
1979	381	14	3.21	3.72	.29	.85
1980	1,596	12	2.91	3.55	.07	.82
1981	2,816	33	2.29	5.02	.13	.65
1982	1,557	33	3.23	4.98	.22	.63
1983	1,915	26	3.25	4.70	.14	.68
1984	1,473	25	2.96	4.67	.17	.62
1985	2,095	33	3.27	5.03	.17	.64
1986	1,080	24	2.96	4.50	.21	.64
1987	2,352	33	3.16	5.01	.15	.62
1988	2,631	22	2.65	4.46	.09	.59

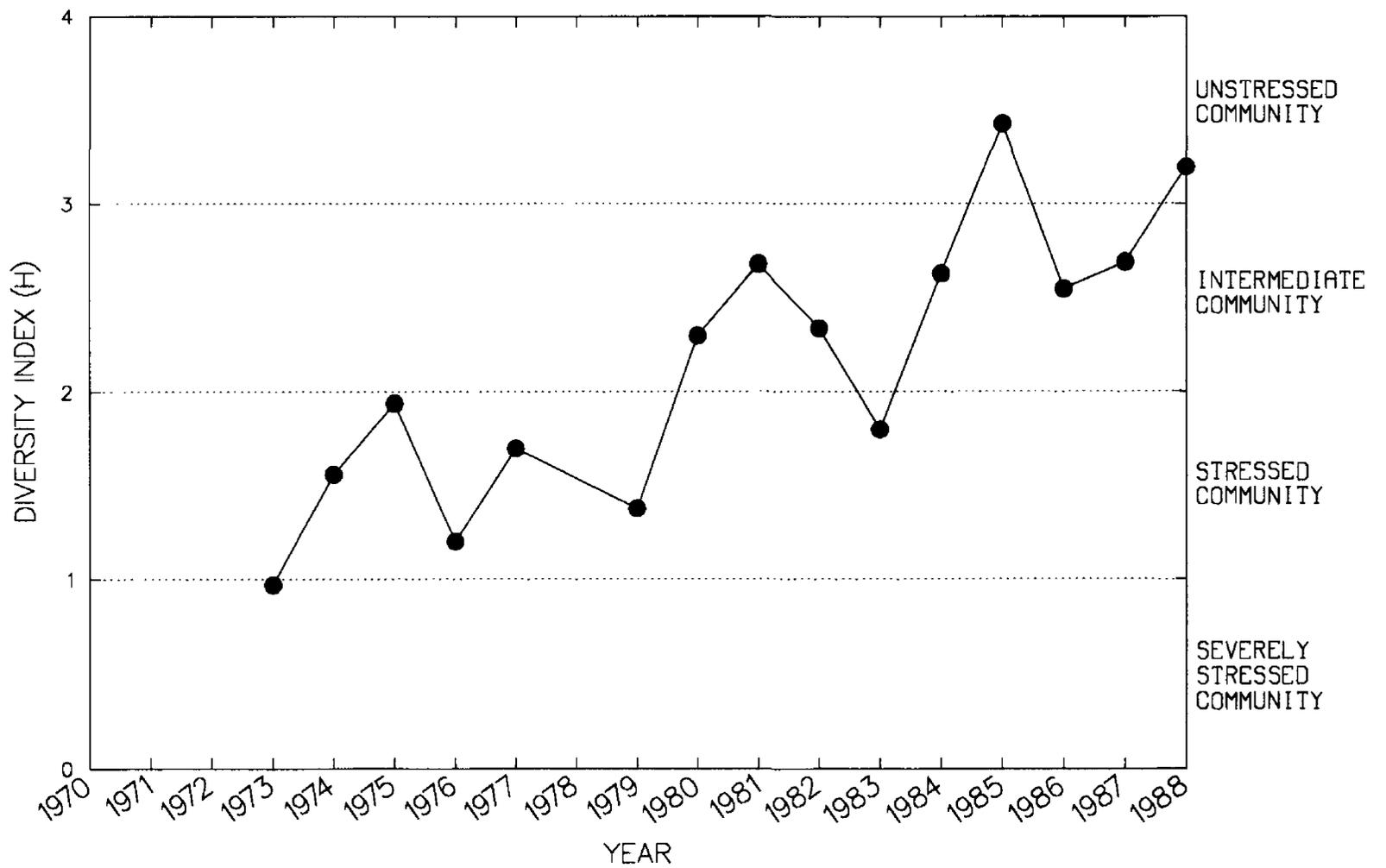


Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1973	15	7	1.45	2.22	1.45	0
1974	147	7	1.12	2.67	.29	.35
1975	575	18	2.48	4.21	.27	.56
1976	836	22	2.19	4.36	.24	.47
1977	665	16	3.00	3.99	.21	.74
1979	150	15	2.71	3.64	.67	.69
1980	628	14	2.86	3.83	.19	.73
1981	1,123	24	3.30	4.60	.21	.71
1982	1,626	25	2.93	4.58	.16	.63
1983	1,401	23	2.93	4.55	.16	.63
1984	1,600	22	3.11	4.46	.14	.69
1985	980	20	2.67	4.24	.19	.61
1986	774	19	2.92	4.25	.22	.67
1987	1,619	26	3.00	4.66	.16	.63
1988	1,808	22	3.30	4.42	.13	.74

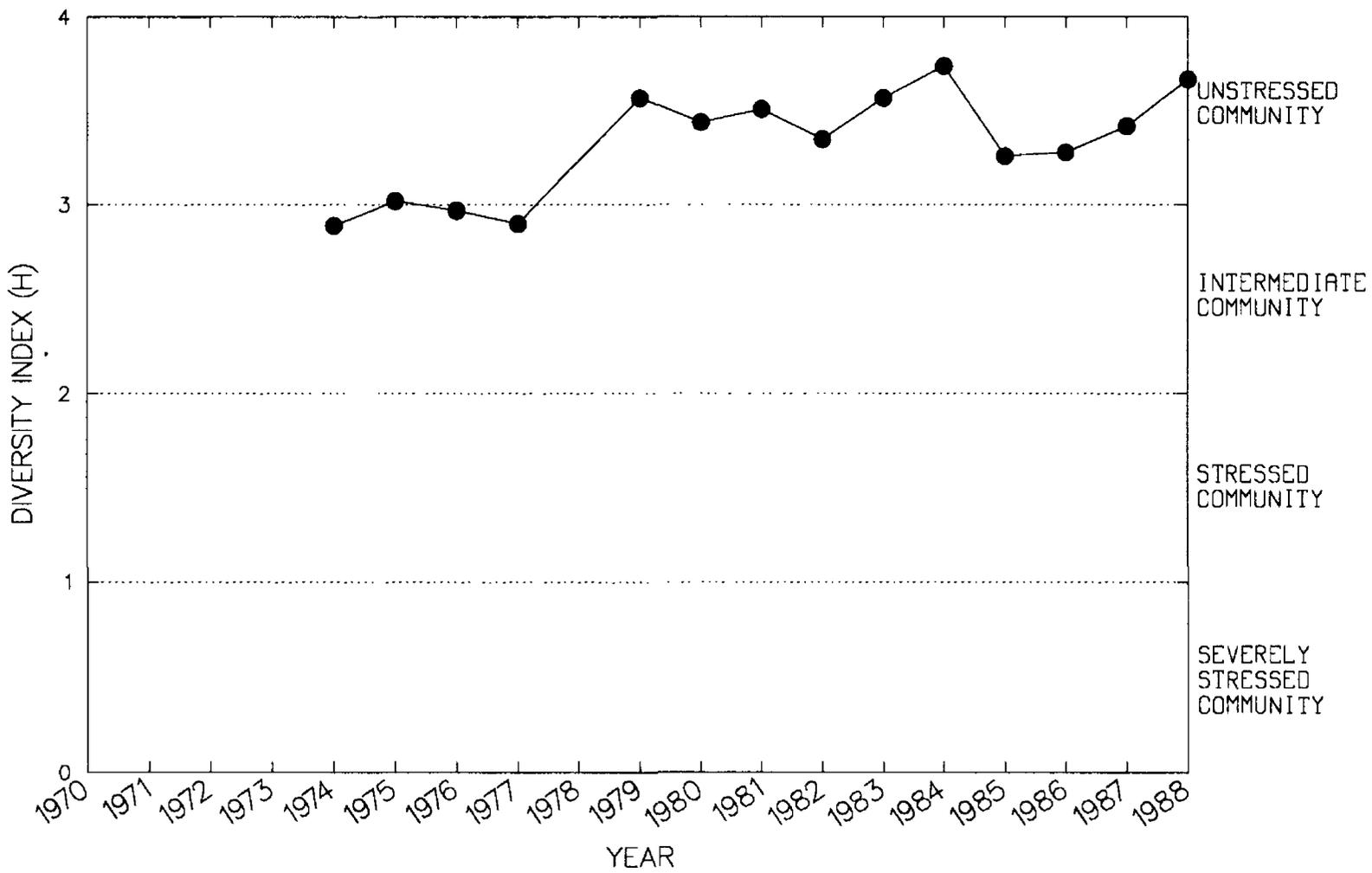


Site 46

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1973	346	8	0.97	2.95	0.17	0.29
1974	54	5	1.56	2.37	.42	.58
1975	790	16	1.94	3.97	.18	.46
1976	218	9	1.20	3.09	.28	.33
1977	795	18	1.70	4.11	.21	.38
1979	5	5	1.38	1.38	1.38	1.00
1980	420	10	2.30	3.24	.19	.69
1981	1,022	19	2.68	4.26	.18	.61
1982	1,642	16	2.34	4.00	.10	.57
1983	1,853	17	1.80	4.05	.09	.43
1984	2,266	21	2.63	4.41	.10	.59
1985	1,090	21	3.43	4.42	.18	.77
1986	1,771	23	2.55	4.47	.13	.56
1987	1,645	25	2.69	4.66	.16	.56
1988	2,065	24	3.20	4.54	.12	.70



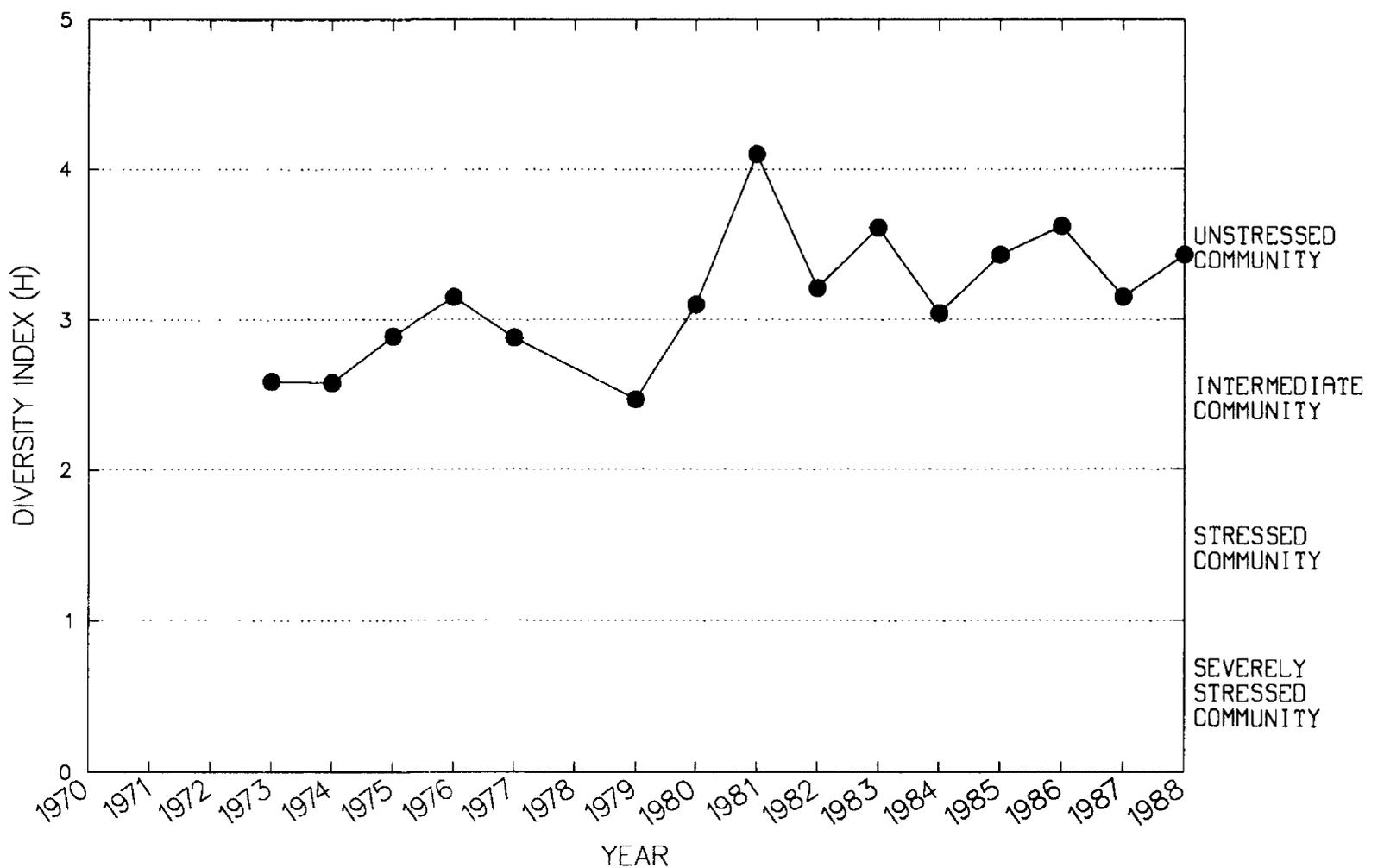
Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1974	188	21	2.89	4.43	0.80	0.58
1975	446	28	3.02	4.84	.53	.58
1976	135	18	2.97	4.03	.88	.66
1977	42	15	2.90	3.69	1.71	.60
1979	185	28	3.57	4.68	1.08	.69
1980	622	28	3.44	4.70	.40	.71
1981	1,052	37	3.51	5.16	.34	.66
1982	1,882	40	3.35	5.24	.23	.62
1983	1,169	38	3.57	5.25	.32	.66
1984	1,028	33	3.74	4.95	.31	.74
1985	726	29	3.26	4.73	.37	.66
1986	684	34	3.28	4.95	.45	.63
1987	641	35	3.42	5.02	.49	.65
1988	789	29	3.67	4.77	.34	.75



**Site 48**

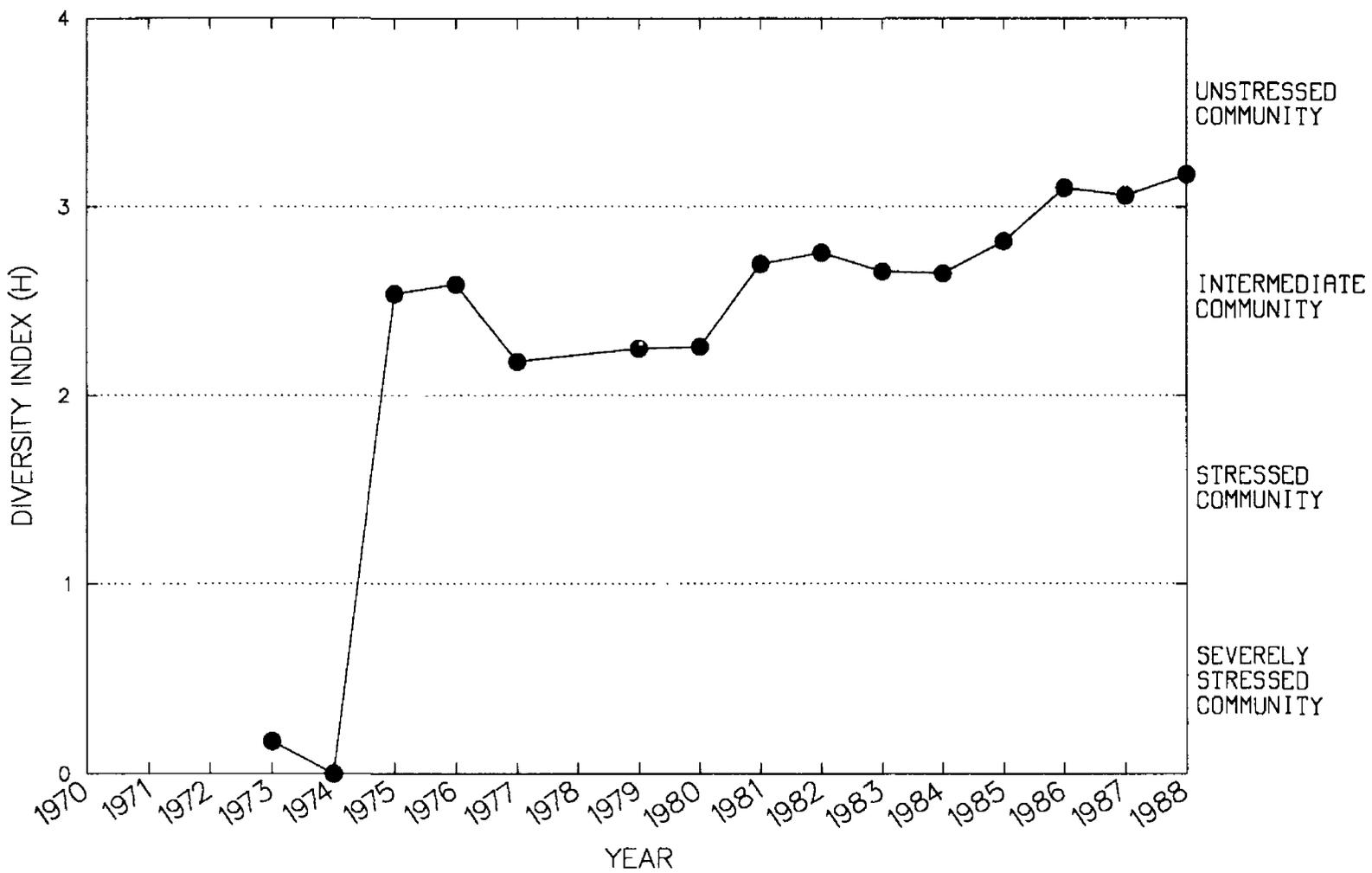
Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1973	218	14	2.59	3.76	0.46	0.65
1974	188	17	2.58	3.86	.64	.60
1975	749	28	2.89	4.81	.34	.57
1976	518	23	3.15	4.48	.38	.67
1977	583	21	2.88	4.40	.31	.63
1979	166	21	2.47	4.41	.88	.45
1980	624	16	3.10	3.91	.22	.78
1981	1,307	43	4.10	5.37	.33	.75
1982	2,525	35	3.21	5.08	.15	.62
1983 <sup>1</sup>	733	32	3.61	5.03	.40	.69
1984	1,648	24	3.04	4.58	.15	.65
1985 <sup>1</sup>	684	28	3.43	4.75	.37	.70
1986 <sup>1</sup>	604	28	3.62	4.77	.41	.74
1987	1,139	31	3.15	4.96	.27	.61
1988	1,985	32	3.43	4.94	.17	.68

<sup>1</sup> Sampled upstream riffle because of bridge construction.



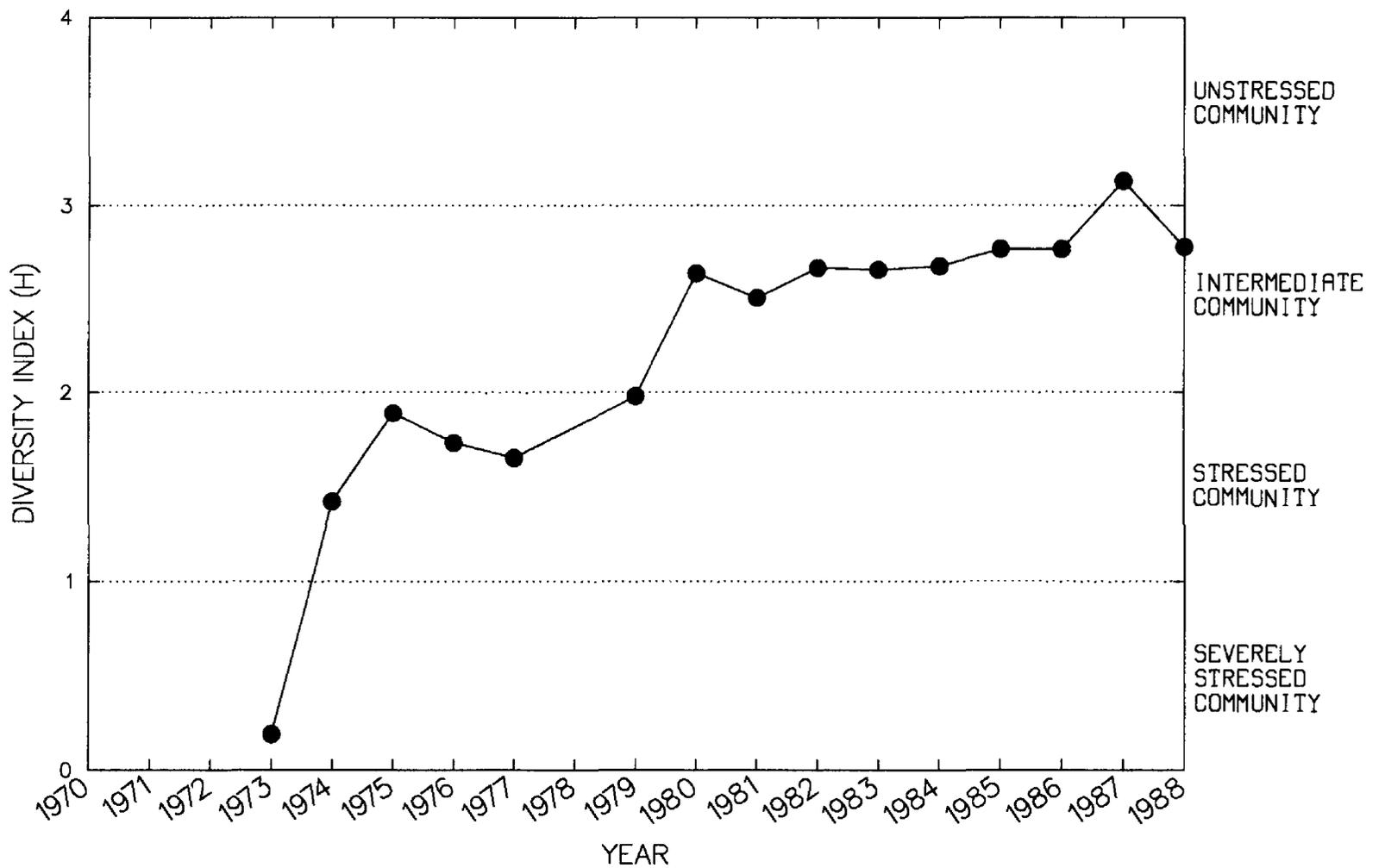
Site 49

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1973	29	2	0.17	1.04	0.17	0
1974	0	0	0	0	0	0
1975	988	12	2.54	3.56	.11	.70
1976	449	12	2.59	3.55	.22	.71
1977	279	13	2.18	3.65	.35	.56
1979	222	14	2.28	3.84	.45	.54
1980	1,983	15	2.26	3.88	.08	.57
1981	2,907	20	2.70	4.31	.08	.62
1982	2,442	21	2.76	4.37	.09	.62
1983	1,227	18	2.66	4.13	.14	.63
1984	1,211	17	2.65	4.05	.14	.64
1985	548	20	2.82	4.27	.31	.63
1986	1,093	17	3.10	4.05	.15	.75
1987	1,357	15	3.06	3.89	.11	.78
1988	1,373	20	3.17	4.32	.14	.73



**Site 50**

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1973	25	2	0.19	1.04	0.19	0
1974	153	8	1.42	2.88	.33	.43
1975	534	10	1.89	3.30	.15	.55
1976	849	14	1.73	3.81	.15	.43
1977	1,003	13	1.65	3.66	.12	.43
1979	263	9	1.98	3.10	.24	.61
1980	1,412	12	2.64	3.59	.08	.73
1981	2,201	20	2.51	4.29	.10	.58
1982	3,155	20	2.67	4.33	.07	.61
1983	1,744	16	2.66	3.96	.09	.66
1984	2,058	21	2.68	4.35	.11	.61
1985	1,362	19	2.77	4.25	.14	.64
1986	1,824	19	2.77	4.20	.11	.65
1987	1,623	22	3.13	4.47	.14	.69
1988	2,277	15	2.78	3.92	.07	.71



Site 51

Year	Total number of organisms	Total number of taxa	Brillouin's diversity index (H)	Maximum diversity (Hmax)	Minimum diversity (Hmin)	Evenness (E)
1983	2,889	22	2.41	4.44	0.08	0.53
1984	2,879	22	2.81	4.47	.08	.62
1985	4,264	19	2.18	4.24	.05	.51
1986	1,520	23	2.39	4.47	.15	.52
1987	12,157	20	1.75	4.33	.02	.40
1988	3,921	17	2.58	4.09	.05	.63

