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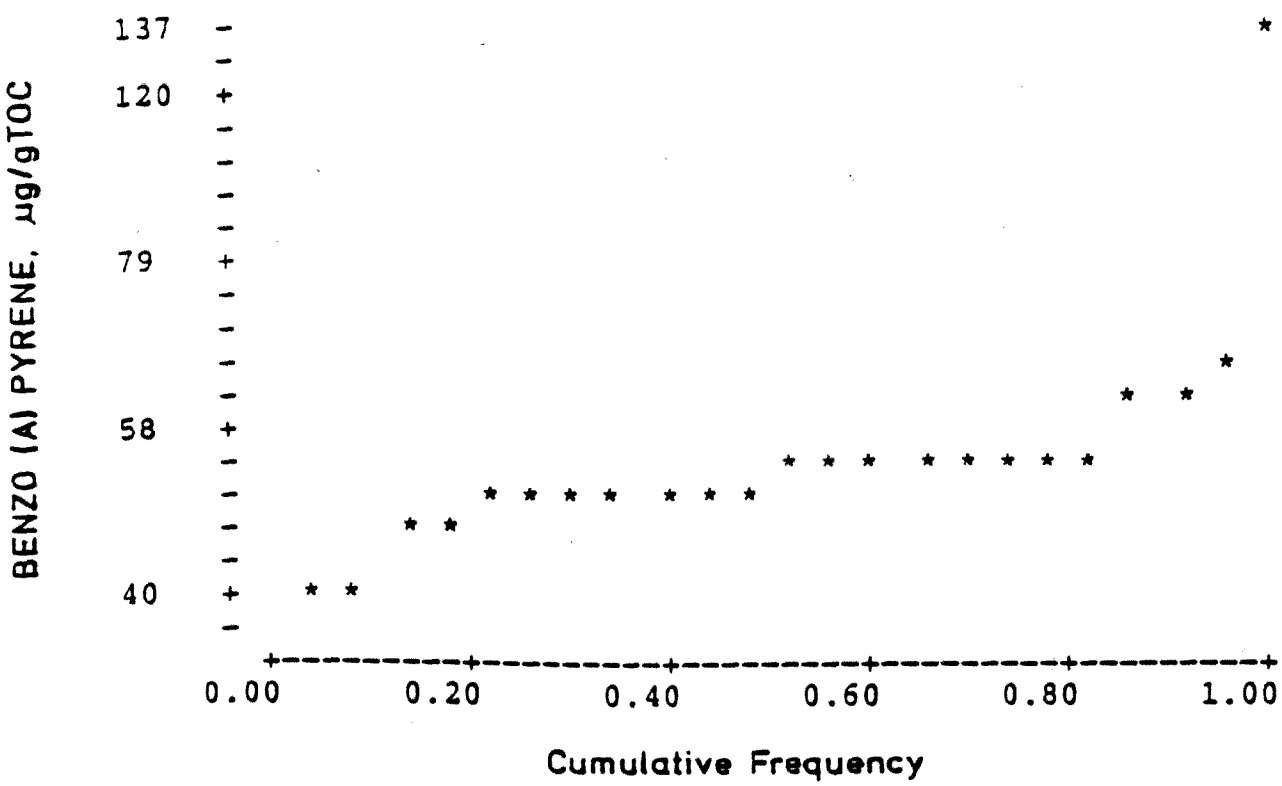
PROTOCOL FOR SEDIMENT TOXICITY TESTING FOR NONPOLAR ORGANIC COMPOUNDS



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Work Assignment 56, Task 1

April 1986

for
U.S. Environmental Protection Agency
Criteria and Standards Division
Washington, D.C.

Submitted by
BATTELLE
Washington Environmental Program Office
Washington, D.C.

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SEDIMENT CRITERIA METHODOLOGY VALIDATION

Work Assignment 56, Task 1

PROTOCOL FOR SEDIMENT TOXICITY TESTING OF NONPOLAR ORGANIC COMPOUNDS

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PROTOCOL FOR SEDIMENT TOXICITY TESTING OF NONPOLAR ORGANIC COMPOUNDS

1.0 SCOPE

This protocol outlines the methods to be used to evaluate the organic carbon normalization theory with respect to nonpolar organic compounds (NOC). The carbon normalization theory states that the toxicity of NOC to benthic infaunal organisms is determined by the total organic content of the sediment. Toxicity of NOC in the sediments is generally attributed to the compound found in the interstitial water, not adsorbed to the sediments. Sediments high in total organic carbon (TOC) have a greater capacity to adsorb NOC. The relationship between the concentration of NOC in sediments and interstitial water is defined by the aqueous solubility of the NOC, the octanal water partition coefficient (Kow), and the concentration of sediment TOC (Staples et al. 1985). As sediment TOC levels increase, the toxicity expressed per gram of sediment decreases. This relationship can be normalized by expressing the toxicity of the NOC in terms of the TOC level of the sediment.

The toxicant to be tested has been selected to maximize the potential for evaluating the influence of sediment TOC on toxicity. The three criteria are:

1. The reported median lethal concentration, or median effective concentration (LC50 or EC50, respectively), for 48- or 96-h acute toxicity tests with amphipods must fall at or below 20% of the reported solubility of the toxicant in water.
2. The sediment sorption coefficient (Koc) should be greater than 1,000 to ensure that the toxicant will establish reasonable concentrations in interstitial water to elicit a toxic response in the test organisms.
3. The toxicant must have a low vapor pressure, i.e., less than 0.001-mm mercury, to ensure that excessive volatilization does not cause a loss of toxicant when amending the sediment.

The nonpolar organic compounds lindane, endrin, and DDT meet these criteria (Guenzi and Beard 1974, Johnson and Finley 1980, Staples et al. 1985).

The general approach involves using a screening water column test to establish the toxicity of the toxicants in the water, a screening sediment toxicity test with three levels of sediment TOC to establish the range of sediment toxicant concentrations to be used in a definitive test, and the definitive sediment toxicity test to provide 10-day LC50 values for the toxicants at three levels of sediment TOC. The relationship between sediment TOC and toxicity will be used to evaluate the organic carbon normalization theory.

2.0 TEST ORGANISMS

The test organisms used are the amphipods Rhepoxynius abronius for marine tests and Hyallela azteca for freshwater tests.

2.1 ACCLIMATION

Test organisms must be acclimated before testing. The suggested method is to acclimate the organisms to each of the three sediment TOC levels to be tested. This acclimation eliminates the need for a sediment control treatment in the experimental design and provides a more direct evaluation of the influence of sediment TOC on the toxicity of nonpolar organic compounds. If the test organisms do not adapt to the different sediment types, they must be cultured on a suitable substrate, i.e., native sediment, and the substrate must be incorporated as an extra control treatment. This protocol assumes that acclimation of the test organisms to three different sediment TOC levels is possible. Sediments will be sieved as described in Section 3. The test organisms will be acclimated for at least 10 days to each sediment TOC, with only a residual level of mortality (less than 5%) during acclimation. Sediment acclimation will initially be attempted on a bench-scale level prior to committing the entire research population. Marine and freshwater species will be cultured under a 16:8-h light to dark photoperiod.

2.1.1 R. Abronius

R. abronius will be collected from clean areas of Puget Sound and/or the Strait of Juan de Fuca. Clean sediment from the collection site will be collected for maintaining initial cultures in the laboratory. Once acclimated to the laboratory, the cultures will be split into three groups for acclimation to the three sediment TOC levels. Sediment depth in the culture aquaria will be 2.5 cm. Cultures will be grown in seawater at 15°C under flow-through conditions (100 to 200 mL/min per 200-L aquaria). Cultures will be fed a diet consisting of Oregon moist pellets ad libitum once weekly. Feeding will be curtailed if excessive amounts of food accumulate on the bottom of the aquarium.

2.1.2 H. Azteca

Cultures of H. azteca will be reared and tested at the Environmental Protection Agency's laboratory in Corvallis, Oregon. Cultures are grown in oak leaves with well water adjusted to 200 mg/L total hardness. Organisms are fed newly hatched brine shrimp or Oregon moist pellets ad libitum once weekly. Excess food is not removed and feeding amounts will be curtailed when excessive amounts of food accumulate in the aquaria. Organisms are cultured at 20°C under flow-through conditions.

2.2 PROJECT REQUIREMENTS

A total of 5,050 organisms for either the freshwater or marine tests are needed to complete the project. Because brood-bearing females and immature ($\leq$2 mm) organisms are not tested, the test population will consist of three groups of 2,500 organisms acclimated to each of the three sediment TOC levels. The required number of organisms per test is summarized below.

1. Screening water column test. This test consists of 6 to 8 exposure treatments, including exposures of 5 to 7 dilutions of the toxicant and 1 control exposure. With 3 replicate beakers per treatment and 20 organisms per beaker, the test will require a maximum of 480 organisms.

2. Screening sediment test. This test may have a maximum of 7 exposure treatments for each sediment TOC level, including exposures to 5 dilutions of the toxicant, 1 control exposure, and a sediment control exposure if needed (see Section 6 for a complete description of the experimental design). Assuming 3 replicate beakers per treatment with 20 organisms per beaker, the total number of organisms required for testing 3 sediment TOC levels is 1,260. An additional reference water column test will be run concurrently with the sediment test, with 6 exposure treatments (including the control exposure), 3 replicate beakers per treatment, and 20 organisms per beaker, or a total of 360 organisms. Therefore, the maximum number of organisms required for the sediment screening tests is 1,620.

3. Definitive sediment test. This test may have a maximum of 7 exposure treatments for each sediment TOC level, including exposures to 5 dilutions of the toxicant, 1 control exposure, and a sediment control exposure if needed (see Section 6 for a complete description of the experimental design). Assuming 3 replicate beakers per treatment with 20 organisms per beaker, the total number of organisms required for testing 3 sediment TOC levels is 1,260. An additional reference water column test will be run concurrently with the sediment test, with 6 exposure treatments (including the control exposure), 3 replicate beakers per treatment, and 20 organisms per beaker, or a total of 360 organisms. Finally, 480 organisms will be used in the chemical monitoring beakers, so that a maximum of 2,100 organisms will be needed for the definitive sediment test.

3.0 SEDIMENT HANDLING

Sediments collected for this study should have the largest possible range in TOC. The sediments must not contain toxic compounds because interactions with other sediment-bound toxicants would prevent the development of a sound relationship between sediment TOC and the test toxicant concentration. The desired range of freshwater sediment TOC levels is 2%, 10%, and 20%; the range for marine sediments is 0.5%, 2.5%, and 5%. Measured TOC levels should fall within 10% of these specified TOC levels. Several lots of sediment will be collected to ensure that a broad range of sediment TOC is available. Ideally, sediments with the desired TOC levels (after sieving) will be collected. If it is not possible to locate and collect sediments with high TOC levels that are not contaminated with oil, grease, and other types of anthropogenic pollution, then two alternative methods to obtain the desired levels of sediment TOC may be evaluated. In the first method, sediments of high and low TOC would be mixed to obtain the desired TOC level. In the second method, sediments that are highly enriched with TOC could be mixed in very small amounts with sediments that are low in TOC to achieve the desired test sediment TOC level. The advantage to the second method is a consistent particle size distribution among the test sediments. The method will be chosen after experience has been gained in culturing the organisms in sediments of different TOC, and after the range of sediment TOC levels available for testing has been determined.

3.1 COLLECTION AND STORAGE OF SEDIMENT

An effort will be made to collect sediments from sites that have been minimally influenced by industrial, agricultural, or domestic sewage effluents. Notes will be taken during collection about the presence of biota, oil, or grease in the sediment, the odor of the sediment, or other abnormal characteristics of the sediment.

The sediment will not be collected from a depth greater than 15 cm and must appear to be uniform in texture and color. Sediment will be stored on ice while in transit from the field to the laboratory. Five-gallon plastic

buckets with plastic lids will be used for transporting and storing the sediment. The sediment will be stored at 4°C with no more than 1 cm of water overlaying the surface of the sediment.

3.2 SIEVING OF SEDIMENT

Sediment will be wet sieved with a 1.0-mm sieve to remove gravel and other coarse debris. After a batch of sediment has been sieved, it will be thoroughly mixed with a spatula and subsampled for TOC analysis. Resulting sieved sediment will be predominately fine sand (<0.2 mm) to silt (>0.005 mm), with a low clay (<0.002 mm) content (<5%). The actual particle size distribution of the sediments will be determined for the sediments used for test organism acclimation and testing. Particle size characterization will be determined for the sand, silt, and clay fractions. The primary criteria for use of a sediment is that it contains the desired TOC and that the organisms can be cultured on it.

3.3 RECONSTITUTION OF SEDIMENT

If the sediment must be reconstituted to obtain a desired TOC level, the following formula can be used:

$$X \text{ g sed (low percentage of TOC)} + (Y-X)\text{g sed (high percentage of TOC)} = Y \text{ g sed (desired percentage of TOC)}$$

In this formula, the desired weight of the sediment (Y) and the desired percentage of TOC are determined by the investigator and the percentage of TOC of the two available sediments is determined by analysis. Enough sediment must be prepared for culture of the amphipods and sediment testing. Each batch of sediment must be wet sieved at 1.0 mm prior to reconstitution. The sediment TOC of the reconstituted sediment must be verified before acclimating the test organisms and sediment toxicity testing.

The reconstituted sediment must be thoroughly mixed before being dispensed into tagging flasks. A proposed method of mixing the sediment is to simultaneously pass equal amounts (200 to 400 g) of each sediment through a

sieve into a glass battery jar. The sieved sediments should be mixed with a stainless steel or plastic spatula before adding the second batch of sediments. The process is repeated until a sufficient amount of reconstituted sediment (~1500 g) has been prepared. After the last batch of sieved sediments have been added to the jar, the entire mixture must be thoroughly mixed with a spatula to ensure homogeneity of the reconstituted sediment.

4.0 DILUTION WATER

The dilution water used for culturing test organisms and toxicity testing will be of such a quality that none of the water constituents will adversely affect the test organisms. The water used for culturing the test organisms will be of a constant quality. Dechlorinated tap water will not be used. Monthly fluctuations in pH will be $\pm$ 0.5 units, and will fall between 6.5 and 8.5 for freshwater and 7.5 to 8.5 for salt water. Dissolved oxygen will range from 80% to 100% saturation. Other routine water quality measurements (EDTA hardness, conductivity, alkalinity, dissolved organic carbon) should not vary by more than 10% on a monthly basis.

The dilution water used is assumed to be the supply normally used by the laboratory to culture and test aquatic organisms. Water quality data indicating the acceptability of the dilution water will be provided in historical records of water quality monitoring for basic water quality parameters, or from recent analysis for inorganic and organic contaminants in the water. Specific analysis of water will include trace metal analysis for Al, As, Cd, Cr, Cu, Hg, Mn, Ni, and Zn. Organic analysis will include analysis for dissolved organic carbon, PCBs, toxaphene, total organophosphorus pesticides, total carbamate insecticides, and organochloride pesticides (DDT and metabolites, lindane, chlordane, dieldrin, and endrin). Dilution water will be judged acceptable if the metals do not exceed water quality standards for the protection of aquatic life, as developed by the Environmental Protection Agency (EPA), and the identified organic constituents do not exceed 50 ng/L. In lieu of these analyses, historical demonstration that Daphnia magna or D. pulex live and successfully reproduce in the freshwater dilution water or oyster larvae or other marine crustaceans endemic to the site of the laboratory can successfully reproduce in the marine dilution water may be used as criteria for acceptance of the water as a dilution source.

The marine water used for amending the sediments with toxicant and toxicity testing should be membrane filtered at 50 µm.

5.0 TOXICANT

The toxicant to be tested on this project will be DDT. Radiolabeled compounds will be used as a radiochemical tracer with the "cold" compound to enhance the ability to monitor the toxicant in the column water, interstitial water, and bound to the sediment. The radiolabeled compound will be mixed with appropriate amounts of a nonlabeled compound to produce a concentration of tracer at five times the limit of detectability (estimated at this time to be 250 dpm above background). The expected specific activity of the toxicant is 22.73 pCi ^{14}C-labeled DDT per ng "cold" DDT. A total of 30 mCi (15 per species tested) will provide an adequate amount of radiolabeled compound to complete the testing program.

6.0 EXPERIMENTAL DESIGN

Definitive toxicity tests will allow the comparison of the dose-response relationships (EC50 and slope of the response curve) of nonpolar organic compounds tested at three levels of TOC. Before the definitive tests, two screening tests will be performed to determine the toxicity of the compound in the water column, and to determine the range of exposure concentrations of the compound when adsorbed to sediment that will be used in the definitive sediment tests. The sediment adsorption coefficient for organic carbon (Koc) will be determined for each of the three concentrations of sediment TOC values during sediment tagging. Sediment Koc levels will be determined by counting the amount of radioactivity bound to the sediment and found in the interstitial water, as described in the next section under Sampling of Beakers. The Koc values and the EC50 value estimated from the water column screening test will be used to establish the range of sediment toxicant concentrations for the screening tests with sediments. During the second screening test, sediment toxicant concentrations at and around the predicted median lethal values will be tested for each sediment TOC level to verify that the predicted range of sediment toxicant concentrations brackets toxic concentrations of the sediment-sorbed compound. This screening test will also verify that a sufficiently broad range of sediment TOC levels was selected to test the carbon normalization theory.

6.1 SCREENING TESTS

The objective of the first screening test is to estimate the EC50 value of the toxicants in the water column. The median lethal concentration will be estimated from literature values. This may involve interpolation of acute and chronic data sets that span the 10-day test duration, or an extrapolation of acute test data. Depending on the amount of extrapolation required from the literature data, five to seven concentrations will be tested in the water column screening test. The range of test concentrations for five treatments will encompass at least 0.2, 0.6, 1.0, 1.6 and 5.0 times the estimated water column EC50. A tentative list of exposure concentrations based on toxicity data in Johnson and Finley (1980) is found in the next section under

"Procedure." The higher the uncertainty associated with the data base, the broader the range of test concentrations that will be used in the screening tests. Three replicate beakers with 20 organisms per beaker will be tested at each exposure concentration. Control treatments consist of three replicate beakers (20 organisms each) with dilution water amended with an amount of carrier solvent equal to that used in the highest test concentration. Ethanol will be used as a carrier solvent for the water column tests and will not exceed a concentration of 0.5 mL/L. Treatments will be randomly assigned to a grid with assignments made from a table of random numbers. The data will be analyzed to produce an EC50, slope of the dose-response curve, and associated 95% confidence intervals (Finney 1971, 1978).

The objective of the second screening test is to estimate the range of exposure concentrations of sediment-sorbed toxicant to be tested in the definitive tests. The EC50 value for each level of sediment TOC will be predicted from the water column EC50 and the Koc values (theoretical values from the literature (Staples et al. 1985), and empirical values determined when dosing the sediment with tagging flasks and the syringe method). Because the ratio of sediment to water used during sediment labelling is greater than that used to determine Koc values published in the literature, Koc values must be estimated for the labeled sediments (Section 7.1). Five toxicant doses bracketing the predicted EC50 sediment value will be tested. The initial range in doses will be 0.2, 0.6, 1.0, 5.0, and 10.0 times the predicted EC50 concentration for sediment. Additional treatments will be added if there is high variability in the Koc values used to establish the test sediment concentrations. The three test sediments will be tested at the same time; however, the addition of organisms to the exposure beakers may be staggered over three days if manpower restrictions won't allow the work to be completed in one day. Each treatment will consist of three replicate beakers containing 20 organisms each. Control treatments for each sediment will consist of three replicate beakers with the test sediment to which no toxicant has been added. The control sediment will undergo the same manipulations that the test sediments experience during tagging; however, only the carrier solvent will be added to the tagging flask. A control treatment with native (or culture) sediment will be included in the design if the organisms cannot be cultured in the test

sediment. All treatments for all three sediments will be randomly assigned to a grid. EC50 estimates and 95% confidence intervals will be calculated for each sediment TOC level tested (Finney 1971, 1978).

6.2 DEFINITIVE TESTS

The definitive sediment test will be similar to the screening tests. Sediments with the three levels of TOC will be tested at the same time. Five concentrations of toxicant for each sediment TOC level will be tested. Concentrations will be chosen that should theoretically produce 12%, 31%, 50%, 69%, and 88% mortality based on the data from the screening tests (Finney 1978). The number of replicates per treatment will be determined from the level of control mortality observed in the screening test (mortality of 5% to 15% in the control treatments will require 5 replicates; less than 5% mortality would require 3 or 4 replicates). Higher control mortality in the screening tests will require additional control beakers. Control mortality in excess of 15% will invalidate the test. A sediment control (tagged with carrier only) and a native (culture) sediment control (if the organisms cannot be acclimated to the three test sediments) will be included in the experimental design. All exposure and chemistry beakers will be randomly assigned to positions in a grid using a table of random numbers.

6.3 REFERENCE TOXICANT (INTERNAL CONTROL)

During the screening and definitive sediment tests, water column tests with the test compound will be conducted. The tests will provide information on any changes in the sensitivity of the test organisms to the toxicant over the duration of the project. The test will consist of five exposure concentrations designed to theoretically produce 12%, 31%, 50%, 69%, and 88% mortality and a control treatment (dilution water). These levels of mortality are predicted from the slope of the toxicity curve established in the screening water column test and are not criteria for acceptance. There will be three replicate beakers with 20 organisms per beaker for each treatment. The beakers will be randomly assigned to positions in the grid used in the sediment toxicity test and loaded in sequence with the sediment test beakers.

6.4 DATA ANALYSIS

Data will be analyzed using techniques described in Finney (1971, 1978). After a linearizing transformation, the dose-response lines from the three types of sediment will be compared for parallelism. Nonparallelism of the lines will indicate different modes of action of the toxicant (i.e., potential interactions with sediment TOC or an undefined effect due to other differences in the sediments). The EC50 values of the toxicant for each sediment TOC will be calculated and used to evaluate the carbon normalization theory. In the event that the data cannot be linearized by any of the routinely used transformations, the data will be analyzed using the Spearman-Karber method (Hamilton et al. 1977).

7.0 PROCEDURE

Three tests will be conducted under this protocol: a screening water column test, a screening sediment toxicity test, and a definitive sediment toxicity test. Theoretical test concentrations of DDT (based on data in Johnson and Finley 1980 and an arbitrary 96-h LC50 value of 1.0 µg/L) for the water column and screening sediment toxicity test are listed in Table 7.1. Only a 10% sediment TOC level is listed. [Consult Staples et al. (1985) to determine the actual amounts of toxicant to be added to each sediment TOC level.] The final selection of test concentrations for the screening and definitive sediment toxicity tests depends on the results of the water column tests and the partitioning of the toxicants during sediment labeling. The 2.5 and 0.1-µg/L test concentrations are optional.

TABLE 7.1. Exposure Concentrations of DDT

Screening Water Column Test (µg/L)	Screening Sediment Toxicity Test[a] (µg toxicant/kg sediment)	Definitive Sediment Toxicity Test (µg toxicant/g sediment)
5.0	40,230	To be determined
2.5	20,120	To be determined
1.6	12,875	To be determined
1.0	8,046	To be determined
0.6	4,830	To be determined
0.2	1,610	To be determined
0.1	805	To be determined
control	0	0

(a) Assumes a Kp of 8,046 for 10% TOC (Staples et al. 1985)

The water column tests will be conducted following routine methods for acute toxicity testing (ASTM 1980). The exposure system includes 700 mL of exposure solution in 1-L beakers with aeration. Exposure solution will be replaced when the concentration of DDT drops below 90% of the desired value. This may occur due to volatilization and adsorption to the surfaces of the glass beakers.

7.1 SEDIMENT DOSING

Sediment is dosed with the toxicant (including the radioactive tracer) in 1,500-mL batches in 2.8-L Fernback flasks (tagging vessel). Acid bottles placed on rollers can be used as tagging vessels as an alternative to using Fernback flasks. The acid bottles may be used if laboratory shakers cannot be used for tagging. The amount of radiolabeled compound added is determined by the Koc for the compound, the organic carbon content of the sediment, and the expected LC50 based on the toxicity of the compound in water.

The toxicant (with radiolabeled tracer) is dissolved in a carrier solvent (ethanol or methylene chloride), added to a tagging vessel and swirled onto the bottom and lower walls of the vessel by gently rotating the vessel. Nitrogen (500 mL/min) is added to purge the evaporated solvent. The flask is tagged in a HEPA-filtered hood. Once the toxicant has been tagged, the sediment may be labeled outside of the hood. When labeling sediments, toxicant solutions will be prepared so that equal volumes of carrier-toxicant solution are added to each tagging flask. After the carrier solvent has evaporated, a 4:1 slurry[(a)] (1,500 mL) of sediment and dilution water is added to the flask and placed on a rotating shaker at sufficient revolutions per minute to keep the sediment suspended (120 rpm). The tagging continues for 7 days or until equilibrium has been reached.

The concentrations of radiolabeled compounds in the water and sorbed to the sediment are determined daily to verify that equilibrium has been reached. Two measurements of the slurry are required to determine equilibrium: 1 mL of water filtered at 0.45 µm and a sediment-sorbed toxicant measurement. The second measurement is done by placing a filter pad with sediment in a 13-mL glass centrifuge tube (with screw cap) and adding 5 mL of methylene chloride to the tube. The solution is sonicated for 5 minutes in a water bath sonicator and centrifuged at 10000 x g. The supernatant is decanted into a 50-mL volumetric flask. The process is repeated three times and the combined extracts are taken to 50 mL in the flask with the methylene chloride. A 1-mL

(a) This ratio is different from the ratio used to determine Kp and Koc values in the laboratory and may result in a lower Kp value for this particular system.

subsample is transferred to a liquid scintillation vial, amended with a 20-mL scintillation cocktail, and analyzed on a liquid scintillation detector. Equilibrium is indicated by three consecutive values differing by less than 10% in the filtered water and sediment samples.

The day before the test,[a] 175 mL of sediment are transferred to a 1,000-mL Pyrex beaker and overlayed with approximately 700 mL of dilution water. A plastic disk cut from black plastic sheeting is laid over the sediment to minimize disruption and suspension when the dilution water is added to the beaker. A separate plastic disk will be prepared for each treatment (i.e., level of dosed sediment). A nylon monofilament line is attached to the disk to facilitate its removal from the beaker.

After the sediment and water have been added to each beaker, they are placed in their proper position in the grid and aeration initiated.

7.2 LOADING TEST ORGANISMS

An adequate number of test organisms for a test must be collected from the culture aquaria and pooled to prevent bias in the allocation of organisms to exposure beakers. Females with developing broods or immature animals ($\leq$ 2mm) will not be used for testing.

Both species of amphipod can be transferred to beakers with a glass tube (5.5 to 6.5 mm ID) and rubber bulb. Organisms used for testing will measure greater than 2 mm in length. Exposure beakers are loaded in groups of six in the order of their placement within the grid. To facilitate handling, groups of six beakers may be removed, but the order of loading will not be altered. Arbitrarily, the order is left to right and top to bottom starting with the upper left beaker.

To load the exposure beakers, test organisms are collected in lots of twenty and transferred to 50-mL pyrex transfer beakers filled with 40 mL of dilution water ($\pm$ 2°C of the desired test temperature). The test organisms are introduced into the exposure beaker by inverting the transfer beaker under

(a) Twenty-four hours may not be adequate for toxicant concentrations in the water to come to equilibrium with sediment levels. The 24 h equilibrium period may have to be extended.

the surface of the exposure solution, taking care to ensure that no organisms are left clinging to the side of the transfer beaker when it is removed. At this time, any organisms found floating on the surface of the water may be gently pushed beneath the surface with the transfer pipet by a drop of water on the organism, or by gently pushing the organism under the water with the edge of the pipet. This process is repeated until all the exposure beakers are loaded.

Each beaker containing organisms will be examined for floating or injured organisms one hour after loading. Floating and injured organisms will be replaced. A record will be kept for all beakers that receive new organisms and the number of new organisms added.

7.3 AERATION

Aeration is supplied to each beaker with a glass pasteur or 1-mL disposable pipet. The pipet tip is positioned between 2 and 3 cm above the sediment water interface. The air flow must not disturb the sediment and may be regulated with adjustable tubing clamps or needle valves. The air will pass through a glass wool and activated charcoal filter prior to delivery to the exposure beakers. Aeration is started when the beakers are placed in the grid, 24 hours before the addition of organisms.

7.4 PHOTOPERIOD

Lighting will be 16 h light to 8 h dark throughout the test.

7.5 TEMPERATURE

Test organisms are cultured and tested at the same temperature (i.e., 20°C for H. azteca and 15°C for R. abronius). Exposure beakers will be partially submerged in a constant temperature water table.

7.6 MONITORING OF MORTALITY

Exposure beakers will be observed once daily during the 10-day duration of the test. Under no circumstances will the sediment be disturbed or

resuspended during the exposure. Lighting and aeration will be checked daily. Temperature will be checked in a special beaker and continuously monitored in the water bath. Floating and emergent amphipods are noted as dead, alive, and/or moribund. Dead organisms are not removed.

7.7 TEST DURATION

Definitive and screening tests will run for 10 days.

7.8 TERMINATION OF TEST

On the tenth day, mortality will be determined in all beakers. Each beaker will be examined for emergent and floating amphipods (dead, moribund, and alive). A dead organism is one which shows no sign of movement. A moribund organism is one that cannot walk or swim in a normal manner, but can move its appendages when prodded. An organism is classified as alive if it can crawl or swim in a normal manner. To calculate an LC50, moribund organisms are considered alive. Test organisms are removed from the beaker by pipet before sieving. A 1-mm sieve is used to locate organisms that have burrowed into the mud. Total mortality is determined by adding the total dead organisms over the 10-day observation period. Missing organisms are assumed to have died and been eaten.

7.9 SEDIMENT CHEMISTRY MONITORING

Additional beakers will be set up to monitor sediment chemistry. Additional beakers are required because sampling would be stressful to the test organisms. Resuspension of the sediment would change the exposure of the test organisms to the sediment-bound toxicant. The additional beakers will be treated the same as the exposure beakers (i.e., they will receive test organisms, be aerated, be placed within the randomized grid, etc.). Three chemistry monitoring beakers will be prepared for the sediment control, high, middle, and low treatments for each level of sediment TOC tested. Radiochemical analysis will be performed on column water, interstitial water, and sediment at the first, fifth, and last day of exposure. Selected sediment and

water extracts collected at the end of the test from the highest exposure concentrations will also be analyzed by high-pressure liquid chromatography (HPLC) to check for breakdown of the toxicant.

7.10 SAMPLING OF BEAKERS

The chemistry monitoring beakers are removed from the water table to measure dissolved oxygen and pH in the water column. A 1-mL sample of column water is removed, transferred to a liquid scintillation vial, amended with a 20-mL scintillation cocktail, and analyzed with a liquid scintillation detector. For selected chemistry beakers, the column water is siphoned into a separate container for extraction and HPLC analysis of the toxicant. Care is taken to minimize the resuspension of sediment during siphoning. To prevent contamination of the water sample, the beaker will be slowly tipped to one side, and the last 10 to 20 mL of water will be removed and discarded with a pipet. All surviving and dead organisms are removed and tabulated from any sediment that undergoes sample processing.

A 40-g subsample of the sediment is transferred to a tared, glass centrifuge tube, weighed, and centrifuged at 64,000 x g for 10 minutes at 4°C. One milliliter of supernatant which is assumed to be interstitial water is removed with a pipet, transferred to a liquid scintillation vial, amended with a 20-mL scintillation cocktail, and analyzed for toxicant with a liquid scintillation detector. The remaining supernatant can be decanted into a vial and saved as a backup sample in case the original sample is lost.

The remaining sediment is divided into three samples. Two 4- to 5-g samples are retained for dry weight determinations. The remaining sediment (10 ± 2 g) is extracted three times with methylene chloride (10 mL solvent per gram of sediment). A 10-g sediment sample should be amended with 50-g anhydrous sodium sulfate (Na_2SO_4) to adsorb water in the sediment. The three extracts are combined and concentrated to 5 mL under nitrogen. A 1-mL subsample (or an appropriate dilution) of the extract is analyzed by liquid scintillation to estimate the amount of labeled compound present in the sediment. The remaining extract may be analyzed by HPLC/gas chromatography (GC) for the presence of breakdown products. A standard operating procedure will

be written based on the operating instructions for the particular instrument used and the authentic standards used in the analysis. The level of effort committed to this activity depends on available funding for the project. Alternatively, sediment samples may be analyzed for ^{14}C labeled DDT in a sample oxidizer; however, selected samples will be extracted for HPLC/GC analysis.

7.11 WATER COLUMN MONITORING

Dissolved oxygen (DO) will be monitored daily in the chemistry monitoring beakers with a YSI DO meter and in all exposure beakers at the end of the test. Water samples (1 mL) will also be taken from each exposure beaker immediately before the test organisms are added and at the termination of the exposure. The 1-mL water samples will be collected in scintillation vials, amended with a 20-mL scintillation cocktail, and analyzed for the presence of toxicant in a liquid scintillation detector.

8.0 QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance (QA) and quality control (QC) will be guaranteed by the implementation of a rigorous QA plan following the EPA/ORD 16-point format or its equivalent. Responsibility for the QA/QC plan lies with the project manager for each respective research facility where the research is conducted.

9.0 MATERIALS AND EQUIPMENT

Generally, plastics and rubber should not be used when they may come in contact with exposure solutions or exposure sediments that have been amended with the toxicant. Stainless steel, Teflon, and glass are the preferred materials.

Materials

1-L beakers	180
50-mL beakers	10
1-mL pipets (aeration)	300
Tagging flasks	20
Scintillation vials	2000
Scintillation cocktail (1-gal bottles)	10
Tygon tubing (1/8 in. ID; ft)	250
Needle valves/tubing clamps	180
Plastic buckets and lids (5-gal)	6
Centrifuge tubes (50-mL)	25
Radiolabeled compound (mCi)	15
"Cold" compound (g)	50
Sheet plastic (sq. ft)	6
Monofilament line (ft)	50

Equipment

Water table (4' x 6' minimum)
Dissolved oxygen meter
pH meter
HPLC/GC
Sonicator
Liquid Scintillation Counter
Temperature recorder
Drying oven
Refrigerated centrifuge
Culture aquaria/tanks
Sieve (1.0-mm)
Well-stocked laboratory

10.0 REFERENCES

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EPA

IMENT QUALITY CRITERIA VALIDATION: CALCULATION OF SCREENING LEVEL CONCENTRATIONS FROM FIELD DATA

FINAL REPORT

SEDIMENT QUALITY CRITERIA METHODOLOGY VALIDATION: CALCULATION OF SCREENING LEVEL CONCENTRATIONS FROM FIELD DATA

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ABSTRACT

The U.S. Environmental Protection Agency, Criteria and Standards Division has initiated an effort to develop sediment quality criteria. Sediment quality criteria are to be used in conjunction with water quality criteria to protect U.S. freshwater and saltwater bodies and their uses. Sediment quality criteria are needed because credible national water quality criteria alone are not sufficient to ensure protection of aquatic ecosystems consistent with provisions of the Clean Water Act.

EPA is evaluating several different approaches to developing technically sound and defensible sediment quality criteria. The Screening Level Concentration (SLC) approach is one of the approaches EPA is evaluating. The objectives of the investigation described in this report are to evaluate the SLC approach empirically for nonpolar organic contaminants in sediments and to assess its strengths and weaknesses for use in conjunction with other methods for deriving sediment quality criteria.

The SLC approach uses field data on the co-occurence in sediments of benthic infaunal invertebrates and different concentrations of the nonpolar organic contaminant of interest. The SLC is an estimate of the highest concentration of a particular nonpolar organic contaminant in sediment that can be tolerated by approximately 95 percent of benthic infauna. As such, the SLC value could be used in a regulatory context as the concentration of a contaminant in sediment which, if exceeded, could lead to environmental degradation and therefore would warrant further investigation.

To calculate a SLC, large databases are required that contain synoptic observations of the concentrations of the specific nonpolar organic chemicals of interest in the sediments, concentrations of total organic carbon in the sediments, and the species composition of the benthic infauna. A cumulative frequency distribution of all stations at which a particular species of infaunal invertebrate is present is plotted against the organic carbon-normalized concentration in sediment of the contaminant of interest. The concentration of the contaminant at the locus representing the 90th percentile of the total number of stations at which the species was present is estimated by interpolation and termed the species screening level concentration (SSLC). Next, SSLCs for a large number of species are plotted as a frequency distribution. the concentration above which 95 percent of the SSLCs are found is termed the SLC.

SLCs were calculated in this way for five contaminants in freshwater sediments (total polychlorinated biphenyls, DDT, heptachlor epoxide, chlordane, and dieldrin) and nine

contaminants in saltwater sediments (total polychlorinated biphenyls, DDT, naphthalene, phenanthrene, fluoranthene, benz(a)anthracene, chrysene, pyrene, and benzo(a)pyrene). Freshwater SLCs ranged from 0.008 ug/g sediment organic carbon for heptachlor epoxide to 0.290 ug/g sediment organic carbon for total PCBs. Saltwater SLCs ranged from 4.26 ug/g sediment organic carbon for total PCBs to 43.4 ug/g sediment organic carbon for pyrene. There are several possible reasons for the large differences in the freshwater and saltwater SLC values. The most important probably is the differences in ranges of organic carbon normalized contaminant concentrations in sediments covered by each database. The concentrations of contaminants in freshwater sediments tended to be low as evidenced by the many zero contaminant values. The saltwater database tended toward more highly contaminated sediments. Based on these observations, the freshwater SLC values may be conservative and the saltwater SLC values may be too high.

the SLC approach has demonstrated sufficient merit to warrant further evaluation and elaboration . Given a large enough database and minor modifications to the methods for calculating SSLCs and SLCs, the approach will provide a conservative estimate of the highest organic carbon normalized concentrations of individual contaminants in sediments that can be tolerated by approximately 95 percent of benthic infauna. It is essential that the database contain organic carbon normalized concentrations of the sediment contaminants of interest that span a wide range (preferably two orders of magnitude or more) and include values from locations known to be heavily contaminated. Low and intermediate sediment contaminant concentrations are also needed to ensure that pollutant-sensitive species are not excluded from the analysis. High values are needed to ensure that benthic communities are in fact being adversely affected at some stations by the contaminant of interest. Before SLCs can be used in a regulatory context, the databases upon which they are based must be subjected to a rigorous quality assurance review. Both the biological and the chemical data should be evaluated for accuracy, comparability, and representativeness.

SEDIMENT QUALITY CRITERIA METHODOLOGY VALIDATION: CALCULATION OF SCREENING LEVEL CONCENTRATIONS FROM FIELD DATA

1.0 INTRODUCTION

1.1 BACKGROUND

The U.S. Environmental Protection Agency, Criteria and Standards Division (EPA-CSD) has initiated an effort to develop sediment quality criteria. Sediment quality criteria are to be used in conjunction with water quality criteria to protect U. S. freshwater and saltwater bodies and their uses, including fisheries, recreation, and drinking water.

Sediment quality criteria are needed because credible national water quality criteria alone are not sufficient to ensure protection of aquatic ecosystems consistent with provisions of the Clean Water Act. Section 304(a) of the Clean Water Act authorizes EPA to develop and implement sediment criteria analogous to EPA's water quality criteria (Gilford and Zeller, 1986). Many instances have been recorded in recent years of environmental degradation or unacceptable environmental quality in freshwater and saltwater ecosystems in which water quality criteria have not been exceeded. Probable explanations are that: 1) contaminated sediments can serve as reservoirs for continual recontamination of the overlying water column (ie., Larsson, 1985); and 2) aquatic organisms interact with sediments either directly through physical contact or indirectly through consumption of food organisms that are intimately associated with sediments, and through this mechanism may become contaminated with pollutants associated with sediments (ie., Pavlou and Dexter, 1979; Varanasi et al., 1985). Thus, to prevent environmental degradation, specific protection limits are required for both aqueous and sediment phase contaminant concentrations.

The development of technically sound sediment quality criteria that can be applied widely to sediments from different sources is a difficult task. Chemical contaminants interact in complex, often poorly understood ways with sediment particles and may be present in sediments in a variety of adsorbed or solid forms. As a general rule, chemical pollutants associated with sediments are much less bioavailable and toxic to aquatic organisms than the same pollutants in solution in the water (Neff, 1984; Lake et al., 1985). However, there is no known simple relationship between the concentration of a contaminant in sediment and its toxicity to aquatic organisms in contact with that sediment.

EPA, in recognition of the complexity of the sediment contamination problem, has adopted a phased approach to

developing sediment quality criteria. In the first phase, EPA sponsored two Sediment Quality Criteria Workshops, the first in November 1984, and the second in February 1985. At the workshops, experts on sediment chemistry and toxicology identified and described several approaches or strategies for deriving sediment quality criteria for three classes of chemical contaminants: nonpolar organics, heavy metals, and polar organics. EPA-CSD currently is supporting several research projects to evaluate and refine some of the methods proposed at the workshop for developing sediment quality criteria. The results of an evaluation of one of those methods, the Screening Level Concentration (SLC) approach, is the subject of this report. These SLCs will be used with data generated by other tasks in the sediment criteria program dealing with elaboration of sediment normalization theory and development of solid phase bioassay protocols for nonpolar organic chemicals to develop a method for deriving sediment quality criteria.

The objectives of the investigation described in this report are to evaluate the SLC approach empirically and to assess its strengths and weaknesses for deriving sediment quality criteria. The SLC approach was evaluated by using several existing databases to derive a minimum of five SLCs each for freshwater and saltwater sediments.

1.2 THE SCREENING LEVEL CONCENTRATION APPROACH

The screening level concentration approach uses field data on the concentration of specific nonpolar organic contaminants in sediments and the presence of specific taxa of benthic infauna in that sediment to calculate screening level concentrations (SLCs). The SLC is defined here as the concentration of a nonpolar organic contaminant in sediment which, if exceeded, could lead to environmental degradation and therefore would warrant further investigation. It is an estimate of the highest concentration of a particular nonpolar organic pollutant in sediment that can be tolerated by approximately 95 percent of benthic infauna. The SLC approach is consistent with the strategy that assessments of sediment quality must involve at a minimum measurements of concentrations of toxic chemicals in the sediments, toxicity of the sediments to representative infauna, and evidence of modified resident infaunal community structure in the contaminated sediments (Chapman and Long, 1983; Long and Chapman, 1985).

Before an SLC can be derived, a large database must be compiled. This database must contain synoptic observations of the concentrations of the specific nonpolar organic chemicals of interest in the sediments, concentrations of total organic carbon in the sediments, and the species composition of the benthic infauna.

In the first step of the calculation, a cumulative frequency distribution of all stations at which a particular

species of infaunal invertebrate is present is plotted against the organic carbon-normalized concentration in sediment of the contaminant of interest. The concentration of the contaminant at the locus representing the 90th percentile of the total number of stations at which the species was present is estimated by interpolation and termed the species screening level concentration (SSLC). Next, SSLCs for a large number of species are plotted as a frequency distribution. The concentration above which 95 percent of the SSLCs are found is termed the SLC.

This approach to developing sediment quality criteria has several intuitively appealing attributes. It makes use of field data on the coexistence of specific levels of sediment contamination and a resident infauna, making extrapolations from laboratory to field conditions unnecessary. It utilizes data on only the presence of species in sediments containing given concentrations of contaminants. Thus, no a priori assumptions are made about a causal relationship between levels of sediment contamination and the distribution of infaunal populations. Because no causal relationship is assumed, it is not necessary take into account the wide variety of natural environmental factors, such as water depth, sediment texture, and salinity, that affect the composition and distribution of benthic infaunal communities. However, because the method uses actual observations from the field of the co-occurence in the sediments of multiple species of benthic infauna and concentrations of contaminants, valid a posteriori inferences can be made about the range of contaminant concentrations in the sediment that the benthic infauna can tolerate.

Nearly always, contaminated sediments contain more than one contaminant at an elevated concentration. The infauna resident in the contaminated sediments, as well as the populations that have been eliminated from the contaminated sediments, are responding to the multiple contaminants present and not just to the contaminants of interest. The SLC approach can not take into account multiple contimant interactions in sediments. As a result, the SLC value for a particular contaminant will tend to be conservative (eg., lower than the benthic infauna could tolerate if the contaminant of interest was the only contaminant present in the sediment). Because the mix and relative proportions of different contaminants present in the sediments will vary substantially from location to location, this conservative bias in the SLC will tend to decrease as the number of observations upon which SSLCs are based is increased.

SLCs are calculated from organic carbon-normalized contaminant concentrations rather than concentrations in bulk sediment. This normalization is based on the premise, supported by much theory and experimental data, that bioavailability of nonpolar organic pollutants from sediments is dependent upon the organic carbon content of the sediment, the lipid content of the organism, and the relative affinities of the chemical for sediment organic carbon versus animal lipid (Karickhoff and

Morris, 1986; Kadeg et al., 1986). A nonpolar organic contaminant will be distributed among three phases, the sediment organic fraction, the tissue organic fraction, and the sediment pore water, in proportion to the respective sediment organic carbon-water and tissue lipid-water partition coefficients of the contaminant. Thus, the bioavailability and, by inference, the toxicity of a nonpolar organic pollutant in sediment will be proportional to the ratio of the partition coefficient of the pollutant in the tissue organic fraction of the animal to the partition coefficient of the pollutant in the sediment organic fraction, and the sediment organic carbon concentration.

1.3 GENERAL DATA REQUIREMENTS

Large databases containing information on the biology and chemistry of surficial sediments from freshwater and saltwater ecosystems are required for the calculation of screening level concentrations (SLCs). The calculation of an SLC for a given nonpolar organic contaminant requires data bases containing matched (synoptic if possible) observations of species composition of benthic infauna, concentration of the organic contaminant of interest in the sediment, and concentration of total organic carbon in the sediment. Sediment grain size data also are useful, but not essential. At a minimum, 20 observations of the presence of a particular species in sediments containing different concentrations of the contaminant of interest are required for calculation of a species screening level concentration (SSLC). A minimum of ten SSLCs are required to calculate an SLC. These numbers were chosen somewhat arbitrarily for the initial evaluation of the SLC approach.

The benthic infauna should be identified to species. A limited number of identifications to only the genus level are acceptable if a majority of the infauna in the database are identified to species. Data sets containing only higher level taxonomic identifications (e.g., family, order, class) are not acceptable. Due to time and budget constraints, only a superficial attempt was made during the course of this study to assure the accuracy and consistency of the taxonomy within and among data sets. Several taxonomic discrepancies were discovered during this review and recalculation of SLCs based on the revised species lists did not modify the SLCs significantly.

Data also are required on the concentration of the specific nonpolar organic contaminant of interest in sediment from the same location as the benthic data, and preferably collected at the same time, as the biota sample. The chemical contaminant must be identified specifically. Data for broad generic pollutant classes (e.g., total petroleum hydrocarbons, oil and grease, total organohalogens, etc.) are not used. However, narrower designations of chemical class (e.g., total PCBs, total polycyclic aromatic hydrocarbons, DDT and major degradation products, etc.) are acceptable.

Data also are required on the total organic carbon (TOC) concentration of the same sediments used for analysis of benthic infauna and organic contaminant concentrations. If TOC values are not available, measurements that can be converted readily to TOC (e.g., total volatile solids, total organic matter, or total sediment carbon for noncarbonate sediments) are acceptable.

Due to the preliminary nature of this approach, databases were sought which fulfilled the aforementioned minimum criteria. These databases were not subjected to any extensive quality assurance review, nor were the QA/QC backgrounds of the databases evaluated. Lacking this more extensive review, SLCs developed using these data sources will be illustrative of the validity of the approach, but are not proposed at this stage of development for regulatory purposes. Before SLCs could be used in a regulatory context, the methodology used to collect and assess geological, chemical, and biological data would require a comparability assessment. Inconsistencies in taxonomic identifications, for instance, may affect SLC values, yet only a superficial review of taxonomic criteria has been conducted in this study. A more thorough review of the biological, chemical, and geological data may also result in refinements to and improvements in the sensitivity of the SLC methodology.

2.0 MATERIALS AND METHODS

2.1 ACQUISITION OF FRESHWATER DATA

The freshwater data sets used in this study were located by systematically contacting various government agencies, private consulting firms, and universities, and by searching the open literature. Government agencies contacted included the U.S. Environmental Protection Agency (ten regions), U.S. Army Corps of Engineers (Division and District offices), Ohio EPA, International Joint Commission, and Environment Canada. Approximately 120 individuals were interviewed in these organizations during the initial data search. Results of this preliminary survey indicated that the greatest amount of usable and accessible information appeared to be available for the Great Lakes region. A concentrated search in this geographic area revealed the following sources of acceptable data: the Region V Office of the U.S. EPA, Office of Federal Information, Chicago, IL; the Illinois Environmental Protection Agency; the Buffalo District of the U.S. Army Corps of Engineers; and the Ministry of Environment, London, Ontario, Canada.

These sources yielded approximately 125 data sets which were evaluated based on the data requirements described previously to determine if they should be included in the analysis. Based on the data requirements, sufficient data were available in the freshwater databases for calculating freshwater screening level concentrations for DDT, total polychlorinated biphenyls (PCBs), dieldrin, chlordane, and heptachlor epoxide.

The database compiled for calculating freshwater SLCs consisted of 80 individual data sets representing 323 separate sampling stations. Sampling stations were located in six states (Table 1), with a majority of stations located in Illinois (97 sites or 30 percent of the total) and Michigan (95 sites or 30 percent of the total). The remaining 40 percent of the stations were from Indiana (21 stations), New York (28 stations), Ohio (50 stations), and Wisconsin (32 stations). Data from both lotic and lentic ecosystems were included in the analysis.

Sufficient data were available in the freshwater data sets to calculate a screening level concentration for five conpounds: DDT, PCBs, dieldrin, chlordane, and heptachlor epoxide.

2.2 ACQUISITION OF SALTWATER DATA

Potentially useful saltwater data sets were identified by searching a computerized inventory of marine pollution monitoring programs. This inventory was recently prepared by Battelle for NOAA-Ocean Assessment Division. The focus of the data search was on three U.S. coastal regions for which large databases that contained relevant information were thought to

exist: the New York Bight; the southern California Bight; and Puget Sound. Several potentially applicable data sets were identified in this inventory. The group that sponsored or performed the data collection was contacted to determine the suitability and availability of the data sets. Government agencies contacted included the U.S. Environmental Protection Agency (Regions 1,2,9, and 10), the National Oceanic and Atmospheric Administration, the U.S. Army Corps of Engineers, and the Minerals Management Service. Several sewage treatment districts of major metropolitan areas that discharge treated wastewater or sludge to the ocean were contacted. In addition, several consulting firms, universities, or individual investigators that were known to have performed or participated in marine benthic monitoring and assessment programs were contacted. Approximately 100 individuals or institutions were contacted by telephone or letter during this data search.

From these saltwater databases, a total of 19 field surveys or monitoring cruises were identified that contained data suitable for derivation of SLCs (Table 2). The 19 data sets contained data from 293 sampling stations. Nearly equal numbers of stations were located in each of the three regions. These sampling stations contained 114 species of benthic infauna identified to the species level. About 50 percent of these species occurred with sufficient frequency to be used for calculating an SSLC.

Sufficient data were available in the saltwater data sets to calculate a screening level concentration for nine compounds: DDT, PCBs, and the polycyclic aromatic hydrocarbons naphthalene, phenanthrene, fluoranthene, benz(a)anthracene, pyrene, chrysene, and benzo(a)pyrene.

2.3 CALCULATION OF SCREENING LEVEL CONCENTRATIONS (SLCs)

Separate SLCs were derived for freshwater and saltwater sediments and were based exclusively on the respective freshwater and saltwater databases. However, the procedures used to calculate freshwater and saltwater SLCs were the same.

First, we identified all the stations in the database at which the contaminant of interest was analyzed in the sediments. For each of these stations, we prepared a list of all species of benthic infauna that were present at that station. We then normalized contaminant concentrations to the total organic carbon concentration of the sediment at each station by the simple formula:

$$\text{TOC-normalized contaminant concentration (ug contaminant/g organic carbon)} = X/TOC$$

where X is the contaminant concentration in the bulk sediment (ug contaminant/kg sediment dry wt.), and TOC is the concentration of total organic carbon in the sediment (g organic carbon/kg

sediment dry wt.).

For each species that was present at 20 or more stations, we plotted the organic carbon normalized concentration of the chemical in the sediment for all samples (or stations) in which the species was present, versus the station number, proceeding from the least to the most contaminated station (Figure 1a). From this plot, we estimated the sediment contaminant concentration below which 90 percent of the samples containing the species occurred. This concentration was defined as the species screening level concentration (SSLC) of the contaminant. This procedure was repeated for each benthic species present in the data set at 20 or more stations, thereby generating a number of SSLCs for a given contaminant.

We then constructed a cumulative frequency distribution (based on rank, which in turn was based on the SSLC values) of all SSLCs for the contaminant (Figure 1b) and calculated the fifth percentile (the SSLC value above which 95 percent of all SSLCs fall) of that distribution by linear interpolation between the two nearest quantiles. This interpolated value was designated as the screening level concentration (SLC) of the contaminant.

Because the SSLCs for each contaminant were not normally distributed (Kolmogorov D-Statistic, α=0.05) (Sokol and Rohlf, 1969), standard statistical (distribution-free) techniques were used to calculate a confidence interval for the SLCs . Order statistics were employed to set a confidence interval for the fifth percentile of the SSLC cumulative frequency distribution for each contaminant. Confidence intervals were set using the binomial distribution as described by Mood et al. (1974). The interval that provided a confidence coefficient greater than 95 percent was chosen.

Estimates of the SLC were also made using the jackknife procedure (Quenouille, 1956) in an effort to set confidence intervals. However, this approach proved unsuitable. For example, the pseudo-variables generated for DDT by this procedure were not normally distributed (Shapiro-Wilk, w=0.625; n=21, ns, Shapiro and Wilk, 1965). Furthermore, the pseudo-variables gave negative estimates for the SLC.

3.0 RESULTS

3.1 FRESHWATER DATA

The freshwater database contained presence data for a total of 103 different infaunal invertebrate taxa. However, only a total of 23 species, representing seven families, orders or classes were present at a sufficient number of sampling stations to be included in the analysis. The freshwater benthic species used in the analysis included eight oligochaetes (annelid worms), five ephemeropterans (mayflies), three trichopterans (caddisflies), one chironomid (midge), one isopod (aquatic sow bug), two amphipods (scuds), and one gastropod (snail). For all five contaminants for which freshwater SLCs were calculated, the taxa found most frequently in the sample were Oligochaeta and Ephemeroptera.

The distribution of total organic carbon concentrations in freshwater sediments ranged from 5.0 to 366 g/kg dry wt. The ranges of concentrations of the five nonpolar organic contaminants in sediments, for which freshwater SLCs were calculated, are summarized in Table 3. In each case, the lowest concentration was below the detection limit of the analytical technique used and is given as zero. The distribution of total organic carbon, bulk contaminant concentrations, and organic carbon normalized contaminant concentrations were not normally distributed (Kolmogorov D-Statistic, with =0.05). In all cases, the range of organic carbon normalized concentrations of contaminants spanned at least one order of magnitude.

3.2 SCREENING LEVEL CONCENTRATIONS FOR CONTAMINANTS IN FRESHWATER SEDIMENTS

The values of the SSLCs for DDT, total PCBs, dieldrin, chlordane, and heptachlor epoxide in freshwater sediments are presented in Tables 4 through 8, and their cumulative frequency distributions are plotted in Figures 2 through 6. The confidence envelope around the cumulative distribution of the SSLCs, generated using the Kolmogorov D-Statistic, was approximately ± 30 - 40 percent. The cumulative frequency distributions from which the SSLCs for each contaminant were extracted are contained in the Appendix.

SSLCs for DDT were calculated for 21 freshwater species and ranged from 0.189 to 20.0 ug/g organic carbon (Table 4). The number of observations used to calculate each SSLC ranged from 20 to 56. The cumulative frequency distribution curve of the SSLCs showed an irregular concave shape and was dominated by low concentrations of DDT. Nearly 50 percent of the SSLCs were less than 0.35 ug/g organic carbon (Figure 2). The SLC for DDT in freshwater sediments is 0.190 ug/g organic carbon (confidence interval, 0.0 - 0.283, = 0.02). This SLC value is 0.005 percent of the highest normalized concentration of DDT in the database.

SSLCs for total PCBs were calculated for the same 21 species used to calculate freshwater SSLCs for DDT. The SSLCs ranged from 0.286 to 103.4 ug/g organic carbon (Table 5). The number of observations used to calculate each SSLC ranged from 20 to 56. The shape of the cumulative frequency distribution curve for the SSLCs was approximately linear, with PCB concentrations evenly distributed over the entire range (Figure 3). The SLC for total PCBs in freshwater sediments is 0.290 ug/g organic carbon (confidence interval, 0.0 - 0.65, α = 0.02). This SLC value is 0.05 percent of the highest normalized concentration of PCB in the database. Although their specific rank order was different, the species below the 50th percentile for both DDT and PCB were identical(Tables 4 and 5).

SSLCs for dieldrin were calculated for 16 freshwater species and ranged from 0.026 to 1.00 ug/g organic carbon (Table 6). The number of observations used to calculate each SSLC ranged from 23 to 56. The cumulative distribution curve of the SSLCs had a markedly sigmoid shape with most of the concentrations falling in the range of 0.12 to 0.26 ug/g organic carbon (Figure 4). The SLC for dieldrin in freshwater sediments is 0.021 ug/g organic carbon (confidence interval, 0.0 - 0.084, α = 0.04). This SLC value is 0.09 percent of the highest normalized concentration of dieldrin in the database. Four of the eight species present below the 50th percentile in the calculations for dieldrin were the same as for DDT (Tables 4 and 6).

SSLCs for chlordane were calculated for 16 species of freshwater animals and ranged from 0.124 to 8.51 ug/g organic carbon (Table 7). The number of observations used to calculate each SSLC ranged from 20 to 56. The distribution curve of the SSLC values was essentially flat from the origin to the 63rd percentile, above which the values increased sharply (Figure 5). The SLC for chlordane in freshwater sediments is 0.098 ug/g organic carbon (confidence interval, 0.0 - 0.136, α = 0.04). This SLC value is about 0.01 percent of the highest normalized concentration of chlordane in the database. With the exception of the oligochaete, Peloscolex ferox, all species present below the 50th percentile were the same as for DDT (Tables 4 and 7).

SSLCs for heptachlor epoxide were calculated for 12 freshwater species and ranged from 0.013 to 4.88 ug/g organic carbon (Table 8). The number of observations used to calculate each SSLC ranged from 23 to 56. The cumulative distribution curve of the SSLCs was dominated by values less than 0.053 ug/g organic carbon (Figure 6). The SLC for heptachlor epoxide in freshwater sediments is 0.008 ug/g organic carbon (confidence interval, 0.0 - 0.029, α = 0.02) This SLC value is 0.03 percent of the highest concentration of heptachlor epoxide in the database. With the exception of the oligochaete, Limnodrilus hoffmeisteri, all of the species below the 50th percentile were the same as for DDT (Tables 4 and 8).

3.3 SALTWATER DATA

The saltwater database contained data for the presence of a total of 117 species of marine benthic invertebrates. Of these, only 60 species were present at a sufficient number of sampling stations to be included in the analysis. The most abundant saltwater taxa used to calculate SLCs were the Polychaeta, followed by the Crustacea and Mollusca.

In the saltwater database, the concentration of total organic carbon in the sediments ranged from 0.31 to 303 g/kg. The highest value was somewhat anomalous, in that the second highest value was 160 g/kg. The range in the concentrations of the nine nonpolar organic contaminants in sediments, for which saltwater SLCs were calculated, are summarized in Table 9. In all cases the lowest concentration used was above the detection limit of the analytical technique. In addition, the range of concentrations of the organic carbon normalized contaminants spanned more than two orders of magnitude, for all nine contaminants.

3.4 SCREENING LEVEL CONCENTRATIONS FOR CONTAMINANTS IN SALTWATER SEDIMENTS

The values of the SSLCs for DDT, total PCBs, naphthalene, phenanthrene, fluoranthene, benz(a)anthracene, chrysene, pyrene, and benzo(a)pyrene in saltwater sediments are presented in Tables 10 through 18, and the cumulative frequency distributions of the SSLCs are plotted in Figures 7 through 15. The cumulative frequency distributions from which the SSLCs for each contaminant were calculated are contained in the Appendix.

SSLCs for DDT were calculated for 17 saltwater species from the Southern California Bight and ranged from 50.488 to 2069.586 ug/g organic carbon (Table 10). The number of observations used to calculate each SSLC ranged from 20 to 101. As reflected in the cumulative frequency distribution, there was a bimodal distribution of SSLC values for DDT, with nine of the values falling below 210 ug/g organic carbon and the remaining ten values falling above 1100 ug/g organic carbon (Figure 7). The SLC for DDT in saltwater sediments is 42.8 ug/g organic carbon (confidence interval, 0.0 - 113.7, α = 0.03). This SLC value is 0.6 percent of the highest normalized concentration of DDT in the saltwater database.

SSLCs for total PCBs were calculated for 51 saltwater species from the New York Bight and the Southern California Bight and ranged from 3.394 to 71.315 ug/g organic carbon (Table 11). The number of observations used to calculate each SSLC ranged from 20 to 109. The shape of the frequency distribution curve for the SSLCs was nearly linear, with PCB concentrations evenly distributed over the entire range of observed values (Figure 8). The SLC for total PCBs in saltwater sediments is 4.26 ug/g organic carbon (confidence interval, 0.0 - 4.63, α = 0.03). This

SLC value is 1.6 percent of the highest normalized concentration of PCBs in the saltwater database. Four of the five most tolerant species (highest SSLC values) were the same for both DDT and PCBs. None of the species used to calculate the saltwater SLC for DDT occurred below the 50 percentile concentration of SSLC values for PCBs.

SSLCs for naphthalene were calculated for 24 species of saltwater animals from the New York Bight and Puget Sound and ranged from 36.036 to 57.059 ug/g organic carbon (Table 12). The number of observations used to calculate each SSLC ranged from 20 to 55. The shape of the frequency distribution curve for the SSLCs was relatively linear, with naphthalene concentrations evenly distributed over the entire range of observed values (Figure 9). The SLC for naphthalene in saltwater sediments is 36.7 ug/g organic carbon (confidence interval, 0.0 - 41.4, α=0.03). This SLC value is 10.7 percent of the highest normalized concentration of naphthalene in the saltwater database.

SSLCs for phenanthrene were calculated for 25 species of saltwater animals from the New York Bight and Puget Sound and ranged from 22.368 to 75.0 ug/g organic carbon (Table 13). The number of observations used to calculate each SSLC ranged from 20 to 56. The shape of the frequency distribution curve was relatively linear, with phenanthrene concentrations nearly evenly distributed over the entire range of observed values (Figure 10). The SLC for phenanthrene in saltwater sediments is 25.9 ug/g organic carbon (confidence interval, 0.0 - 38.4, α= 0.03). This SLC value is 5.9 percent of the highest normalized concentration of phenanthrene in the saltwater database. Five of the six most sensitive species (lowest SSLC values) were the same for both naphthalene and phenanthrene(Tables 12 and 13).

SSLCs for fluoranthene were calculated for 26 species of saltwater invertebrates from Puget Sound and ranged from 36.184 to 164.384 ug/g organic carbon (Table 14). The number of observations used to calculate each SSLC ranged from 20 to 59. The cumulative distribution of SSLCs was skewed toward higher values, with 16 of the 25 values above 100 ug/g (Figure 11). The SLC for fluoranthene in saltwater sediments is 43.2 ug/g organic carbon (confidence interval, 0.0 - 64.3, α= 0.04). This SLC value is 9.8 percent of the highest normalized concentration of fluoranthene in the saltwater database. The two most sensitive species, the polychaetes Glycinde armigera and Prionospio cirrifera were the same for both naphthalene and fluoranthene (Tables 12 and 14).

SSLCs for benz(a)anthracene were calculated for 23 species of saltwater invertebrates from Puget Sound and covered a relatively narrow range from 24.348 to 51.802 (Table 15). The number of observations used to calculate each SSLC ranged from 20 to 57. The cumulative distribution of SSLCs was quite flat, with all but three values falling in the narrow range between 41 and

52 ug/g (Figure 12). The SLC for benz(a)anthracene in saltwater sediments is 26.1 ug/g organic carbon (confidence interval, 0.0 - 41.0, α =0.03). This SLC value is 7.1 percent of the highest normalized concentration of benz(a)anthracene in the saltwater database.

SSLCs for pyrene were calculated for 27 saltwater species from Puget Sound and ranged from 31.579 to 105.882 ug/g organic carbon (Table 16). The number of observations used to calculate each SSLC ranged from 20 to 58. The cumulative distribution of SSLCs was skewed slightly toward the high side, with half the values occupying the narrow range between 94 and 106 ug/g (Figure 13). The SLC for pyrene in saltwater sediments is 43.4 ug/g organic carbon (confidence interval, 0.0 - 74.4, α = 0.06). This SLC value is 5.6 percent of the highest normalized concentration of pyrene in the saltwater database. The three most sensitive species were the same for phenanthrene and pyrene (Tables 13 and 16).

SSLCs for chrysene were calculated for 23 saltwater species from Puget Sound and ranged from 35.652 to 76.471 ug/g organic carbon (Table 17). The number of observations used to calculate each SSLC ranged from 20 to 57. The cumulative distribution of SSLCs was relatively flat, with all but one value falling between 53 and 77 ug/g (Figure 14). The SLC for chrysene in saltwater sediments is 38.4 ug/g organic carbon (confidence interval, 0.0 - 60.5, α = 0.03). This SLC value is 10.3 percent of the highest normalized concentration of chrysene in the saltwater database.

SSLCs for benzo(a)pyrene were calculated for 23 saltwater species from Puget Sound and ranged from 39.604 to 137.386 ug/g organic carbon (Table 18). The number of observations used to calculate each SSLC ranged from 20 to 56. The cumulative distribution of SSLCs was rather flat, with all but the lowest two and highest values falling in the narrow range of 47 to 67 ug/g (Figure 15). The SLC for benzo(a)pyrene in saltwater sediments is 39.6 ug/g organic carbon (confidence interval, 0.0 - 46.8, α = 0.03). The SLC value is 11.5 percent of the highest normalized concentration of benzo(a)pyrene in the saltwater database. The two most sensitive species, the polychaetes Prionospio cirrifera and Spionophanes berkeleyorum were the same for chrysene and benzo(a)pyrene (Tables 17 and 18). In addition, either Glycinde armigera or Prionospio cirrifera was the most sensitive species for all seven polycyclic aromatic hydrocarbons. However, these two species ranked forty-second and thirty-fourth, respectively, in apparent sensitivity to total PCBs (Table 11).

4.0 DISCUSSION

All SLCs determined in this project are summarized in Table 19. Some interesting patterns emerge. All SLCs for freshwater sediments are lower than all SLCs for saltwater sediments by at least one order of magnitude. This pattern is exemplified best by the two contaminants for which we have comparative freshwater and saltwater SLCs: PCBs and DDT. The SLC for PCBs in saltwater sediments is 15 times higher than the corresponding value for freshwater sediments. There is a 225-fold difference in the SLCs for DDT in freshwater and saltwater sediments. There are several possible reasons for these differences. The most important are the following: 1) differences in the range and distribution of values of organic carbon normalized contaminant concentrations for freshwater and saltwater sediment in the two databases; 2) differences in the relative sensitivity of the freshwater and saltwater benthic infauna used in this analysis; and 3) differences in the solubility of the nonpolar organic contaminants in fresh water and salt water. In addition, the freshwater database included zero values for organic contaminants in sediments, whereas the saltwater database did not.

The range and distribution of contaminant concentrations in the database used to calculate an SLC will have a marked effect on the value of the SSLCs, and therefore the SLCs generated. The SLC calculation process, by its very nature, makes no *a priori* assumptions about a causal relationship between a given concentration of the contaminant of interest in sediments and the presence or absence of a particular species of benthic infauna in those sediments. Therefore, it is possible to have a data set in which all concentrations of the contaminant of interest are well below the concentration in sediments that would adversely affect the distribution of benthic infauna. SLCs calculated with such a data set would be conservative and the SLC would have little regulatory relevance. On the other hand, if most observations are from a heavily contaminated area, most of the pollutant-sensitive species would be absent and the SLC would be based primarily on pollutant-tolerant species. In such a case, the SLC would be too high. As the range of contaminant concentrations upon which the SLC is based increases, the likelihood of these types of biases in the SLC decreases.

In the freshwater and saltwater data sets used to calculate SLCs, the observed organic carbon normalized concentrations of the contaminants in sediments were distributed quite differently. This could account for much of the difference in the SLC values between freshwater and saltwater sediments. For example, in the freshwater data set, approximately 10 percent of the observations of the organic carbon normalized concentration of DDT in sediments were below 0.5 ug/g, and only 10 percent of observations were above 30 ug/g. However, in the corresponding saltwater data set, approximately 10 percent of observations were

below 1.0 ug/g, and approximately 75 percent of observations were above 30 ug/g. As a result, 47.6 percent of the SSLCs for DDT in freshwater sediments were below 0.35 ug/g organic carbon (Table 4), whereas 47.4 percent of the SSLCs for DDT in saltwater sediments were at or below 208 ug/g organic carbon (Table 10). The differences between freshwater and saltwater data sets for PCBs are similar to but not as large as those described above for DDT.

To further illustrate the differences between the freshwater and saltwater databases, the SLCs can be compared to the corresponding maximum concentrations of the contaminants in the database. For freshwater sediments, each SLC was 0.01 to 0.09 percent of the highest organic carbon normalized concentration of the corresponding contaminant in the freshwater database. In the case of both DDT and PCBs, the SLC value was 0.05 percent of the highest concentration in the freshwater database. For saltwater sediments, each SLC was 0.6 to 11.5 percent of the highest organic carbon normalized concentration of the corresponding contaminant in the saltwater database. The SLC values for DDT and PCBs were 0.6 and 1.6 percent, respectively, of their highest concentrations in the saltwater database.

Although differences in the sensitivity of freshwater and saltwater benthic invertebrates to sediment-associated nonpolar contaminants could result in some differences in the SLC values, it is unlikely that such differences would be large enough to account for more than a fraction of the differences in SLC values observed here for freshwater and saltwater sediments. Current water quality criteria for DDT and PCBs indicate that there are only small differences in the apparent sensitivity of freshwater and saltwater animals to these two chemicals (FR 45:231, Nov. 28,1980, 79318-79379). For DDT, the criterion to protect freshwater aquatic life is 0.001 ug/l as a 24-hour average, not to exceed 1.1 ug/l at any time. The corresponding criterion to protect saltwater aquatic life is 0.001 ug/l as a 24-hour average, not to exceed 0.13 ug/l at any time. For PCBs, the criterion to protect freshwater aquatic life is 0.014 ug/l as a 24-hour average. The corresponding criterion to protect saltwater aquatic life is 0.030 ug/l. Thus, based on the water quality criteria and assuming similarity in the sensitivity of the organisms used to calculate water quality criteria and the benthic infaunal invertebrates used to calculate SLCs, there should be only a moderate difference in the sensitivity of freshwater and saltwater animals to DDT and PCBs. Recently, Palawski et al.(1985) reported that striped bass, a euryhaline species of fish, was more sensitive to several pollutants, including PCBs, several polycyclic aromatic hydrocarbons, and pesticides, in hard fresh water than in low salinity sea water. However, the differences in LC50 values were never greater than about two-fold for any of the chemicals tested. The major difference in sensitivity of freshwater and saltwater organisms to sediment-adsorbed nonpolar organic contaminants is probably due more to differences in partitioning behavior of the

contaminants in freshwater and saltwater systems than to differences in the sensitivity of freshwater and saltwater organisms themselves.

Salinity of the ambient medium does affect the physical and chemical behavior of many chemicals. Kadeg et al. (1986) reviewed the effects of salinity on the behavior of nonpolar organic chemicals in aqueous media. The aqueous solubility of PCBs, DDT, and polycyclic aromatic hydrocarbons decreases with increasing salinity. As a result, the presence of electrolytes (salts) in solution increases the sorption of nonpolar organic chemicals by sediments. Therefore, it is reasonable to infer that nonpolar organic chemicals adsorbed to sediments will be less bioavailable in salt water than in fresh water. There are relatively few data available that are suitable for testing this inference (Neff, 1984). Boehm (1982) measured the concentration of several nonpolar organic pollutants in sediments and resident infaunal polychaetes and bivalves from the New York Bight. Bioaccumulation factors for the contaminants from the sediments (concentration in animal tissues/concentration in sediment) ranged from 0.001 to 0.7 in the polychaetes Nephthys sp. and Pherusa affinis and from 0.002 to 4.46 in the bivalve, Nucula proxima. Bioaccumulation factors for several polycyclic aromatic hydrocarbons (PAH) ranged from 0.01 to 0.24 in the polychaetes and 0.002 to 3.20 in the bivalve. Eadie et al. (1982a,b;1983) studied the concentrations of several PAHs in sediments and benthic oligochaetes and arthropods from the Great Lakes. Bioaccumulation factors from sediments for individual PAHs in the amphipod Pontoporeia hoyi ranged from 1 to 45. Bioaccumulation factors from sediments for different PAHs in the oligochaete Limnodrilus hoffmeisteri ranged from 0.1 to 2.3. This limited comparison lends support to the inference that bioavailability of nonpolar organic contaminants from sediments will be inversely related to salinity of the overlying water. Because bioavailability and toxicity of a nonpolar organic chemical are directly related, we can infer that there will be a tendency for freshwater organisms to be more sensitive than saltwater organisms to sediment-adsorbed contaminants. This conclusion is consistent with our analysis and may account for a small part of the difference in SLCs for freshwater and saltwater sediments. This conjecture is very preliminary and requires further experimental verification.

Zero values for contaminant concentrations in sediments were used to calculate freshwater but not saltwater SLCs. The use of zero values would tend to decrease the value of the SLCs calculated. In order to determine the magnitude of the effect of this difference in calculating freshwater and saltwater SLCs, a few of the freshwater SLCs were recalculated without inclusion of the zero values. This procedure approximately doubled the resultant SLCs. Therefore, the contribution of this procedural difference to the differences in freshwater and saltwater SLCs for DDT and PCBs was small. Zero values were used in the calculation of the freshwater SLCs so that there would be the

minimum number of 20 observations required to calculate an SSLC.

Of the four possible reasons for the differences between the freshwater and saltwater SLC values, the most important probably is the differences in ranges of organic carbon normalized contaminant concentrations in sediments covered by each database. The freshwater concentrations tended to be low as evidenced by the many zero contaminant values. The saltwater database tended toward the more highly polluted sediments. Based on these observations, the freshwater SLC values may be conservative and the saltwater SLC values may be too high.

Recently, Tetra Tech (1986) evaluated the SLC and several other approaches to developing sediment quality criteria. They used field data from Puget Sound. The only chemical for which both Tetra Tech and Battelle calculated an SLC was naphthalene. Our SLC for naphthalene, based on data from Puget Sound and the New York Bight, is 36.7 ug/g organic carbon. This value compares very favorably with the value of 37 ug/g organic carbon reported by Tetra Tech, based on data from Puget Sound alone.

Tetra Tech also calculated an SLC of 230 ug/g organic carbon for total high molecular weight polycyclic aromatic hydrocarbons in marine sediments. Nine PAHs were included in the total, including five PAHs for which we calculated individual SLCs (fluoranthene through benzo(a)pyrene). Assuming addativity, the Tetra Tech data would indicate an average SLC for each of the nine PAH of 26 ug/g organic carbon. The SLCs that we calculated for the five PAH range from 26.1 to 41.9 ug/g organic carbon (mean, 37.6 ug/g organic carbon). Again, there is reasonable agreement between the two independent estimates. Although Tetra Tech did not calculate a saltwater SLC for DDT or PCBs, they did apply another approach, which they named the apparent effects threshold (AET) approach, to deriving sediment quality indices for these contaminants. The AET values for PCBs and the different PAHs were similar to one another, whereas the AET value for DDT was much lower than the AETs for PCBs and PAHs. In our analysis of saltwater sediments, the ranking of PCBs and DDT is reversed. DDT and the different PAHs have similar SLCs and the SLC for PCBs is much lower. In addition, the SLCs generated in the present investigation are all less than the corresponding AET values calculated by Tetra Tech, except for DDT. The SLC value for DDT is much larger than the corresponding AET value. This difference in relative ranking can be attributed to the different sources and characteristics of the data sets used to calculate the SLCs for DDT and PCBs. The data set used to calculate the saltwater SLC for DDT was from the Southern California Bight, an area known to be heavily contaminated with DDT residues. Thus, a large fraction of the observations were at stations with sediments containing high concentrations of DDT. The saltwater SLC for PCBs was calculated with data from both the New York Bight and the Southern California Bight. Both areas have sediments with elevated concentrations of PCBs, but not as elevated as locations

in Puget Sound from which Tetra Tech obtained the data set used to calculate the AET for PCBs.

The SLC approach has demonstrated sufficient merit to warrant further evaluation and elaboration. Given a large enough database and minor modifications to the methods for calculating SSLCs and SLCs, the approach will provide a conservative estimate of the highest organic carbon normalized concentrations of individual contaminants in sediments that can be tolerated by approximately 95 percent of benthic infauna. As the number and range of observations contributing to the calculation of the SLC for a contaminant increases, one would expect the SLC values calculated to asymptotically approach some ideal "true" SLC values for freshwater and saltwater sediments. It is essential that the database contain organic carbon normalized concentrations of the sediment contaminants of interest that span a wide range (preferably two orders of magnitude or more) and include values from locations known to be heavily contaminated. Low and intermediate sediment contaminant concentrations are needed to ensure that pollutant-sensitive species are not excluded from the analysis. High values are needed to ensure that benthic communities are in fact being adversely affected at some stations by the contaminant of interest. Data from areas containing clearly defined gradients of concentrations of the contaminant of interest in the sediments would be ideal for use in calculating an SLC. In the present investigation, the freshwater database was dominated by low contaminant concentrations and the saltwater database was dominated by high contaminant concentrations. The result was that freshwater SLCs tended to be low and saltwater SLCs tended to be high. As the number of observations in the database increases, the magnitude of this bias toward high or low values will decrease.

In order to calculate an accurate SLC, the number of species used in the analysis should be as large as possible and should span a wide phyletic range. Whenever possible, taxa known to be sensitive to chemical pollutants, such as benthic amphipods and certain insect larvae, should be included in the analysis. Thompson (1982) identified three zones with different benthic infaunal community structure along a pollution gradient away from point source discharges of treated sewage to the southern California Bight. Species restricted to the unpolluted reference areas can be considered the most pollutant-sensitive, whereas, those that are most abundant in severely impacted areas can be considered the most pollutant-tolerant. Some animals are most abundant in the transitional zone between these extremes. Of the five dominant members of the control (pollutant-sensitive) community, two, the brittle star, Amphiodia (Amphispina) urtica, and the polychaete, Pectinaria californiensis, are included in the calculation of the SLCs for DDT (Table 10) and PCBs (Table 11). These two species ranked number two and eight, respectively, in SSLCs for DDT, and number thirty and forty, respectively, in SSLCs for PCBs. Among the most pollutant-tolerant species, the polychaete, Capitella capitata, ranked number fifteen in SSLCs

for DDT and number forty-three in SSLCs for PCBs. Thus, in the present exercise, there was a fairly good relationship in the case of DDT, but not PCBs, between the apparent sensitivity of benthic species to pollution and their relative rank in a cumulative frequency distribution of SSLC values. However, the important point here is that apparently sensitive and apparently tolerant species were included in the data sets used to calculate the SLCs for DDT and PCBs.

Greater use could be made of taxa that have been identified only to the genus level, if this will increase the number of taxa in the database suitable for SSLC calculation. Inclusion of animals identified only to the genus level should be done with caution. If data sets from different geographic areas are being used to calculate an SLC, a species group identified to the genus level in one region may or may not correspond to the species group from another area identified to the same genus. For example, Tharyx sp. from the southern California Bight may or may not correspond to Tharyx sp. from Puget Sound or the New York Bight. In using data for animals identified to only the genus level, the assumption is implied that all members of that genus have a similar sensitivity to the pollutant of interest. This probably is not true. Organisms of a genus, including benthic infauna, tend to segregate along environmental gradients, including pollution gradients (Grassle and Grassle, 1976). Therefore, the genus mean sensitivity may have little environmental relevance with respect to generation of SLC values.

Another way to increase the number of species that can be used in the analysis is to decrease the number of observations required to calculate an SSLC. It may be possible to reduce this number to ten without seriously compromising the validity of the SSLCs. The requirement for at least 20 observations for calculation of an SSLC was set somewhat arbitrarily at the beginning of this project. It is likely that any disadvantage of using fewer observations to calculate the SSLC would be more than compensated for by the increase in the number of SSLCs that could be calculated and used to determine the SLC. In addition, it is probable that a majority of the additional SSLCs obtained this way would be for the more sensitive species most likely to be eliminated from the more contaminated stations. Ideally, more than 20 SSLCs should be used to calculate each SLC. The more SSLCs used, the more technically and statistically sound the resulting SLC will be.

The requirement of the SLC approach for large databases, and the desirability of using data from different regions to calculate each SLC, raises another potential problem. Different data sources may reach different conclusions regarding what constitutes a genus. For example, one source might designate a polychaete as Pectinaria californiensis and another might designate the same animal as Cistena californiensis. These two designations represent a single species and should be included together for the SSLC determination. As our knowledge of the

freshwat and saltwater benthic infauna grows, revisions of the taxonomy of some taxa are made. These revisions may result in changes ı some genus or species names. In addition, a population original ı designated as a single species may be divided into two or more ɔecies, or several species may be combined into a single species. Thus, when using data sets from several different investig :ors and/or several geographic regions, great care must be take to ensure that the final species list contains no synonymi ɜ or single entries that actually represent multiple species. All data sets used to calculate each SLC must be subjecte to rigorous quality assurance review by a taxonomist familiar with the benthic infauna of the geographic regions from which th data sets were obtained.

ıe chemical data also must be subjected to rigorous quality ɜsurance review. Chemical data sets which do not contain adequate ıocumentation of precision, accuracy, comparability, and represen ıtiveness should be used with caution. Analytical detectic limits should be documented and values less than two-fold greater than the detection limits should not be used to calculat SSLCs. Data sets based on results of analyses using analytic ı techniques which have subsequently been found to be inaccura ɜ or subject to excessive interference should be rejected When several data sets from different regions are being combined to calculate a single SLC value, the analytical techniqu ɜ used to generate the different data sets should be comparab ɜ or at least capable of yielding roughly comparable results.

ıased on the number and distribution (in terms of both range c concentrations and number of different locations from which c ɜervations were used) of observations, the saltwater SLC for PCBs ıs the most technically sound marine SLC value generated in this ɔreliminary evaluation of the SLC approach to developing sediment quality criteria. The SLC value for PCBs in saltwater sediment , 4.26 ug/g organic carbon, compares reasonably well with th permissible sediment chemical concentration (PCC) based on equi ıbrium partitioning for PCBs of 1.84 ug/g organic carbon calculat ı for all sediments according to a sediment normaliz tion approach of Kadeg et al. (1986).

5.0 RECOMMENDATIONS

1. The SLC approach to deriving sediment quality criteria has merit and warrants further evaluation and refinement.

2. The requirements for the number of observations necessary to calculate an SSLC should be reduced to 10 and the number of SSLCs required to calculate an SLC should be increased to at least 20. This relationship should be evaluated statistically in detail to arrive at the most statistically sound approach to deriving SLCs.

3. The choice of the 90th percentile of observations for the SSLC and the 5th percentile of SSLCs for the SLC value also should be evaluated statistically, using real data sets, in order to develop an approach to calculating SLCs that makes optimal use of the available data.

4. Additional data, particularly from sites known to be heavily contaminated with the pollutants of interest, should be acquired and added to the database. The effects of the inclusion of these additional data on the SLCs generated should be evaluated.

5. A statistical analysis should be performed to determine the optimum range and distribution of sediment contaminant concentrations for calculating SLCs.

6. All data bases used to calculate SLCs should be subjected to rigorous quality assurance review. Both the biological and the chemical data should be evaluated for precision, accuracy, comparability, and representativeness. Criteria should be developed for accepting or rejecting databases based on the outcome of this quality assurance review.

7. Investigators should be encouraged in designing new benthic monitoring and pollution assessment programs to include collection of synoptic data on benthic infaunal community structure, sediment contaminant concentrations, and sediment organic carbon concentrations.

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TABLE 1. LIST OF DATA SETS USED TO CALCULATE FRESHWATER SLCs BY STATE AND THE NUMBER OF STATIONS IN EACH DATA SET.

Data Set Location	No. of Stations
ILLINOIS	
Big Muddy River	3
Calumet Channel	4
Casey Fork	4
Des Plaines River	4
Fox River	8
Green River	3
Illinois River	6
Kankanee River	8
Kaskaskia River	8
LaMoine River	3
Little Calumet River	3
Little Wabash River	1
Lusk Creek	4
Middle Fork Saline River	3
Mississippi River	10
North Branch Chicago River	3
North Fork Saline River	2
Rock River	7
Salt Creek	4
Sanitary/Ship Canal	1
South Fork Saline River	3
Vermilion River	2
Wabash River	3
TOTAL	**97**
INDIANA	
Indiana Harbor	21
TOTAL	**21**
MICHIGAN	
Caseville Harbor	1
Detroit River	59
Grand Haven Harbor	8
Hammond Bay Harbor	1
Holland	12

TABLE 1. (Continued)

Data Set Location	No. of Stations
MICHIGAN (CONT)	
Lake St. Clair Channel	7
Manistee River	2
Monroe Harbor	1
Point Lookout Harbor	1
Thunder Bay	3
TOTAL	**95**
NEW YORK	
Cape Vincent	5
Dunkirk	5
Little Salmon River	1
Oak Orchard	4
Ogdensburg Harbor	1
Olcott Harbor	6
Port Ontario	1
Sakets Harbor	5
TOTAL	**28**
OHIO	
Ashtabula Harbor	7
Conneaut	8
Cuyahoga River	14
Fairport	11
Sandusky Bay	10
TOTAL	**50**
WISCONSIN	
Algoma Harbor	4
Ashland Harbor	2
Grant Park	4
Green Bay	17
Kenosha Harbor	3
Port Wing	2
TOTAL	**32**
GRAND TOTAL	**323**

TABLE 2. LIST OF DATA SETS USED TO CALCULATE SALTWATER SLCs BY LOCATION AND NUMBER OF STATIONS.

Region	Cruise/Survey Code		Number of Stations
NY Bight	AL8109		44
	DL8206		4
	AL8201		6
	AL8210		1
	KE8007		33
		TOTAL	**88**
S. Calif. Bight	730		39
	80Q		12
	81S		13
	80m80		33
		TOTAL	**97**
Puget Sound	SAM		4
	DABOB		4
	SEQ		4
	CASE		4
	BELL		8
	ELL		8
	EVER		8
	SINCL		8
	MSQS		50
	URSCCI		10
		TOTAL	**108**
	GRAND TOTAL		**293**

TABLE 3. CONCENTRATION RANGES OF CONTAMINANTS IN SEDIMENTS FROM THE FRESHWATER DATA BASE, EXPRESSED IN TERMS OF BULK SEDIMENT AND NORMALIZED TO SEDIMENT TOTAL ORGANIC CARBON CONCENTRATION.

Compound	Concentration Range µg/g Dry Sed.	Organic Carbon Normalized Concentration Range µg/g Org C
DDT	0.0 - 30.7	0.0 - 3,520
PCBs	0.0 - 23.13	0.0 - 600
Dieldrin	0.0 - 1.00	0.0 - 24.5
Chlordane	0.0 - 1.00	0.0 - 25.1
Heptachlor Epoxide	0.0 - 1.00	0.0 - 29.1

TABLE 4. CUMULATIVE FREQUENCY AND VALUES FOR SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR DDT IN FRESHWATER SEDIMENTS. THE NUMBER OF OBSERVATIONS USED TO CALCULATE EACH SSLC ALSO IS GIVEN.

Rank	Cumulative Frequency (%)	SSLC (µg/g Org. C)	No. of Observations	Organism
1	4.8	0.189	20	Stenonema exiquum
2	9.5	0.208	28	Stenonema pulchellum
3	14.3	0.227	25	Cyrnellus fraternus
4	19.0	0.283	42	Stenonema integrum
5	23.8	0.283	35	Stenonema terminatus
6	28.6	0.286	36	Hyalella azteca
7	33.3	0.286	20	Pentanerua mallochi
8	38.1	0.333	54	Stenacron interpunctatum
9	42.9	0.345	37	Hydropsyche frisoni
10	47.6	0.345	34	Hydropsyche orris
11	52.4	2.471	25	Asellus intermedius
12	57.1	2.667	23	Limnodrilus claparedeianus
13	61.9	2.667	20	Limnodrilus udekemianus
14	66.7	2.667	56	Tubifex tubifex
15	71.4	3.000	55	Limnodrilus hoffmeisteri
16	76.2	3.000	26	Valvata sincera
17	80.9	3.182	20	Limnodrilus cervix
18	85.7	3.182	26	Potamothrix vejdovskyi
19	90.6	4.429	43	Peloscolex ferox
20	95.2	16.842	31	Peloscolex multisetosus
21	100.0	20.000	56	Gammarus fasciatus

TABLE 5. CUMULATIVE FREQUENCY AND VALUES FOR SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR TOTAL POLYCHLORINATED BIPHENYLS (PCBs) IN FRESHWATER SEDIMENTS. THE NUMBER OF OBSERVATIONS USED TO CALCULATE EACH SSLC ALSO IS GIVEN.

Rank	Cumulative Frequency (%)	SSLC (µg/g Org. C)	No. of Observations	Organism
1	4.8	0.286	25	Cyrnellus fraternus
2	9.5	0.379	35	Stenonema terminatum
3	14.3	0.606	28	Stenonema pulchellum
4	19.0	0.650	34	Hydropsyche orris
5	23.8	0.722	37	Hydropsyche frisoni
6	28.6	0.722	42	Stenonema integrum
7	33.3	0.949	20	Stenonema exiquum
8	38.1	1.905	54	Stenacron interpunctatum
9	42.9	3.137	20	Pentaneura mallochi
10	47.6	4.655	25	Asellus intermedius
11	52.4	7.442	36	Hyalella azteca
12	57.1	9.318	26	Potamothrix vejdovskyi
13	61.9	24.260	26	Valvata sincera
14	66.7	29.259	23	Limnodrilus claparedeianus
15	71.4	29.600	56	Tubifex tubifex
16	76.2	34.286	43	Peloscolex ferox
17	81.0	45.714	20	Limnodrilus udekemianus
18	85.7	52.778	20	Linmodrilus cervix
19	90.5	52.778	55	Limnodrilus hoffmeisteri
20	95.2	56.338	56	Gammarus fasciatus
21	100.0	103.448	31	Peloscolex multisetosus

TABLE 6. CUMULATIVE FREQUENCY AND VALUES FOR SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR DIELDRIN IN FRESHWATER SEDIMENTS. THE NUMBER OF OBSERVATIONS USED TO CALCULATE EACH SSLC ALSO IS GIVEN.

Rank	Cumulative Frequency (%)	SSLC (µg/g Org. C)	No. of Observations	Organism
1	6.3	0.026	40	Peloscolex ferox
2	12.5	0.084	24	Cyrnellus fraternus
3	18.8	0.115	34	Stenonema terminatum
4	25.0	0.139	23	Limnodrilus claparedeianus
5	31.2	0.167	52	Limnodrilus hoffmeisteri
6	37.5	0.167	56	Tubifex tubifex
7	43.7	0.178	34	Hydropsyche orris
8	50.0	0.178	40	Stenonema integrum
9	56.2	0.185	51	Stenacron interpunctatum
10	62.5	0.185	26	Stenonema pulchellum
11	68.8	0.186	36	Hydropsyche frisoni
12	75.0	0.194	24	Asellus intermedius
13	81.3	0.200	34	Hyalella azteca
14	87.5	0.260	28	Peloscolex multisetosus
15	93.8	0.370	26	Valvata sincera
16	100.0	1.000	56	Gammarus fasciatus

TABLE 7. CUMULATIVE FREQUENCY AND VALUES FOR SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR CHLORDANE IN FRESHWATER SEDIMENTS. THE NUMBER OF OBSERVATIONS USED TO CALCULATE EACH SSLC ALSO IS GIVEN.

Rank	Cumulative Frequency (%)	SSLC (µg/g Org. C)	No. of Observations	Organism
1	6.3	0.124	38	Stenonema integrum
2	12.5	0.136	40	Peloscolex ferox
3	18.8	0.141	33	Stenonema terminatum
4	25.0	0.143	23	Cyrnellus fraternus
5	31.2	0.172	32	Hydropsyche frisoni
6	37.5	0.172	32	Hydropsyche orris
7	43.8	0.173	23	Stenonema pulchellum
8	50.0	0.185	47	Stenacron interpunctatum
9	56.3	0.208	23	Limnodrilus claparedeianus
10	62.5	0.256	56	Tubifex tubifex
11	68.8	0.309	29	Hyalella azteca
12	75.0	0.466	20	Asellus intermedius
13	81.3	0.714	47	Limnodrilus hoffmeisteri
14	87.5	1.086	28	Peloscolex multisetosus
15	93.8	2.821	26	Valvata sincera
16	100.0	8.511	56	Gammarus fasciatus

TABLE 8. CUMULATIVE FREQUENCY AND VALUES FOR SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR HEPTACHLOR EPOXIDE IN FRESHWATER SEDIMENTS. THE NUMBER OF OBSERVATIONS USED TO CALCULATE EACH SSLC ALSO IS GIVEN.

Rank	Cumulative Frequency (%)	SSLC (µg/g Org. C)	No. of Observations	Organism
1	8.3	0.013	52	Limnodrilus hoffmeisteri
2	16.7	0.029	37	Stenonema integrum
3	25.0	0.029	34	Stenonema terminatum
4	41.7	0.034	33	Hydropsyche frisoni
5	41.7	0.034	31	Hydropsyche orris
6	50.0	0.037	24	Stenonema pulchellum
7	58.3	0.043	48	Stenacron interpunctatum
8	66.7	0.050	23	Asellus intermedius
9	75.0	0.053	34	Hyalella azteca
10	83.3	0.705	26	Valvata sincera
11	91.7	1.086	28	Peloscolex multisetosus
12	100.0	4.878	56	Gammarus fasciatus

TABLE 9. CONCENTRATION RANGES OF CONTAMINANTS IN SEDIMENTS FROM THE SALTWATER DATA BASE, EXPRESSED IN TERMS OF BULK SEDIMENT AND NORMALIZED TO SEDIMENT TOTAL ORGANIC CARBON CONCENTRATION.

Compound	Concentration Range µg/g Dry Sed.	Organic Carbon Normalized Concentration Range µg/g Org C
PCBs	0.0005 - 3.18	0.625 - 271.96
DDT	0.0010 - 149.0	0.109 - 7292.3
Naphthalene	0.0011 - 1.20	0.110 - 342.86
Phenanthrene	0.0062 - 1.50	1.088 - 428.57
Fluoranthene	0.300 - 1.50	1.875 - 428.57
Benz(a)anthracene	0.093 - 1.30	0.581 - 371.43
Chrysene	0.059 - 1.30	0.368 - 371.43
Pyrene	0.290 - 2.60	1.812 - 742.86
Benzo(a)pyrene	0.100 - 1.20	0.625 - 342.86

TABLE 10. CUMULATIVE FREQUENCY AND VALUES FOR SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR DDT IN SALTWATER SEDIMENTS. THE NUMBER OF OBSERVATIONS USED TO CALCULATE EACH SSLC ALSO IS GIVEN.

Rank	Cumulative Frequency (%)	SSLC (µg/g Org. C)	No. of Observations	Organism
1	5.9	50.488	21	Ampelisca brevisimulata
2	11.8	50.488	27	Amphiodia (Amphispina) urti
3	17.6	68.696	29	Euphilomedes carcharodonta
4	23.5	113.684	21	Heterophoxus oculatus
5	29.4	137.692	29	Compsomyax subdiaphana
6	35.3	137.692	20	Sthenelanella uniformis
7	41.2	207.917	20	Chloeia pinnata
8	47.1	954.033	62	Pectinaria californiensis
9	52.9	1186.331	79	Axinopsida sericata
10	58.8	1260.058	45	Paraprionospio pinnata
11	64.7	1392.128	86	Glycera capitata
12	70.6	1407.287	61	Prionospio steenstrupi
13	76.5	1511.990	101	Parvilucina tenuisculpta
14	82.4	1816.188	51	Macoma carlottensis
15	88.2	1999.961	44	Capitella capitata
16	94.1	2069.586	37	Spiophanes berkeleyorum
17	100.0	2069.586	57	Tellina carpenteri

TABLE 11. CUMULATIVE FREQUENCY AND VALUES FOR SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR TOTAL POLYCHLORINATED BIPHENYLS (PCBs) IN SALTWATER SEDIMENTS. THE NUMBER OF OBSERVATIONS USED TO CALCULATE EACH SSLC ALSO IS GIVEN.

Rank	Cumulative Frequency (%)	SSLC (µg/g Org. C)	No. of Observations	Organism
1	2.0	3.394	21	Spiochaetopterus costarum
2	3.9	3.871	32	Nephtys ferruginea
3	5.9	4.583	24	Harmothoe extenuata
4	7.8	4.634	22	Euchone elegans
5	9.8	4.634	22	Scalibregma inflatum
6	11.8	4.714	24	Drilonereis longa
7	13.7	4.714	27	Spiophanes bombyx
8	15.7	4.841	29	Anobothrus gracilis
9	17.6	4.841	27	Arctica islandica
10	19.6	4.841	30	Euchone incolor
11	21.6	4.841	26	Ninoe nigripes
12	23.5	6.000	23	Nephtys incisa
13	25.5	6.000	33	Nucula proxima
14	27.5	7.500	25	Mediomastus ambiseta
15	29.4	7.500	33	Tharyx acutus
16	31.4	8.000	39	Aricidea catherinae
17	33.3	8.000	22	Caulleriella cf killariensis
18	35.3	8.000	24	Goniadella gracilis
19	37.3	8.000	24	Unciola irrorata
20	39.2	8.854	25	Lumbrinereis hebes
21	41.2	9.143	54	Pholoe minuta
22	43.1	10.000	23	Paraonis gracilis
23	45.1	10.000	27	Pherusa affinis
24	47.1	10.000	26	Phyllodoce mucosa
25	49.0	10.000	33	Tharyx annulosus
26	51.0	10.625	30	Lumbrinereis acicularum
27	52.9	10.625	29	Pitar morrhuanus
28	54.9	10.941	32	Tellina agilis
29	56.9	11.417	24	Glycera dibranchiata
30	58.8	11.731	37	Amphiodia (amphispina) urtica
31	60.8	13.769	25	Heterophoxus oculatus
32	62.7	16.935	55	Euphilomedes carcharodonta
33	64.7	18.644	21	Prionospio cirrifera
34	66.7	27.736	28	Cossura longocirrata
35	68.6	30.118	21	Ampelisca brevisimulata
36	70.6	33.103	26	Compsomyax subdiaphana
37	72.5	33.905	20	Sthenelanella uniformis
38	74.5	39.683	20	Armandia brevis
39	76.5	40.017	23	Glycinde armigera
40	78.4	40.017	56	Pectinaria californiensis
41	80.4	41.143	109	Prionospio steenstrupi
42	82.4	42.765	38	Nephtys cornuta franciscana
43	84.3	45.045	74	Capitella capitata
44	86.3	46.025	90	Axinopsida sericata
45	88.2	46.307	20	Chloeia pinnata
46	90.2	47.817	56	Prionospio pinnata
47	92.2	52.058	100	Glycera capitata
48	94.1	52.058	67	Macoma carlottensis
49	96.1	56.307	89	Parvilucina tenuisculpta
50	98.0	58.774	42	Spiophanes berkeleyorum
51	100.0	71.315	40	Tellina carpenteri

TABLE 12. CUMULATIVE FREQUENCY AND VALUES FOR SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR NAPHTHALENE IN SALTWATER SEDIMENTS. THE NUMBER OF OBSERVATIONS USED TO CALCULATE EACH SSLC ALSO IS GIVEN.

Rank	Cumulative Frequency (%)	SSLC (µg/g Org. C)	No. of Observations	Organism
1	4.2	36.036	20	Glycinde armigera
2	8.3	39.565	24	Prionospio cirrifera
3	12.5	40.000	53	Capitella capitata
4	16.7	41.394	25	Armandia brevis
5	20.8	41.765	51	Axinopsida sericata
6	25.0	41.765	22	Euchone incolor
7	29.2	41.765	45	Nephtys cornuta franciscana
8	33.3	41.765	24	Praxillella gracilis
9	37.5	43.333	24	Compsomyax subdiaphana
10	41.7	43.333	25	Goniada brunnea
11	45.8	47.436	52	Euphilomedes carcharodonta
12	50.0	47.436	52	Glycera capitata
13	54.2	47.436	55	Macoma carlottensis
14	58.3	51.980	49	Nephtys ferruginea
15	62.5	51.980	20	Phyllodoce hartmanae
16	66.7	51.980	31	Platynereis bicanaliculata
17	70.8	51.980	50	Prionospio steenstrupi
18	75.0	51.980	26	Spiochaetopterus costarum
19	79.2	51.980	21	Spiophanes berkeleyorum
20	83.3	52.055	29	Glycera americana
21	87.5	52.055	21	Pectinaria californiensis
22	91.7	57.059	28	Amphiodia (Amphispina) urti
23	95.8	57.059	27	Parvilucina tenuisculpta
24	100.0	57.059	30	Pholoe minuta

TABLE 13. CUMULATIVE FREQUENCY AND VALUES FOR SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR PHENANTHRENE IN SALTWATER SEDIMENTS. THE NUMBER OF OBSERVATIONS USED TO CALCULATE EACH SSLC ALSO IS GIVEN.

Rank	Cumulative Frequency (%)	SSLC (µg/g Org. C)	No. of Observations	Organism
1	4.0	22.368	21	Glycinde armigera
2	8.0	36.576	25	Armandia brevis
3	12.0	36.576	25	Prionospio cirrifera
4	16.0	38.356	25	Euchone incolor
5	20.0	38.514	20	Phyllodoce hartmanae
6	24.0	39.726	52	Axinopsida sericata
7	28.0	39.726	27	Goniada brunnea
8	32.0	40.588	25	Compsomyax subdiaphana
9	36.0	40.588	53	Euphilomedes carcharodonta
10	40.0	40.588	51	Nephtys ferruginea
11	44.0	40.588	25	Praxillella gracilis
12	48.0	52.294	56	Capitella capitata
13	52.0	52.294	56	Glycera capitata
14	56.0	52.294	55	Macoma carlottensis
15	60.0	52.294	21	Pectinaria californiensis
16	64.0	54.167	54	Prionospio steenstrupi
17	68.0	55.372	29	Amphiodia (amphispina) uritic
18	72.0	55.372	54	Nephtys cornuta franciscana
19	76.0	55.372	20	Paraprionospio pinnata
20	80.0	55.372	37	Pholoe minuta
21	84.0	55.372	22	Spiophanes berkeleyorum
22	88.0	75.000	29	Glycera americana
23	92.0	75.000	27	Parvilucina tenuisculpta
24	96.0	75.000	32	Platynereis bicanaliculata
25	100.0	75.000	26	Spiochaetopterus costarum

TABLE 14. CUMULATIVE FREQUENCY AND VALUES FOR SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR FLUORANTHENE IN SALTWATER SEDIMENTS. THE NUMBER OF OBSERVATIONS USED TO CALCULATE EACH SSLC ALSO IS GIVEN.

Rank	Cumulative Frequency (%)	SSLC (µg/g Org. C)	No. of Observations	Organism
1	3.8	36.184	21	Glycinde armigera
2	7.7	58.993	27	Prionospio cirrifera
3	11.5	61.321	20	Paraprionospio pinnata
4	15.4	64.286	22	Spiophanes berkeleyorum
5	19.2	66.138	25	Armandia brevis
6	23.1	81.081	20	Phyllodoce hartmanae
7	26.9	81.651	27	Goniada brunnea
8	30.8	81.651	26	Spiochaetopterus costarum
9	34.6	97.872	59	Capitella capitata
10	38.5	111.765	52	Axinopsida sericata
11	42.3	124.658	28	Euchone incolor
12	46.2	124.658	53	Euphilomedes carcharodonta
13	50.0	124.658	55	Macoma carlottensis
14	53.8	124.658	57	Nephtys cornuta franciscana
15	57.7	124.658	51	Nephtys ferruginea
16	61.5	124.658	58	Prionospio steenstrupi
17	65.4	129.412	25	Compsomyax subdiaphana
18	69.2	129.412	57	Glycera capitata
19	73.1	129.412	41	Pholoe minuta
20	76.9	129.412	20	Scalibregma inflatum
21	80.8	135.294	27	Parvilucina tenuisculpta
22	84.6	135.294	21	Pectinaria californiensis
23	88.5	135.294	25	Praxillella gracilis
24	92.3	146.552	32	Platynereis bicanaliculata
25	96.2	164.384	29	Amphiodia (amphispina) urtic
26	100.0	164.384	29	Glycera americana

TABLE 15. CUMULATIVE FREQUENCY AND VALUES FOR SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR BENZ(A)ANTHRACENE IN SALTWATER SEDIMENTS. THE NUMBER OF OBSERVATIONS USED TO CALCULATE EACH SSLC ALSO IS GIVEN.

Rank	Cumulative Frequency (%)	SSLC (µg/g Org. C)	No. of Observations	Organism
1	4.3	24.348	24	Prionospio cirrifera
2	8.7	35.477	25	Armandia brevis
3	13.0	35.477	21	Spiophanes berklyorum
4	17.4	40.952	26	Goniada brunnea
5	21.7	41.322	26	Spiochaetopterus costarum
6	26.1	42.466	52	Axinopsida sericata
7	30.4	44.118	57	Capitella capitata
8	34.8	44.118	25	Compsomyax subdiaphana
9	39.1	44.118	28	Euchone incolor
10	43.5	44.118	53	Euphilomedes carcharodonta
11	47.8	44.118	57	Glycera capitata
12	52.2	44.118	56	Macoma carlottensis
13	56.5	47.647	50	Nephthys ferruginea
14	60.9	47.647	27	Parviculina tennisculpta
15	65.2	47.647	21	Pectinaria californiensis
16	69.6	47.647	25	Praxillella gracilis
17	73.9	47.647	57	Prionospio steenstrupi
18	78.3	47.945	29	Amphoiodia(Amphispina)urtica
19	82.6	51.765	30	Glycera americana
20	87.0	51.765	50	Nephthys cornuta franciscana
21	91.3	51.765	40	Phloe minuta
22	95.7	51.802	20	Phyllodoce hartmanae
23	100.0	51.802	30	Platynereis bicanaliculata

TABLE 16. CUMULATIVE FREQUENCY AND VALUES FOR SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR PYRENE IN SALTWATER SEDIMENTS. THE NUMBER OF OBSERVATIONS USED TO CALCULATE EACH SSLC ALSO IS GIVEN.

Rank	Cumulative Frequency (%)	SSLC (µg/g Org. C)	No. of Observations	Organism
1	3.7	31.579	22	Glycinde armigera
2	7.4	65.217	27	Prionospio cirrifera
3	11.1	73.171	25	Armandia brevis
4	14.8	74.380	22	Spiophanes berkeleyorum
5	18.5	75.000	27	Goniada brunnea
6	22.2	82.375	20	Phyllodoce hartmanae
7	25.9	82.375	26	Spiochaetopterus costarum
8	29.6	84.906	20	Paraprionospio pinnata
9	33.3	84.906	20	Tharyx monilaris
10	37.0	84.932	52	Axinopsida sericata
11	40.7	87.671	53	Euphilomedes carcharodonta
12	44.4	87.671	55	Macoma carlottensis
13	48.1	87.671	51	Nephtys ferruginea
14	51.9	94.118	59	Capitella capitata
15	55.6	94.118	57	Glycera capitata
16	59.3	94.118	58	Prionospio steenstrupi
17	63.0	100.000	25	Compsomyax subdiaphana
18	66.7	100.000	28	Euchone incolor
19	70.4	100.000	21	Pectinaria californiensis
20	74.1	100.000	25	Praxillella gracilis
21	77.8	100.719	57	Nephtys cornuta franciscana
22	81.5	105.882	29	Amphiodia (amphispina) urtic
23	85.2	105.882	29	Glycera americana
24	88.9	105.882	27	Parvilucina tenuisculpta
25	92.6	105.882	41	Pholoe minuta
26	96.3	105.882	32	Platynereis bicanaliculata
27	100.0	105.882	20	Scalibregma inflatum

TABLE 17. CUMULATIVE FREQUENCY AND VALUES FOR SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR CHRYSENE IN SALTWATER SEDIMENTS. THE NUMBER OF OBSERVATIONS USED TO CALCULATE EACH SSLC ALSO IS GIVEN.

Rank	Cumulative Frequency (%)	SSLC (µg/g Org. C)	No. of Observations	Organism
1	4.3	35.652	24	Prionospio cirrifera
2	8.7	52.893	21	Spiophanes berkeleyorum
3	13.0	57.143	26	Goniada brunnea
4	17.4	60.847	25	Armandia brevis
5	21.7	62.084	51	Axinopsida sericata
6	26.1	62.084	57	Capitella capitata
7	30.4	62.084	20	Phyllodoce hartmanae
8	34.8	63.694	28	Euchone incolor
9	39.1	63.694	57	Prionospio steenstrupi
10	43.5	64.706	52	Euphilomedes carcharodonta
11	47.3	64.706	55	Macoma carlottensis
12	52.2	64.706	50	Nephtys cornuta franciscana
13	56.5	64.706	50	Nephtys ferruginea
14	60.9	68.966	56	Glycera capitata
15	65.2	68.966	25	Spiochaetopterus costarum
16	69.6	69.863	21	Pectinaria californiensis
17	73.9	69.863	31	Platynereis bicanaliculata
18	78.3	69.863	25	Praxillella gracilis
19	82.6	75.314	25	Compsomyax subdiaphana
20	87.0	76.471	29	Amphiodia (amphispina) urtica
21	91.3	76.471	29	Glycera americana
22	95.7	76.471	26	Parvilucina tenuisculpta
23	100.0	76.471	40	Pholoe minuta

TABLE 18. CUMULATIVE FREQUENCY AND VALUES FOR SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR BENZO(A)PYRENE IN SALTWATER SEDIMENTS. THE NUMBER OF OBSERVATIONS USED TO CALCULATE EACH SSLC ALSO IS GIVEN.

Rank	Cumulative Frequency (%)	SSLC (µg/g Org. C)	No. of Observations	Organism
1	4.3	39.604	21	Prionospio cirrifera
2	8.7	39.604	21	Spiophanes berkeleyorum
3	13.0	46.552	52	Capitella capitata
4	17.4	46.795	26	Spiochaetopterus costarum
5	21.7	49.315	28	Euchone incolor
6	26.1	49.315	25	Goniada brunnea
7	30.4	50.000	51	Axinopsida sericata
8	34.8	50.000	25	Compsomyax subdiaphana
9	39.1	50.000	52	Euphilomedes carcharodonta
10	43.5	50.000	56	Glycera capitata
11	47.8	50.000	25	Praxillella gracilis
12	52.2	51.887	43	Nephtys cornuta franciscana
13	56.5	52.910	25	Armandia brevis
14	60.9	52.910	55	Macoma carlottensis
15	65.2	52.910	56	Prionospio steenstrupi
16	69.6	55.372	49	Nephtys ferruginea
17	73.9	55.372	26	Parvilucina tenuisculpta
18	78.3	55.372	21	Pectinaria californiensis
19	82.6	55.372	37	Pholoe minuta
20	87.0	61.644	29	Amphiodia (Amphispina) urti
21	91.3	61.644	29	Glycera americana
22	95.7	66.667	29	Platynereis bicanaliculata
23	100.0	137.387	20	Phyllodoce hartmanae

TABLE 19. SUMMARY OF SCREENING LEVEL CONCENTRATIONS (SLCs) FOR FRESHWATER AND SALTWATER SEDIMENTS. VALUES IN μg CONTAMINANT PER g SEDIMENT ORGANIC CARBON (PARTS PER MILLION).

Compound	SLC (Confidence Interval and α)	
	Freshwater	Saltwater
Heptachlor Epoxide	0.008(C.I.=0.0-0.029,α-0.02)	-
Chlordane	0.098(C.I.=0.0-0.136,α=0.04)	-
Dieldrin	0.021(C.I.=0.0-0.084,α=0.04)	-
Polychlorinated Biphenyls	0.290(C.I.=0.0-0.65,α=0.02)	4.26(C.I.=0.0-4.63,α=0.03)
DDT	0.190(C.I.=0.0-0.283,α=0.02)	42.8(C.I.=0.0-113.7,α=0.03)
Naphthalene	-	36.7(C.I.-0.0-41.4,α=0.03)
Phenanthrene	-	25.9(C.I.=0.0-38.4,α=0.03)
Fluoranthene	-	43.2(C.I.=0.0-64.3,α=0.04)
Benz(a)anthracene	-	26.1(C.I.=0.0-41.0,α=0.03)
Chrysene	-	38.4(C.I.=0.0-60.5,α=0.03)
Pyrene	-	43.4(C.I.=0.0-74.4,α=0.06)
Benzo(a)pyrene	-	39.6(C.I.=0.0-46.8,α=0.03)

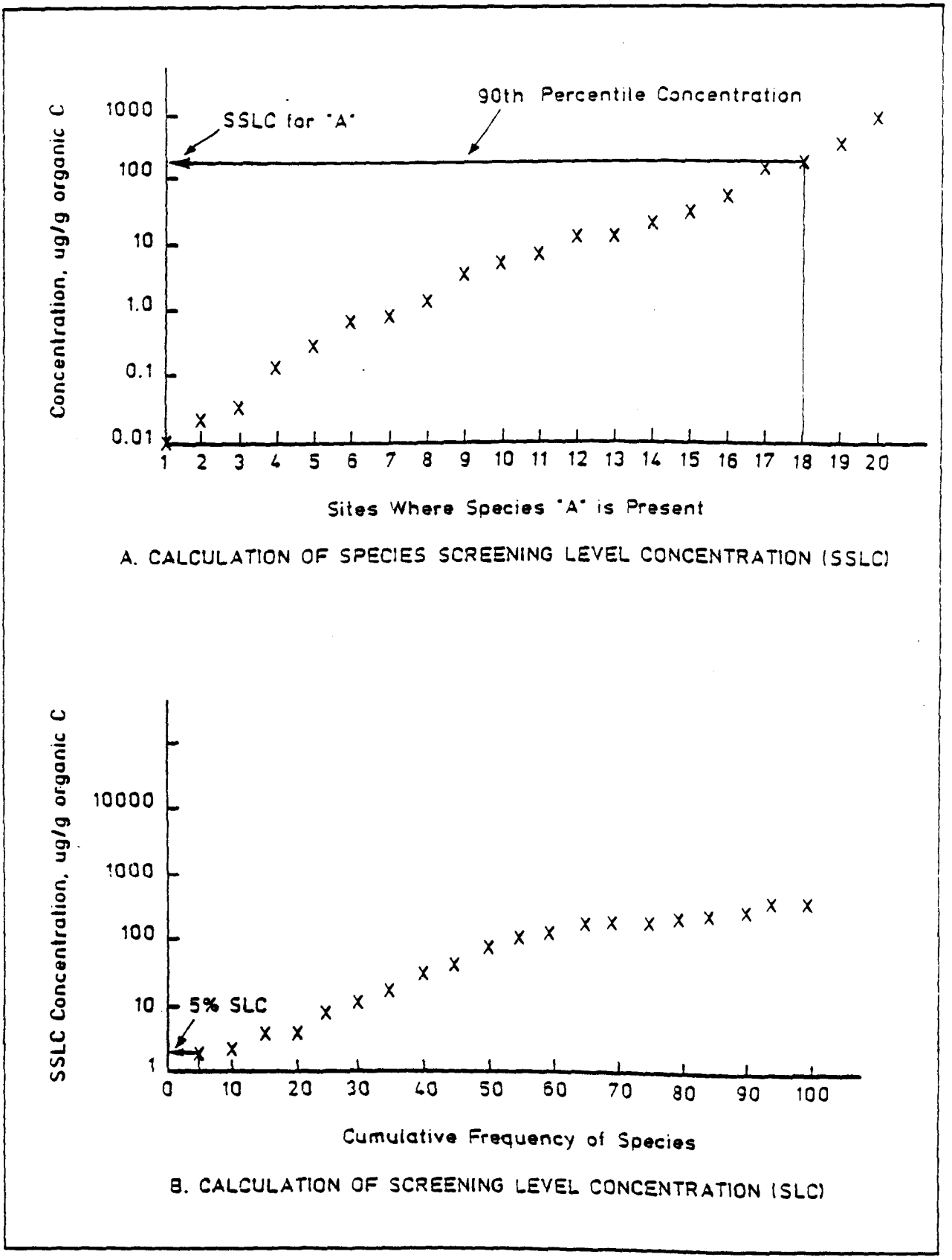


FIGURE 1. A SCHEMATIC ILLUSTRATION OF THE CALCULATION OF SCREENING LEVEL CONCENTRATIONS (SLCs) FOR NONPOLAR ORGANIC CONTAMINANTS IN SEDIMENTS.

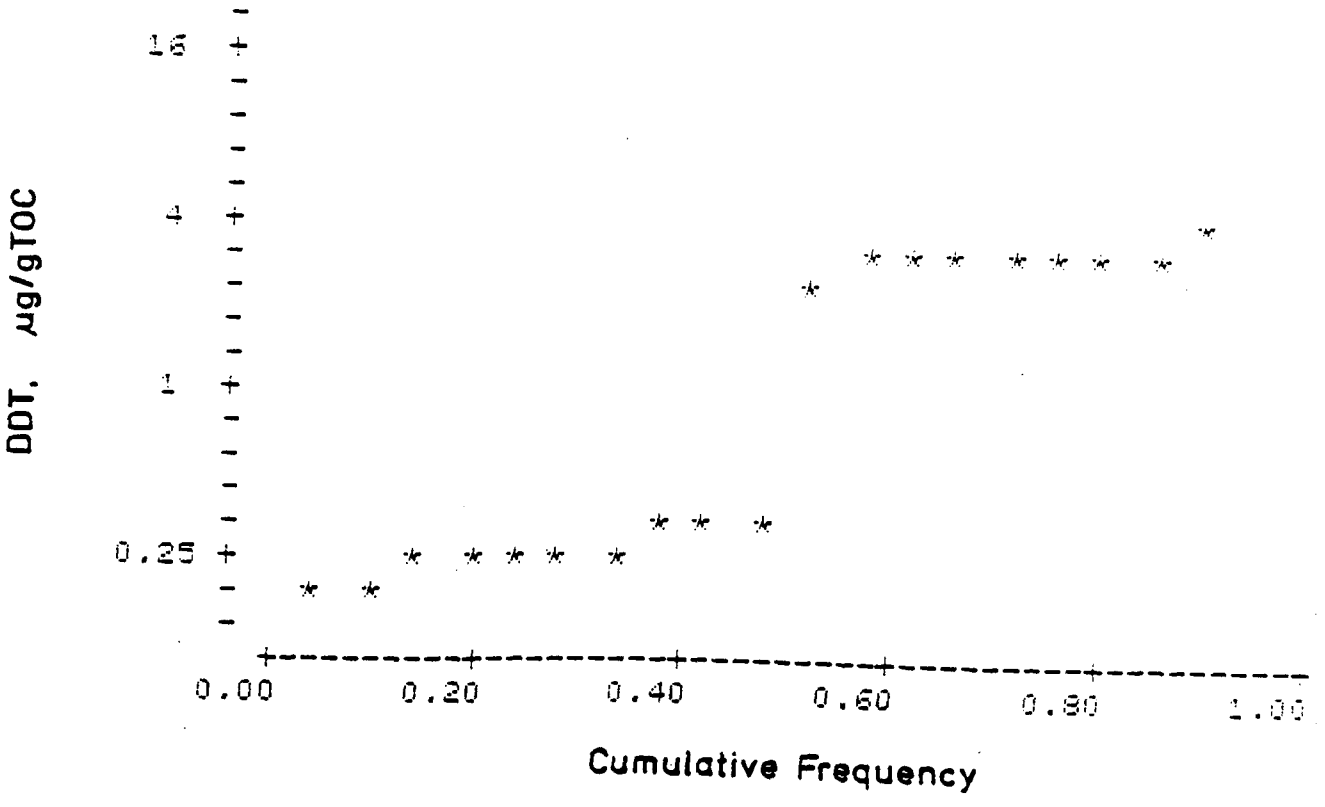


FIGURE 2. CUMULATIVE FREQUENCY DISTRIBUTION OF SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR DDT IN FRESHWATER SEDIMENTS. SSLC VALUES ARE IN µG DDT/G SEDIMENT ORGANIC CARBON.

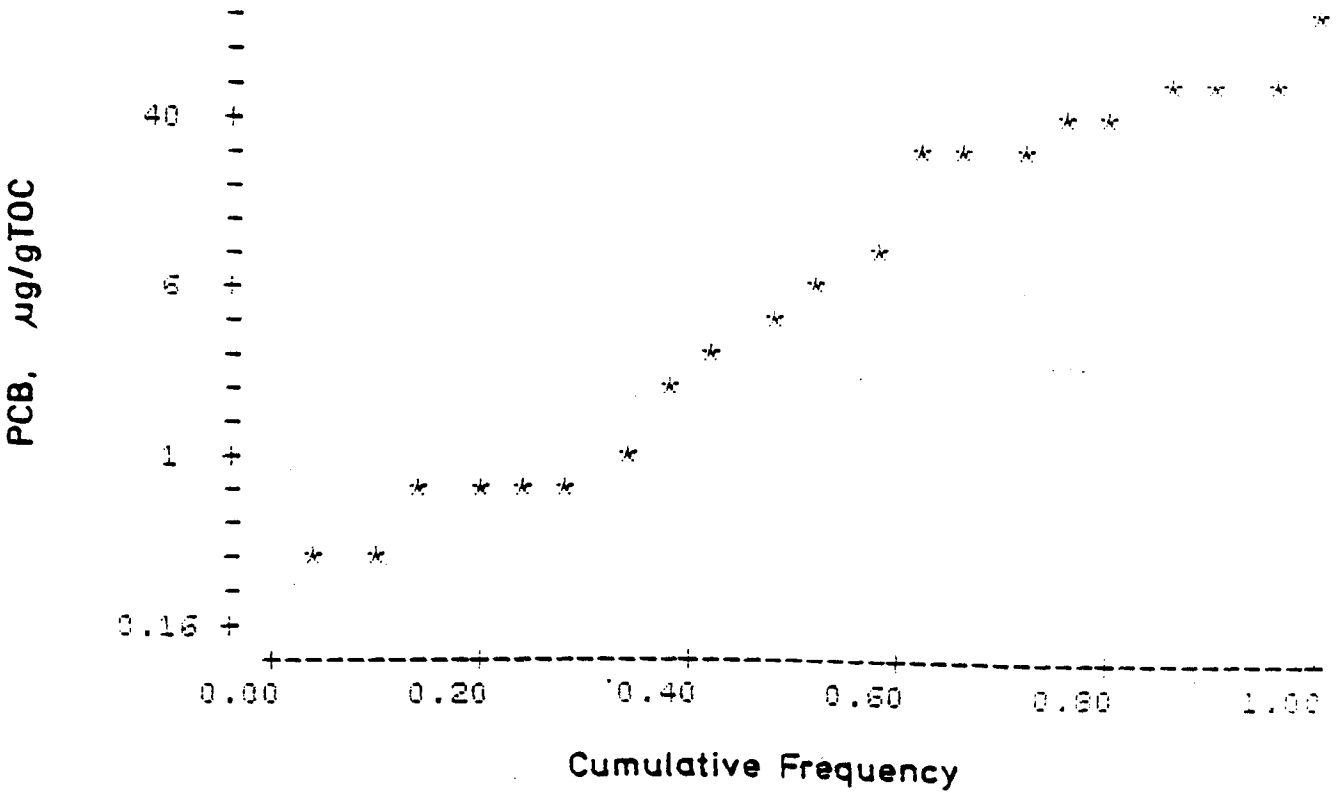


FIGURE 3. CUMULATIVE FREQUENCY DISTRIBUTION OF SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR TOTAL POLYCHLORINATED BIPHENYLS IN FRESHWATER SEDIMENTS. SSLC VALUES ARE IN µG PCB/G SEDIMENT ORGANIC CARBON.

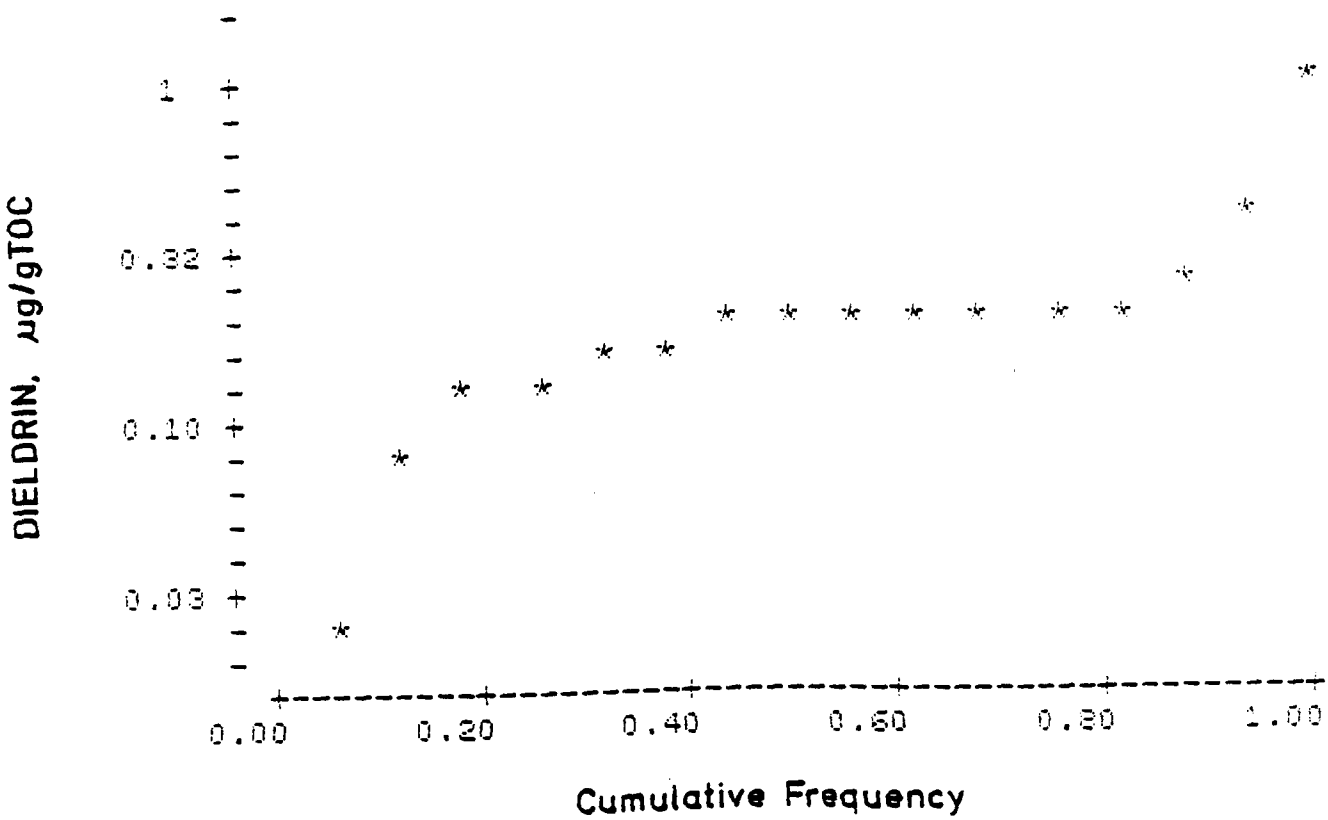


FIGURE 4. CUMULATIVE FREQUENCY DISTRIBUTION OF SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR DIELDRIN IN FRESHWATER SEDIMENTS. SSLC VALUES ARE IN µG DIELDRIN/G SEDIMENT ORGANIC CARBON.

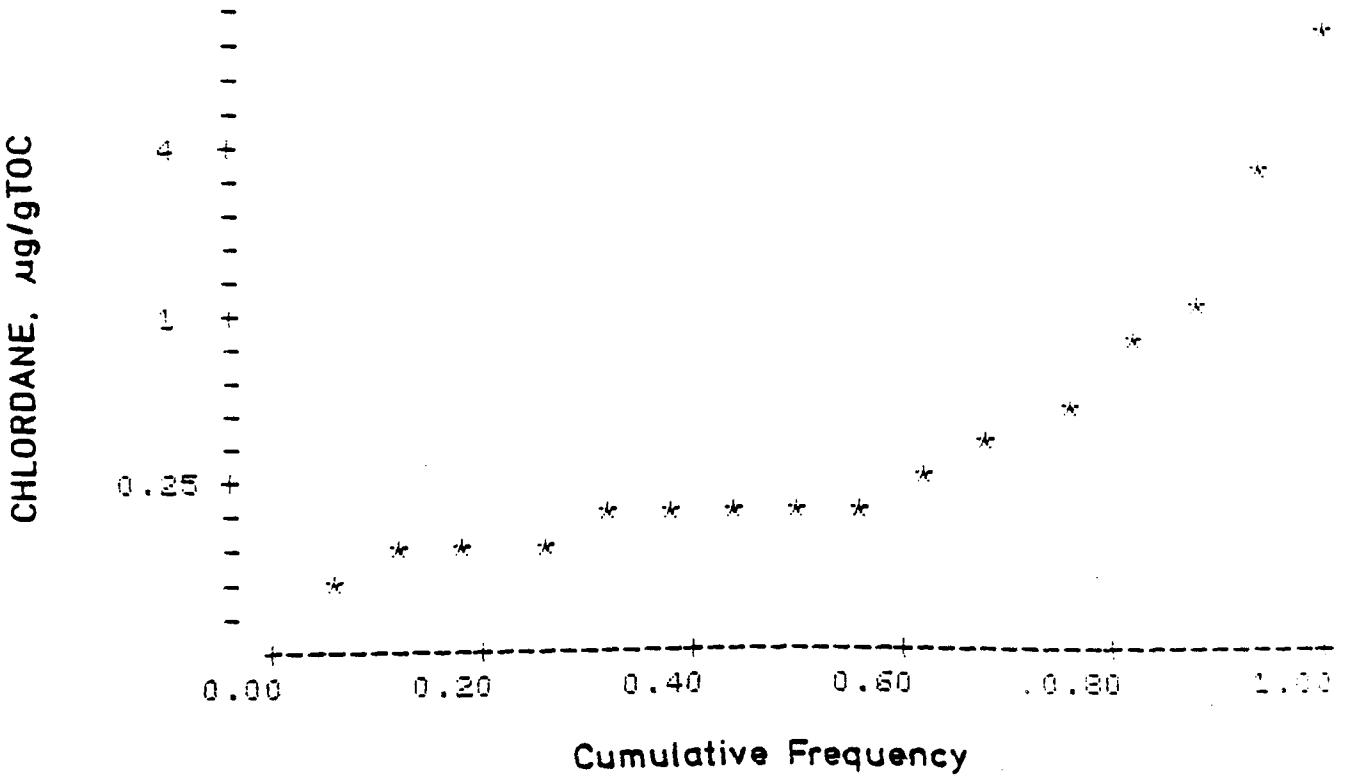


FIGURE 5. CUMULATIVE FREQUENCY DISTRIBUTION OF SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR CHLORDANE IN FRESHWATER SEDIMENTS. SSLC VALUES ARE IN µG CHLORDANE/G SEDIMENT ORGANIC CARBON.

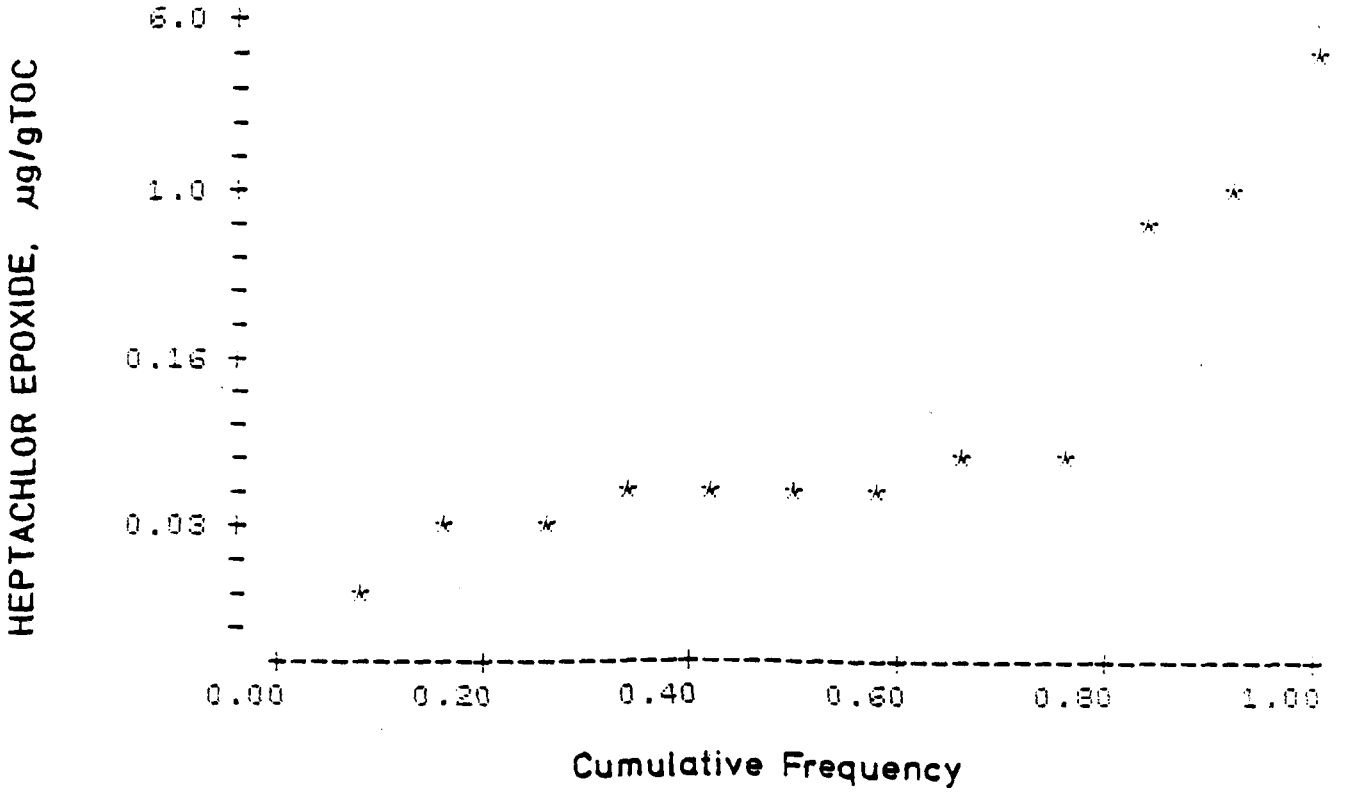


FIGURE 6. CUMULATIVE FREQUENCY DISTRIBUTION OF SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs)) FOR HEPTACHLOR EPOXIDE IN FRESHWATER SEDIMENTS. SSLC VALUES ARE IN µG HEPTACHLOR EPOXIDE/G SEDIMENT ORGANIC CARBON.

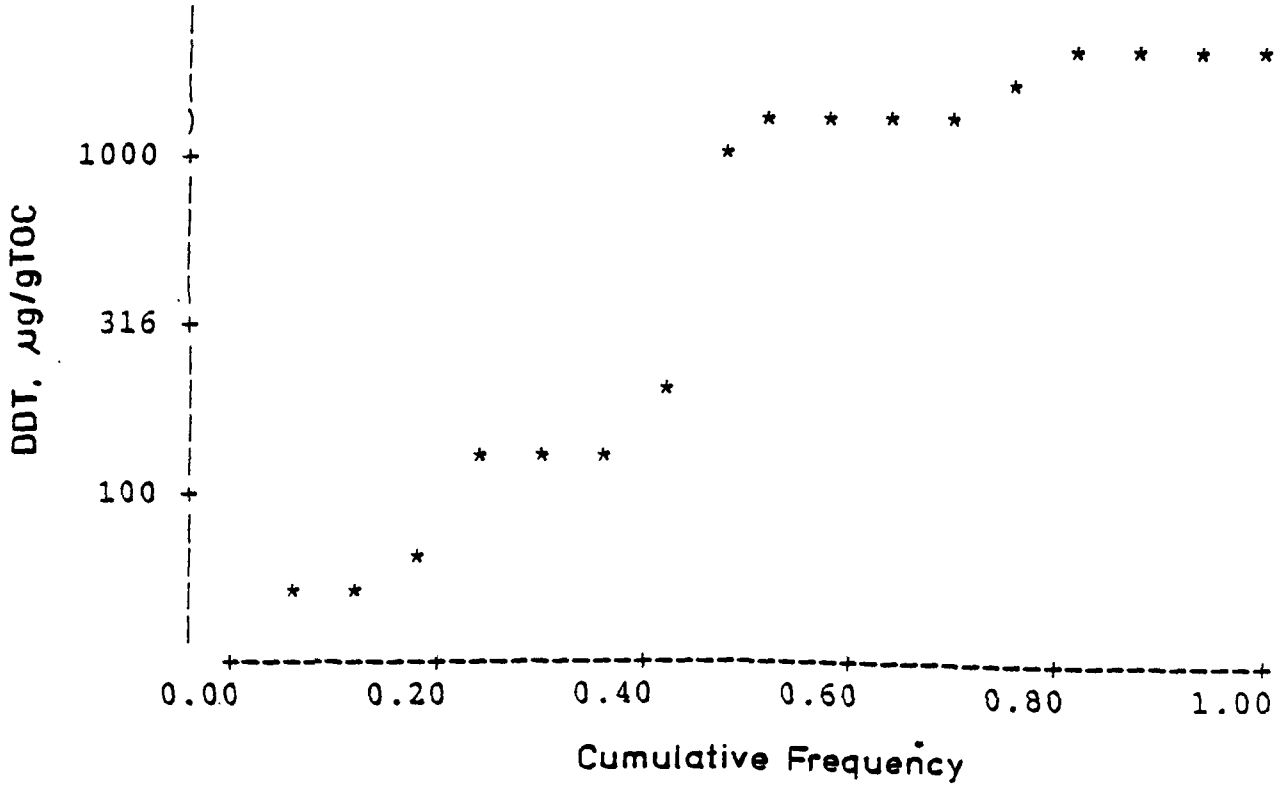


FIGURE 7. CUMULATIVE FREQUENCY DISTRIBUTION OF SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR DDT IN SALTWATER SEDIMENTS. SSLC VALUES ARE IN µG DDT/G SEDIMENT ORGANIC CARBON.

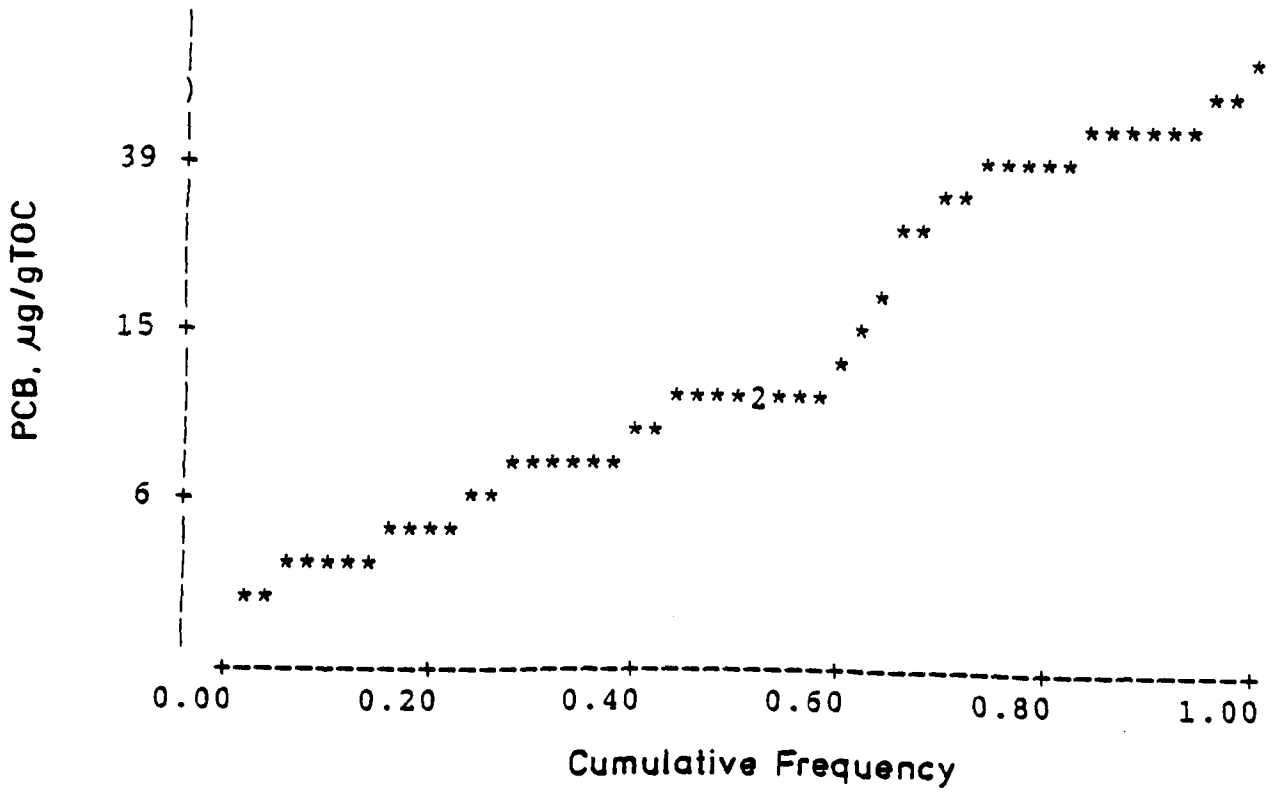


FIGURE 8. CUMULATIVE FREQUENCY DISTRIBUTION OF SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR TOTAL POLYCHLORINATED BIPHENYLS IN SALTWATER SEDIMENTS. SSLC VALUES ARE IN µG PCB/G SEDIMENT ORGANIC CARBON.

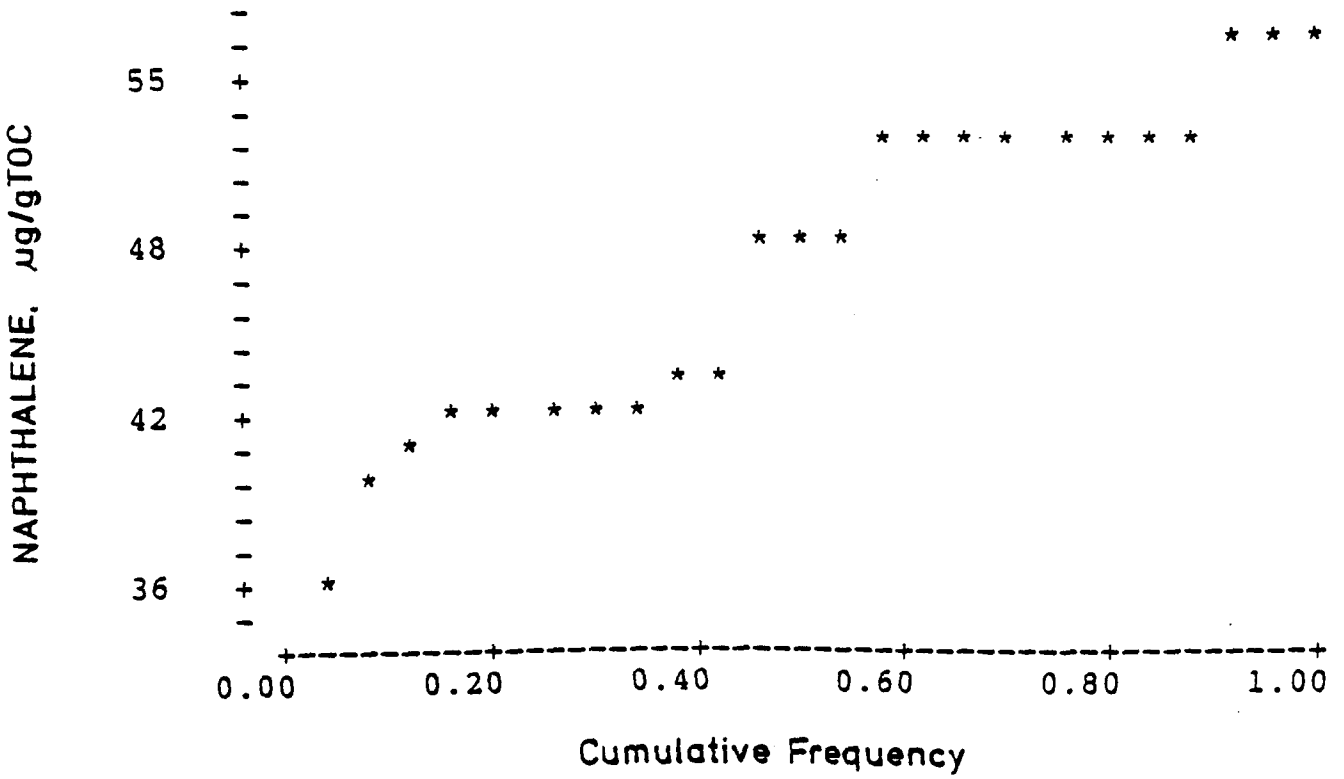


FIGURE 9. CUMULATIVE FREQUENCY DISTRIBUTION OF SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR NAPHTHALENE IN SALTWATER SEDIMENTS. SSLC VALUES ARE IN µG NAPHTHALENE/G SEDIMENT ORGANIC CARBON.

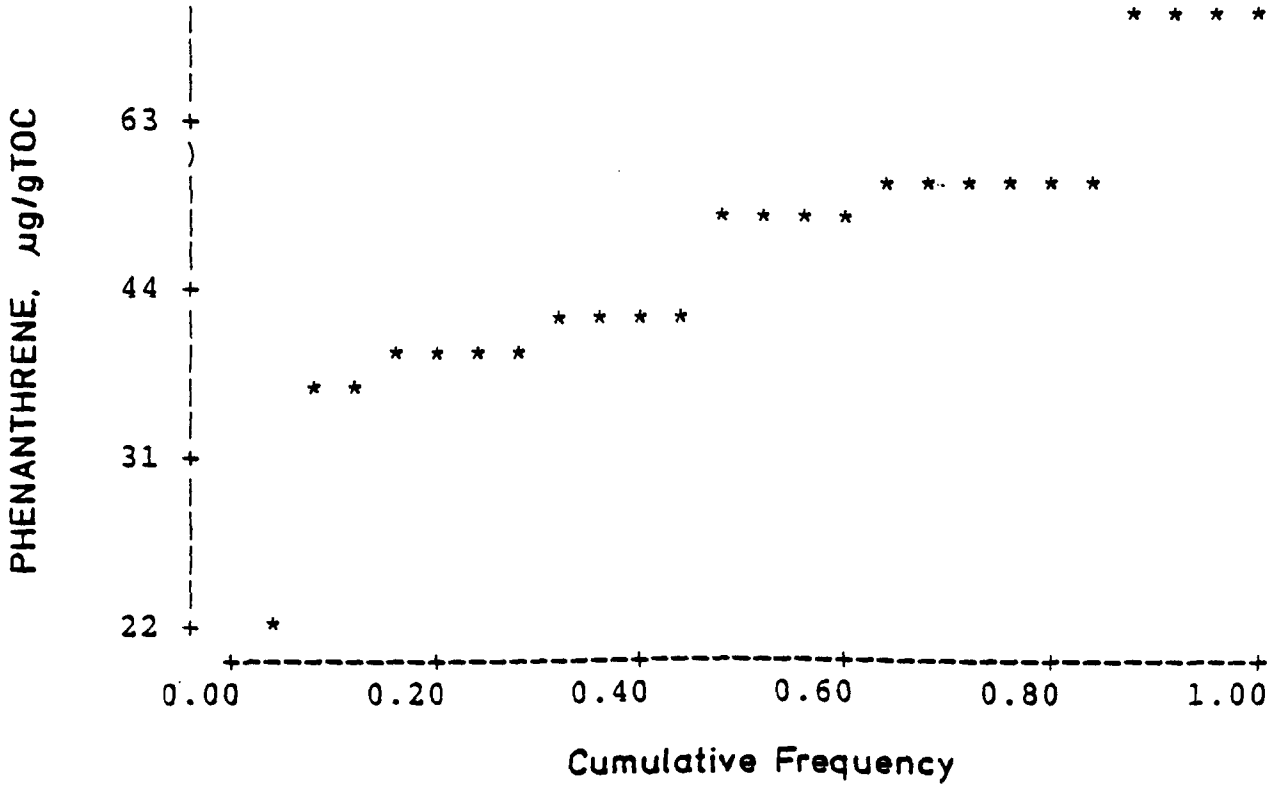


FIGURE 10. CUMULATIVE FREQUENCY DISTRIBUTION OF SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR PHENANTHRENE IN SALTWATER SEDIMENTS. SSLC VALUES ARE IN µG PHENANTHRENE/G SEDIMENT ORGANIC CARBON.

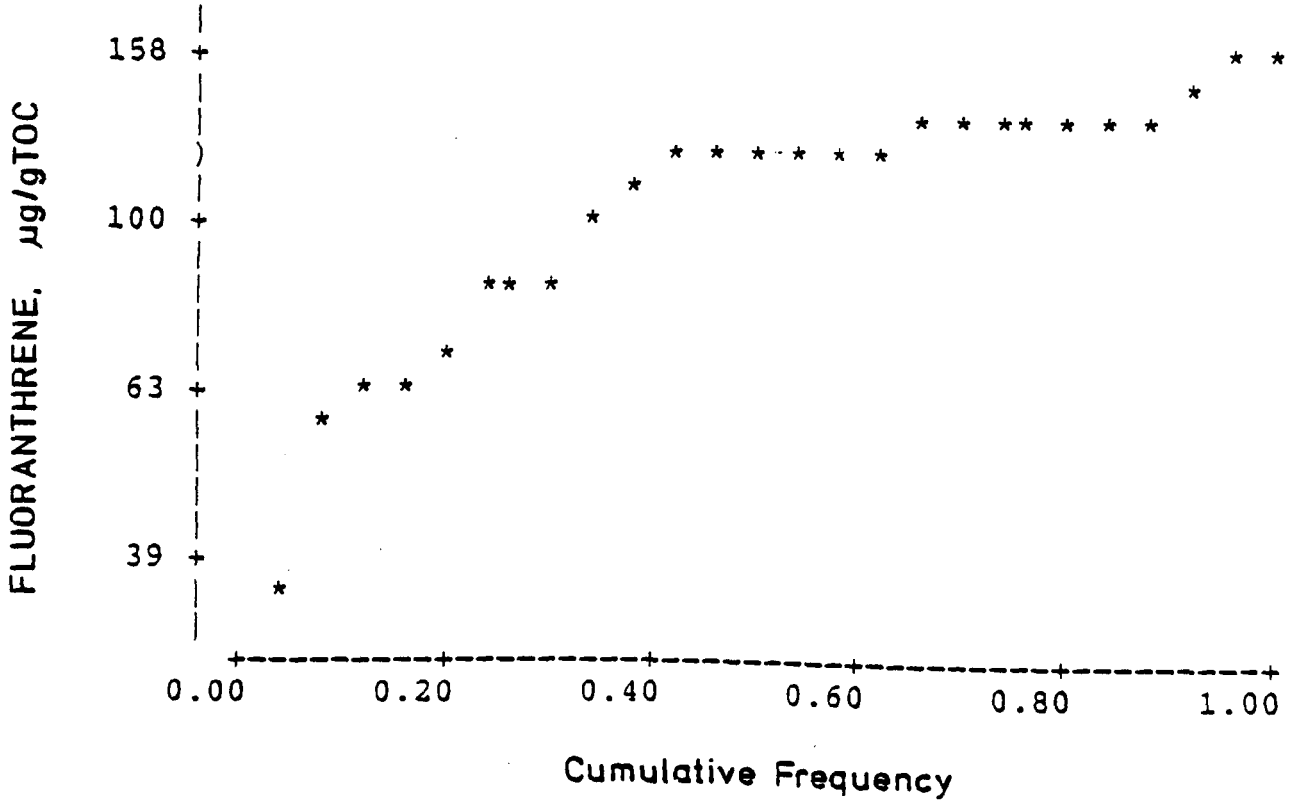


FIGURE 11. CUMULATIVE FREQUENCY DISTRIBUTION OF SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR FLUORANTHENE IN SALTWATER SEDIMENTS. SSLC VALUES ARE IN µG FLUORANTHENE/G SEDIMENT ORGANIC CARBON.

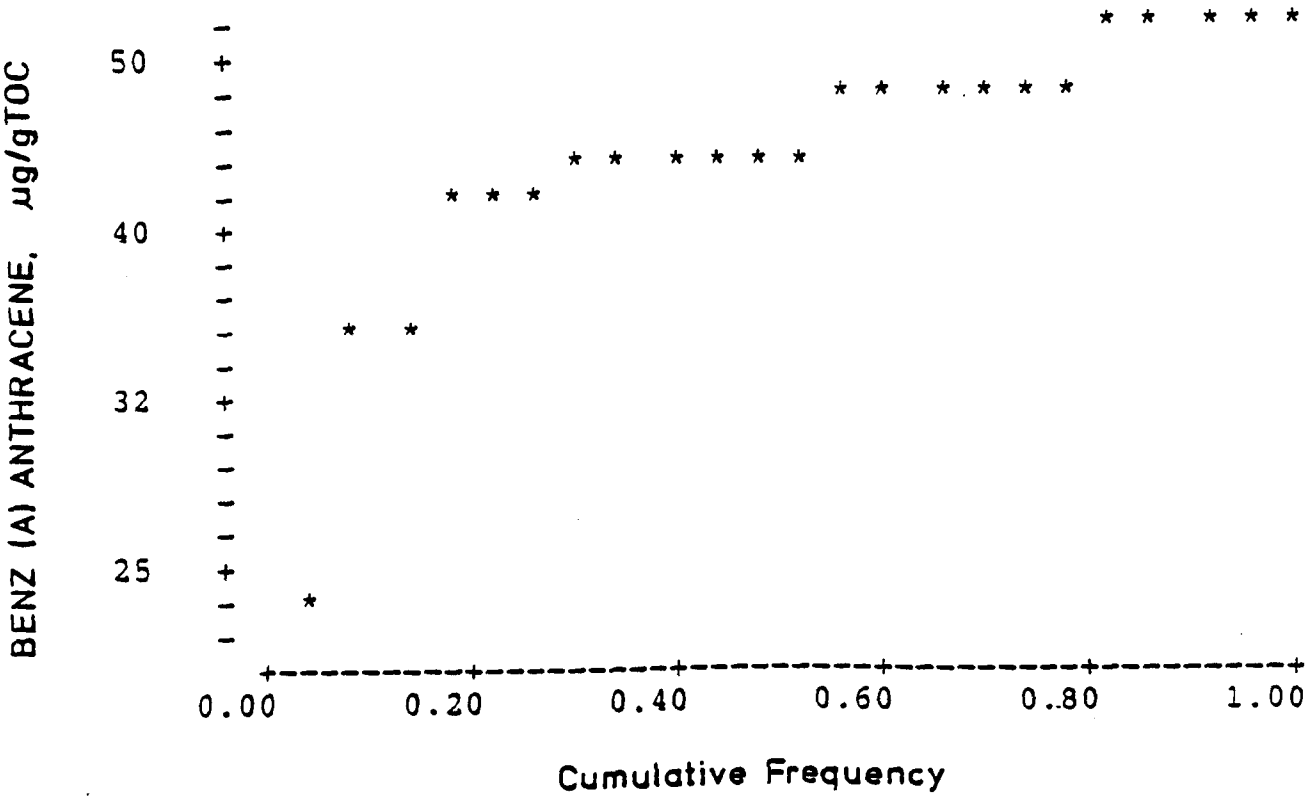


FIGURE 12. CUMULATIVE FREQUENCY DISTRIBUTION OF SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR BENZ(A)ANTHRACENE IN SALTWATER SEDIMENTS. SSLC VALUES ARE IN µG BENZ(A)ANTHRACENE/G SEDIMENT ORGANIC CARBON.

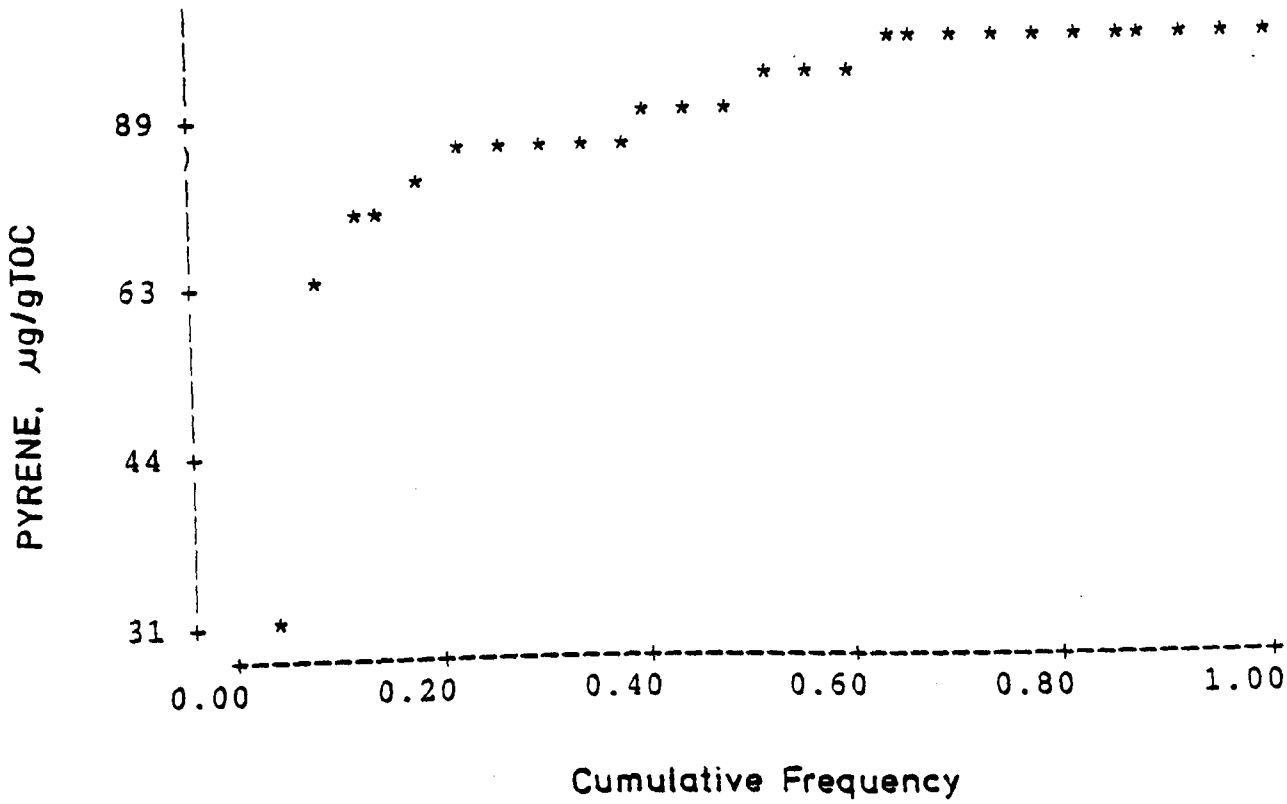


FIGURE 13. CUMULATIVE FREQUENCY DISTRIBUTION OF SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR PYRENE IN SALTWATER SEDIMENTS. SSLC VALUES ARE IN µG PYRENE/G SEDIMENT ORGANIC CARBON.

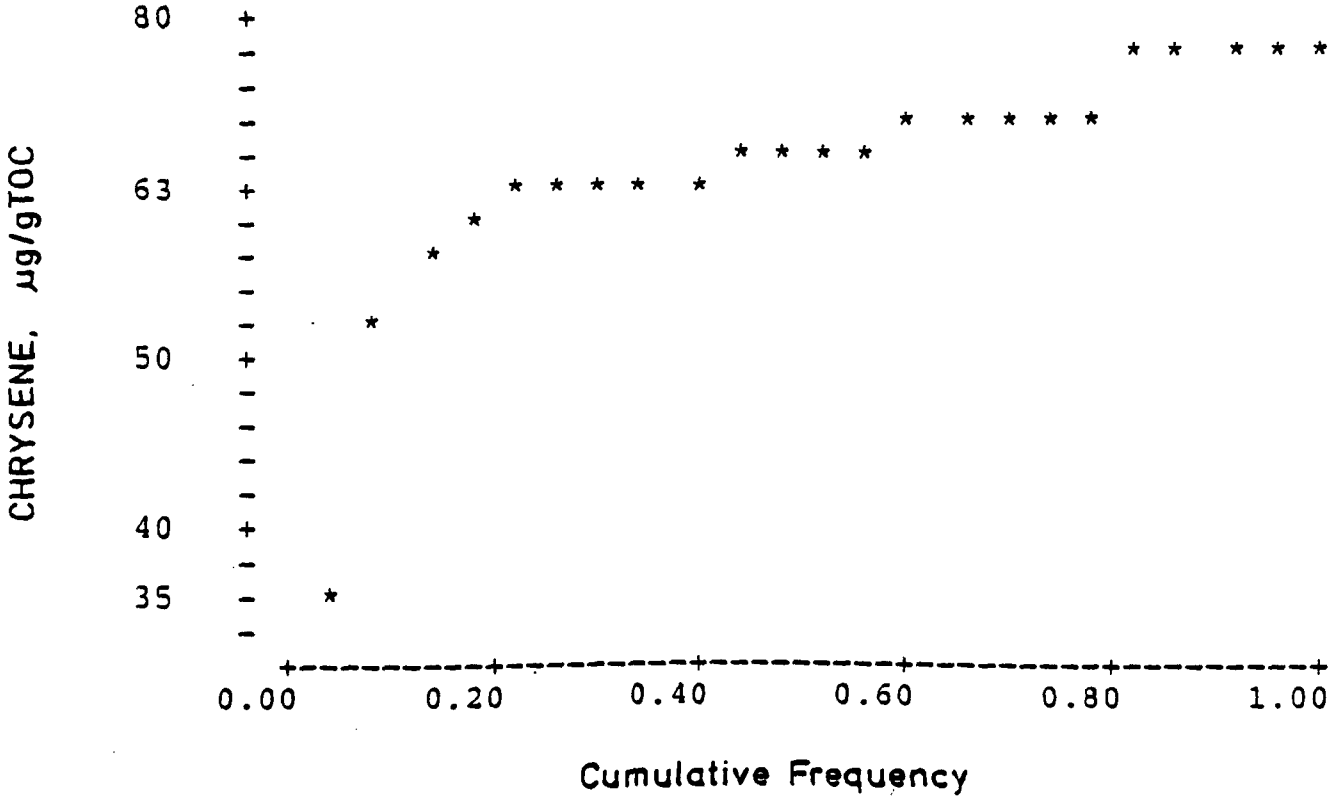


FIGURE 14. CUMULATIVE FREQUENCY DISTRIBUTION OF SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR CHRYSENE IN SALTWATER SEDIMENTS. SSLC VALUES ARE IN µG CHRYSENE/G SEDIMENT ORGANIC CARBON.

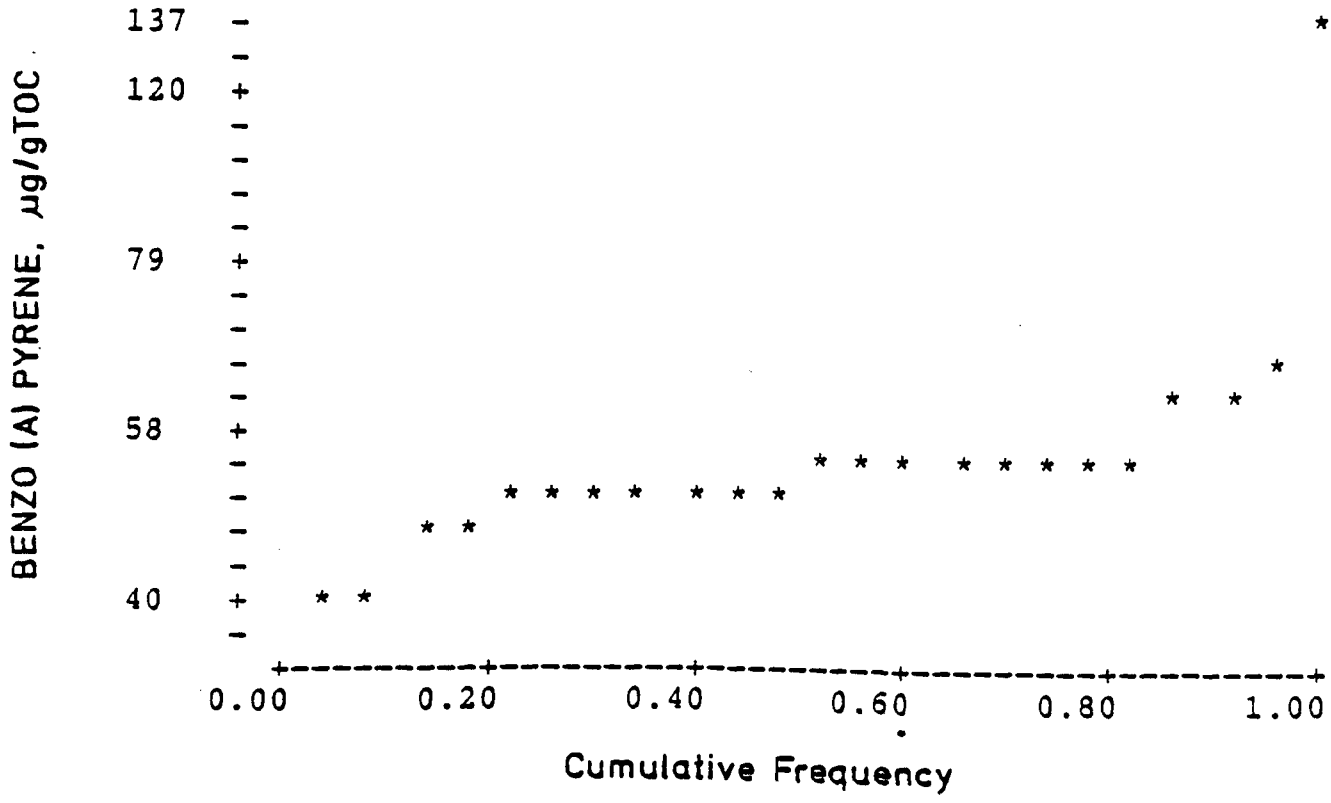


FIGURE 15. CUMULATIVE FREQUENCY DISTRIBUTION OF SPECIES SCREENING LEVEL CONCENTRATIONS (SSLCs) FOR BENZO(A)PYRENE IN SALTWATER SEDIMENTS. SSLC VALUES ARE IN µG BENZO(A)PYRENE/G SEDIMENT ORGANIC CARBON.

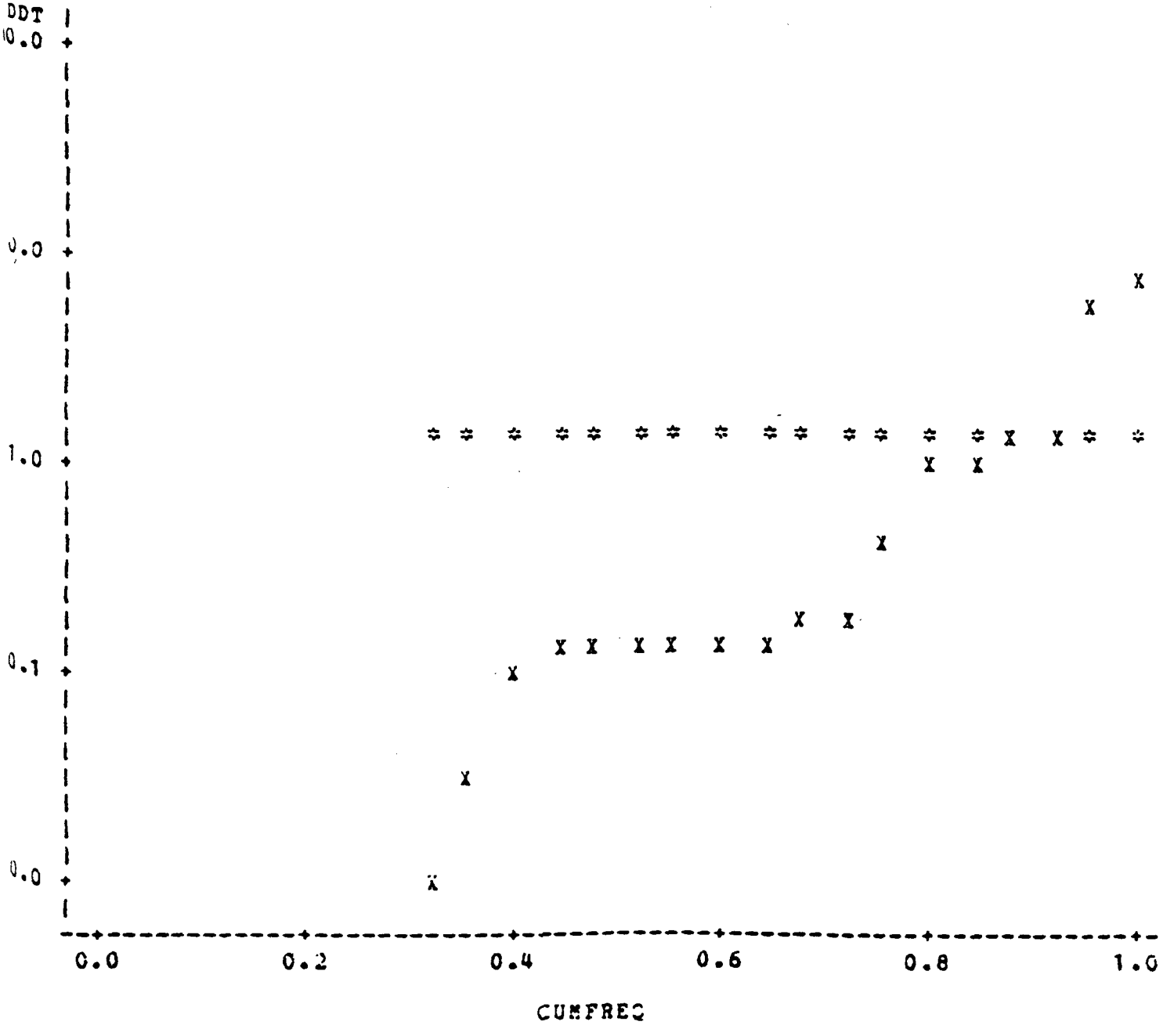
APPENDIX

Cumulative Frequency Distribution Plots Used to Calculate Species Screening Level Concentrations for Contaminants in Freshwater and Saltwater Sediments. Contaminant Concentrations (Vertical Axis) are Given in ug Contaminant/g Sediment Organic Carbon.

APPENDIX. Part I. Species Screening Level Concentration Plots for Contaminants in Freshwater Sediments.

CUMULATIVE FREQUENCY OF NORMALIZED ¢DDT! (UG/G ORGANIC CARBON)
GENUS=ASELLUS SPP=INTERMEDIUS

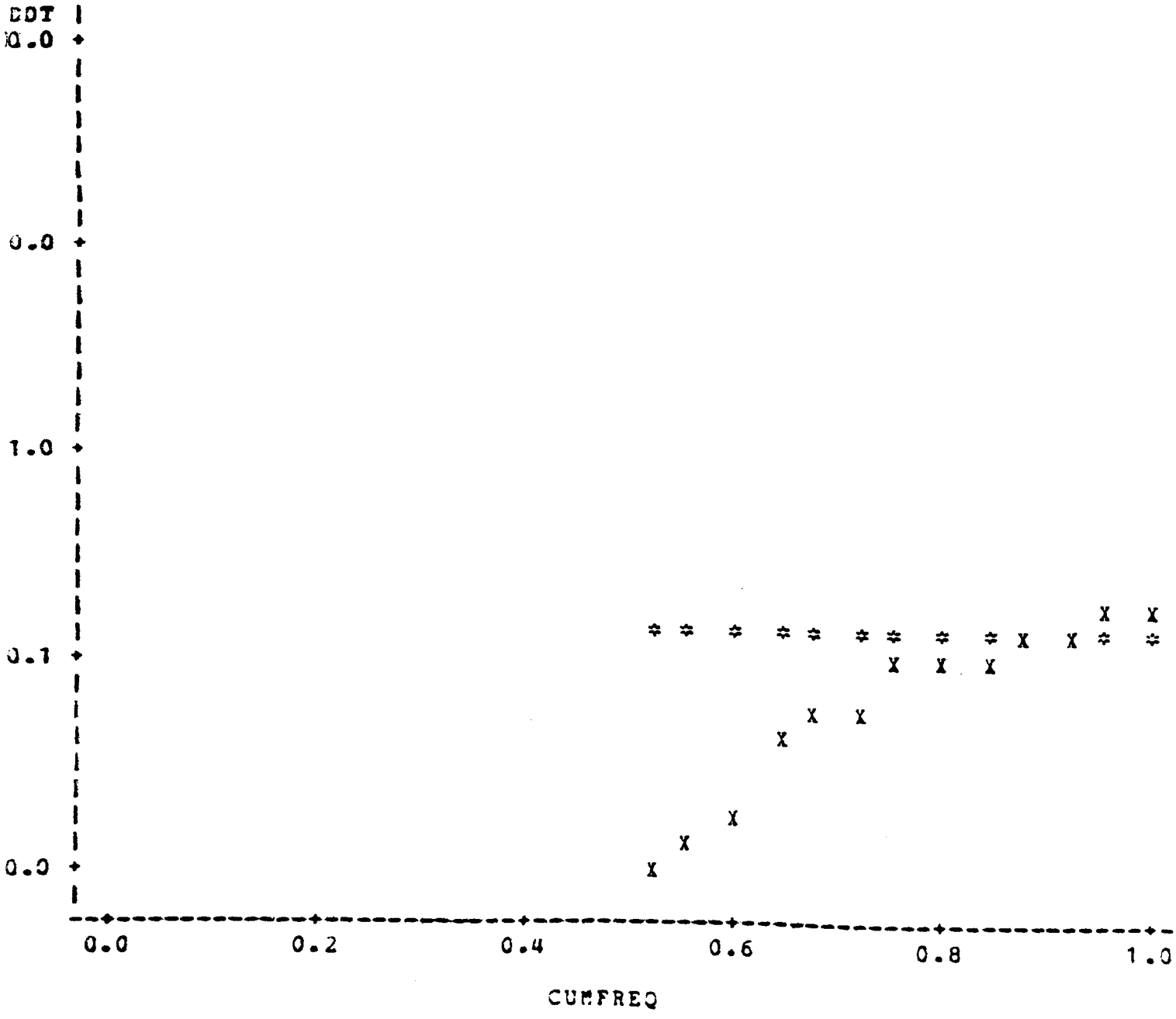
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 16 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ΦDDT! (UG/G ORGANIC CARBON)
GENUS=CYRNELLUS SPP=FRATERNUS

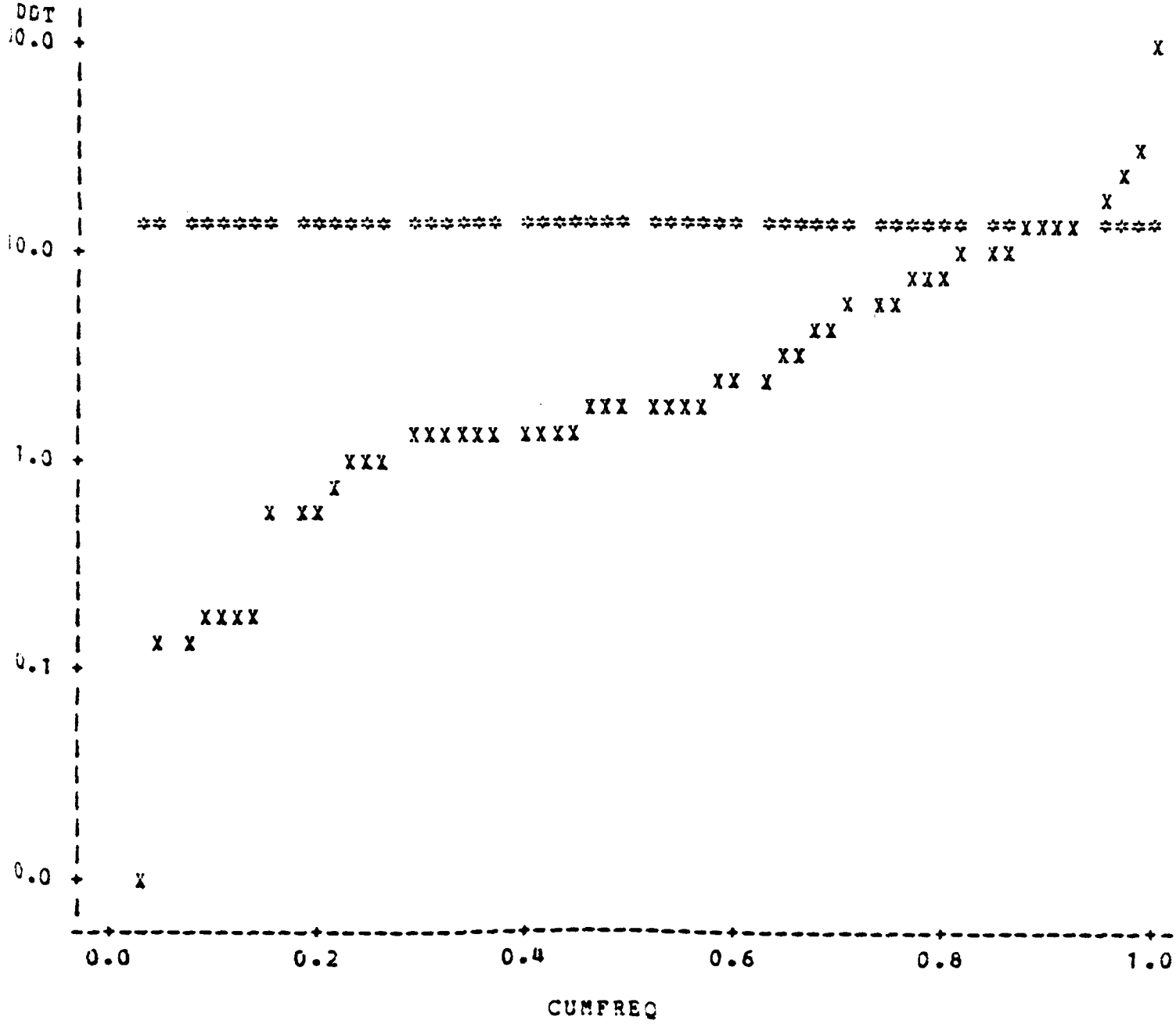
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 26 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DDT! (UG/G ORGANIC CARBON)
GENUS=GAMMARUS SPP=FASCIATUS

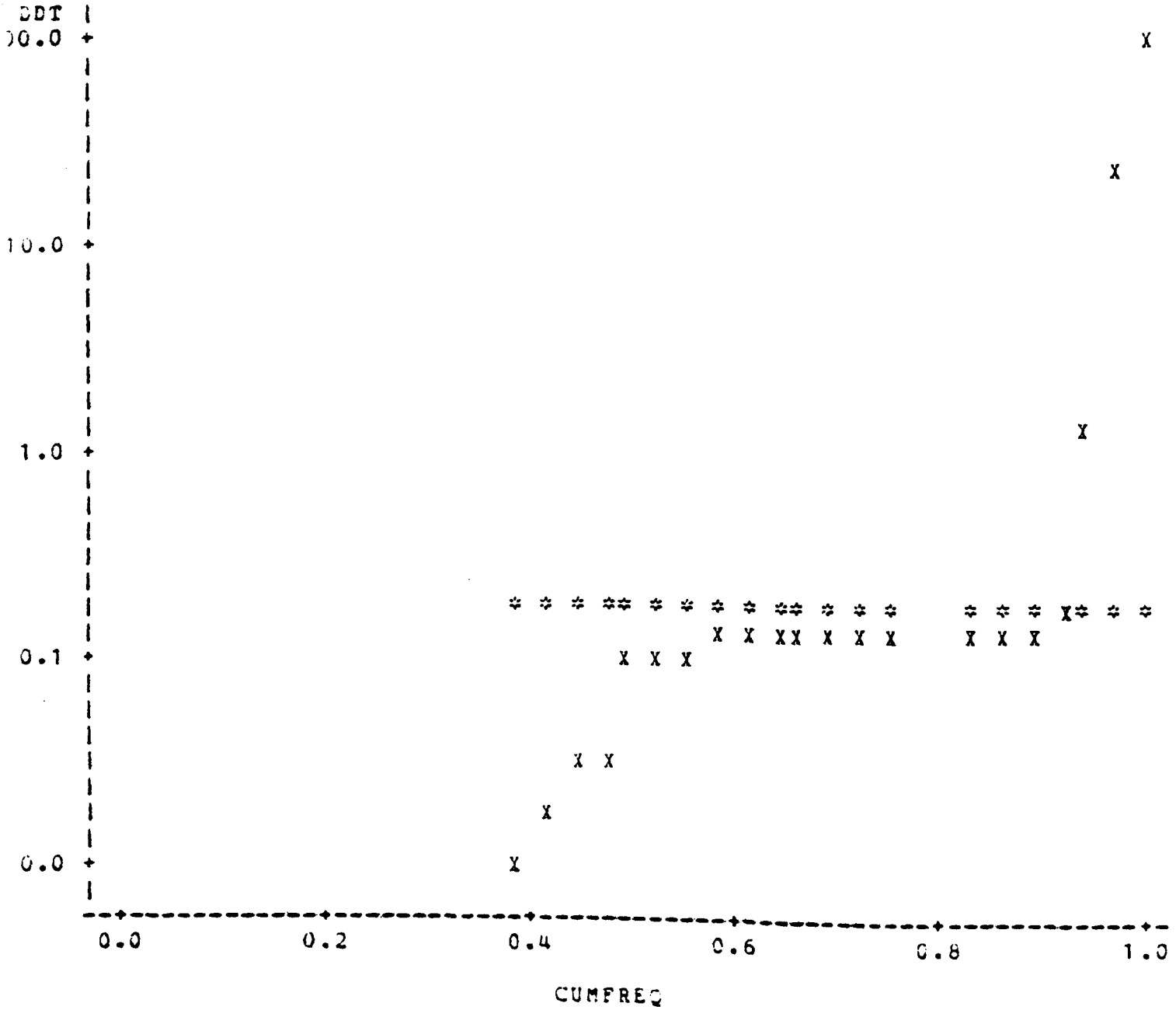
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 6 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ΣDDT! (UG/G ORGANIC CARBON)
GENUS=HYALELLA SPP=AZTECA

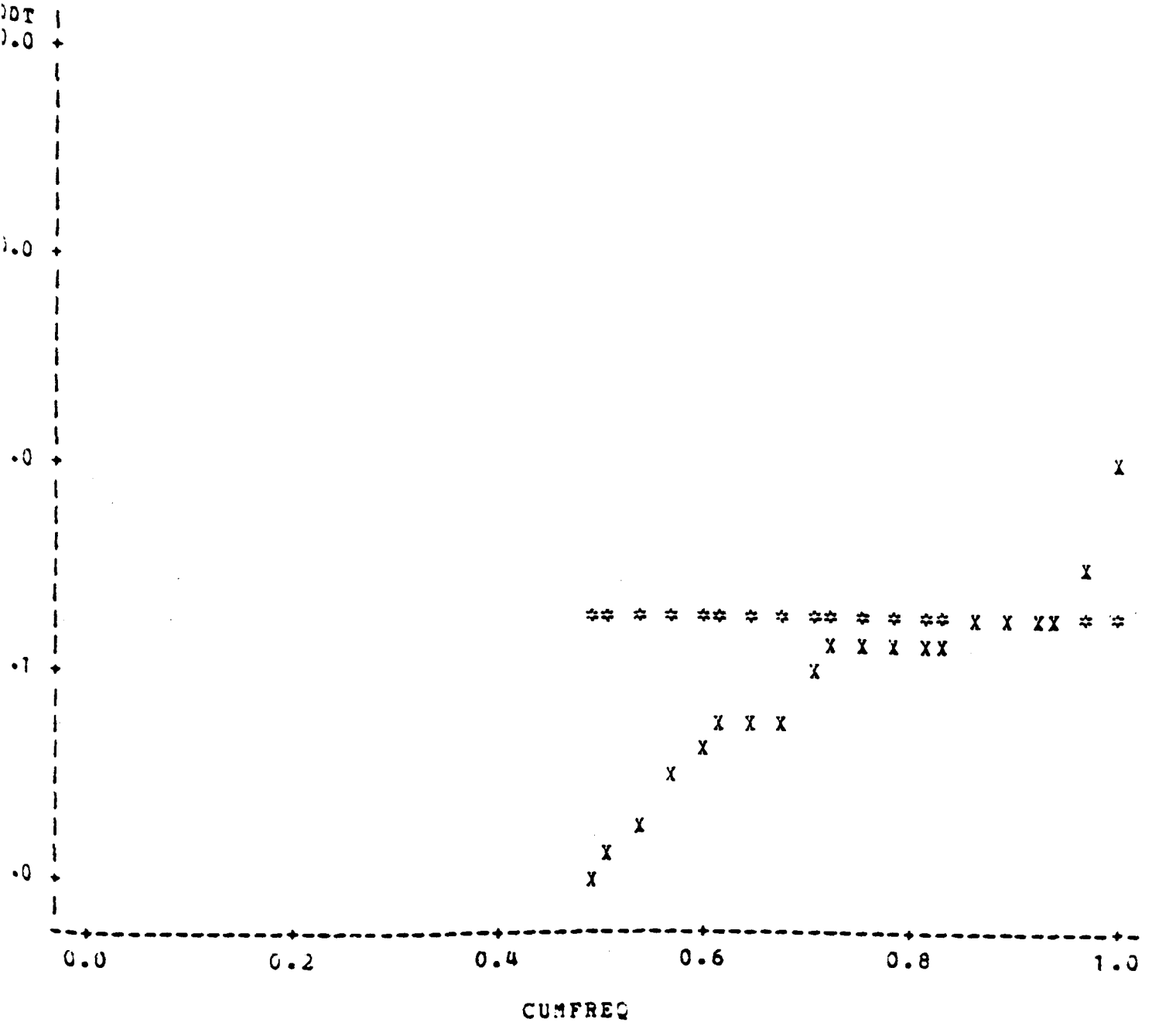
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 31 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DDT! (UG/G ORGANIC CARBON)
GENUS=HYDROPSYCH SPP=FRISONI

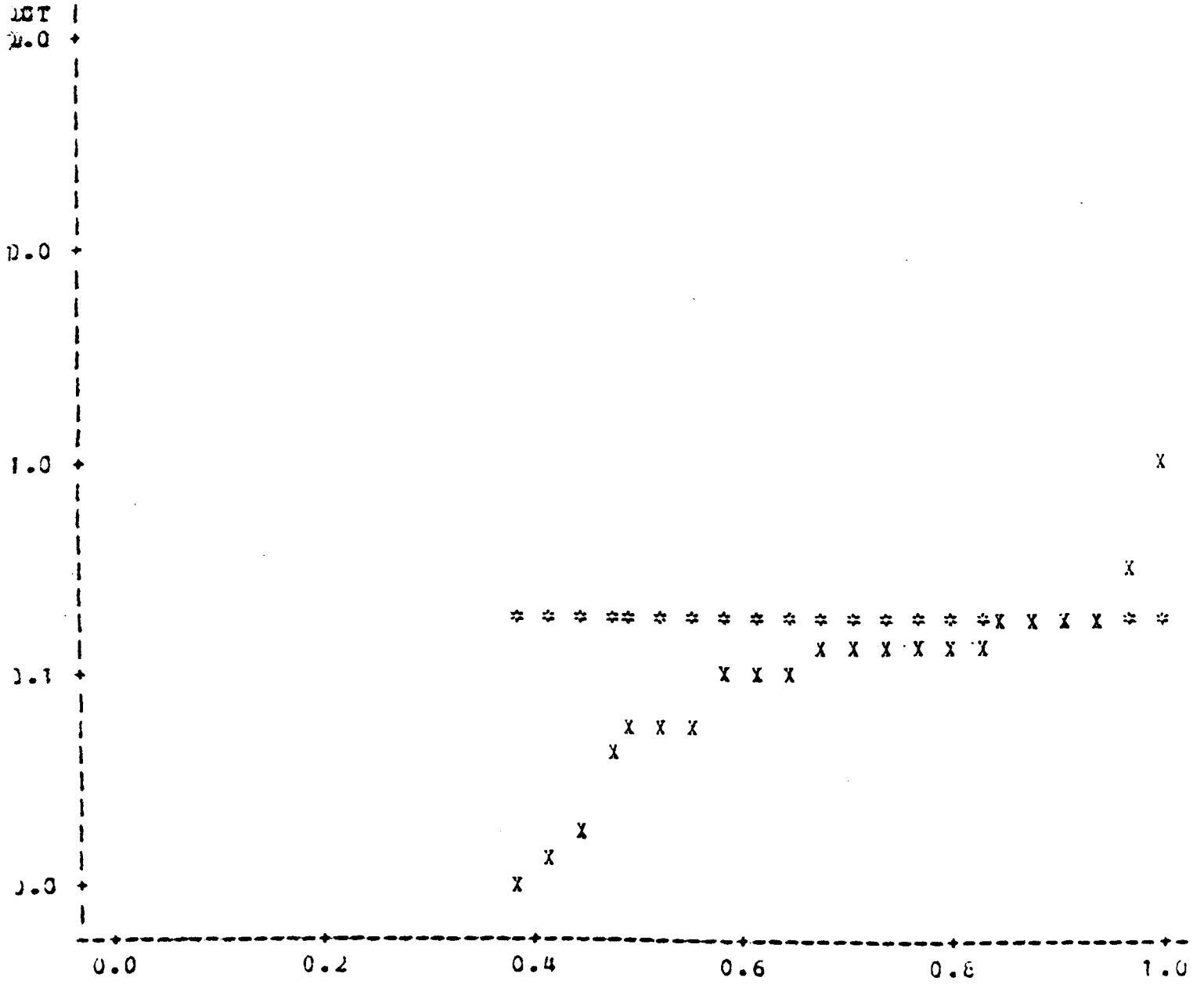
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



E: 38 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DDT! (UG/G ORGANIC CARBON)
GENUS=HYDROPSYCH SPP=ORRIS

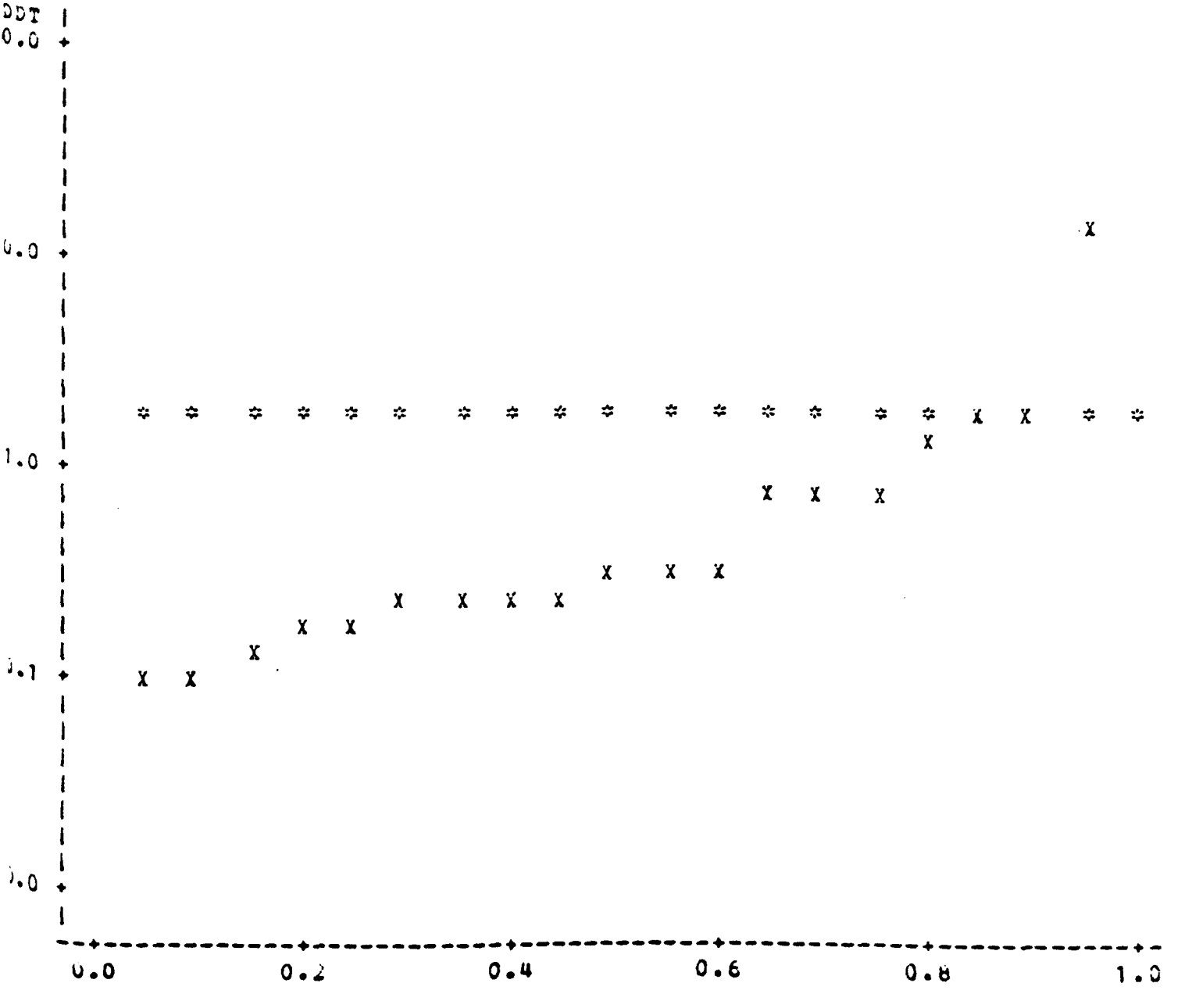
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 26 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DDT! (UG/G ORGANIC CARBON)
GENUS=LIMNODRILUS SPP=CERVIX

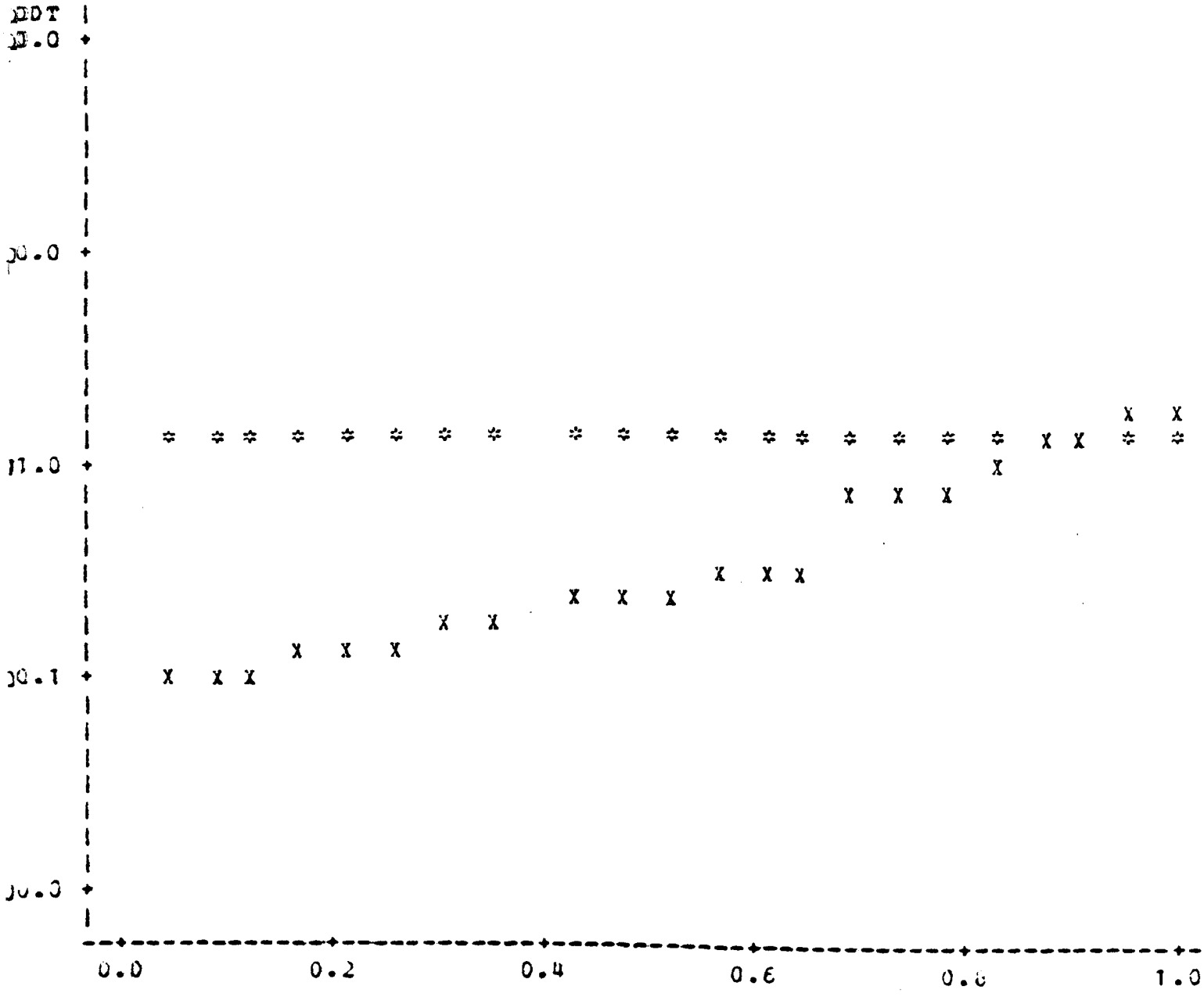
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



E: 1 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 2 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ΣDDT! (UG/G ORGANIC CARBON)
GENUS=LIMNODRILUS SPP=CLAPAREDEIANUS

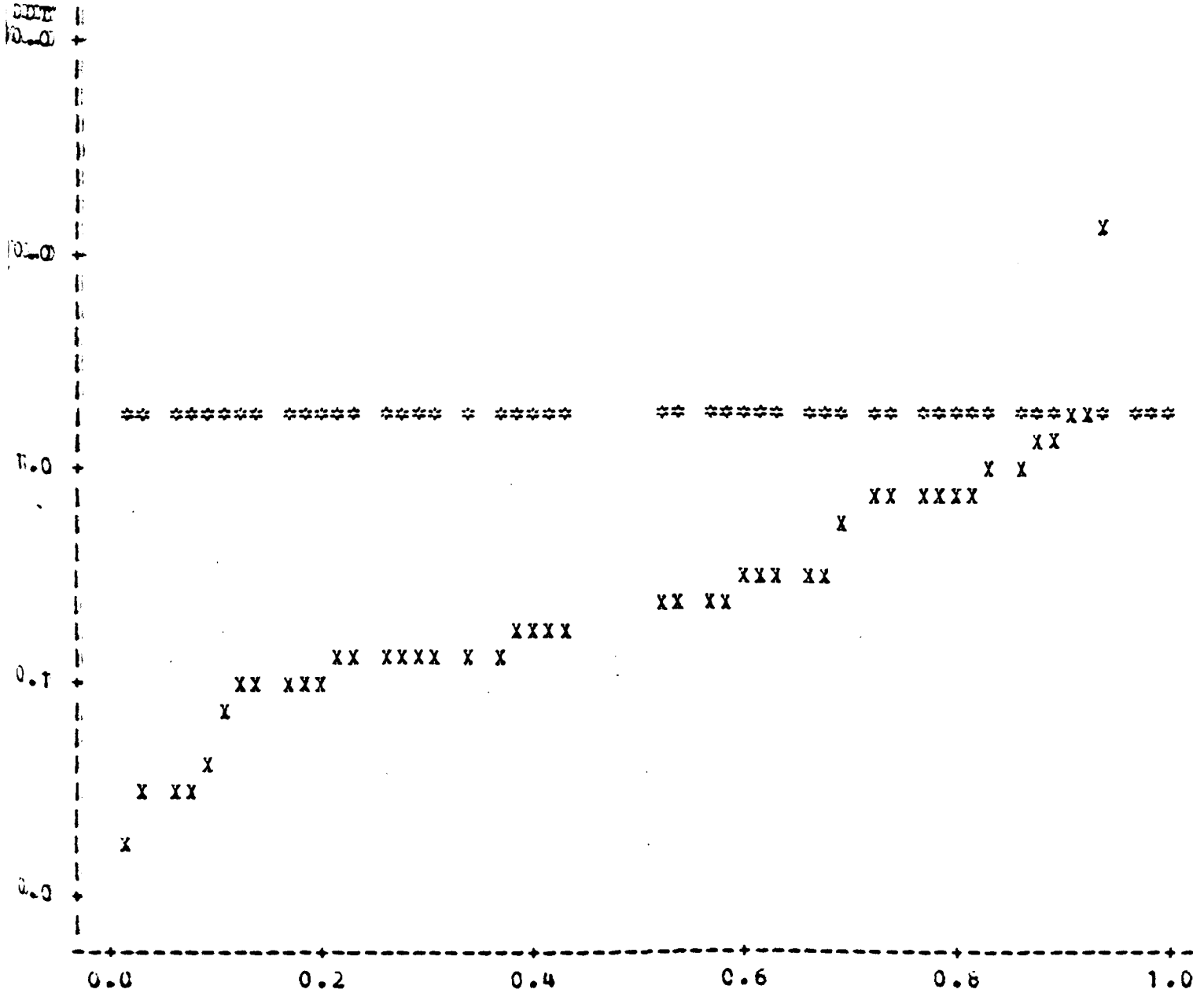
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 4 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ΣDDT! (UG/G ORGANIC CARBON)
GENUS=LIMNODRILUS SPP=HOFFMEISTERI

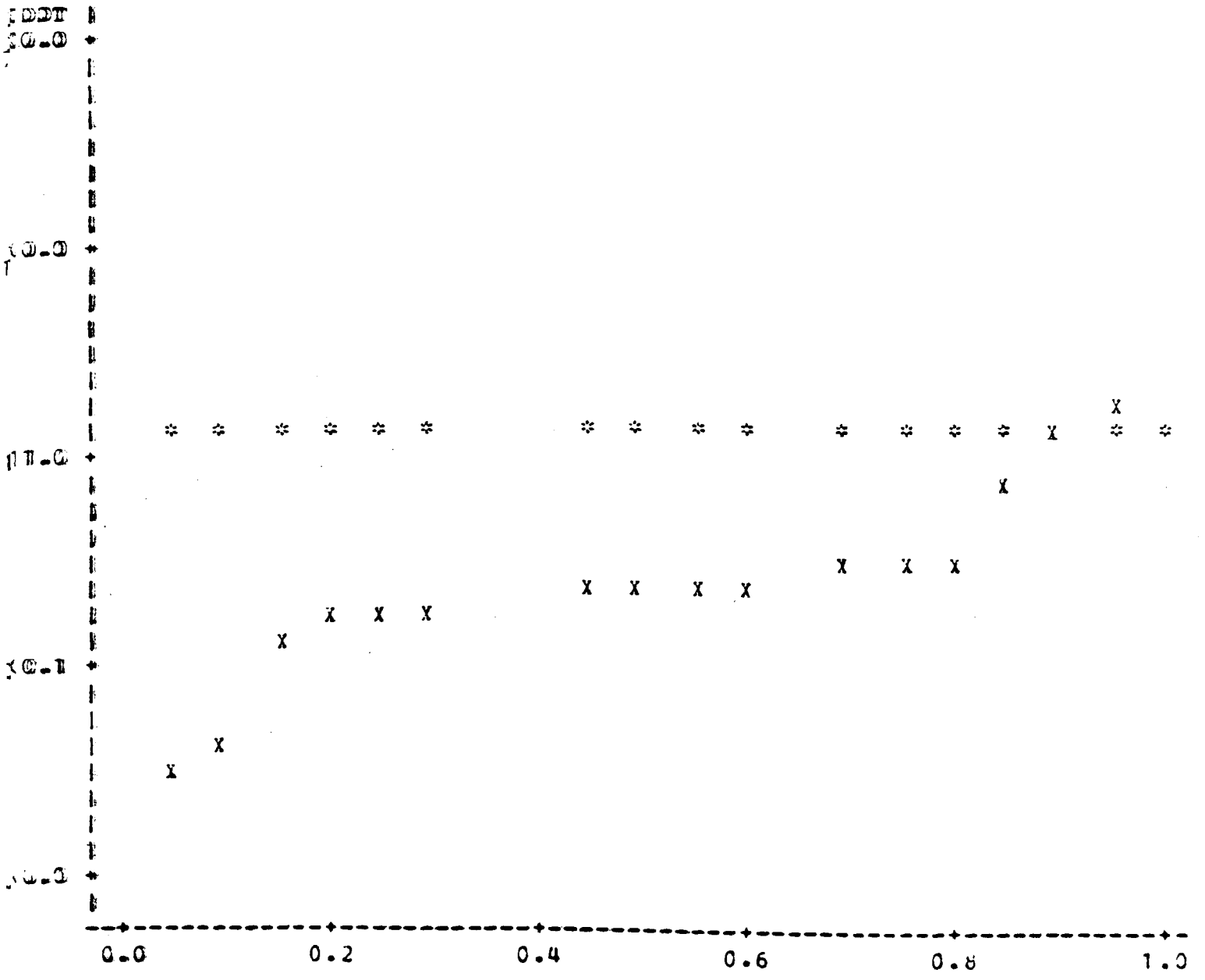
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 3 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 14 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ΣDDT! (UG/G ORGANIC CARBON)
GENUS=LIMNODRILUS SPP=UDEKEMIANUS

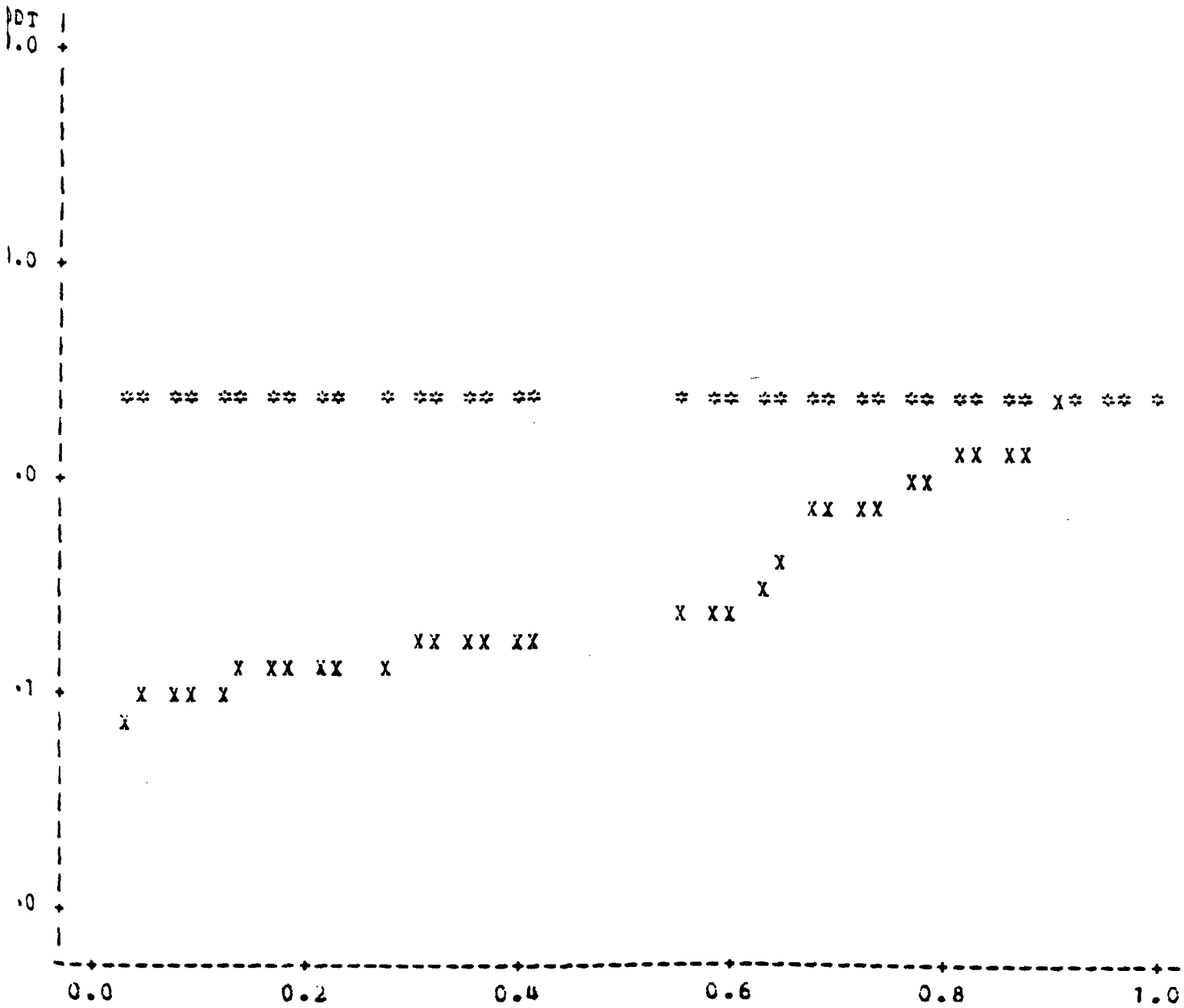
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 1 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 7 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED (DDT) (UG/G ORGANIC CARBON)
GENUS=PELOSCOLEX SPP=FEROX

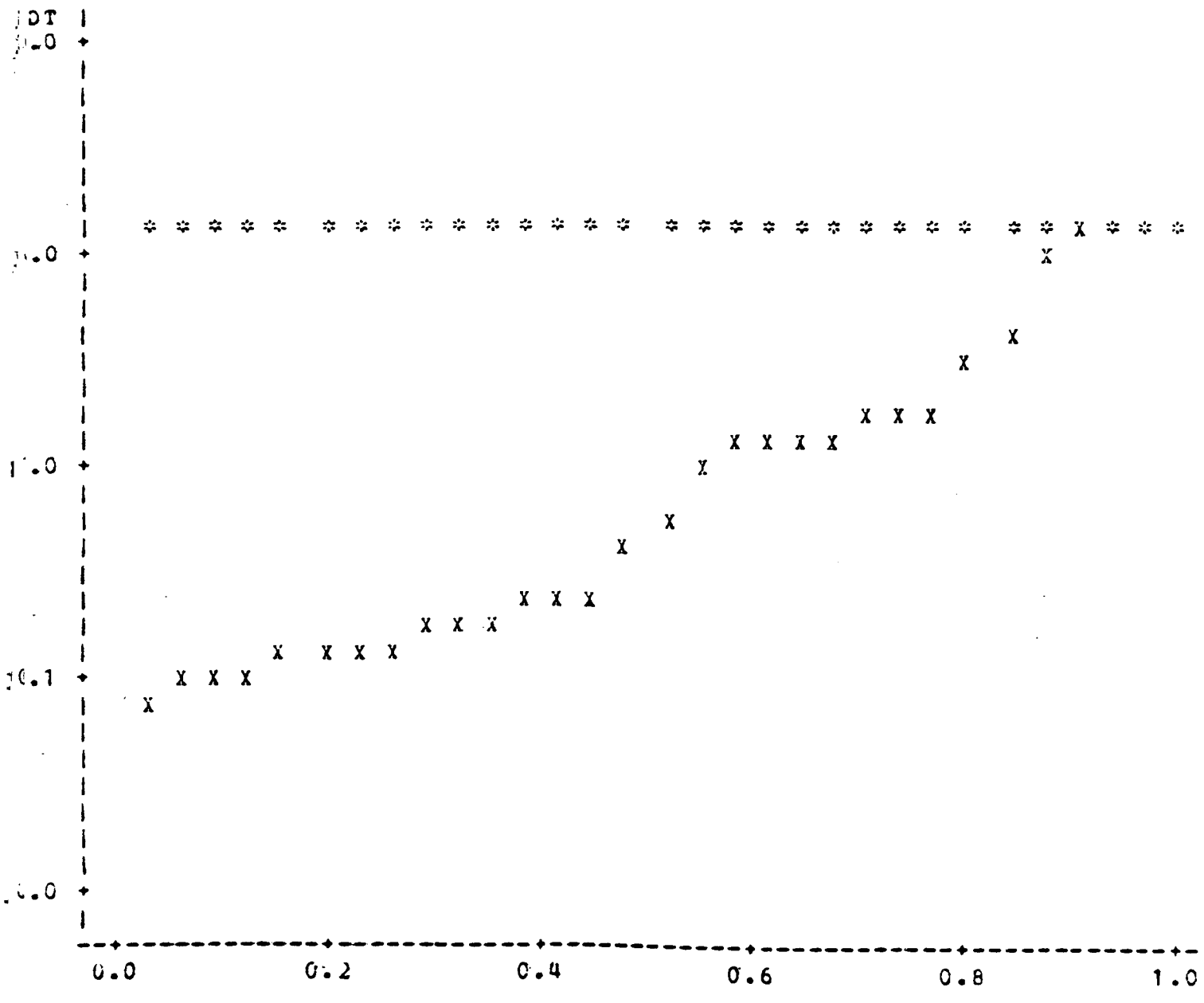
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



4 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 13 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ΣDDT! (UG/G ORGANIC CARBON)
GENUS=PELOSCOLEX SPP=MULTISETOSUS

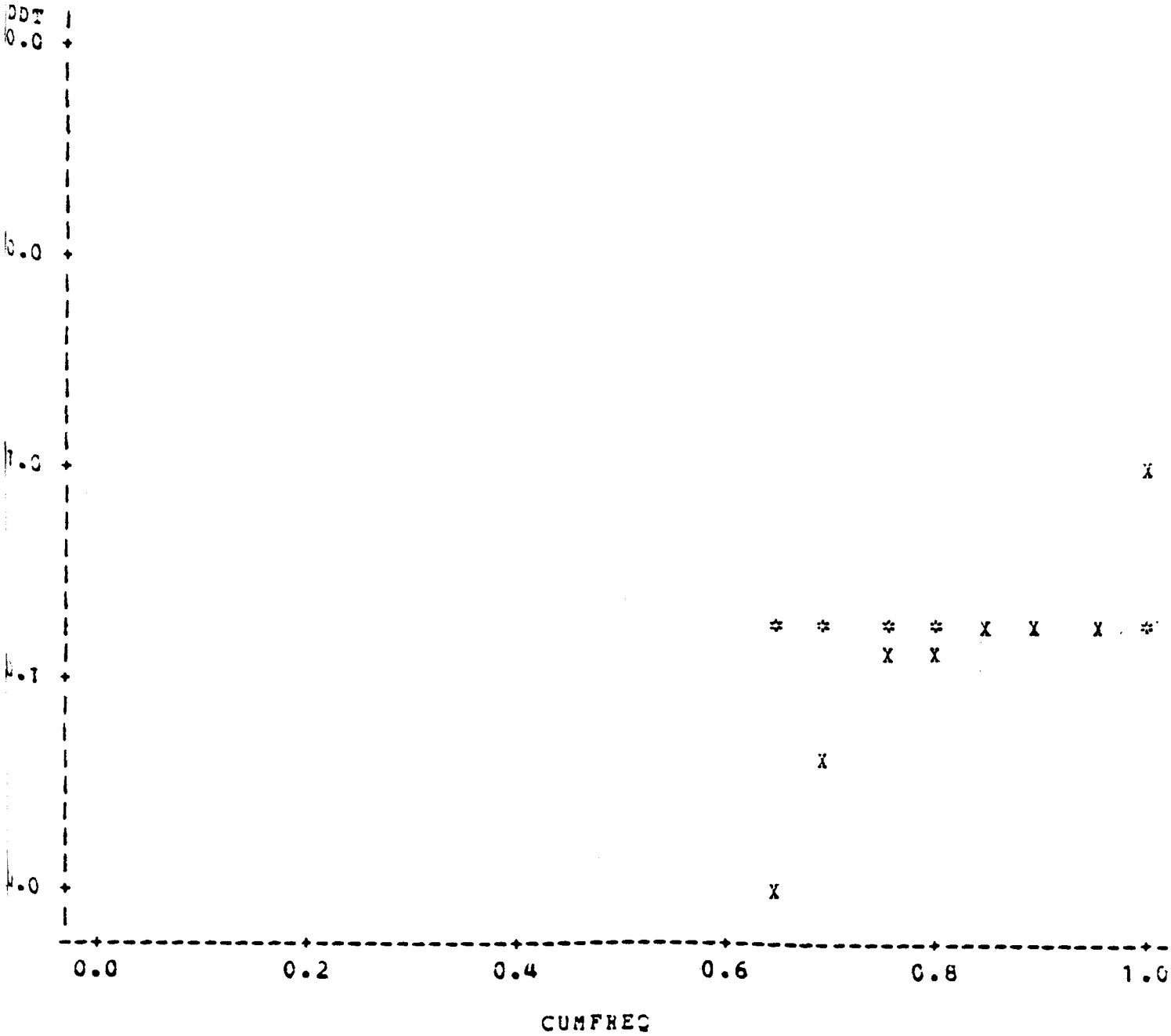
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 3 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 1 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ΣDDT! (UG/G ORGANIC CARBON)
GENUS=PENTANEURA SPP=MALLOCHI

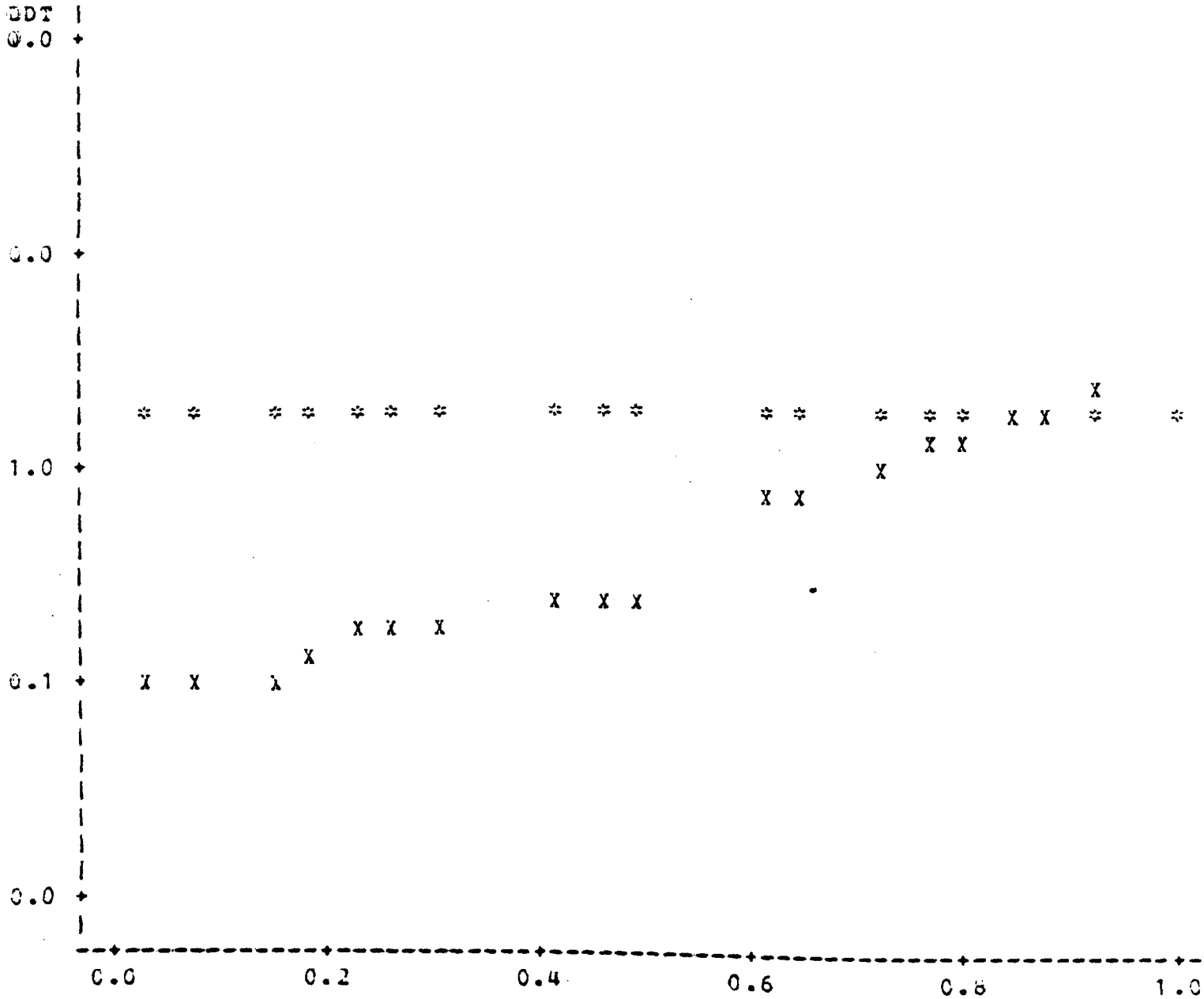
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 27 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ΦDDT! (UG/G ORGANIC CARBON)
GENUS=POTAMOTHRIX SPP=VEJDOVSKYI

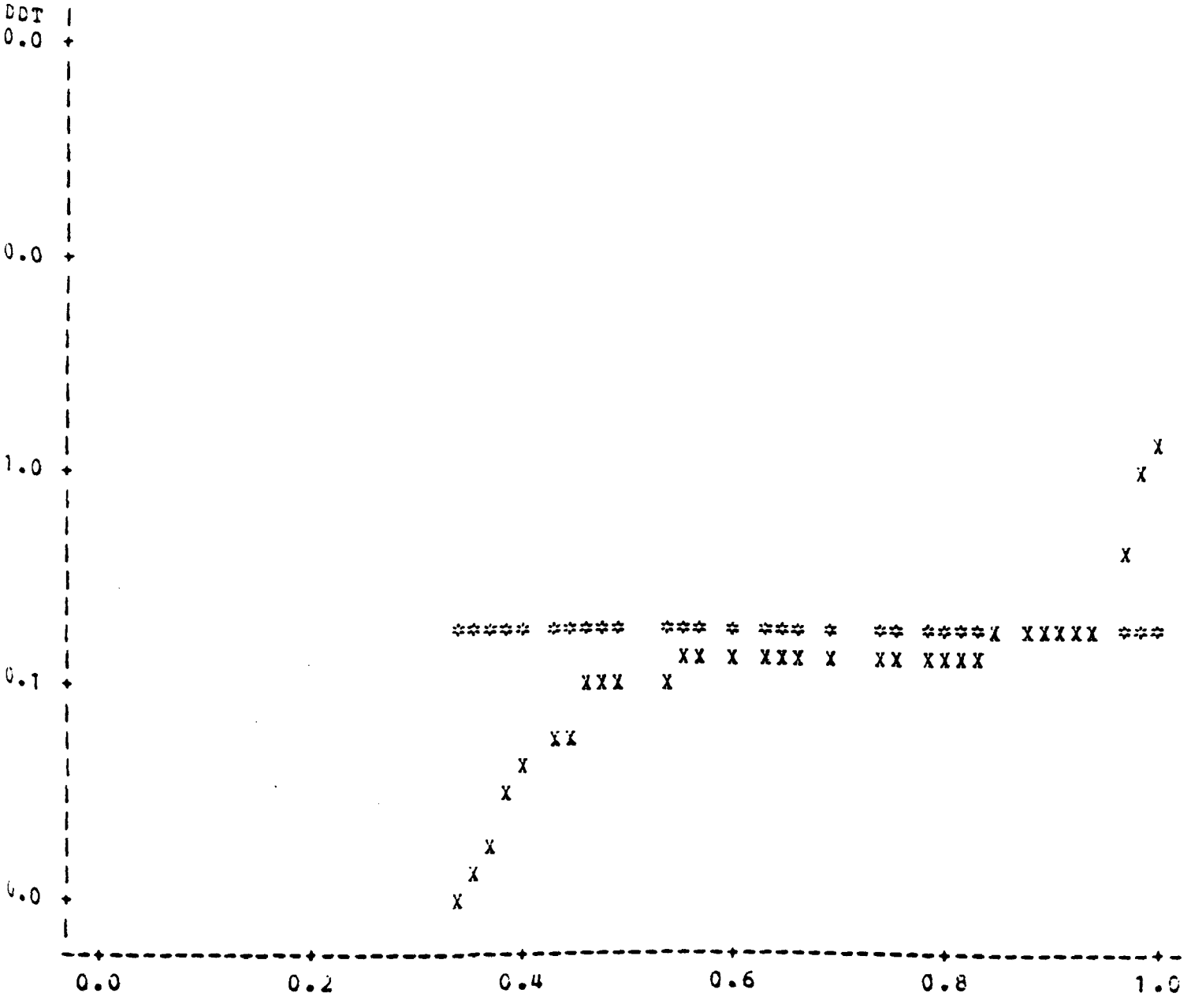
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE
TE: 16 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DDT! (UG/G ORGANIC CARBON)
GENUS=STENACRON SPP=INTERPUNCT

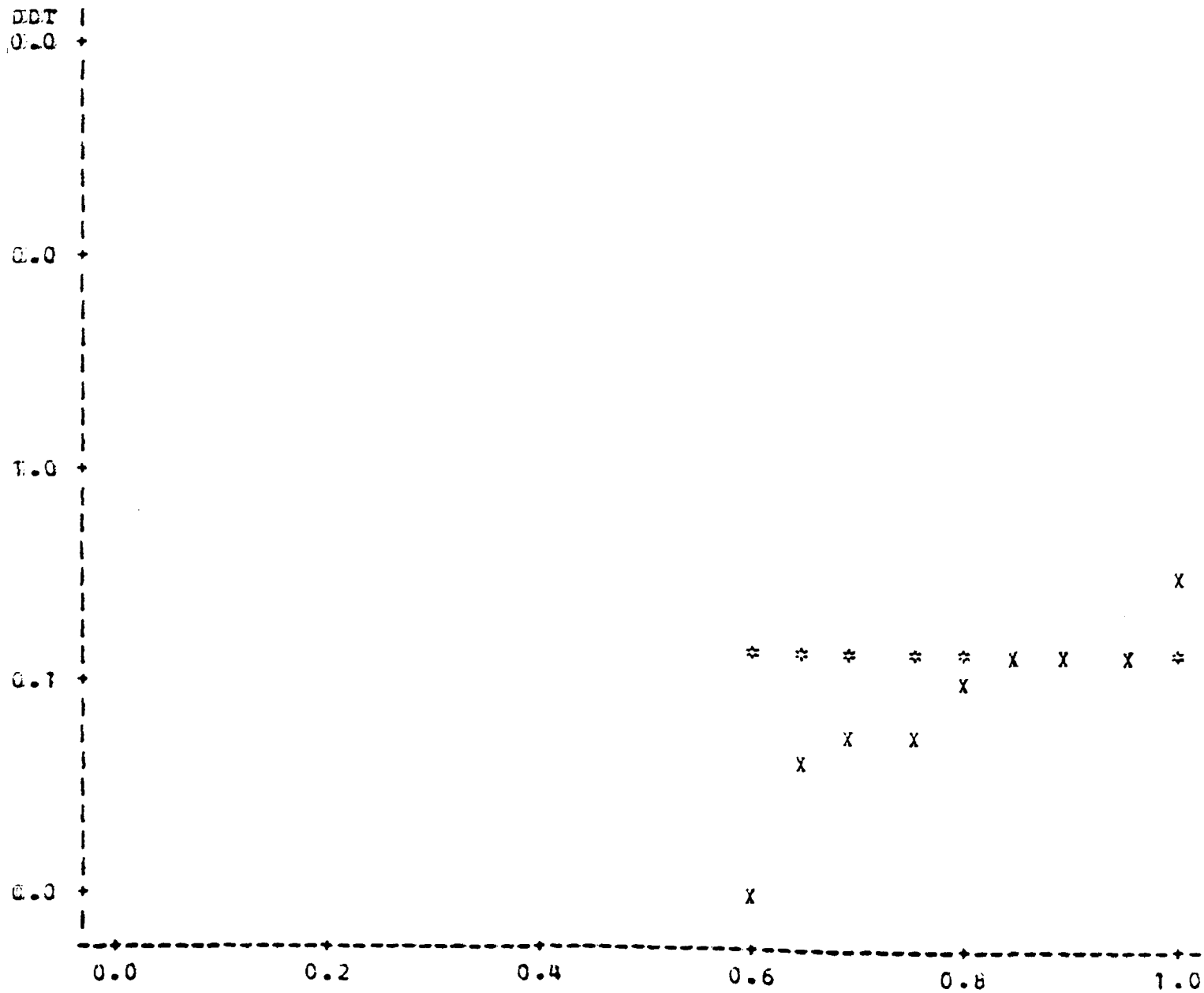
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 48 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ΣDDT! (UG/G ORGANIC CARBON)
GENUS=STENONEMA SPP=EXIQUUM

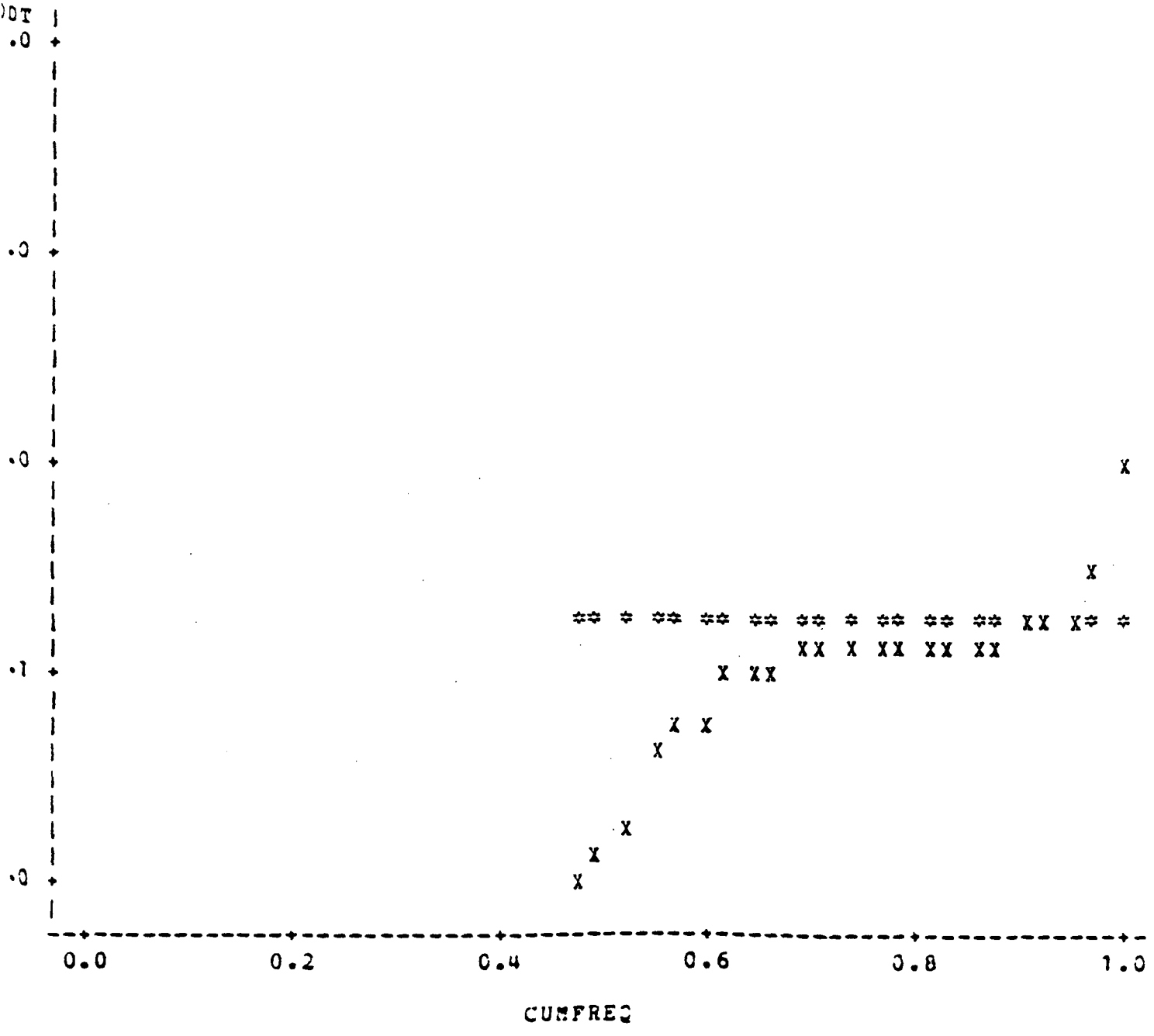
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 25 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DDT! (UG/G ORGANIC CARBON)
GENUS=STENONEMA SPP=INTEGRUM

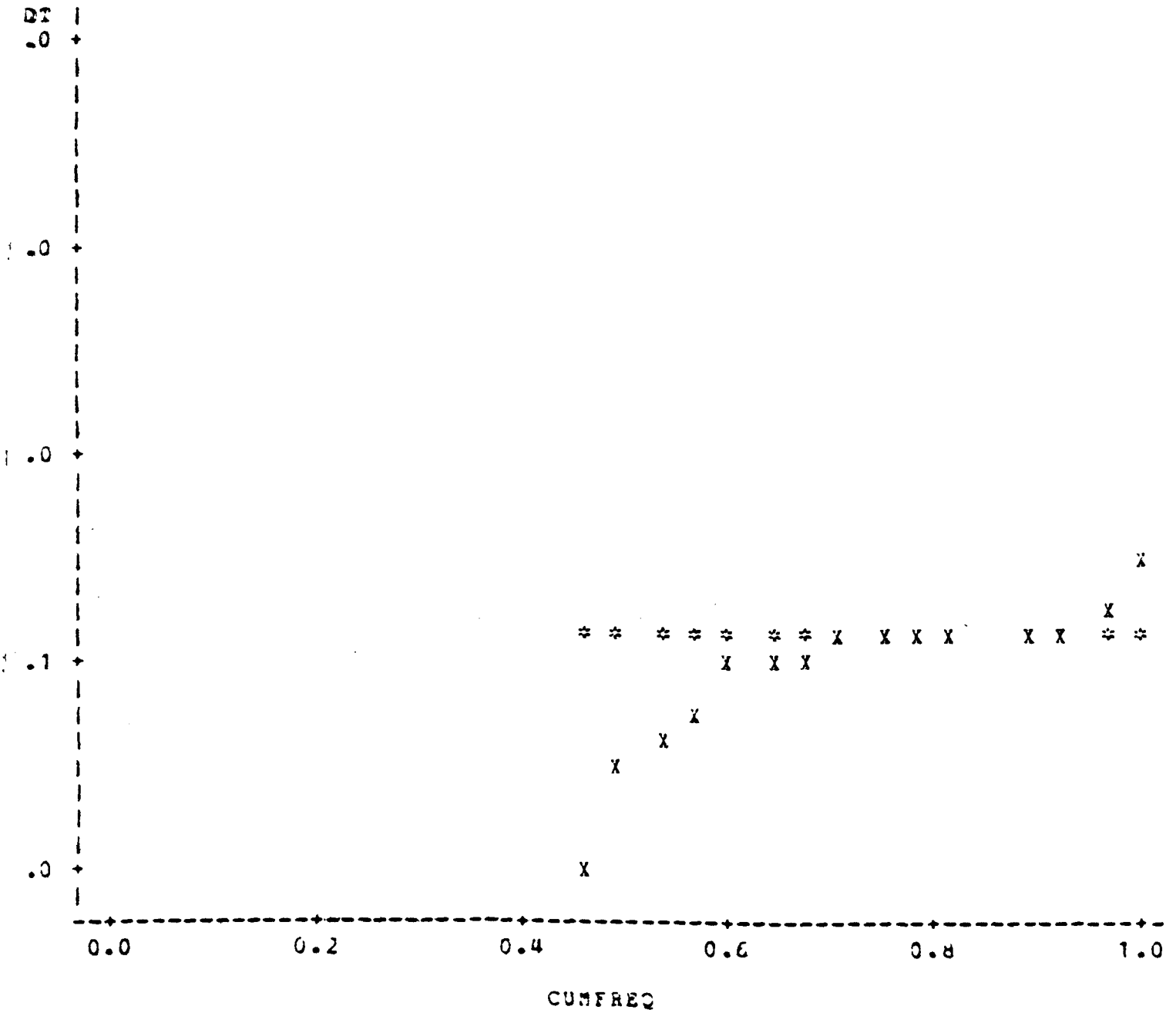
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



41 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DDT! (UG/G ORGANIC CARBON)
GENUS=STENONEMA SPP=PULCHELLUM

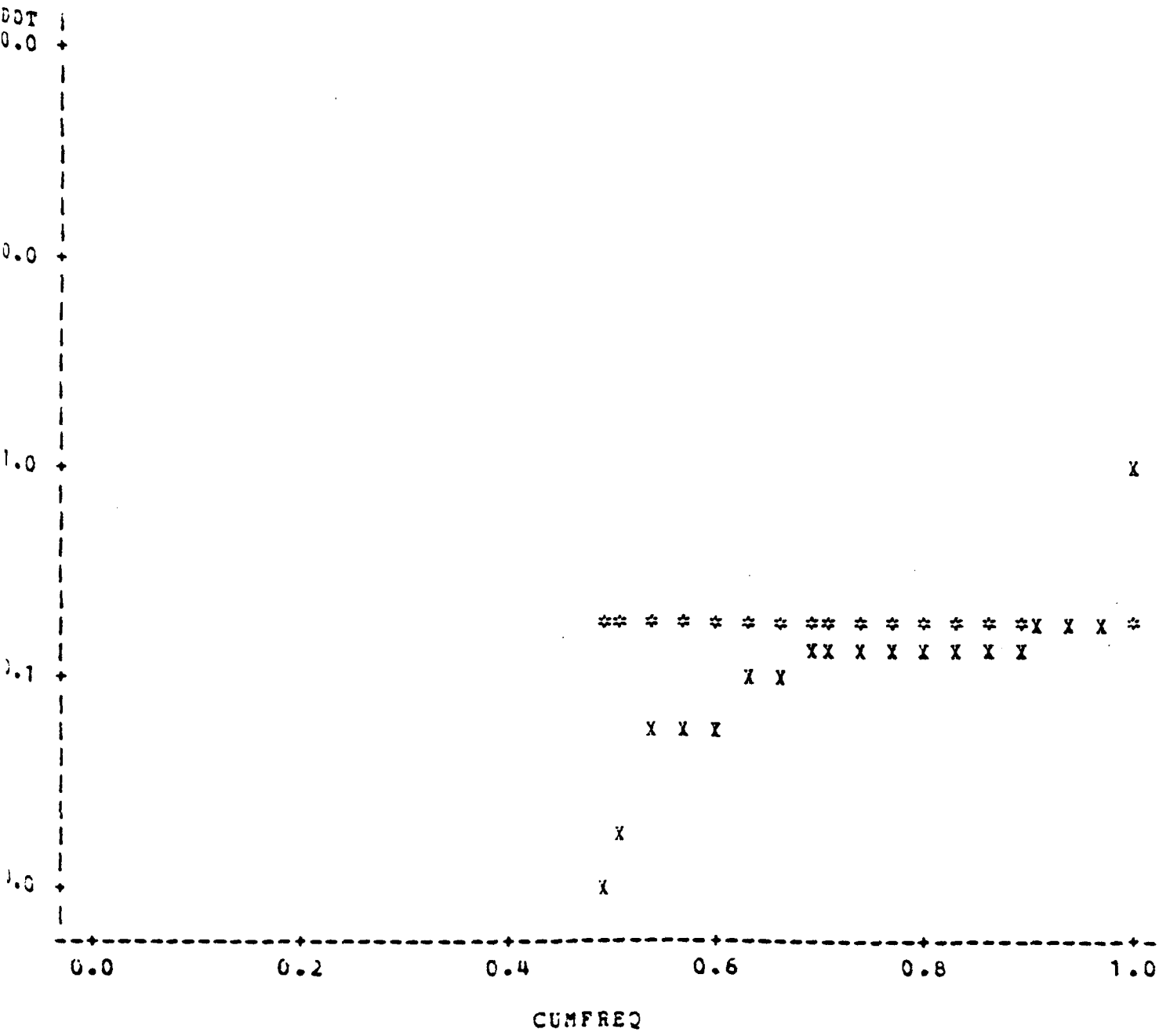
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 32 OBS HILDEN

CUMULATIVE FREQUENCY OF NORMALIZED (DDT) (UG/G ORGANIC CARBON)
GENUS=STENONEMA SPP=TERMINATUM

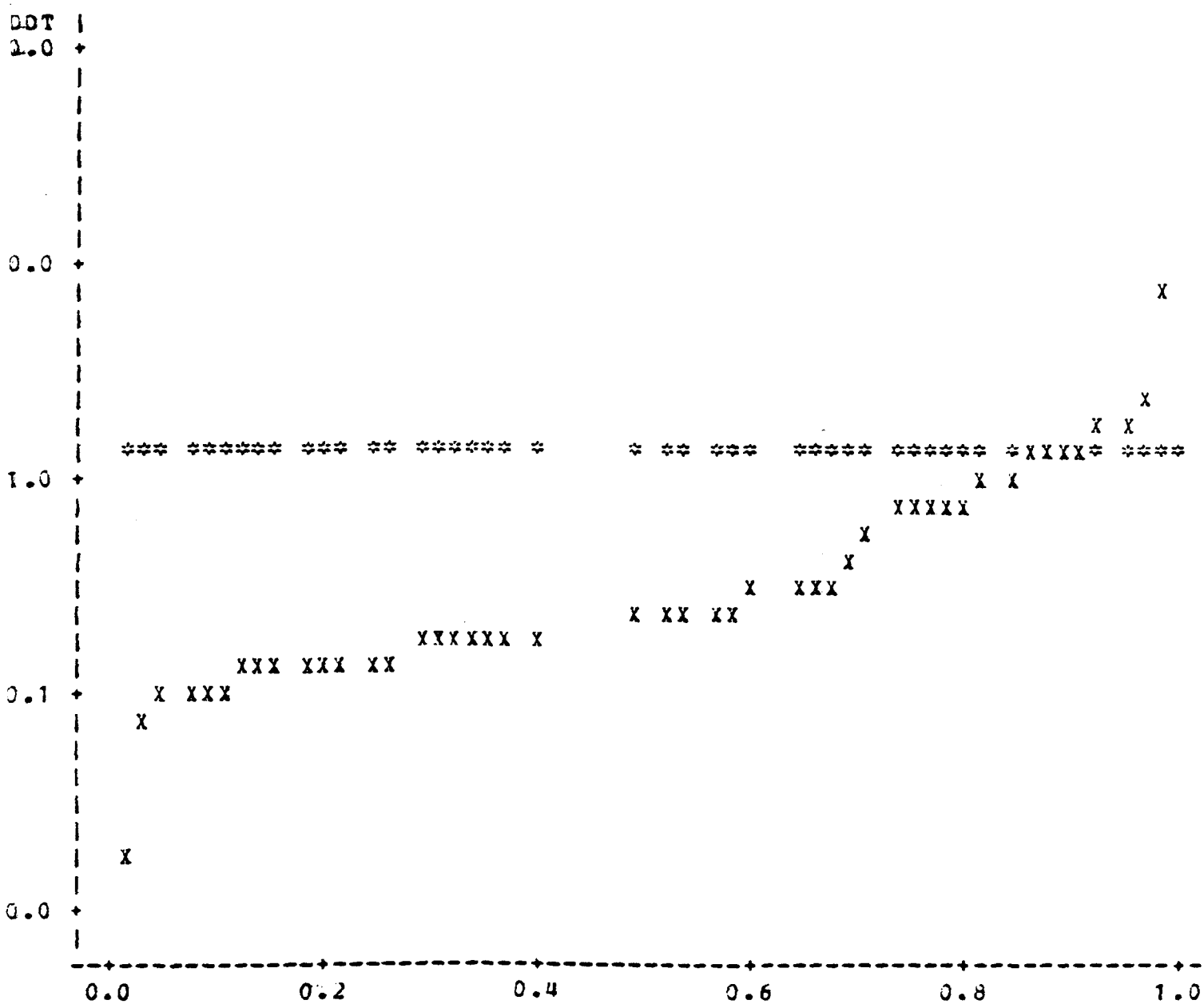
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 35 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ΦDDT! (UG/G ORGANIC CARBON)
GENUS=TUBIFEX SPP=TUBIFEX

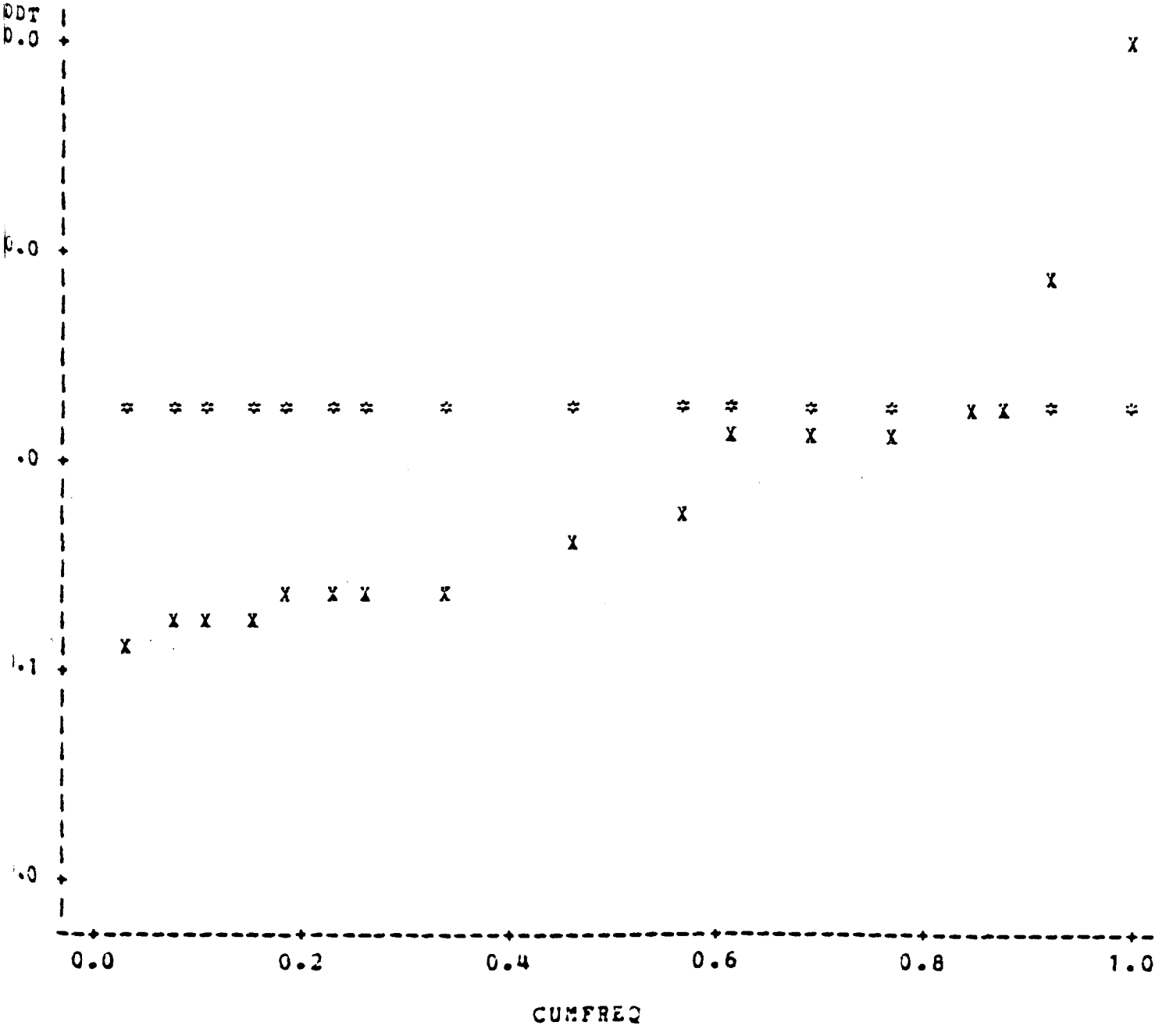
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 1 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 20 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ΣDDT! (UG/G ORGANIC CARBON)
GENUS=VALVATA SPP=SINCERA

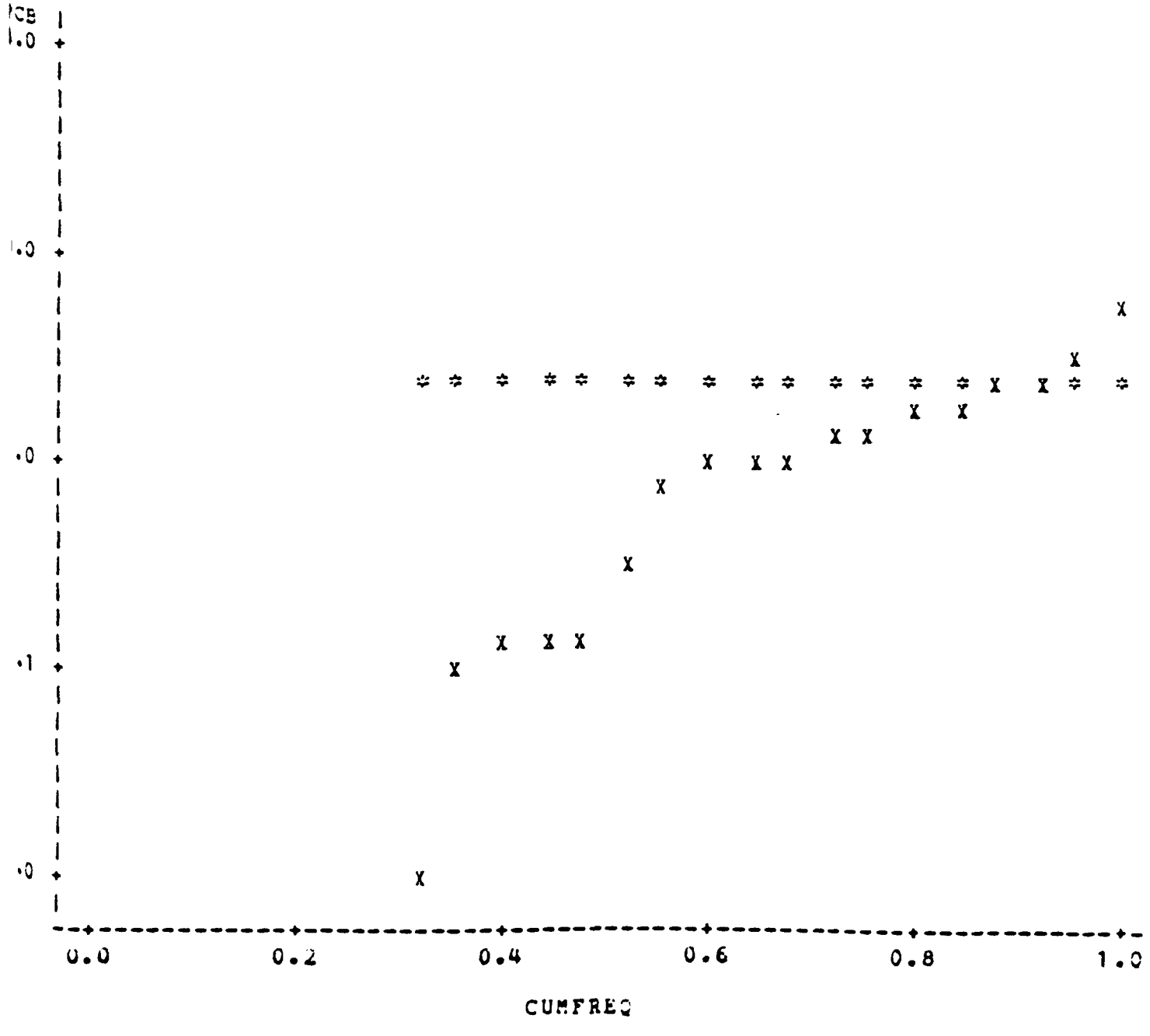
PLOT OF DDT*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



20 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢PCB! (UG/G ORGANIC CARBON)
GENUS=ASELLUS SPP=INTERMEDIUS

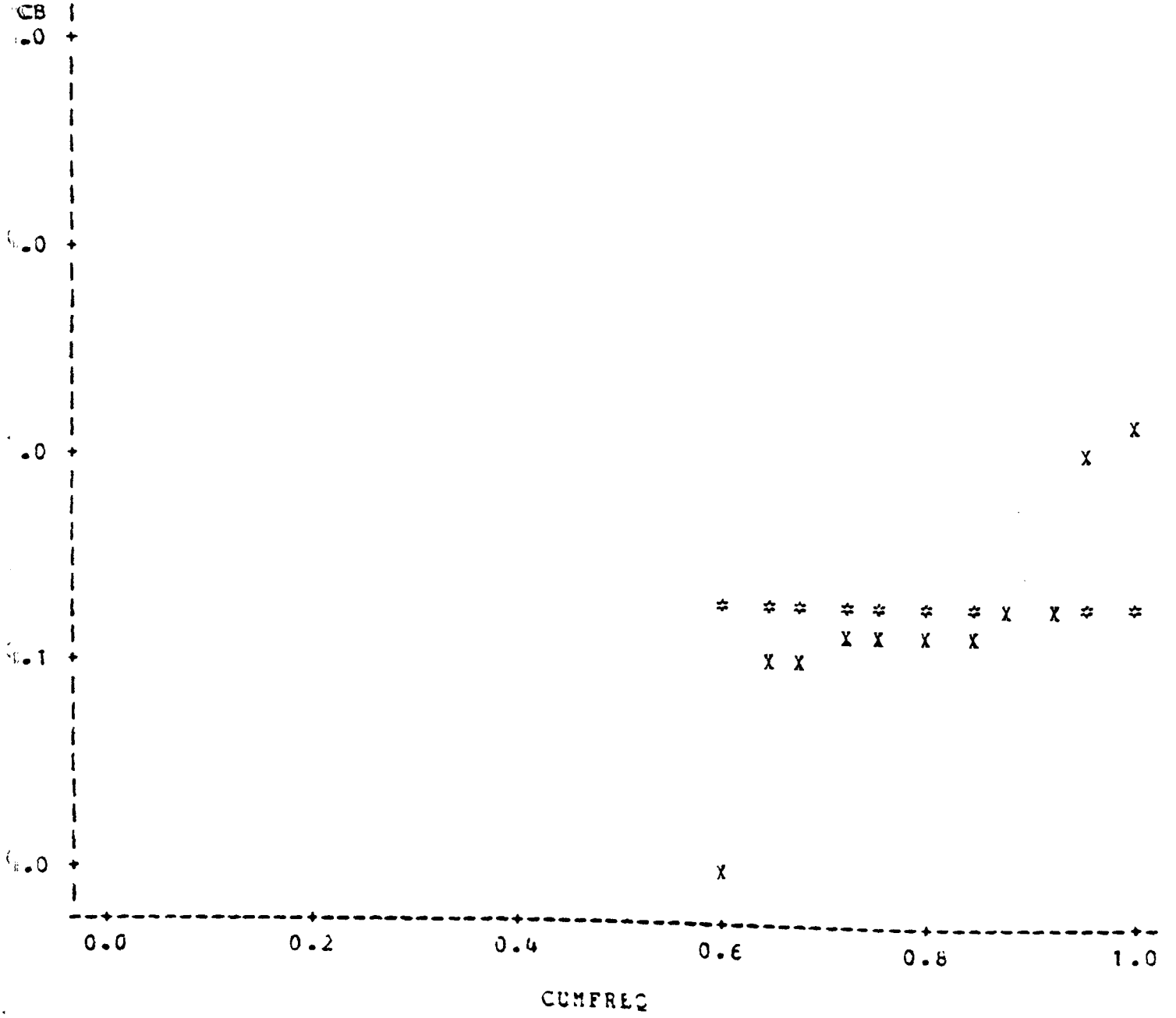
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



16 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢PCB! (UG/G ORGANIC CARBON)
GENUS=CYRNELLUS SPP=FRATERNUS

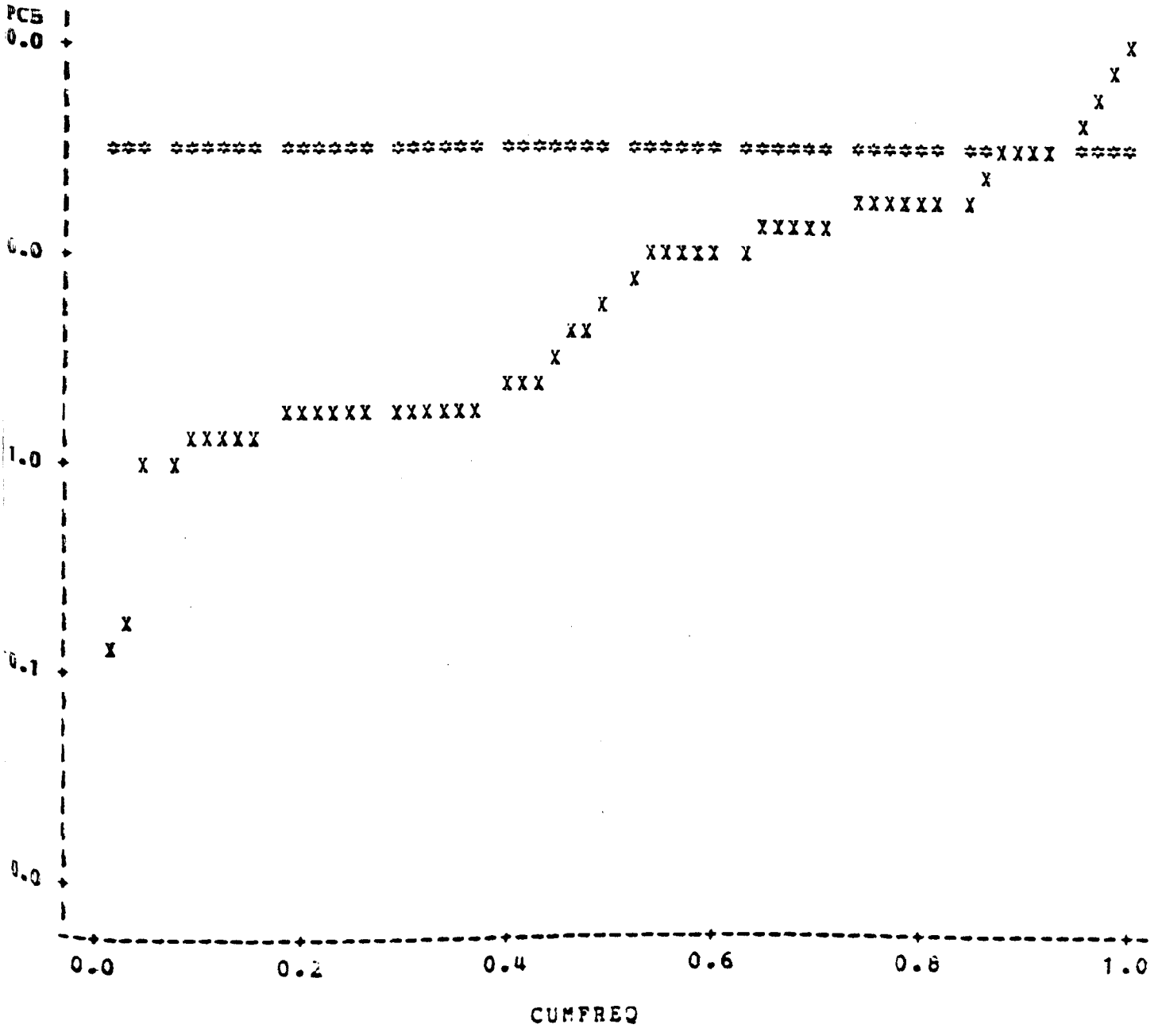
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



E: 30 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢PCB! (UG/G ORGANIC CARBON)
GENUS=GAMMARUS SPP=FASCIATUS

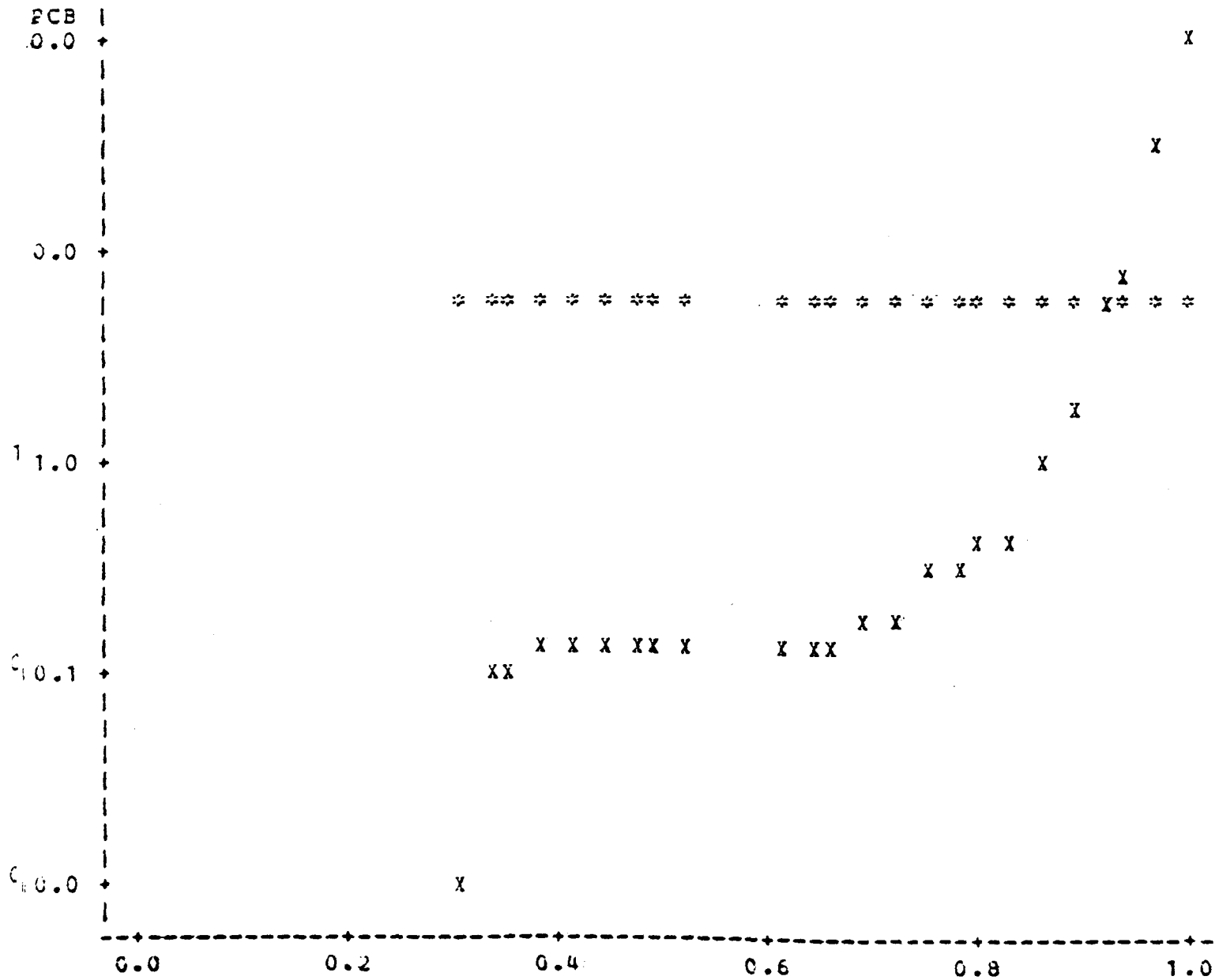
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



4 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢PCB! (UG/G ORGANIC CARBON)
GENUS=HYALELLA SPP=AZTECA

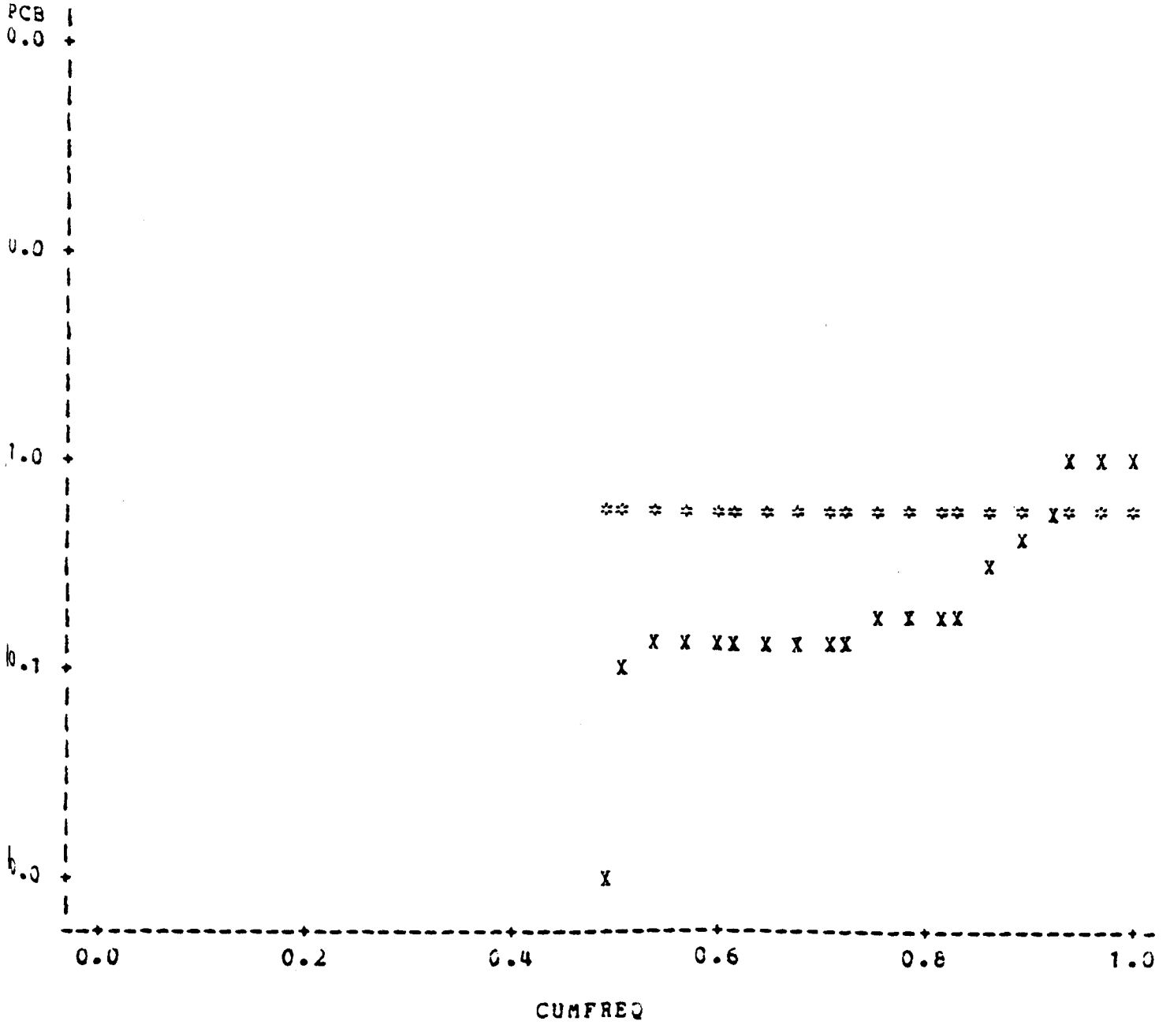
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 25 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢PCB! (UG/G ORGANIC CARBON)
GENUS=HYDROPSYCH SPP=FRISONI

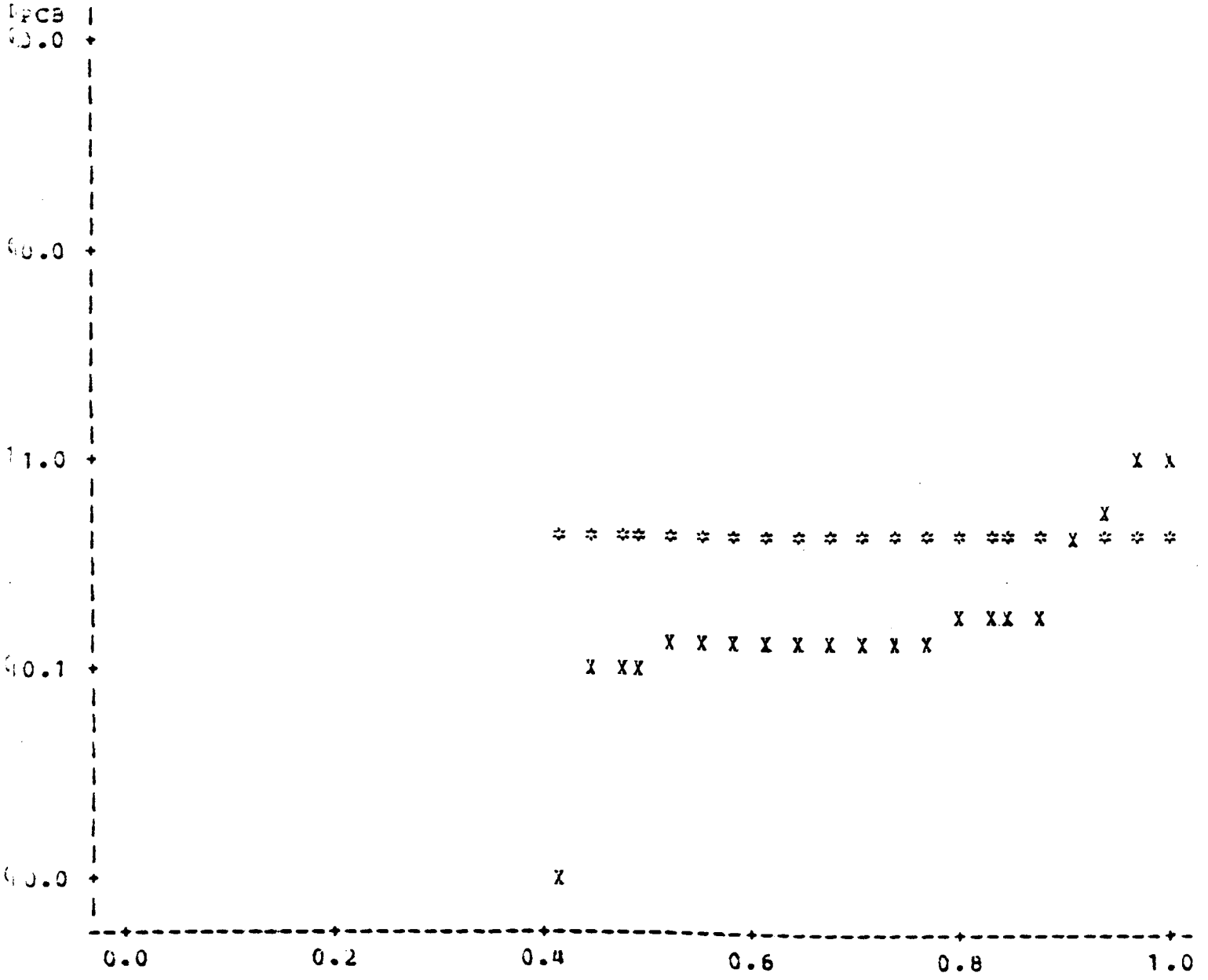
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 35 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢PCB! (UG/G ORGANIC CARBON)
GENUS=HYDROPSYCH SPP=ORRIS

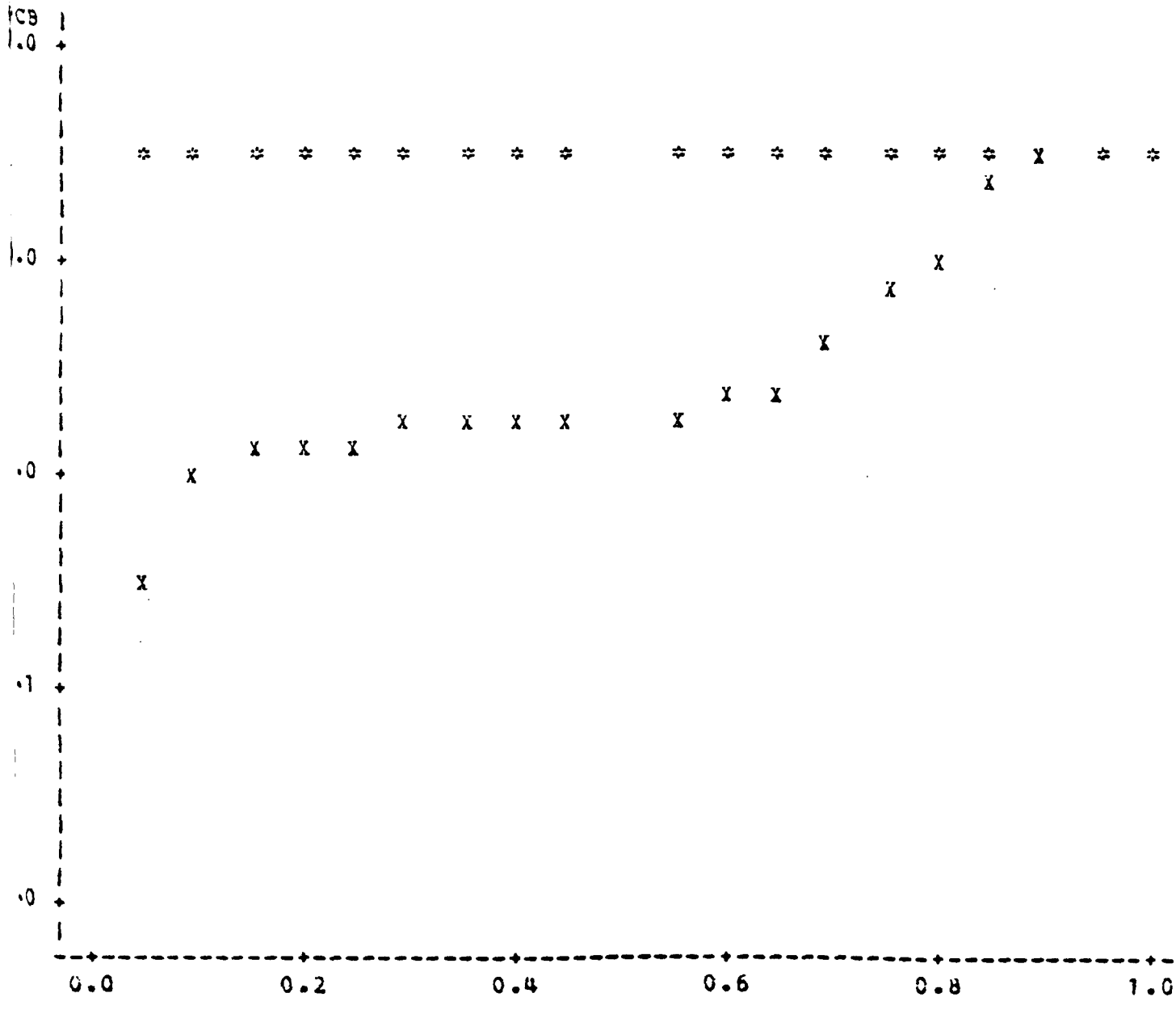
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 27 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢PCB! (UG/G ORGANIC CARBON)
GENUS=LIMNODRILUS SPP=CERVIX

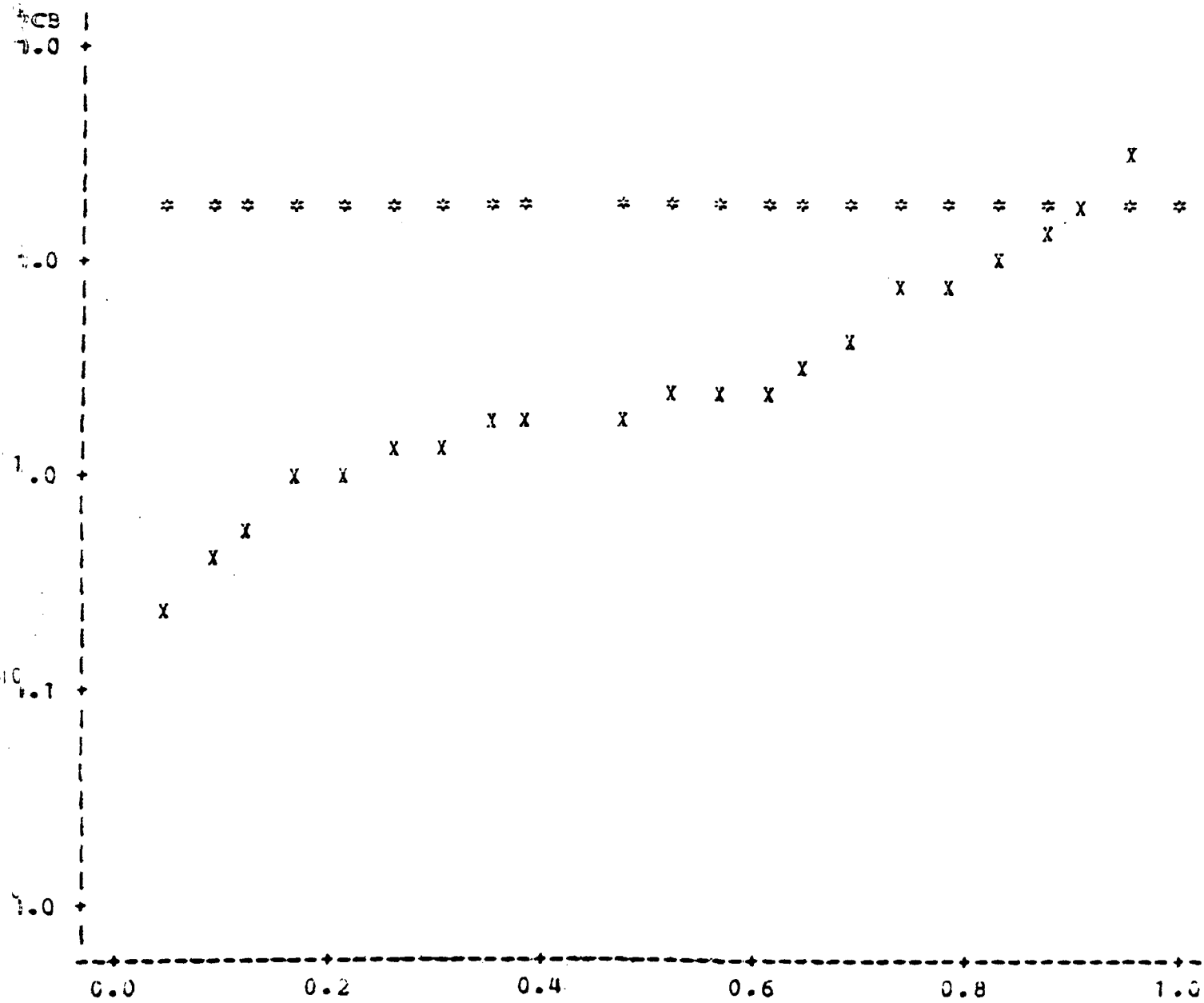
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



2 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 3 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED #PCB! (UG/G ORGANIC CARBON)
GENUS=LIMNODRILUS SPP=CLAPAREDEIANUS

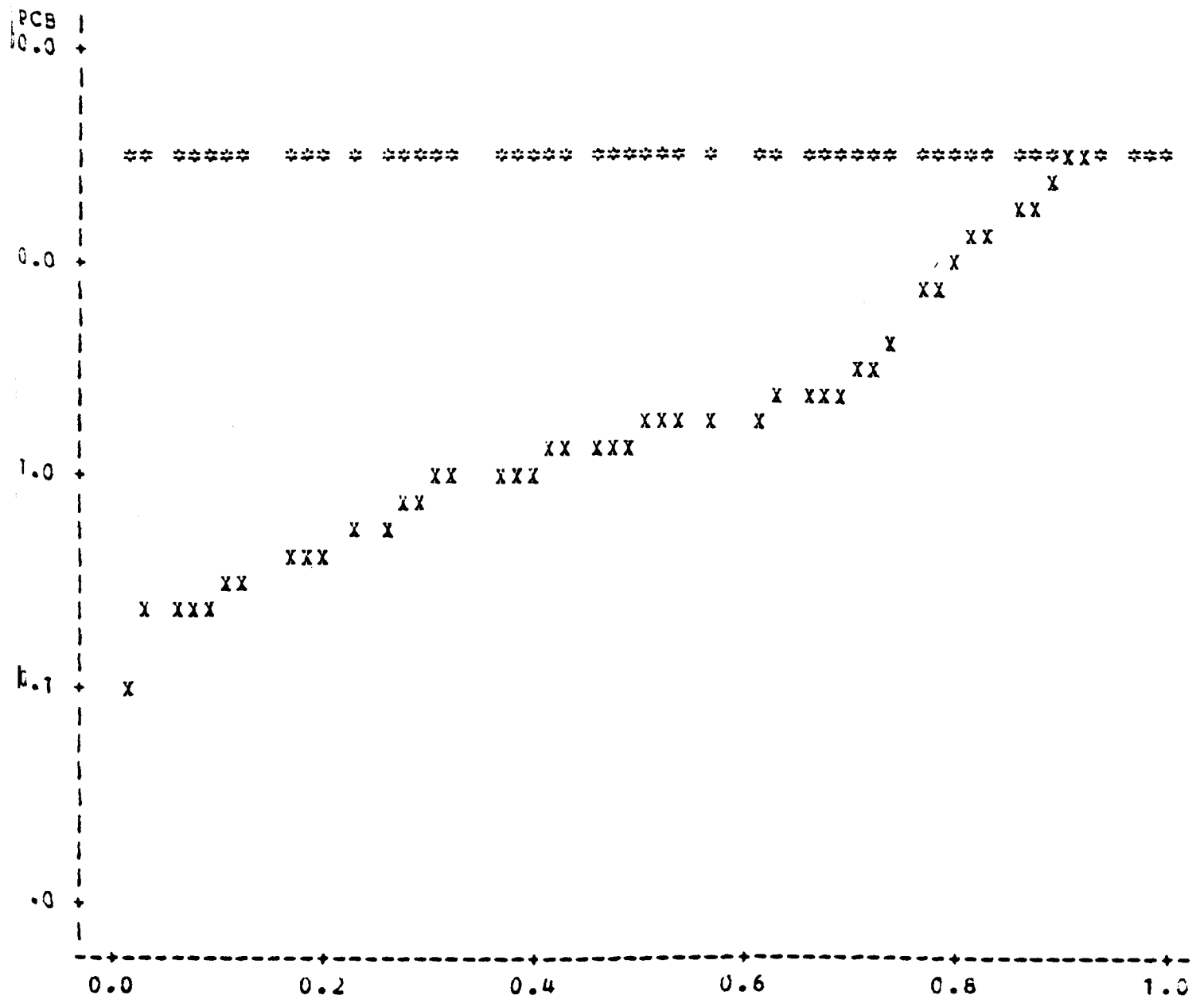
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 1 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 3 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢PCB! (UG/G ORGANIC CARBON)
GENUS=LIMNODRILUS SPP=HOFFMEISTERI

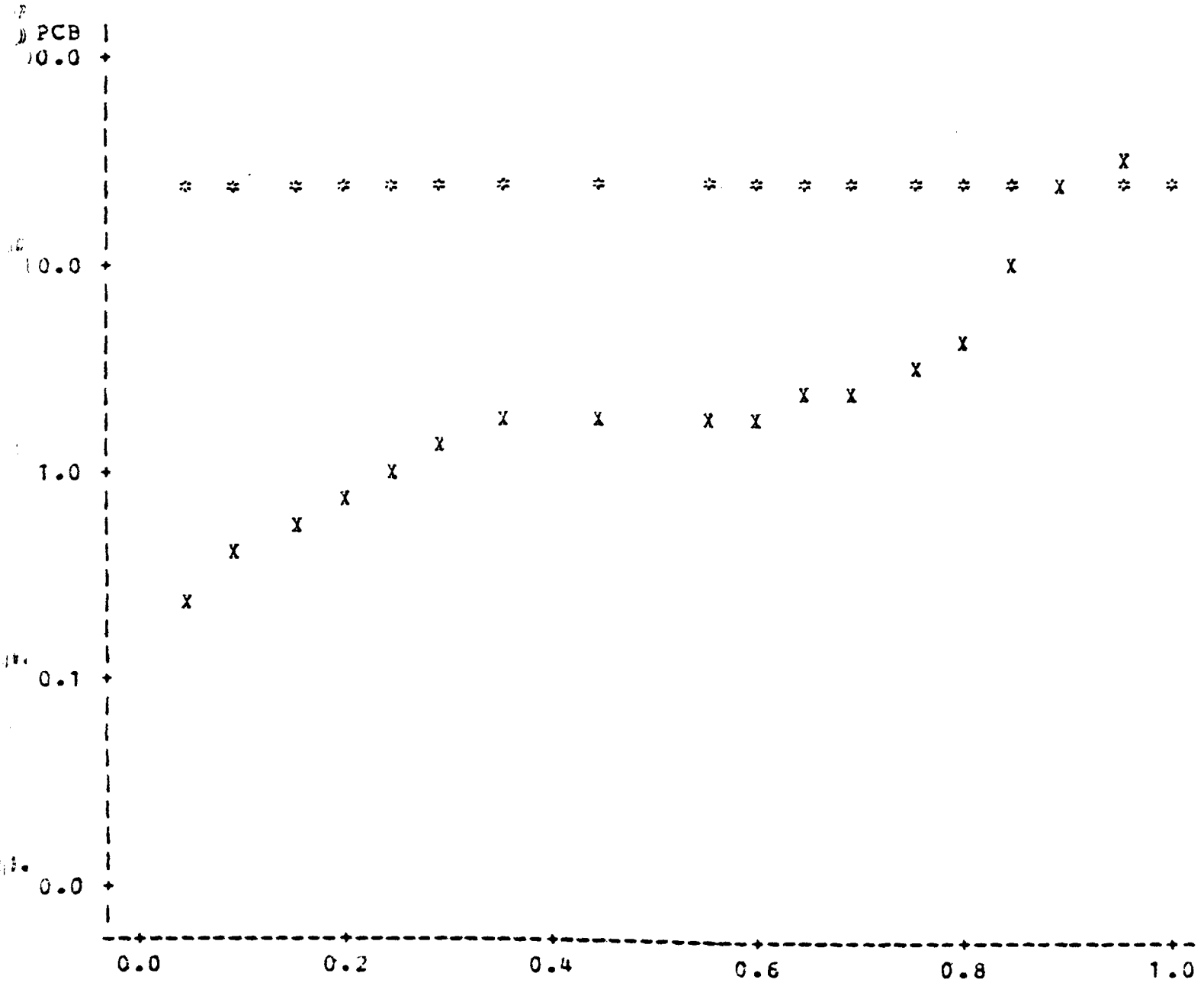
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



E: 4 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 12 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢PCB! (UG/G ORGANIC CARBON)
GENUS=LIMNODRILUS SPP=UDEKEMIANUS

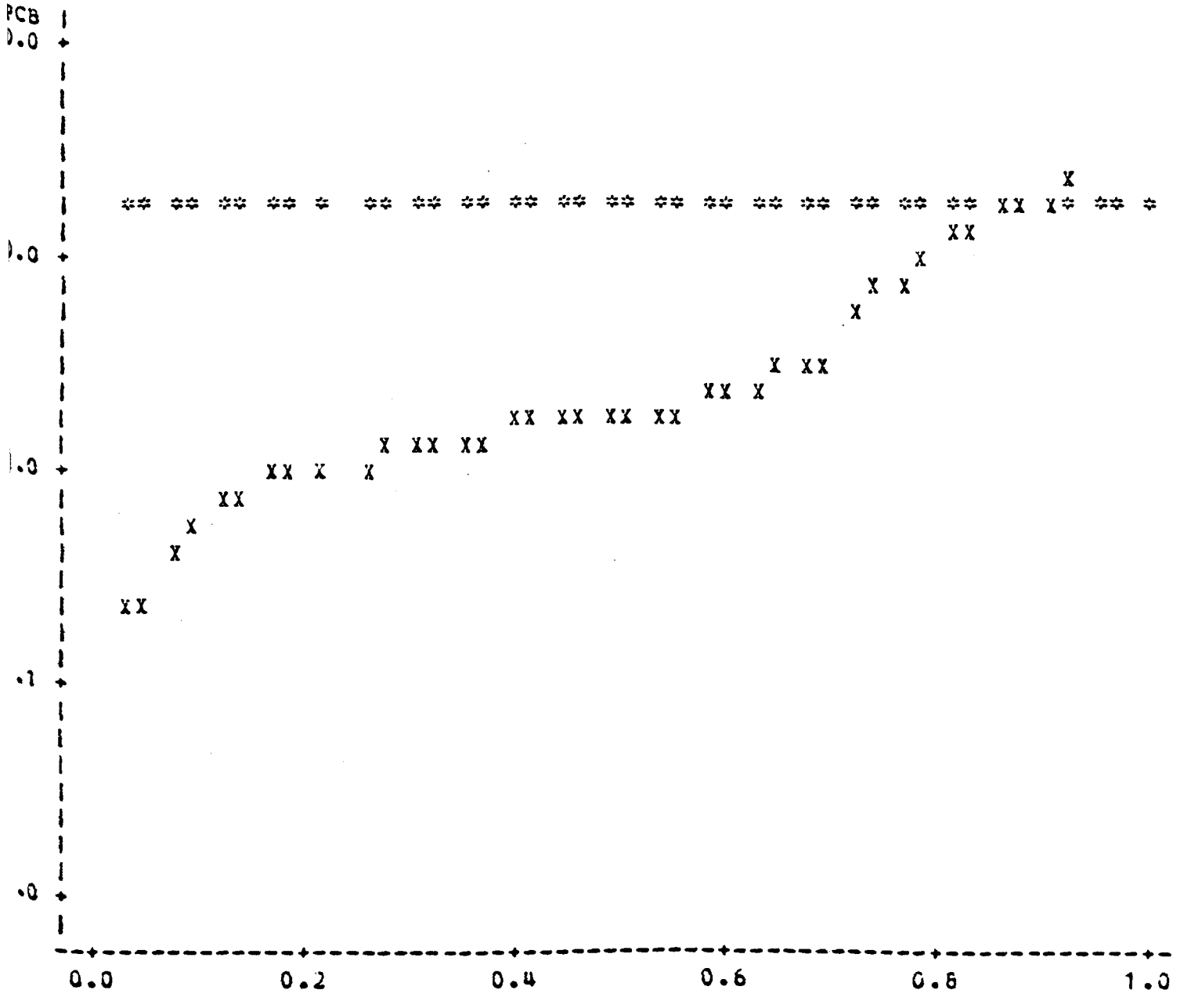
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 1 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 5 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢PCB! (UG/G ORGANIC CARBON)
GENUS=PELOSCOLEX SPP=FEROX

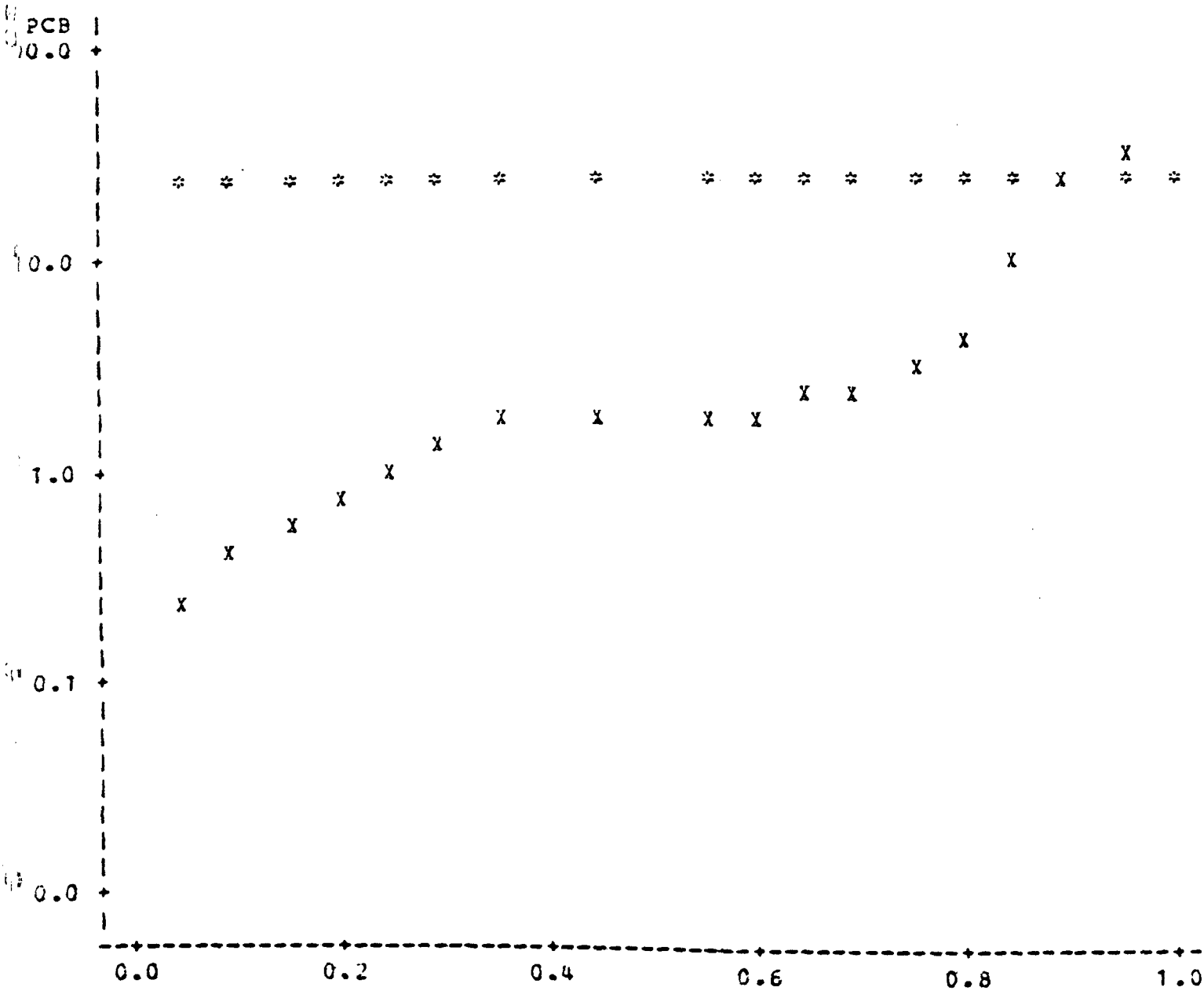
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



B: 3 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 5 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢PCB! (UG/G ORGANIC CARBON)
GENUS=LIMNODRILUS SPP=UDEKEMIANUS

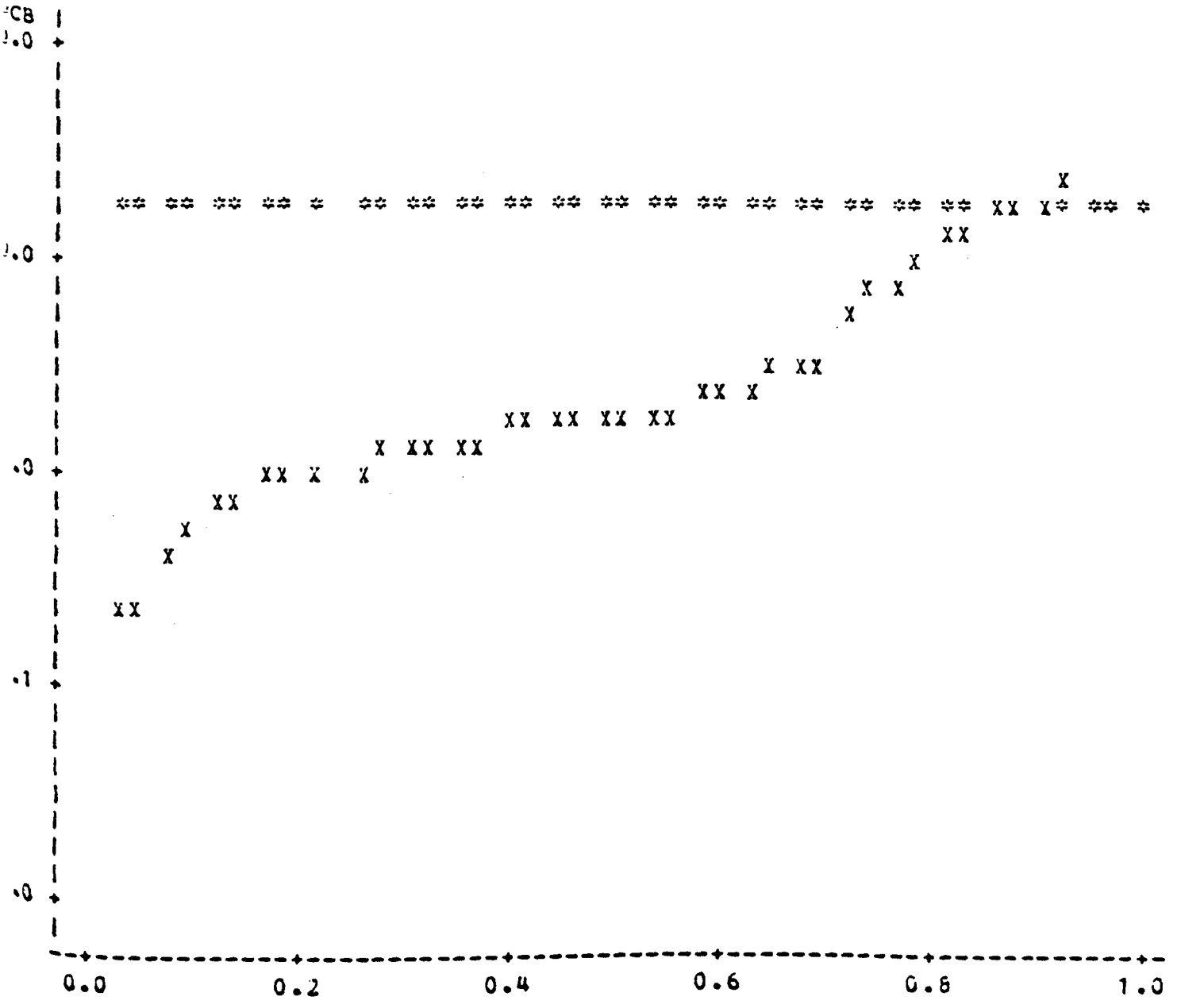
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 1 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 5 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢PCB! (UG/G ORGANIC CARBON)
GENUS=PELOSCOLEX SPP=FEROX

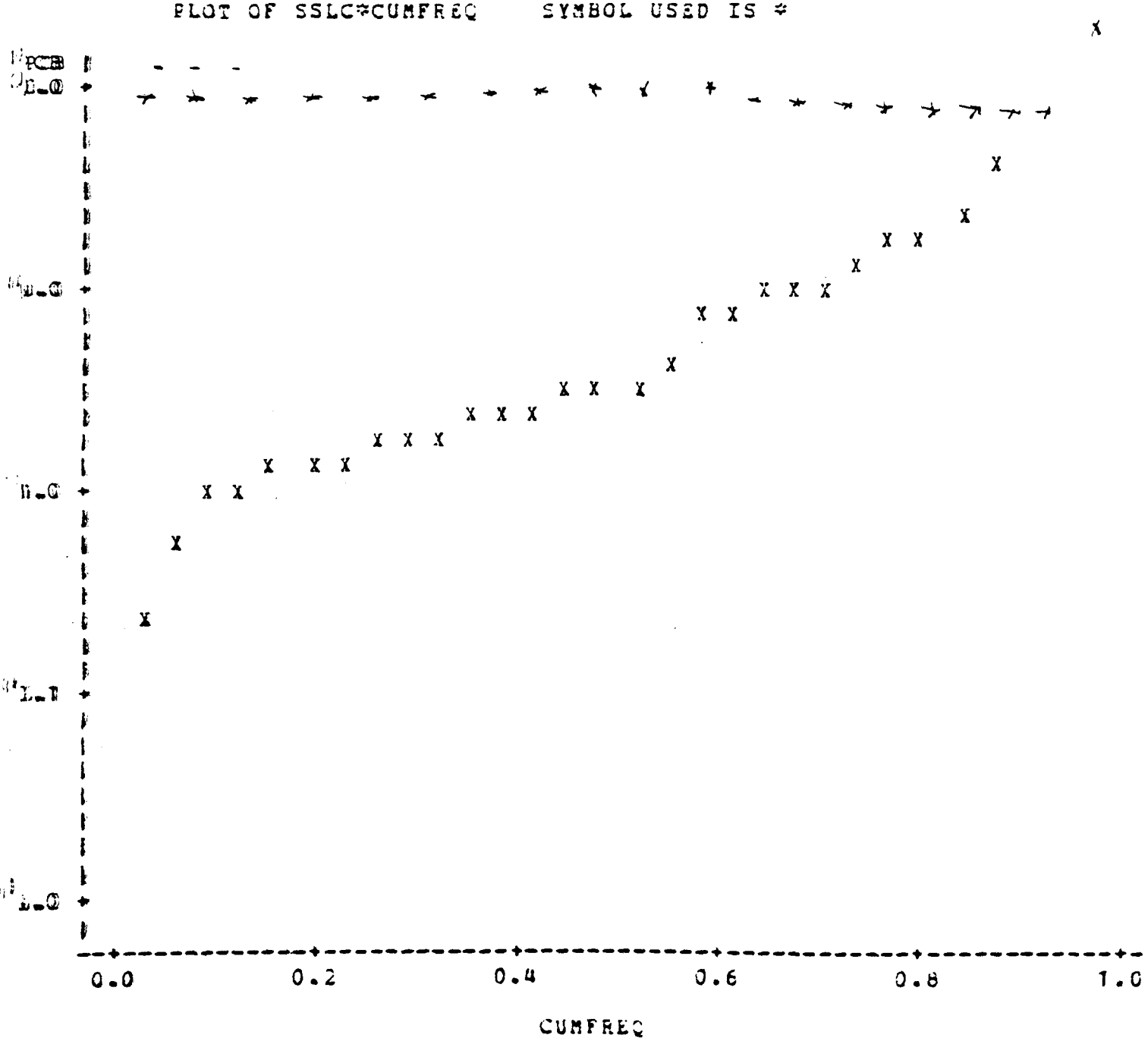
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



3 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 5 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED (PCB) (UG/G ORGANIC CARBON)
GENUS=PELOSCOLEX SPP=MULTISETOSUS

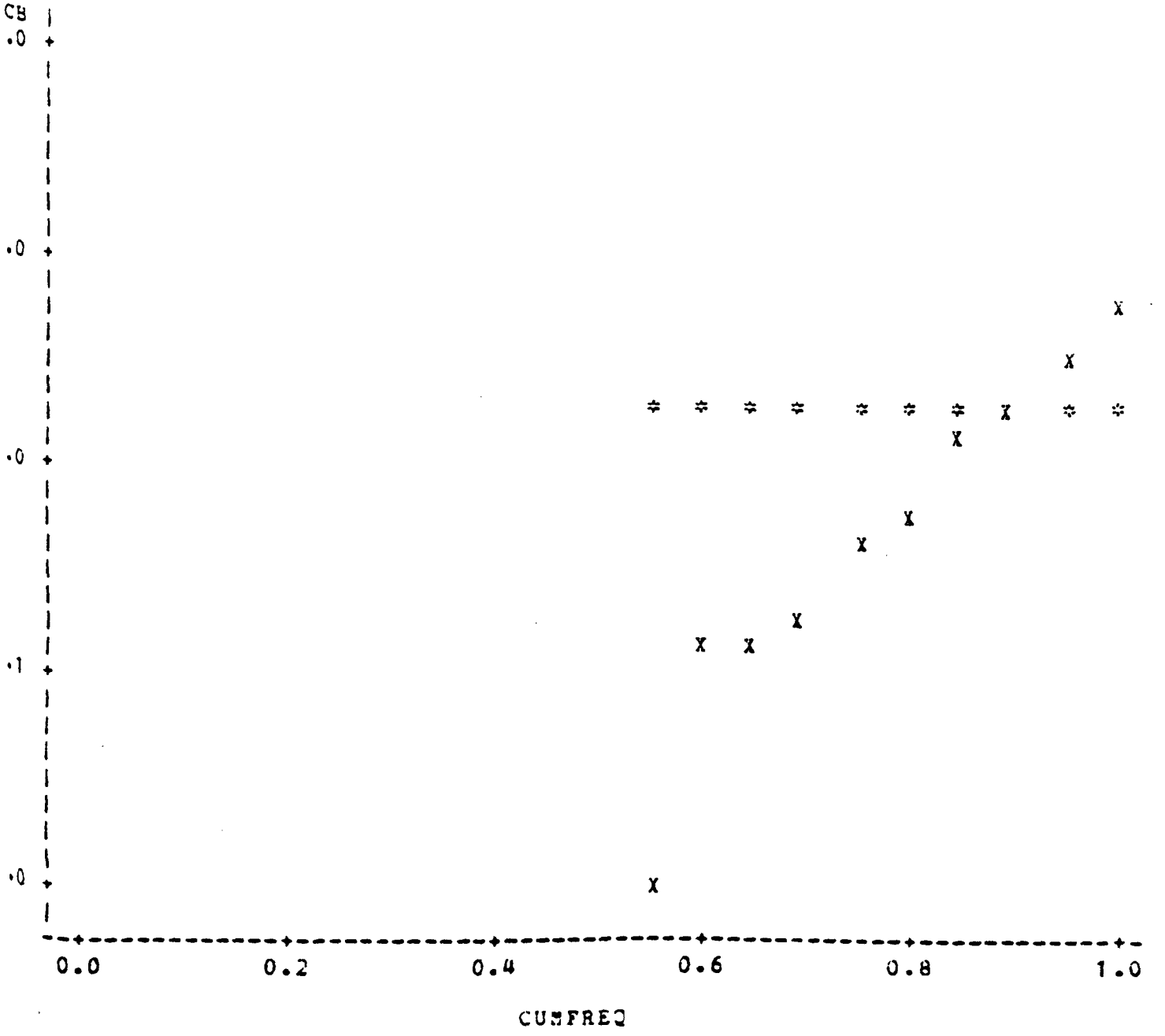
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 35 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

CUMULATIVE FREQUENCY OF NORMALIZED ¢PCB! (UG/G ORGANIC CARBON)
GENUS=PENTANEURA SPP=MALLOCHI

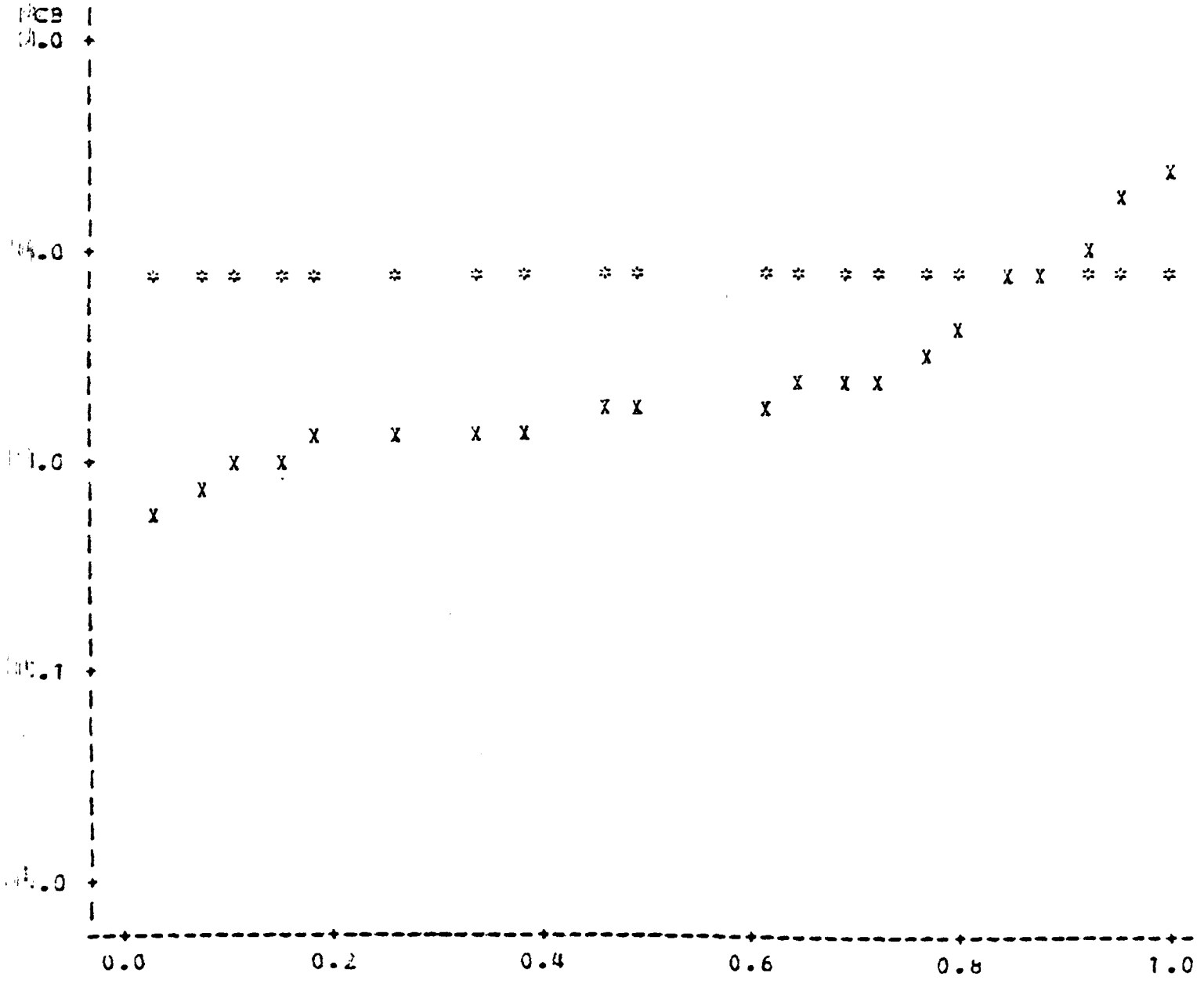
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



21 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ΦPCB! (UG/G ORGANIC CARBON)
GENUS=POTAMOTHRIX SPP=VEJDOVSKYI

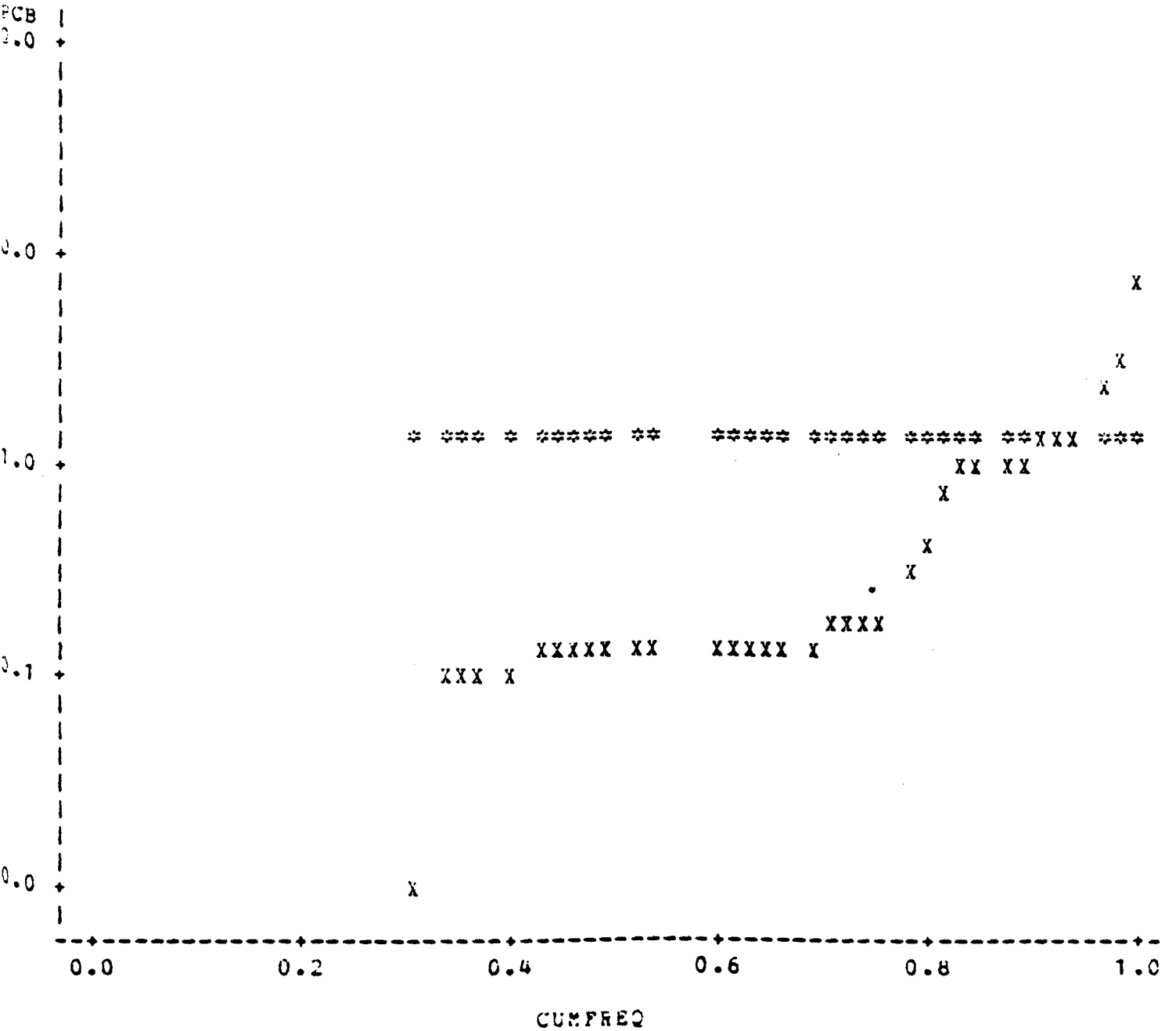
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 12 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢PCB! (UG/G ORGANIC CARBON)
GENUS=STENACRON SPP=INTERPUNCT

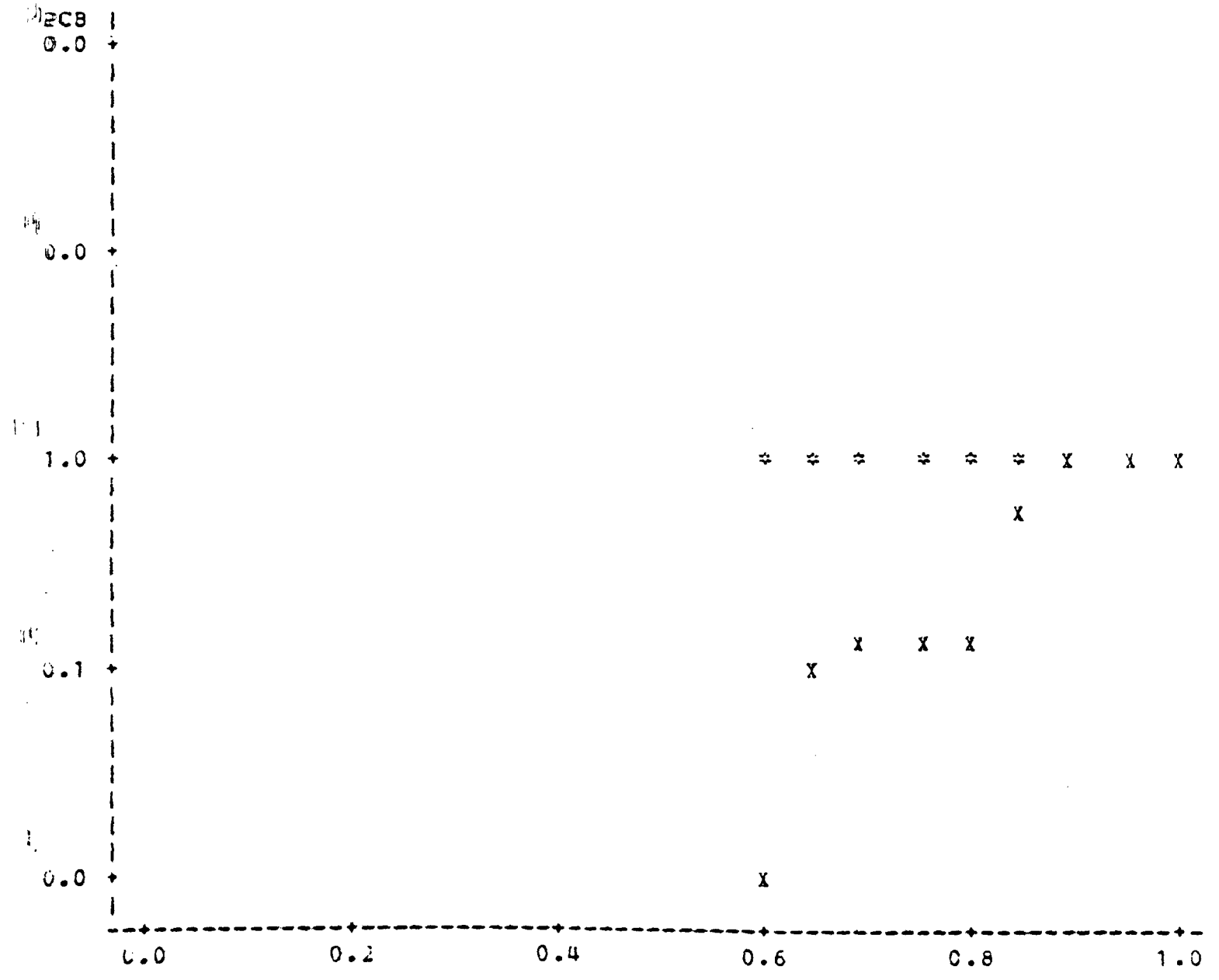
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 41 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢PCB! (UG/G ORGANIC CARBON)
GENUS=STENONEMA SPP=EXIQUUM

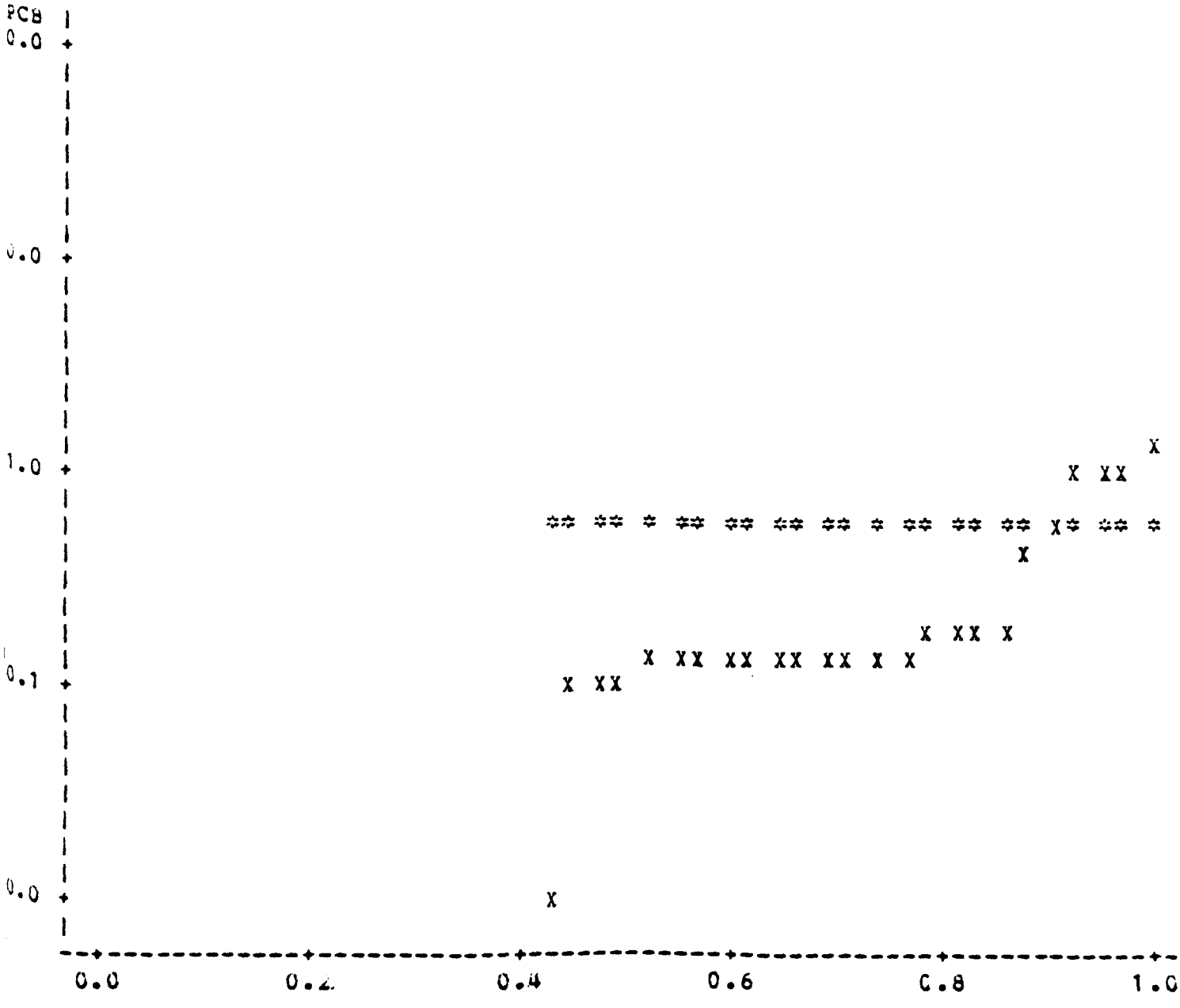
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 25 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢PCB! (UG/G ORGANIC CARBON)
GENUS=STENONEMA SPP=INTEGRUM

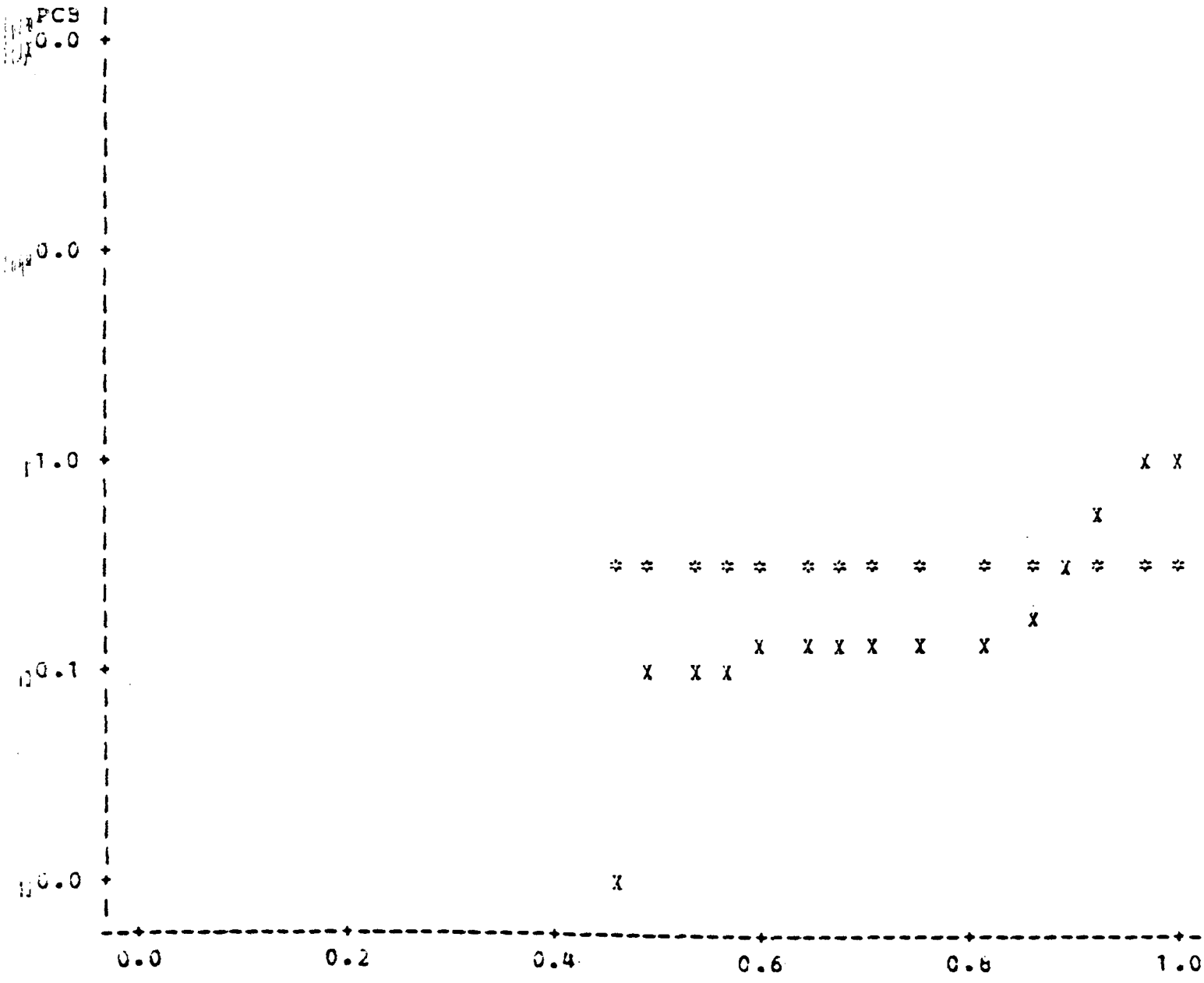
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 35 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ⌀PCB! (UG/G ORGANIC CARBON)
GENUS=STENONEMA SPP=PULCHELLUM

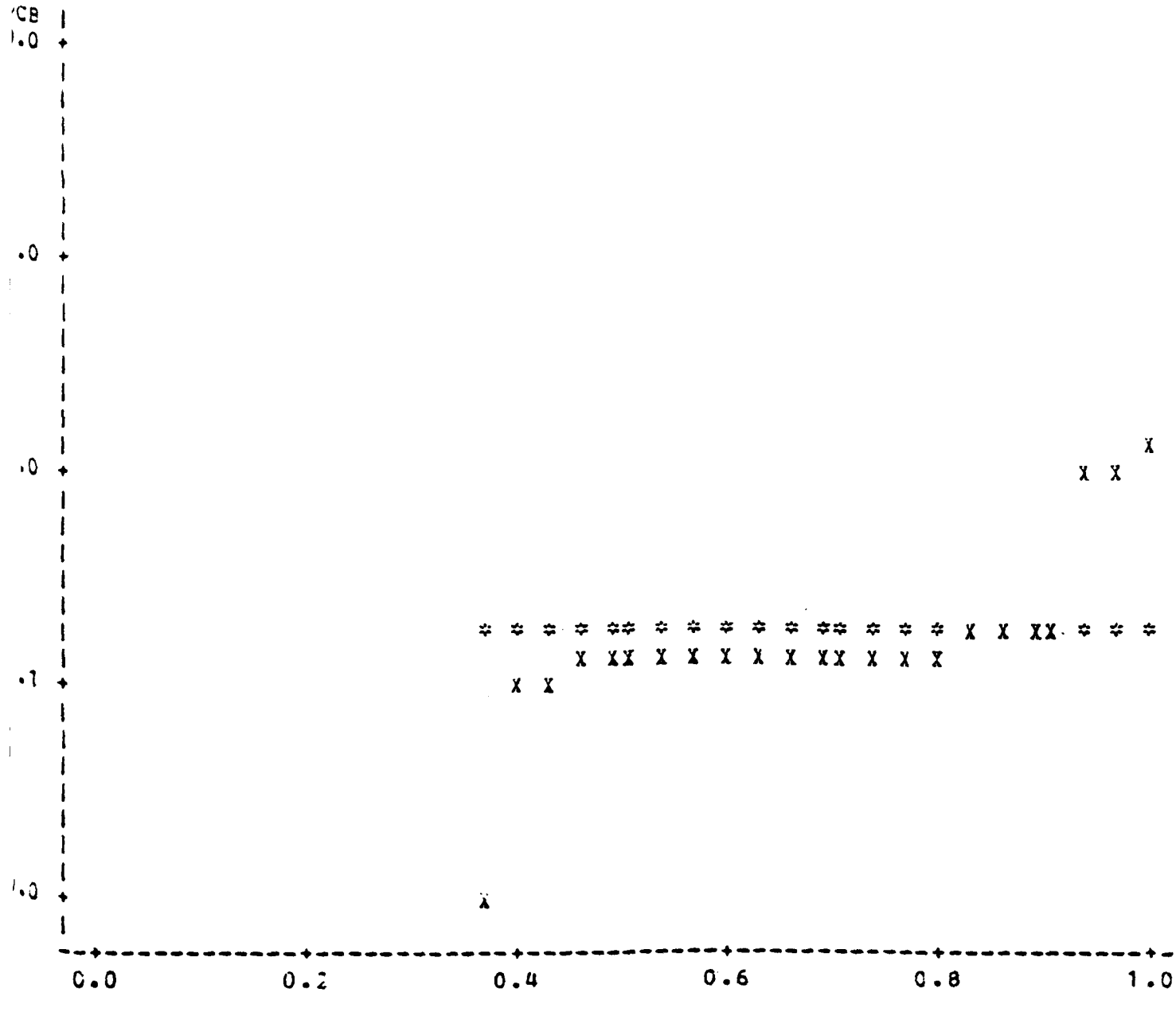
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 27 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED #PCB! (UG/G ORGANIC CARBON)
GENUS=STENONEMA SPP=TERMINATUM

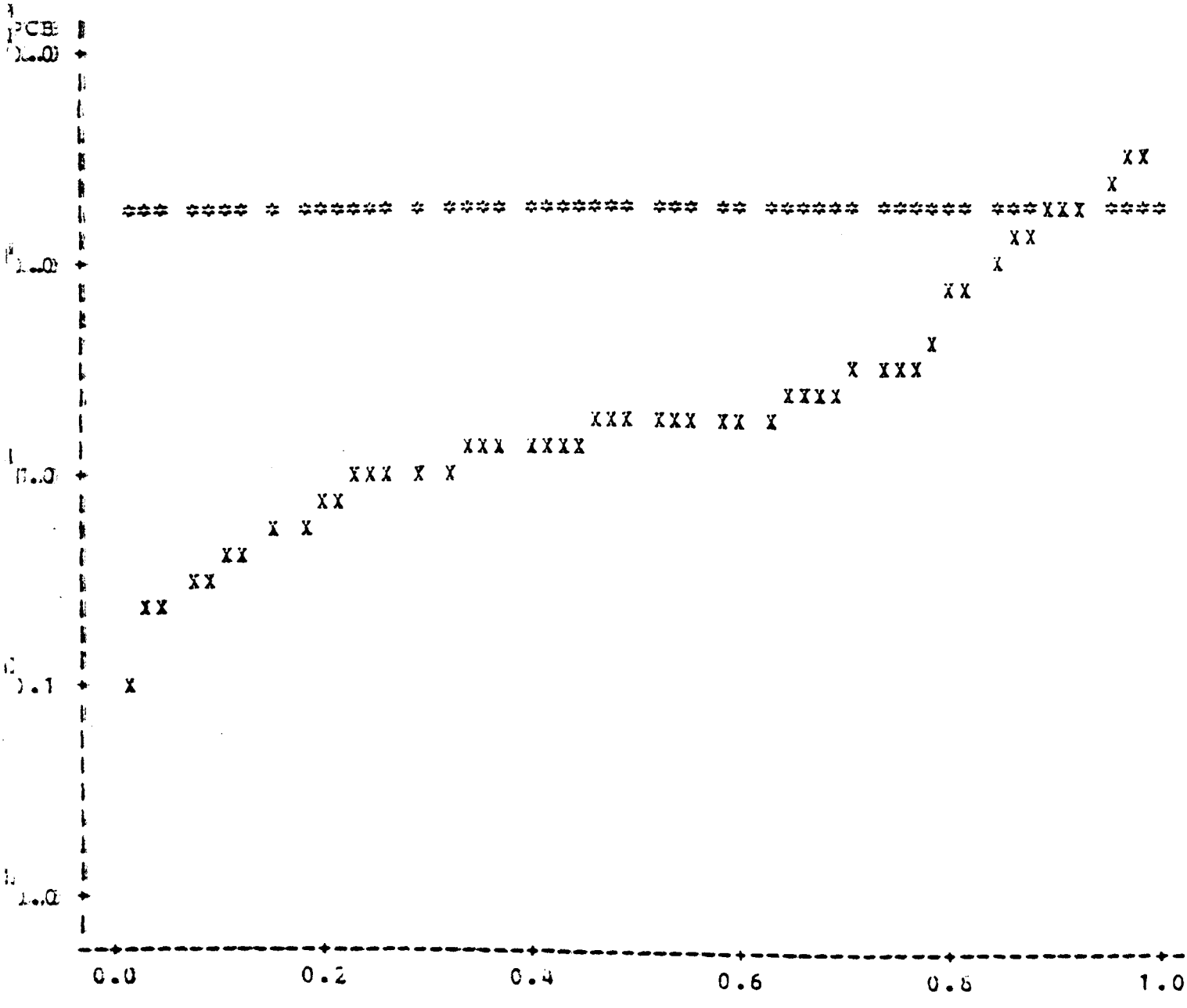
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



28 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED #PCB! (UG/G ORGANIC CARBON)
GENUS=TUBIFEX SPP=TUBIFEX

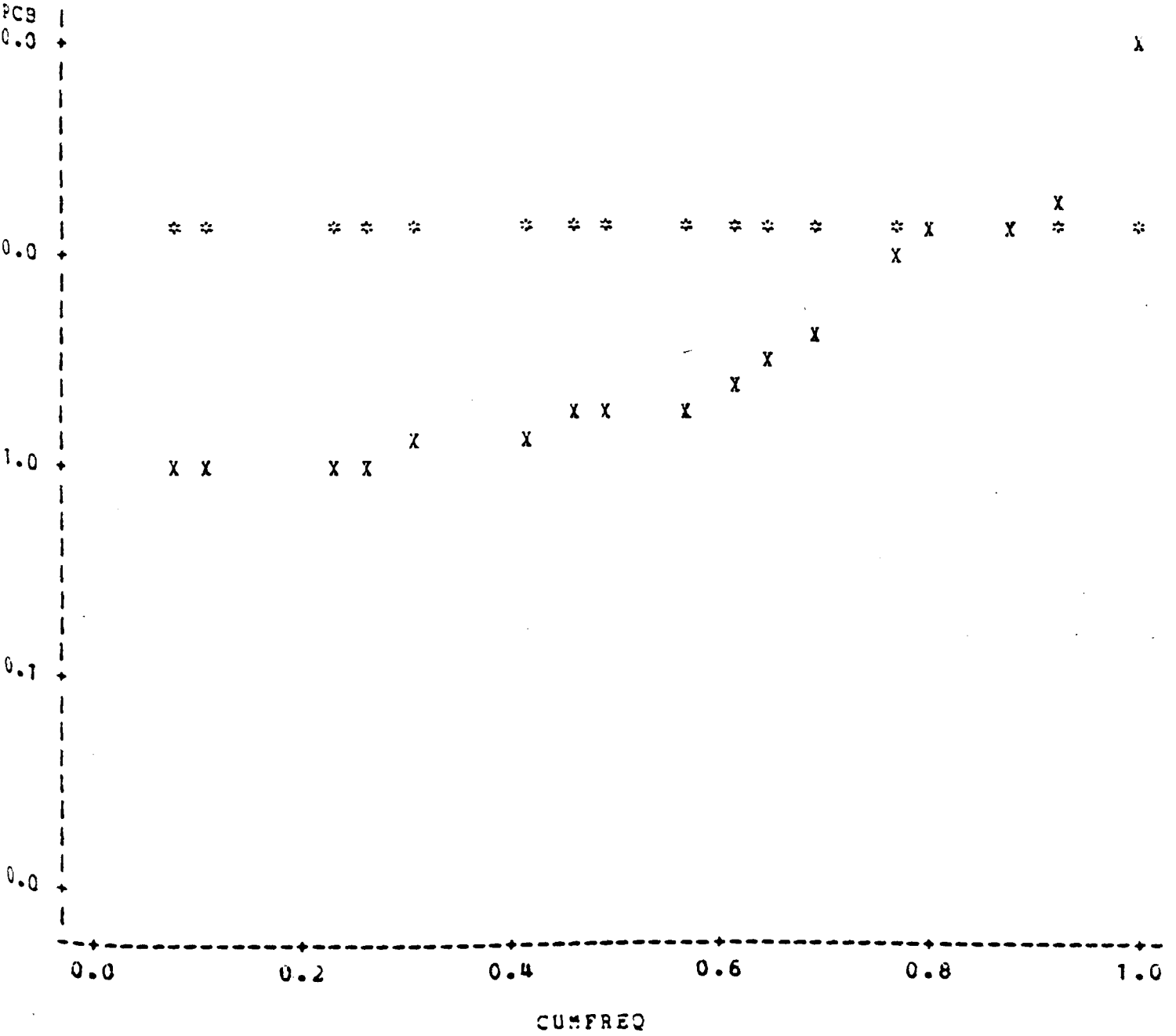
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 1 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 9 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢PCB! (UG/G ORGANIC CARBON)
GENUS=VALVATA SPP=SINCERA

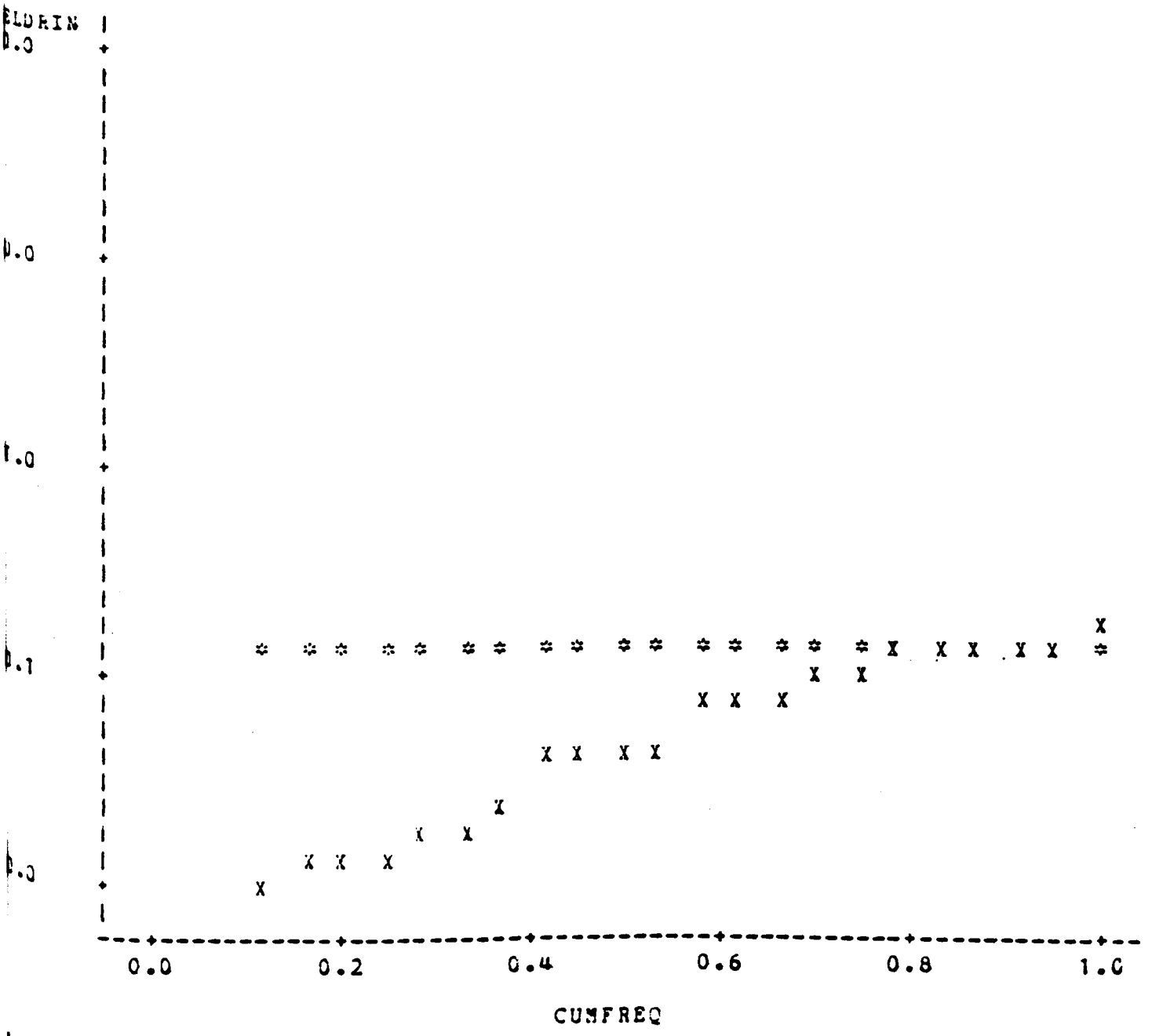
PLOT OF PCB*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 20 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED &DIELDRIN! (UG/G ORGANIC CARBON)
GENUS=ASELLUS SPP=INTERMEDIUS

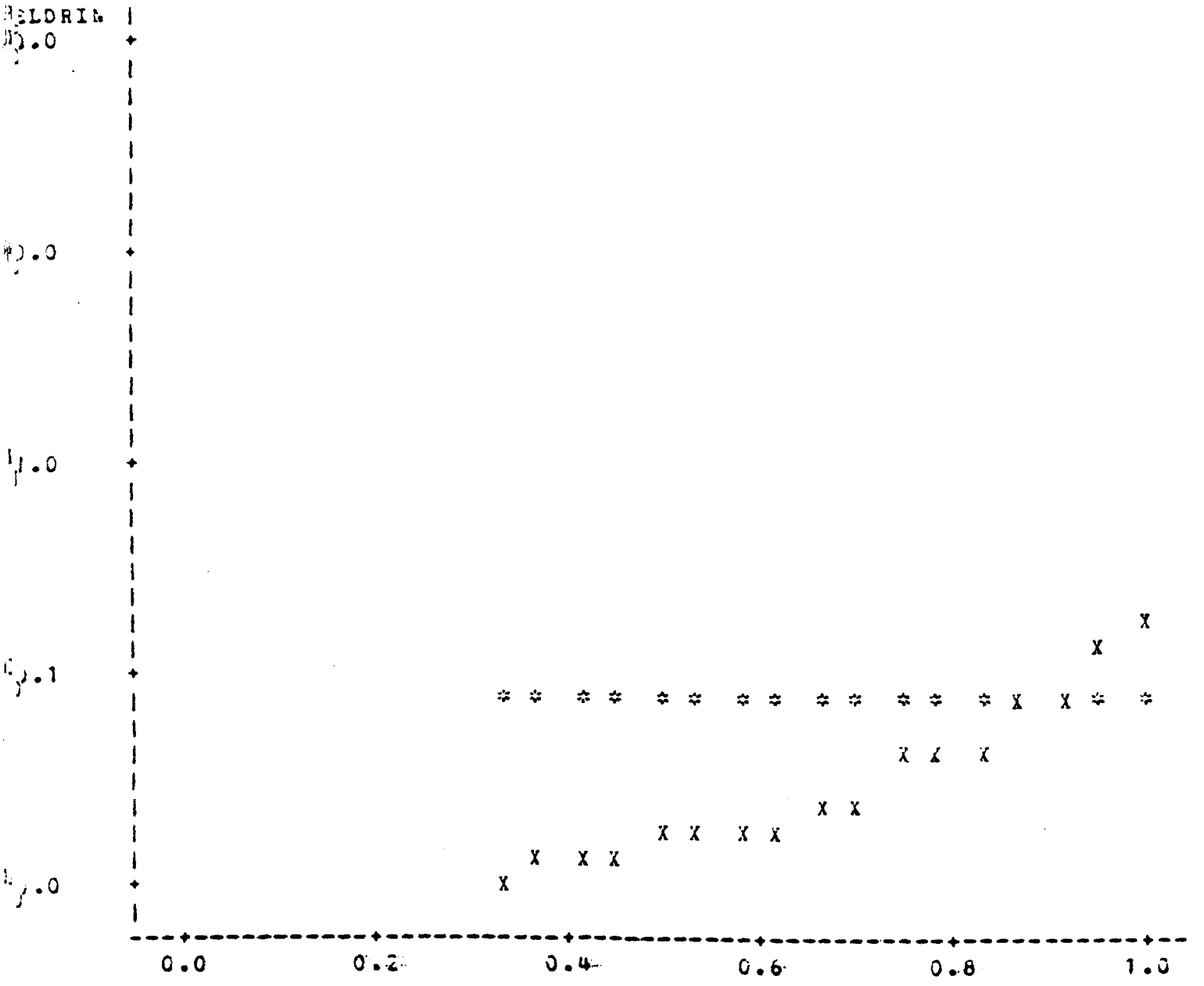
PLOT OF DIELDRIN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE:
9 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DIELDRIN! (UG/G ORGANIC CARBON)
GENUS=CYRNELLUS SPP=FRATERNUS

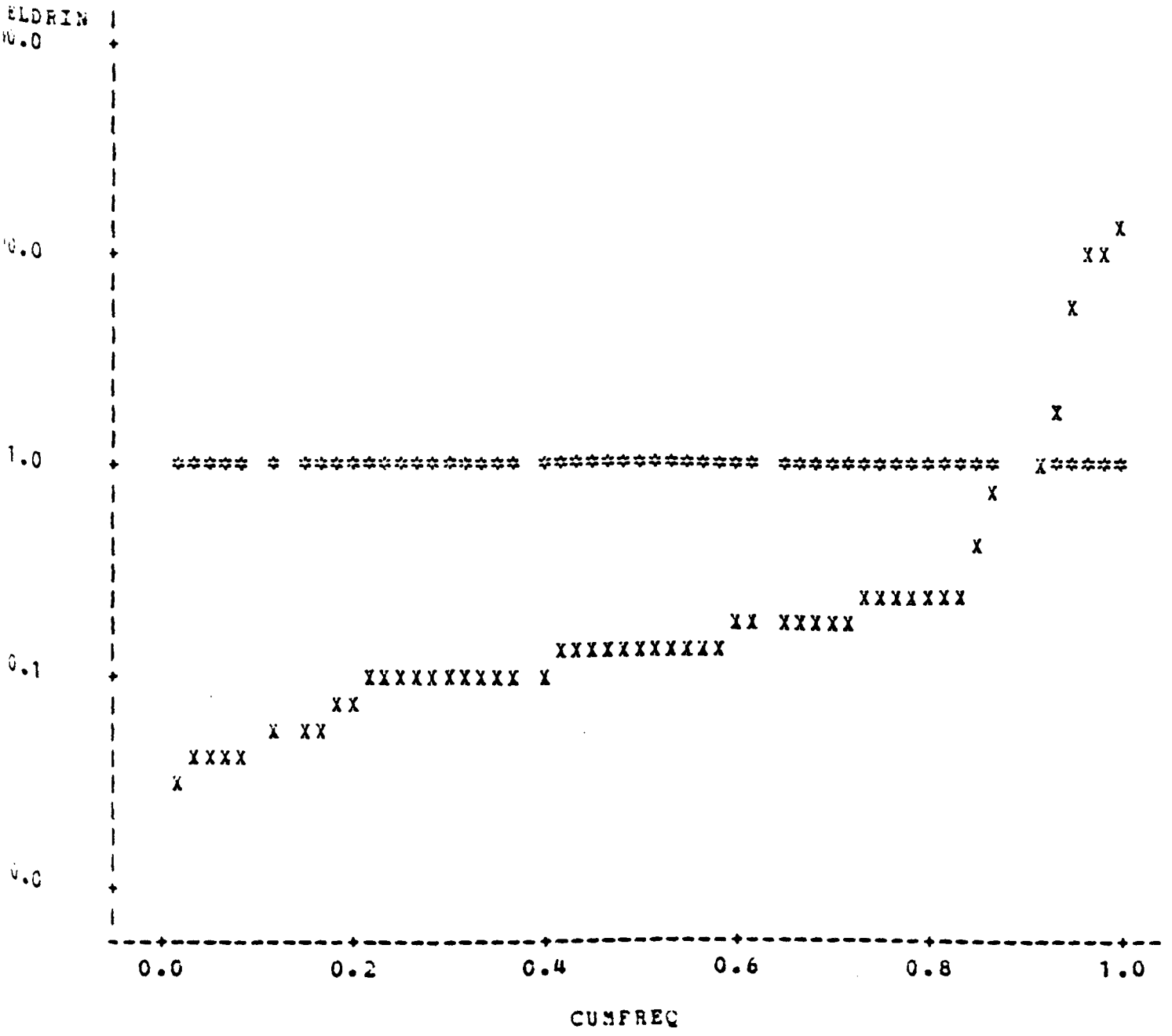
PLOT OF DIELDRIN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 16 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DIELDRIN! (UG/G ORGANIC CARBON)
GENUS=GAMMARUS SPP=FASCIATUS

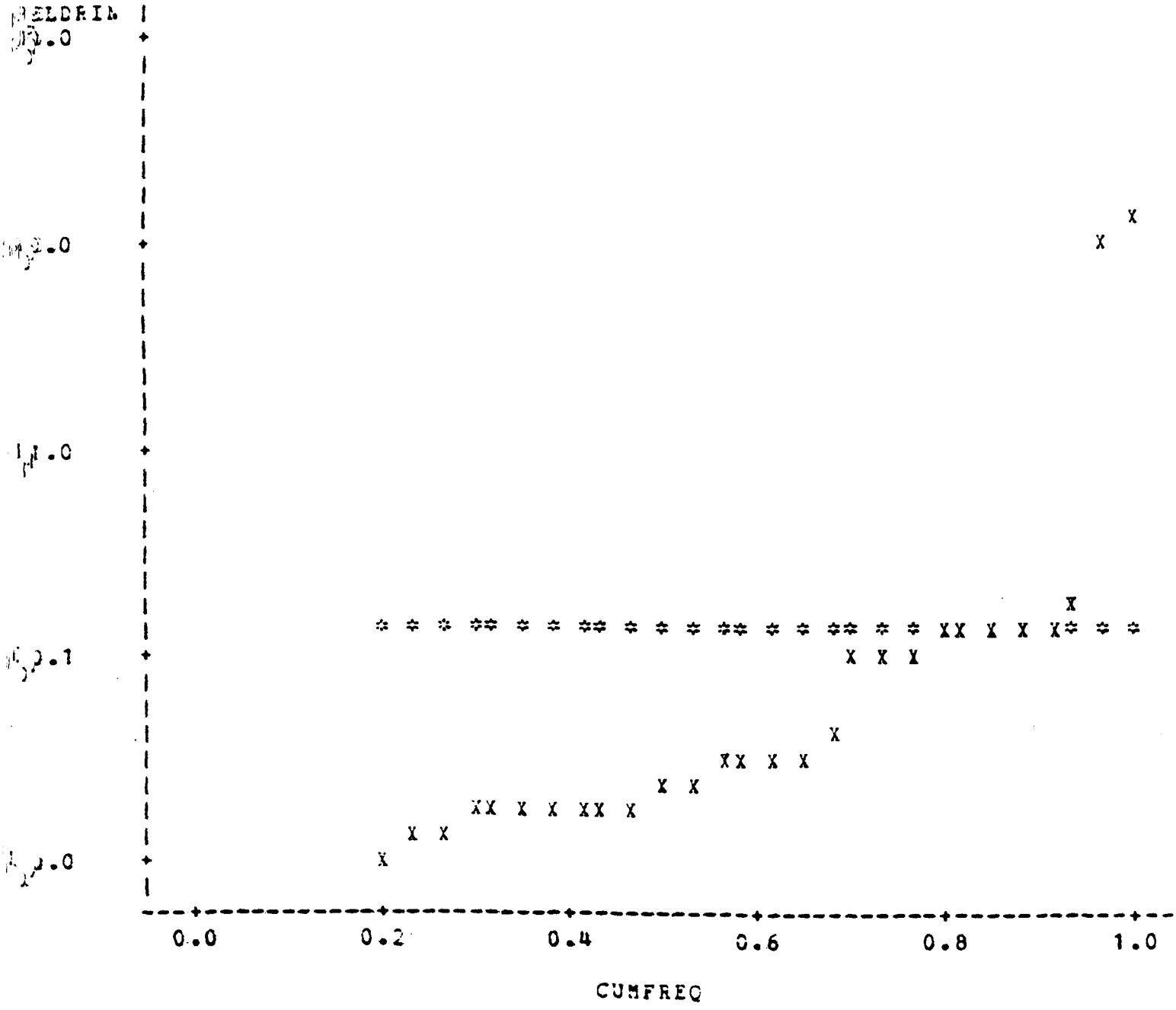
PLOT OF DIELDRIN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 5 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DIELDRIN! (UG/G ORGANIC CARBON)
GENUS=HYALELLA SPP=AZTECA

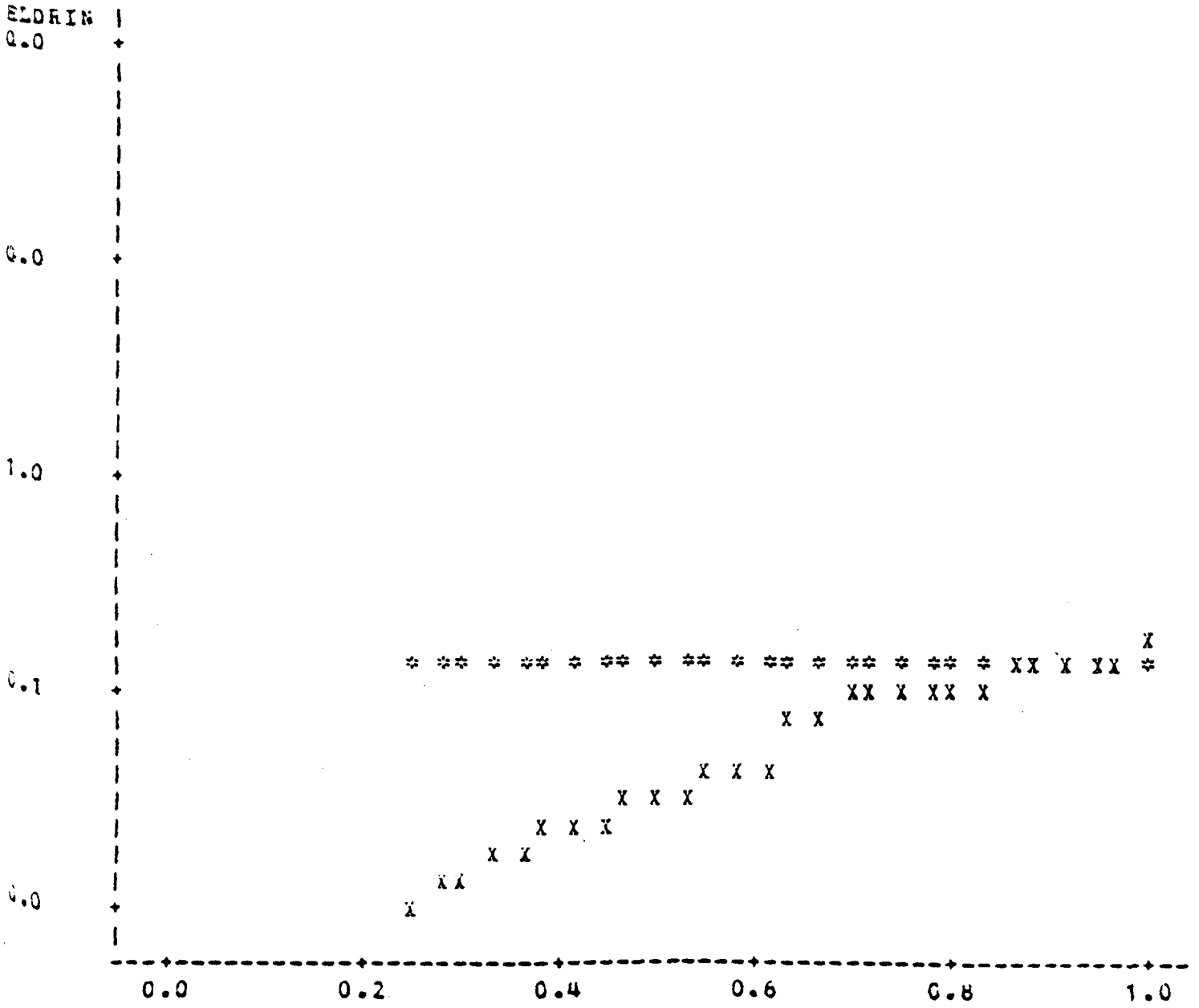
PLOT OF DIELDRIN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 17 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DIELDRIN! (UG/G ORGANIC CARBON)
GENUS=HYDROPSYCH SPP=FRISONI

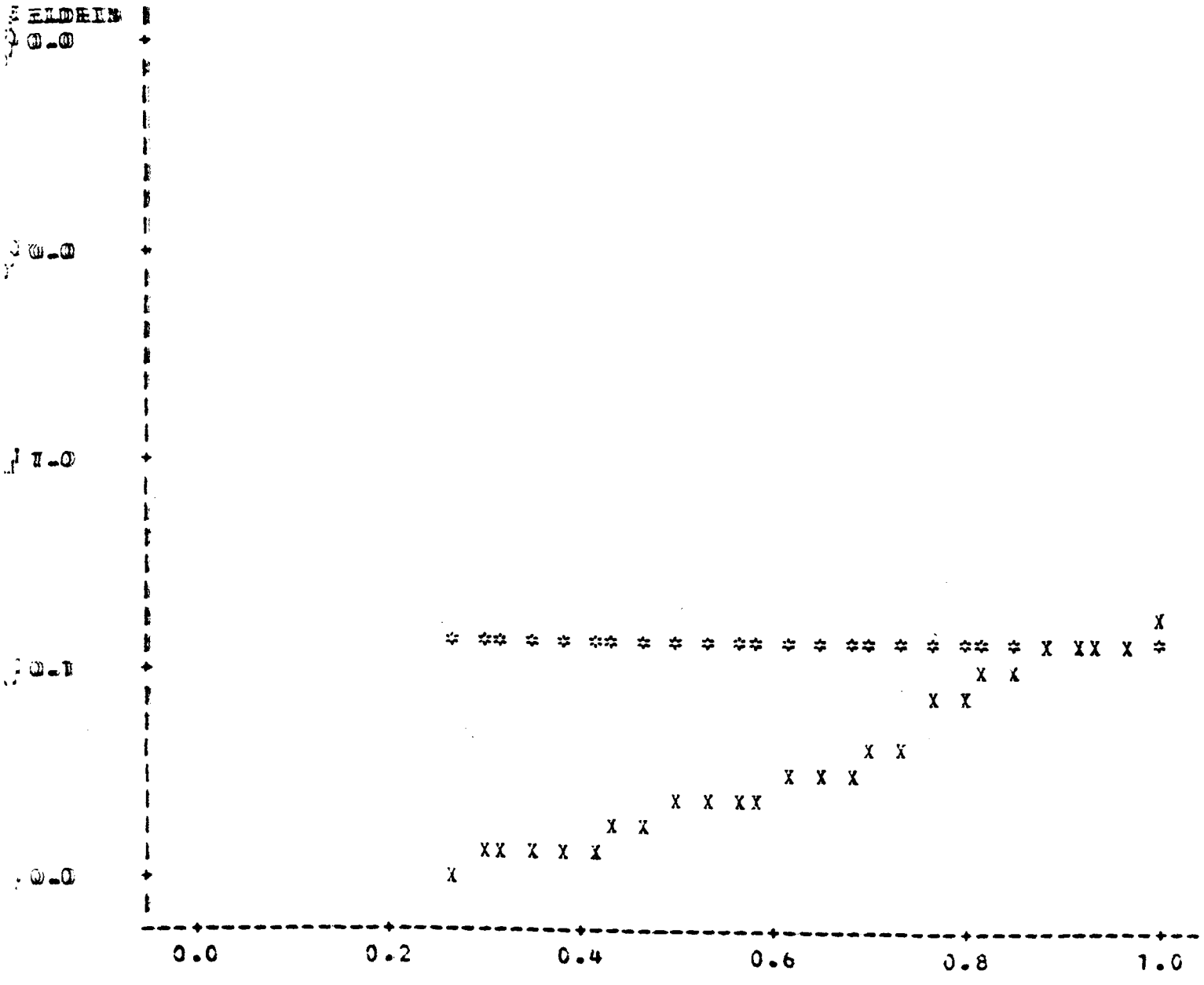
PLOT OF DIELDRIN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 21 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED #DIELDRIN! (UG/G ORGANIC CARBON)
GENUS=HYDROPSYCH SPP=ORRIS

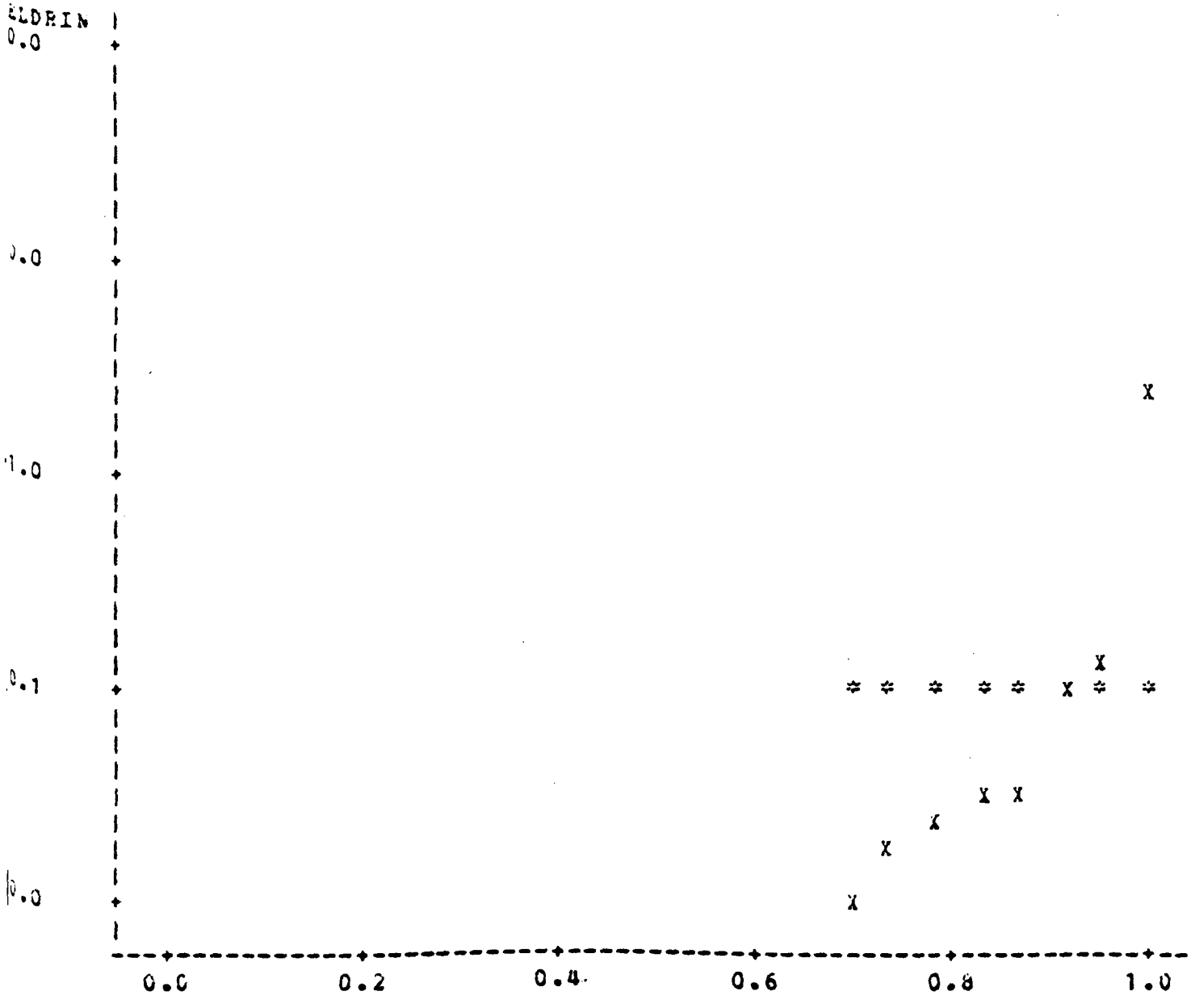
PLOT OF DIELDRIN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 20 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED @DIELDRIN! (UG/G ORGANIC CARBON)
GENUS=LIMNODRILUS SPP=CLAPAREDEIANUS

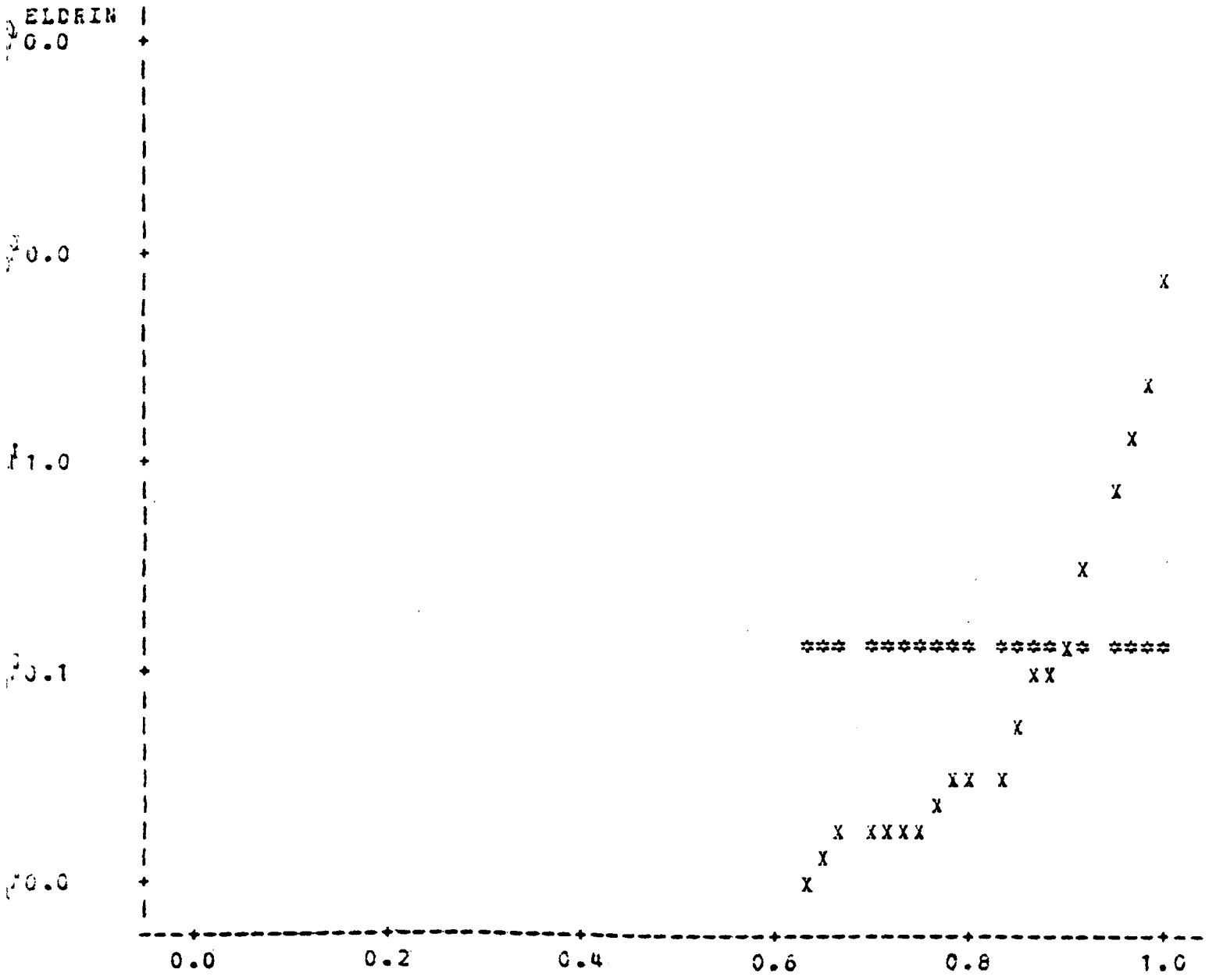
PLOT OF DIELDRIN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 31 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DIELDRIN! (UG/G ORGANIC CARBON)
GENUS=LIMNODRILUS SPP=HOFFMEISTERI

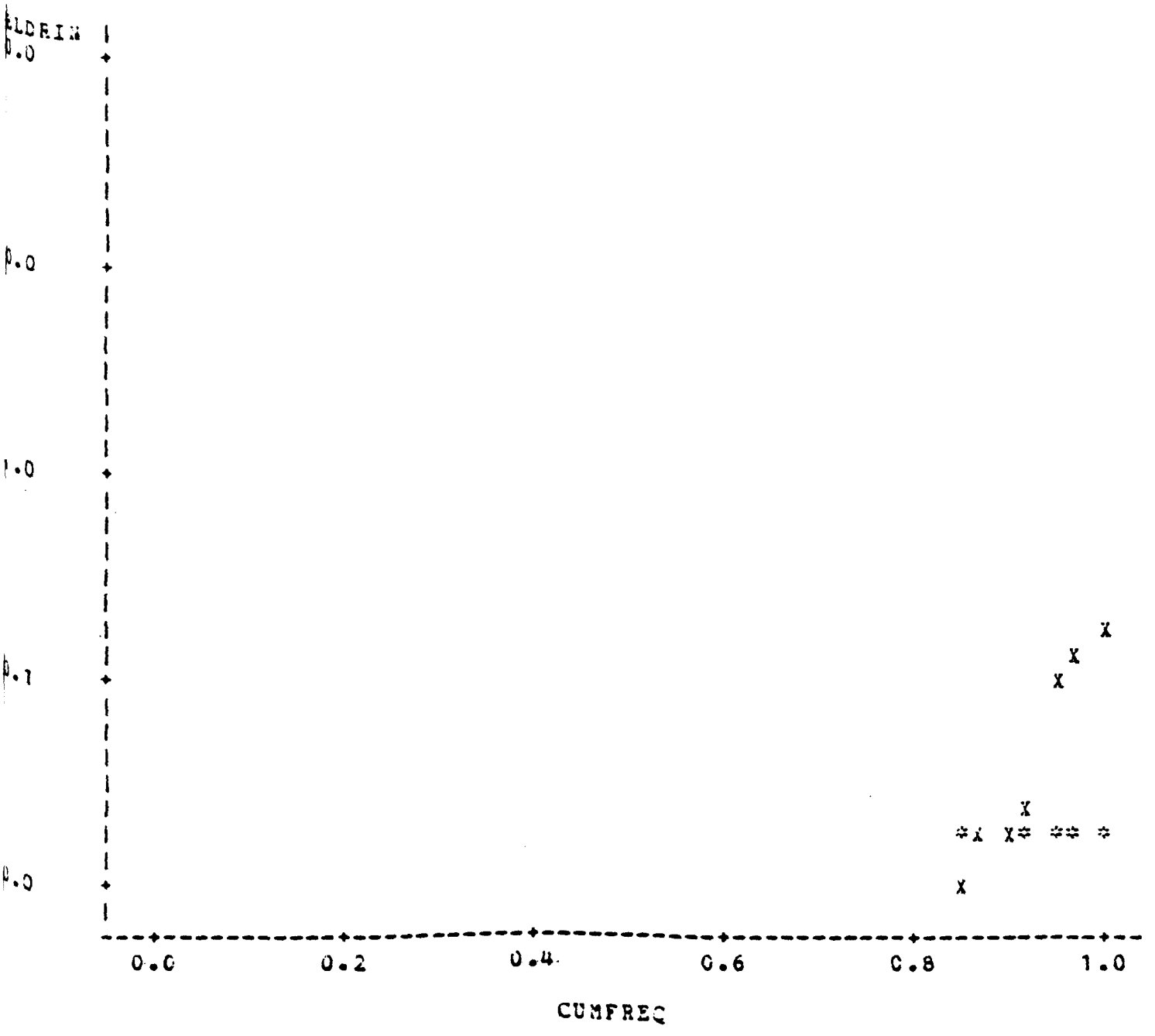
PLOT OF DIELDRIN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 65 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DIELDRIN! (UG/G ORGANIC CARBON)
GENUS=PELOSCOLEX SPP=FEROX

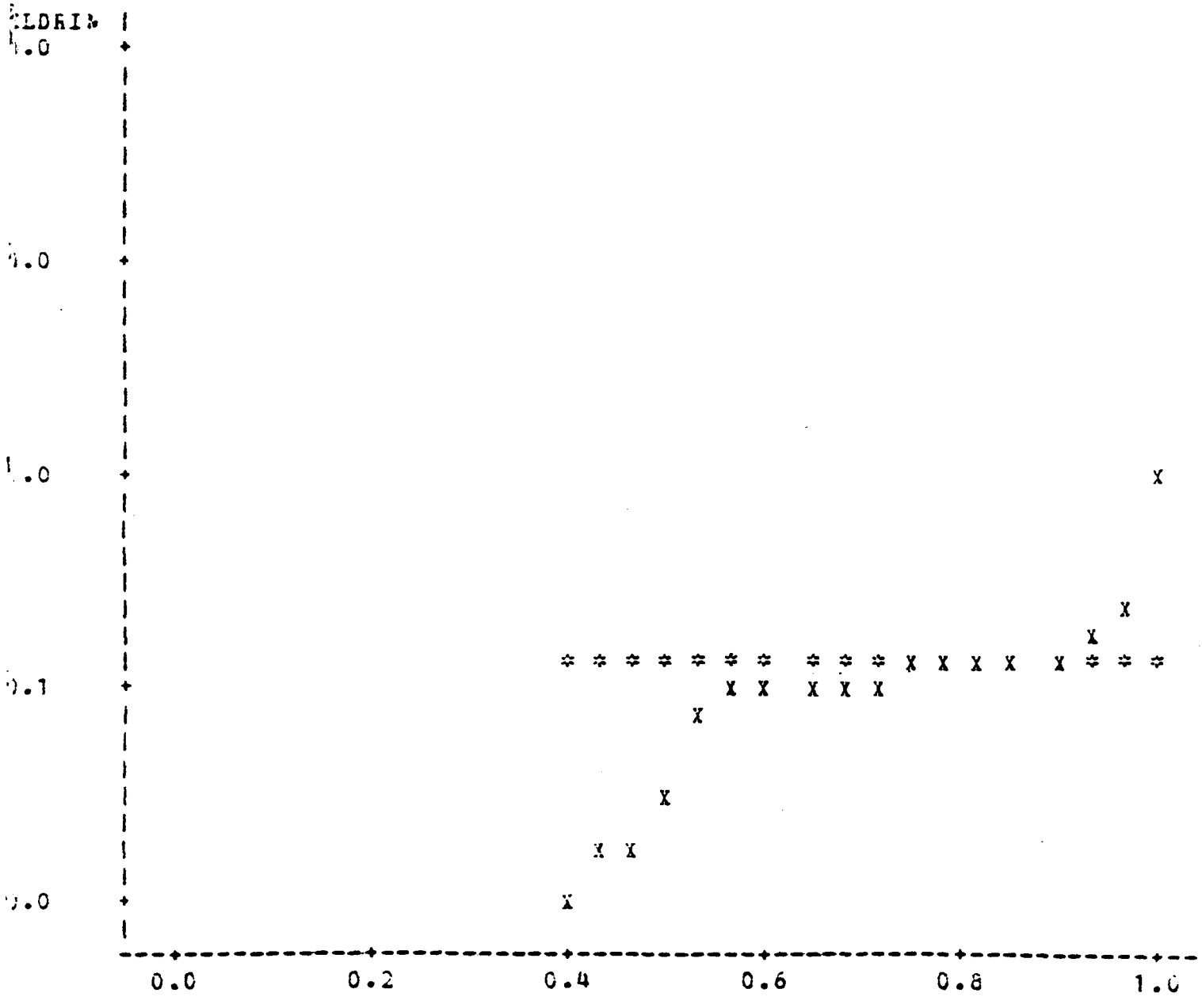
PLOT OF DIELDRIN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 68 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DIELDRIN! (UG/G ORGANIC CARBON)
GENUS=PELOSCOLEX SPP=MULTISETOSUS

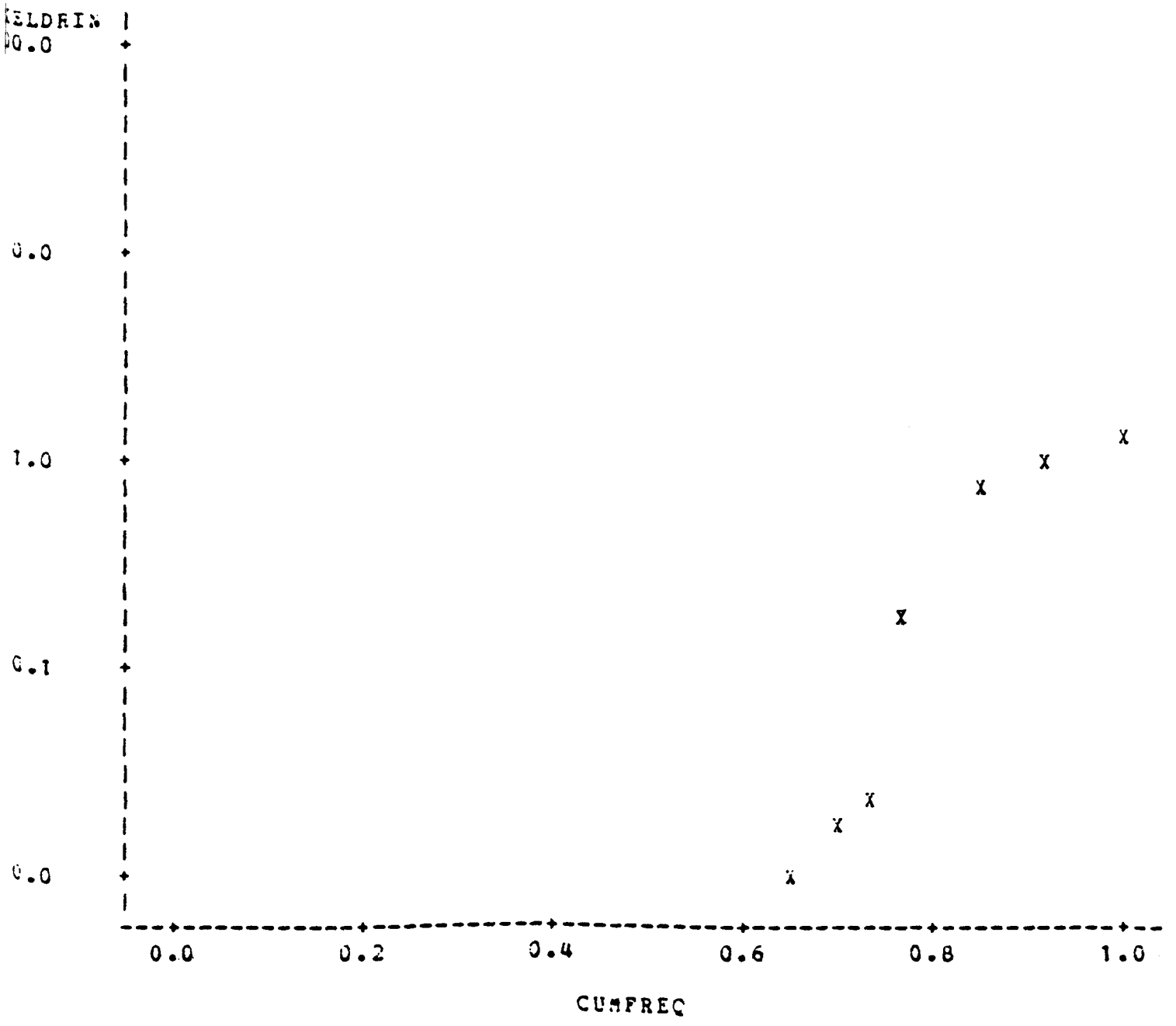
PLOT OF DIELDRIN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 25 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DIELDRIN! (UG/G ORGANIC CARBON)
GENUS=POTAMOTHRIX SPP=VEJDOVSKYI

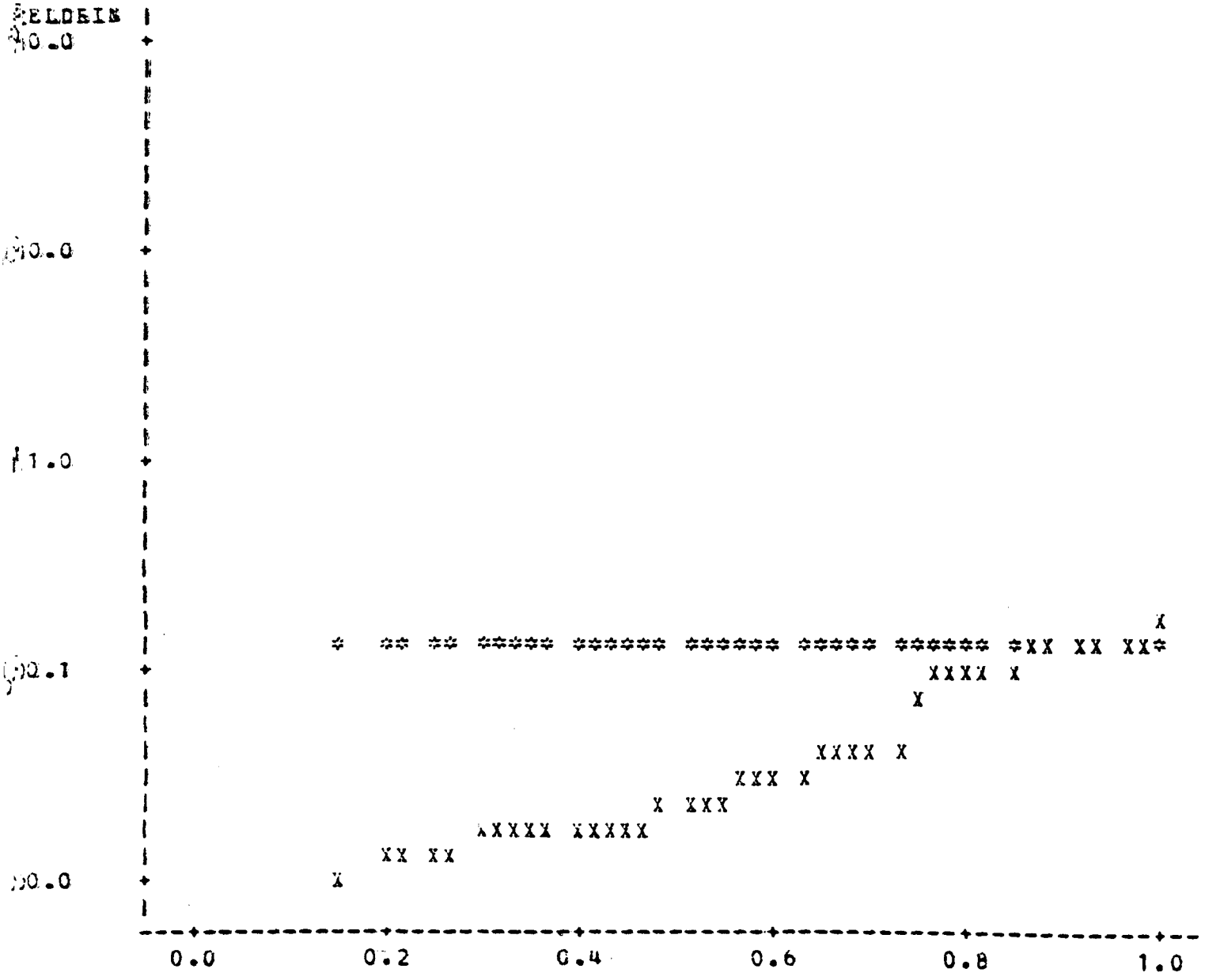
PLOT OF DIELDRIN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 26 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 19 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DIELDRIN! (UG/G ORGANIC CARBON)
GENUS=STENACRON SPP=INTERPUNCT

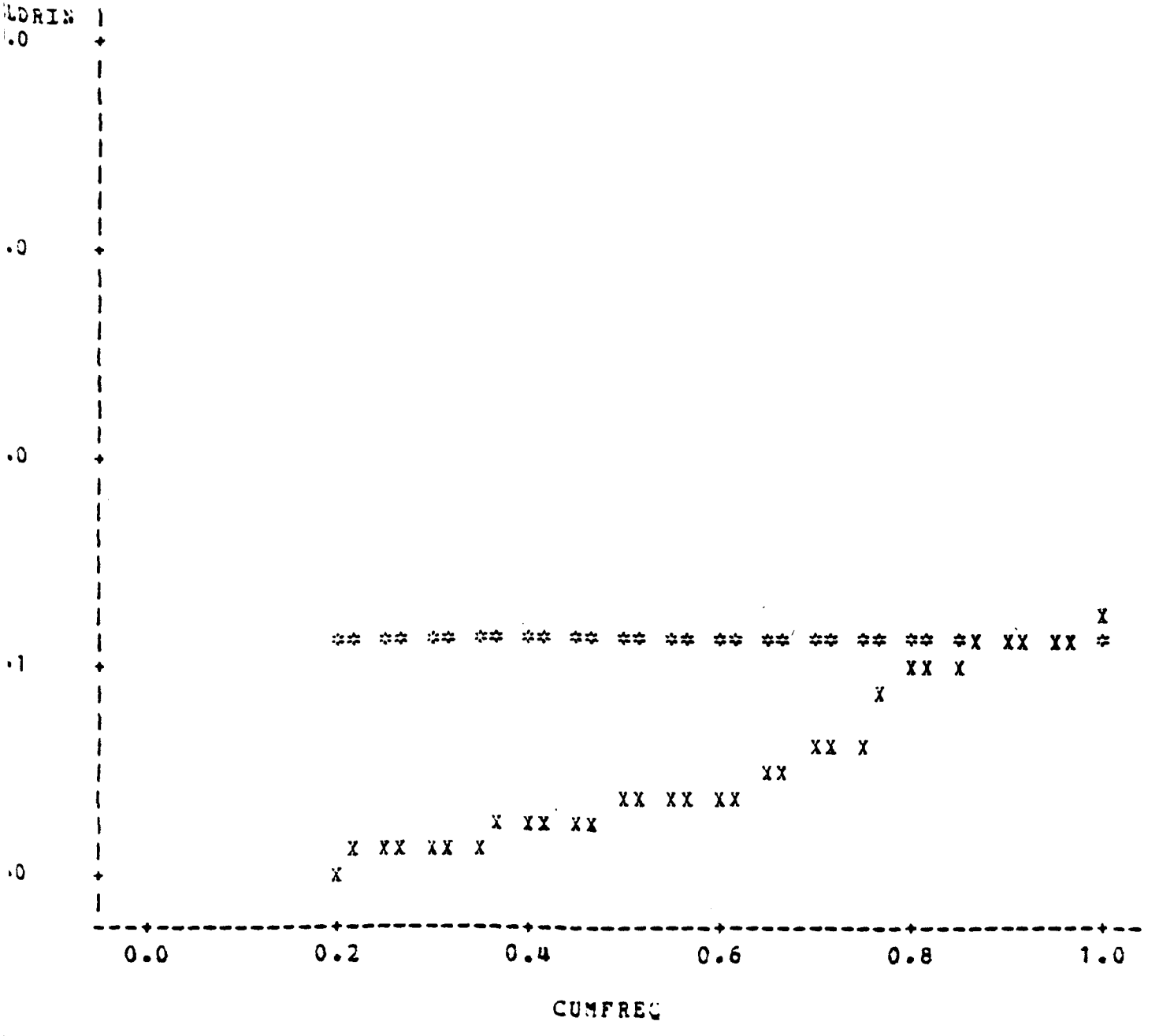
PLOT OF DIELDRIN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 26 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DIELDRIN! (UG/G ORGANIC CARBON)
GENUS=STENONEMA SPP=INTEGRUM

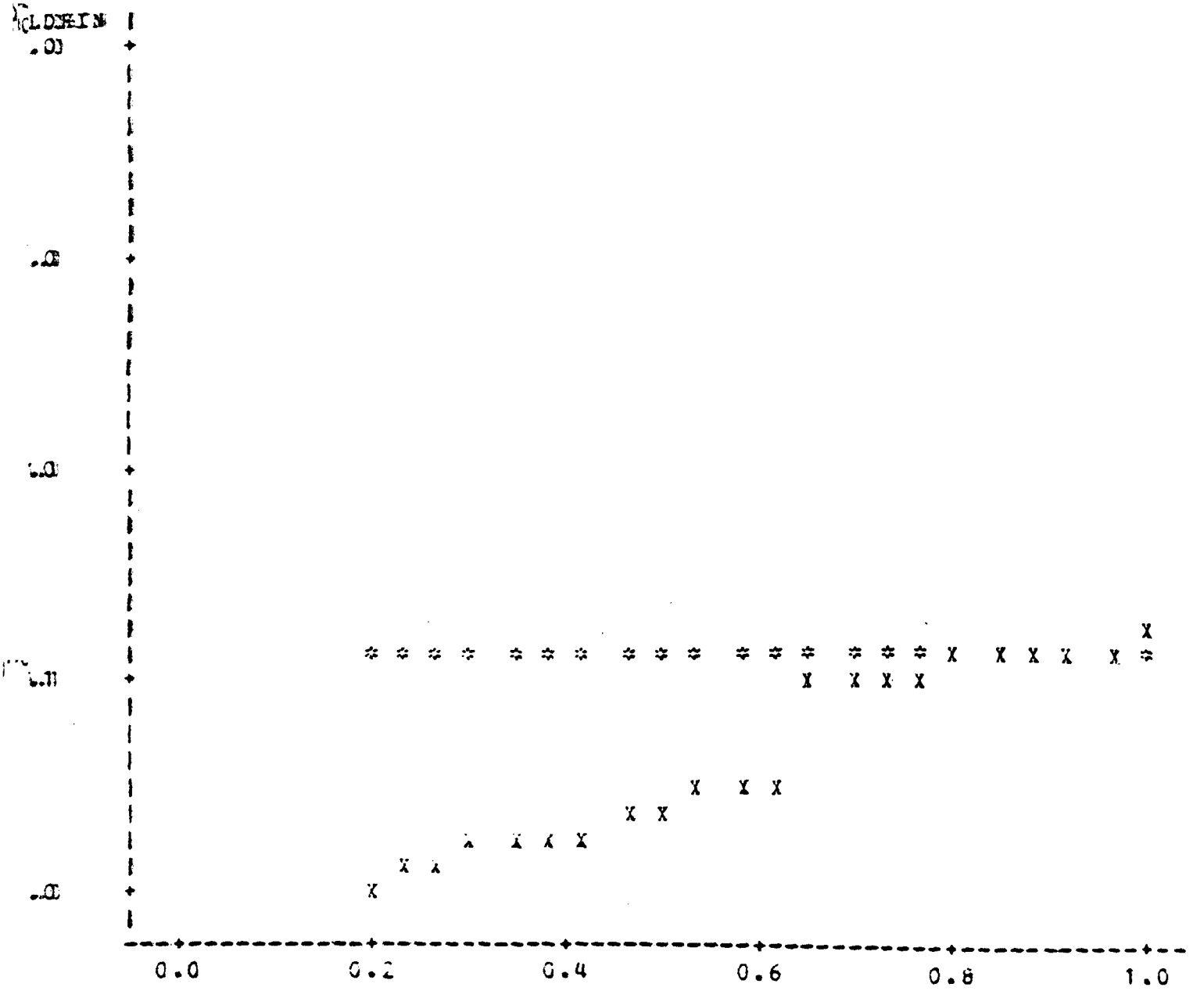
PLOT OF DIELDRIN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



2: 19 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DIELDRIN! (UG/G ORGANIC CARBON)
GENUS=STENONEMA SPP=PULCHELLUM

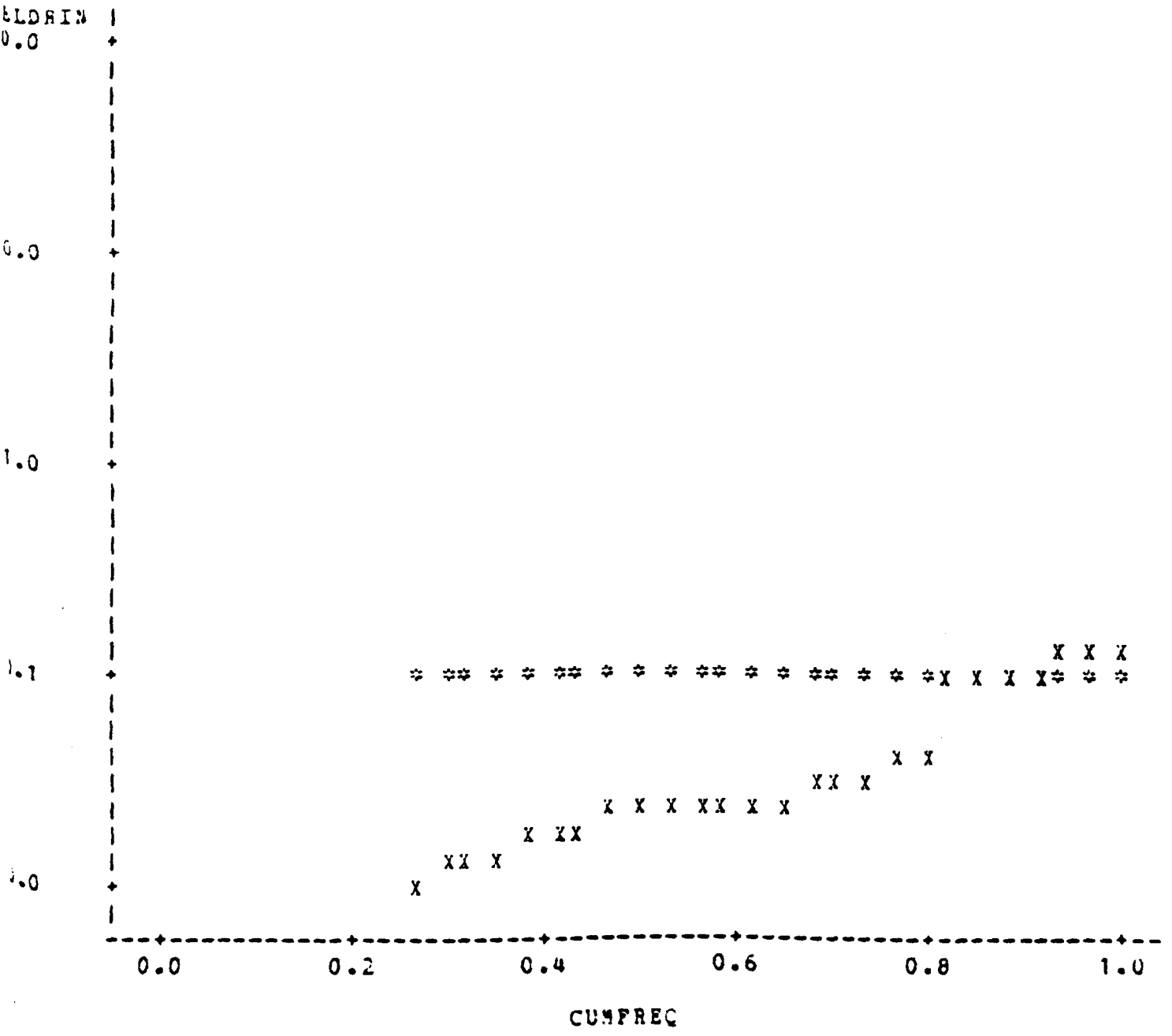
PLOT OF DIELDRIN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 13 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DIELDRIN! (UG/G ORGANIC CARBON)
GENUS=STENONEMA SPP=TERMINATUM

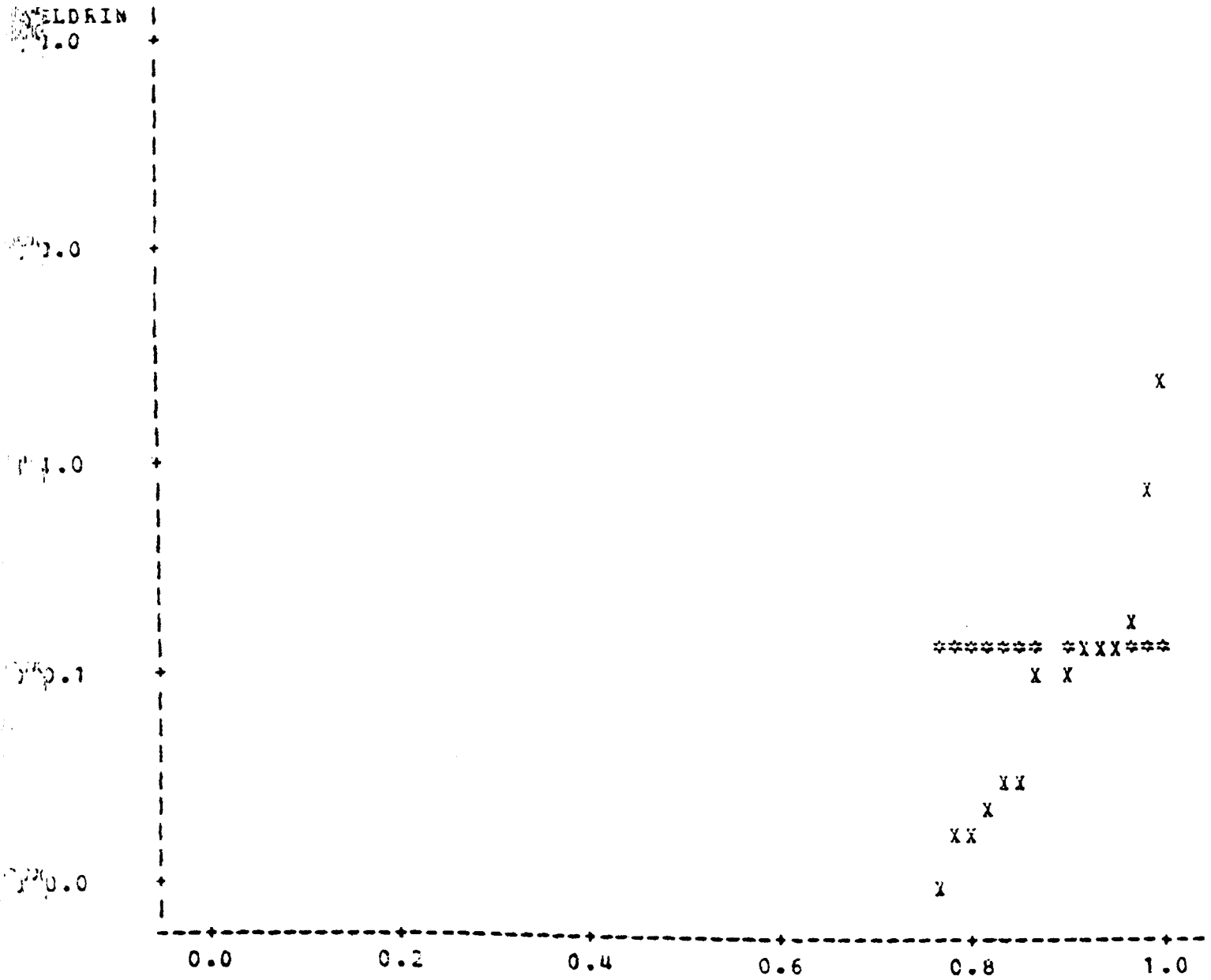
PLOT OF DIELDRIN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



E: 20 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DIELDRIN! (UG/G ORGANIC CARBON)
GENUS=TUBIFEX SPP=TUBIFEX

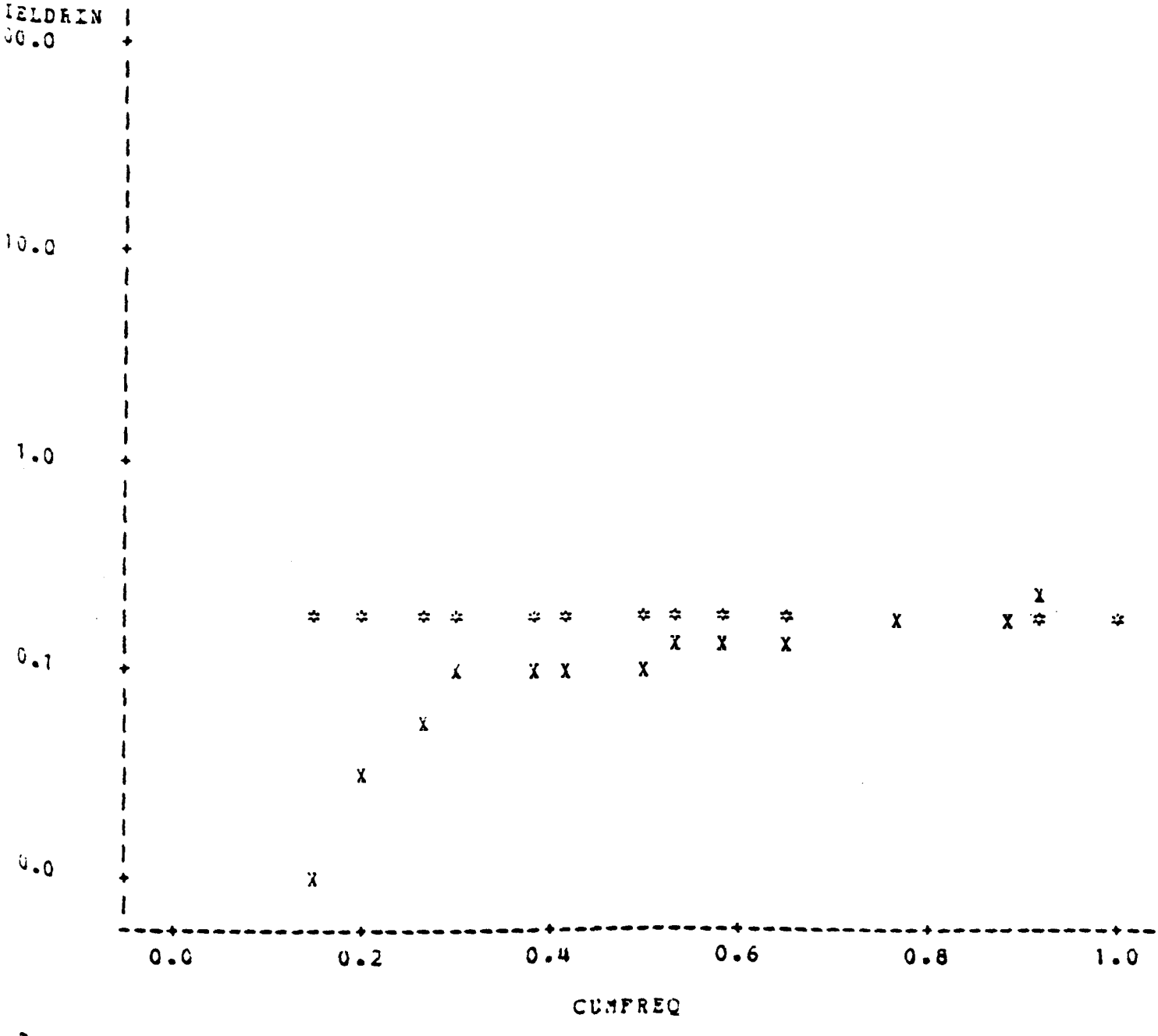
PLOT OF DIELDRIN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 87 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢DIELDRIN! (UG/G ORGANIC CARBON)
GENUS=VALVATA SPP=SINCERA

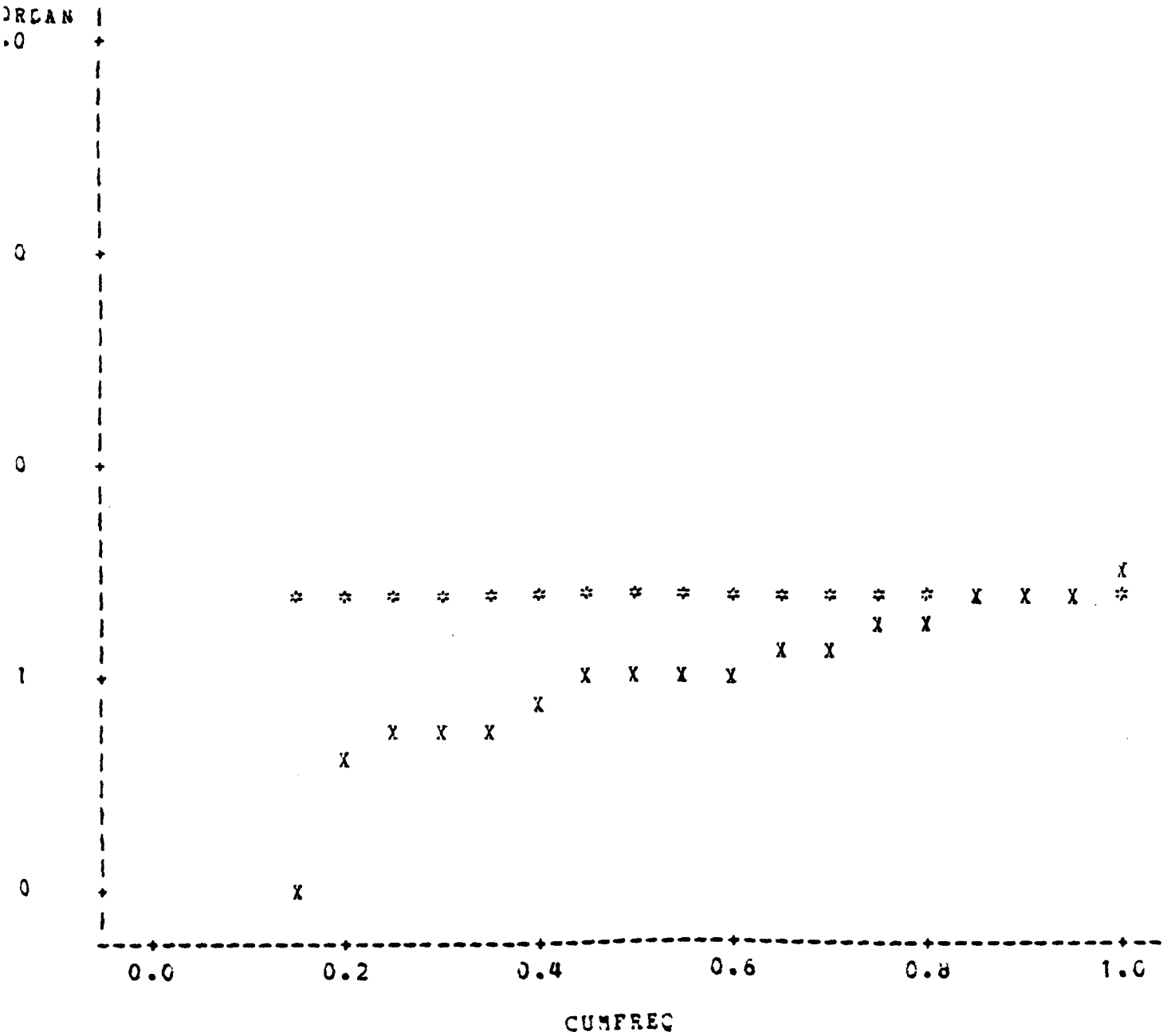
PLOT OF DIELDRIN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 26 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢CHLODANE! (UG/G ORGANIC CARBON)
GENUS=ASELLUS SPP=INTERMEDIUS

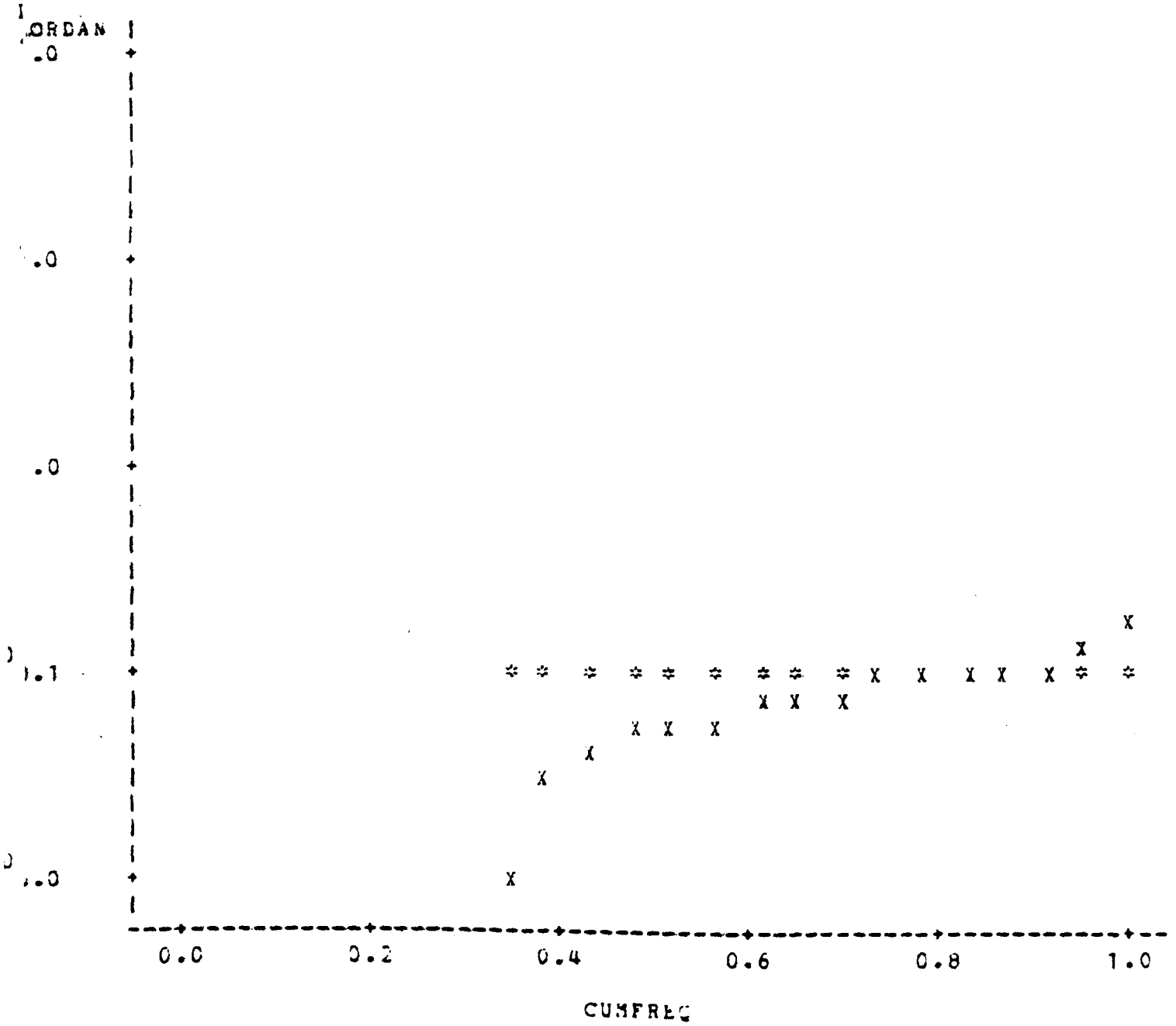
PLOT OF CHLORDAN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



: 7 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢CHLODANE! (UG/G ORGANIC CARBON)
GENUS=CYRNELLUS SPP=FRATERNUS

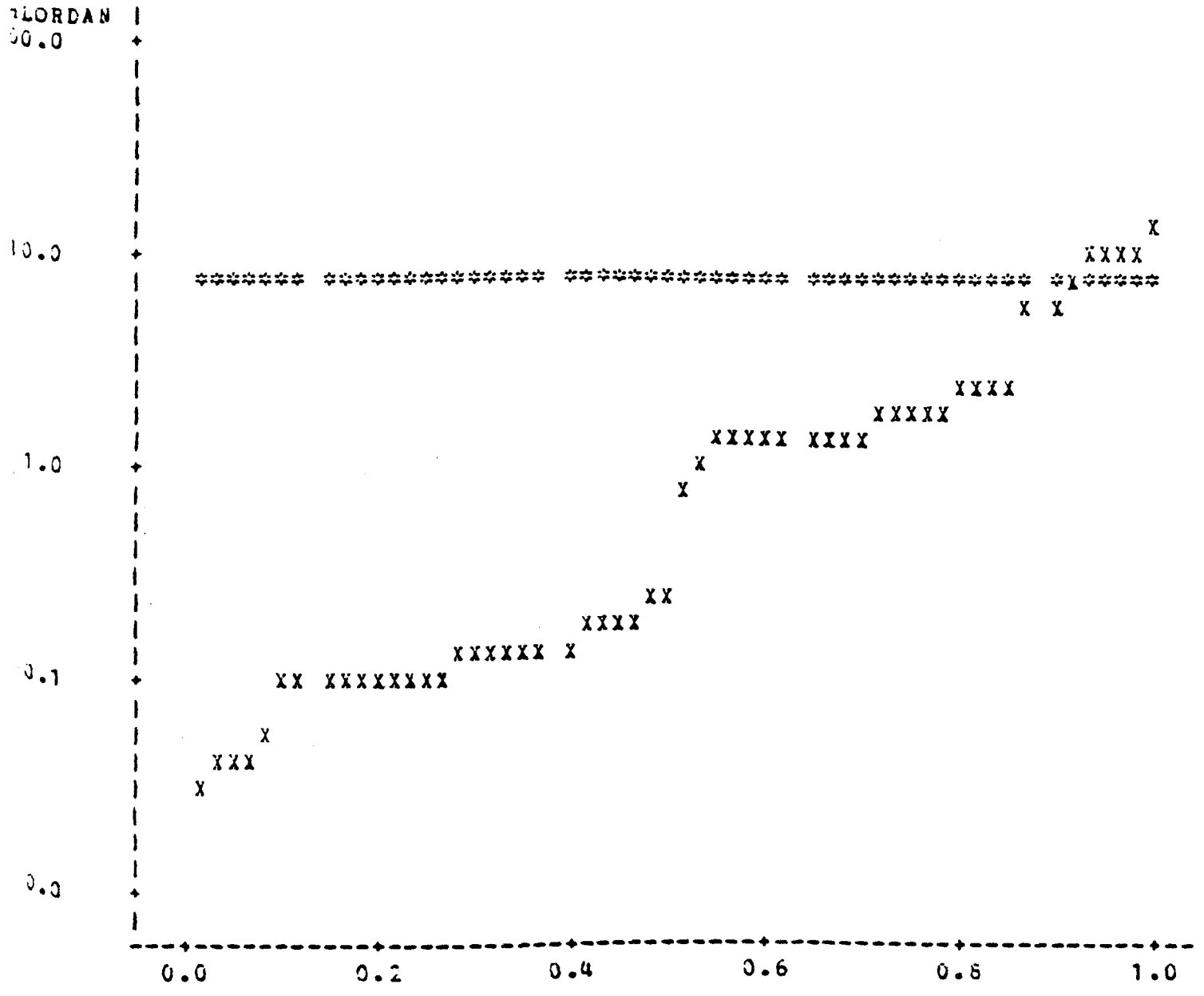
PLOT OF CHLORDAN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



E: 19 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢CHLODANE! (UG/G ORGANIC CARBON)
GENUS=GAMMARUS SPP=FASCIATUS

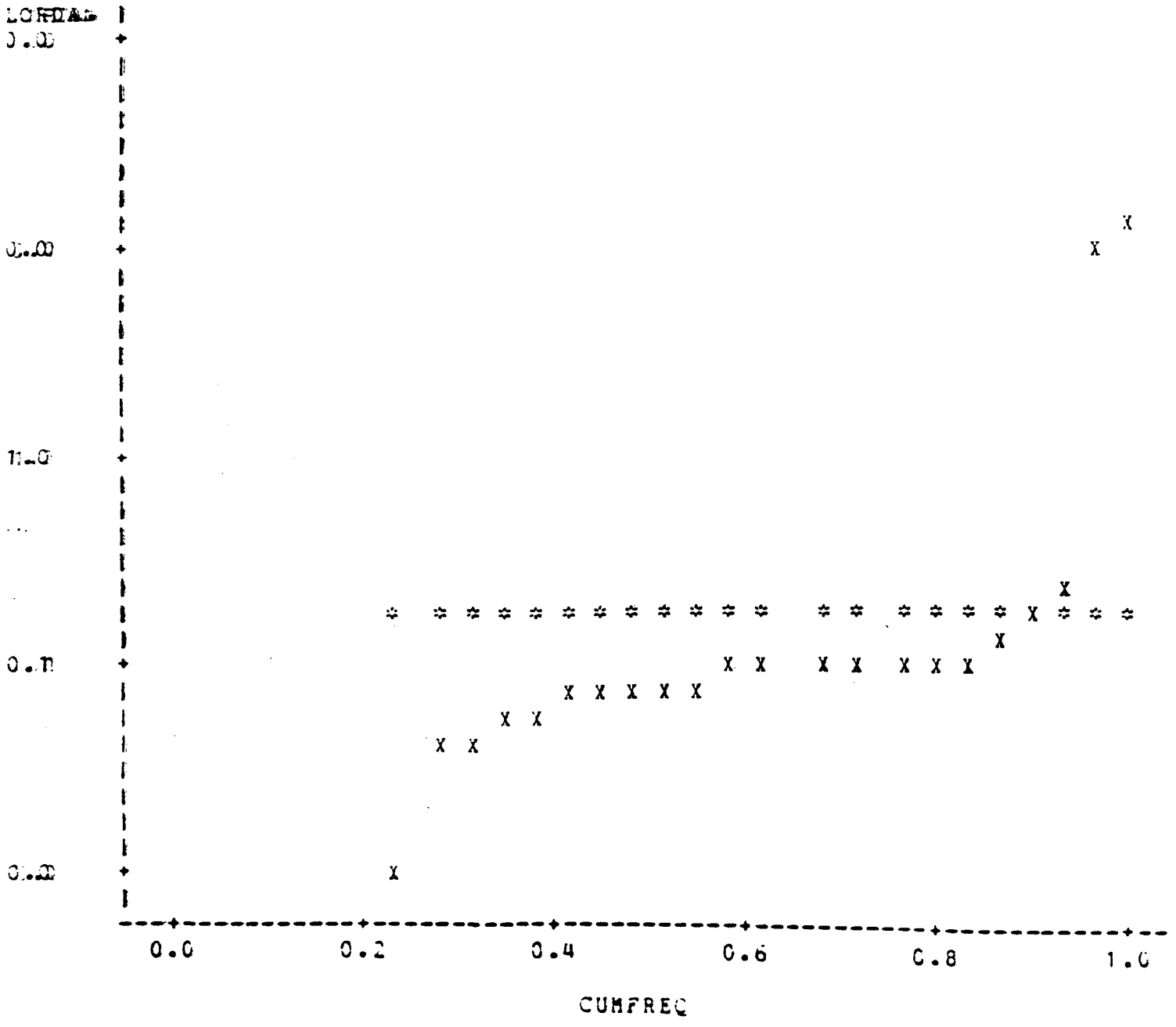
PLOT OF CHLORDAN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 1 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ΣCHLORDANE! (UG/G ORGANIC CARBON)
GENUS=HYALELLA SPP=AZTECA

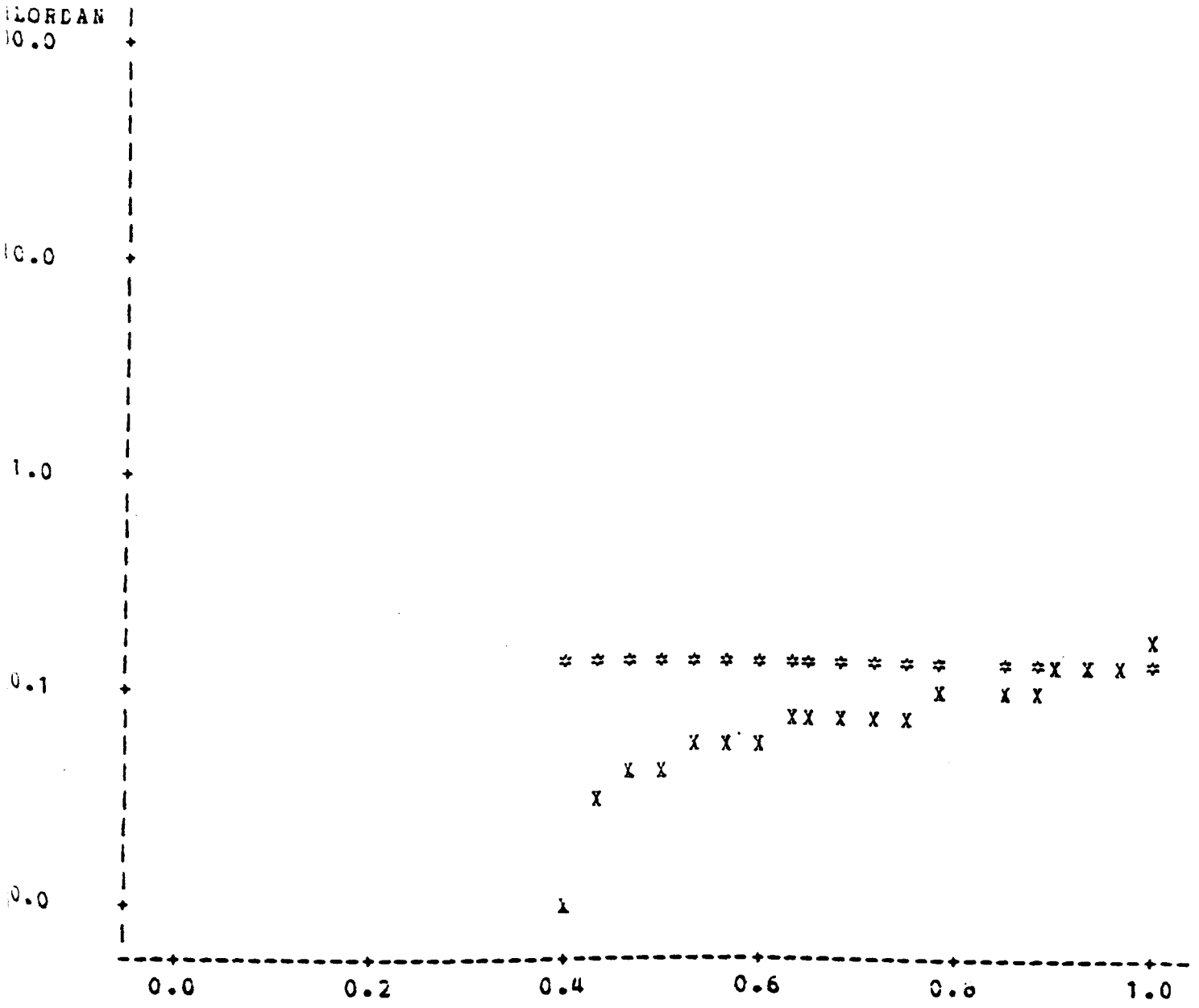
PLOT OF CHLORDAN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 15 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢CHLODANE! (UG/G ORGANIC CARBON)
GENUS=HYDROPSYCH SPP=FRISONI

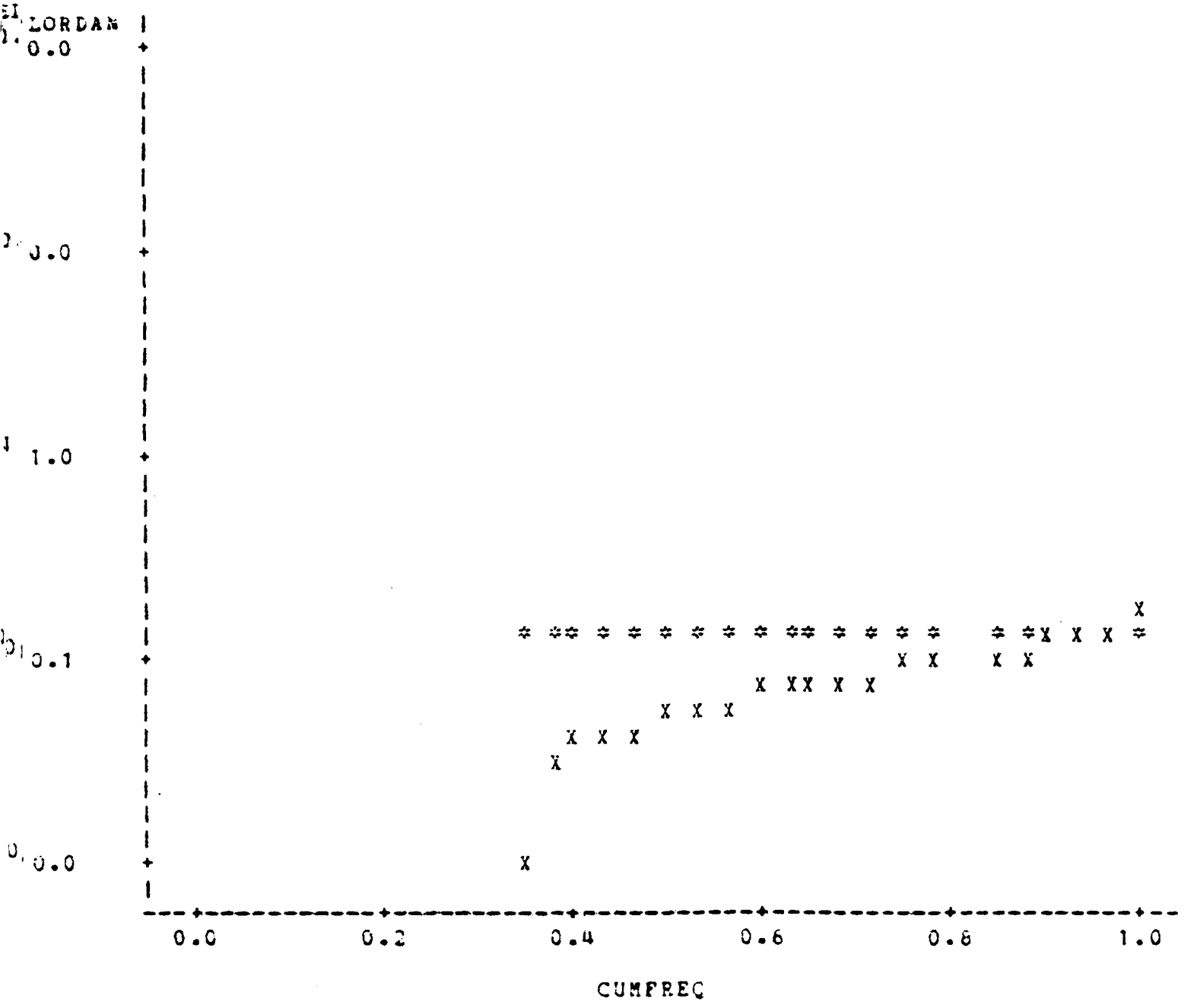
PLOT OF CHLORDAN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



E: 29 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢CHLODANE! (UG/G ORGANIC CARBON)
GENUS=HYDROPSYCH SPP=ORRIS

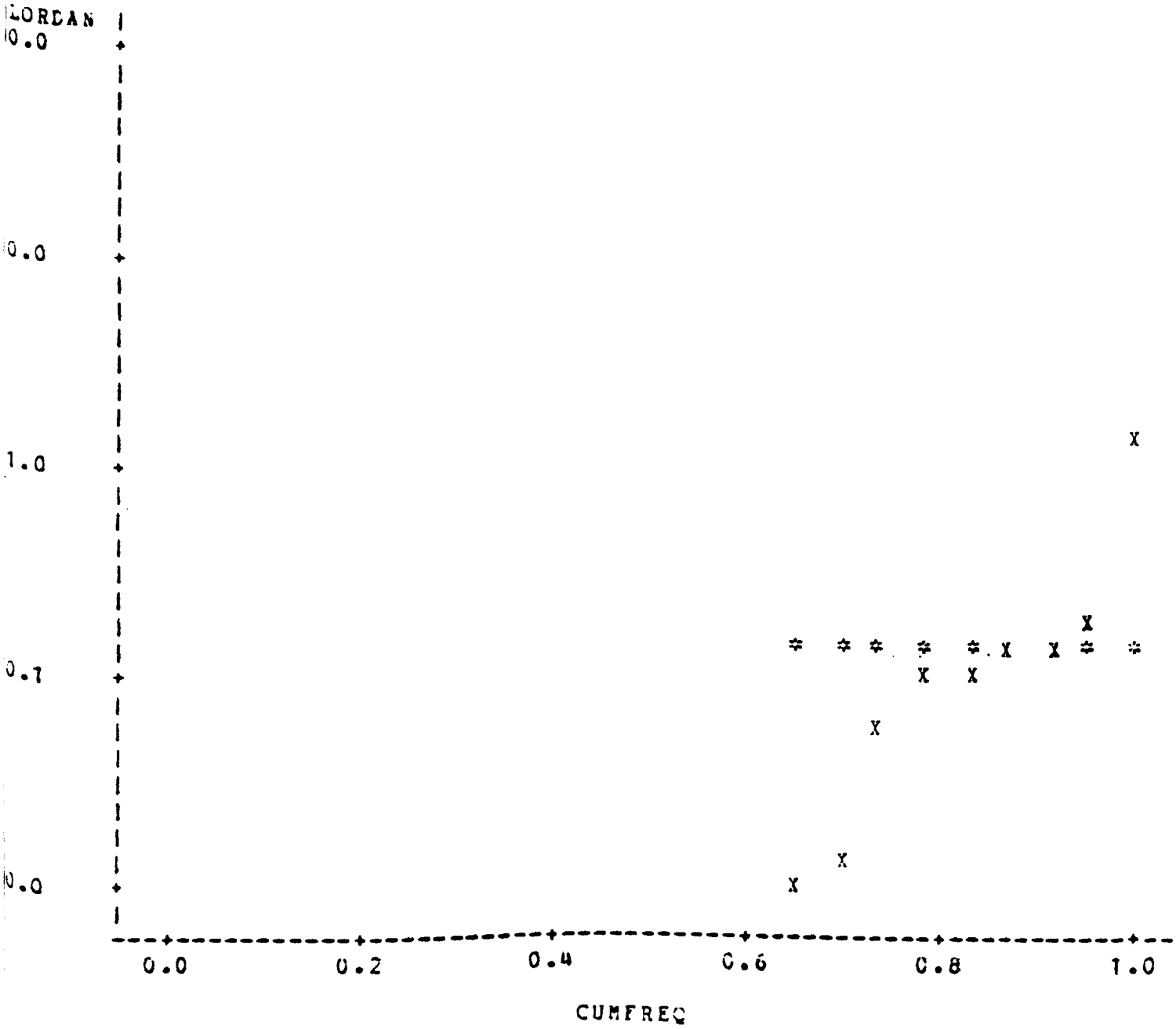
PLOT OF CHLORDAN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 25 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED (CHLORDANE) (UG/G ORGANIC CARBON)
GENUS=LIMNODRILUS SPP=CLAPAREDEIANUS

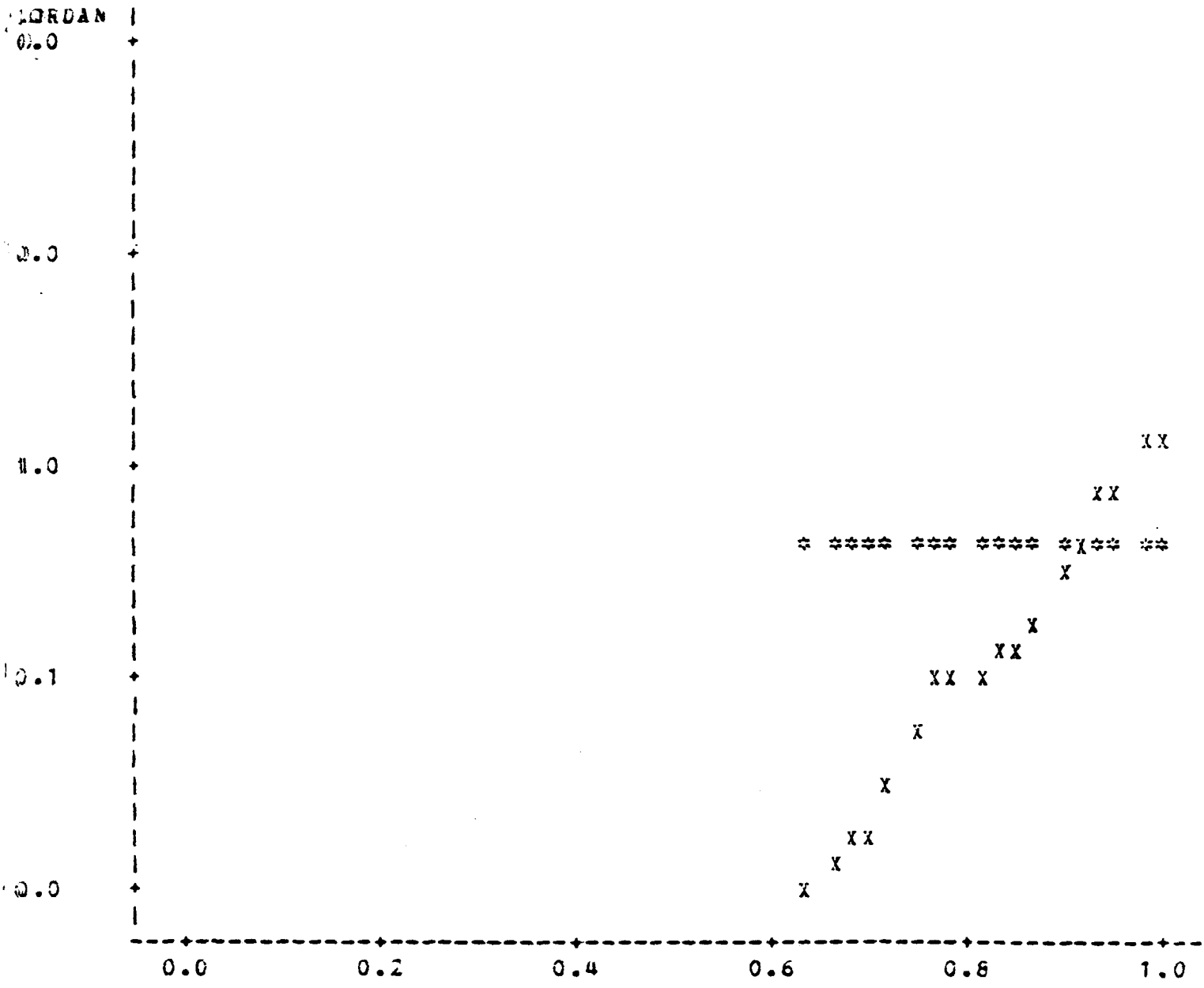
PLOT OF CHLORDAN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 30 OBS HILDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢CHLODANE! (UG/G ORGANIC CARBON)
GENUS=LIMNODRILUS SPP=HOFFMEISTERI

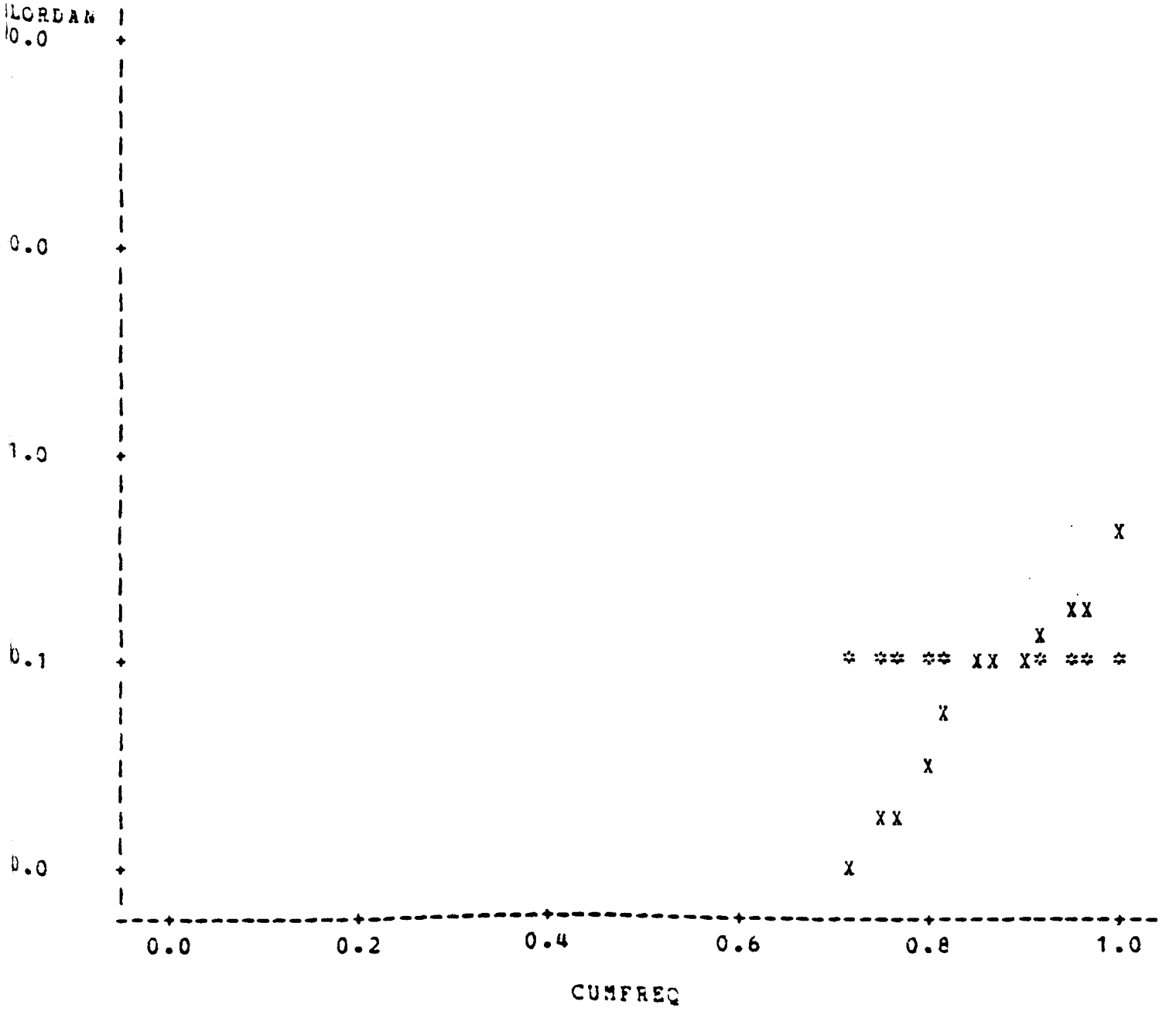
PLOT OF CHLORDAN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 59 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢CHLODANE! (UG/G ORGANIC CARBON)
GENUS=PELOSCOLEX SPP=FEROX

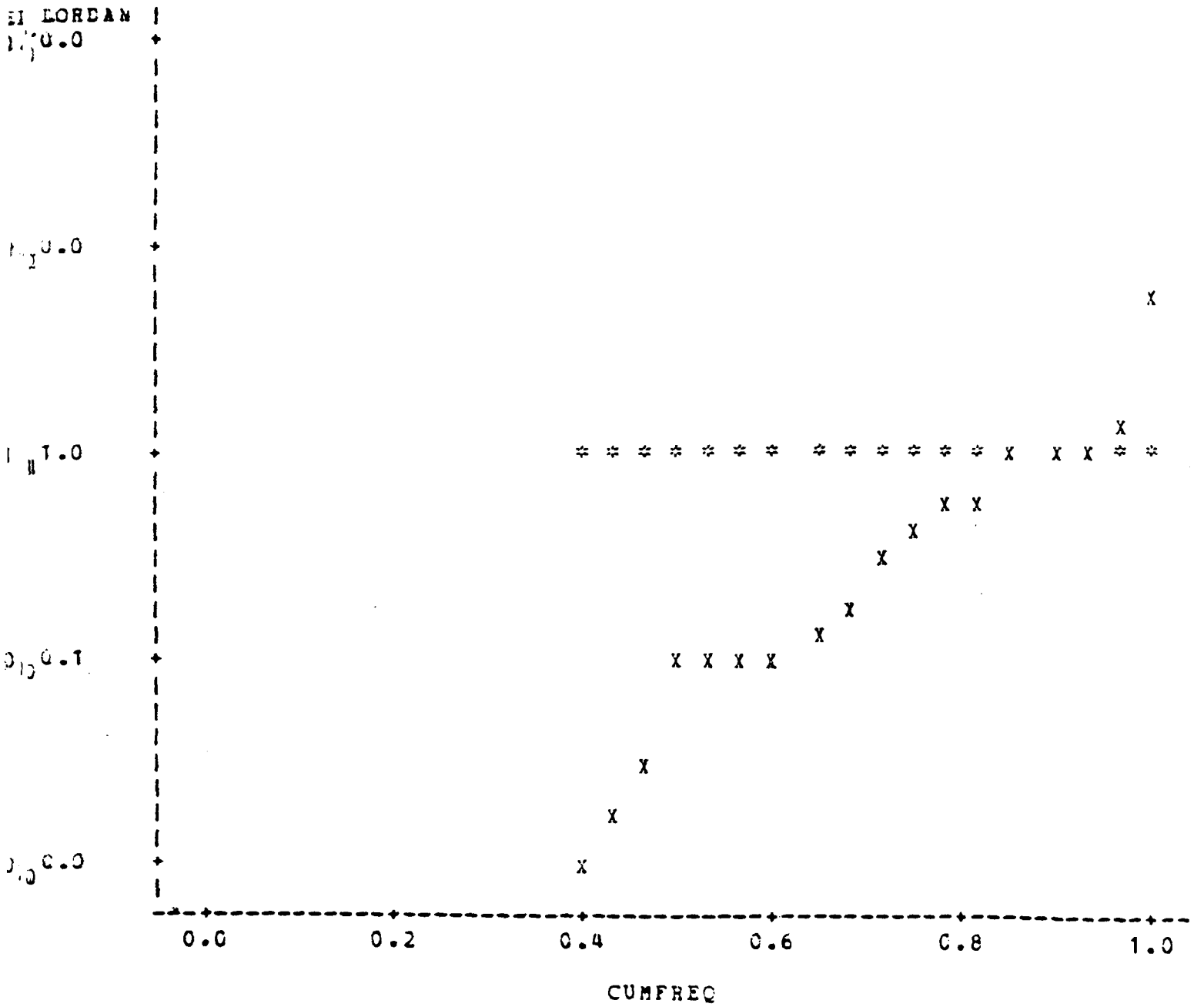
PLOT OF CHLORDAN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



E: 59 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢CHLODANE! (UG/G ORGANIC CARBON)
GENUS=PELOSCOLEX SPP=MULTISETOSUS

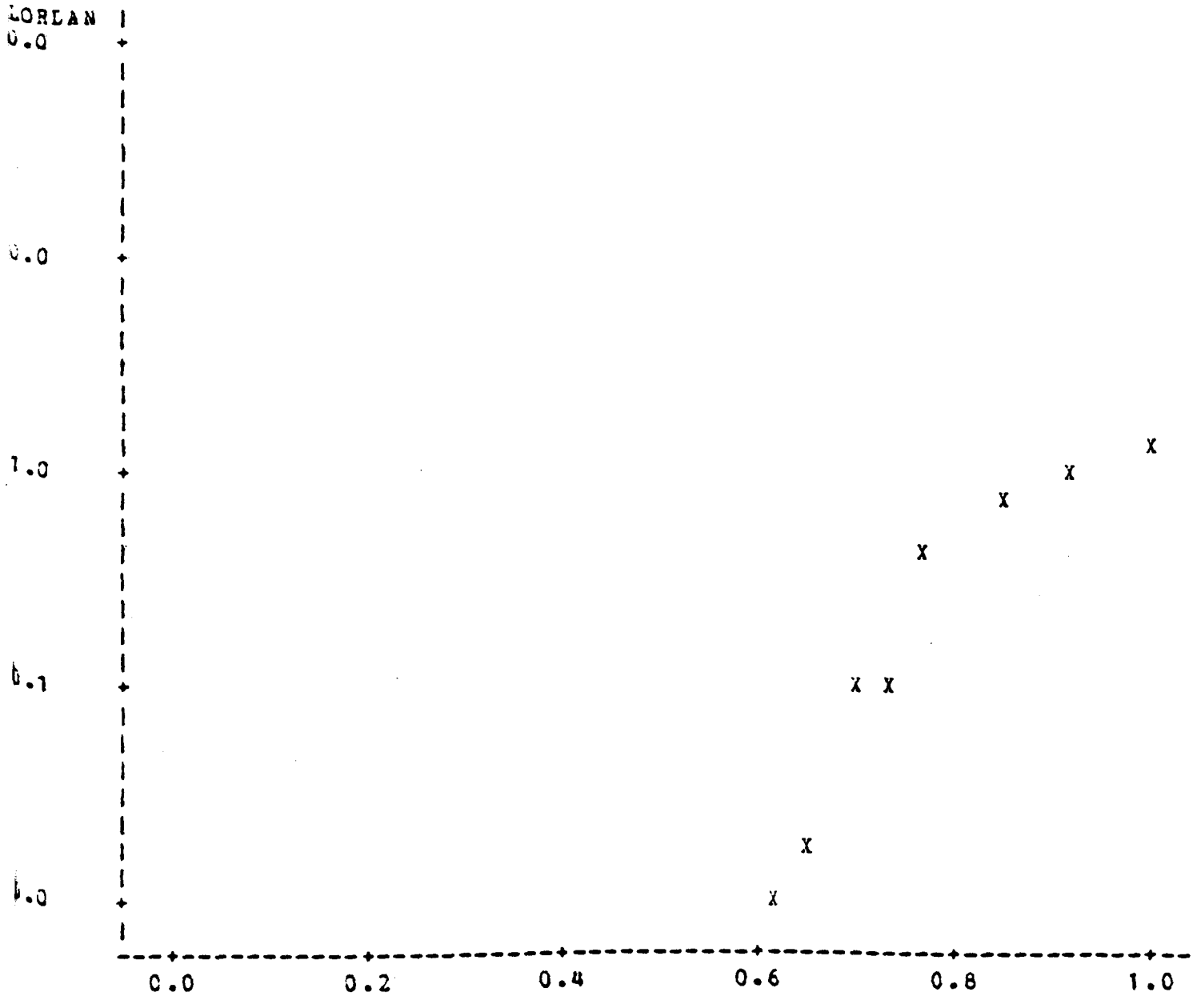
PLOT OF CHLORDAN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 23 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢CHLODANE! (UG/G ORGANIC CARBON)
GENUS=POTAMOTHRIX SPP=VEJDOVSKYI

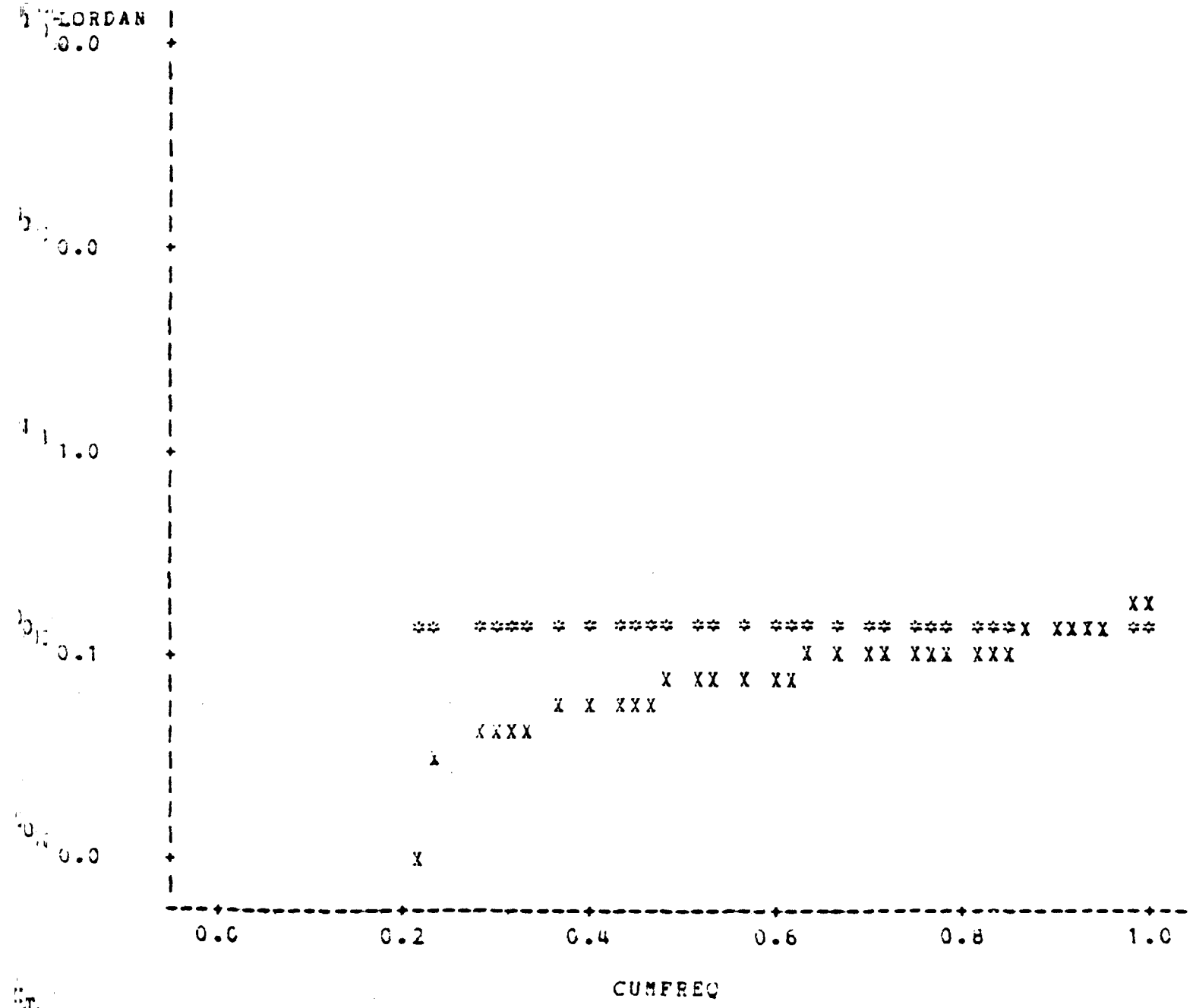
PLOT OF CHLORDAN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



E: 26 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 18 OBS HILDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢CHLODANE! (UG/G ORGANIC CARBON)
GENUS=STENACRON SPP=INTERPUNCT

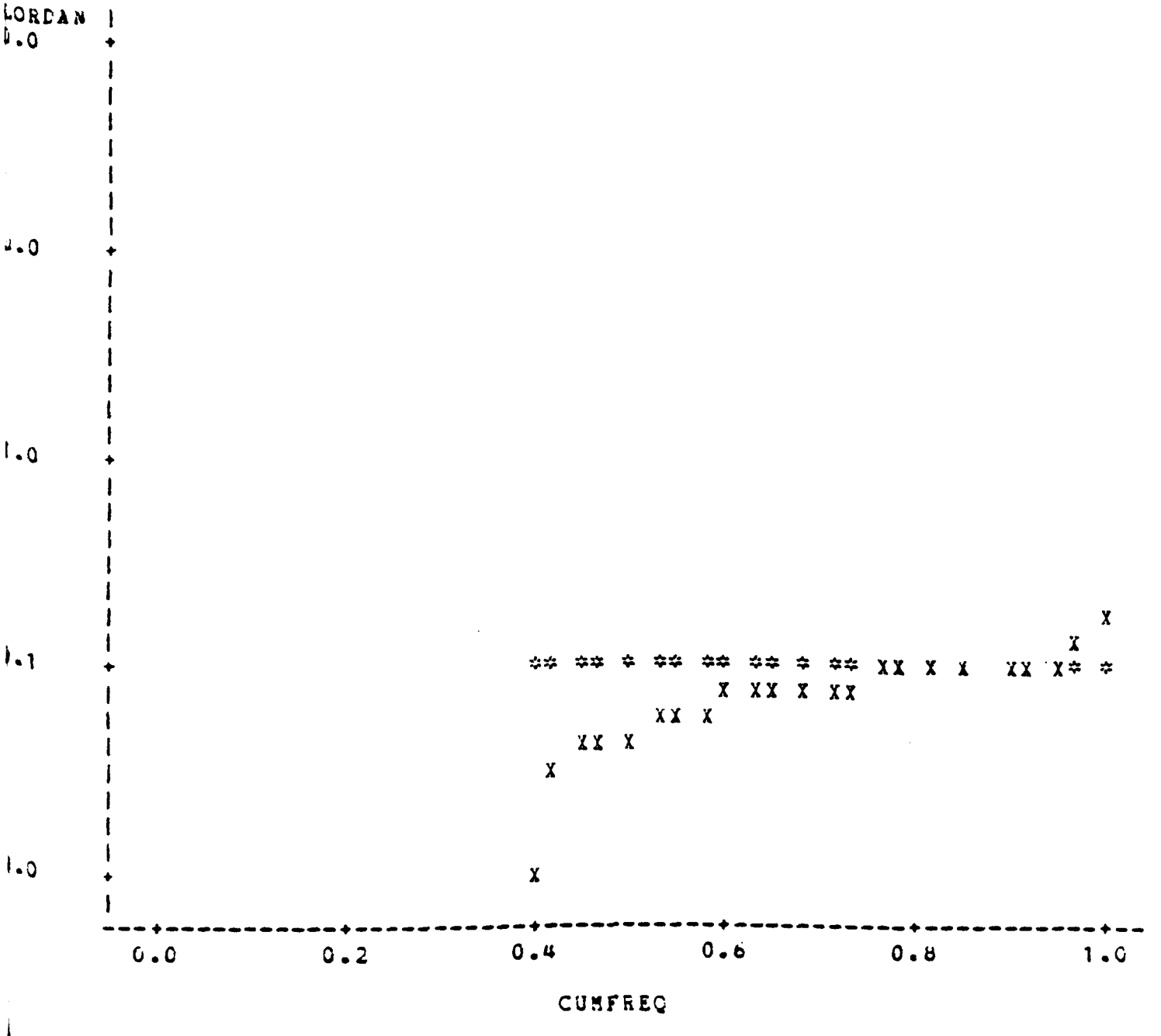
PLOT OF CHLORDAN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 31 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢CHLORDANE! (UG/G ORGANIC CARBON)
GENUS=STENONEMA SPP=INTEGRUM

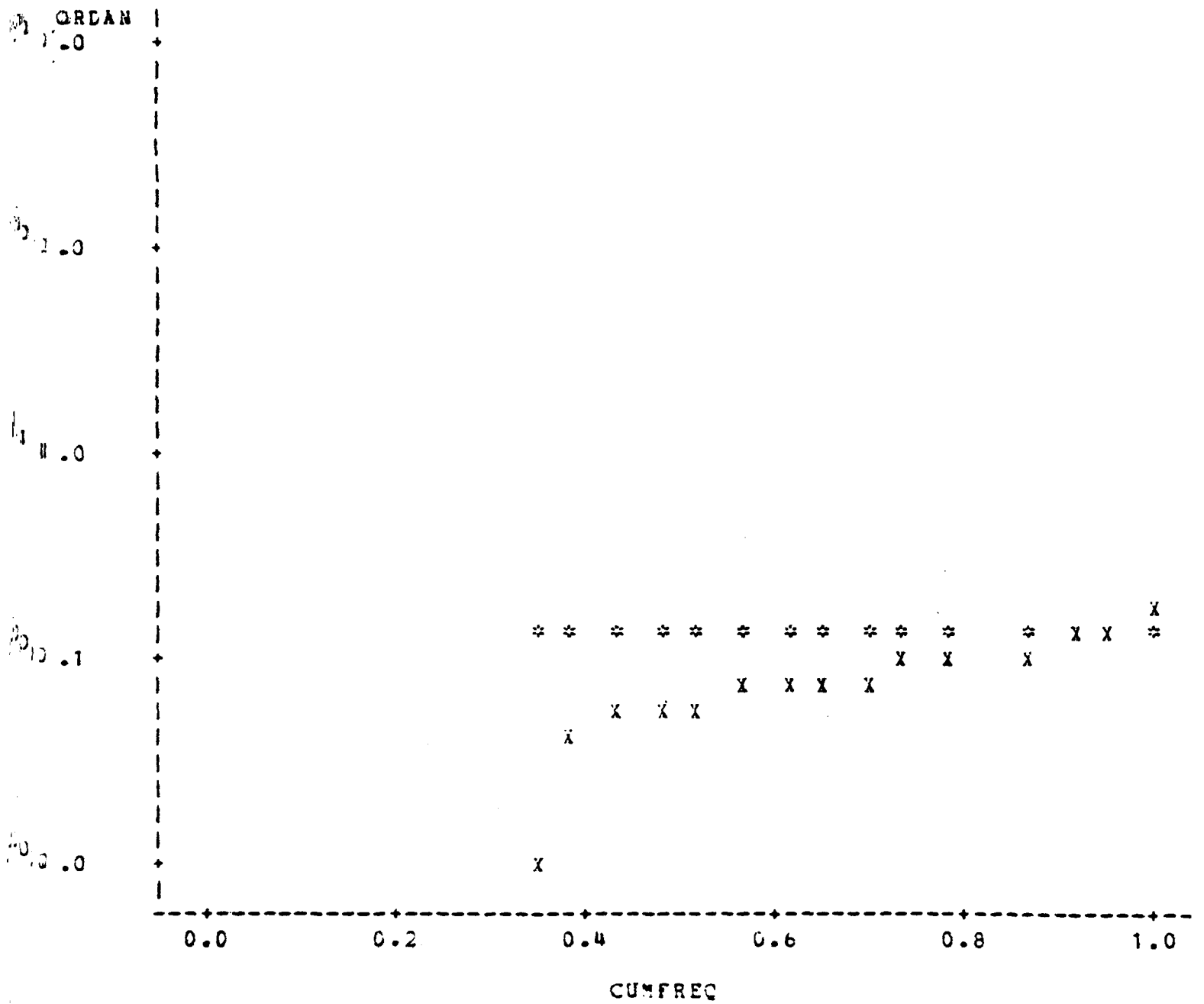
PLOT OF CHLORDAN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



E: 37 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED @CHLODANE! (UG/G ORGANIC CARBON)
GENUS=STENONEMA SPP=PULCHELLUM

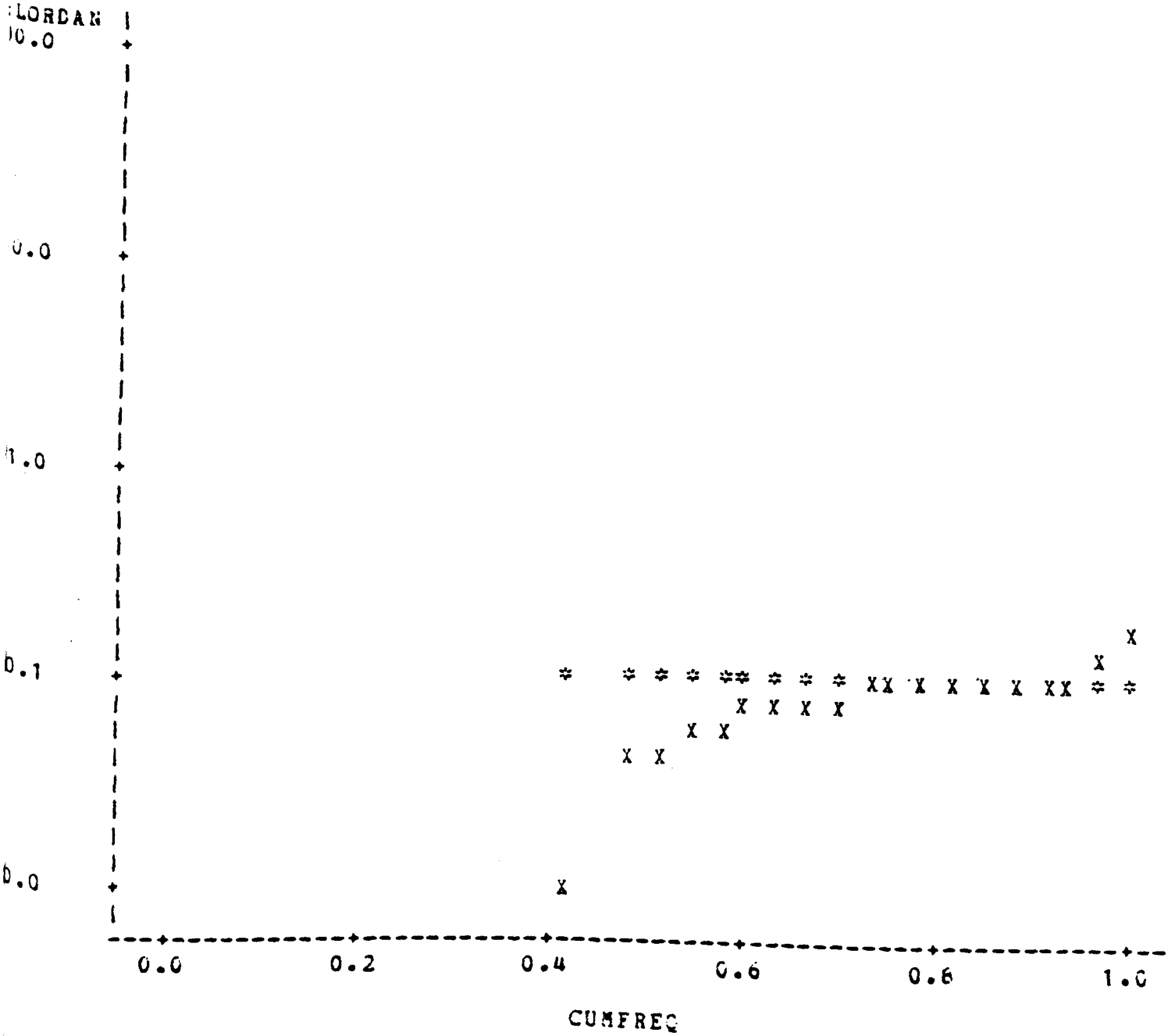
PLOT OF CHLORDAN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 18 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢CHLODANE! (UG/G ORGANIC CARBON)
GENUS=STENONEMA SPP=TERMINATUM

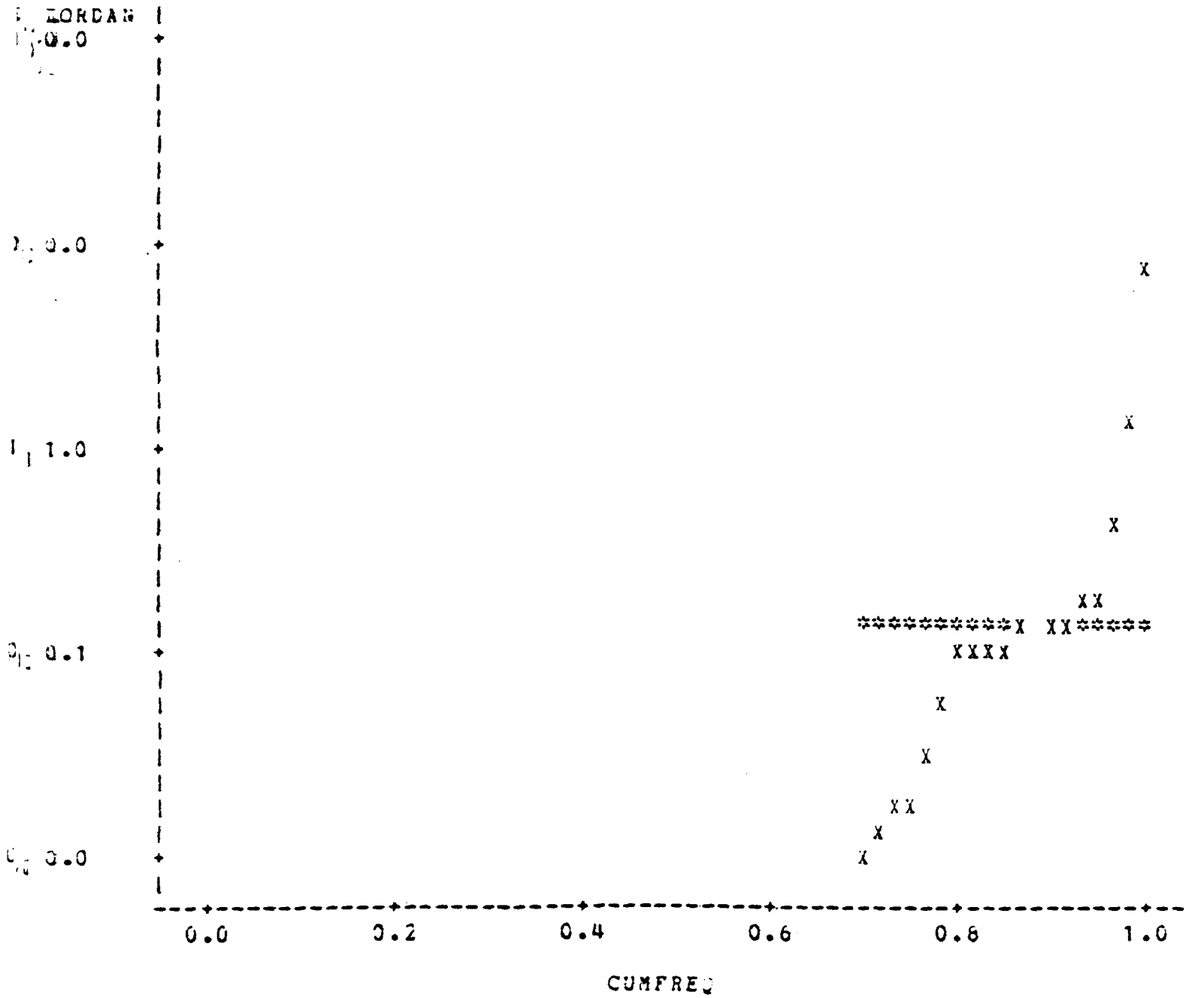
PLOT OF CHLORDAN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



E: 36 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢CHLORDANE! (UG/G ORGANIC CARBON)
GENUS=TUBIFEX SPP=TUBIFEX

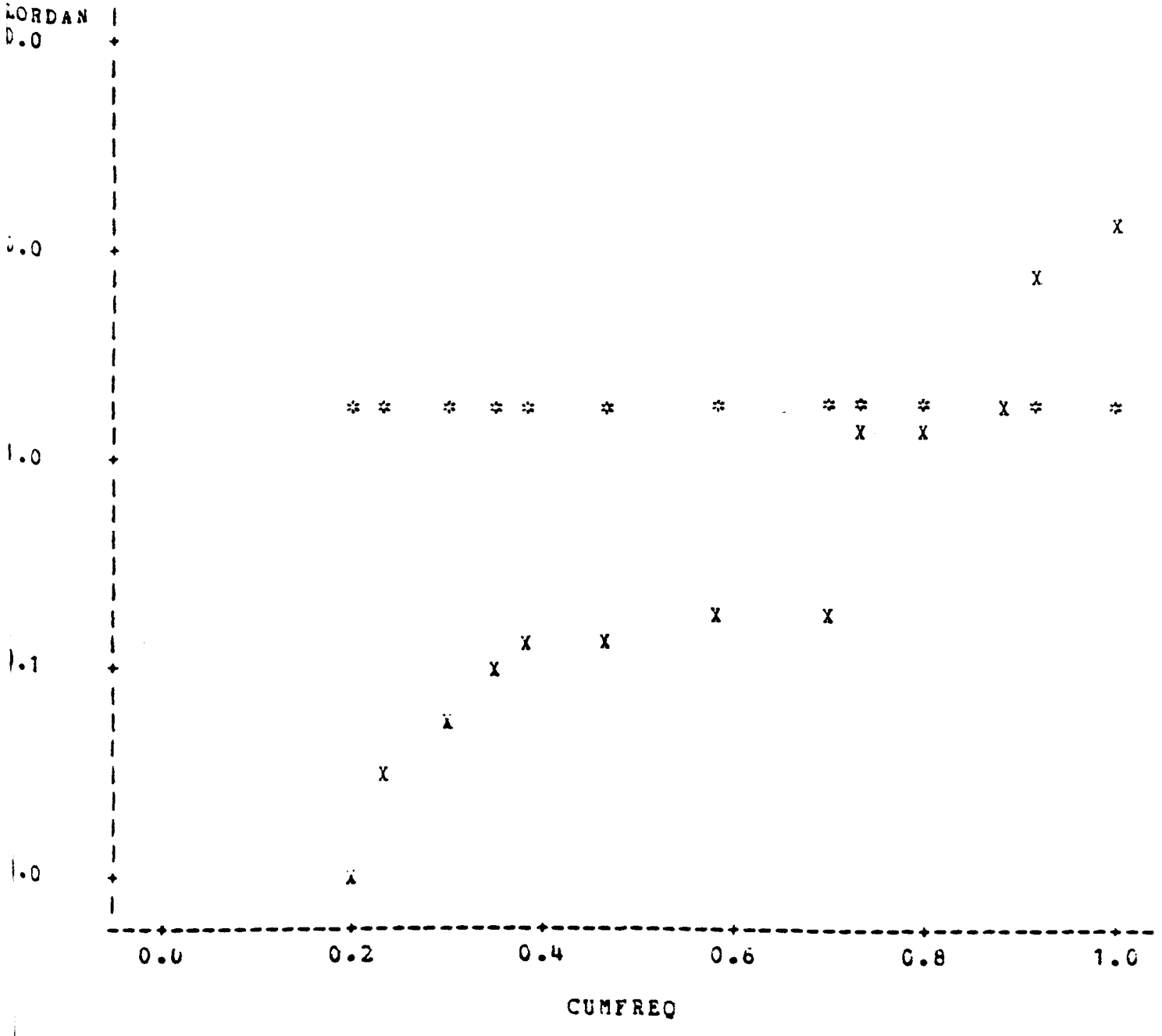
PLOT OF CHLORDAN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 79 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢CHLORDANE! (UG/G ORGANIC CARBON)
GENUS=VALVATA SPP=SINCERA

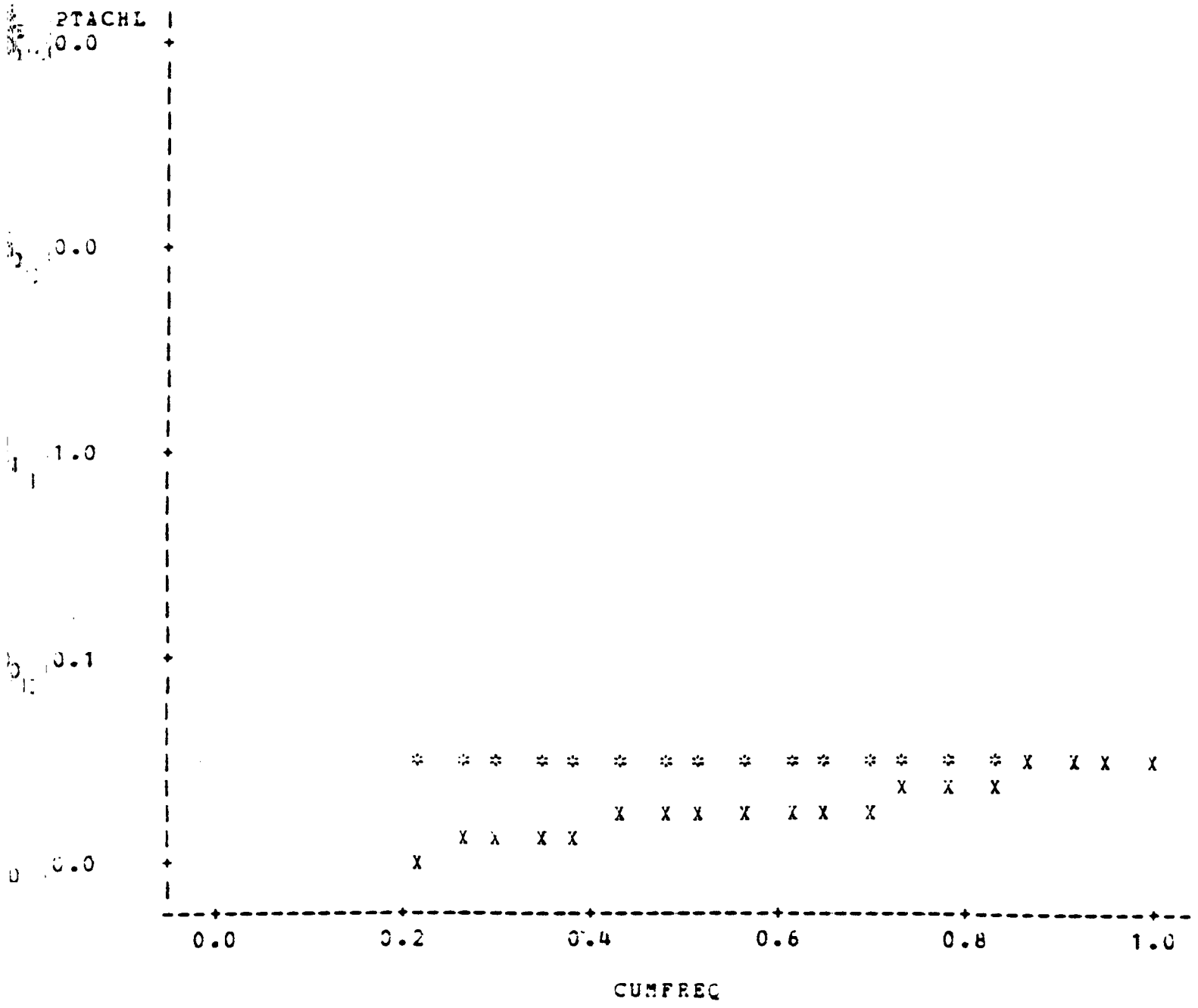
PLOT OF CHLORDAN*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



E: 27 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢HEPTACHLOR! (UG/G ORGANIC CARBON)
GENUS=ASELLUS SPP=INTERMEDIUS

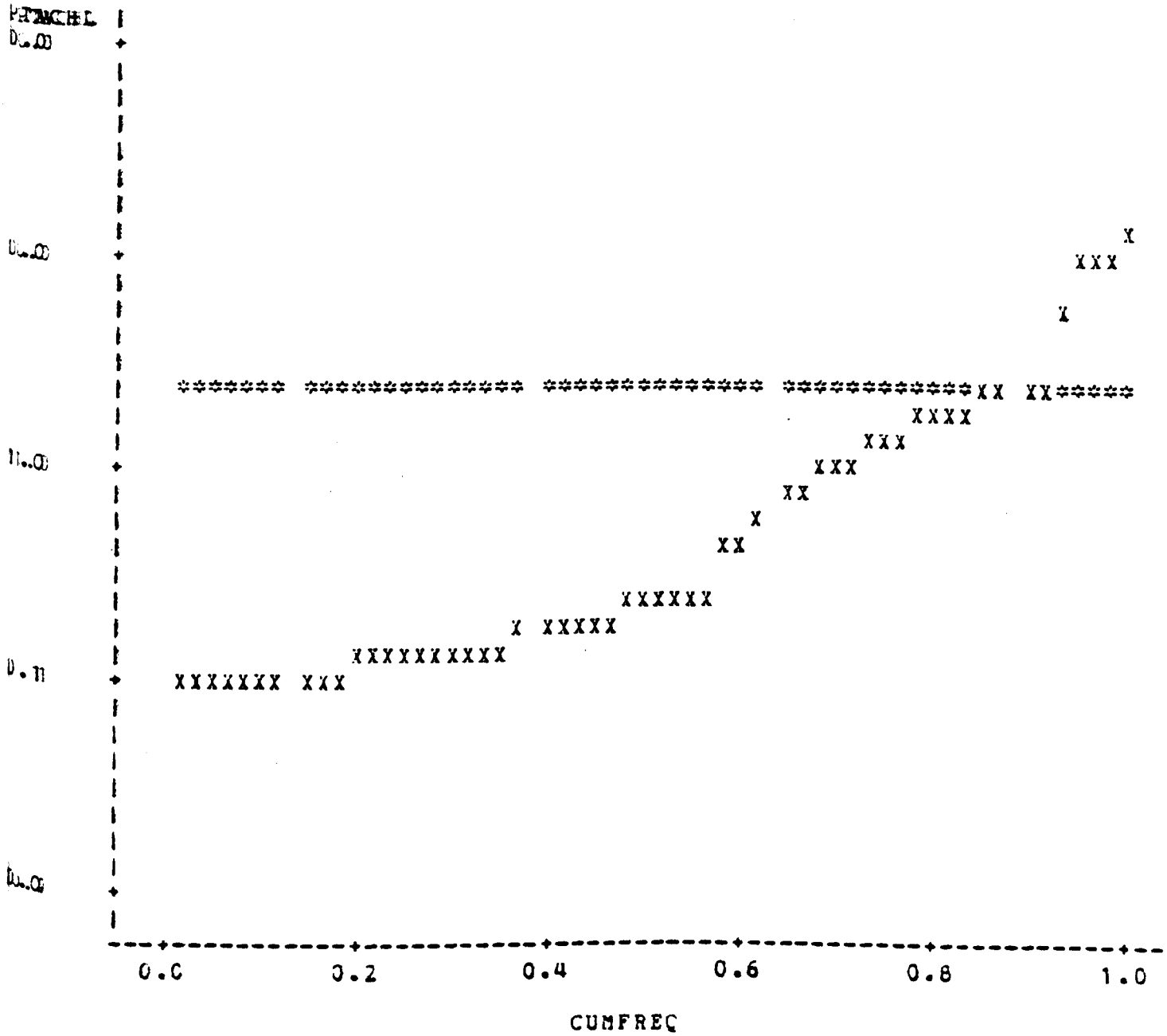
PLOT OF HEPTACHL*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 12 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢HEPTACHLOR! (UG/G ORGANIC CARBON)
GENUS=GAMMARUS SPP=FASCIATUS

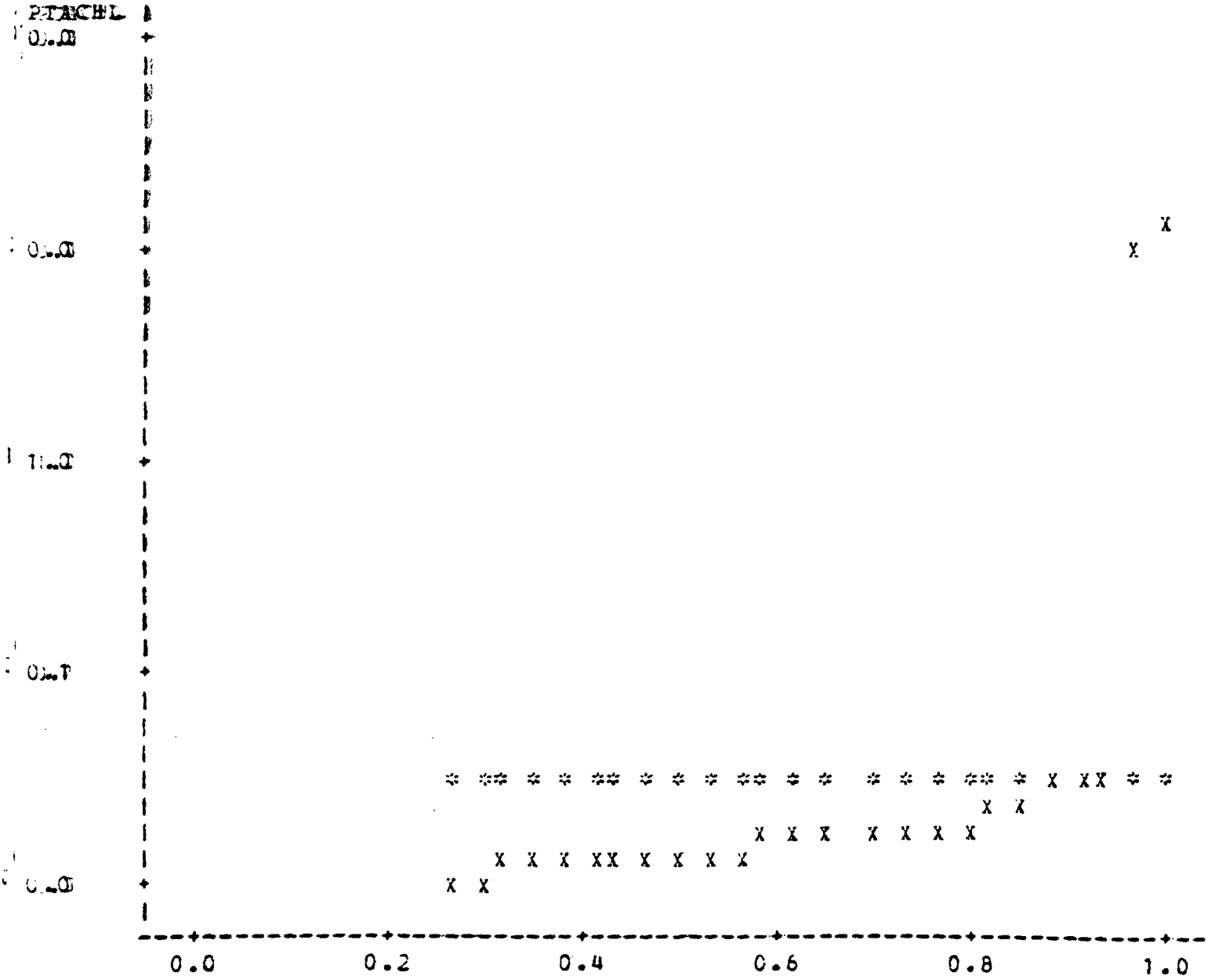
PLOT OF HEPTACHL*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 4 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED (HEPTACHLOR) (UG/G ORGANIC CARBON)
GENUS=HYALELLA SPP=AZTECA

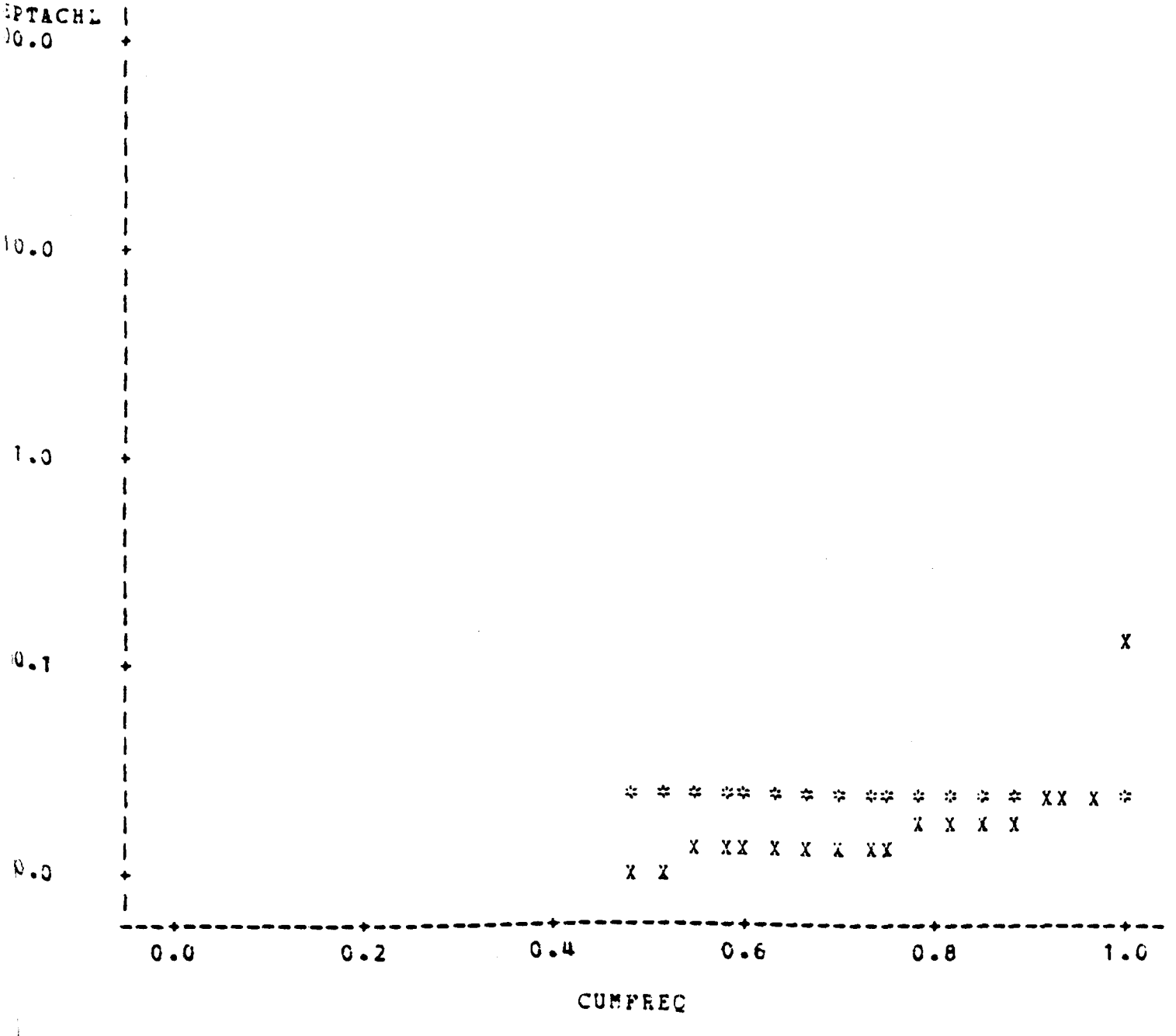
PLOT OF HEPTACHL*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 21 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢HEPTACHLOR! (UG/G ORGANIC CARBON)
GENUS=HYDROPSYCH SPP=PRISONI

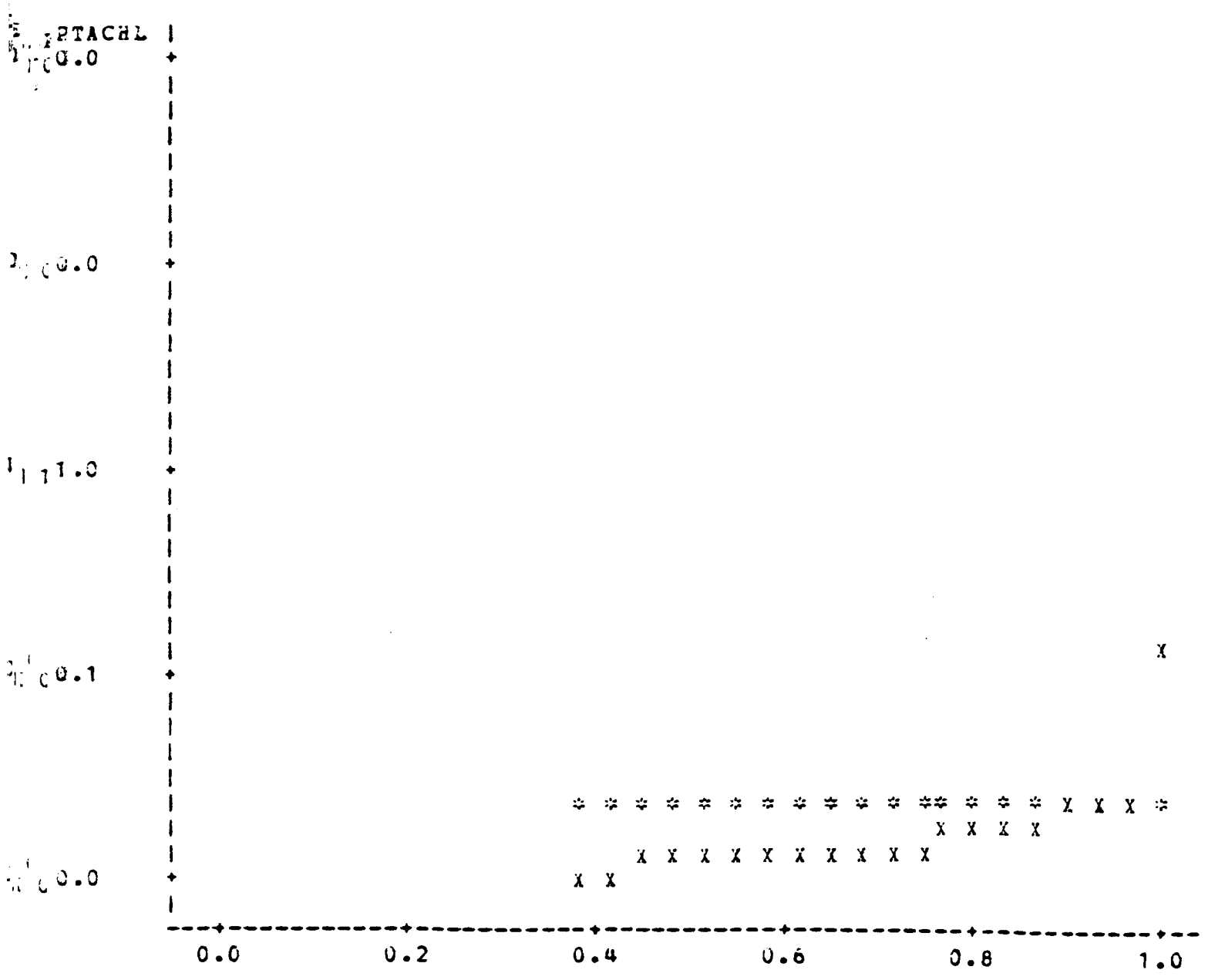
PLOT OF HEPTACHL*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 33 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢HEPTACHLOR! (UG/G ORGANIC CARBON)
GENUS=HYDROPSYCH SPP=ORRIS

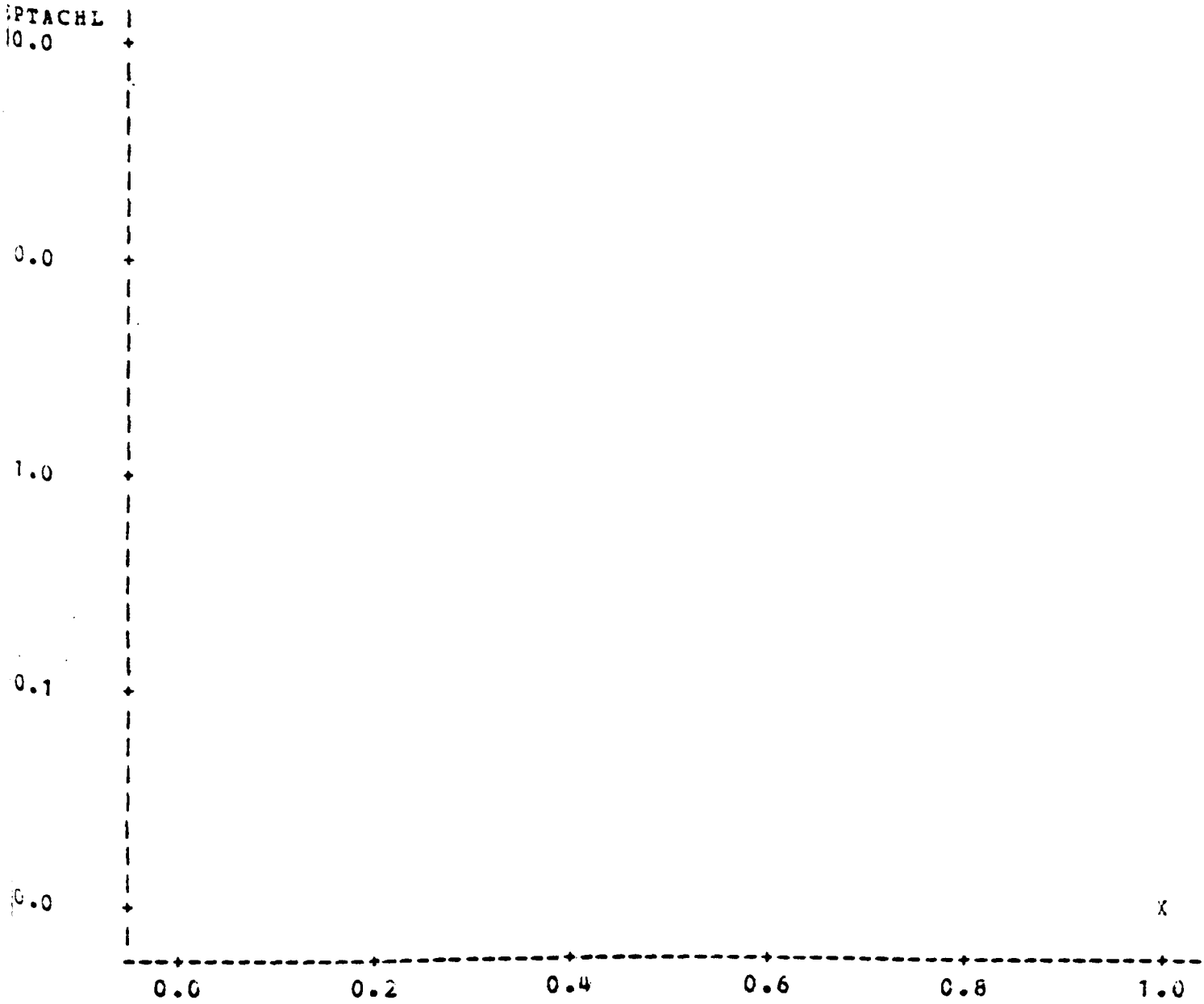
PLOT OF HEPTACHL*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 25 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED #HEPTACHLOR! (UG/G ORGANIC CARBON)
GENUS=LIMNODRILUS SPP=CLAPAREDEIANUS

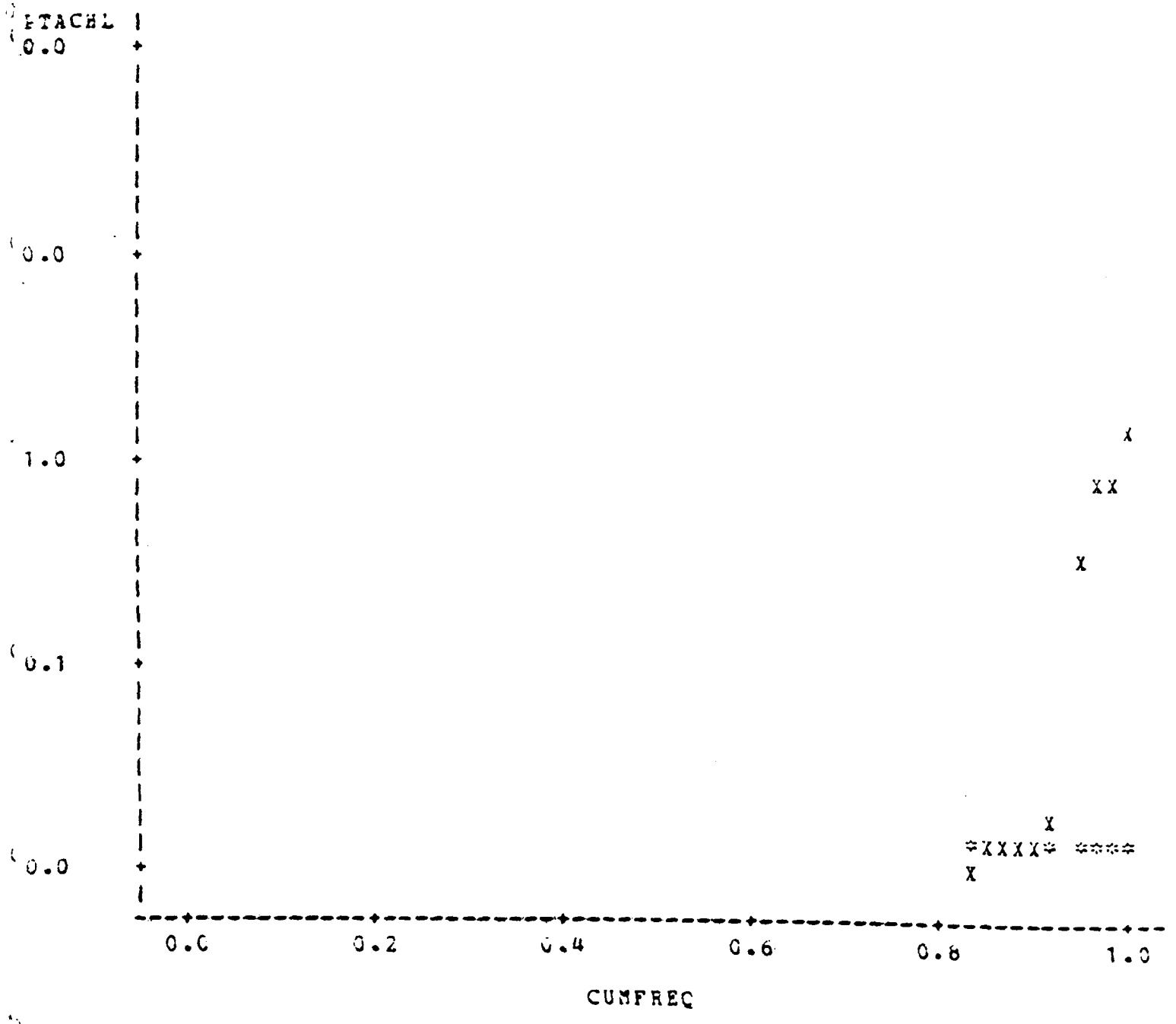
PLOT OF HEPTACHL*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 23 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 22 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED (HEPTACHLOR) (UG/G ORGANIC CARBON)
GENUS=LIMNODRILUS SPP=HOFFMEISTERI

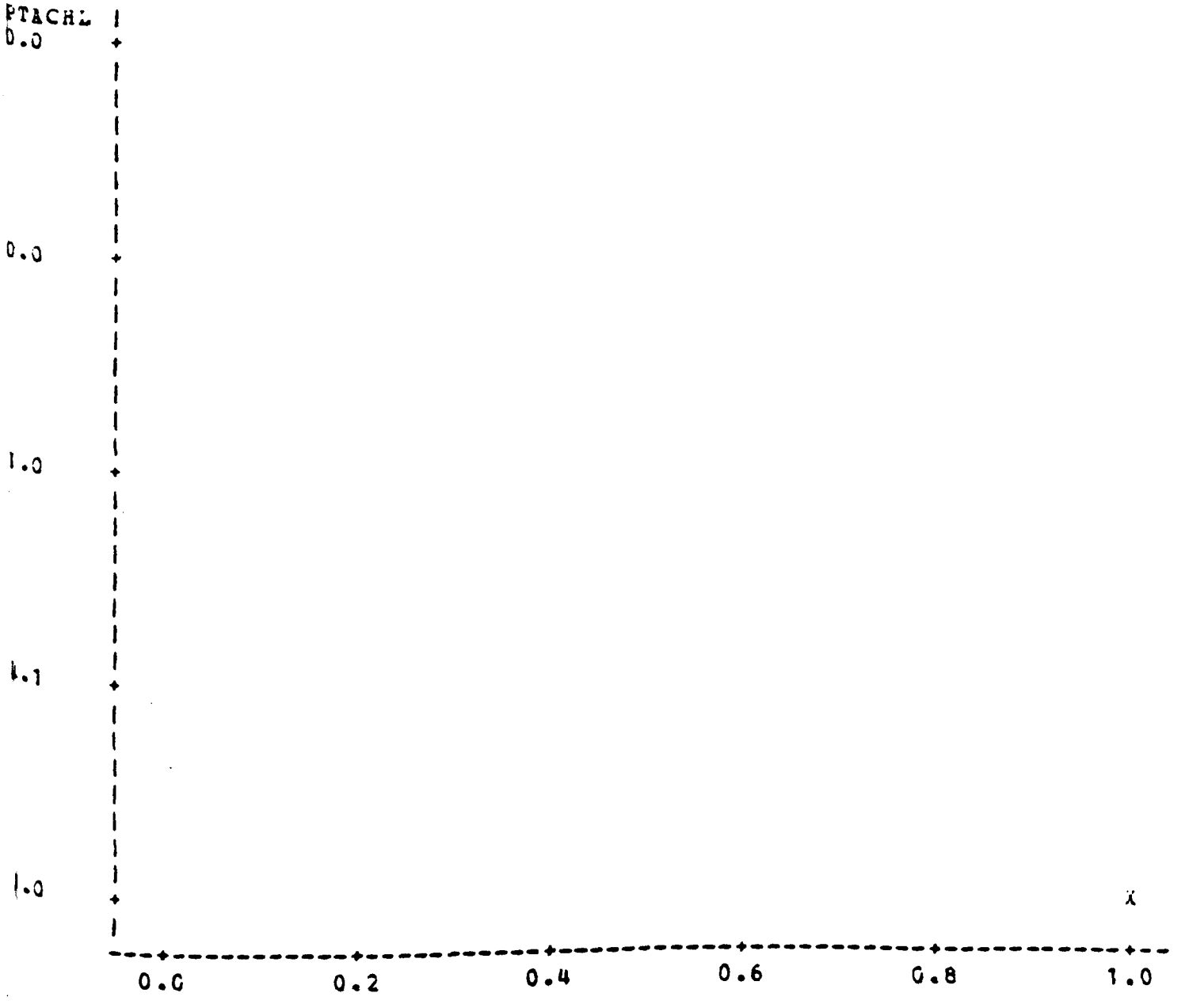
PLOT OF HEPTACHL*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 88 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED #HEPTACHLOR! (UG/G ORGANIC CARBON)
GENUS=PELOSCOLEX SPP=FEROX

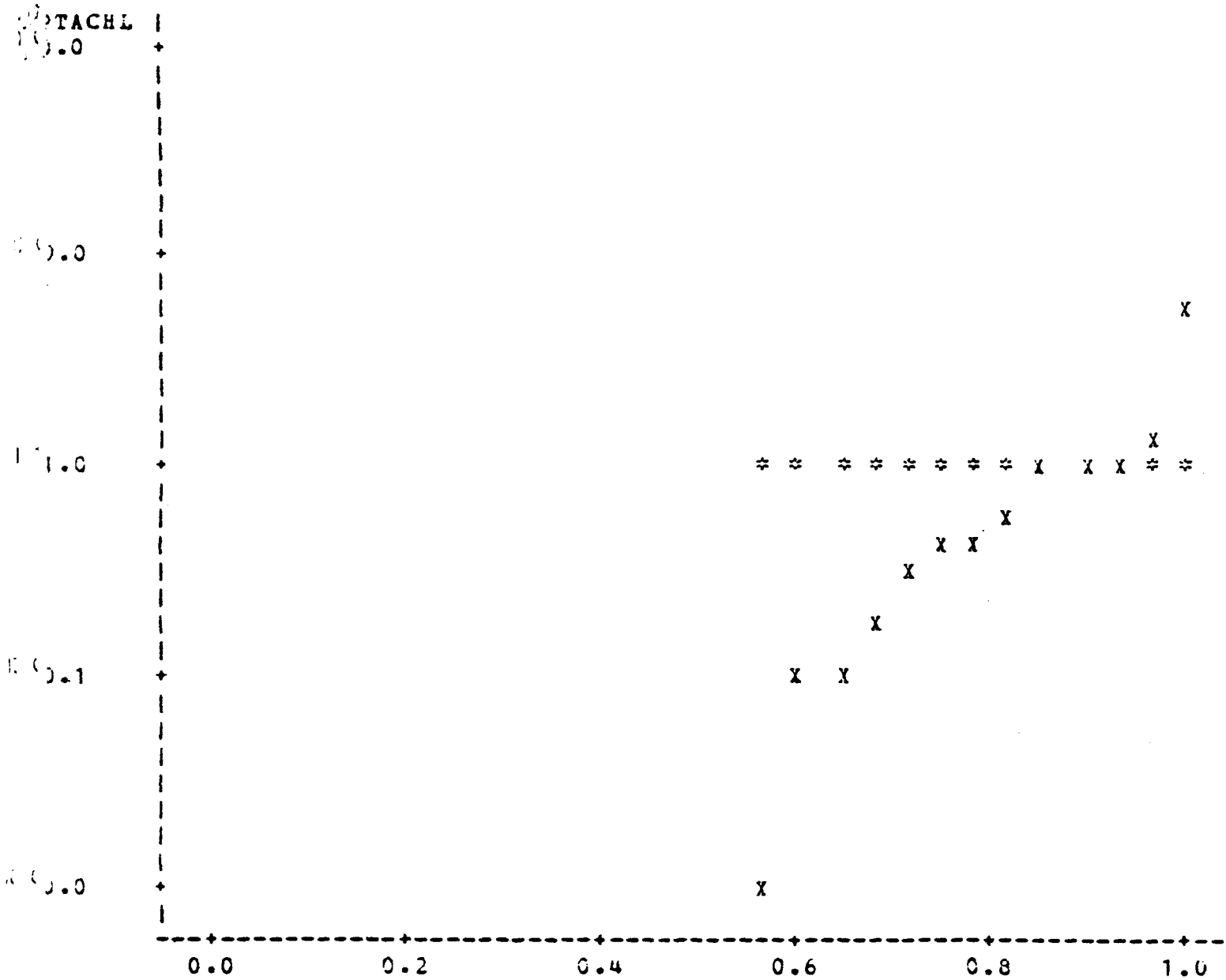
PLOT OF HEPTACHL*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 40 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 39 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢HEPTACHLOR! (UG/G ORGANIC CARBON)
GENUS=PELOSCOLEX SPP=MULTISETOSUS

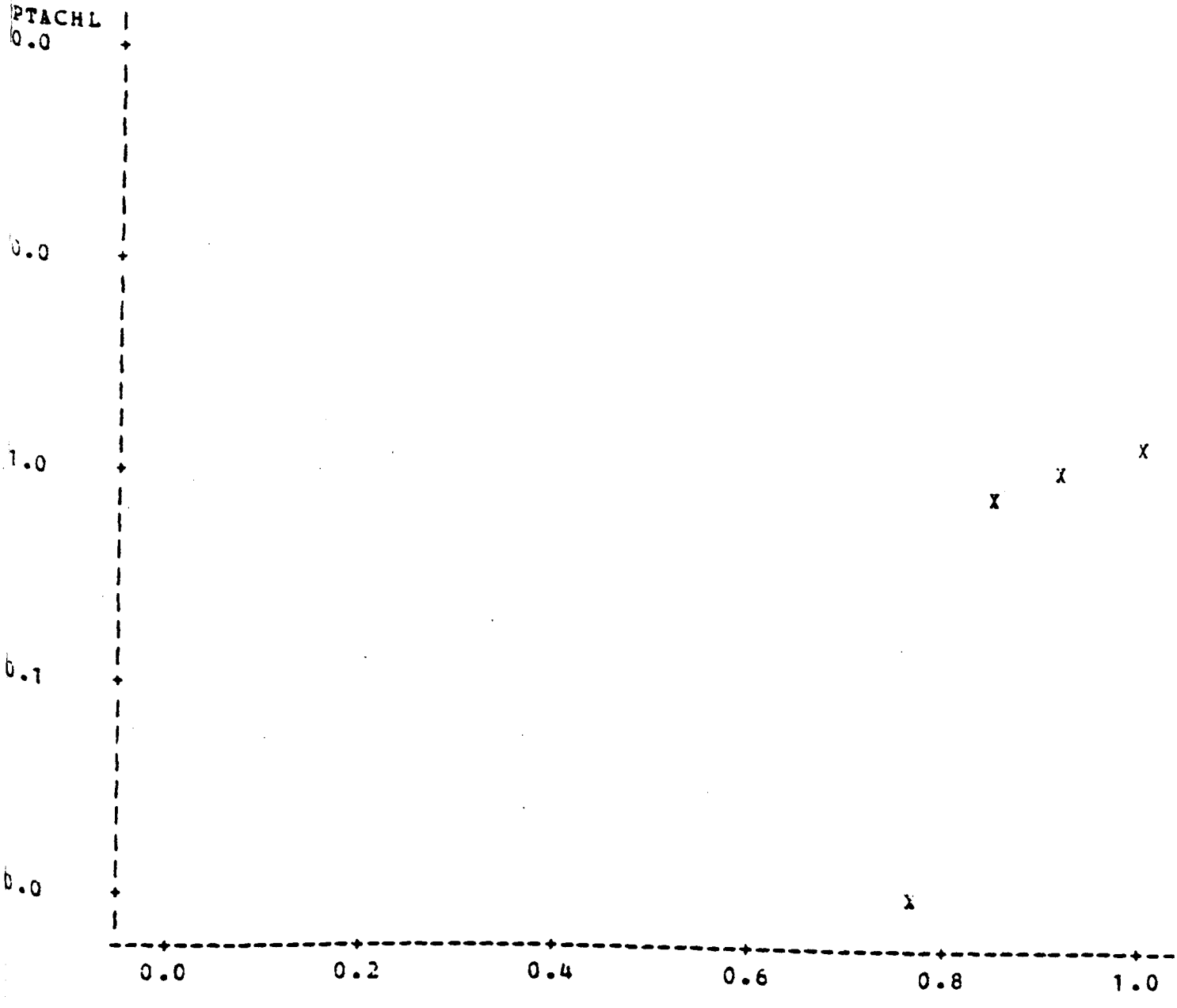
PLOT OF HEPTACHL*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 33 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED #HEPTACHLOR! (UG/G ORGANIC CARBON)
GENUS=POTAMOTHRIX SPP=VEJDOVSKYI

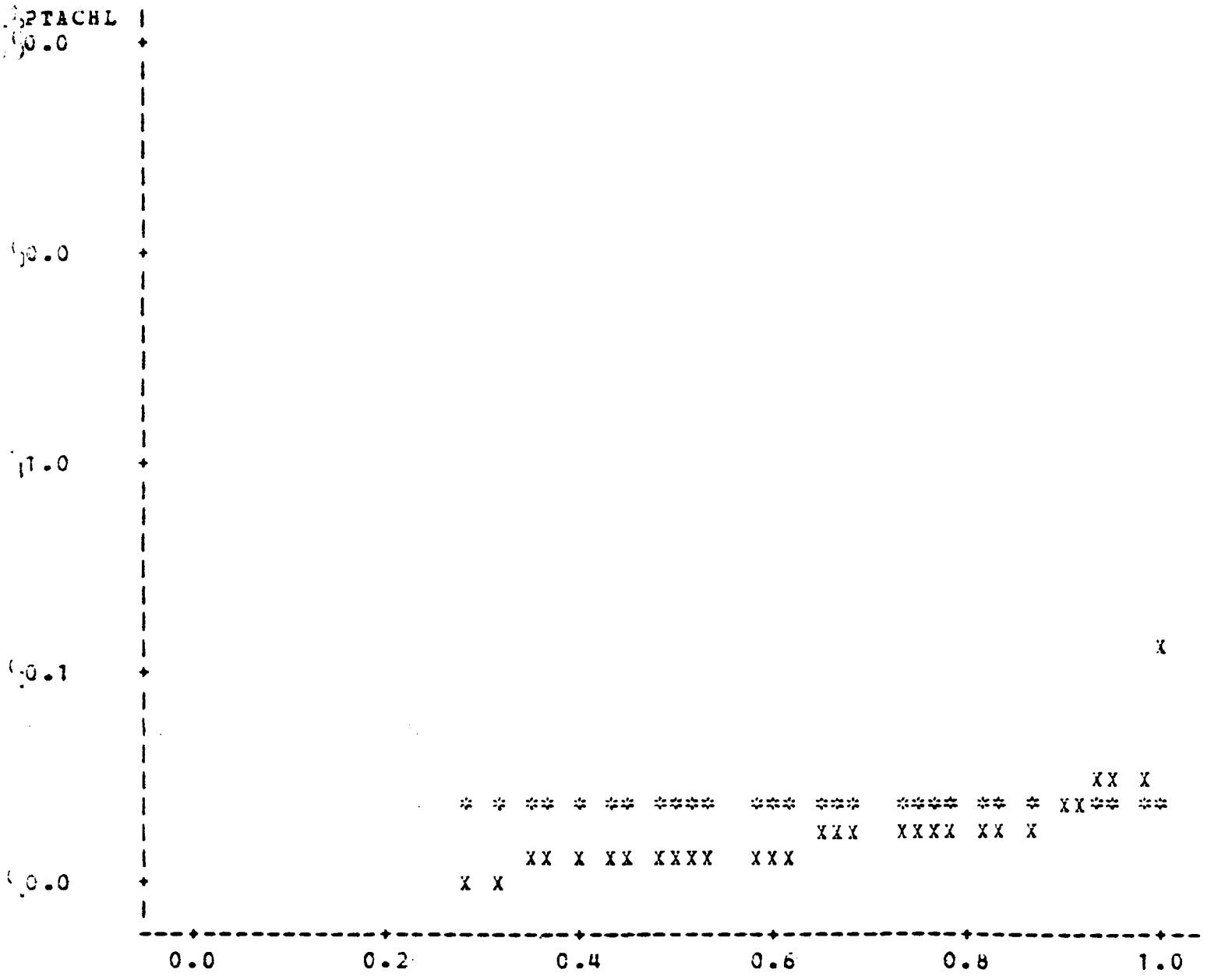
PLOT OF HEPTACHL*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



E: 26 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 22 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢HEPTACHLOR! (UG/G ORGANIC CARBON)
GENUS=STENACRON SPP=INTERPUNCT

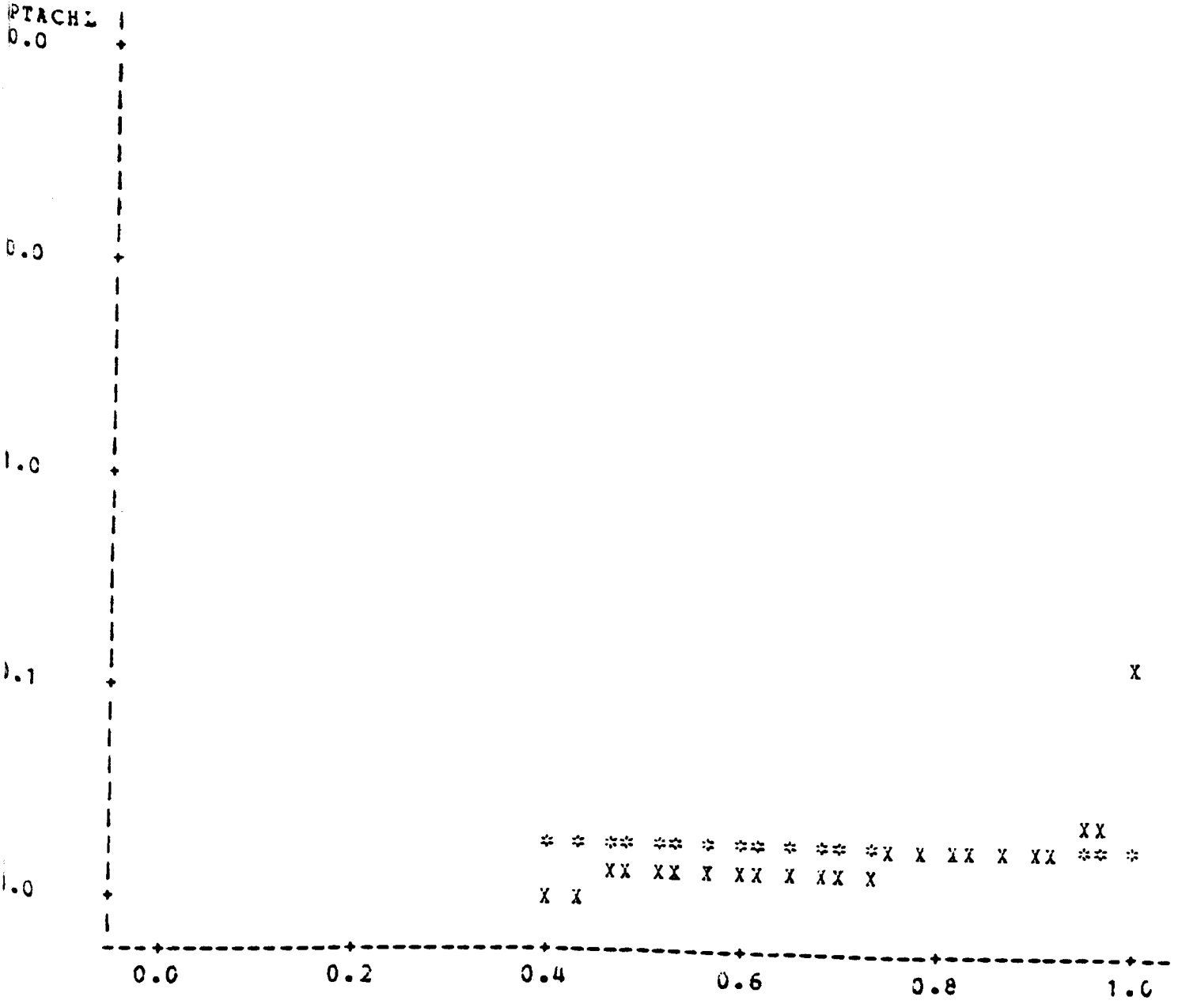
PLOT OF HEPTACHL*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 38 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢HEPTACHLOR! (UG/G ORGANIC CARBON)
GENUS=STENONEMA SPP=INTEGRUM

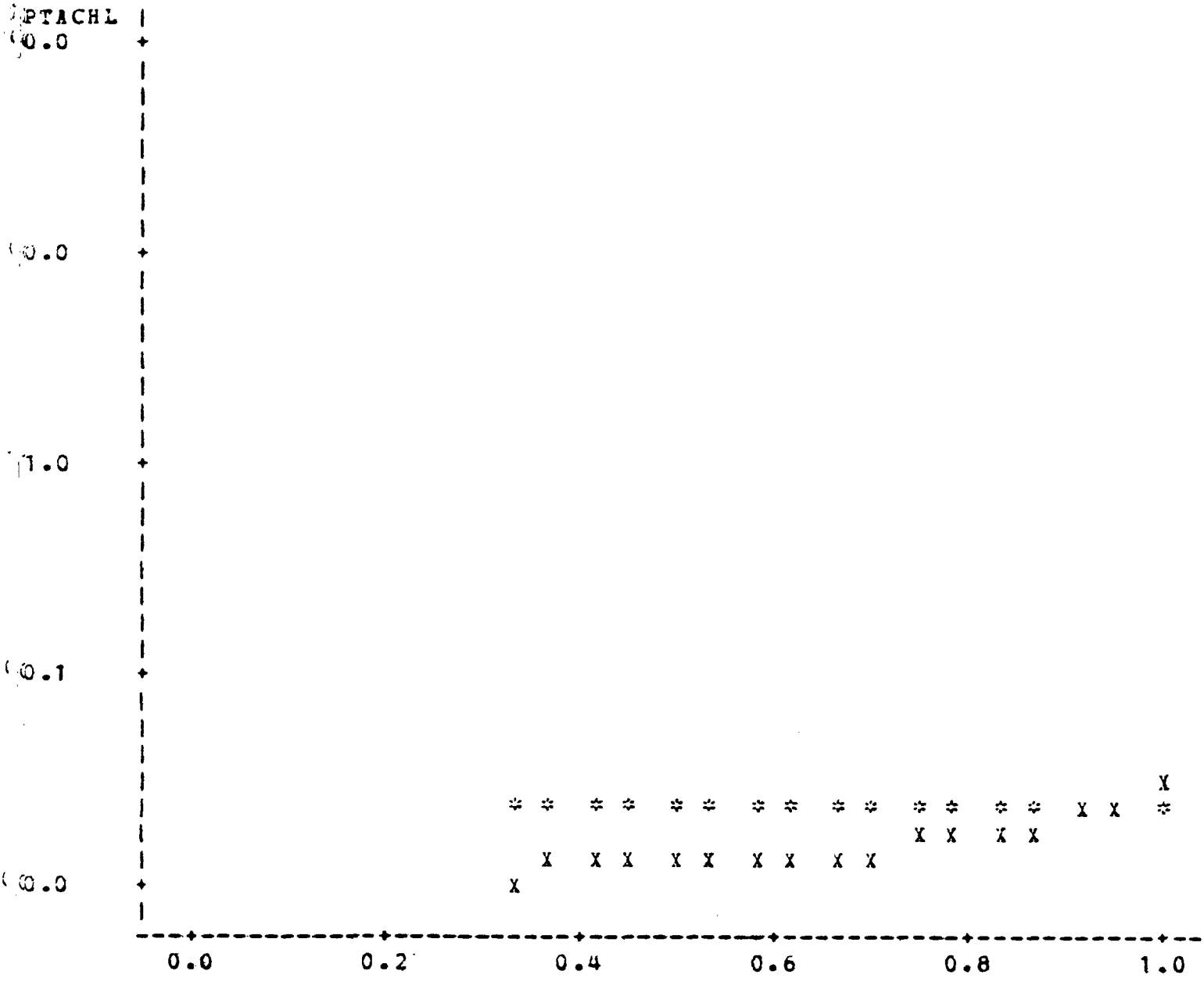
PLOT OF HEPTACHL*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



E: 35 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢HEPTACHLOR! (UG/G ORGANIC CARBON)
GENUS=STENONEMA SPP=PULCHELLUM

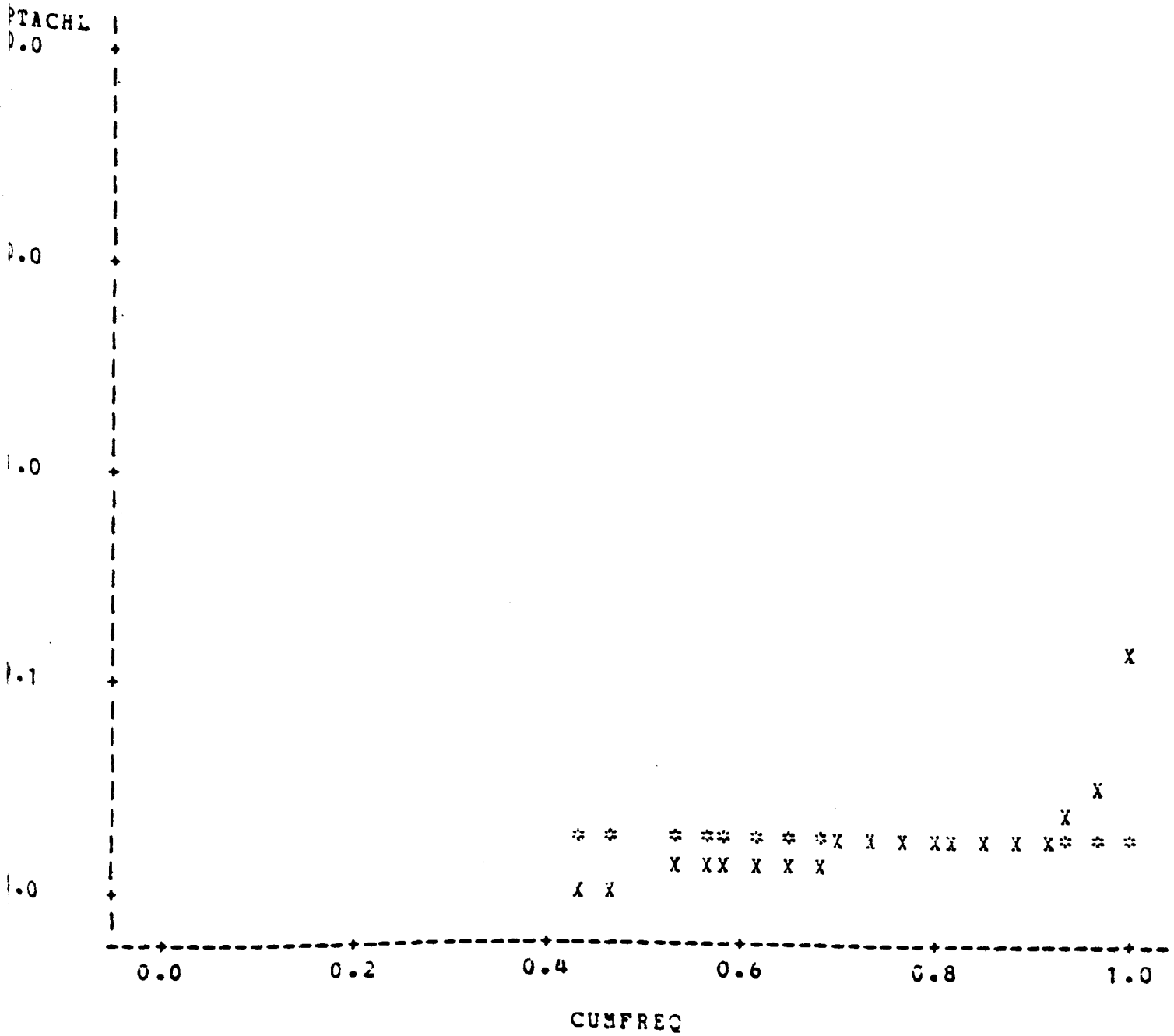
PLOT OF HEPTACHL*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



TE: 16 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED #HEPTACHLOR! (UG/G ORGANIC CARBON)
GENUS=STENONEMA SPP=TERMINATUM

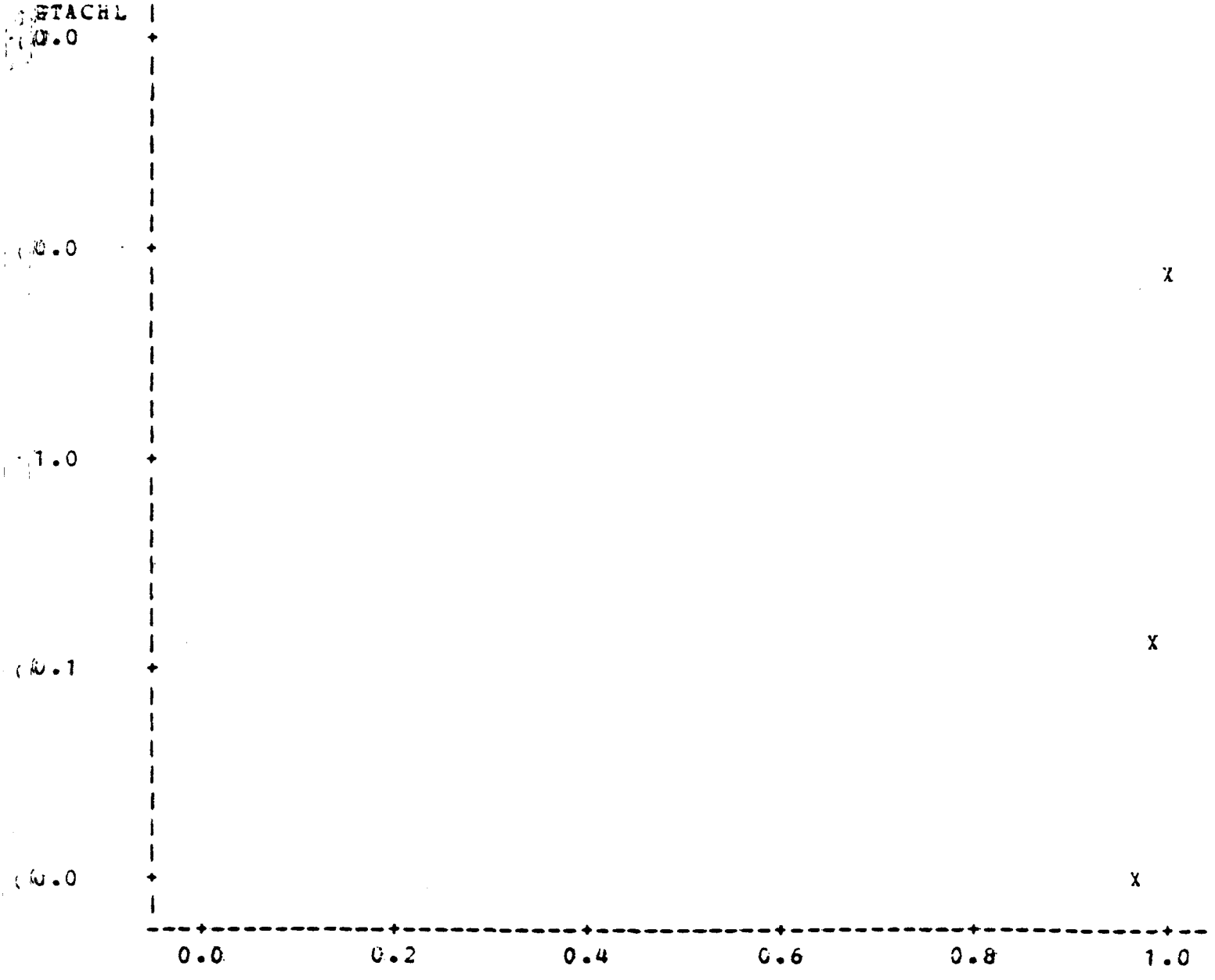
PLOT OF HEPTACHL*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



E: 38 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED #HEPTACHLOR! (UG/G ORGANIC CARBON)
GENUS=TUBIFEX SPP=TUBIFEX

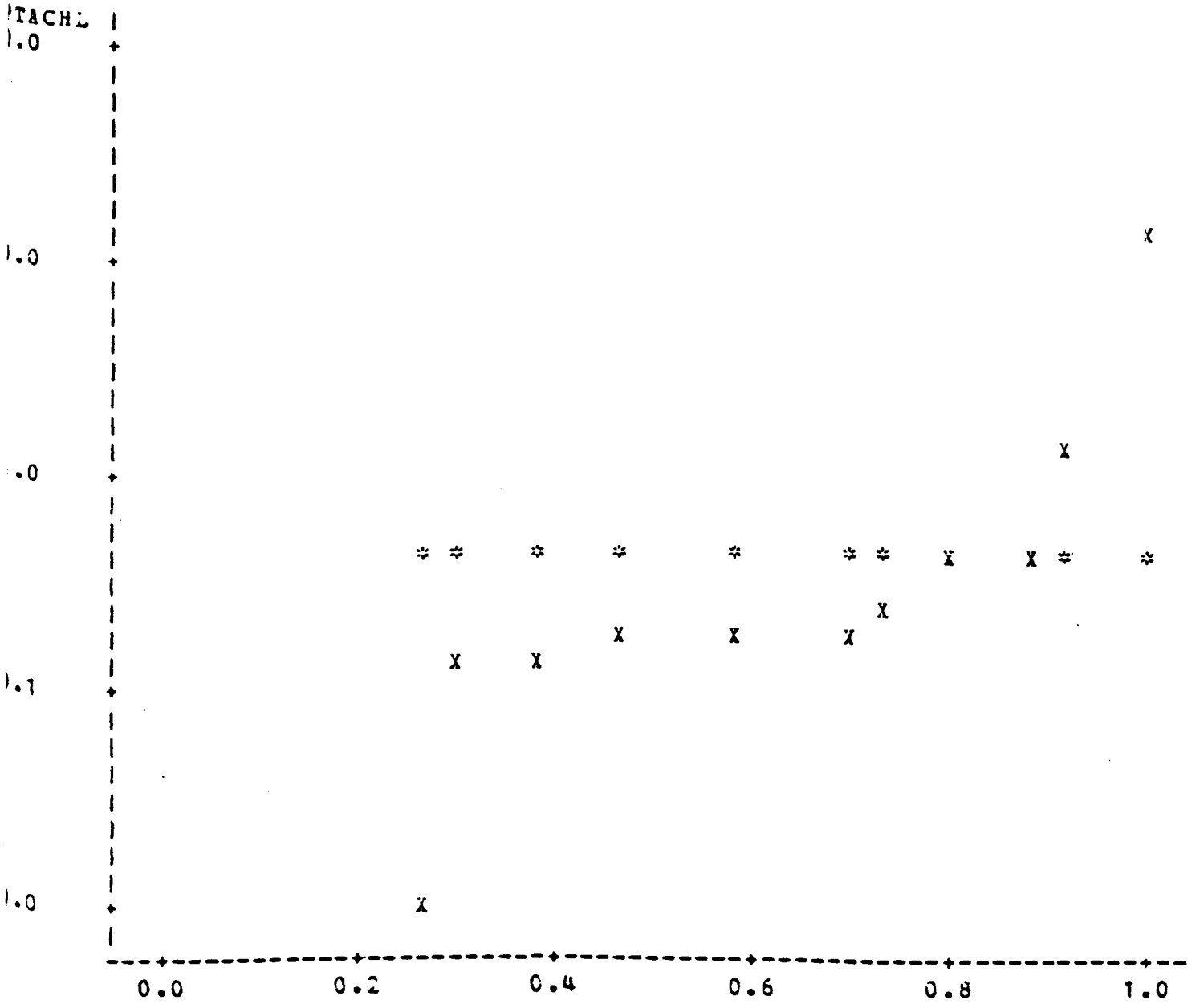
PLOT OF HEPTACHL*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



NOTE: 56 OBS HAD MISSING VALUES OR WERE OUT OF RANGE 53 OBS HIDDEN

CUMULATIVE FREQUENCY OF NORMALIZED ¢HEPTACHLOR! (UG/G ORGANIC CARBON)
GENUS=VALVATA SPP=SINCERA

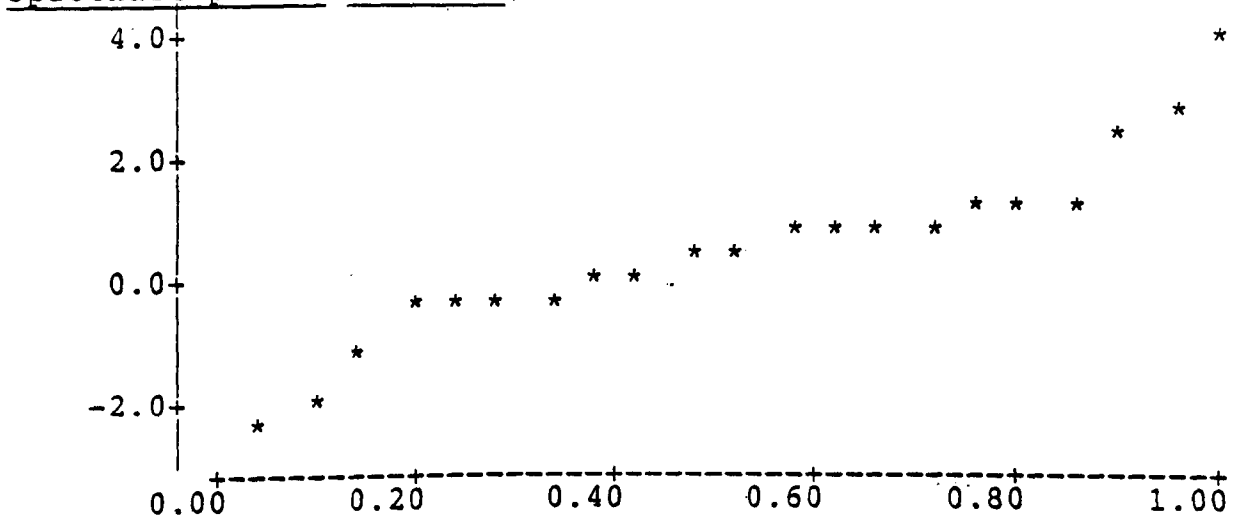
PLOT OF HEPTACHL*CUMFREQ SYMBOL USED IS X
PLOT OF SSLC*CUMFREQ SYMBOL USED IS *



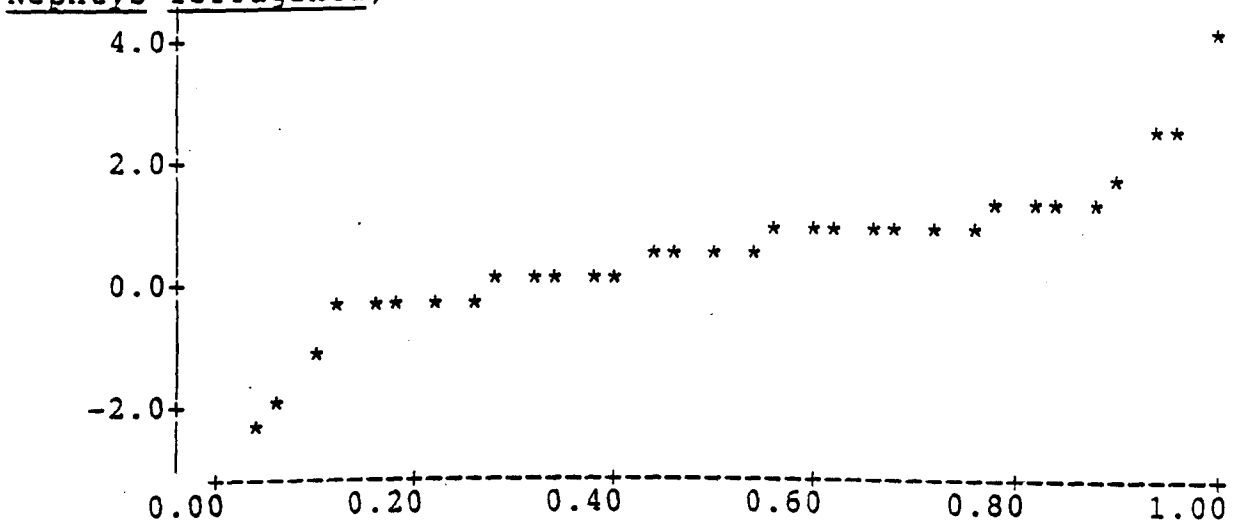
E: 32 OBS HIDDEN

APPENDIX. Part II. Species Screening level Concentration Plots for Contaminants in Saltwater Sediments.

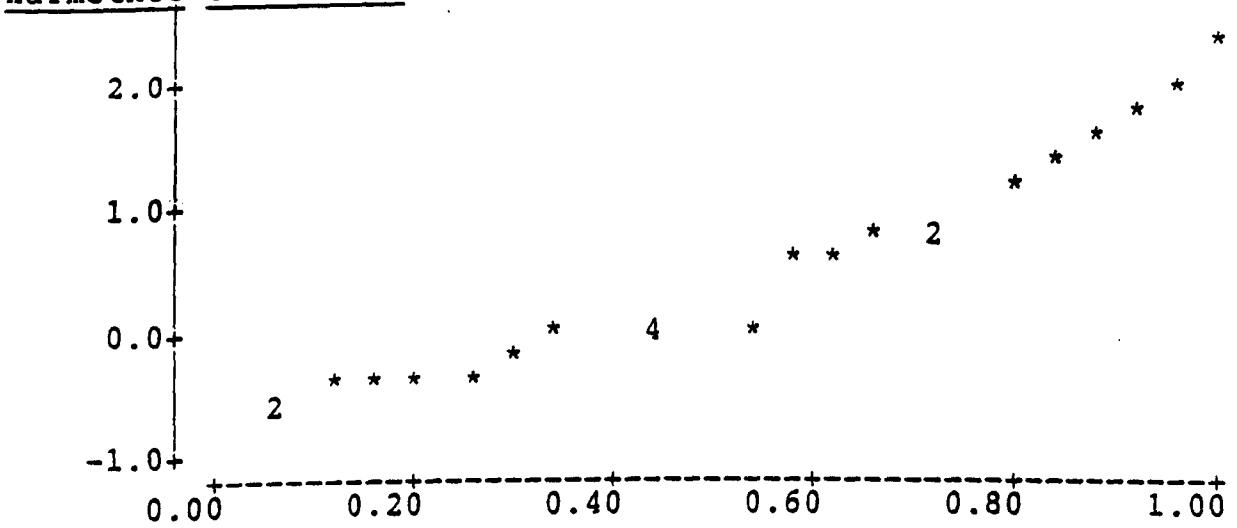
Spiochaetopterus costorum, PCB



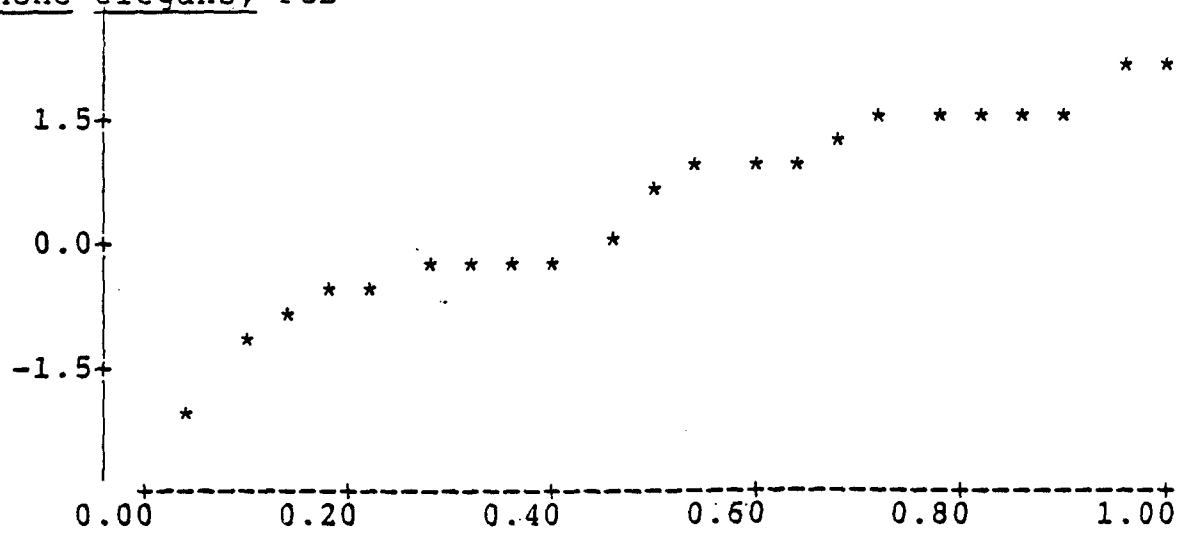
Nephtys ferruginea, PCB



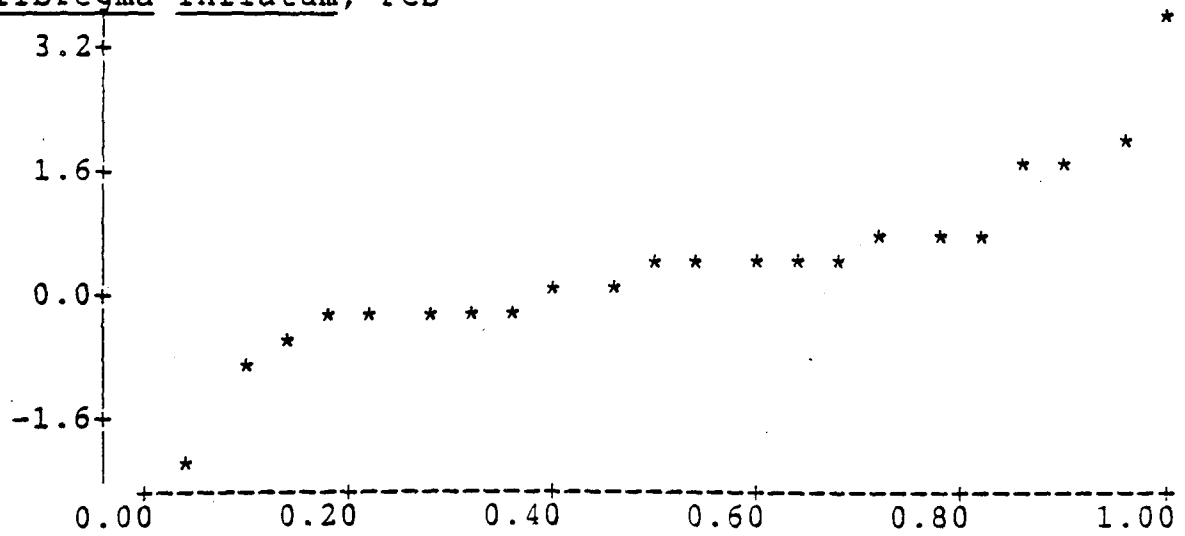
Harmothoe extenuata, PCB



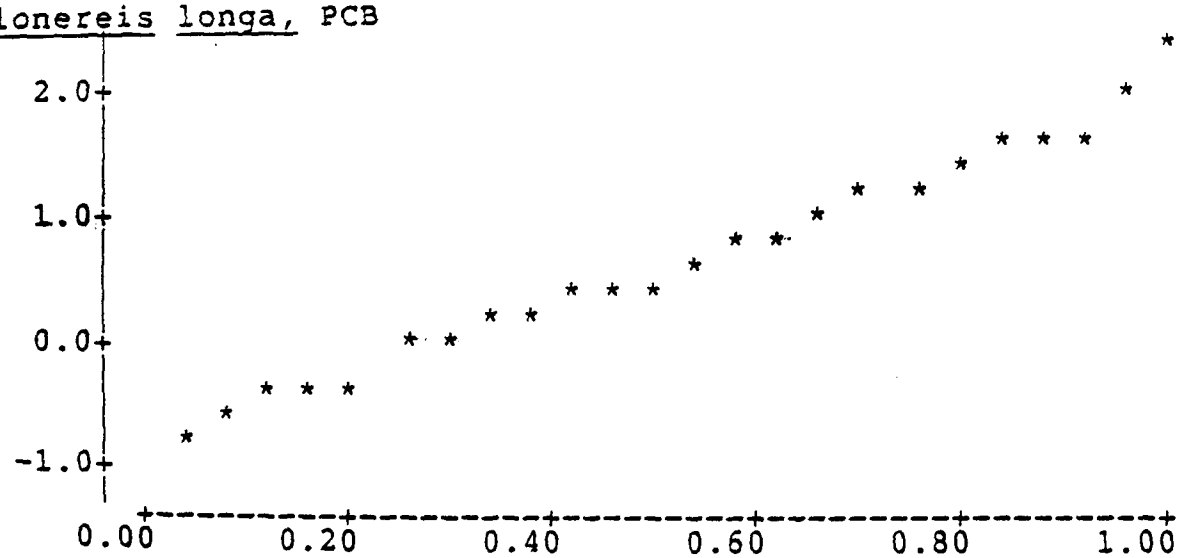
Euchone elegans, PCB



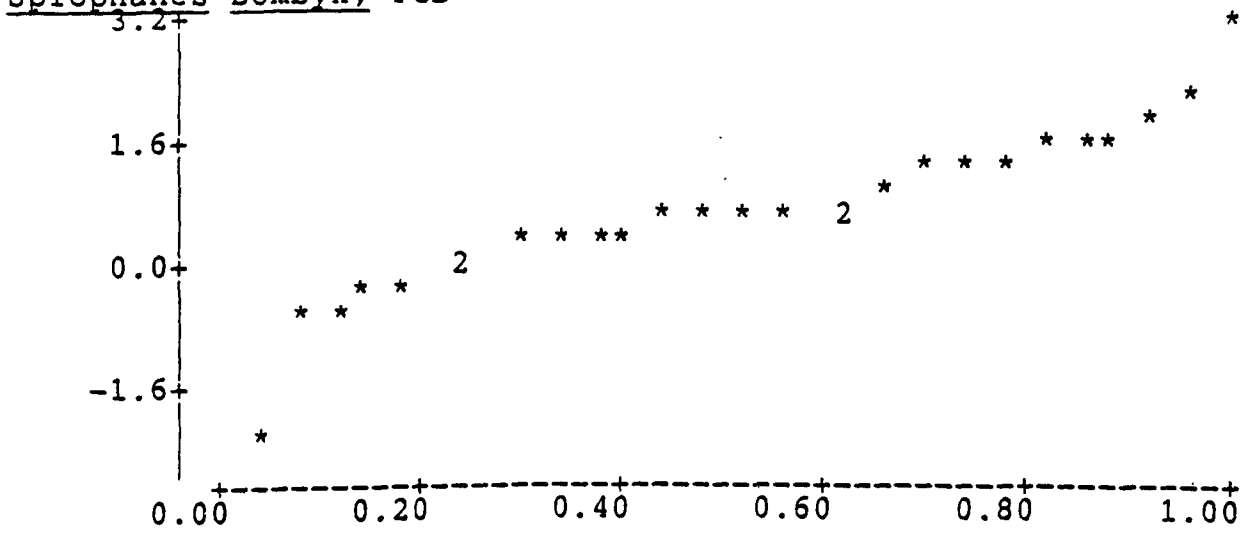
Scalibregma inflatum, PCB



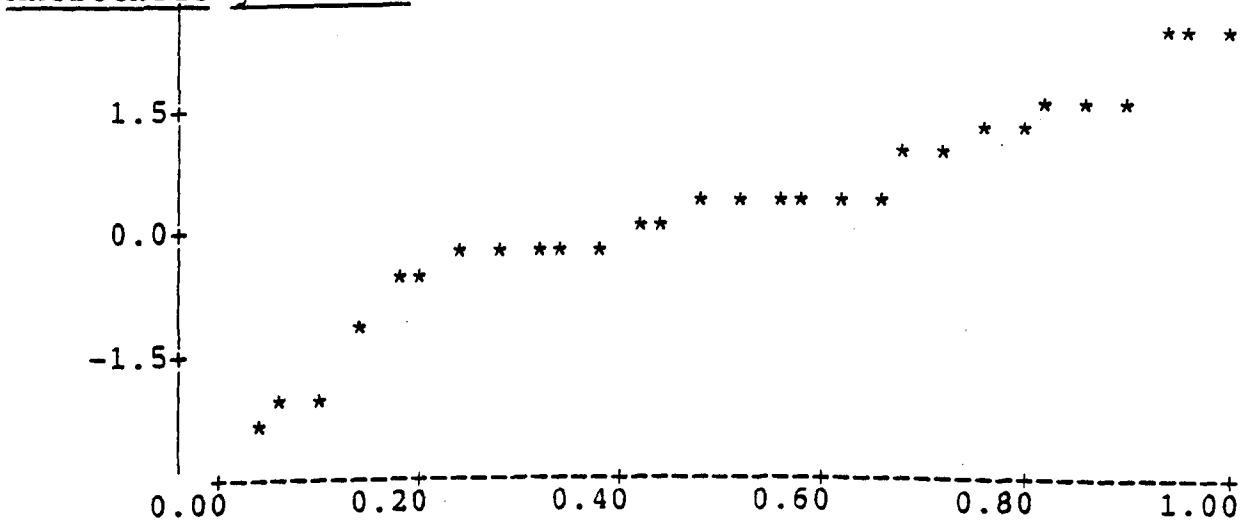
Drilonereis longa, PCB



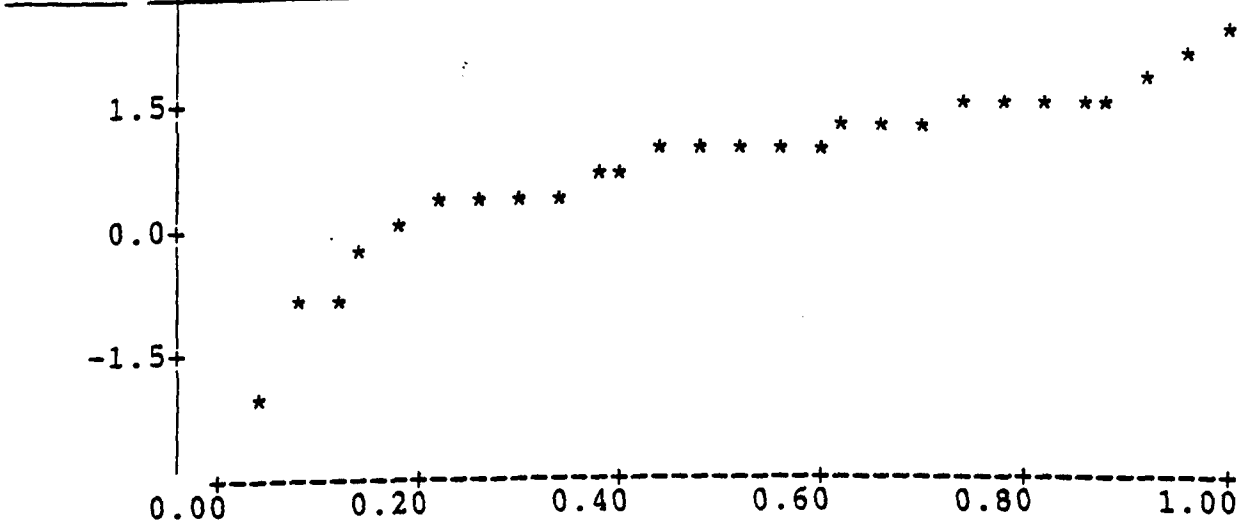
Spiophanes bombyx, PCB



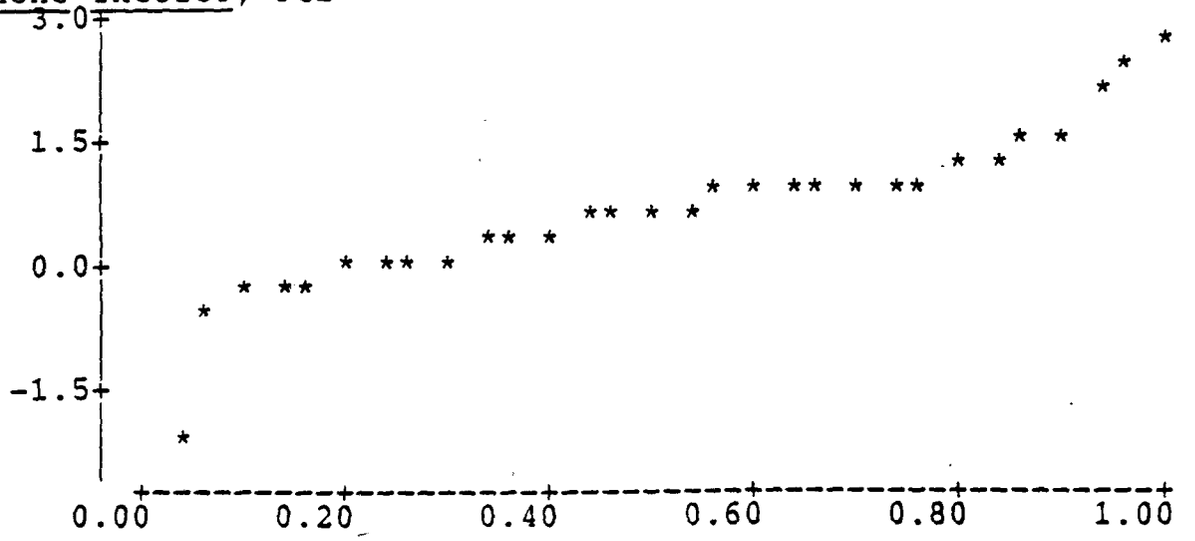
Anobothrus gracilis, PCB



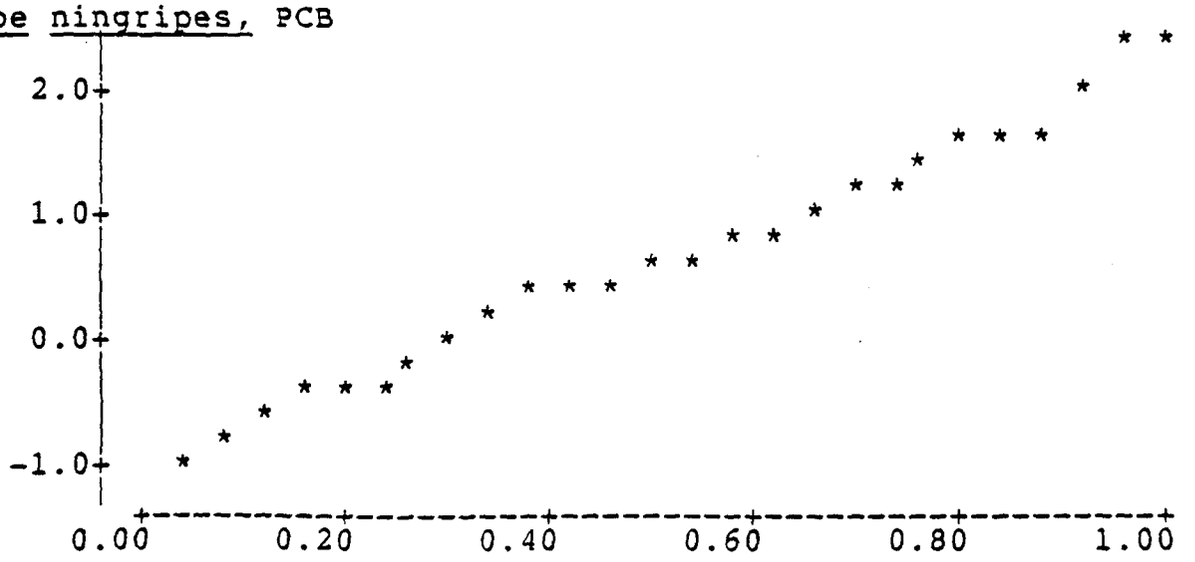
Artica islandica, PCB



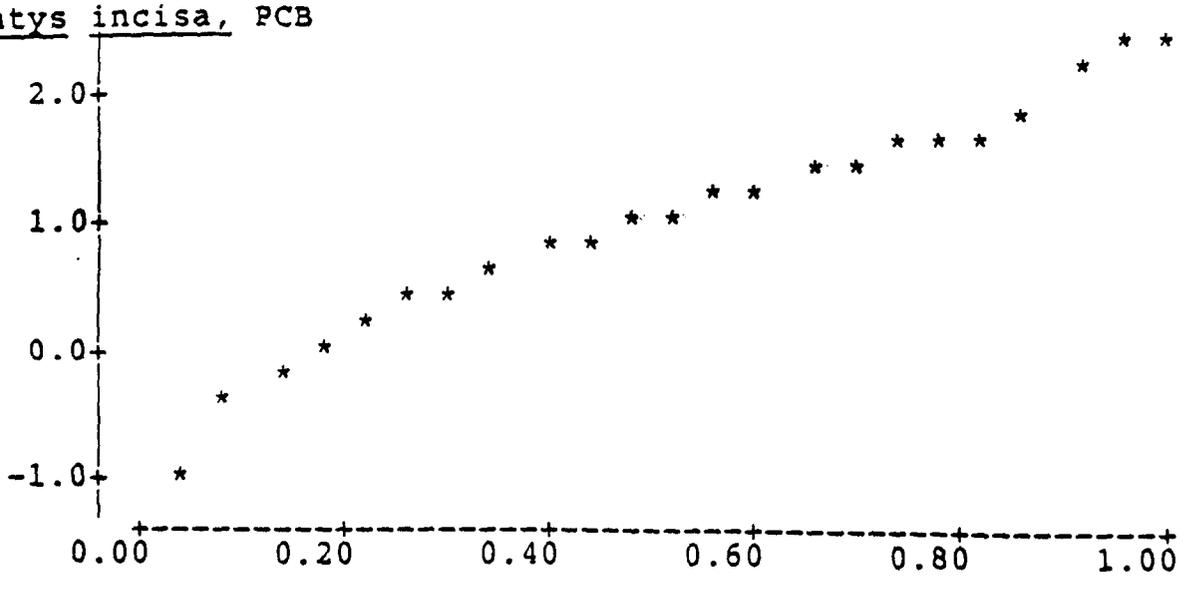
Euchone incolor, PCB



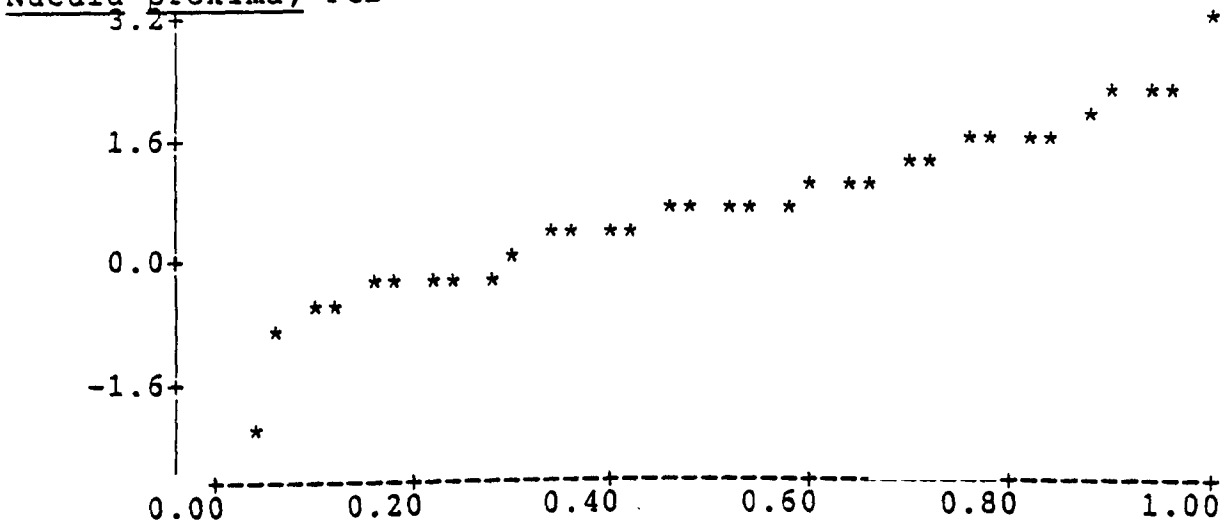
Ninoe ningripes, PCB



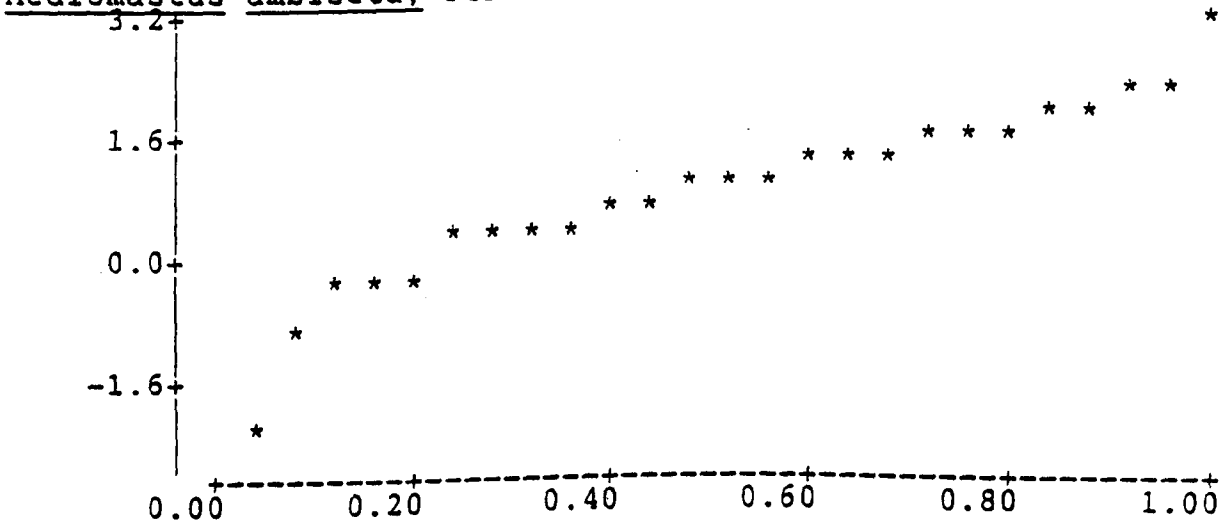
Nephtys incisa, PCB



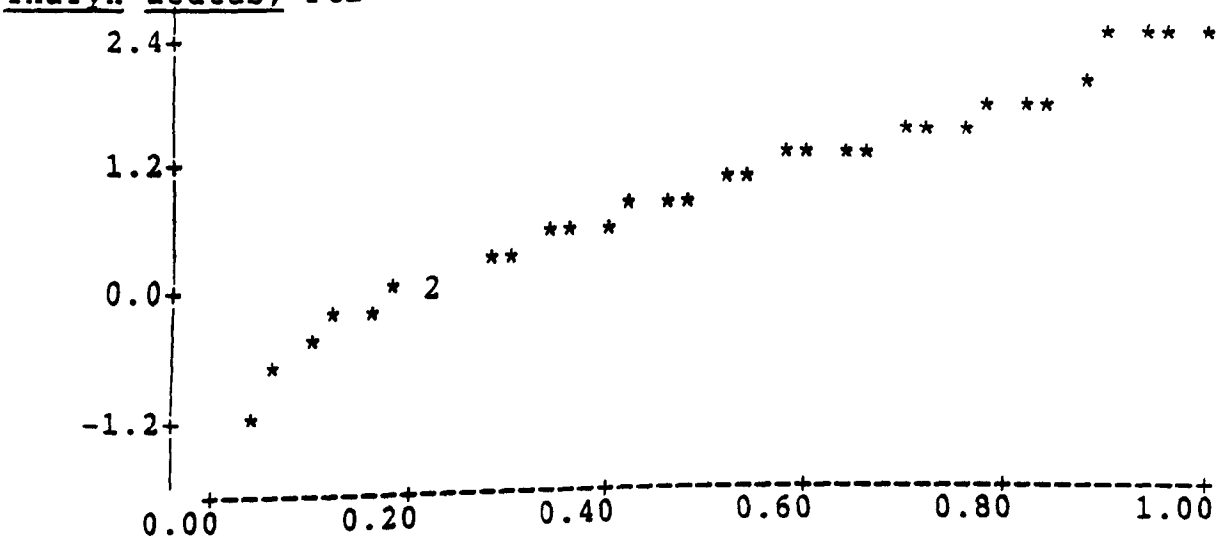
Nucula proxima, PCB



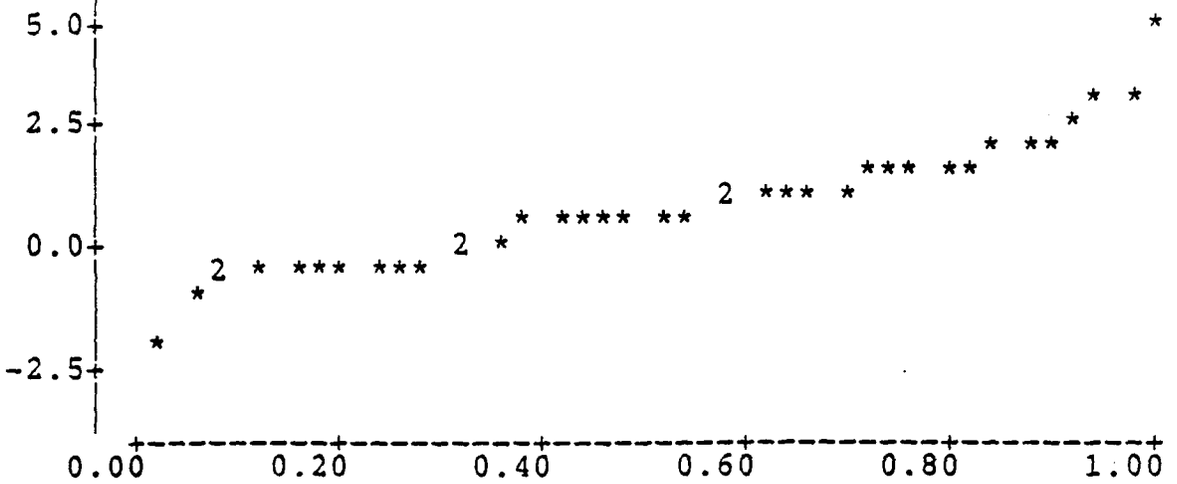
Mediomastus ambiseta, PCB



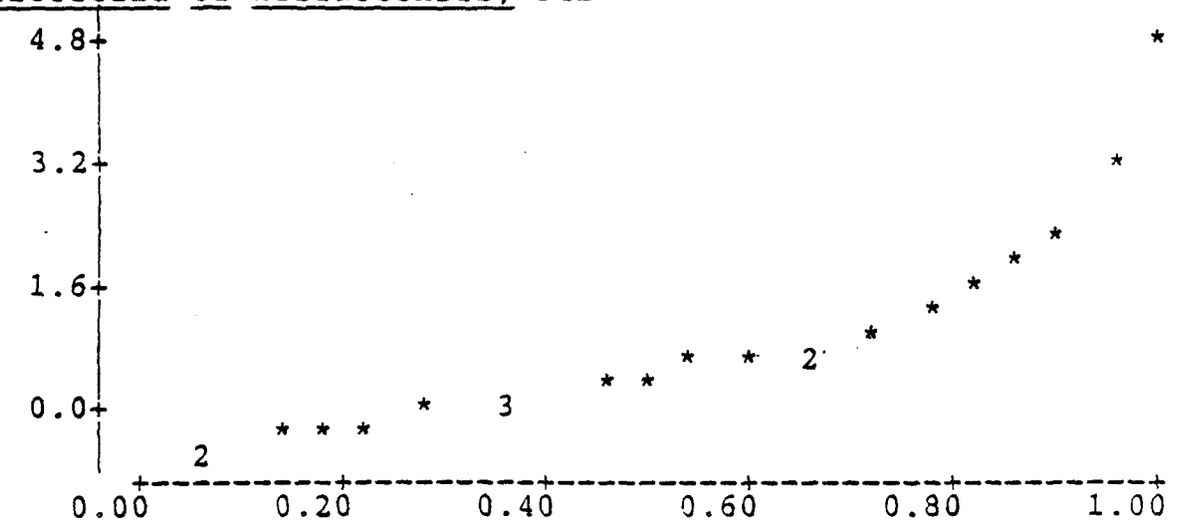
Tharyx acutus, PCB



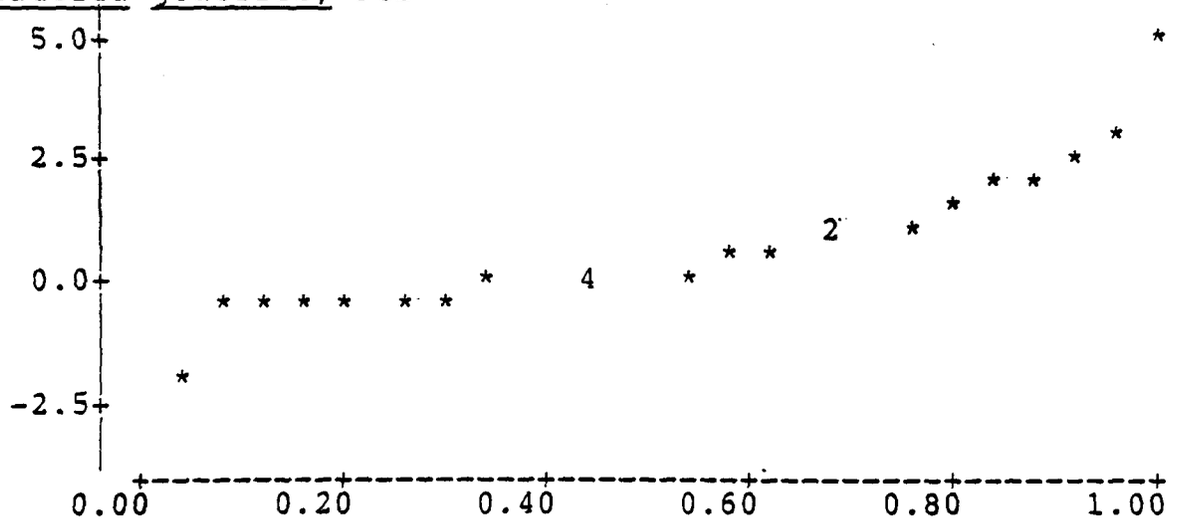
Aricidea catherinae, PCB



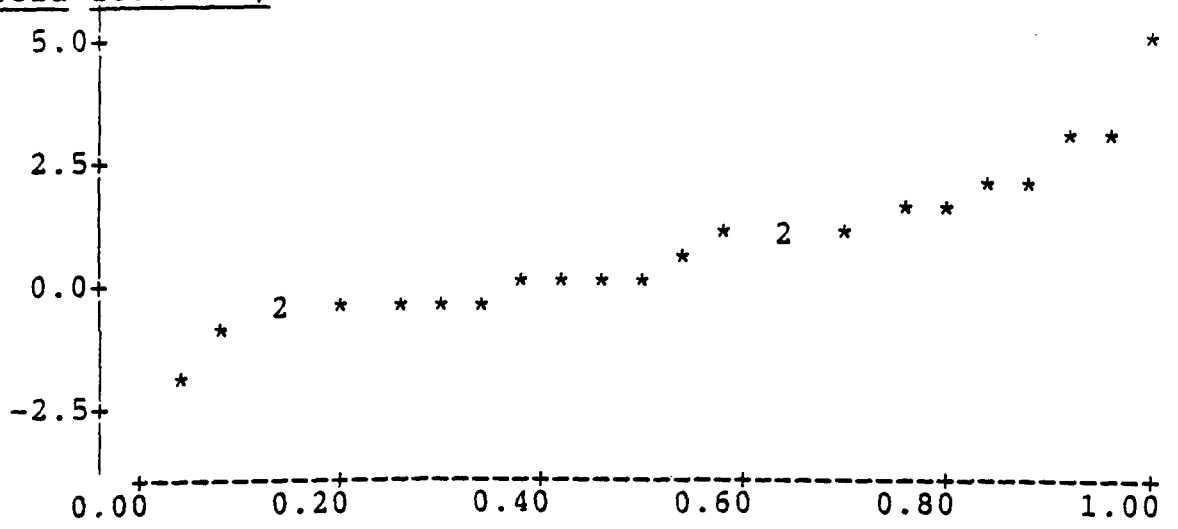
Caulleriella cf killariensis, PCB



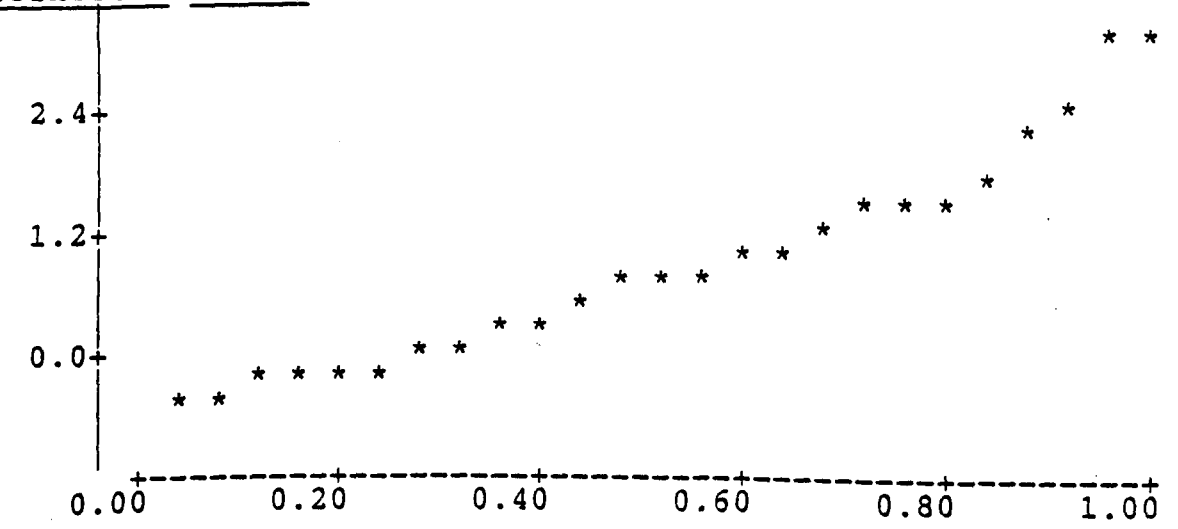
Goniadella gracilis, PCB



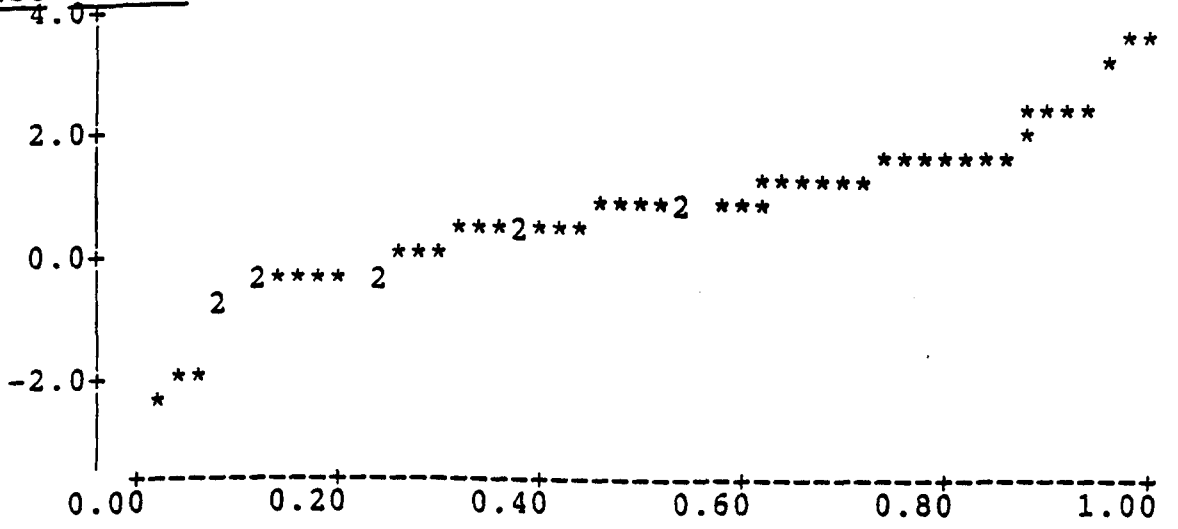
Unciola irrorata, PCB



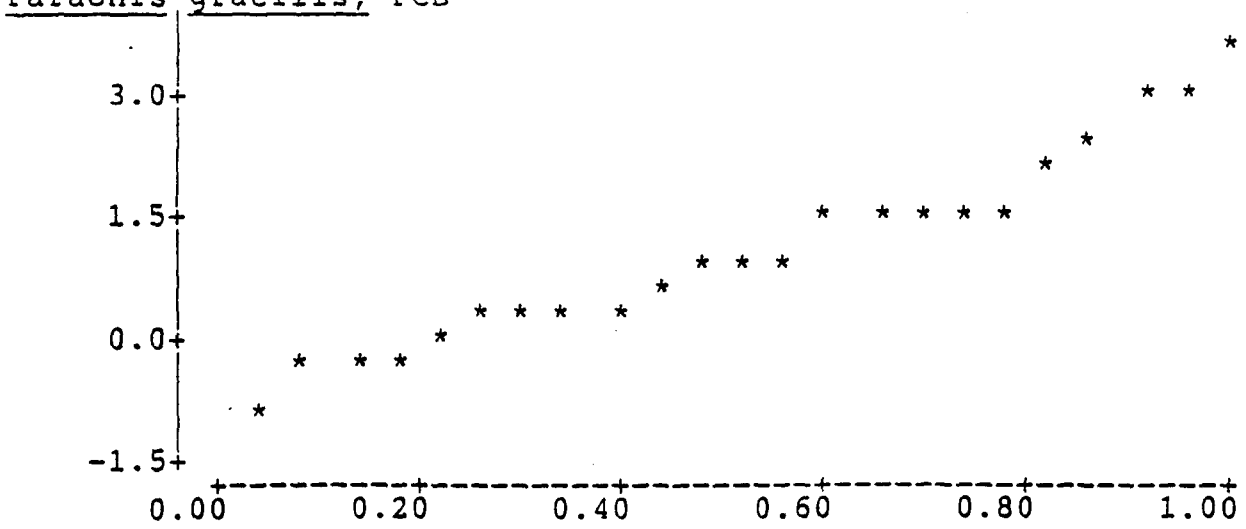
Lumbrinereis hebes, PCB



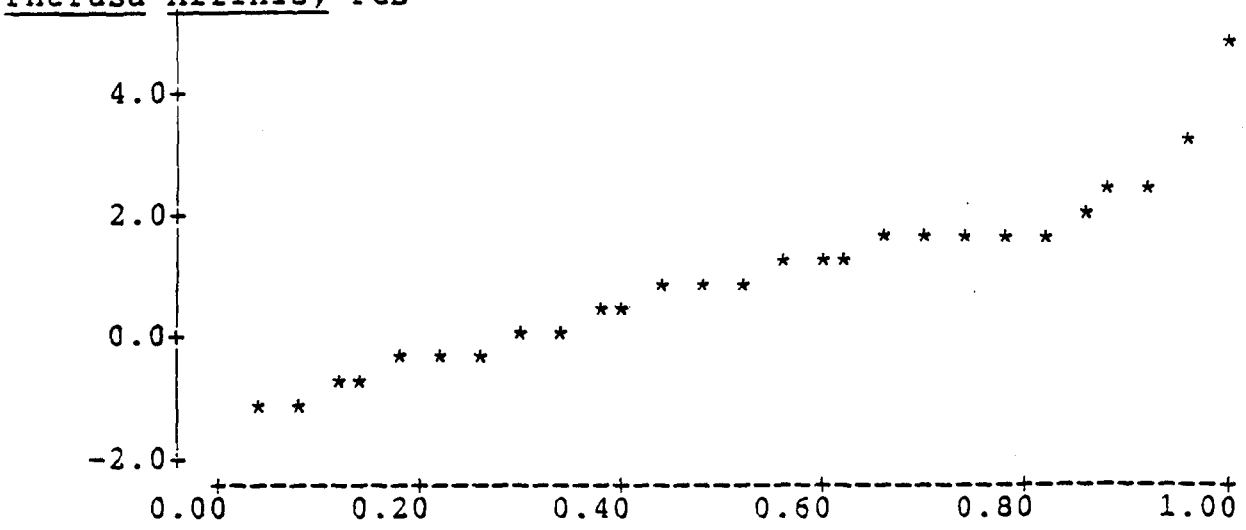
Pholoe minuta, PCB



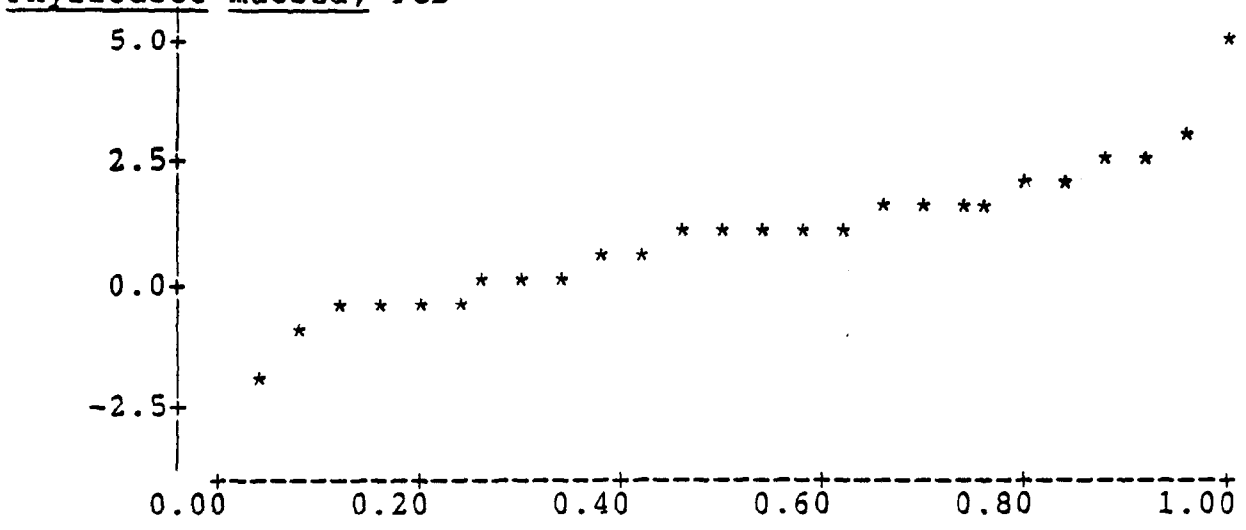
Paraonis gracilis, PCB



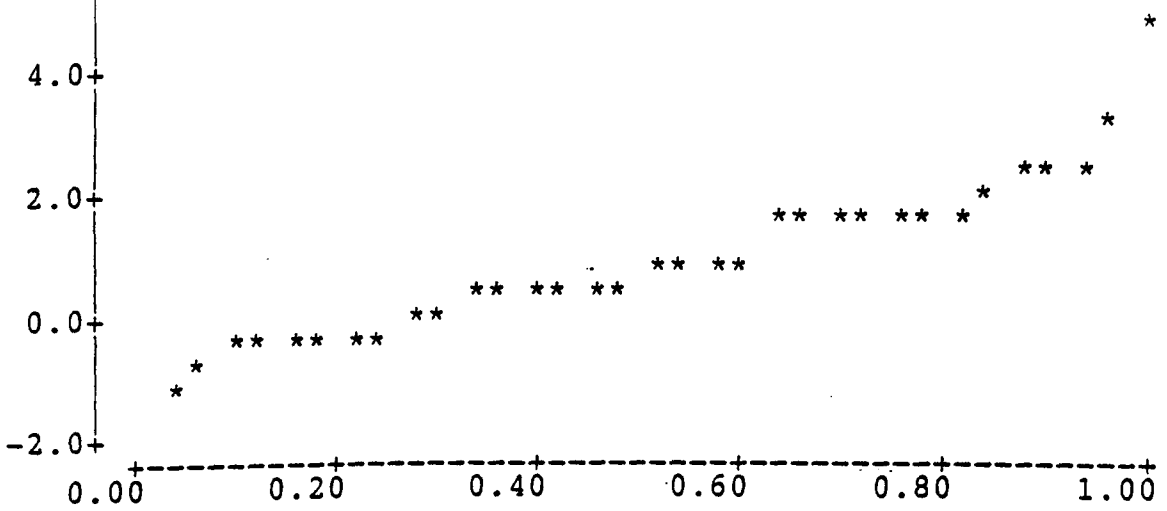
Pherusa Affinis, PCB



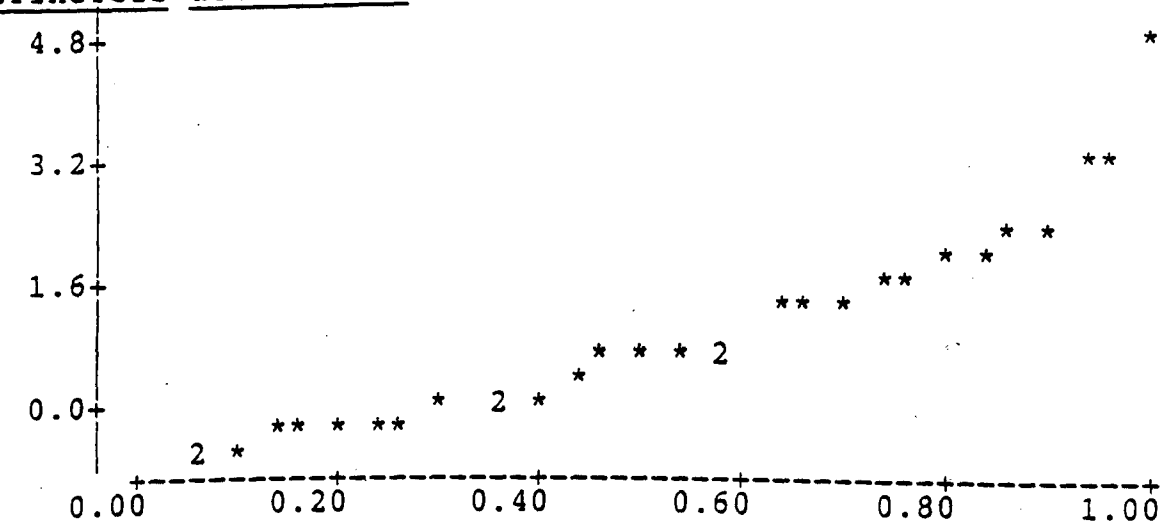
Phyllodoce mucosa, PCB



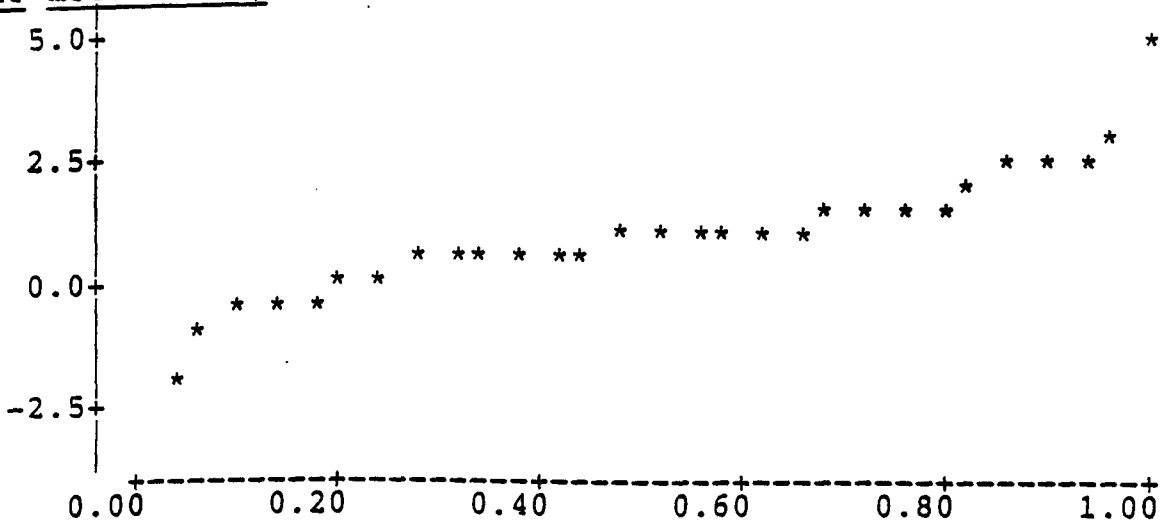
Tharyx annulosus, PCB



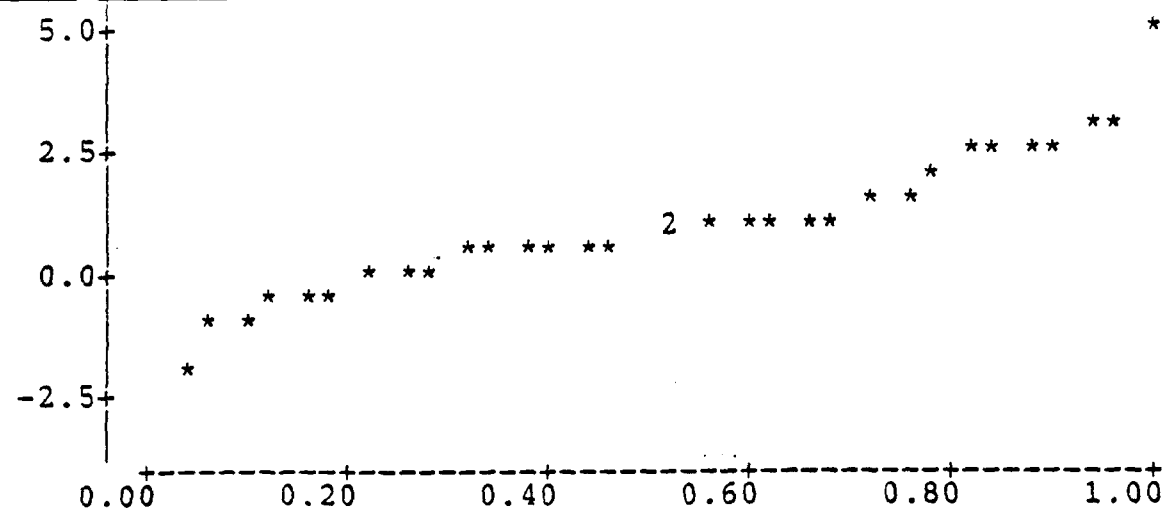
Lumbrinereis aciculars, PCB



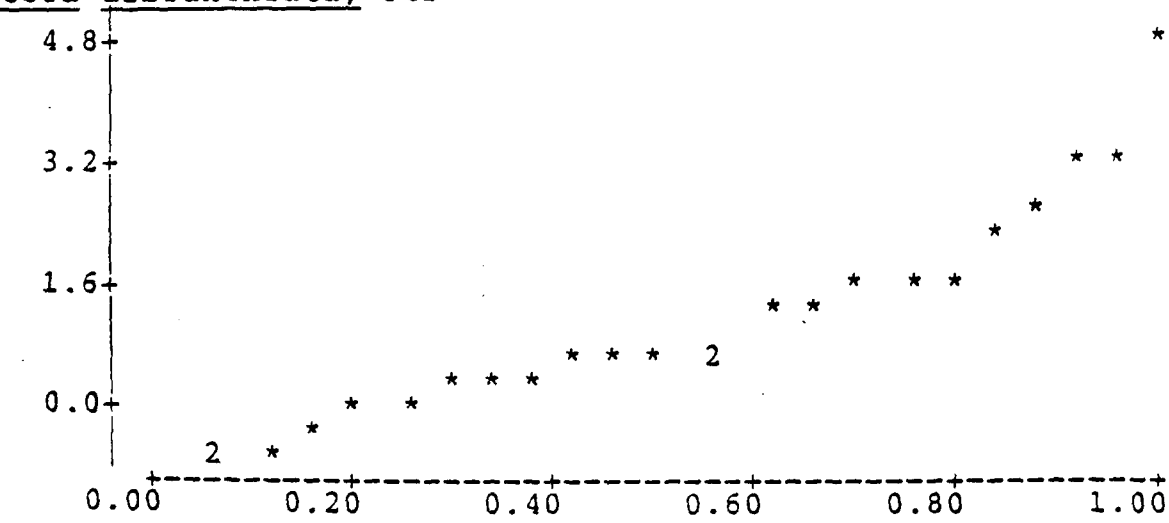
Pitar morrhuanus, PCB



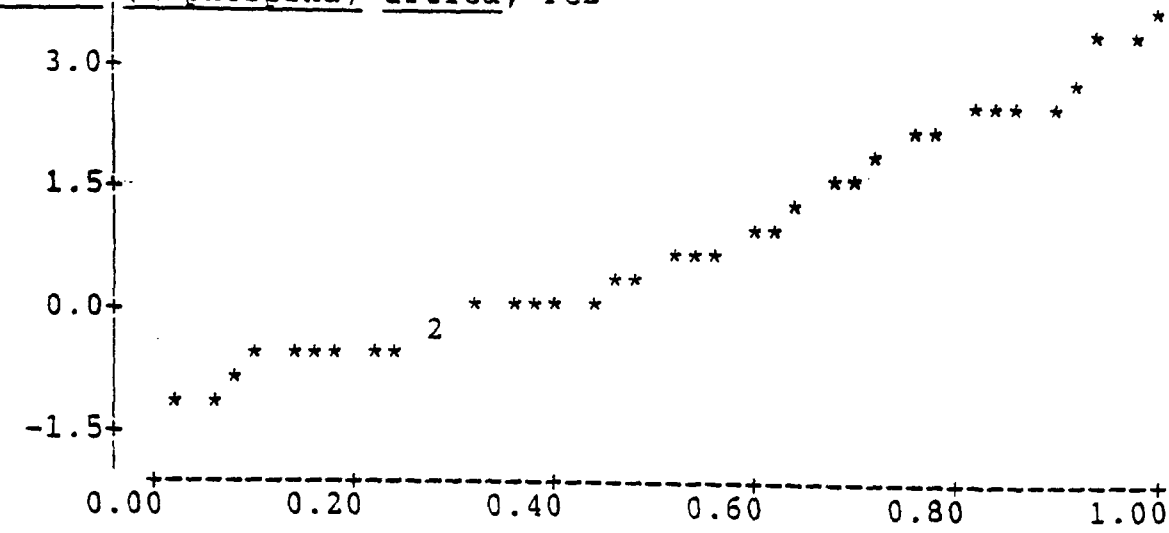
Tellina agilis, PCB



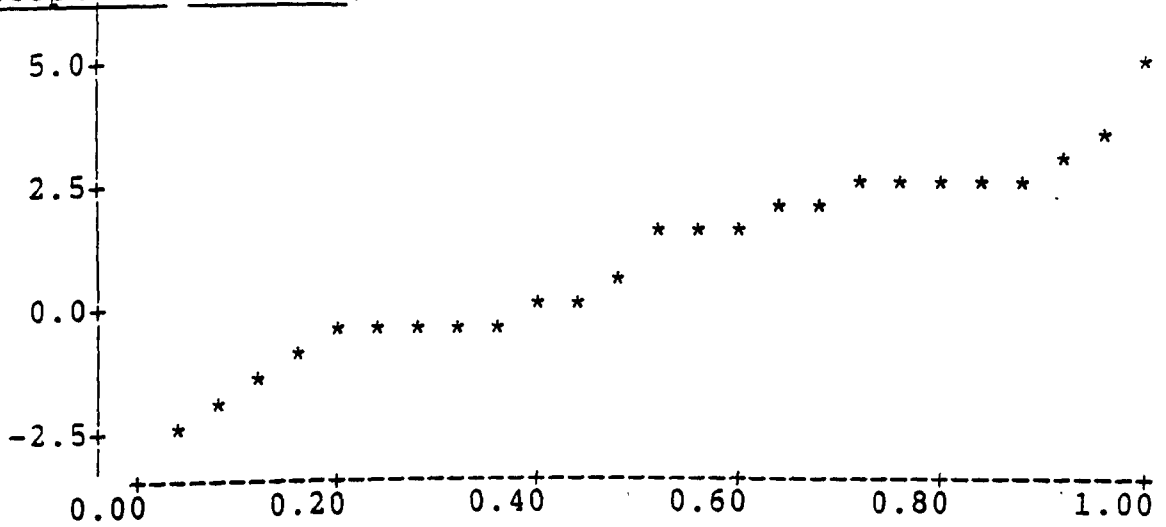
Glycera dibranchiata, PCB



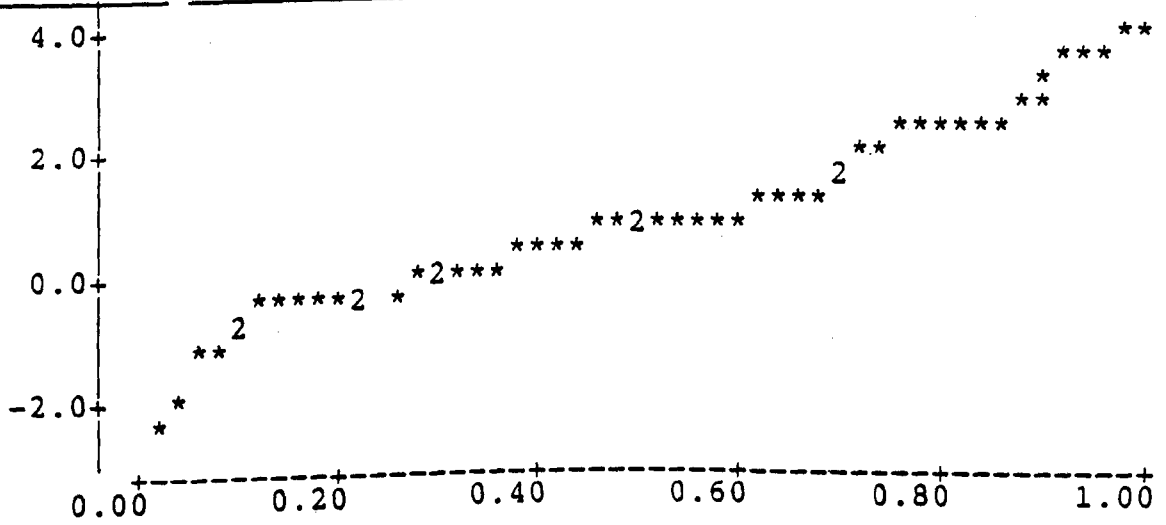
Amphioda (amphispina) urtica, PCB



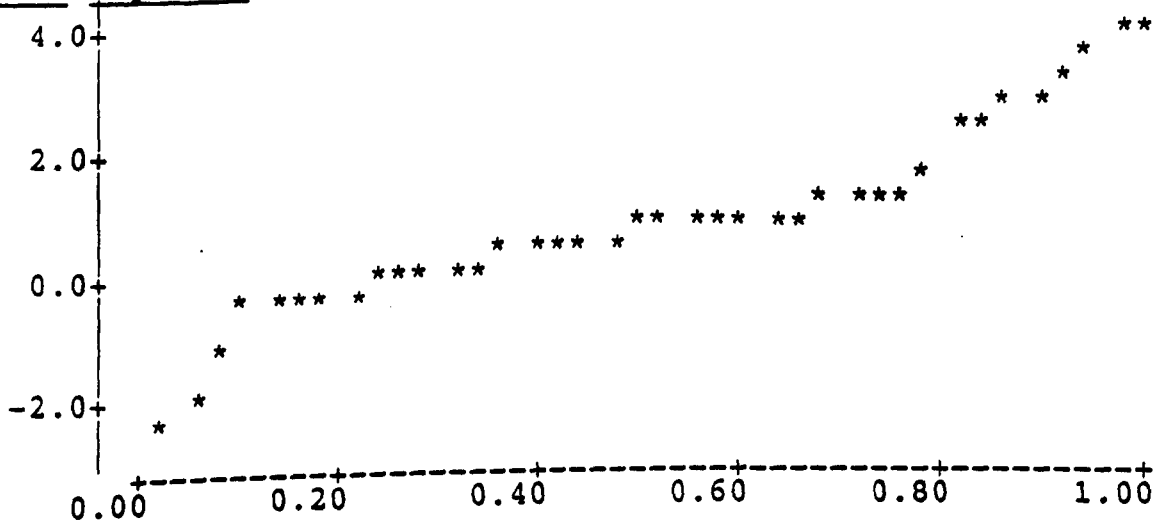
Heterophoxus oculatus, PCB



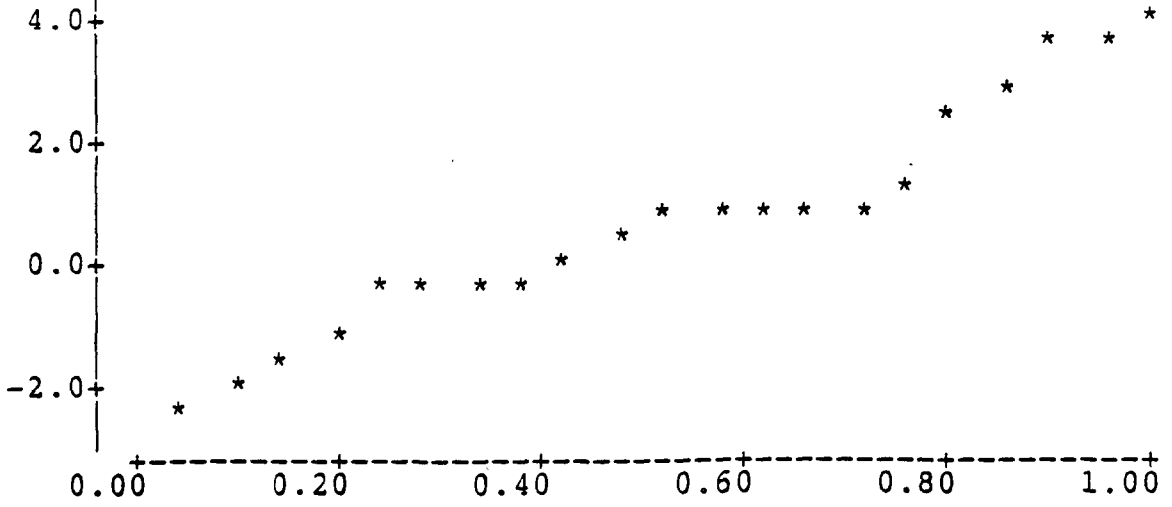
Euphilomedes carcharodonta, PCB



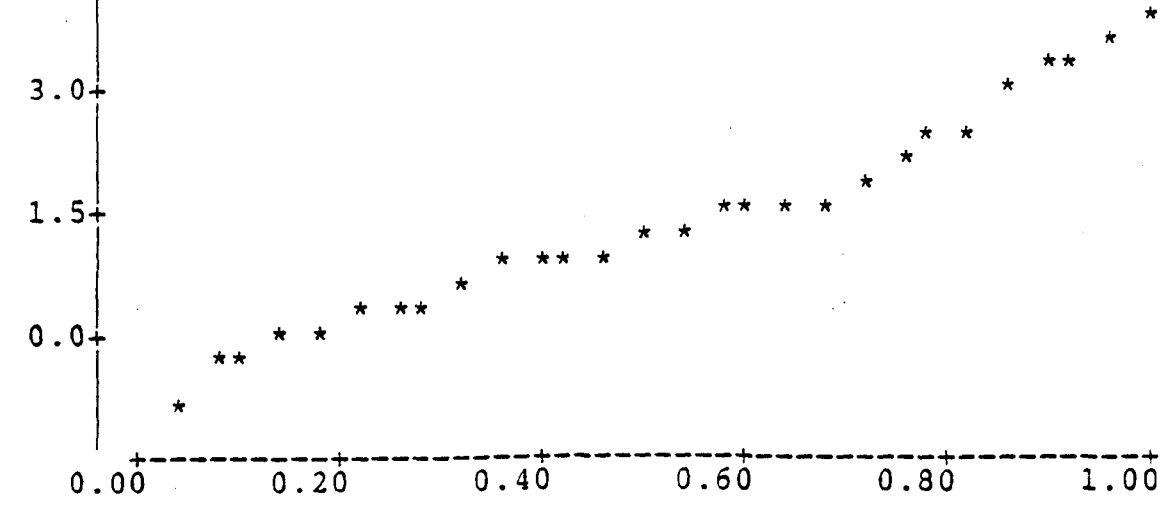
Glycera capitata, PCB



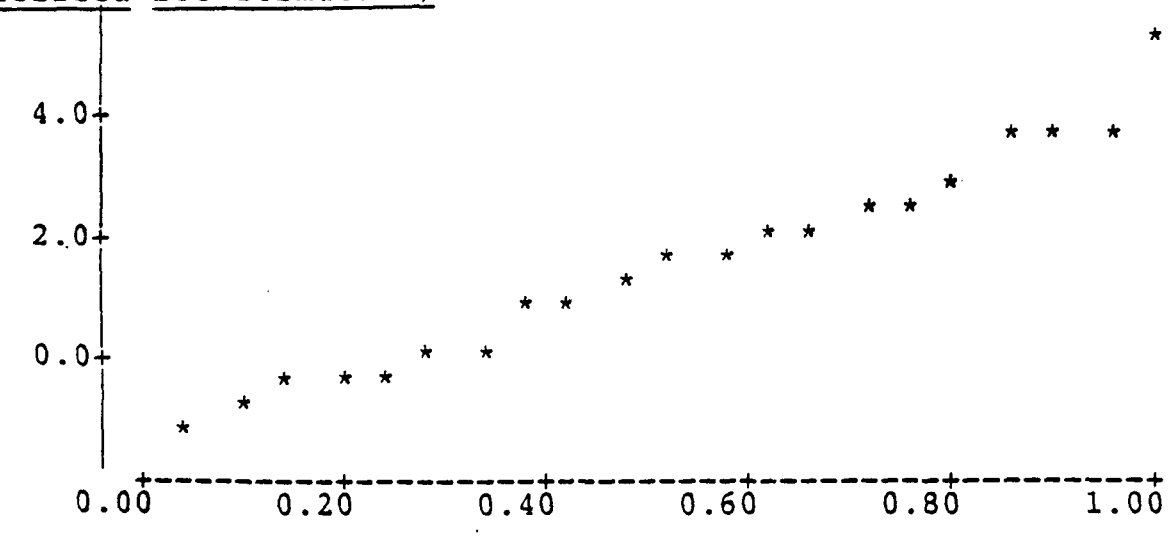
Prionospio cirrifera, PCB



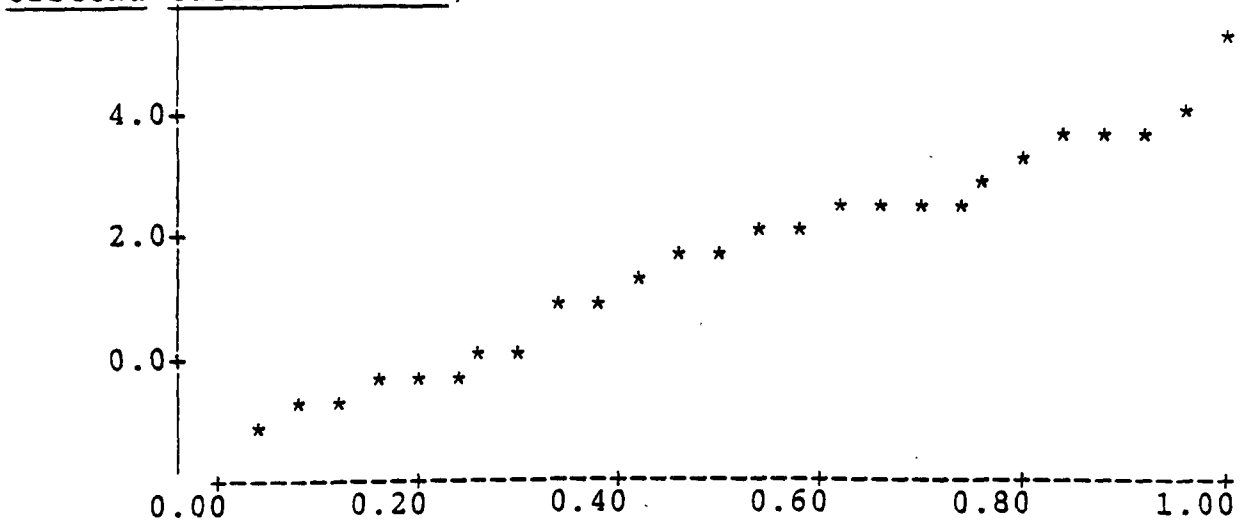
Cossuro longocirrata, PCB



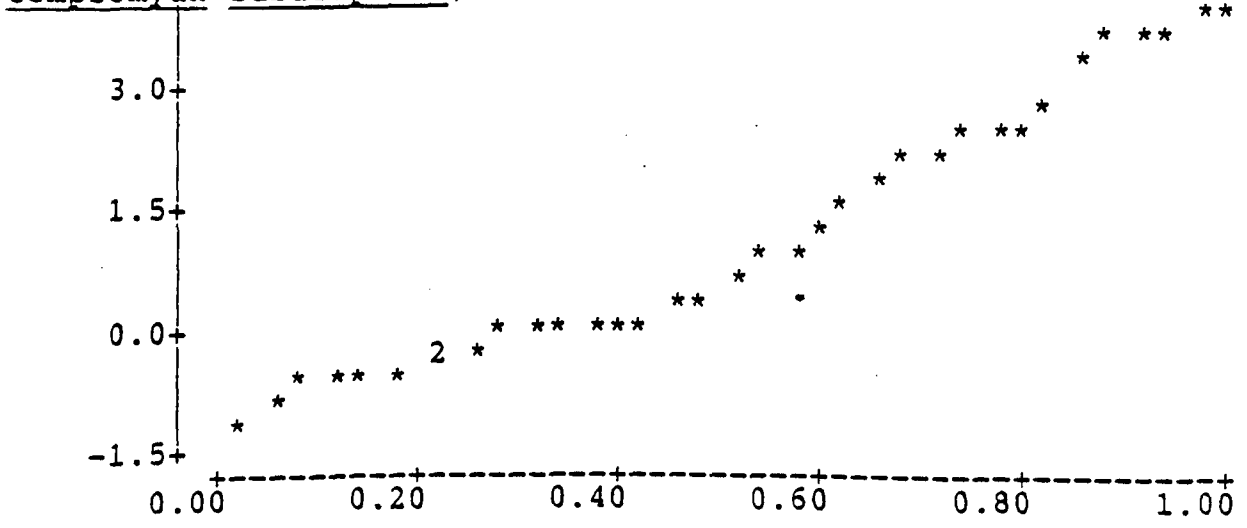
Amplelisca brevisimulata, PCB



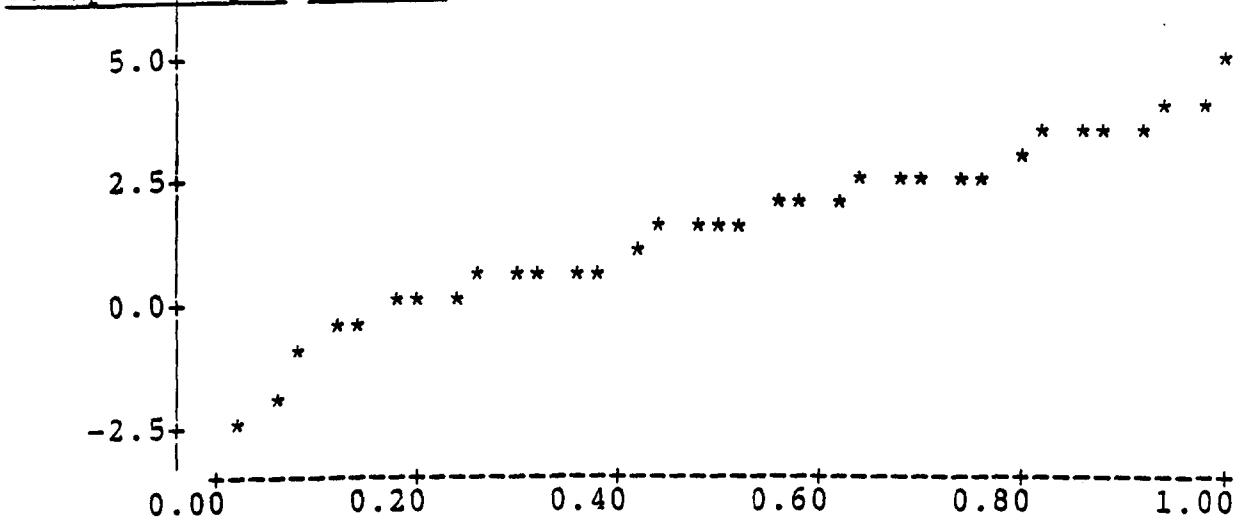
Cistena californiensis, PCB

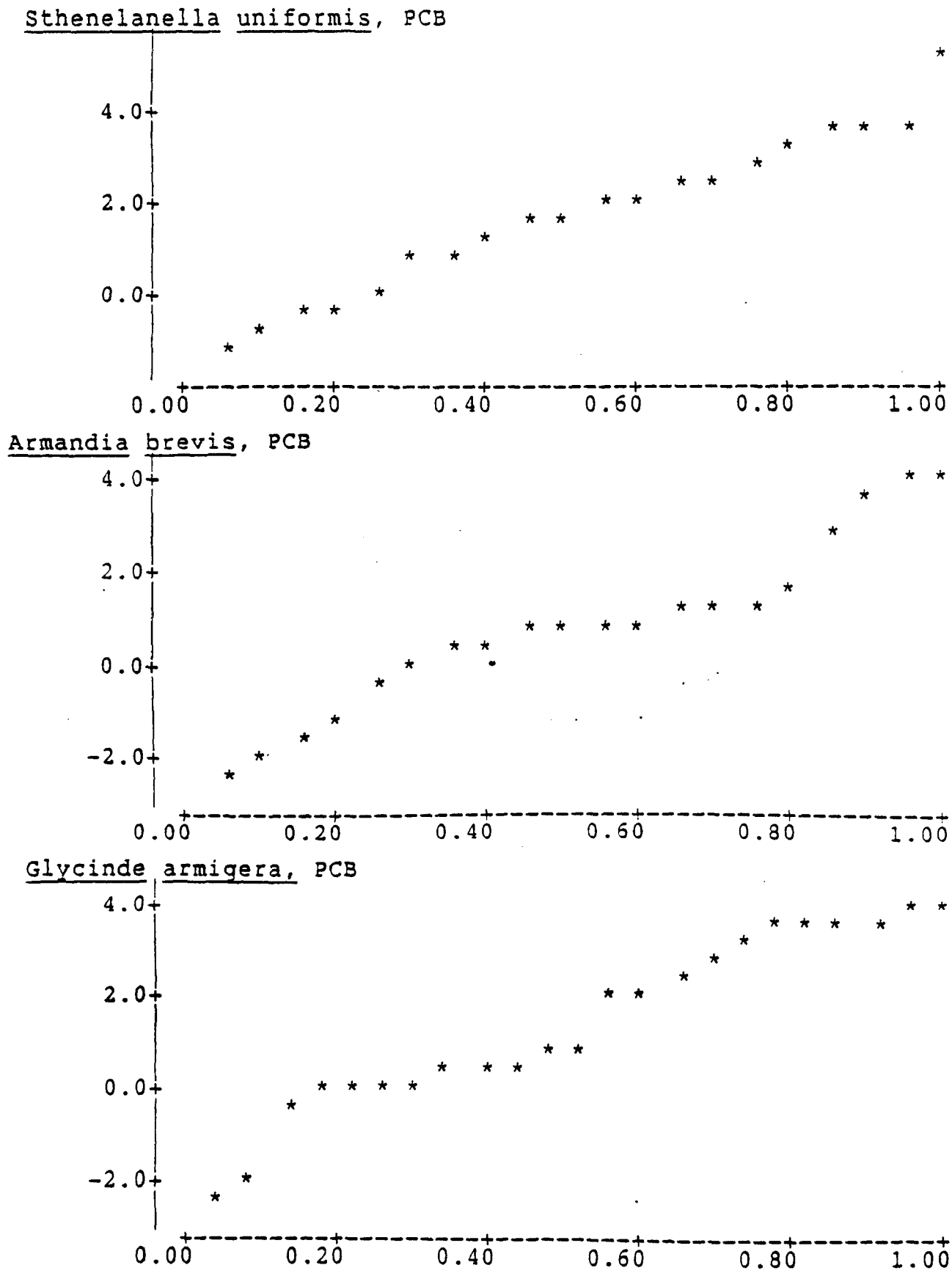


Compsomyax subdiaphana, PCB



Paraprionospio pinnata, PCB




Sthenelanella uniformis, PCB
4.0
2.0
0.0
0.00
0.20
0.40
0.60
0.80
1.00
Armandia brevis, PCB
4.0
2.0
0.0
-2.0
0.00
0.20
0.40
0.60
0.80
1.00
Glycinde armigera, PCB
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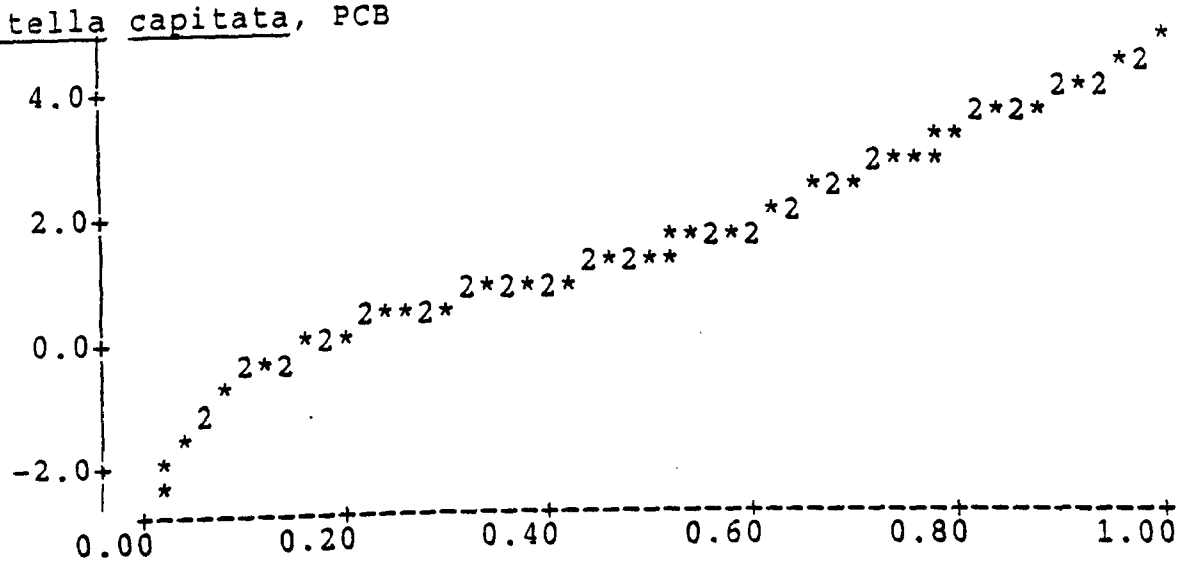
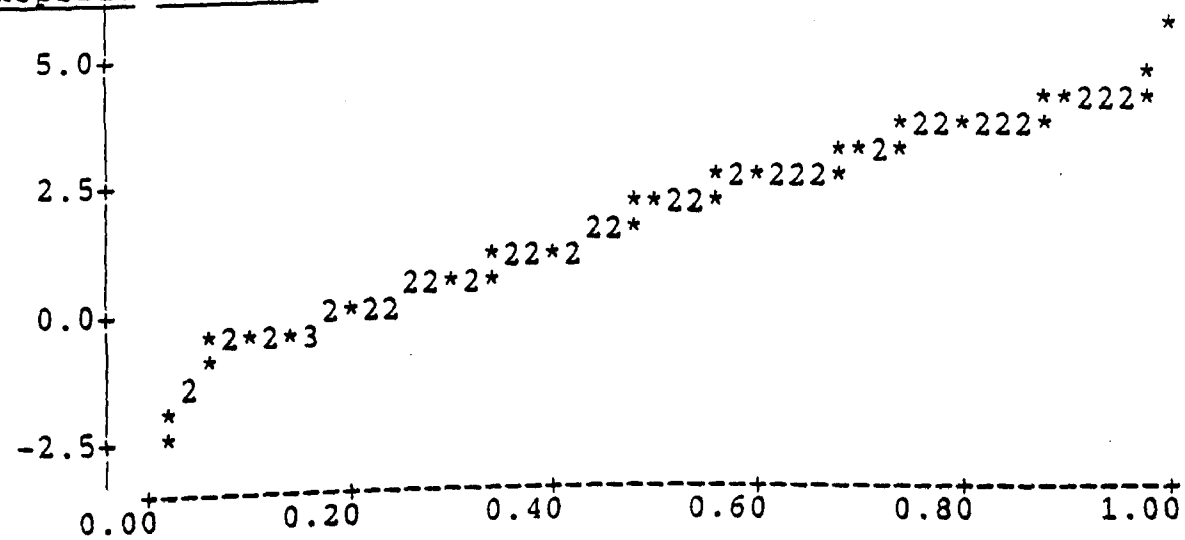
2.0
0.0
-2.0
0.00
0.20
0.40
0.60
0.80
1.00

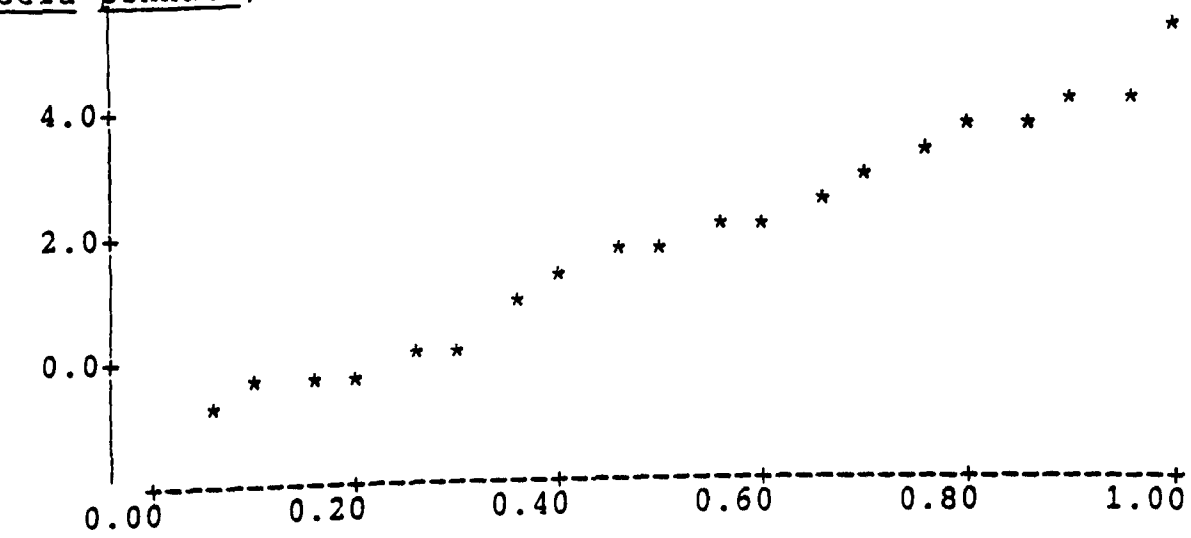
Capitella capitata, PCB



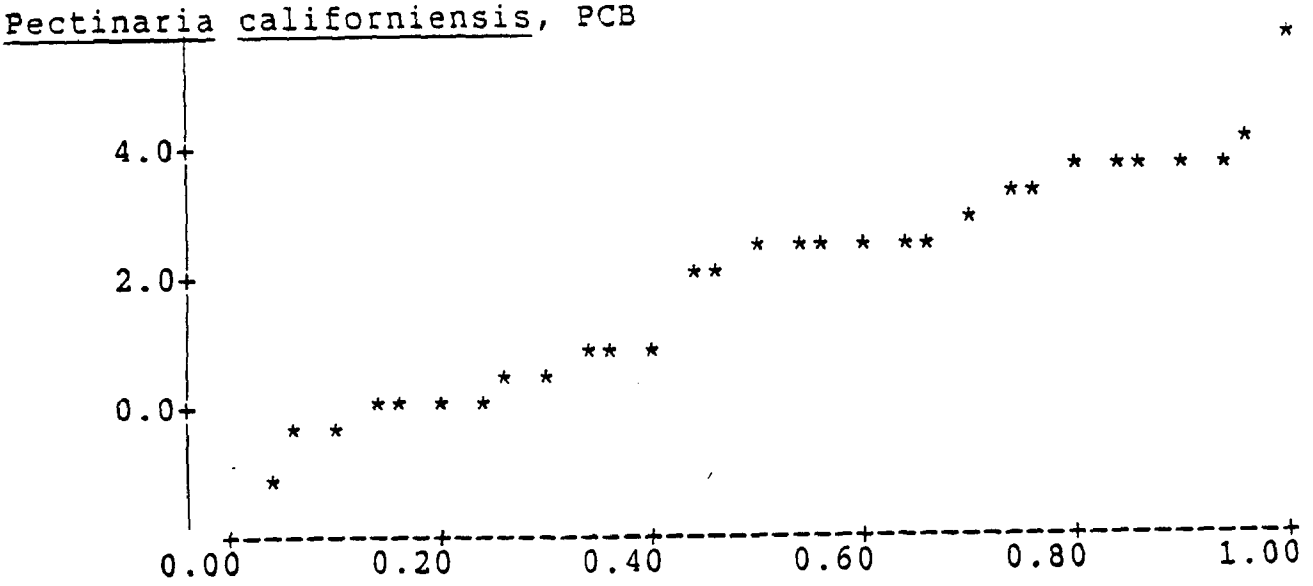
Axinopsida sericata, PCB



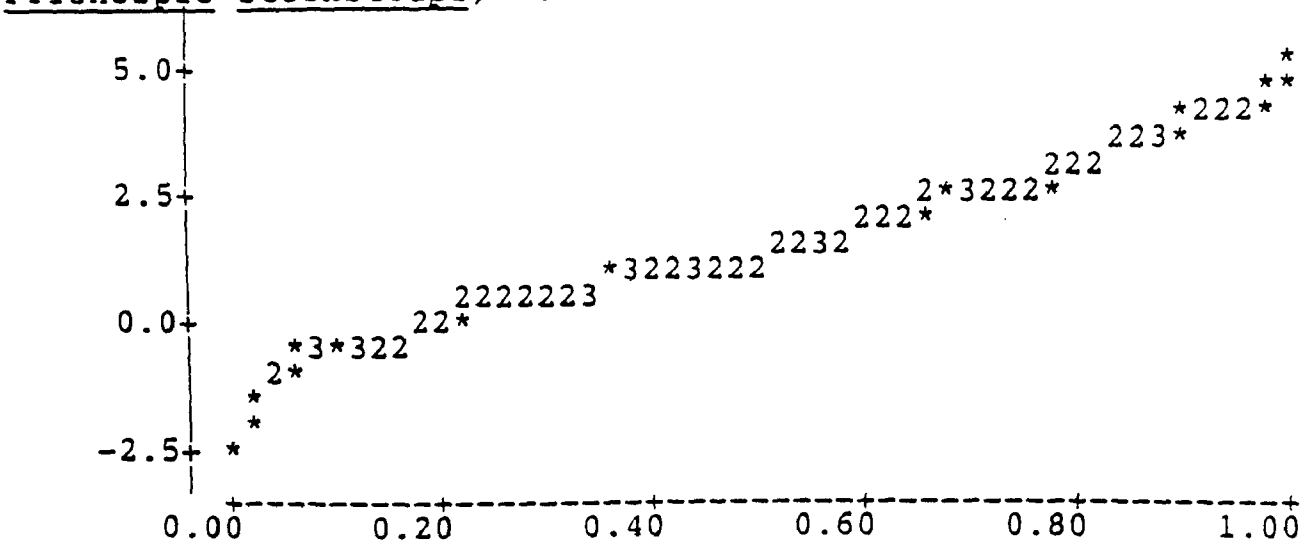
Chloeia pinnata, PCB



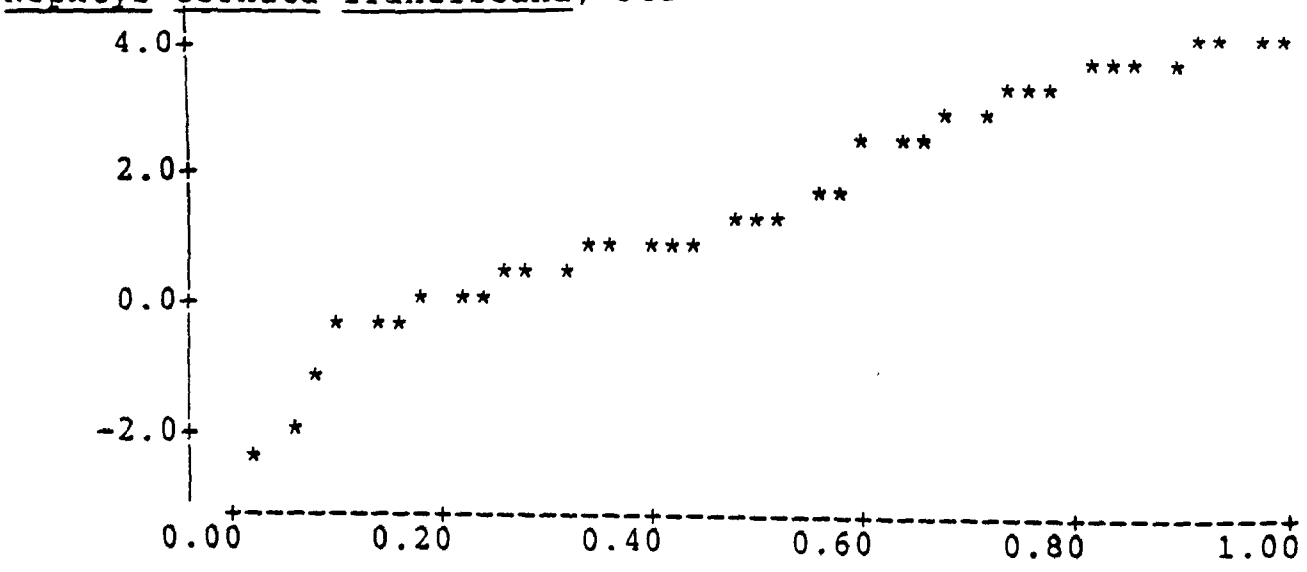
Pectinaria californiensis, PCB



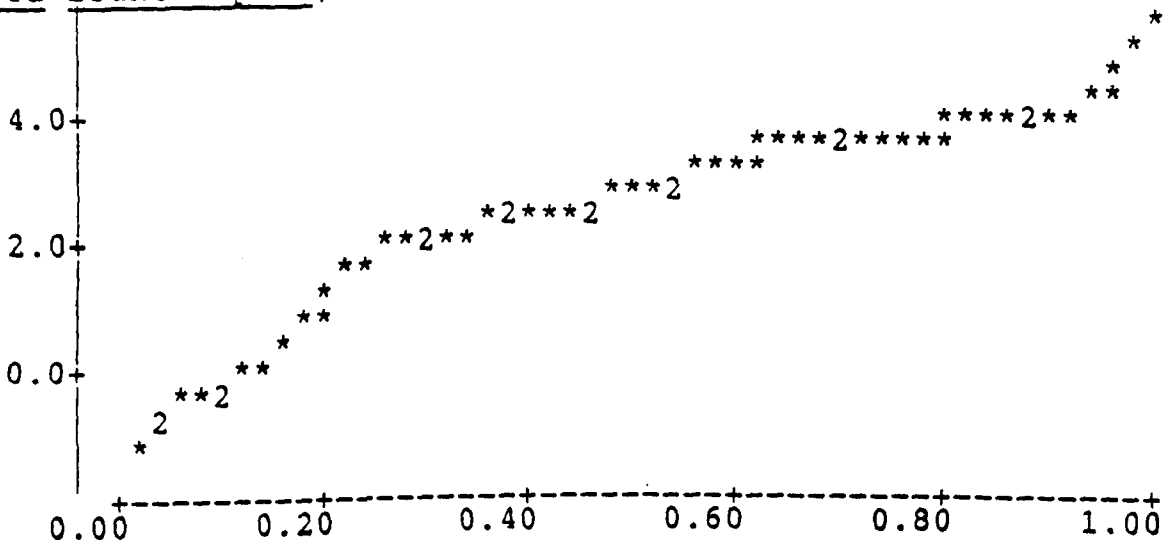
Prionospio steenstrupi, PCB



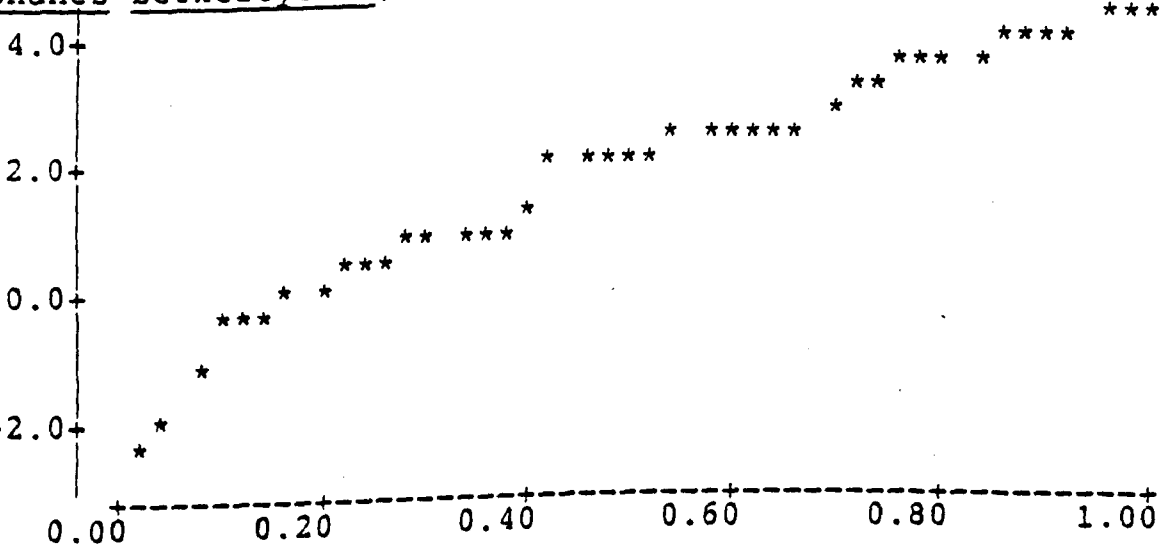
Nephtys cornuta franciscana, PCB



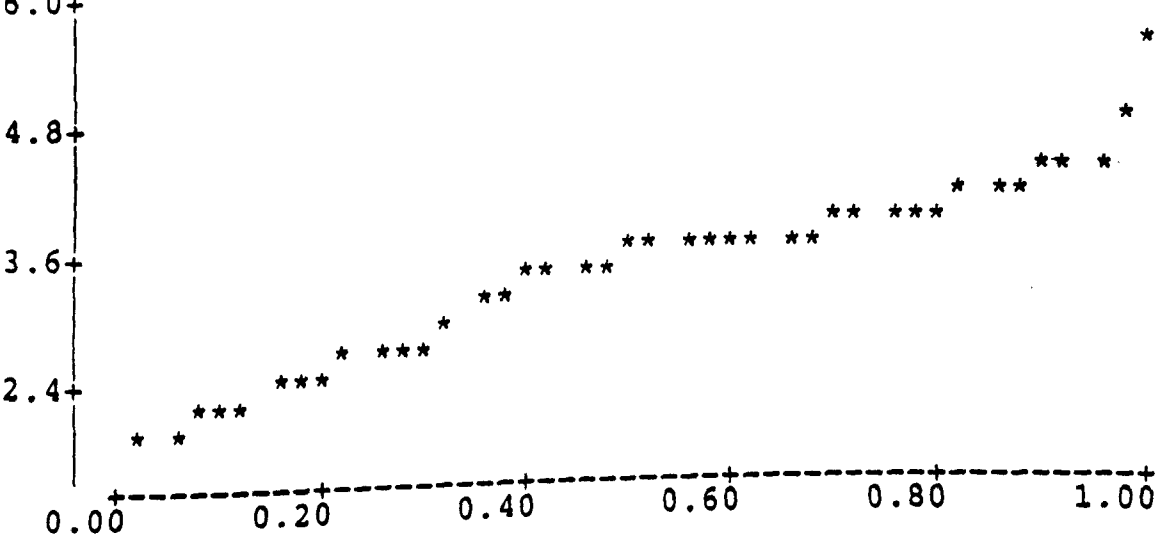
Glycera branchiopoda, PCB



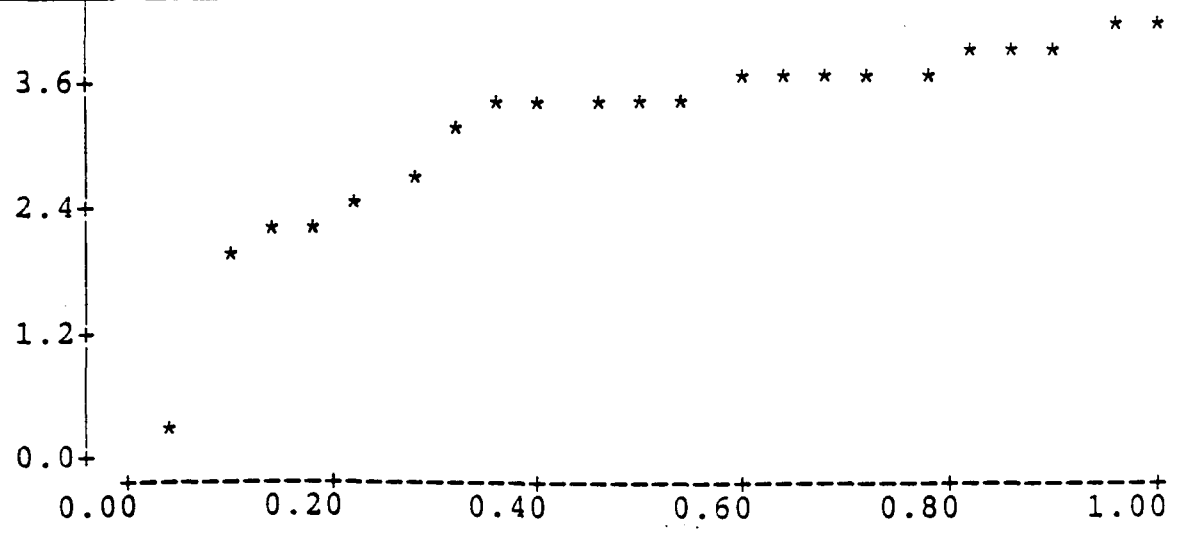
Spiophanes berkeleyorum, PCB



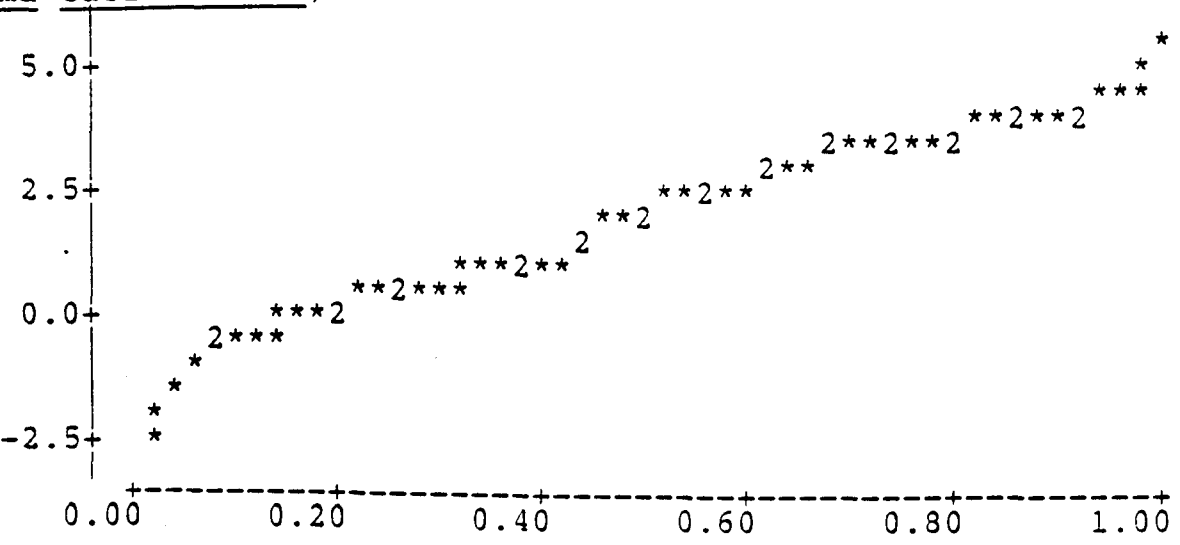
Telliina carpenteri, PCB



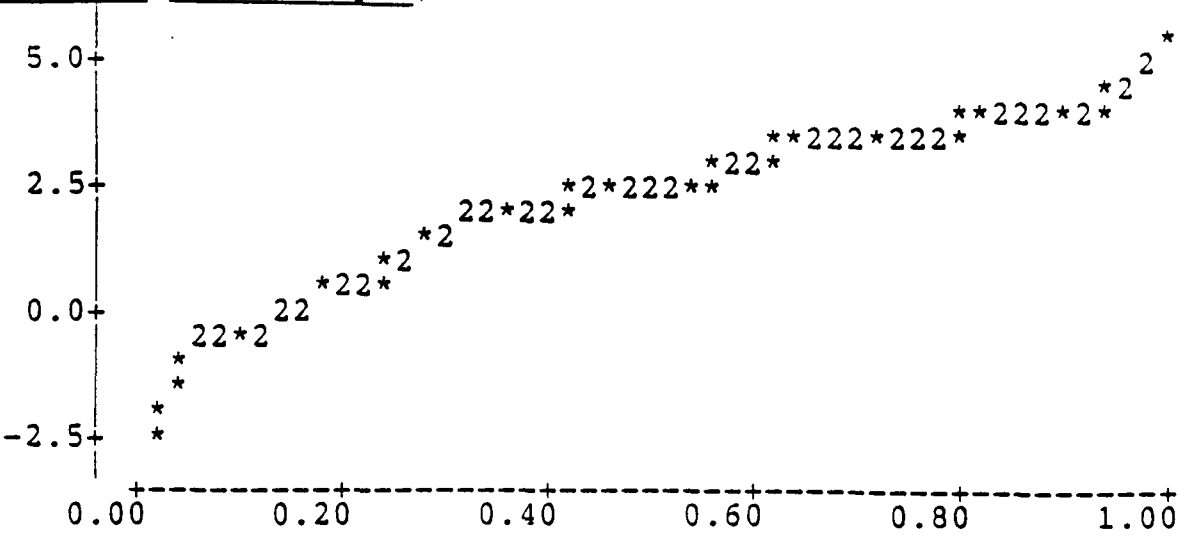
Prionospio pinnata, PCB



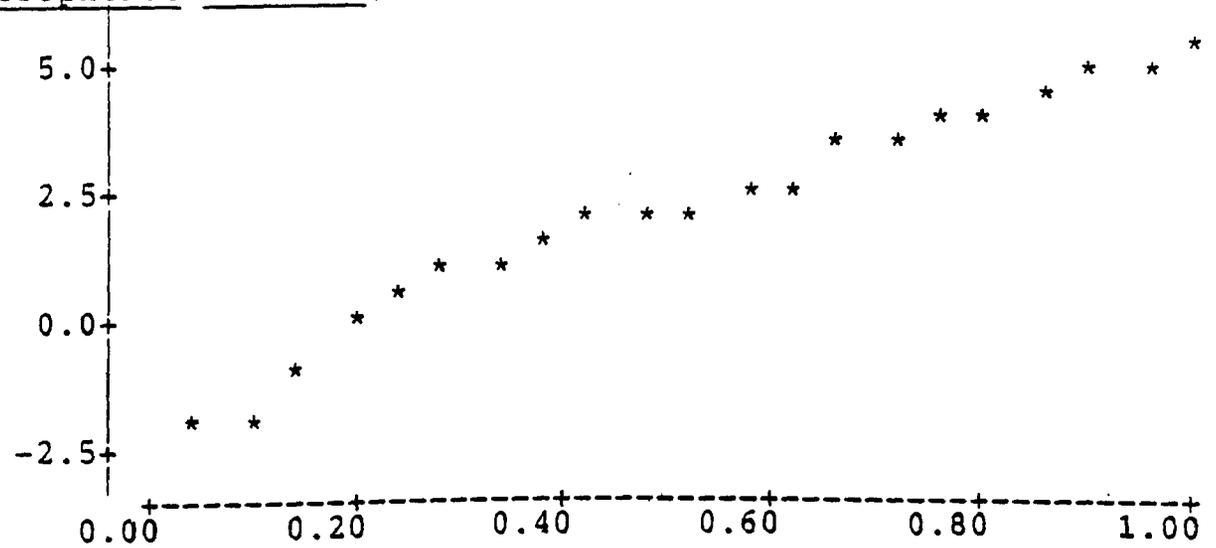
Macoma carlottensis, PCB



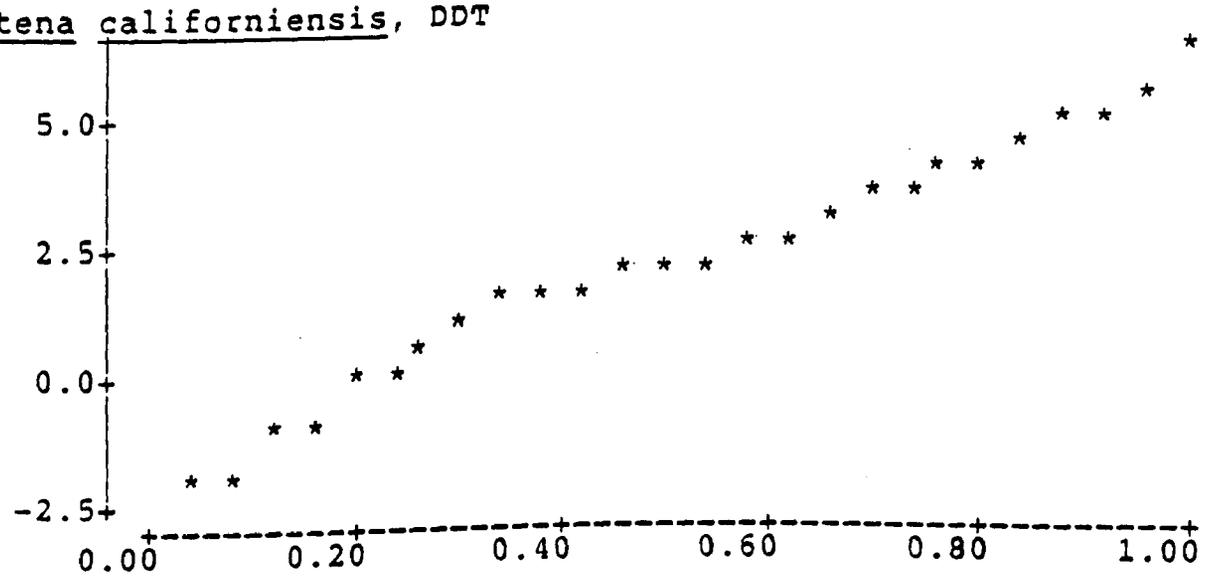
Parvilucina tenuisculpta, PCB



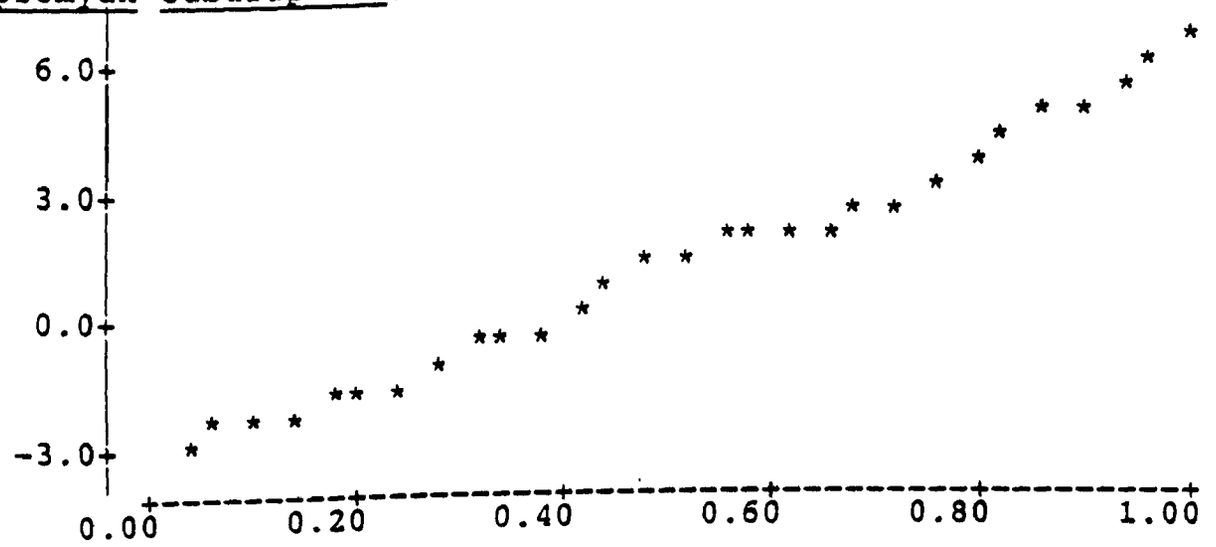
Heterophoxus oculatus, DDT



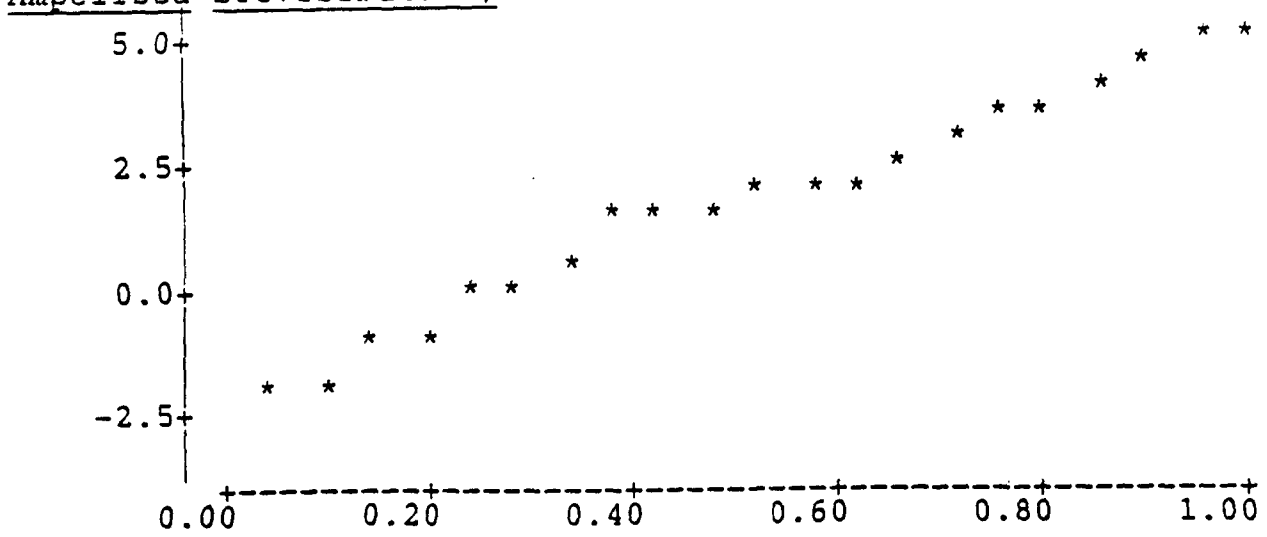
Cistena californiensis, DDT



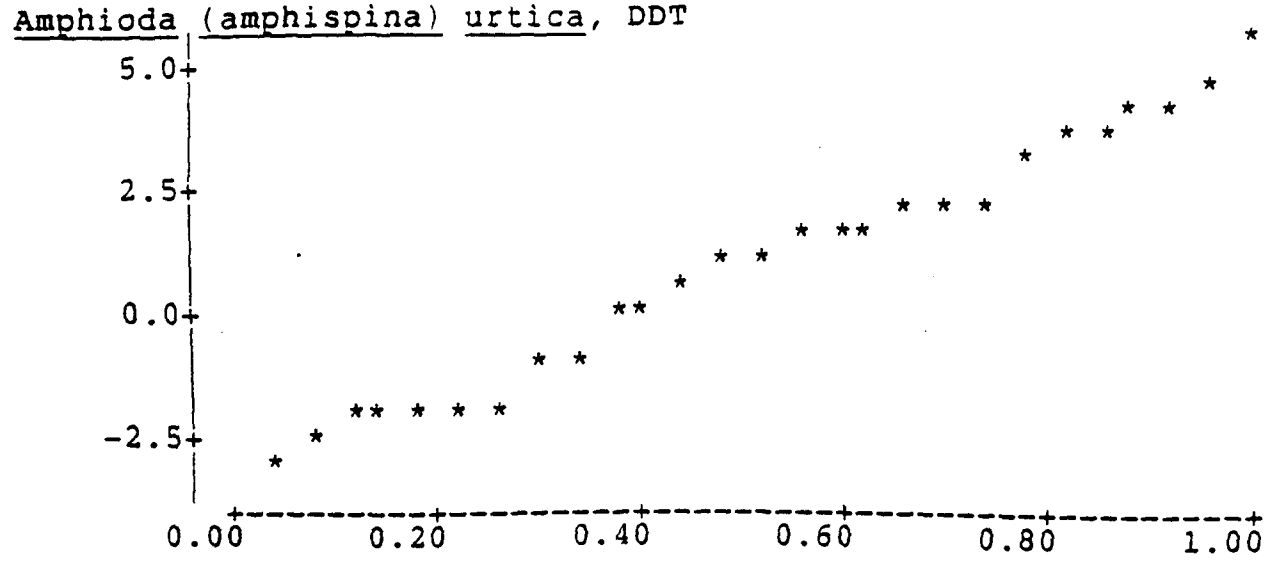
Compsomyax subdiaphana, DDT



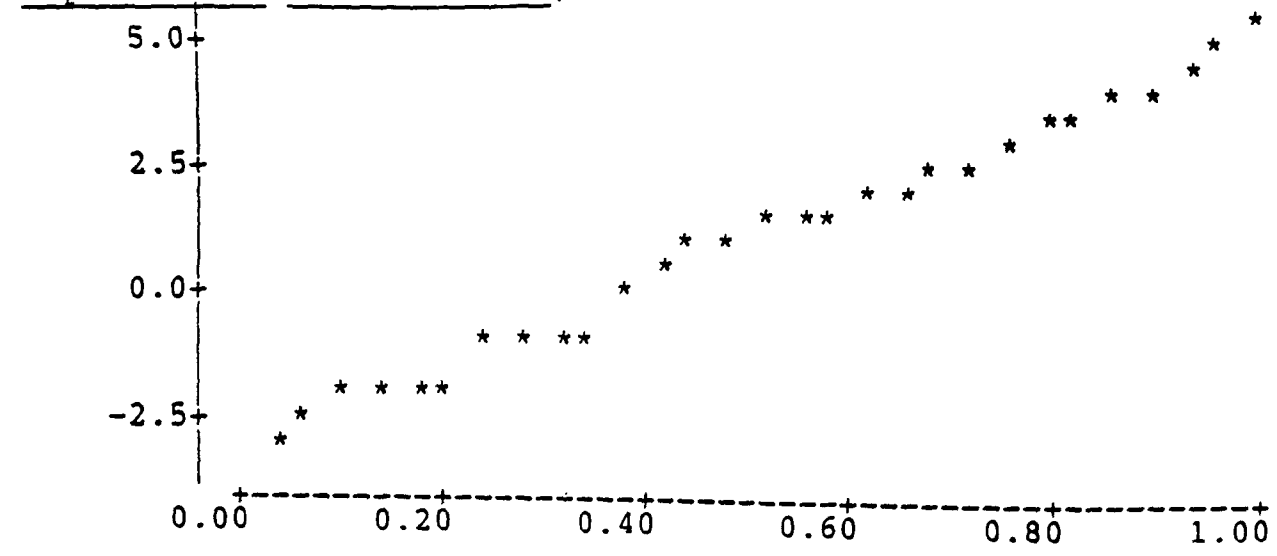
Ampelisca brevisimulata, DDT



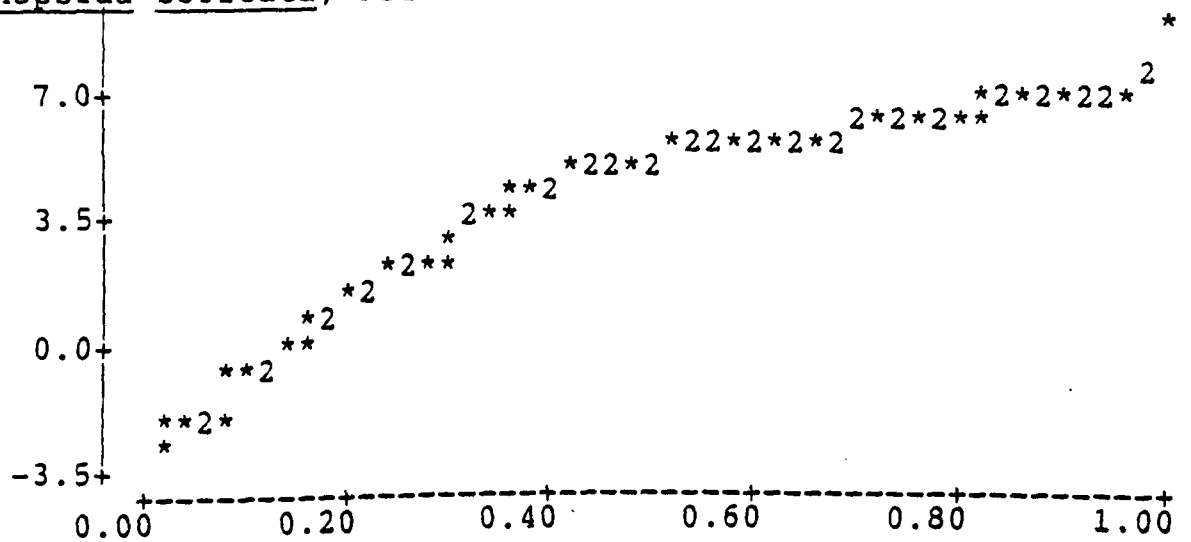
Amphioda (amphispina) urtica, DDT



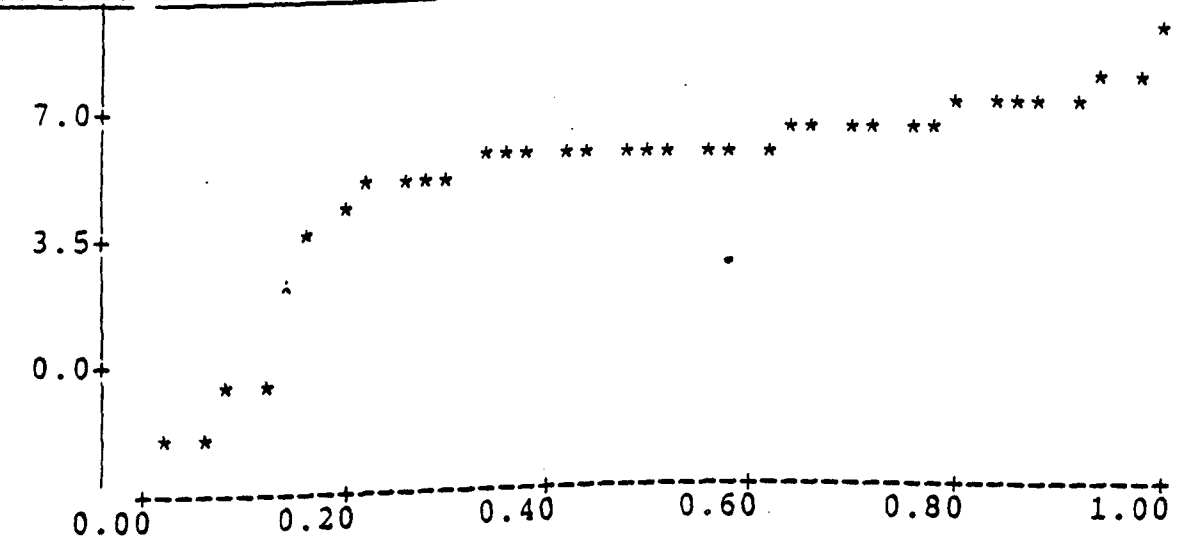
Euphilomedes carcharodonta, DDT



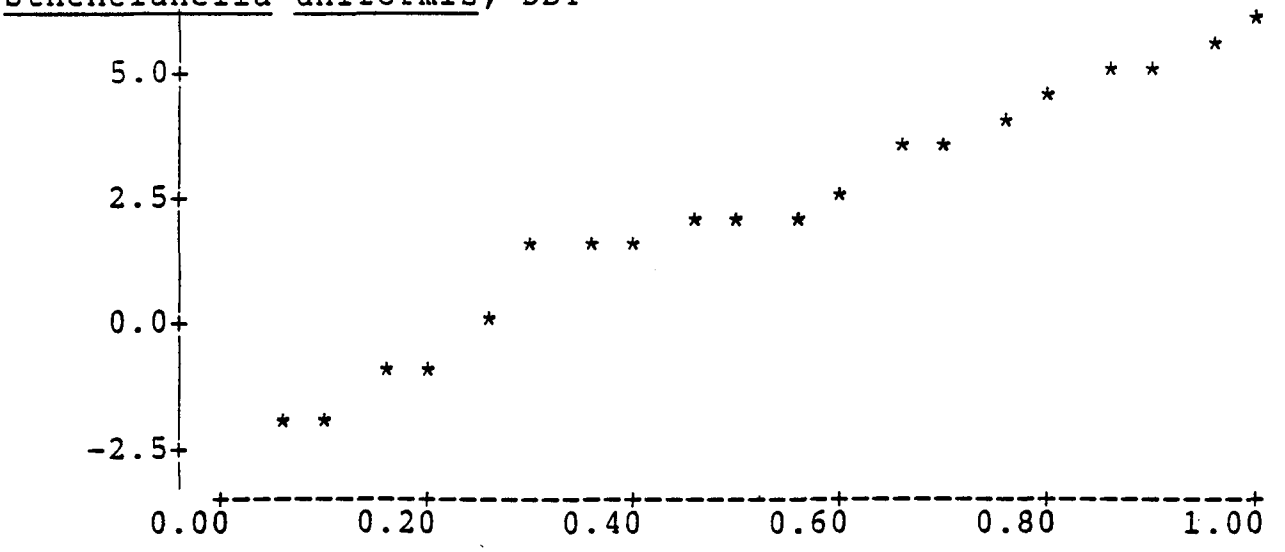
Axinopsida sericata, DDT



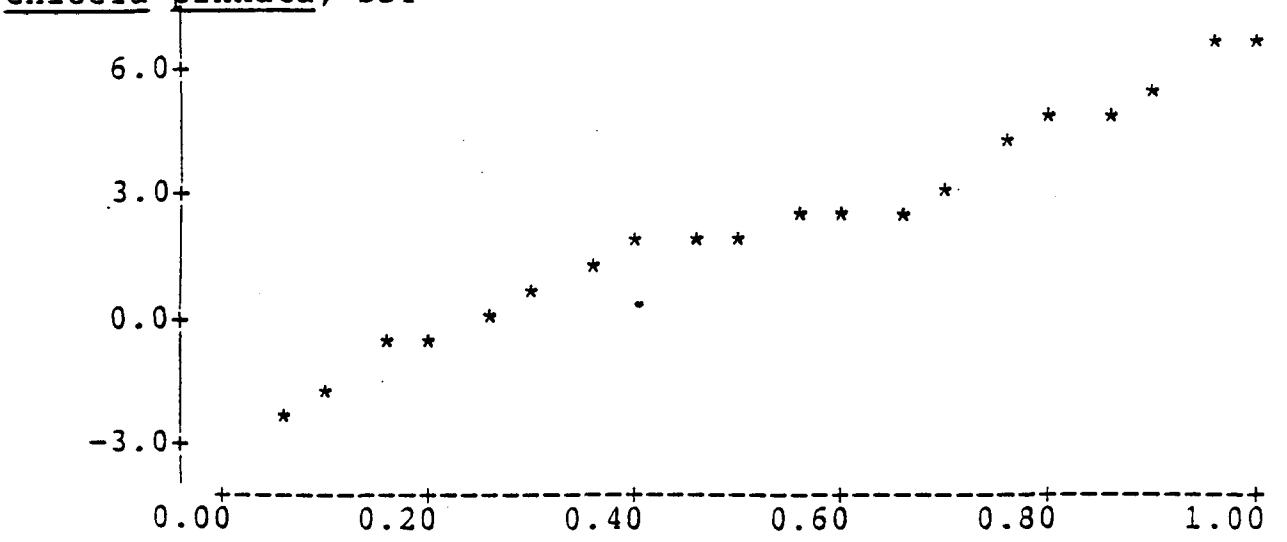
Pectinaria californiensis, DDT



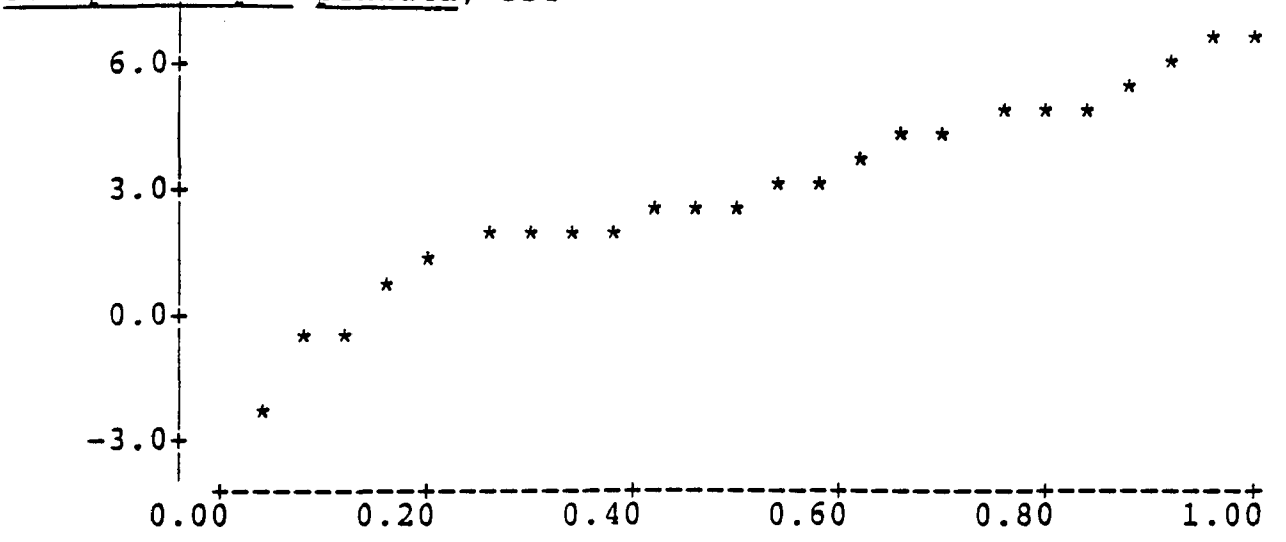
Sthenelanella uniformis, DDT



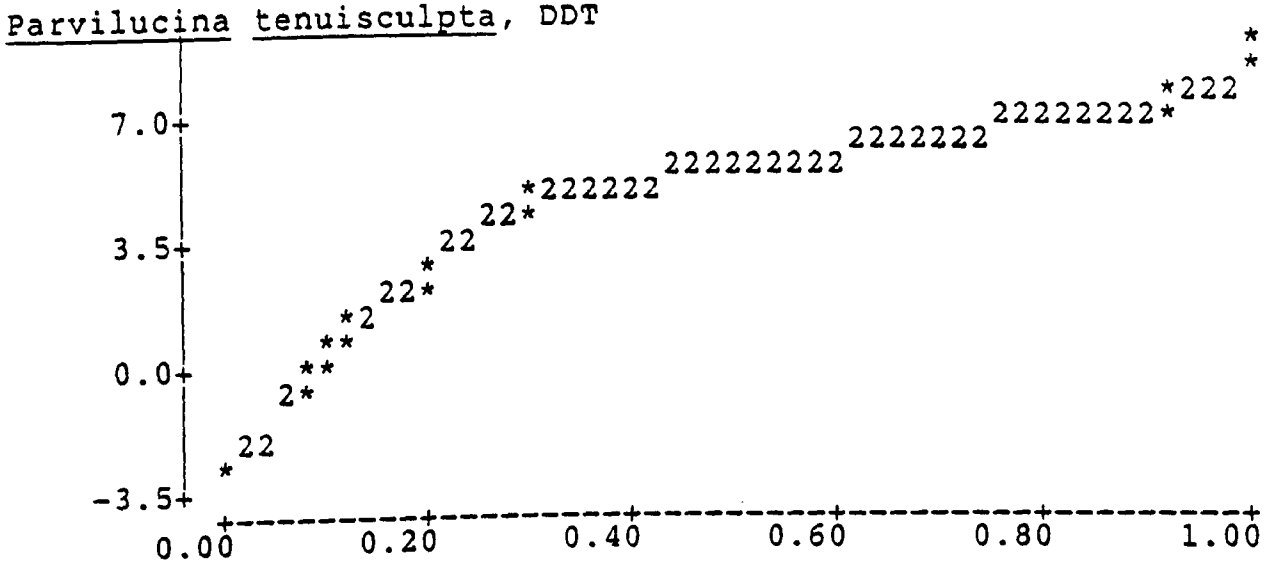
Chloeia pinnata, DDT



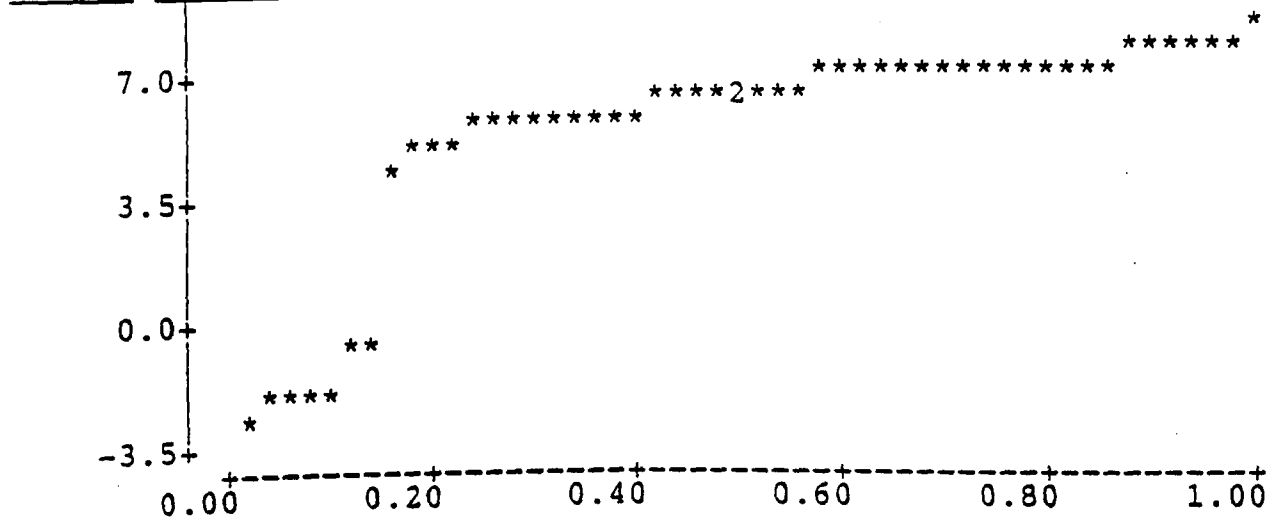
Paraprionospio pinnata, DDT



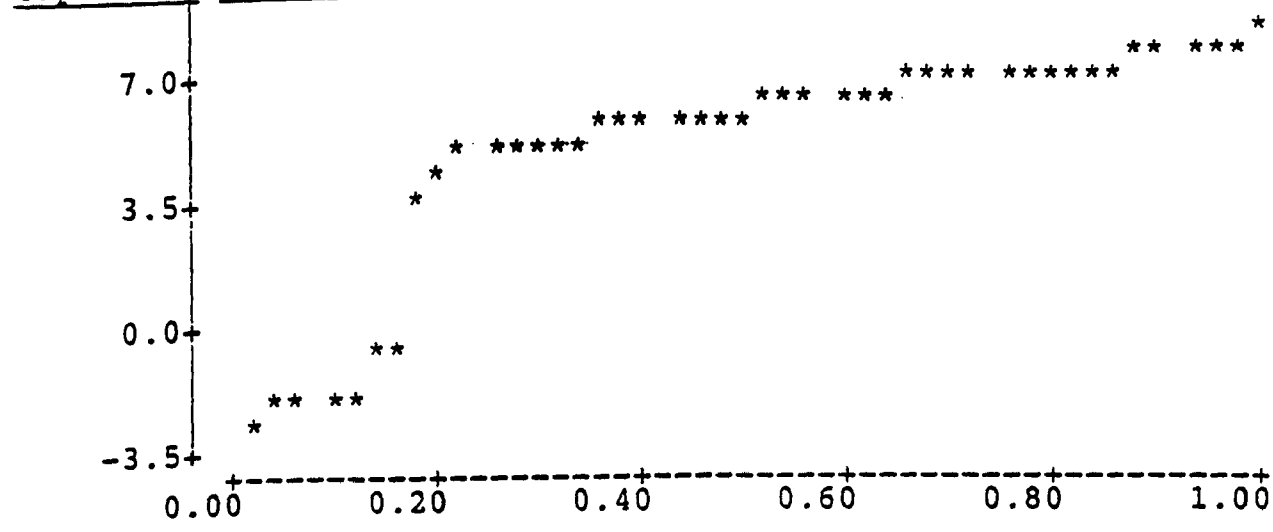
Parvilucina tenuisculpta, DDT



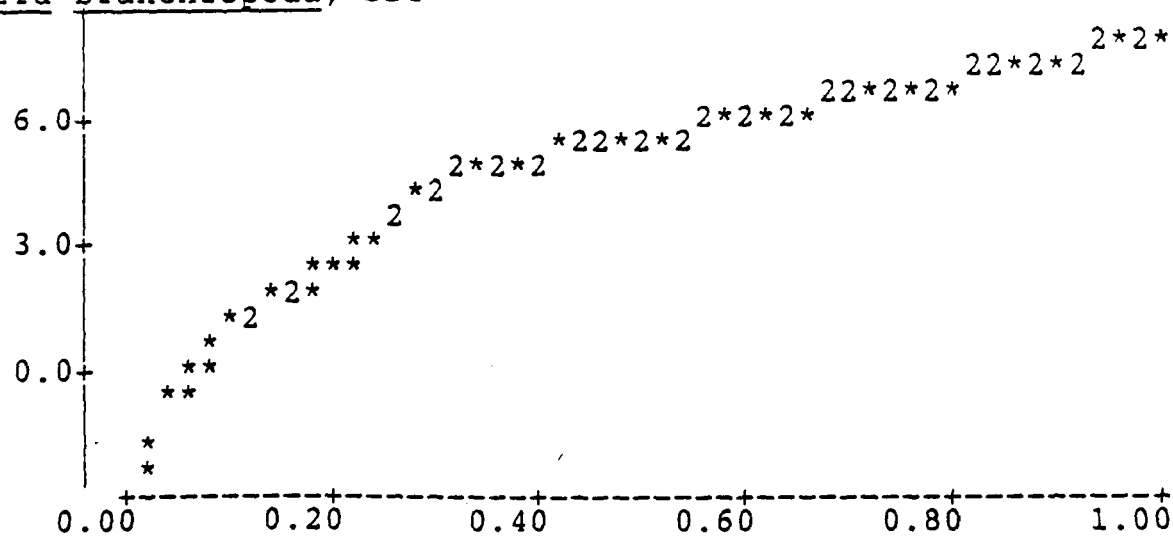
Macoma carlottensis, DDT



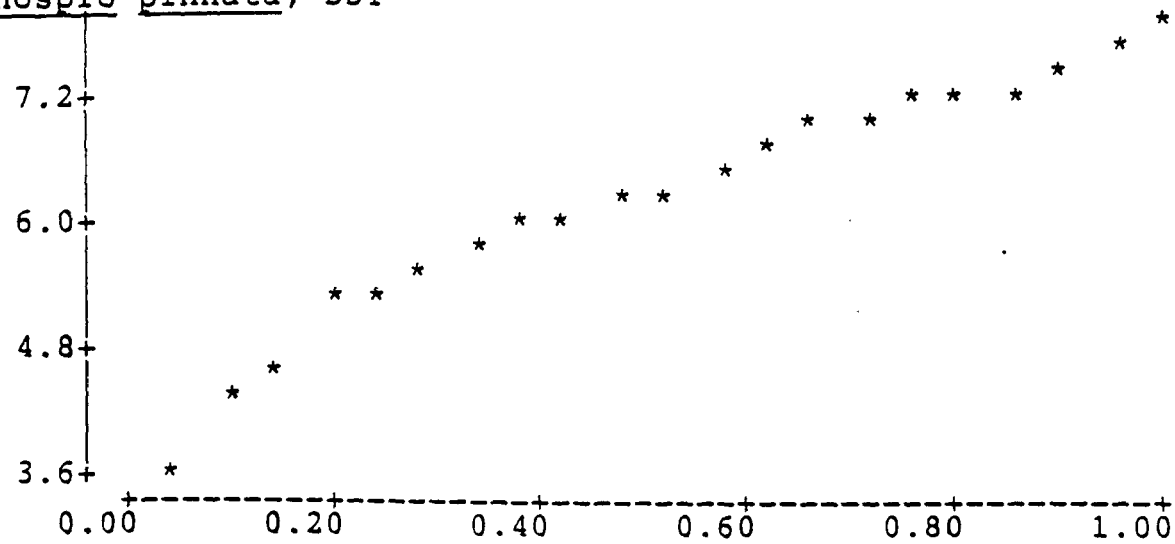
Capitella capitata, DDT



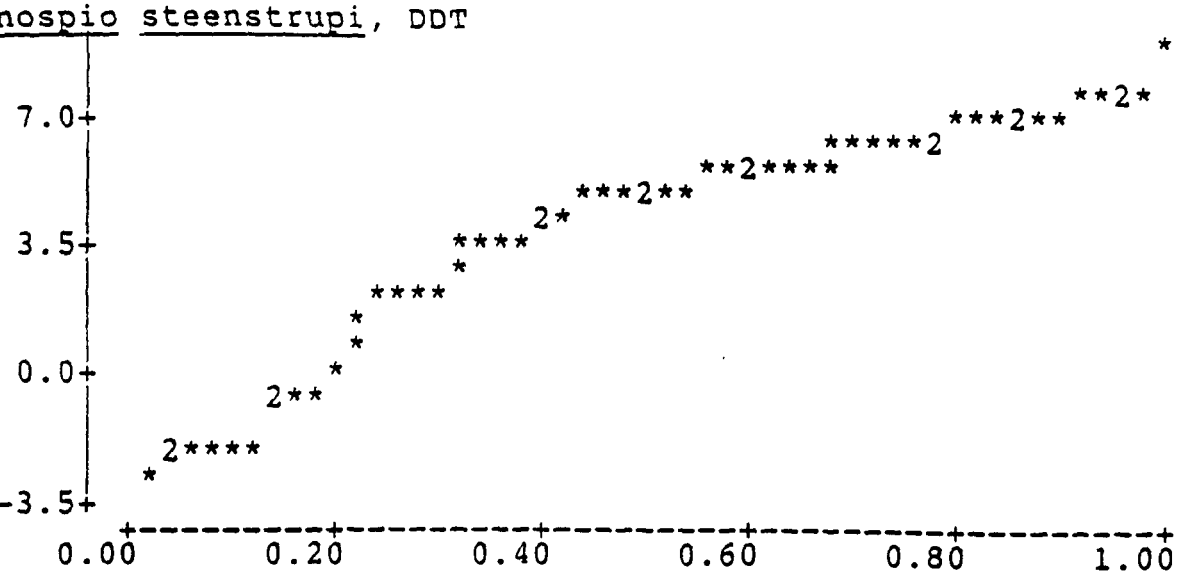
Glycera branchiopoda, DDT



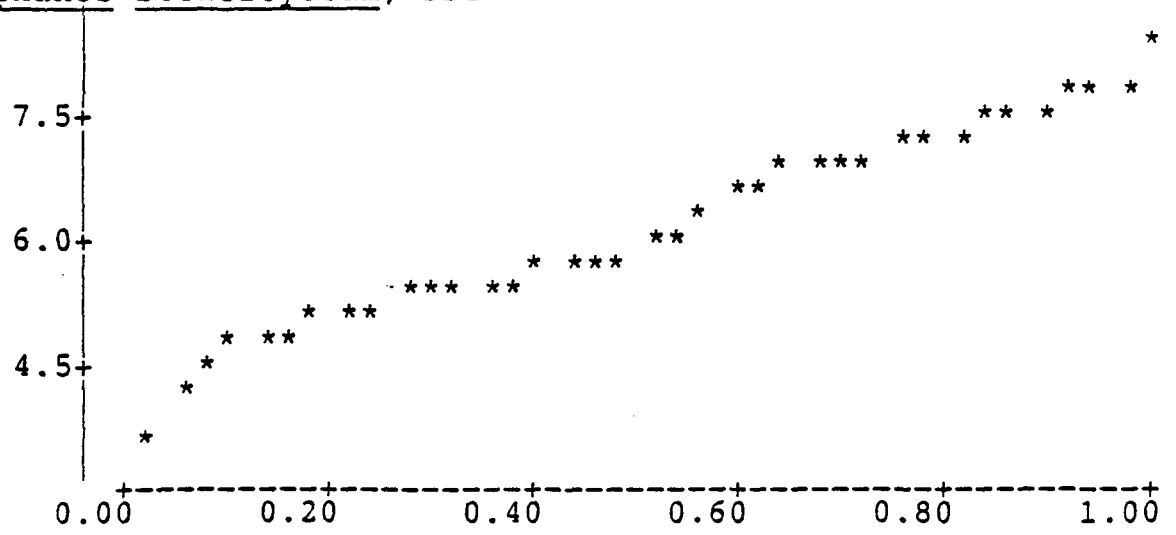
Prionospio pinnata, DDT



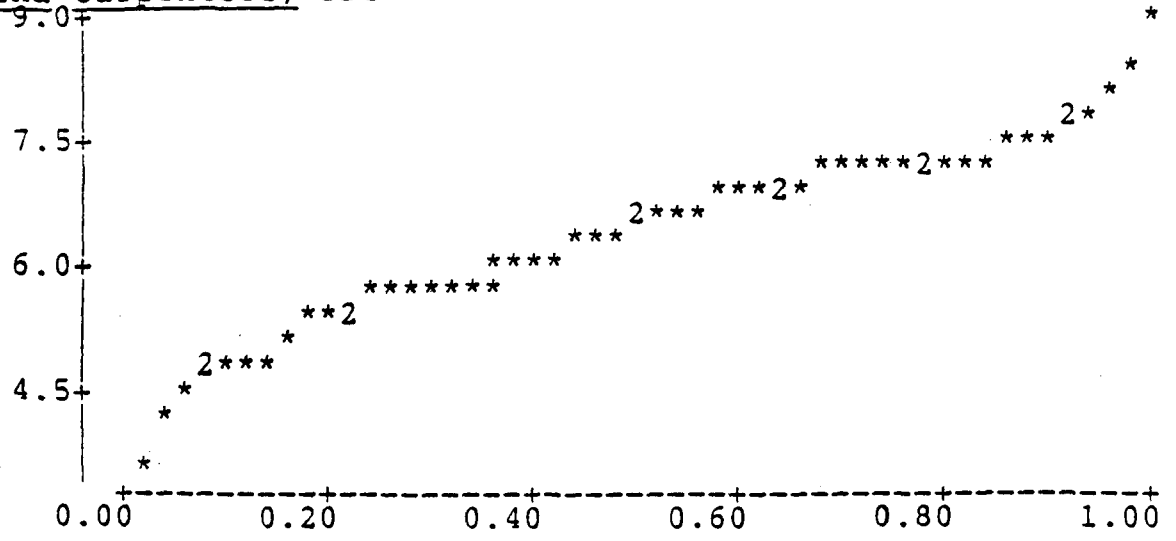
Prionospio steenstrupi, DDT



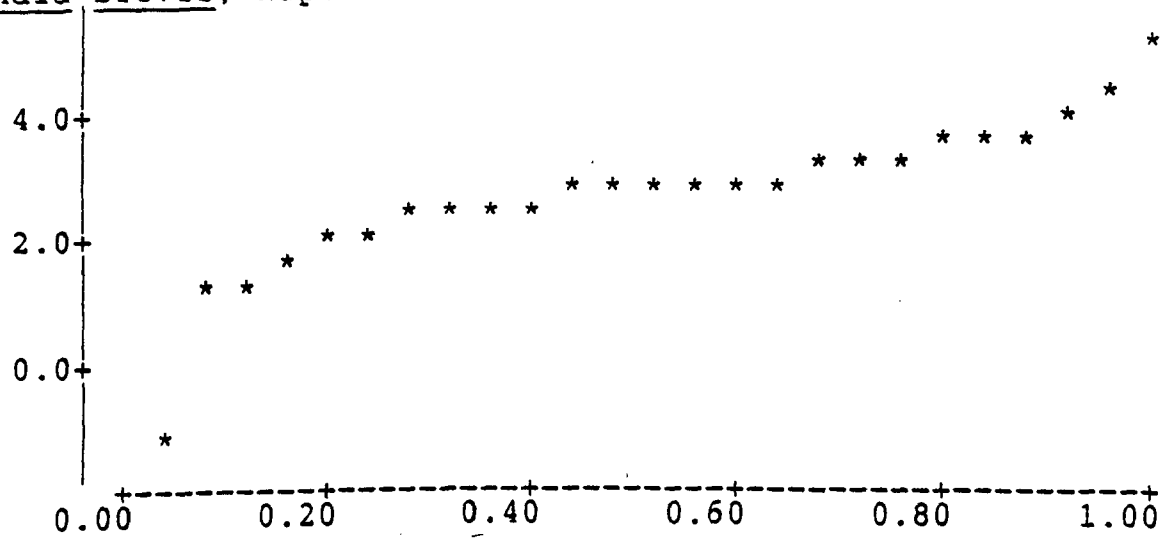
Spiophanes berkeleyorum, DDT



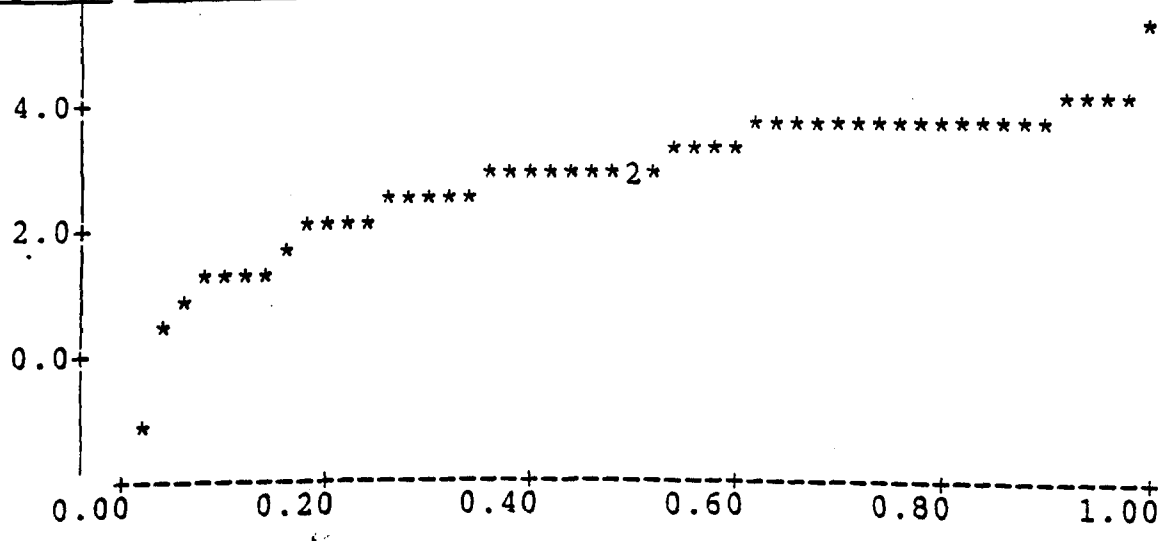
Tellina carpenteri, DDT



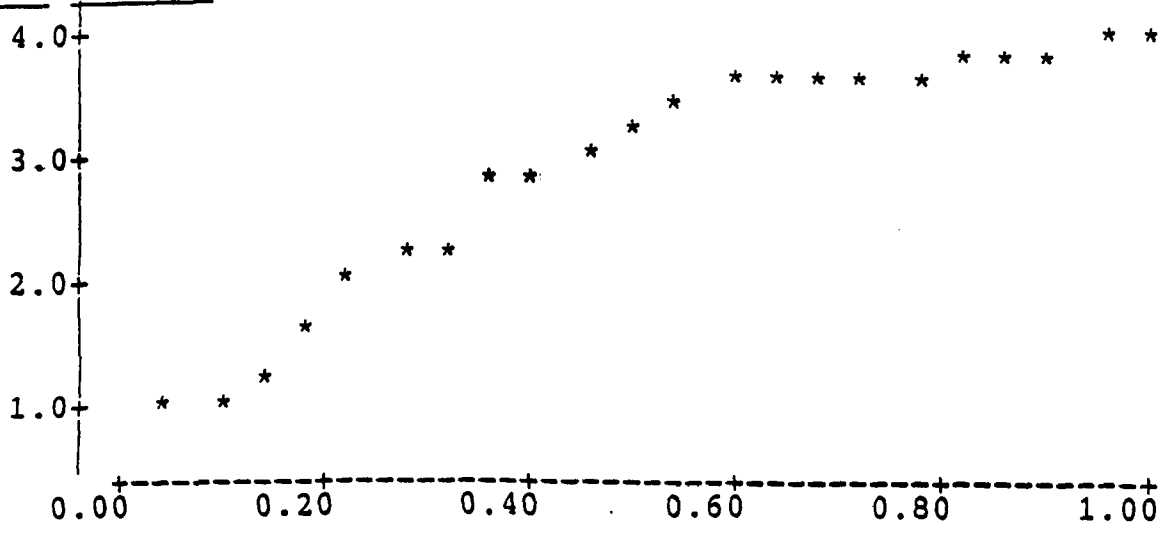
Armandia brevis, Napthalene



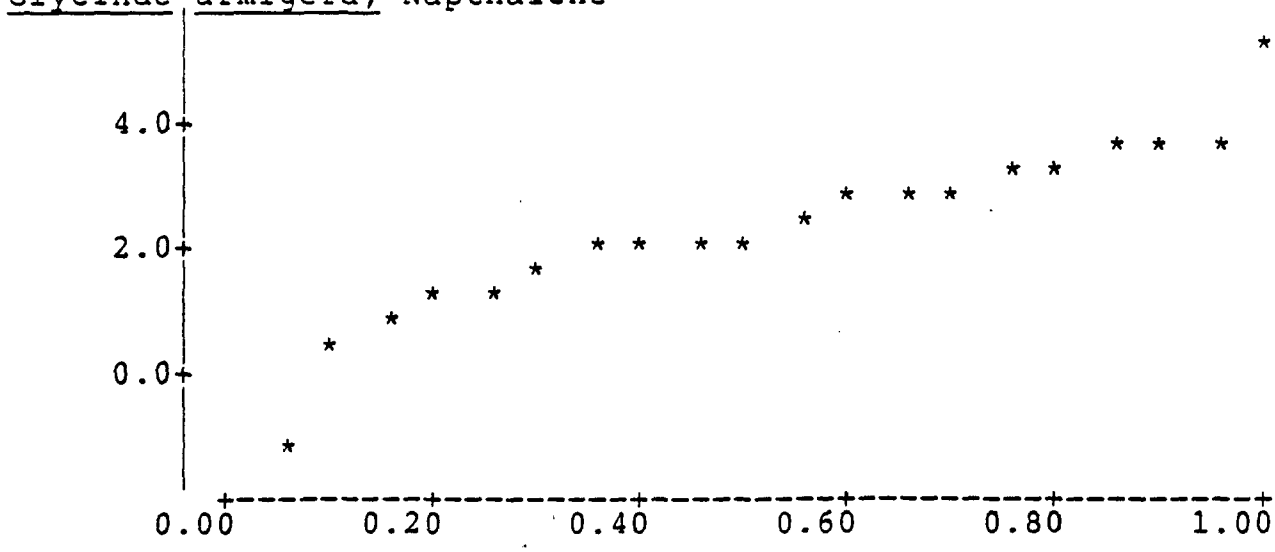
Axinopsida sericata, Napthalene



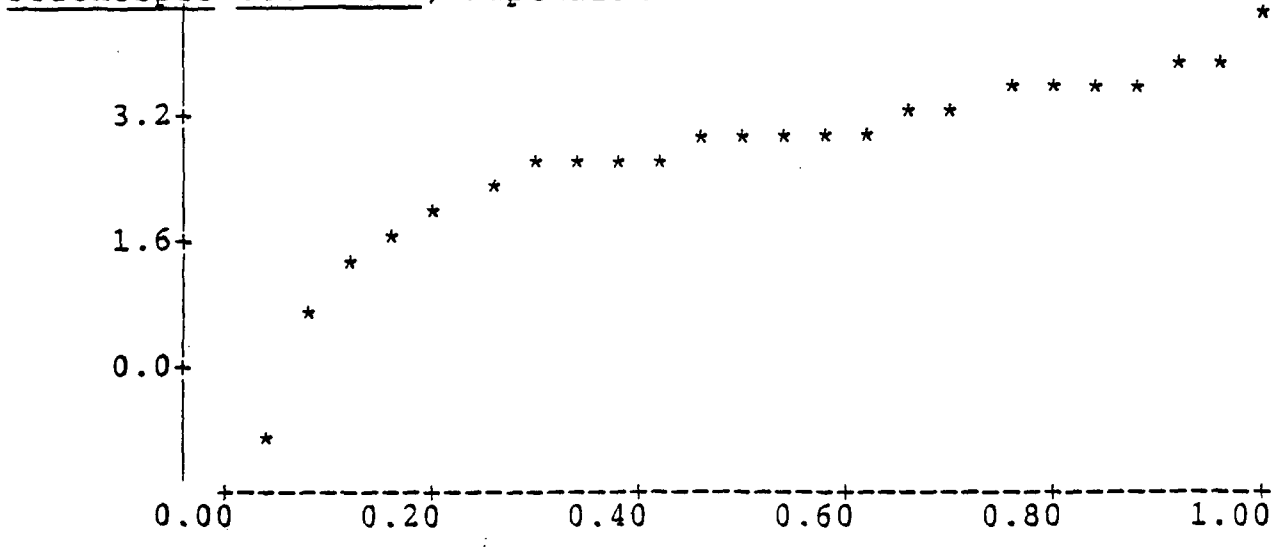
Euchone incolor, Napthalene



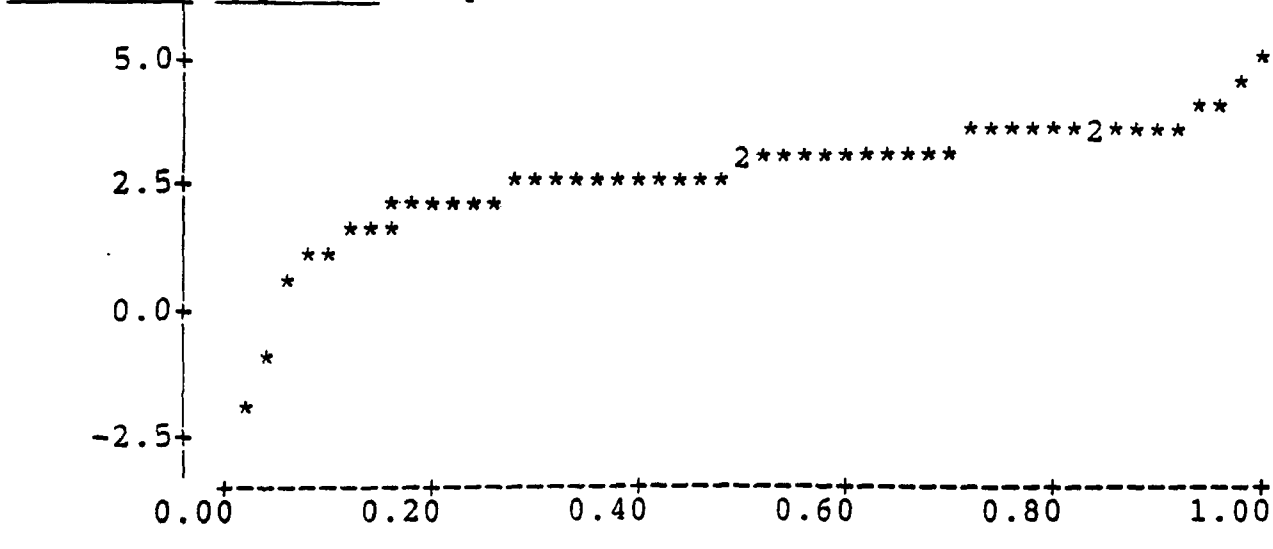
Glycinde armigera, Napthalene



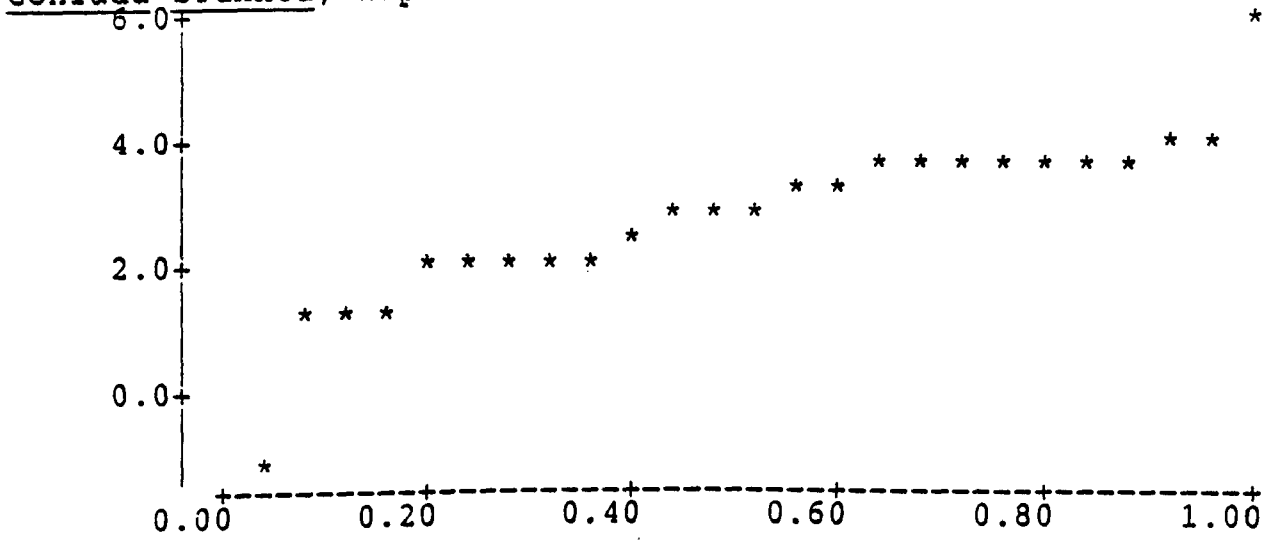
Prionospio cirrifera, Napthalene



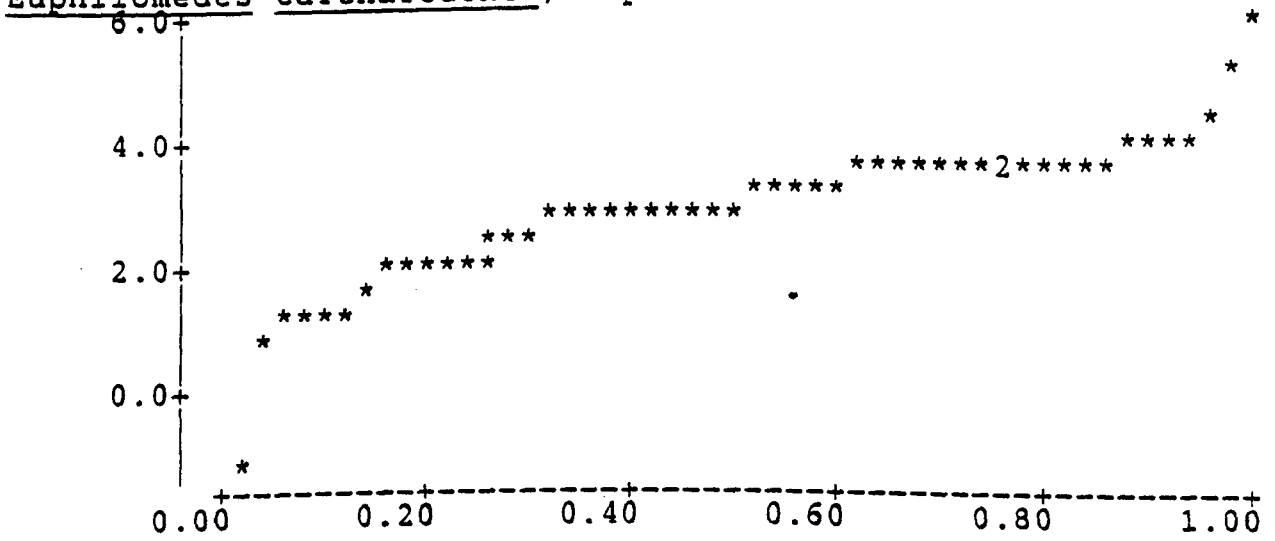
Capitella capitata, Napthalene



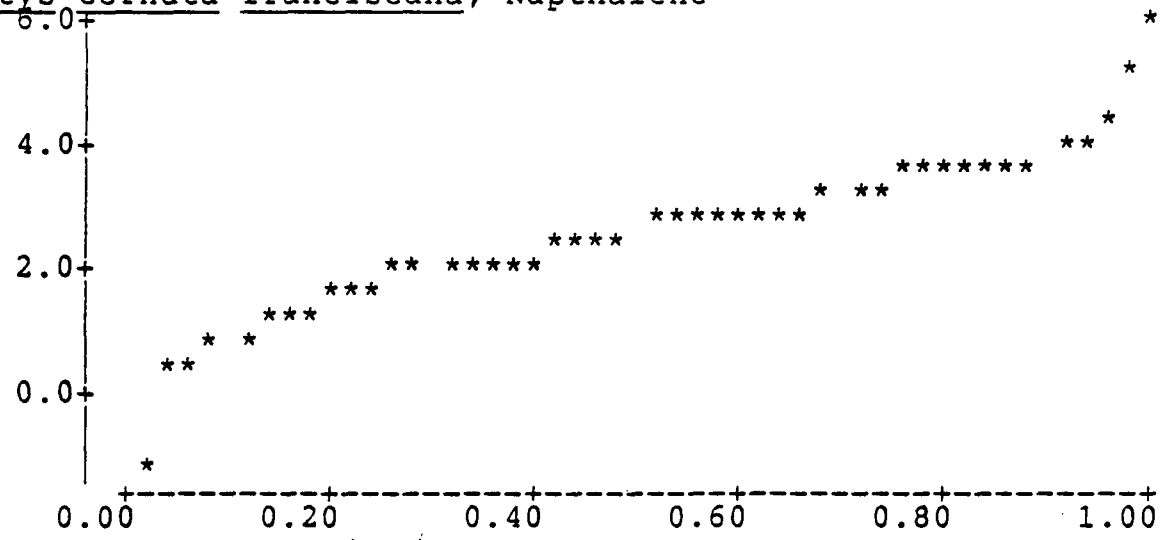
Goniada brunnea, Napthalene



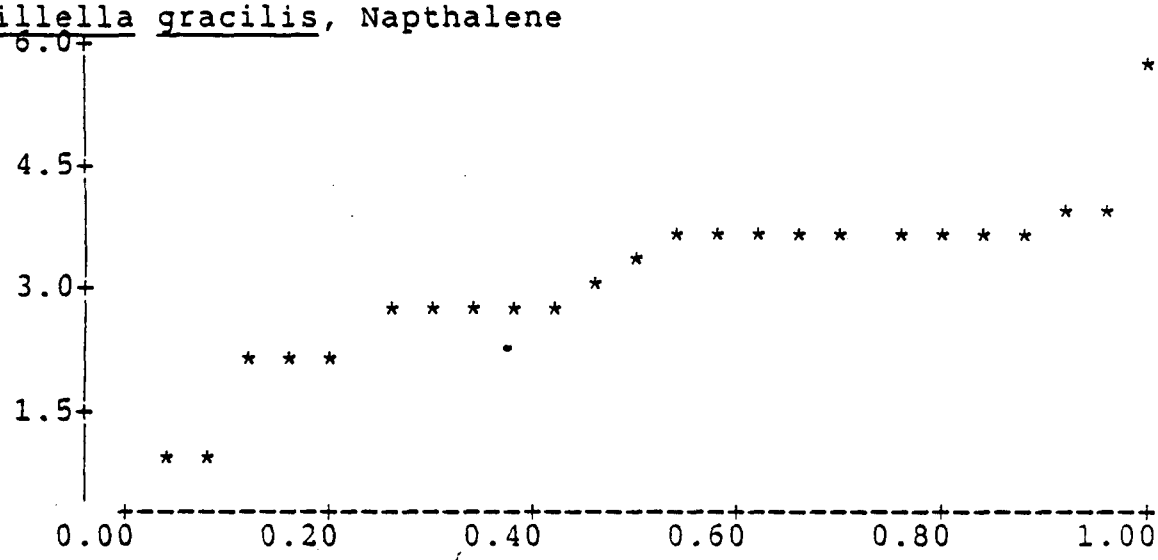
Euphilomedes carcharodonta, Napthalene



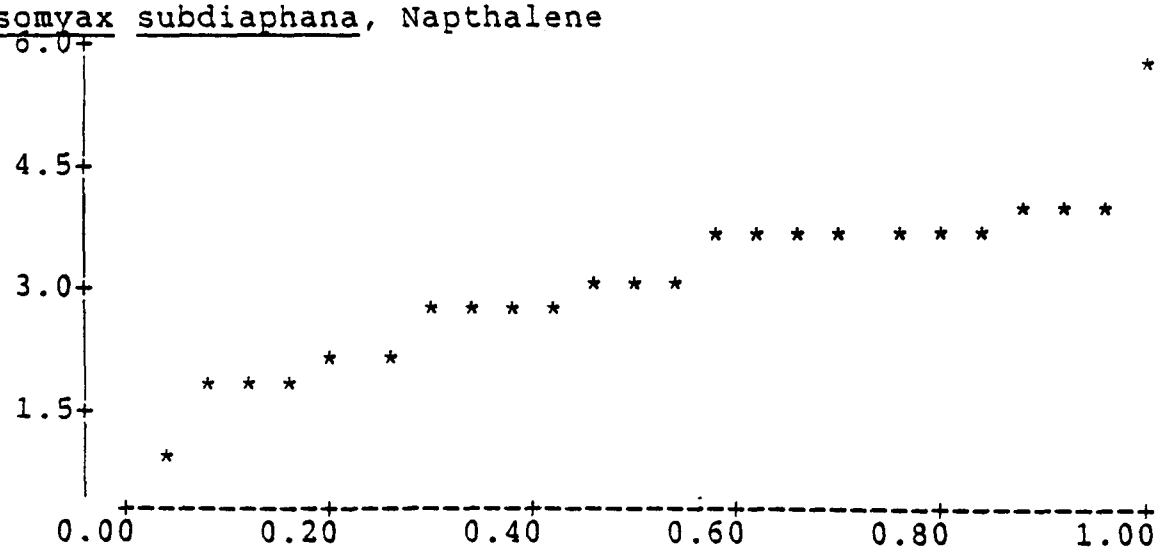
Nephtys cornuta franciscana, Napthalene



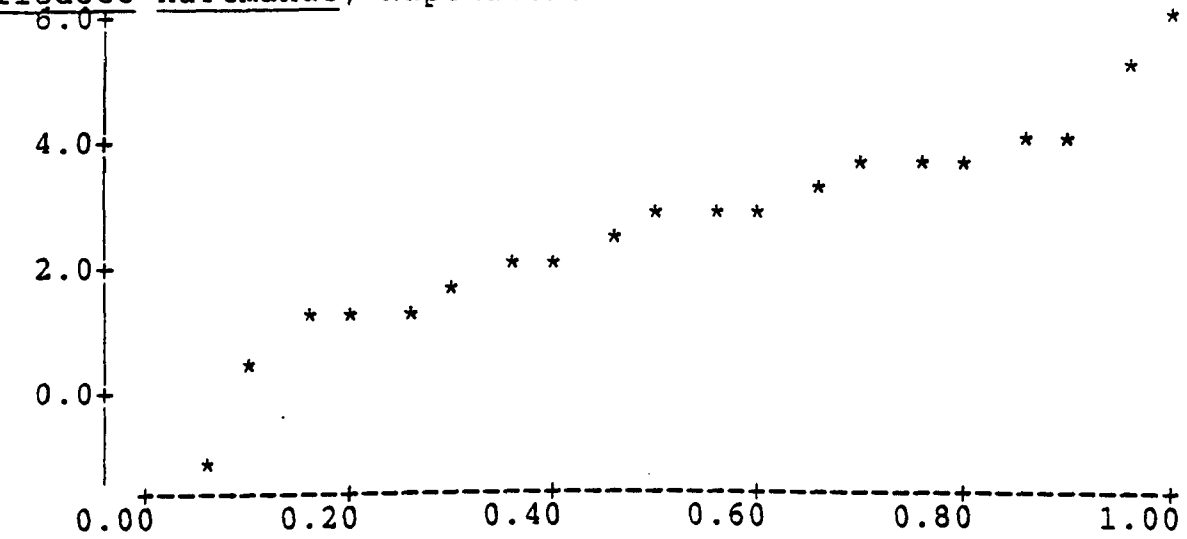
Praxillella gracilis, Napthalene



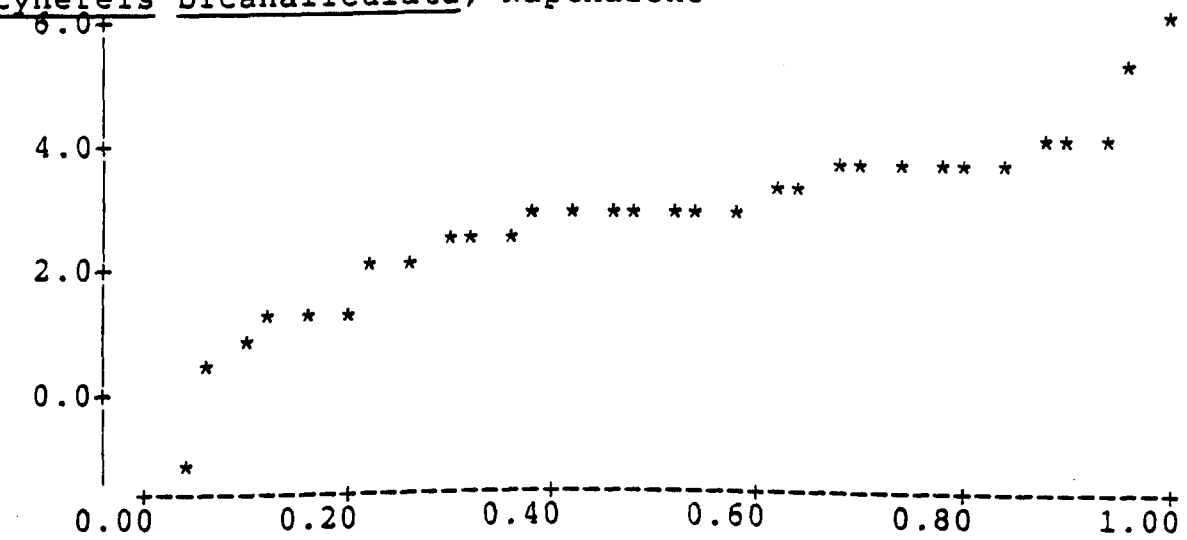
Compsomyax subdiaphana, Napthalene



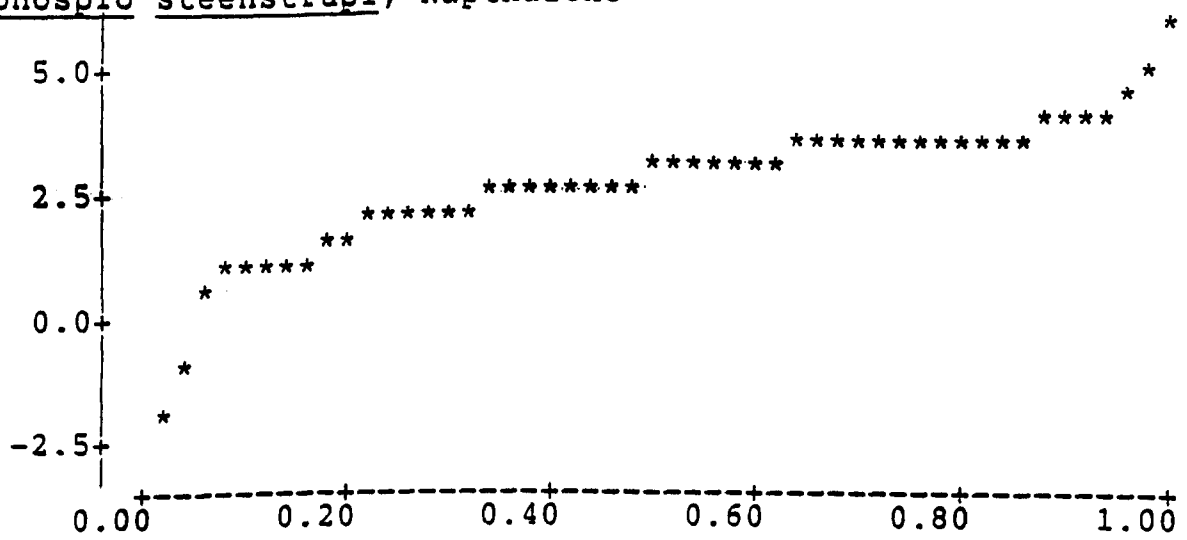
Phyllodoce hartmanae, Napthalene



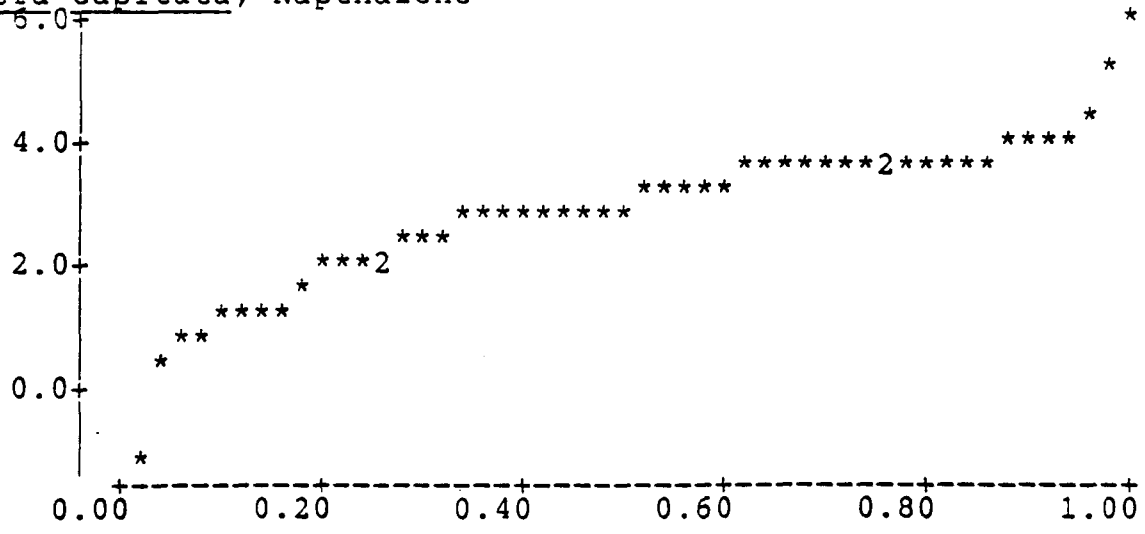
Platynereis bicanaliculata, Napthalene



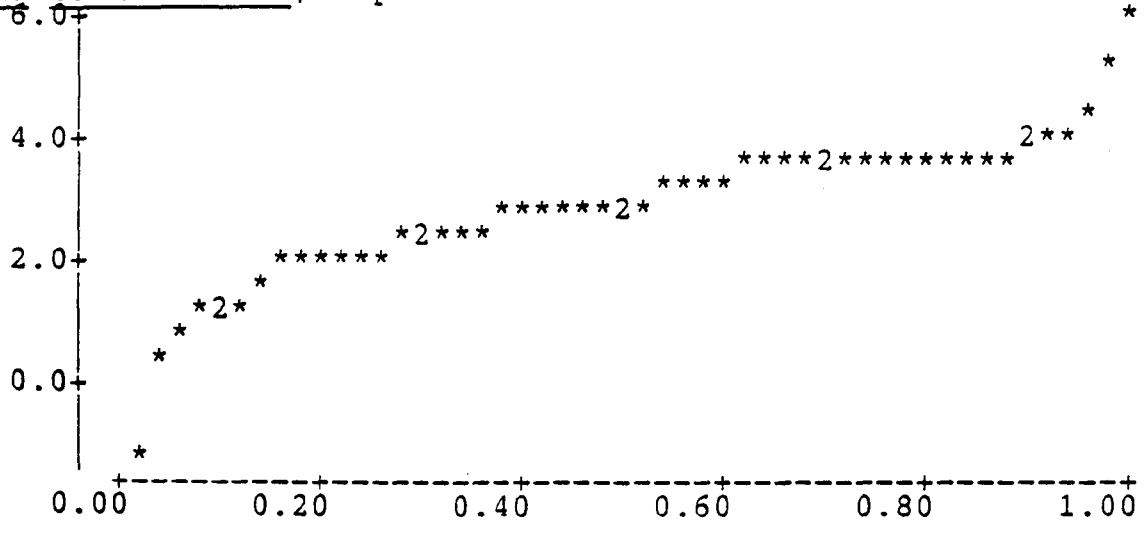
Prionospio steenstrupi, Napthalene



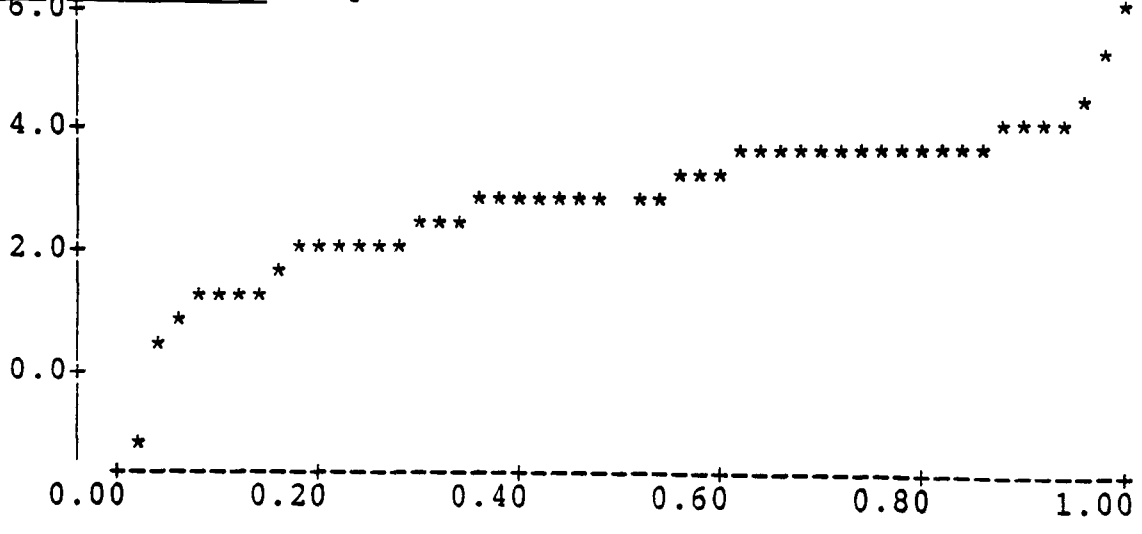
Glycera capitata, Napthalene

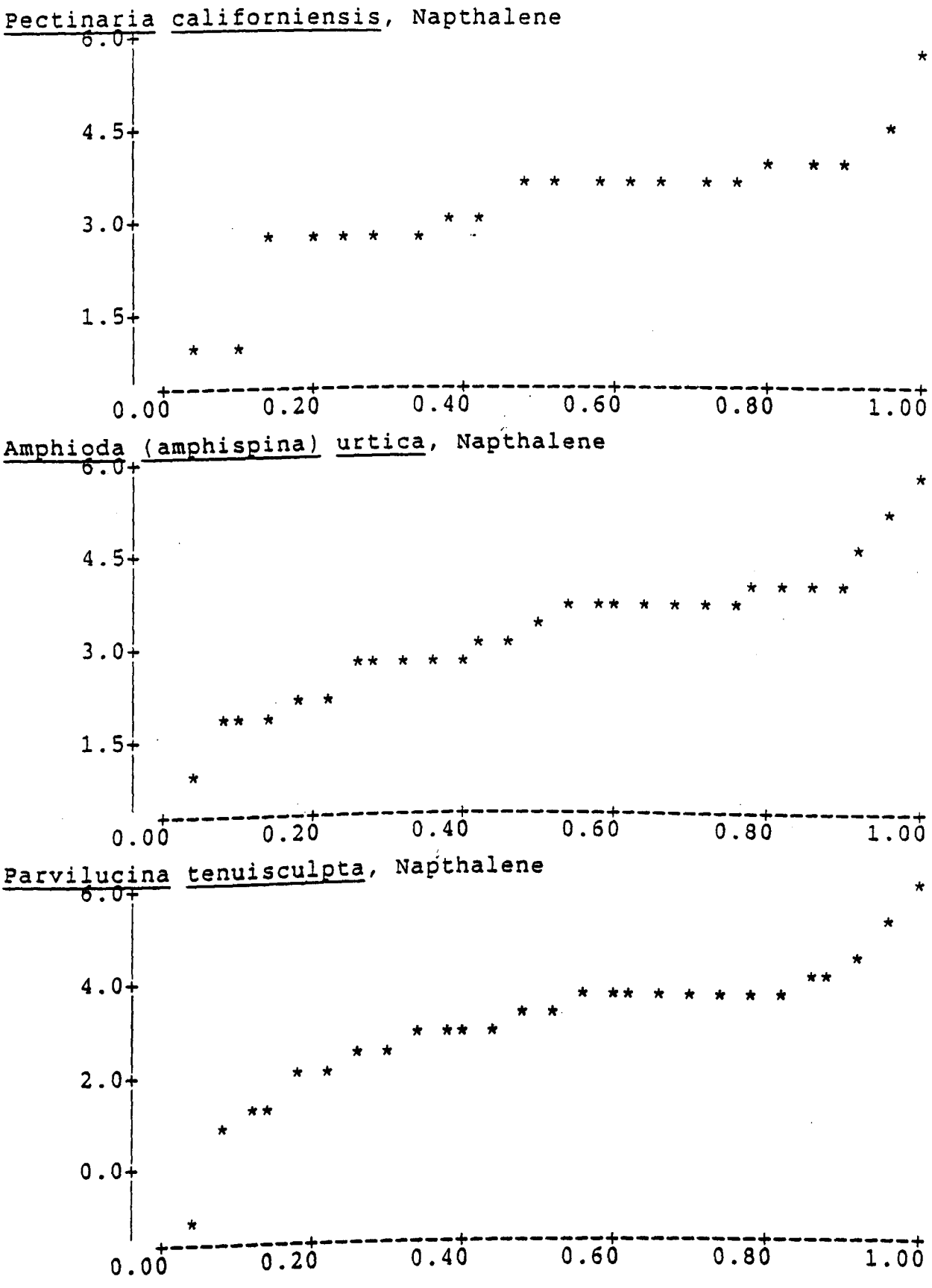


Macoma carlottensis, Napthalene

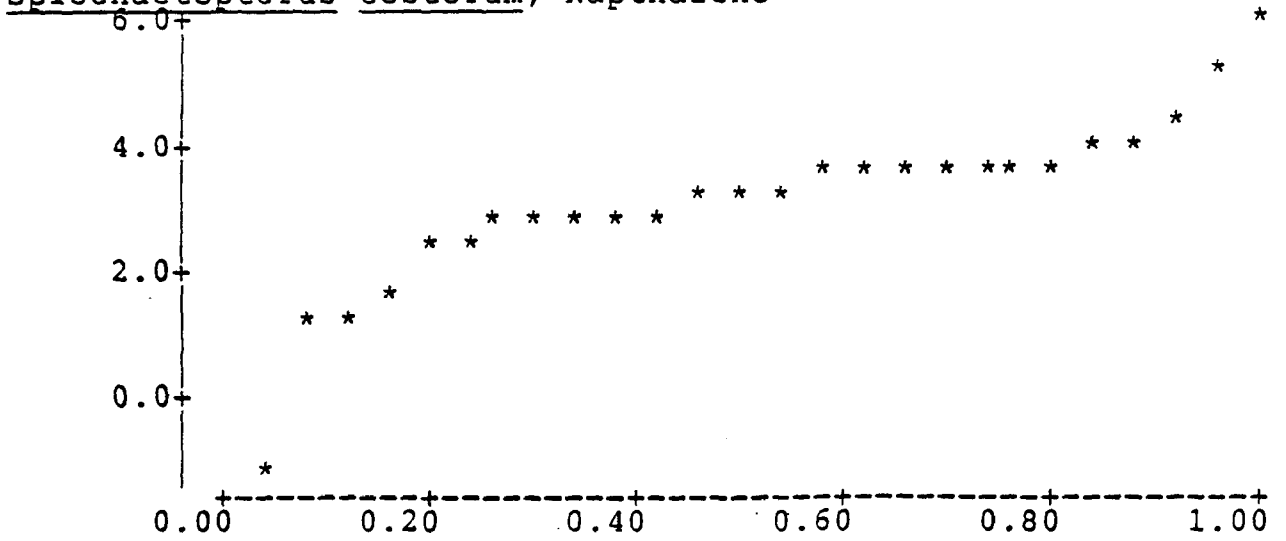


Nephtys ferruginea, Napthalene

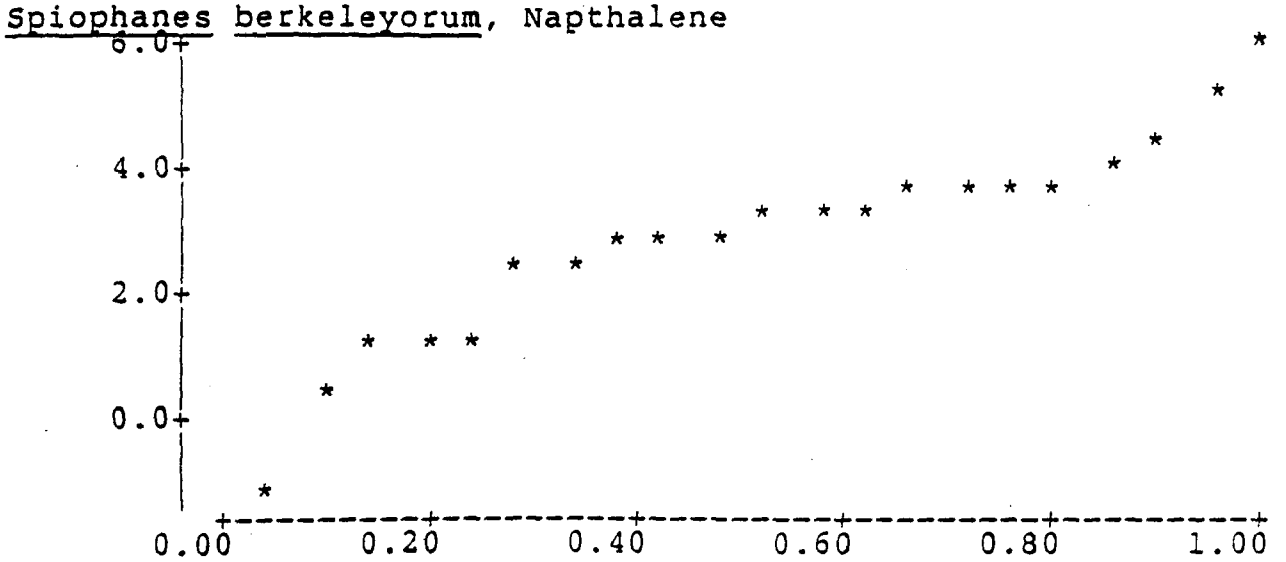



Pectinaria californiensis, Napthalene
6.0
4.5
3.0
1.5
0.00
0.20
0.40
0.60
0.80
1.00
Amphioda (amphispina) urtica, Napthalene
6.0
4.5
3.0
1.5
0.00
0.20
0.40
0.60
0.80
1.00
Parvilucina tenuisculpta, Napthalene
6.0
4.0
2.0
0.0
0.00
0.20
0.40
0.60
0.80
1.00

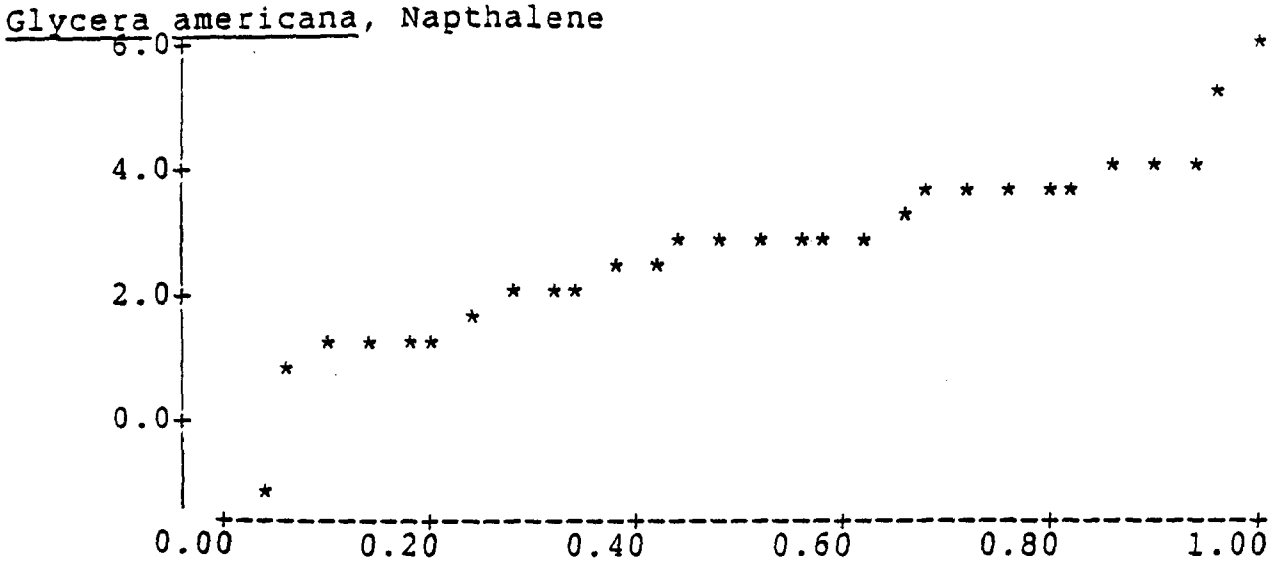
Spiochaetopterus costorum, Napthalene



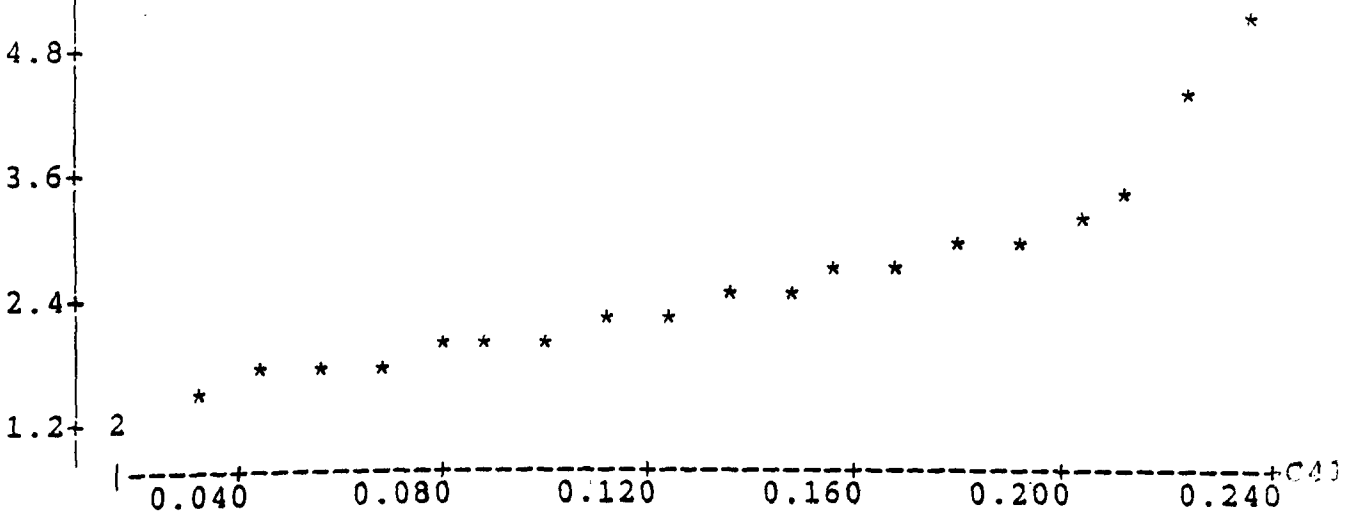
Spiophanes berkeleyorum, Napthalene



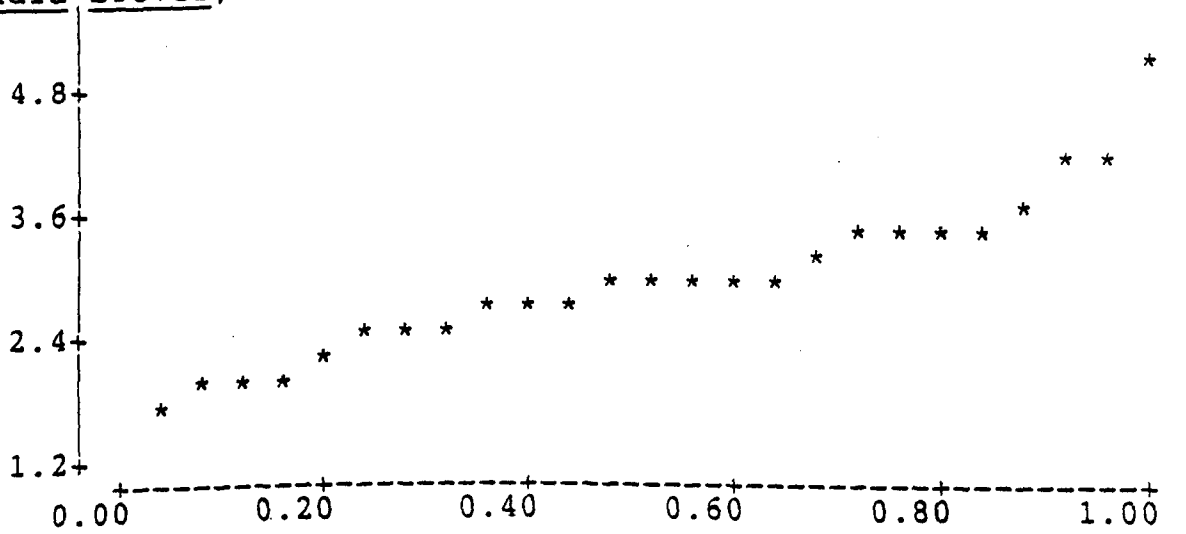
Glycera americana, Napthalene



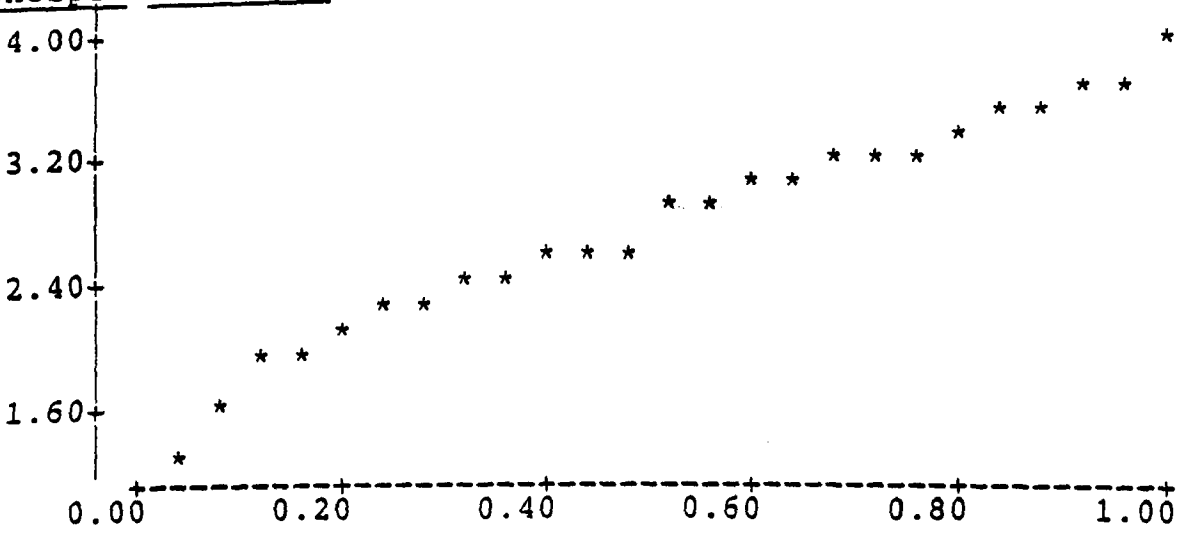
Glycinde armigera, Phenanthrene



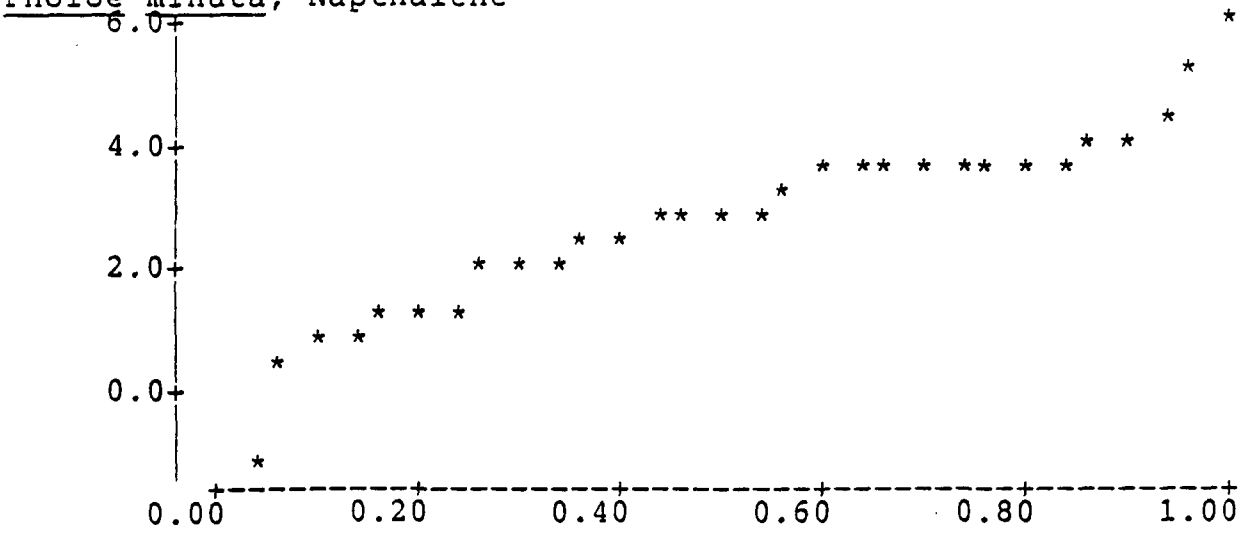
Armandia brevis, Phenanthrene



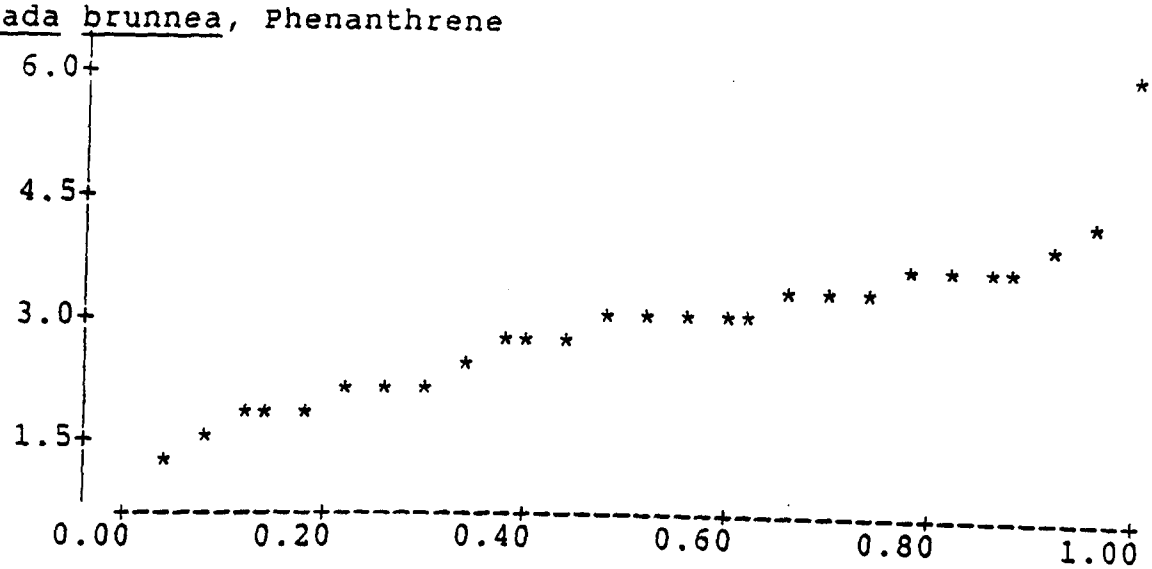
Prionospio cirrifera, Phenanthrene



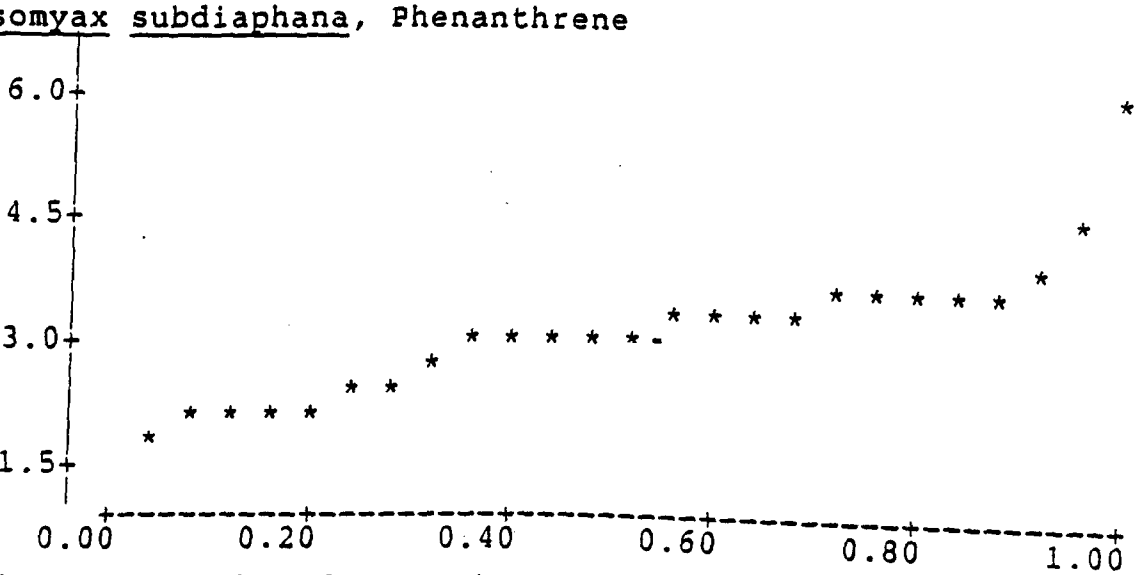
Pholoe minuta, Napthalene



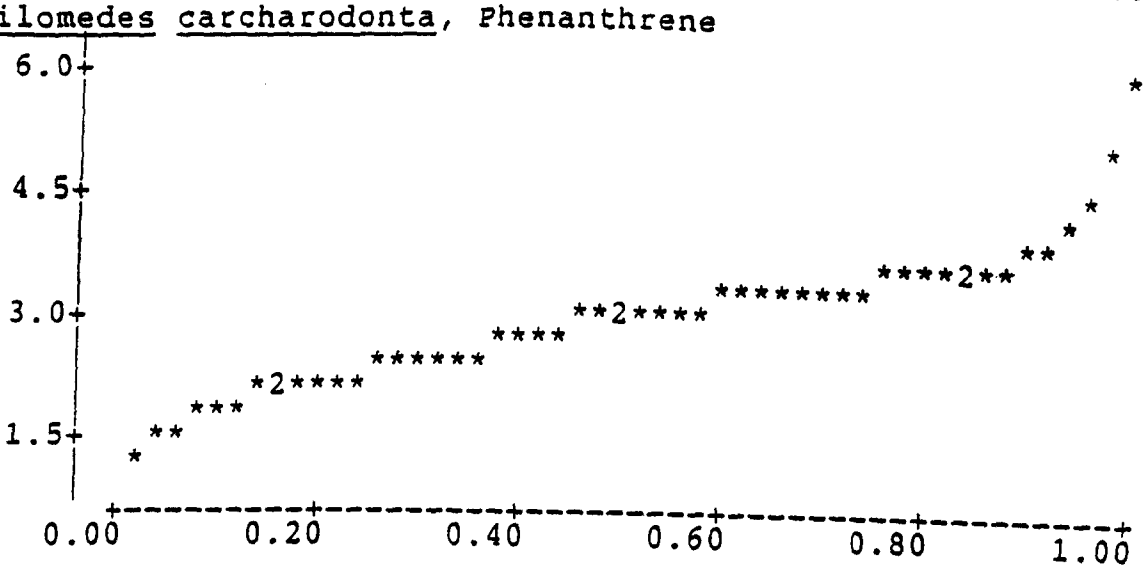
Goniada brunnea, Phenanthrene



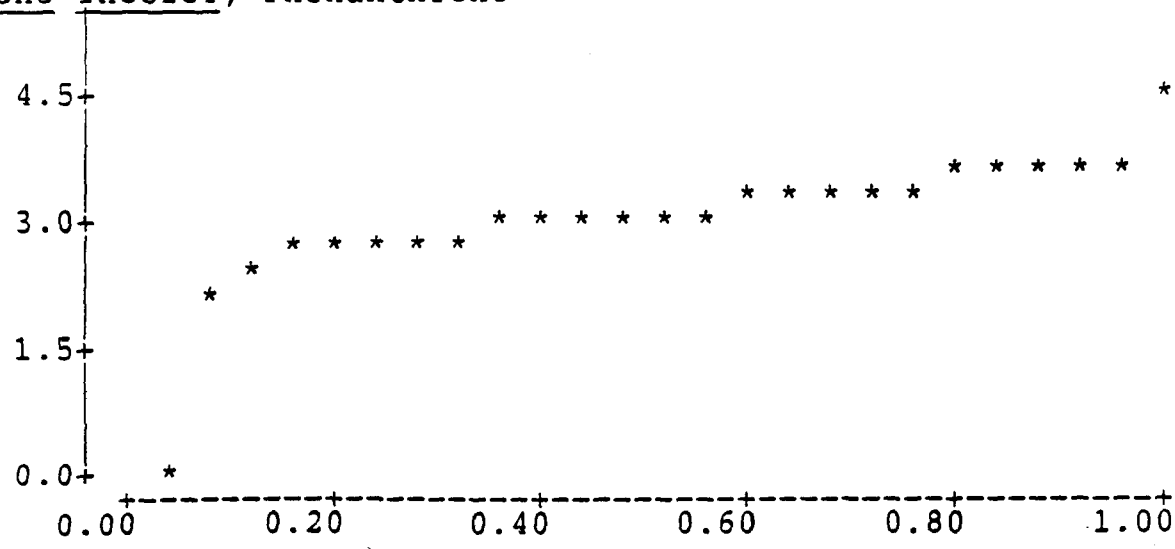
Compsomyax subdiaphana, Phenanthrene



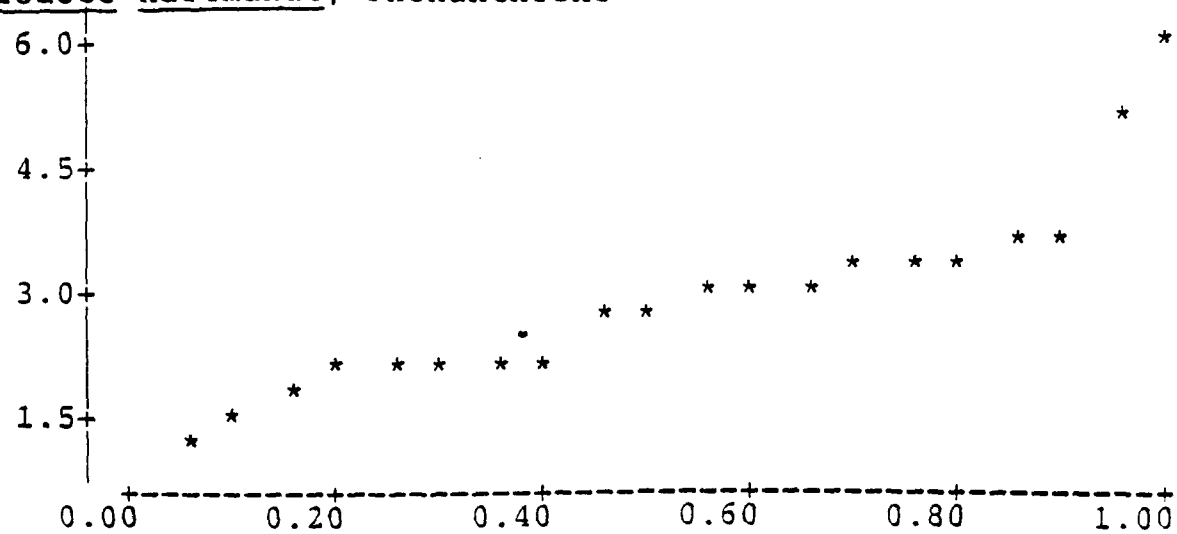
Euphilomedes carcharodonta, Phenanthrene



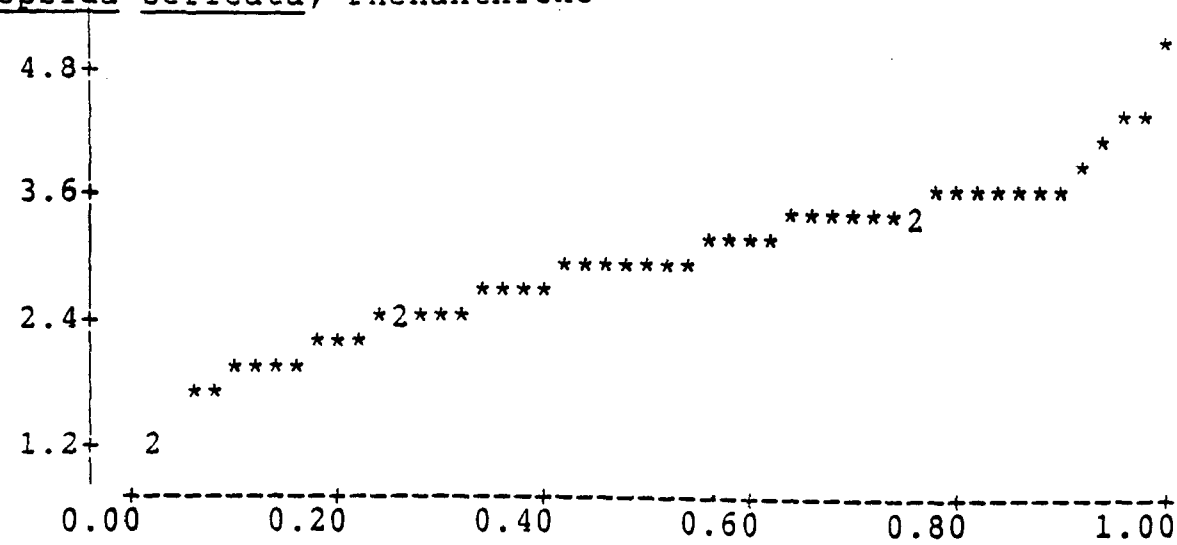
Euchone incolor, Phenanthrene



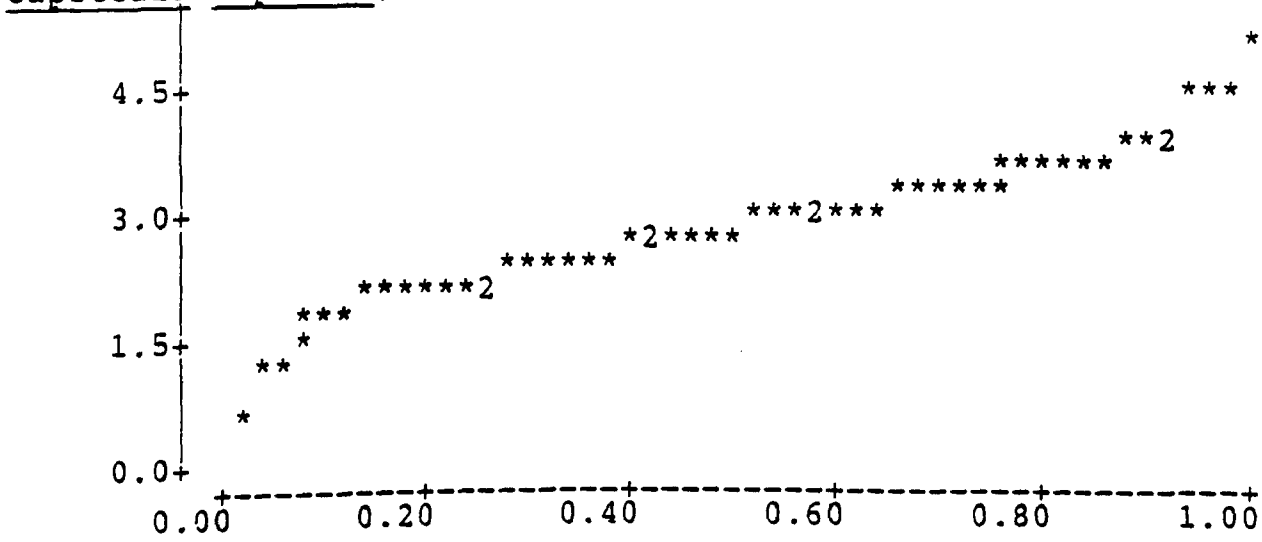
Phyllodoce hartmanae, Phenanthrene



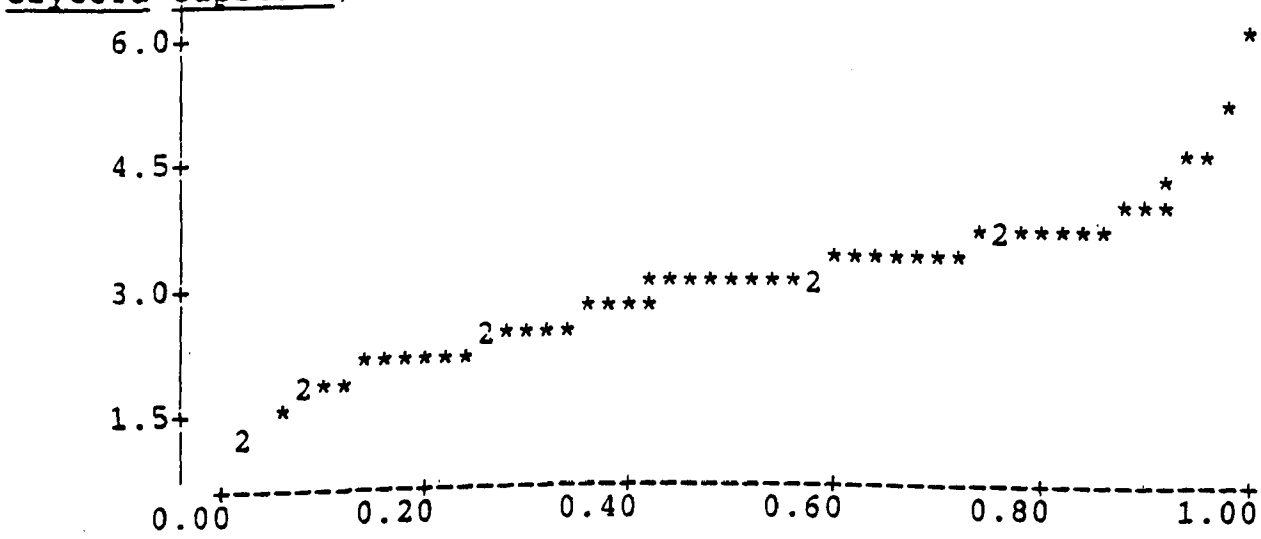
Axinopsida sericata, Phenanthrene



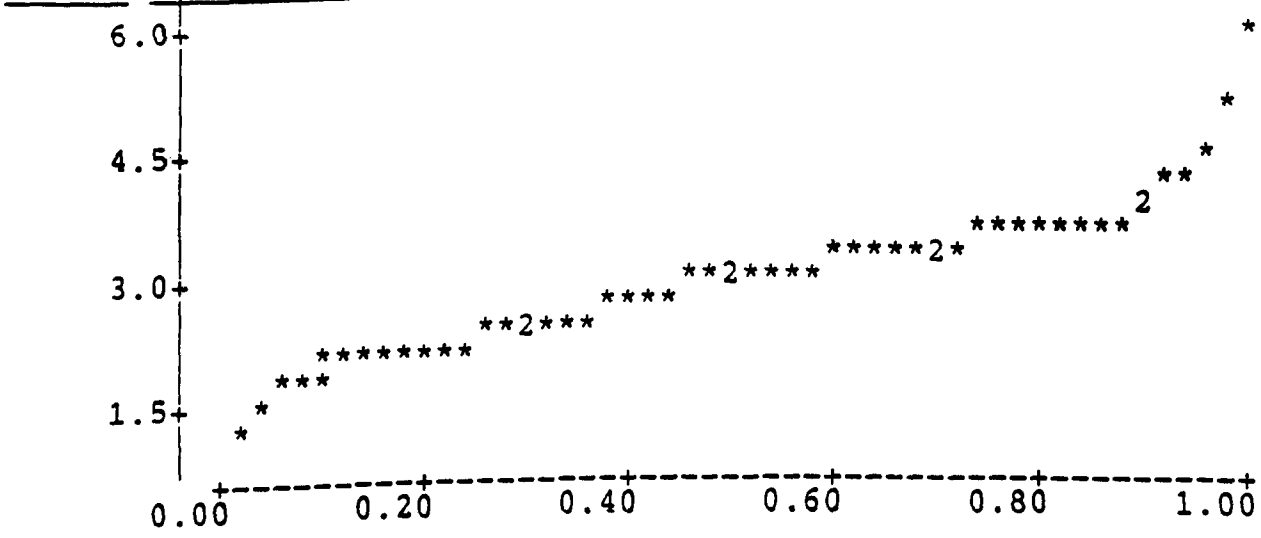
Capitella capitata, Phenanthrene



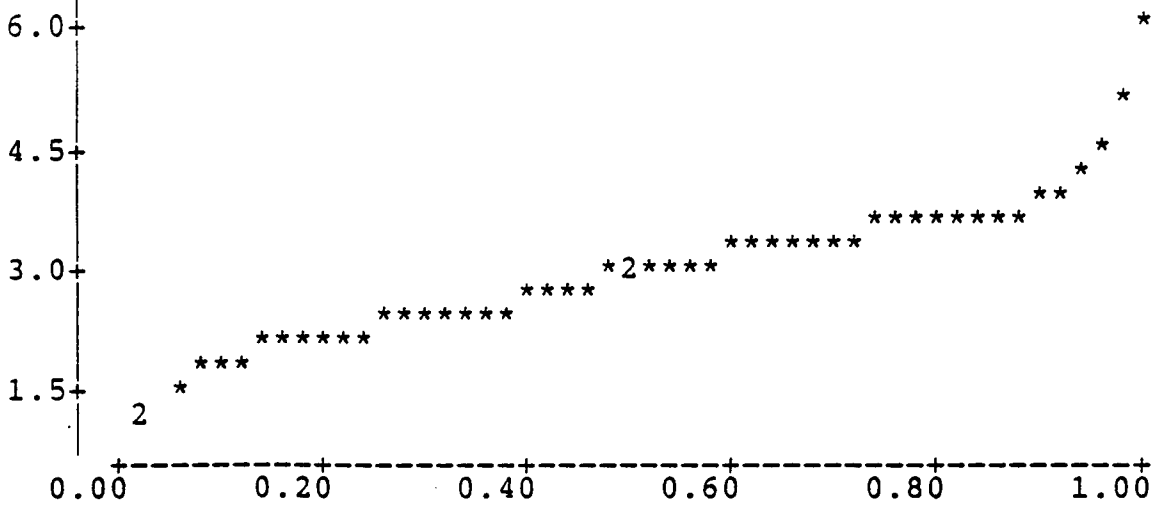
Glycera capitata, Phenanthrene



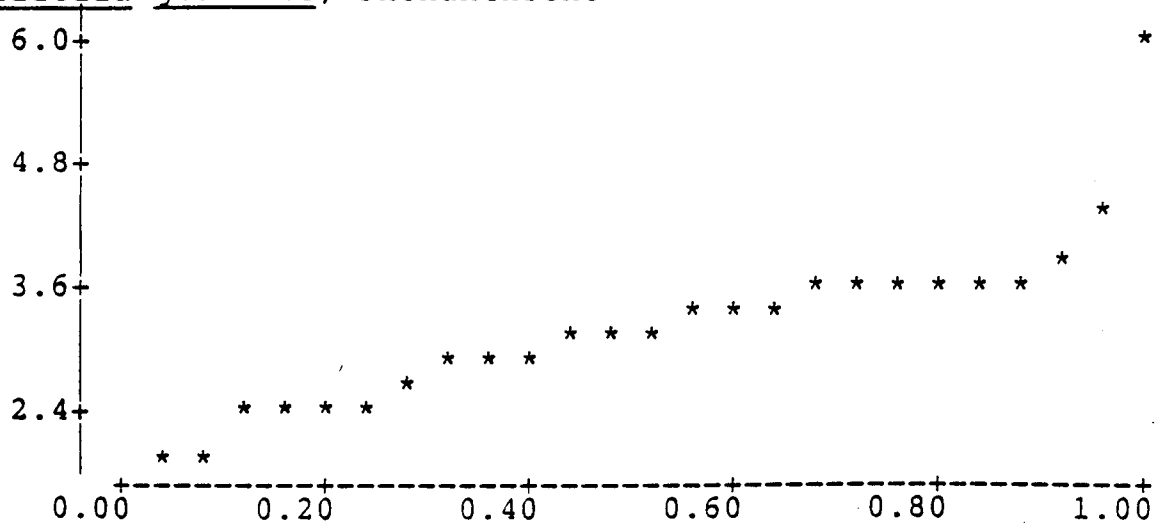
Macoma carlottensis, Phenanthrene



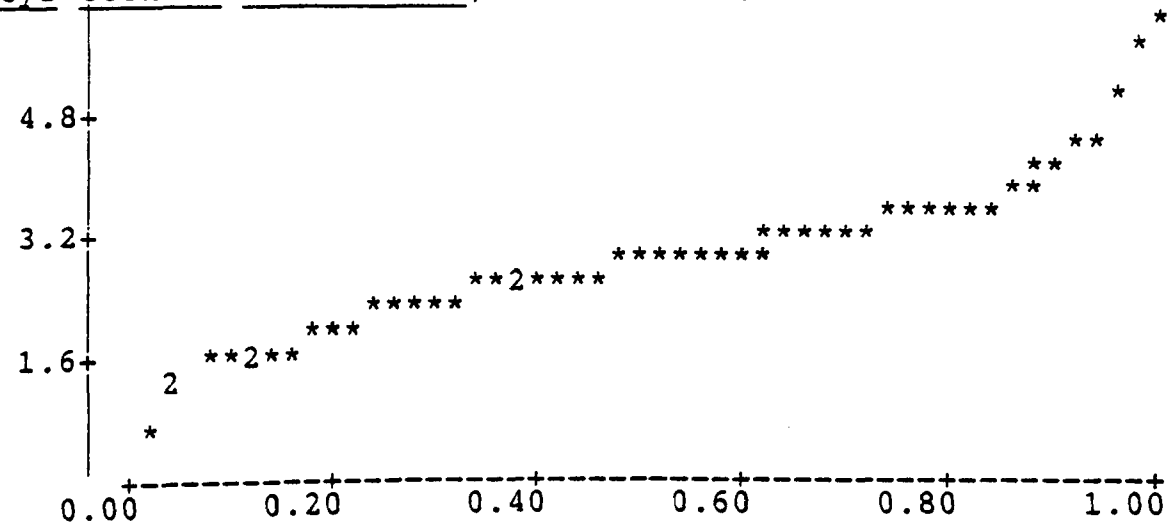
Nephtys ferruginea, Phenanthrene



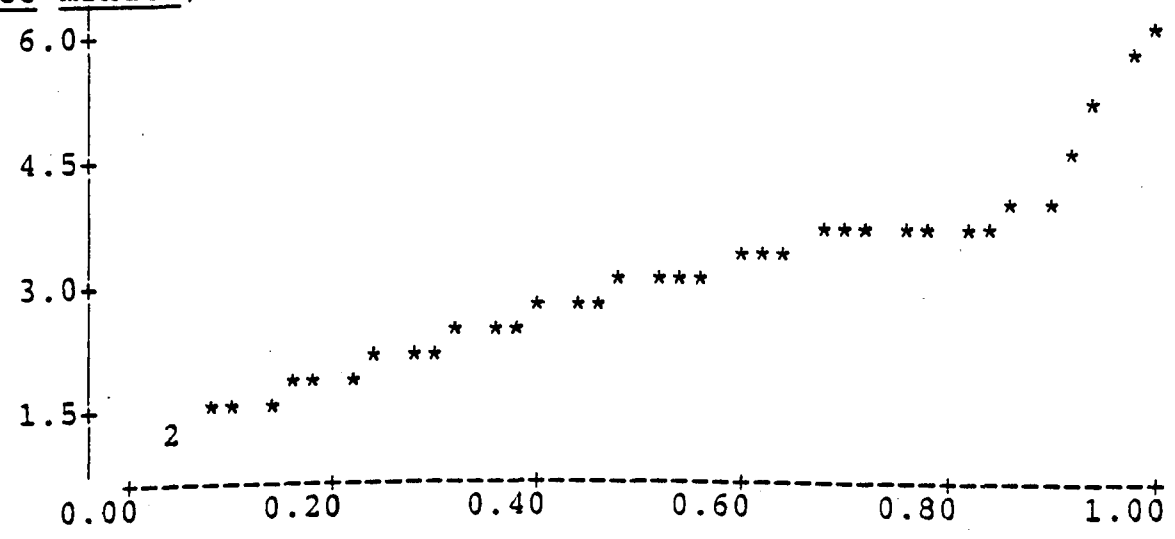
Praxillella gracilis, Phenanthrene



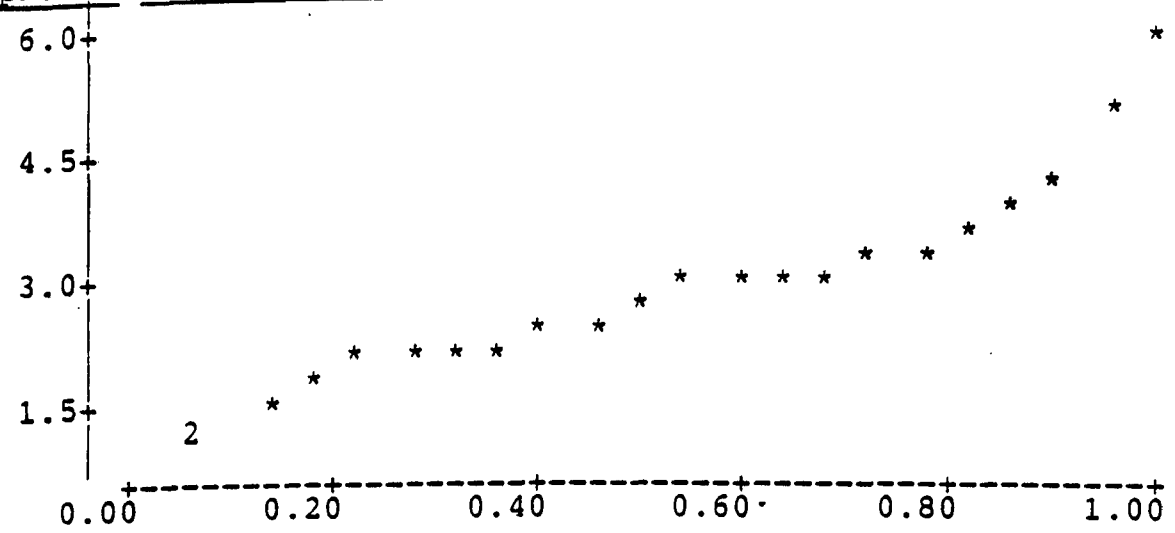
Nephtys cornuta franciscana, Phenanthrene



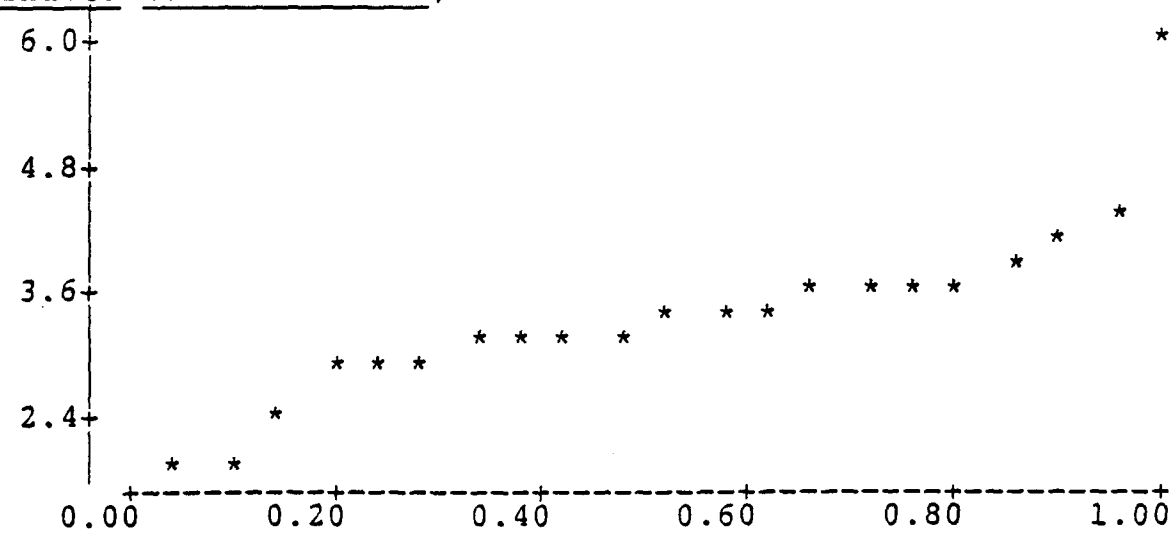
Pholoe minuta, Phenanthrene



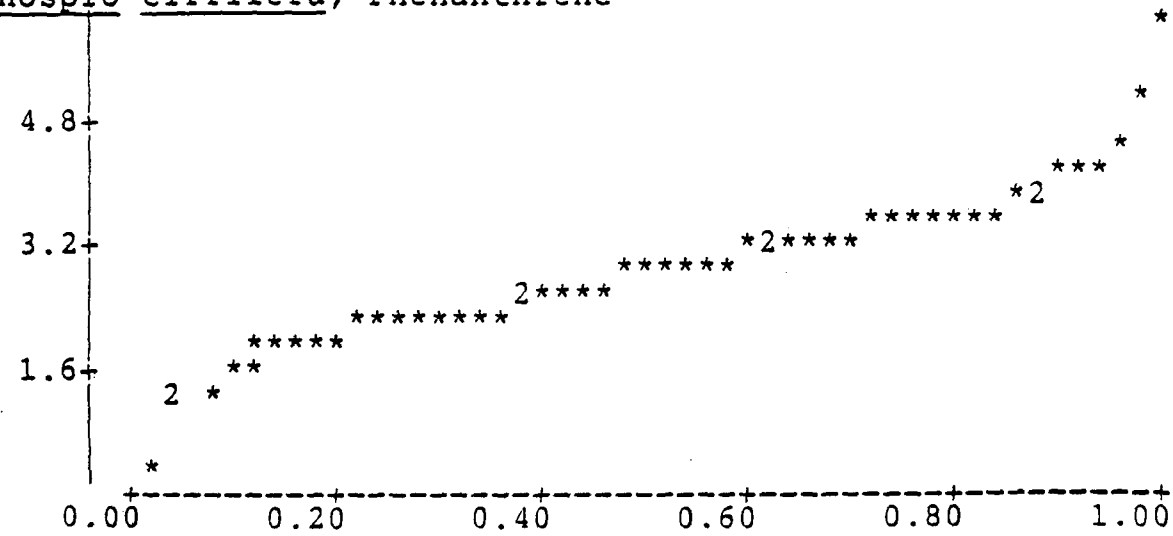
Spiophanes berkeleyorum, Phenanthrene



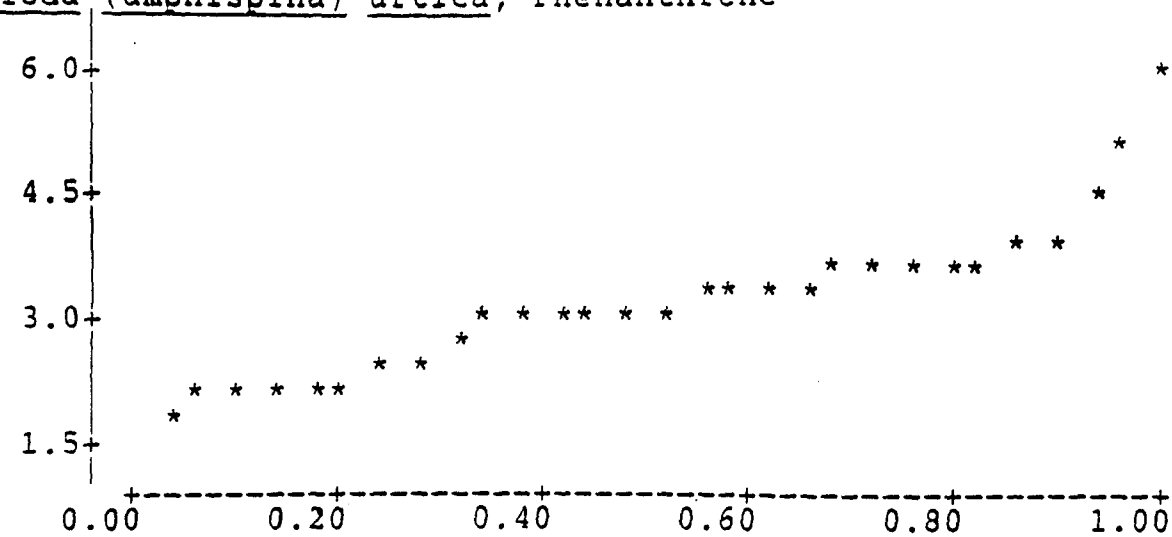
Pectinaria californiensis, Phenanthrene



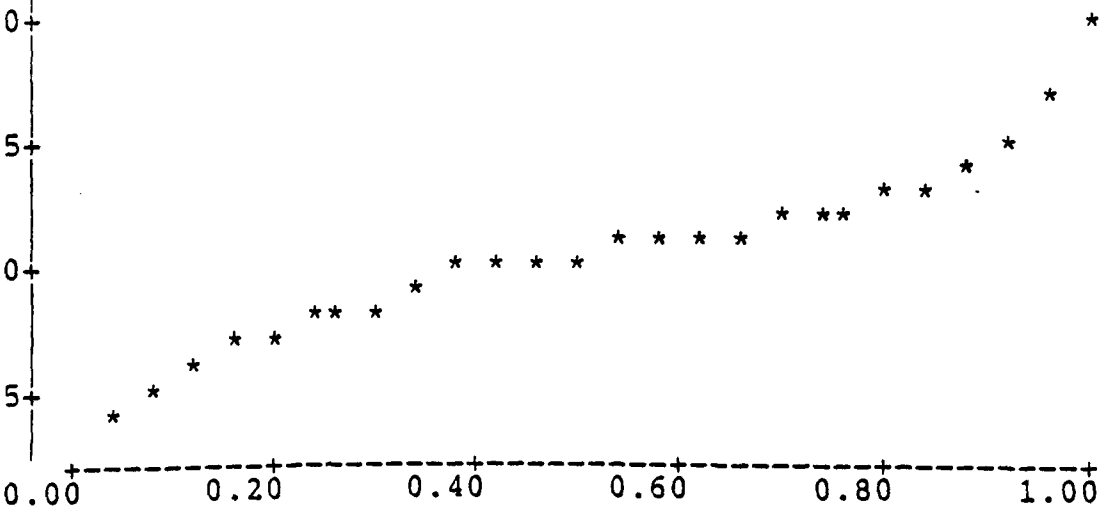
Prionospio cirrifera, Phenanthrene



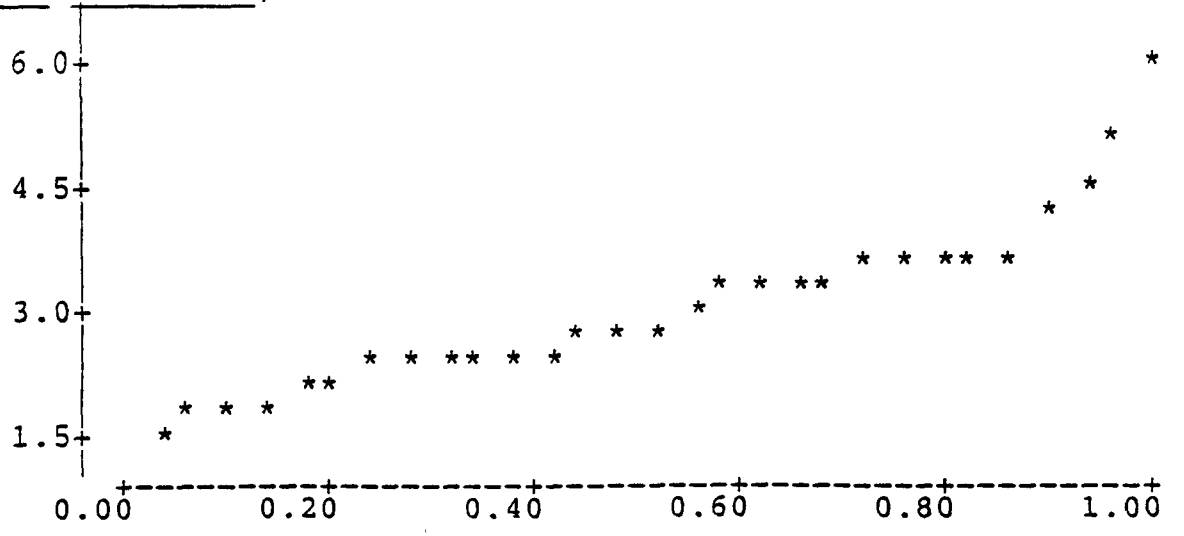
Amphioda (amphispina) urtica, Phenanthrene



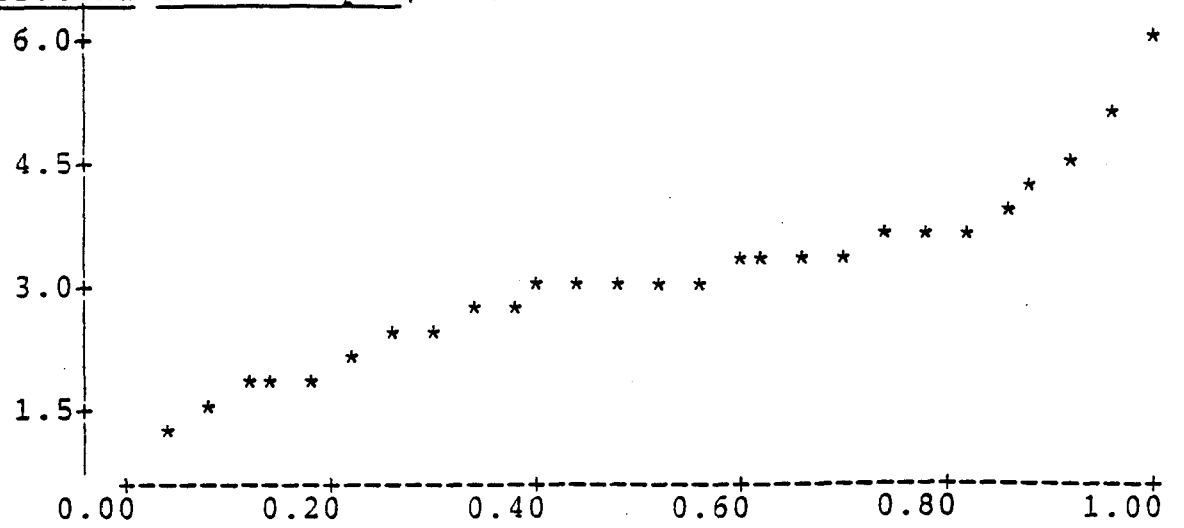
Spiochaetopterus costorum, Phenanthrene



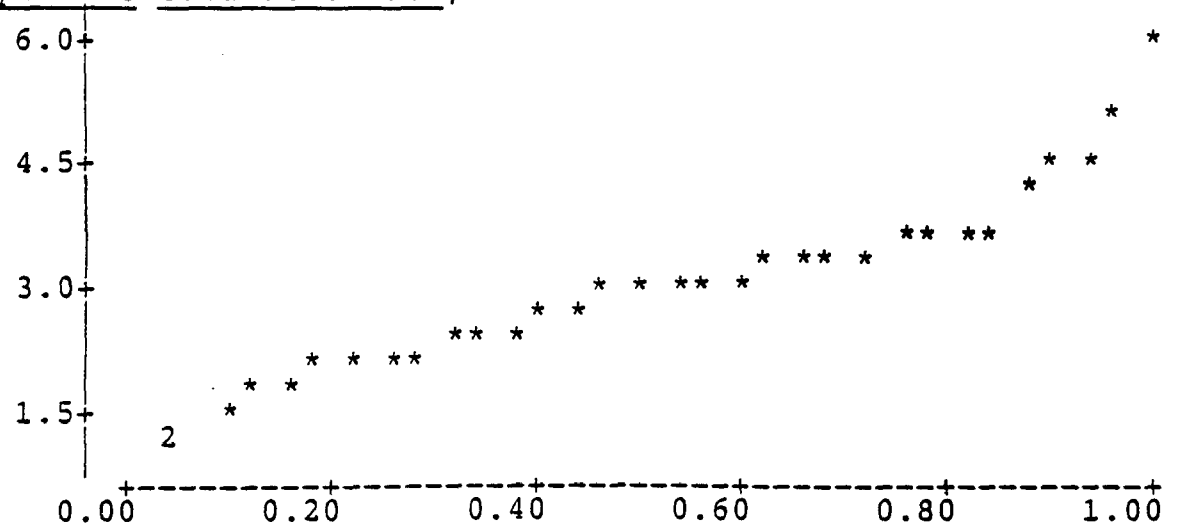
Glycera americana, Phenanthrene



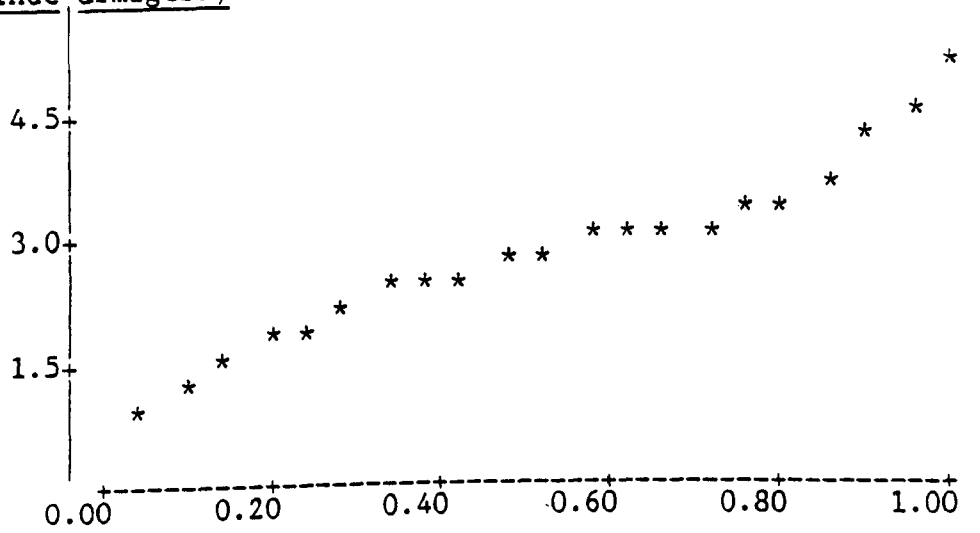
Parvilucina tenuisculpta, Phenanthrene



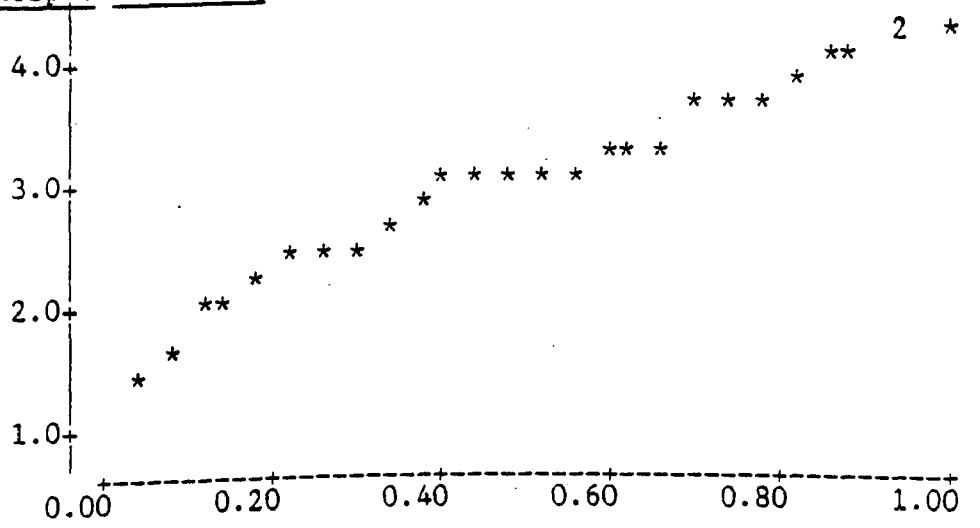
Platynereis bicanaliculata, Phenanthrene



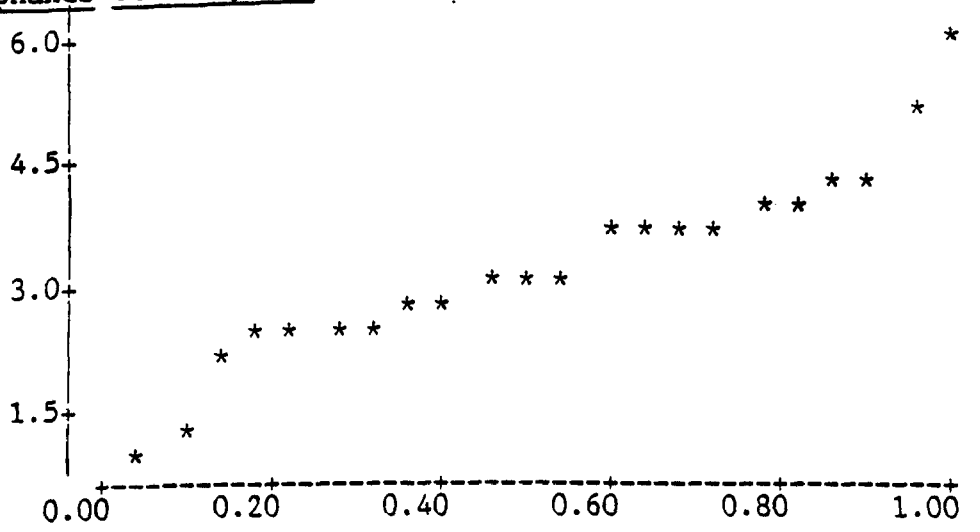
Glycinde armigera, Flouranthrene



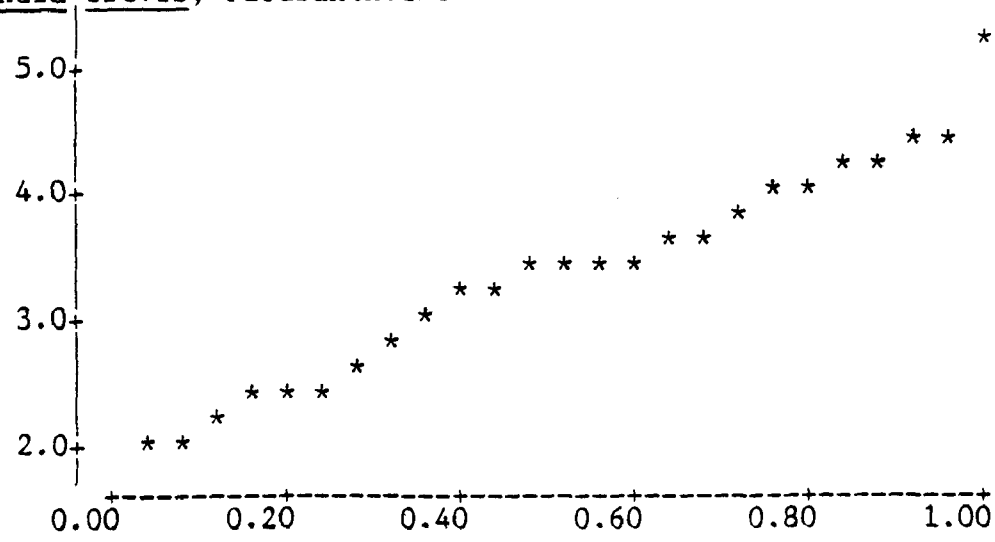
Prionospio cirrifera, Flouranthrene



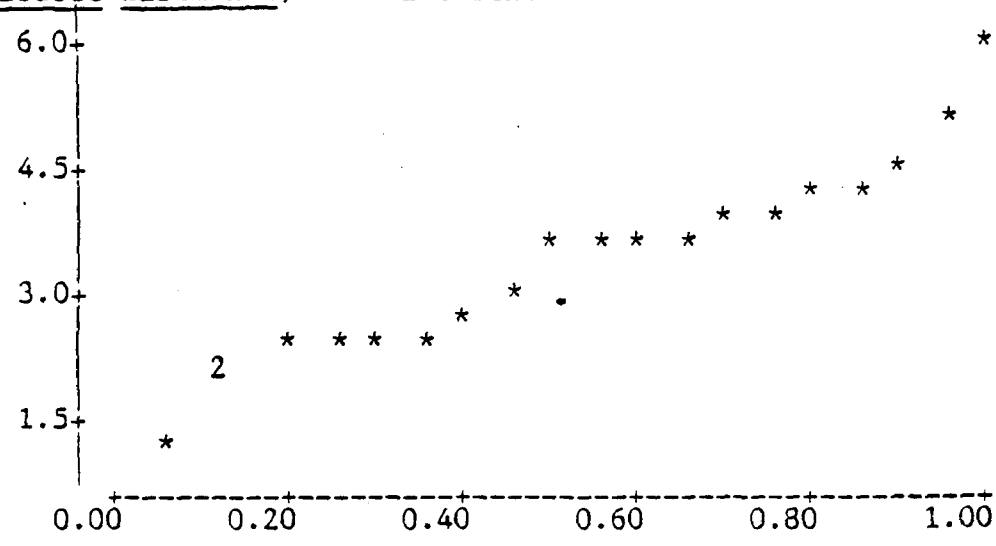
Spiophanes berkeleyorum, Flouranthrene



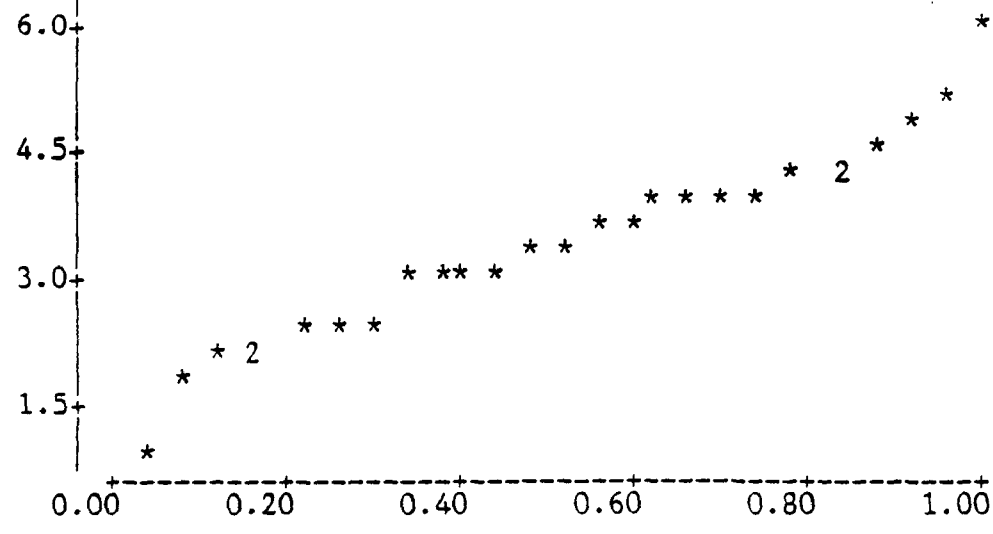
Armandia brevis, Flouranthrene



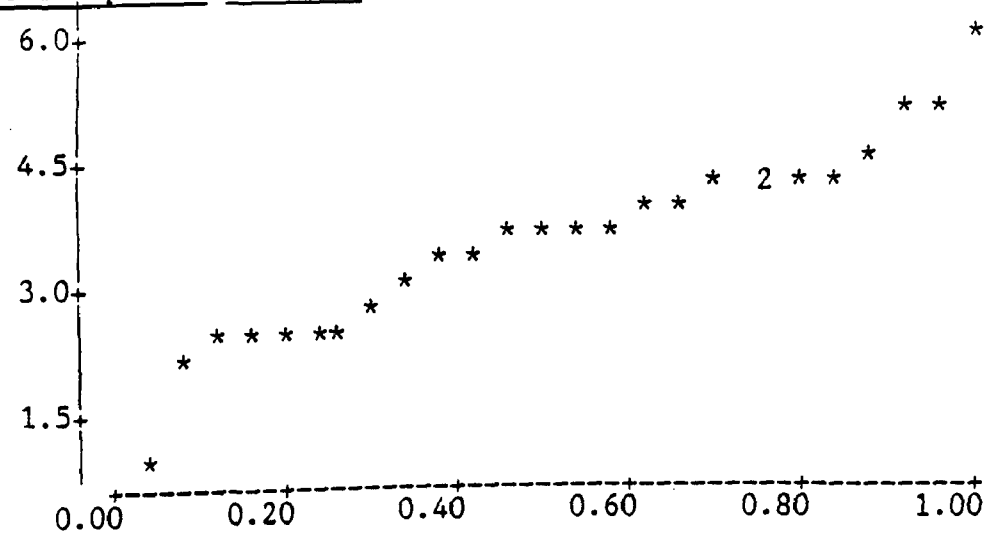
Phyllodoce hartmanae, Flouranthrene



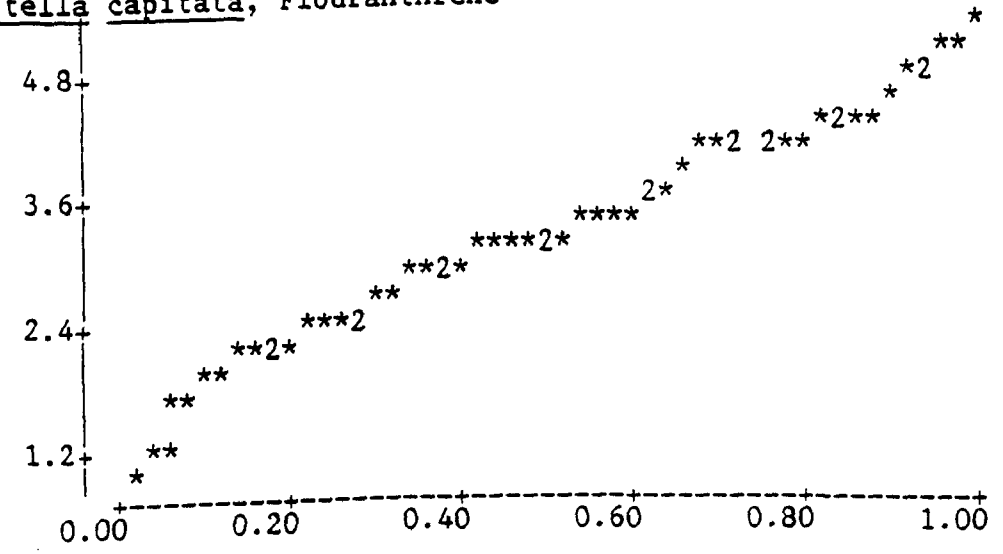
Goniada brunnea, Flouranthrene



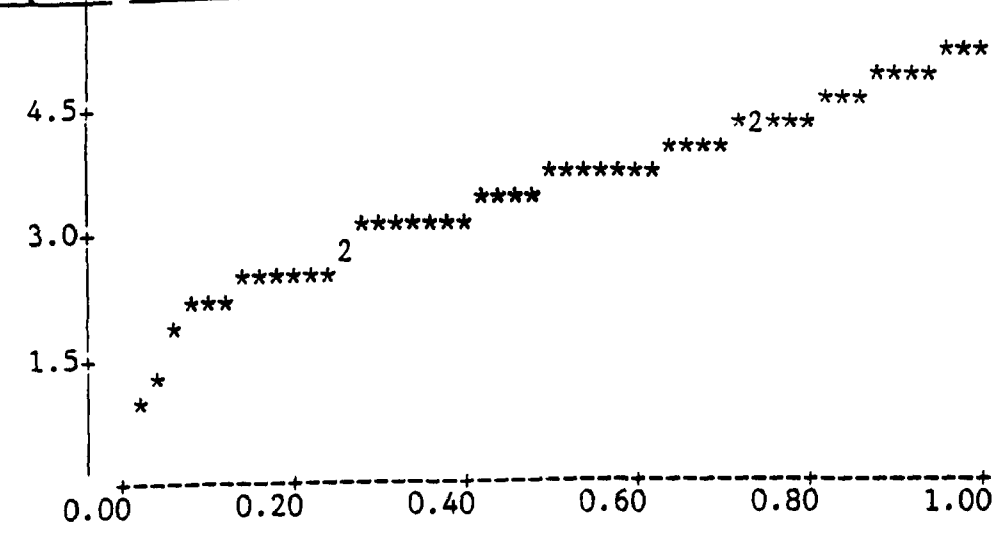
Spiochaetopterus costorum, Flouranthrene



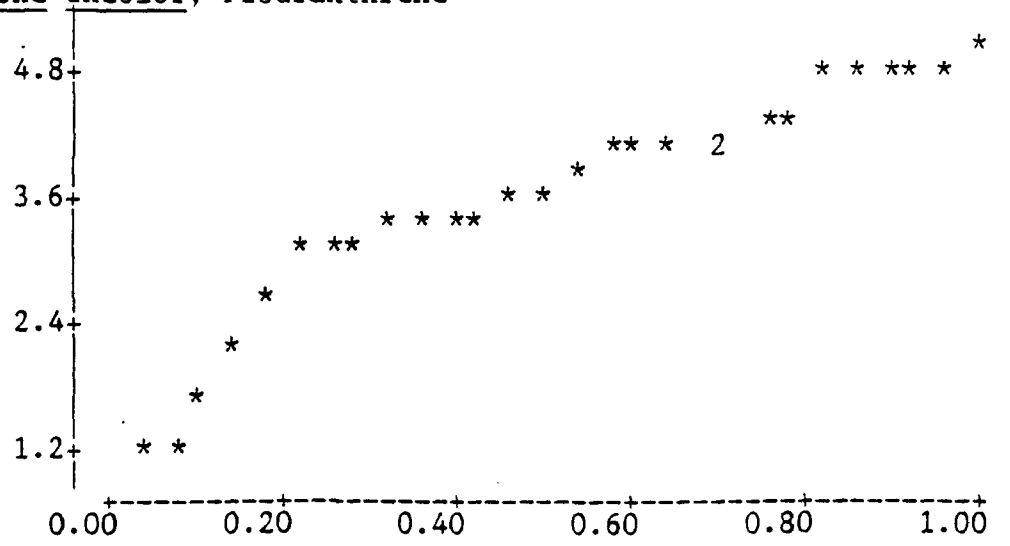
Capitella capitata, Flouranthrene



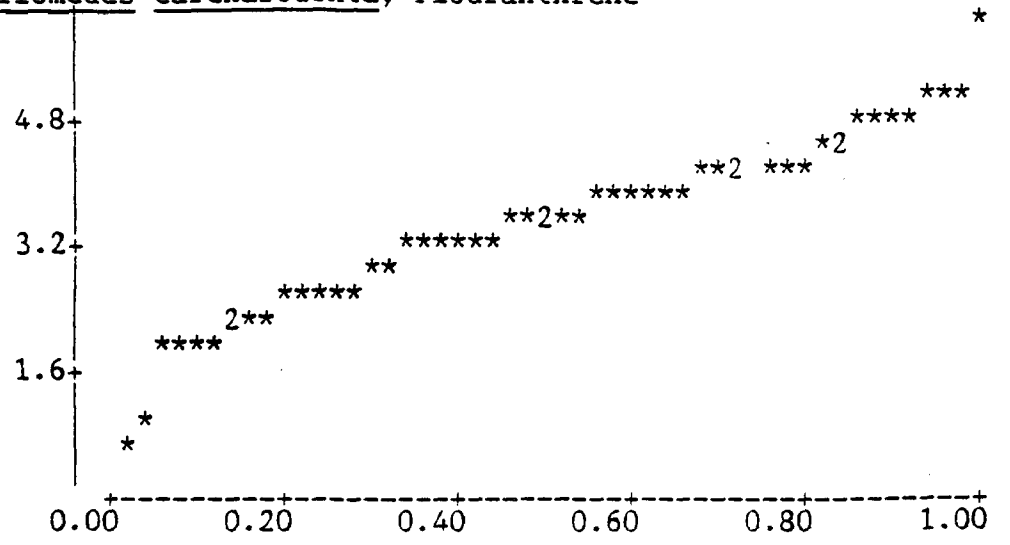
Axinopsida sericata, Flouranthrene



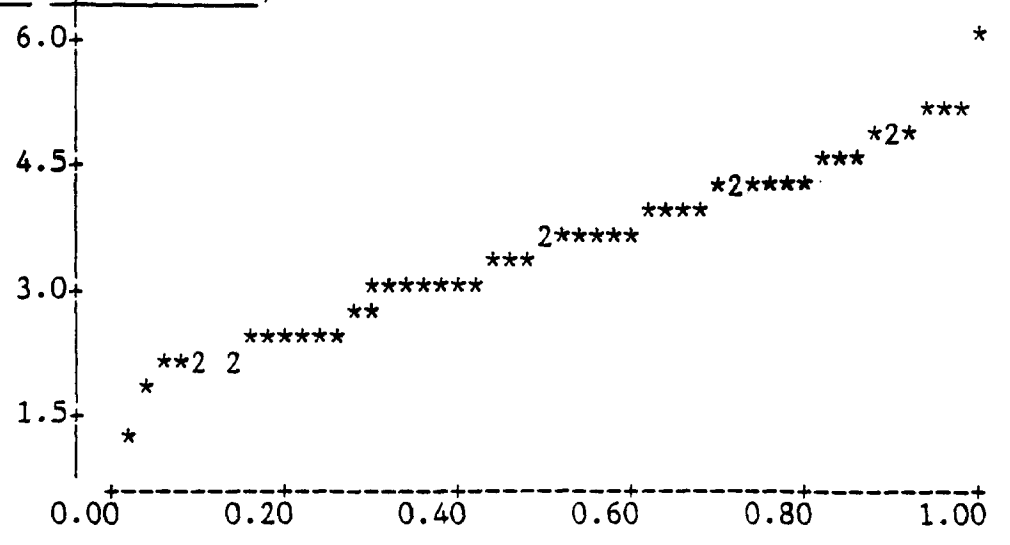
Euchone incolor, Flouranthrene



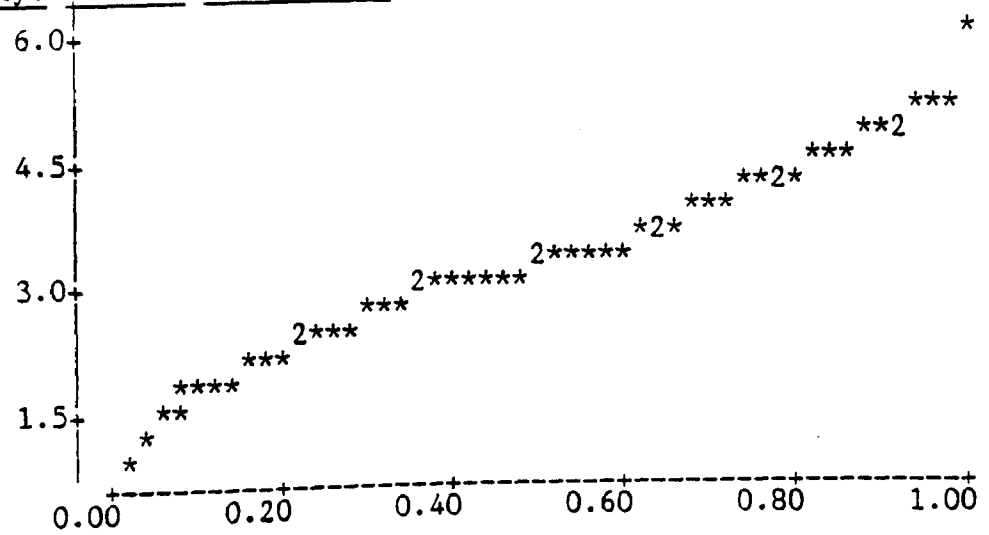
Euphilomedes carcharodonta, Flouranthrene



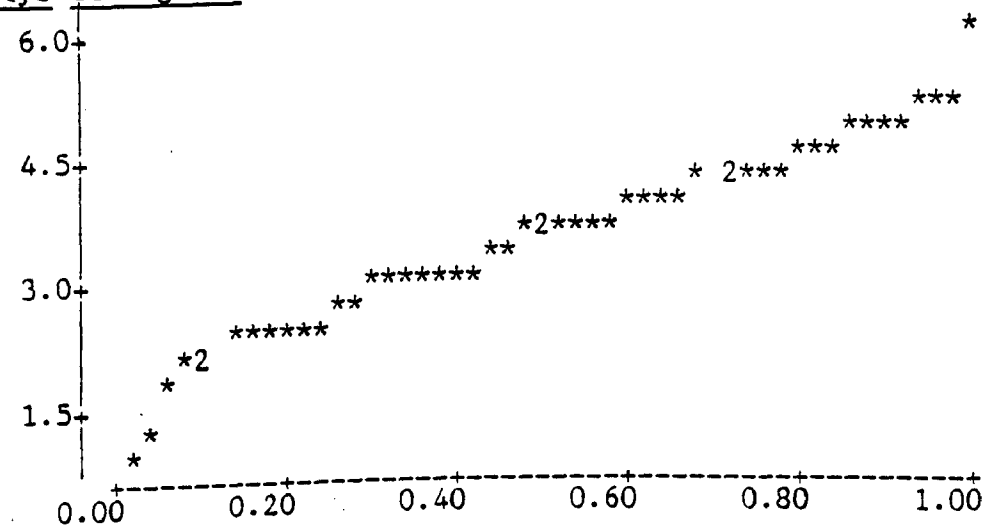
Macoma carlottensis, Flouranthrene



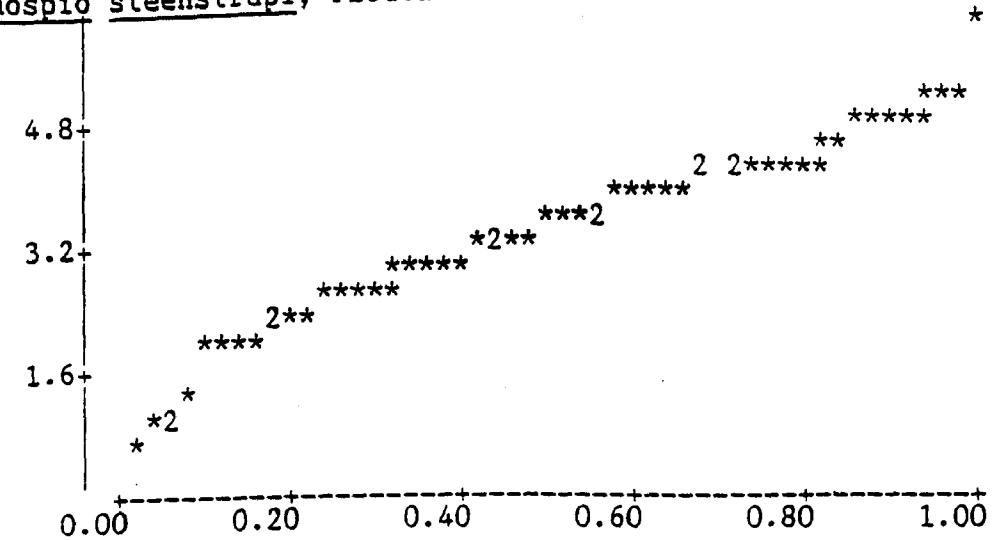
Nephtys cornuta franciscana, Flouranthrene



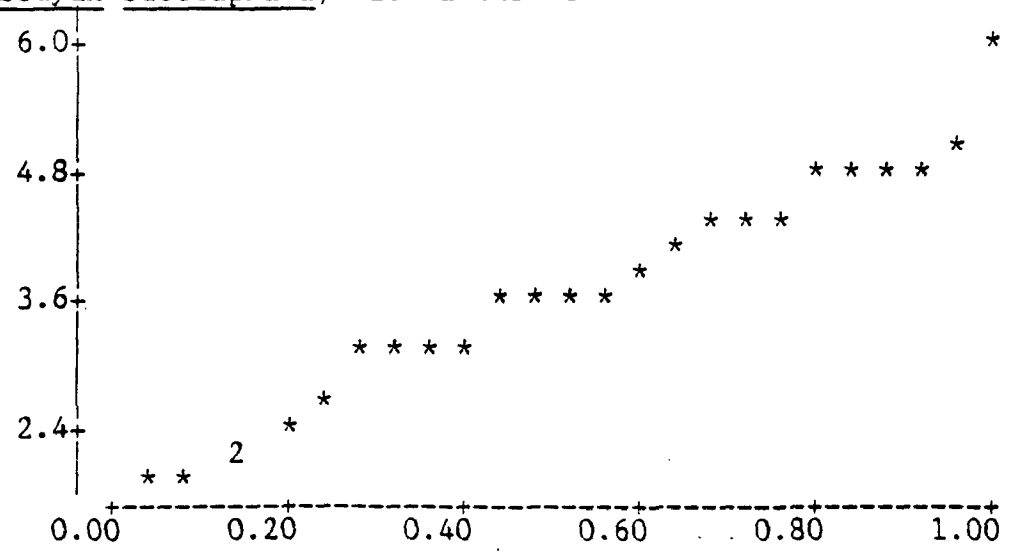
Nephtys ferruginea, Flouranthrene



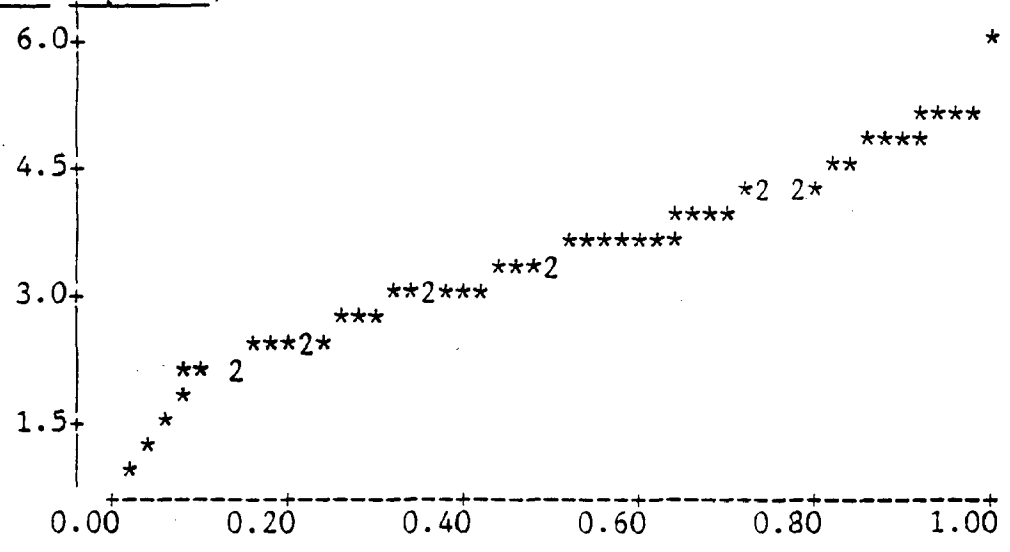
Prionospio steenstrupi, Flouranthrene



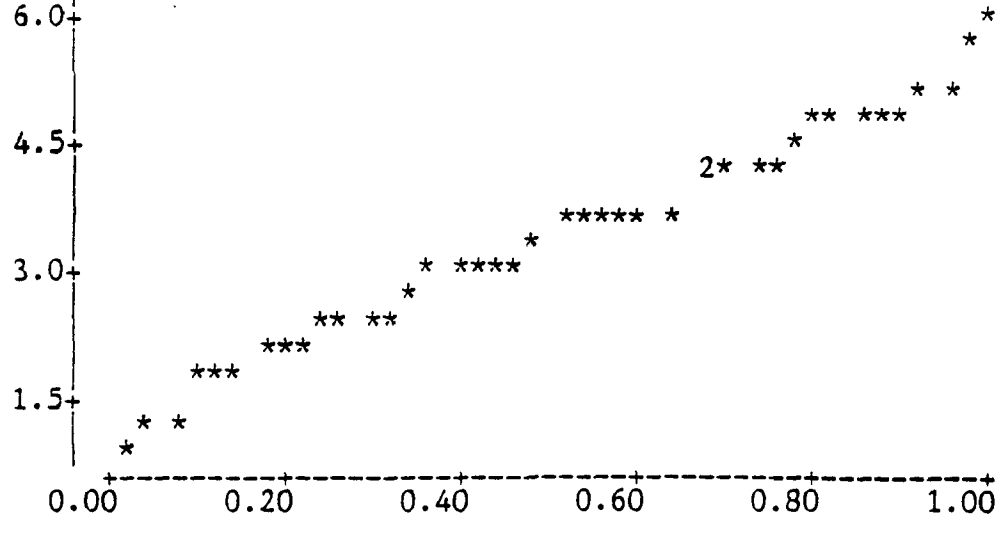
Compsomyax subdiaphana, Flouranthrene



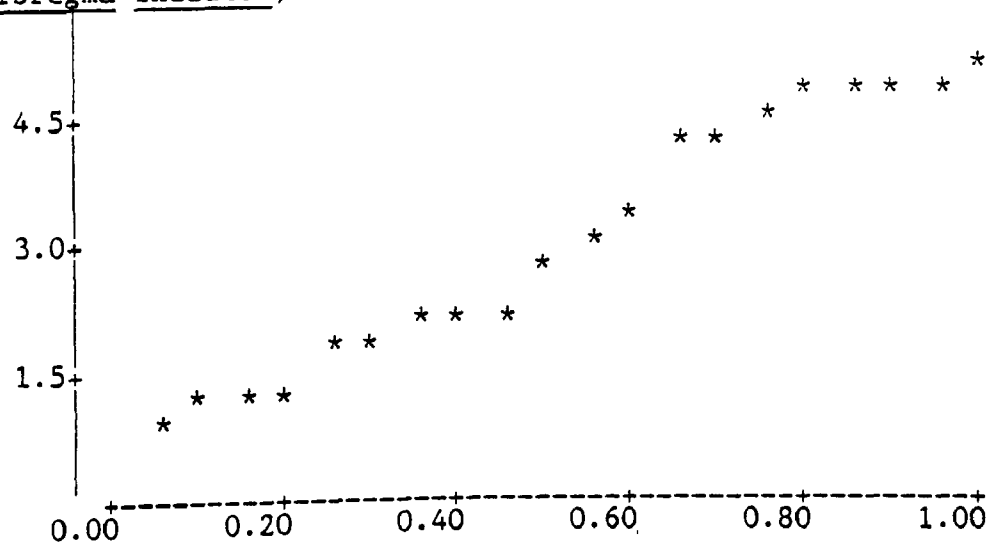
Glycera capitata, Flouranthrene



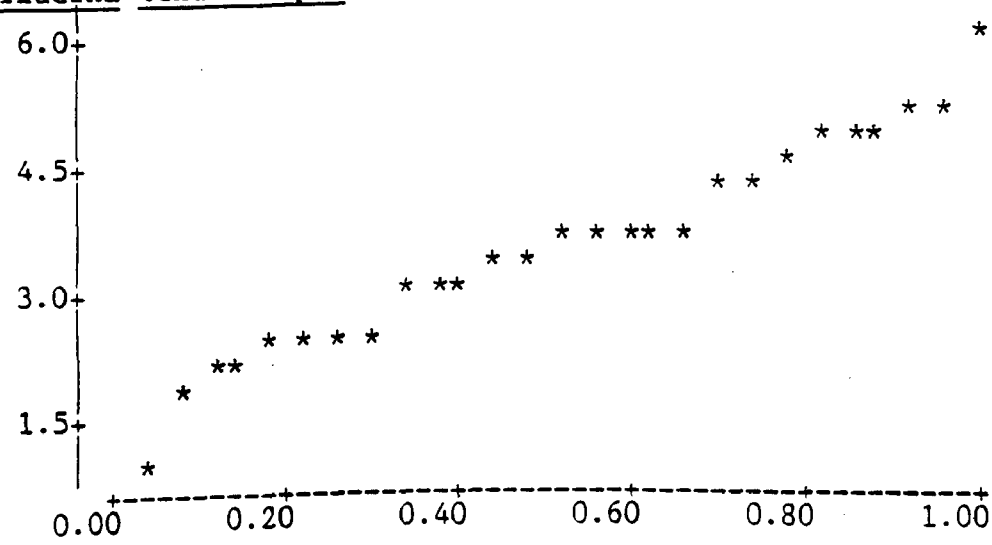
Pholoe minuta, Flouranthrene



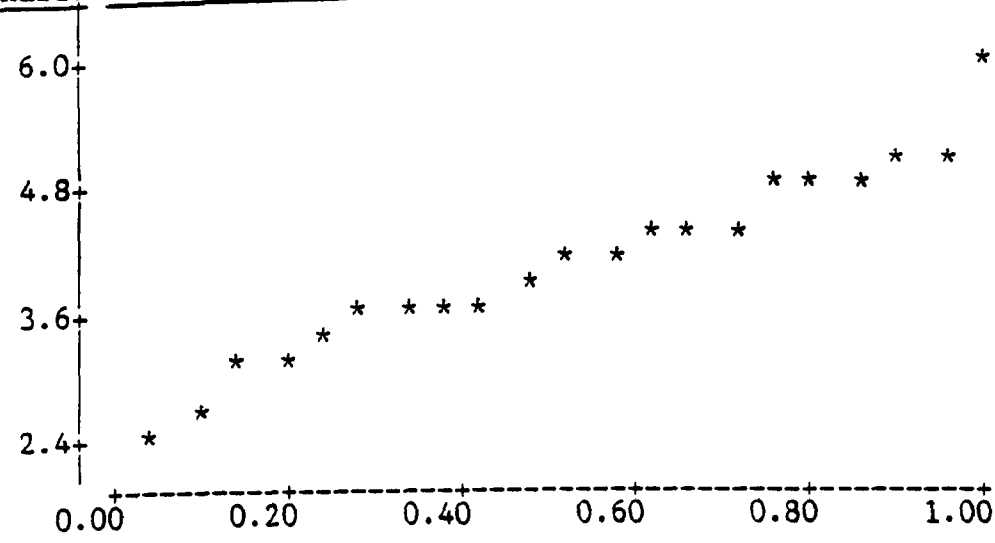
Scalibregma inflatum, Flouranthrene



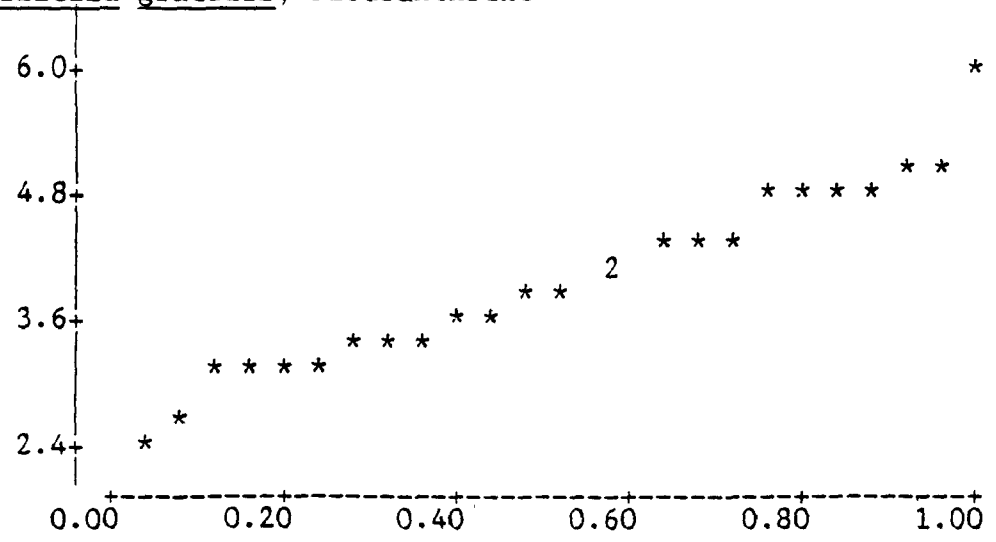
Parvilucina tenuisculpta, Flouranthrene



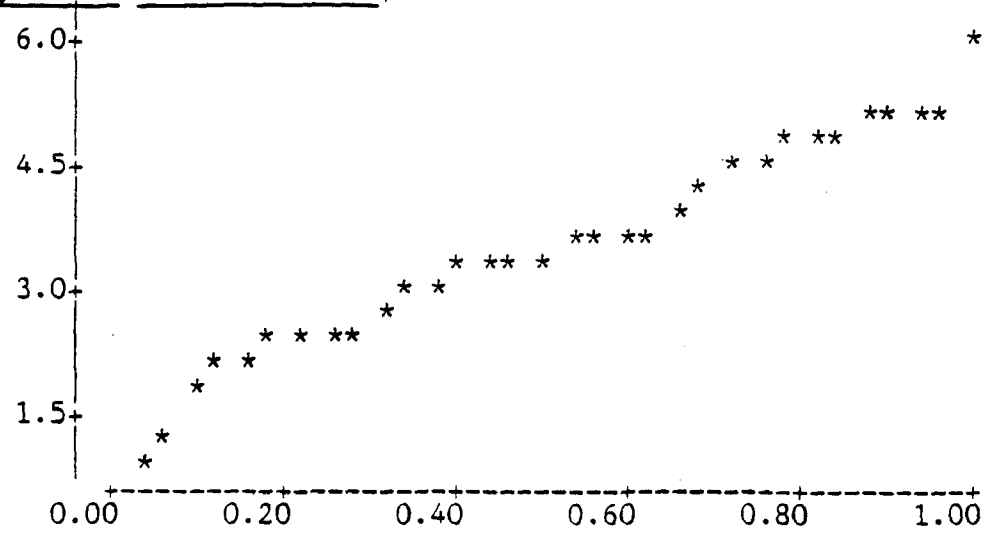
Pectinaria californiensis, Flouranthrene



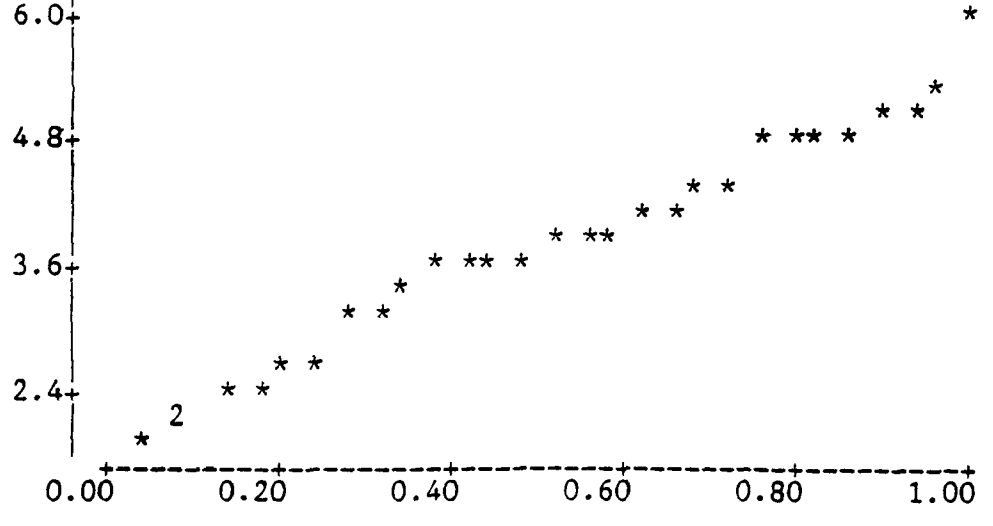
Praxillella gracilis, Flouranthrene



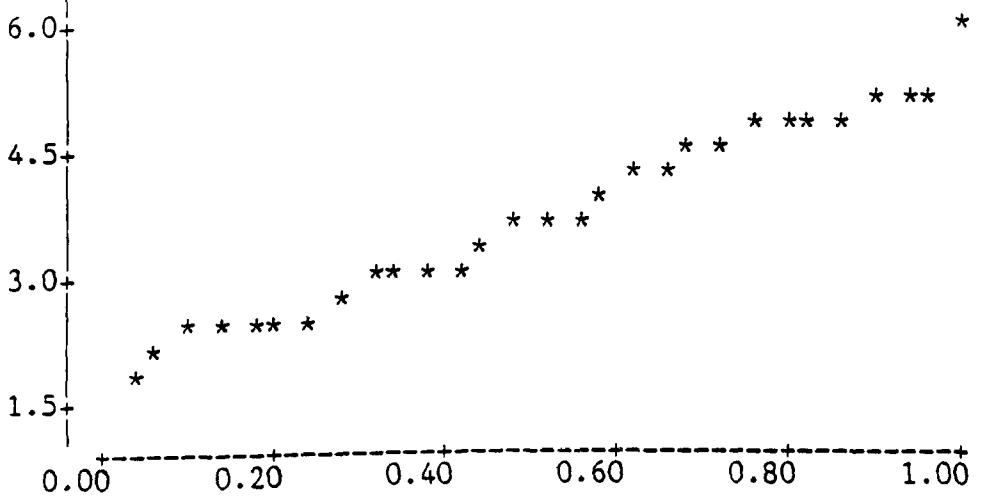
Platynereis bicanaliculata, Flouranthrene



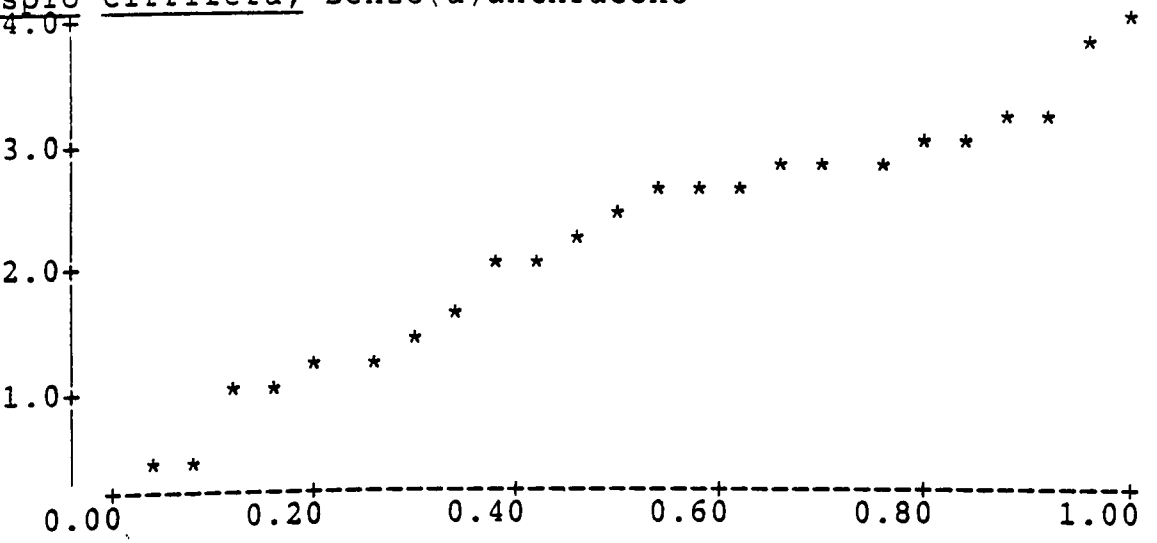
Amphioda (amphispina) urtica, Flouranthrene



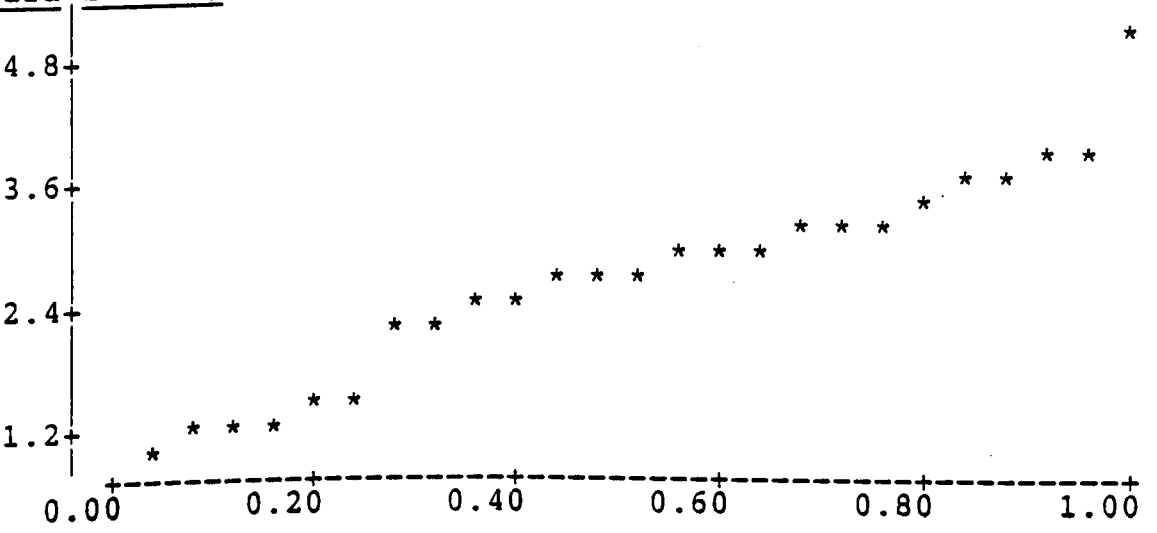
Glycera americana, Flouranthrene



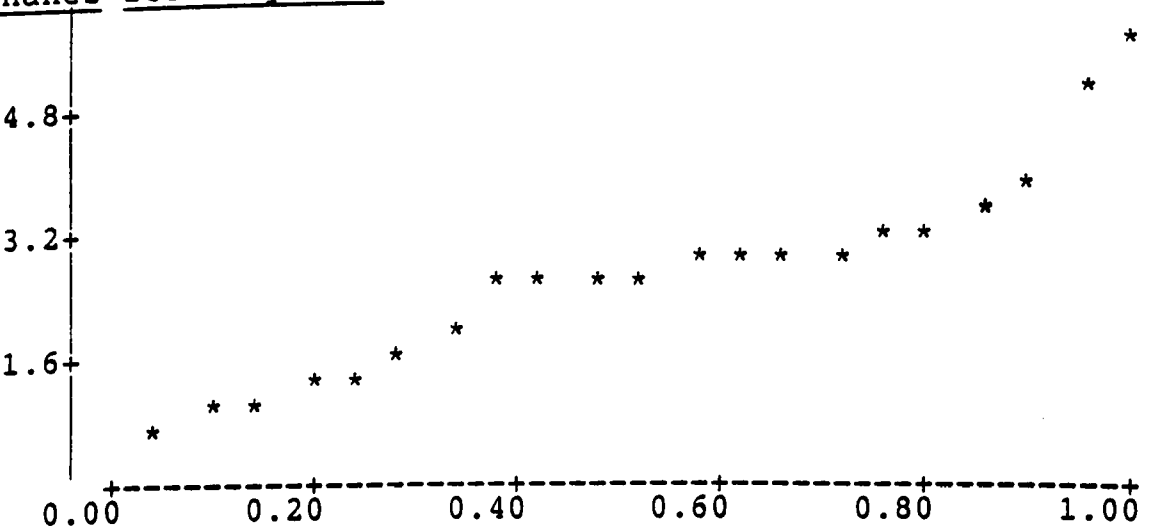
Prionospio cirrifera, Benzo(a)anthracene



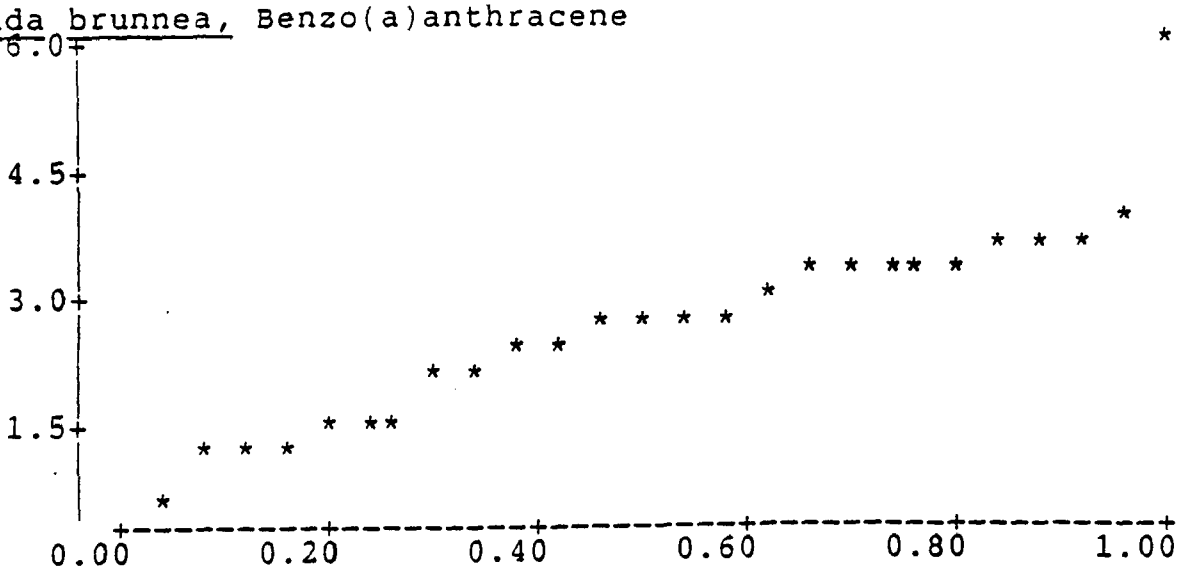
Armandia brevis, Benzo(a)anthracene



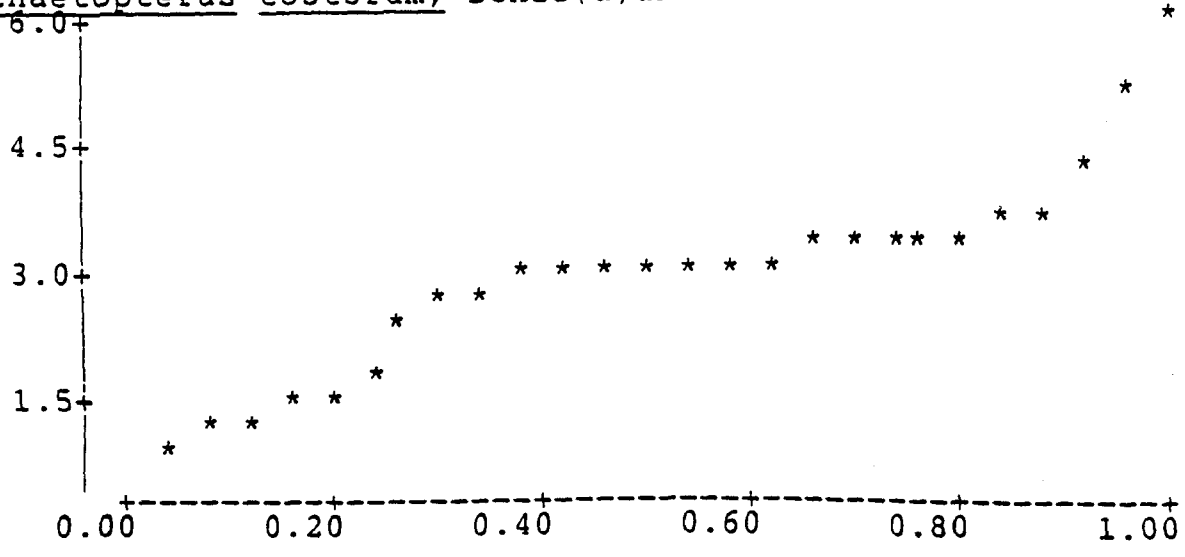
Spiophanes berkeleyorum, Benzo(a)anthracene



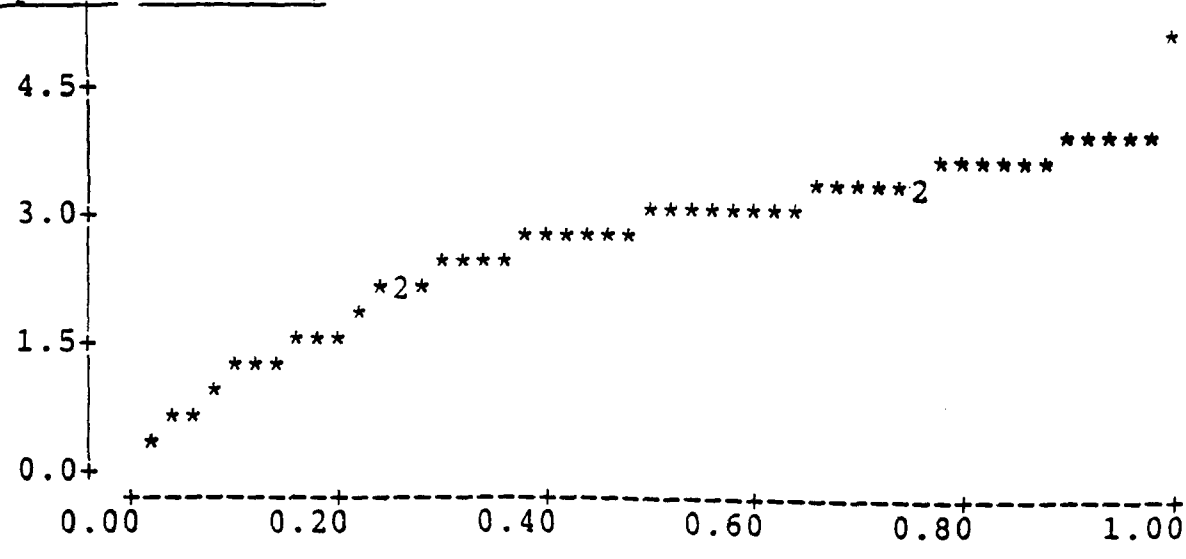
Goniada brunnea, Benzo(a)anthracene



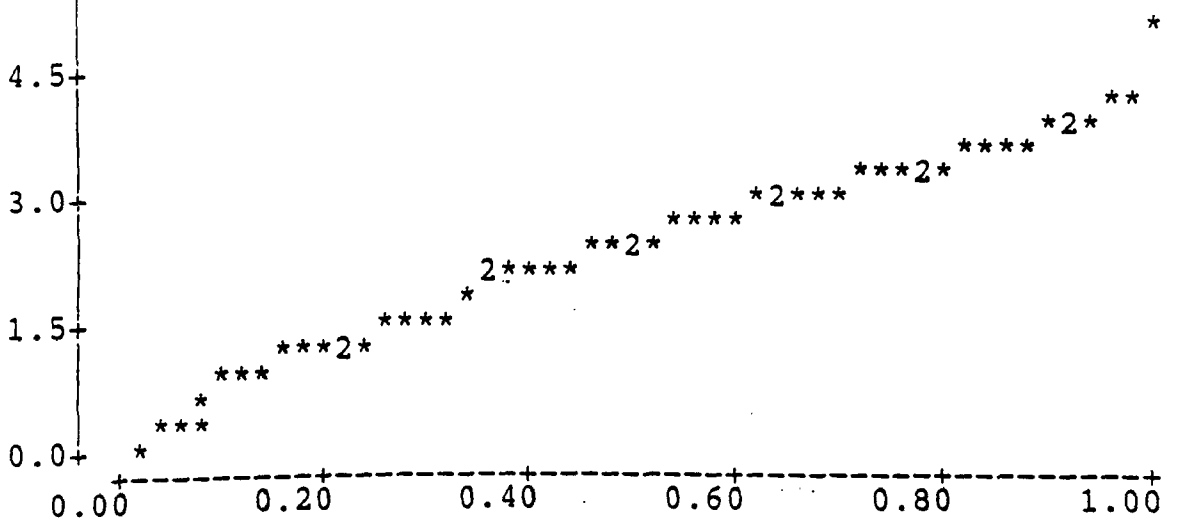
Spiochaetopterus costorum, Benzo(a)anthracene



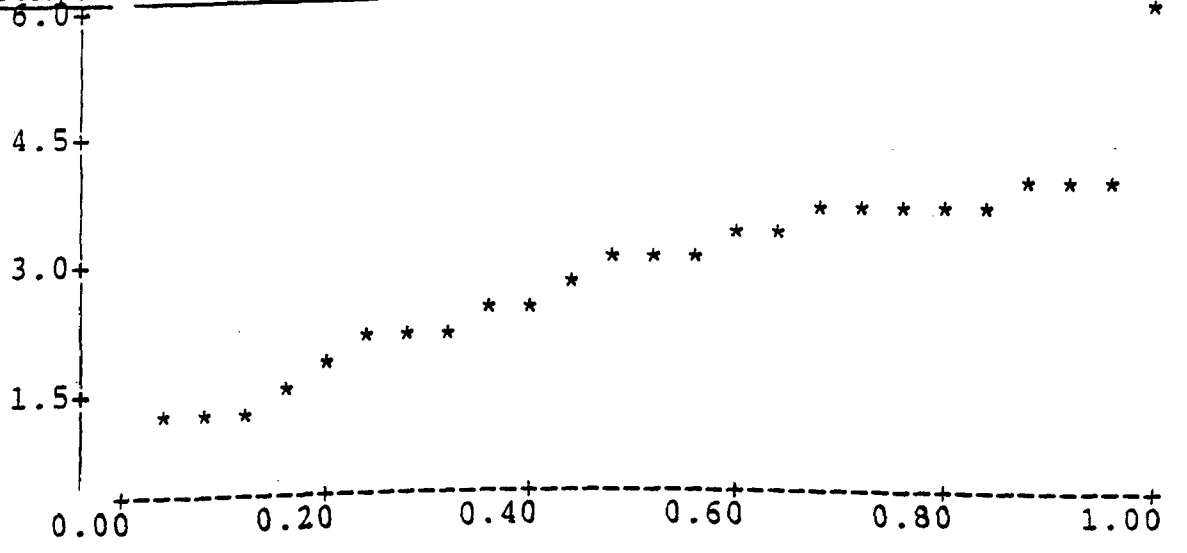
Axinopsida sericata, Benzo(a)anthracene



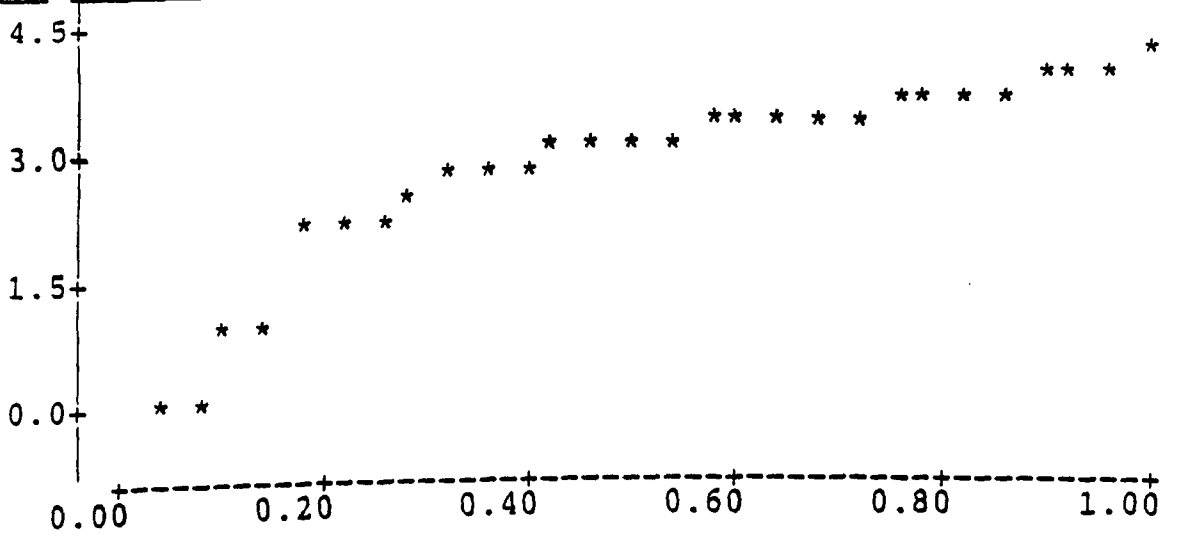
Capitella capitata, Benzo(a)anthracene



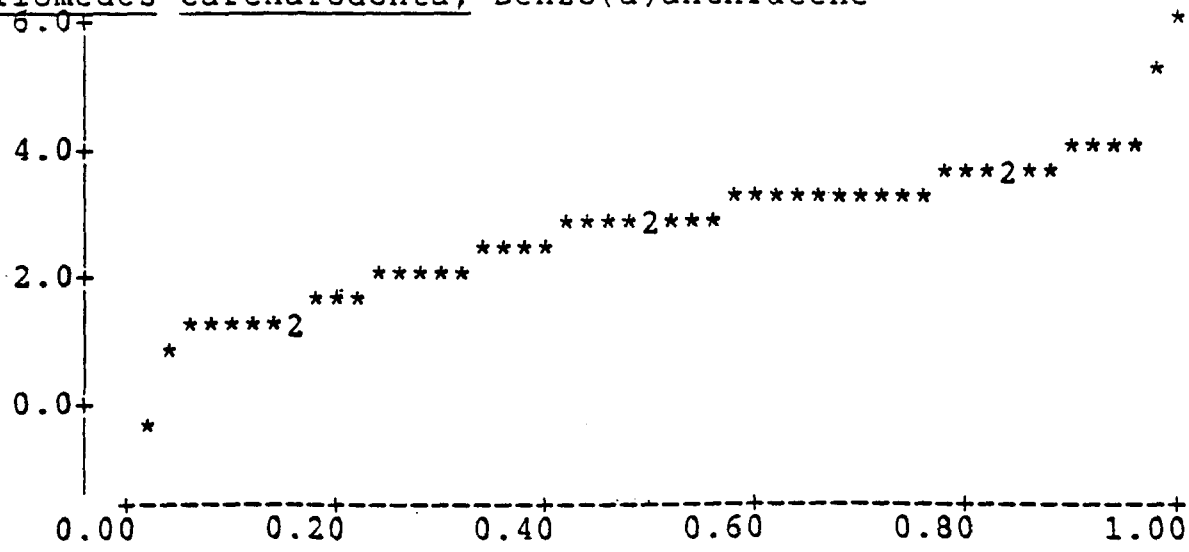
Compsomyax subdiaphana, Benzo(a)anthracene



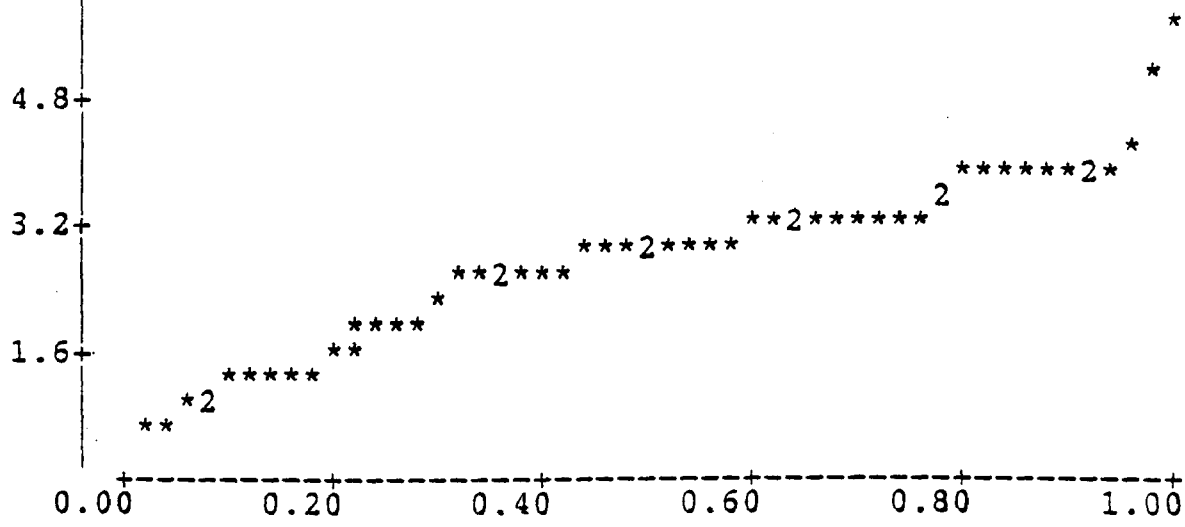
Euchone incolor, Benzo(a)anthracene



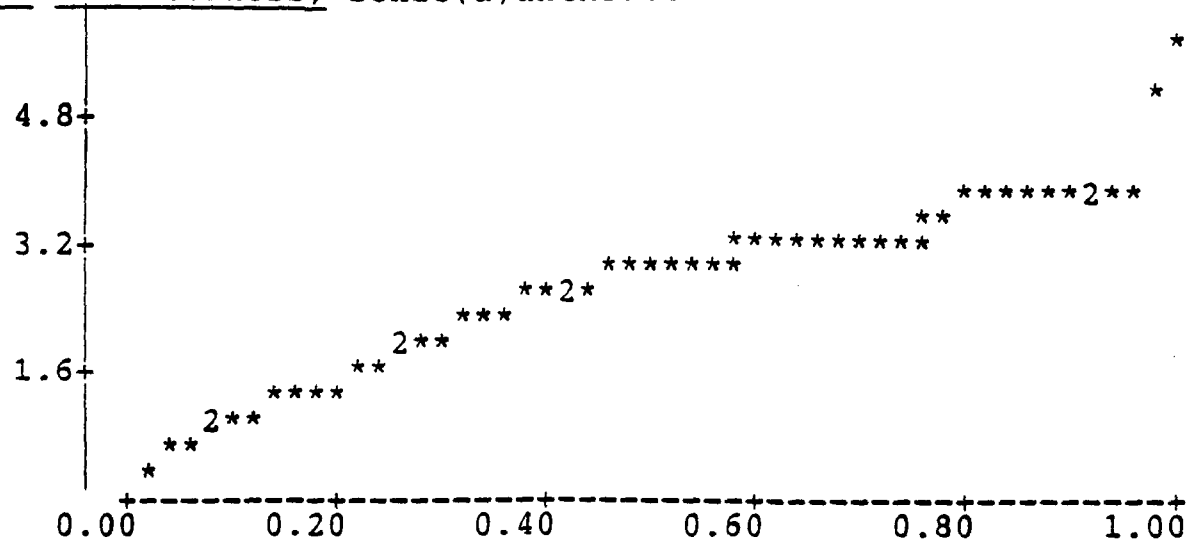
Euphilomedes carcharodonta, Benzo(a)anthracene



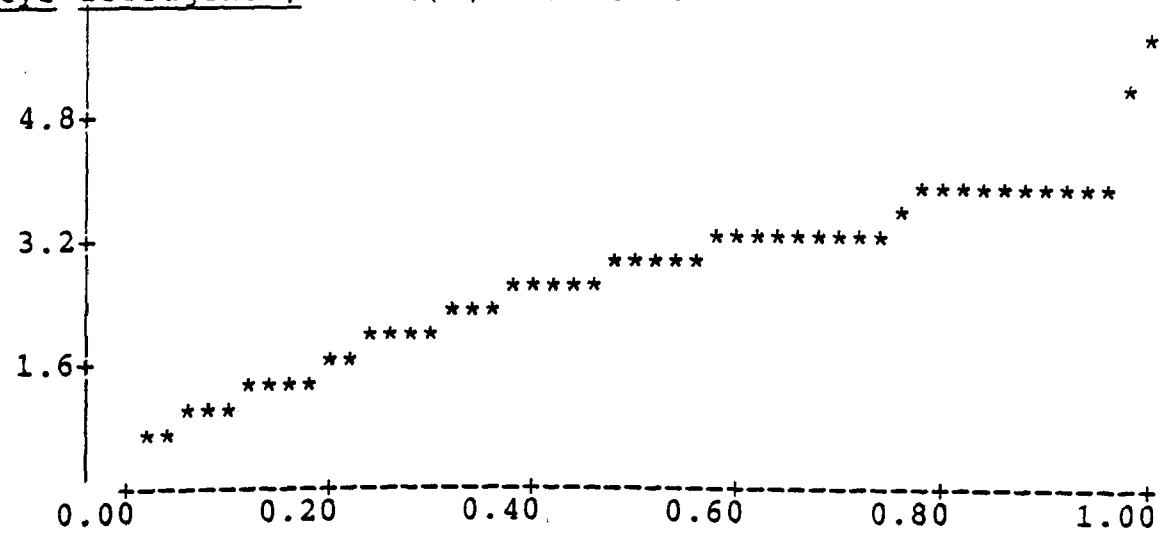
Glycera capitata, Benzo(a)anthracene



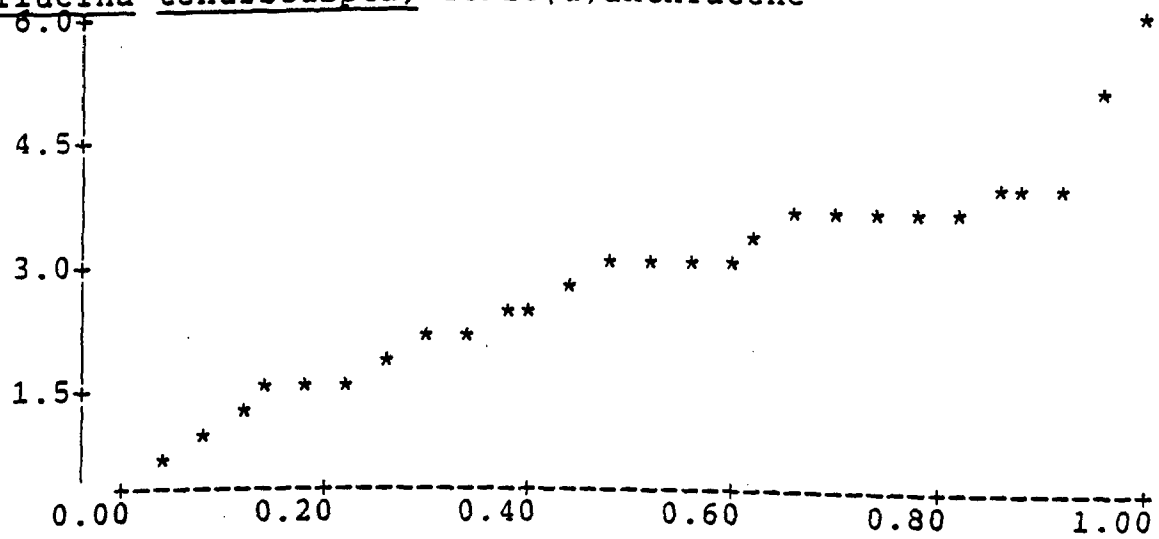
Macoma carlottensis, Benzo(a)anthracene



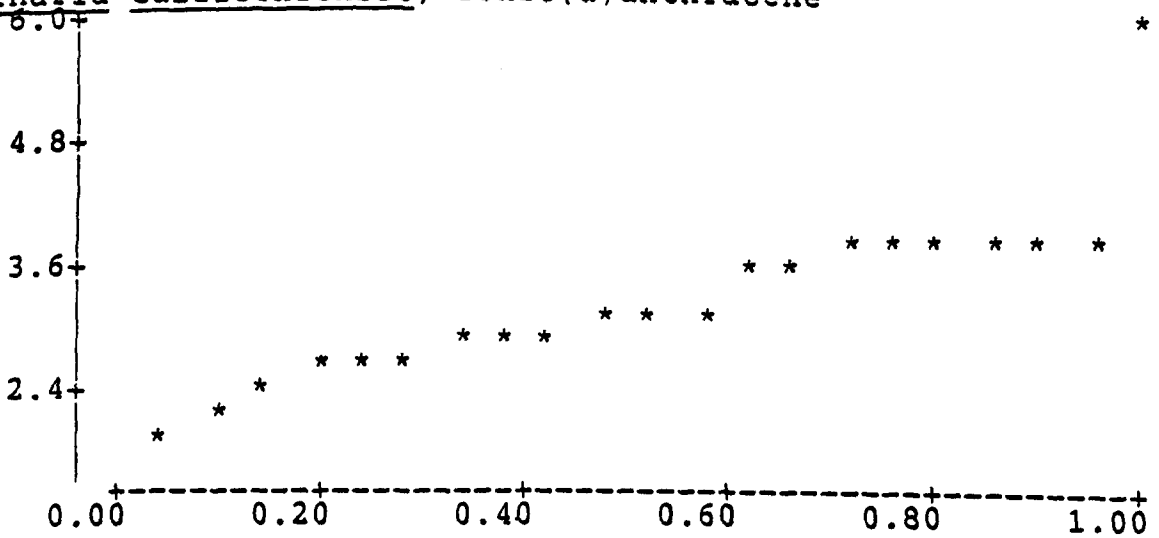
Nephtys ferruginea, Benzo(a)anthracene



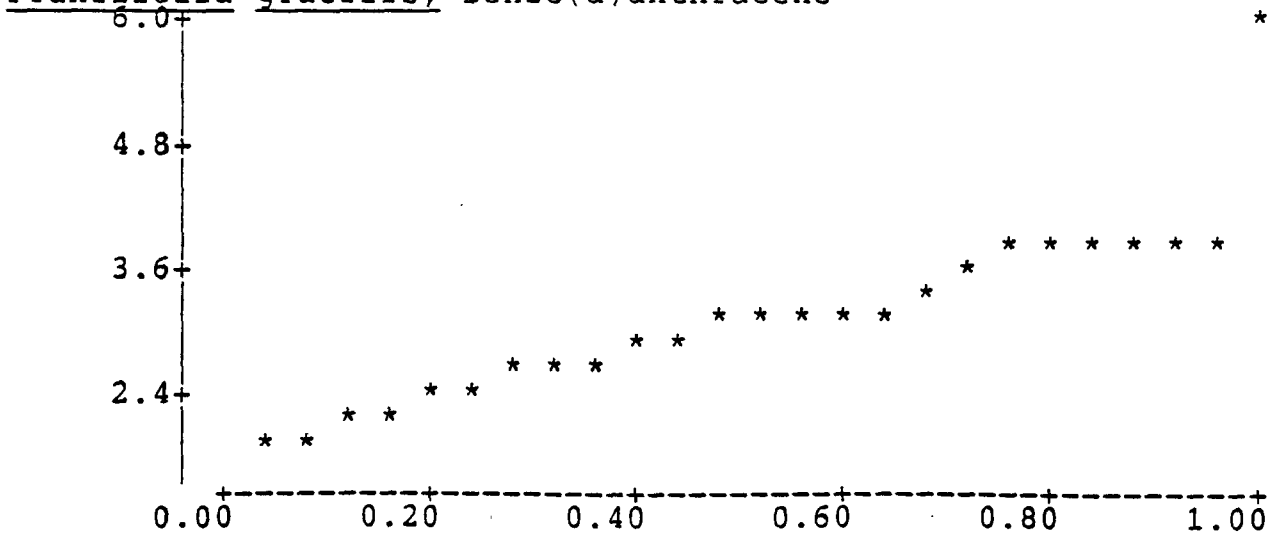
Parvilucina tenuisculpta, Benzo(a)anthracene



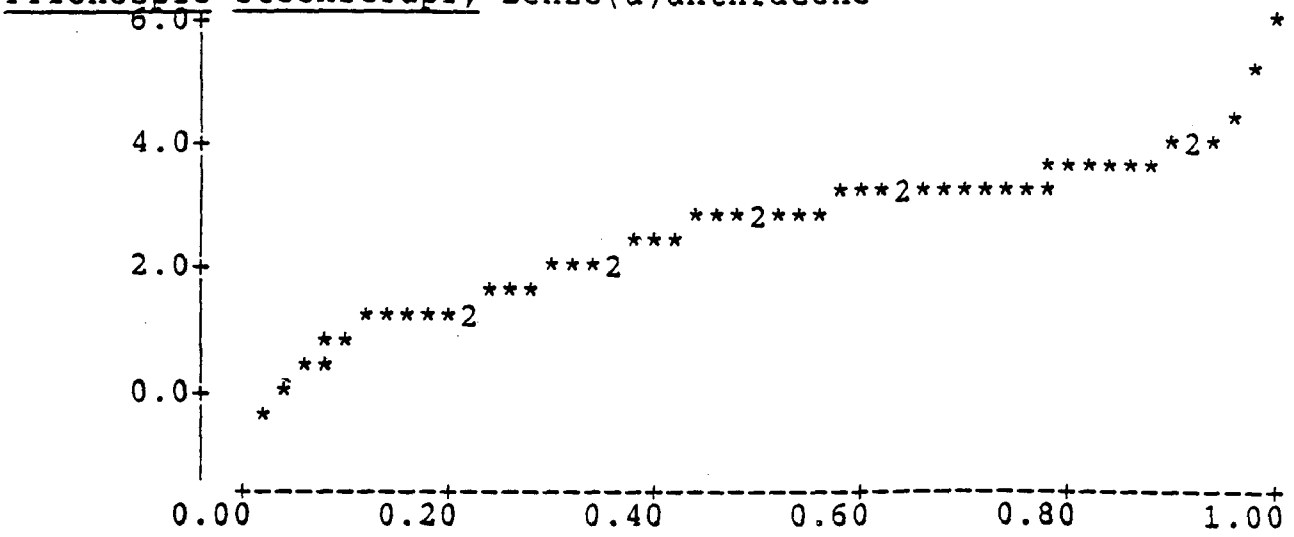
Pectinaria californiensis, Benzo(a)anthracene



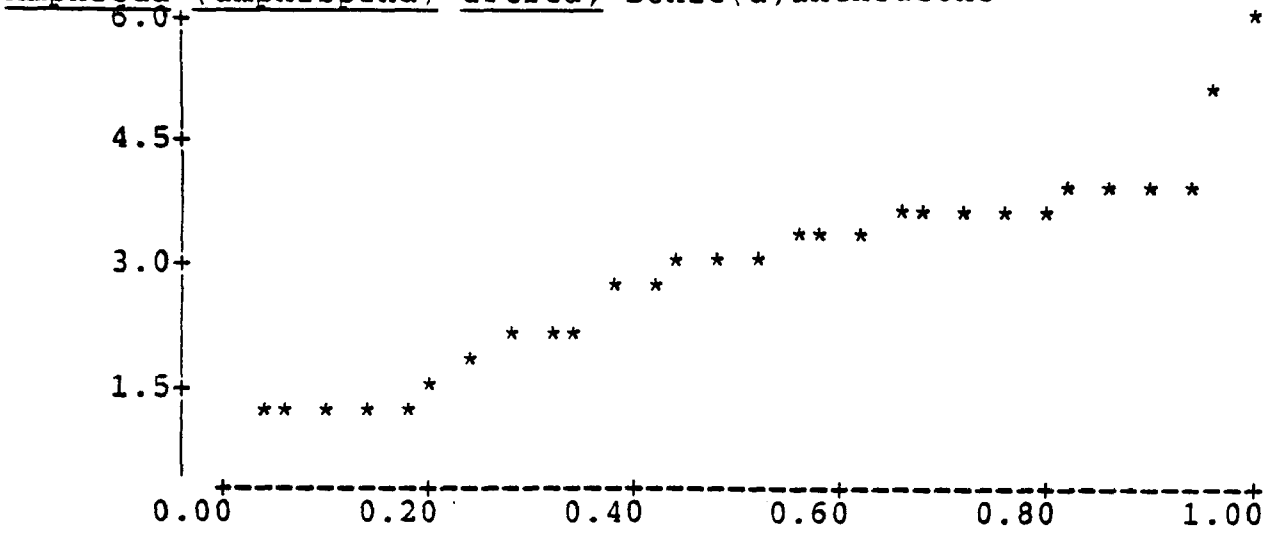
Praxillella gracilis, Benzo(a)anthracene



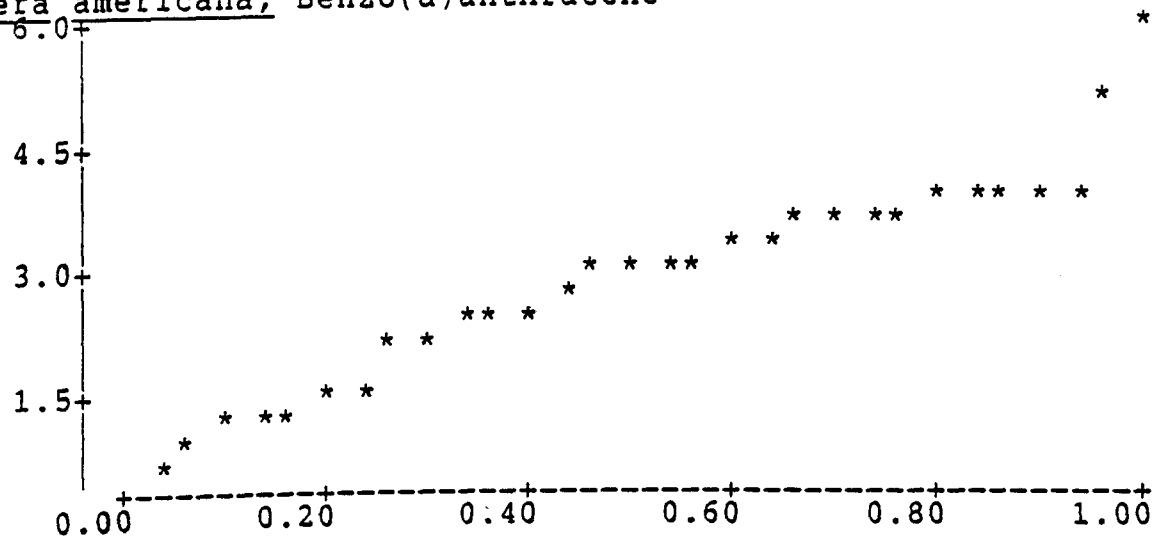
Prionospio steenstrupi, Benzo(a)anthracene



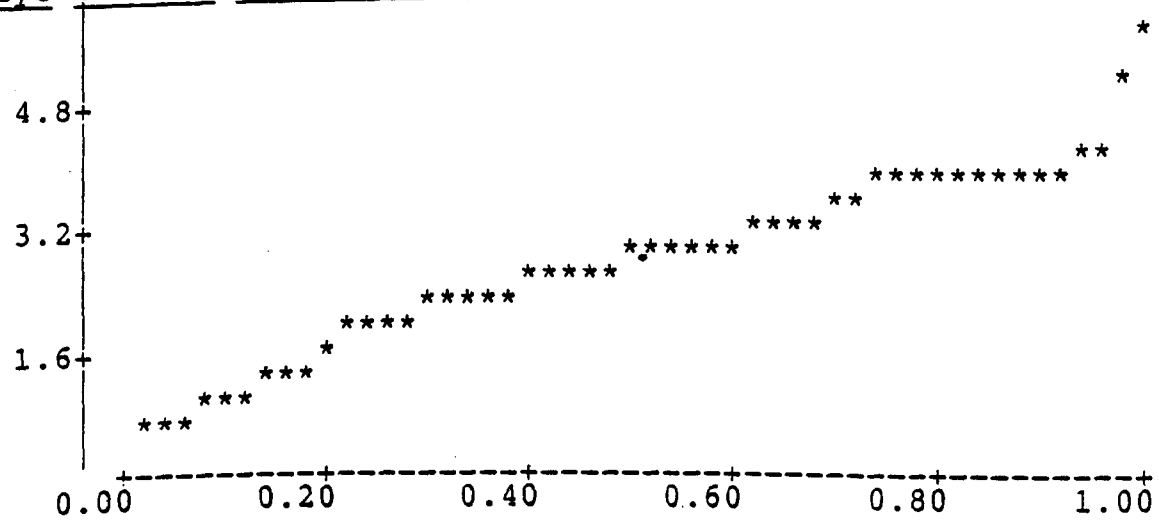
Amphioda (amphispina) urtica, Benzo(a)anthracene



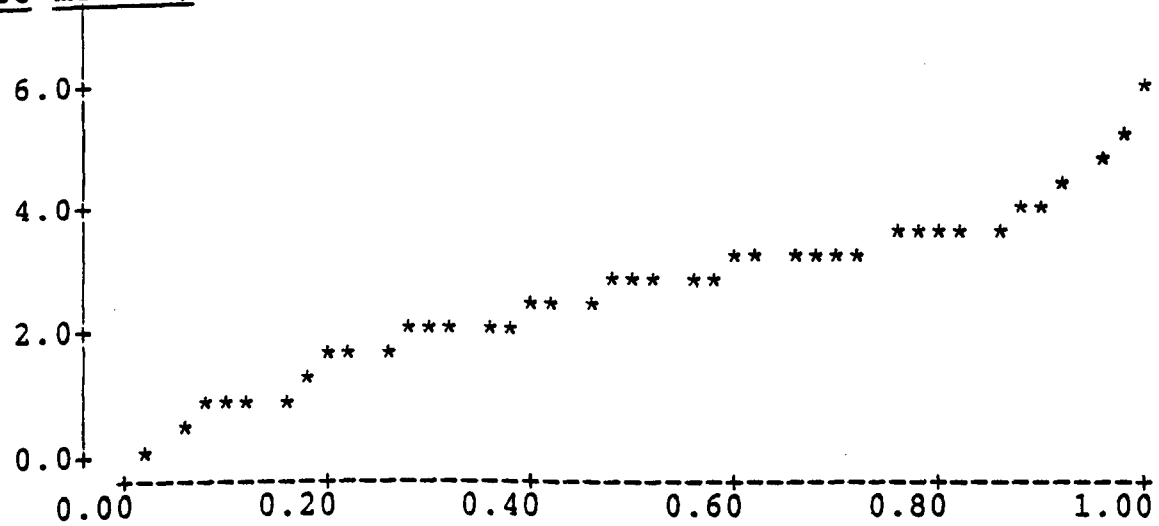
Glycera americana, Benzo(a)anthracene



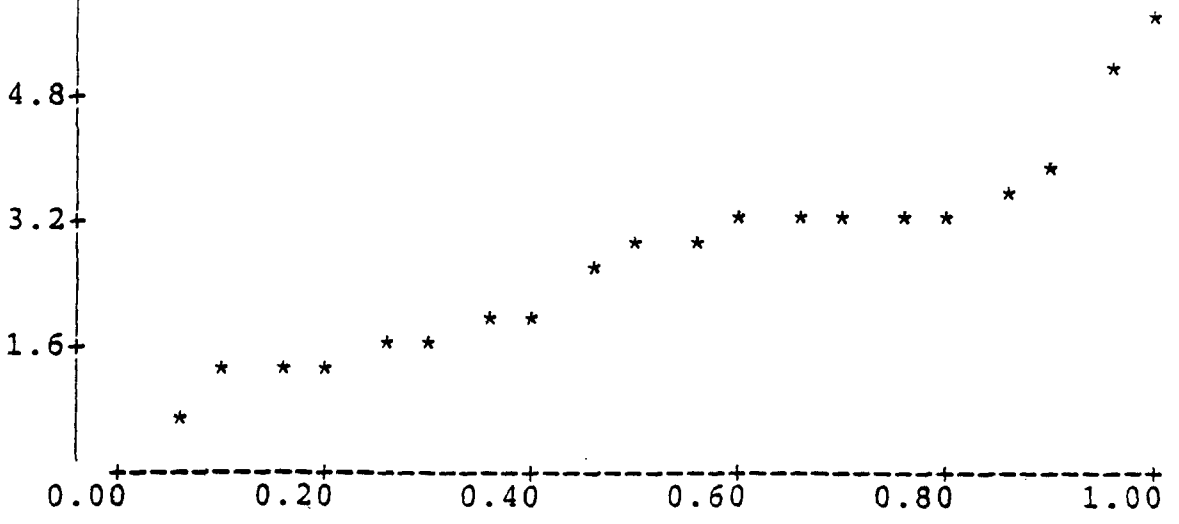
Nephtys cornuta franciscana, Benzo(a)anthracene



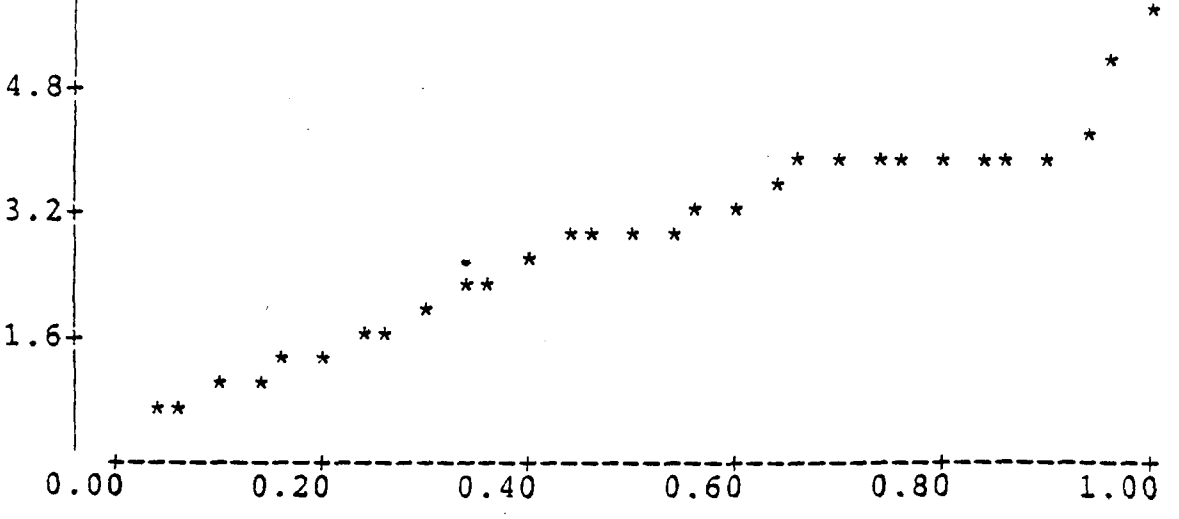
Pholoe minuta, Benzo(a)anthracene



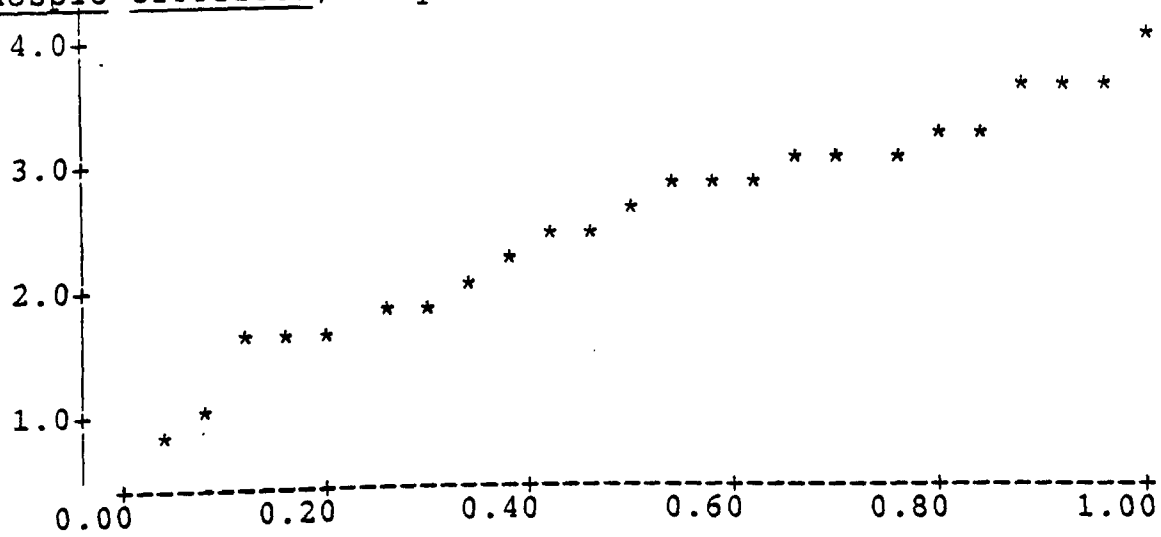
Phyllodoce hartmanae, Benzo(a)anthracene



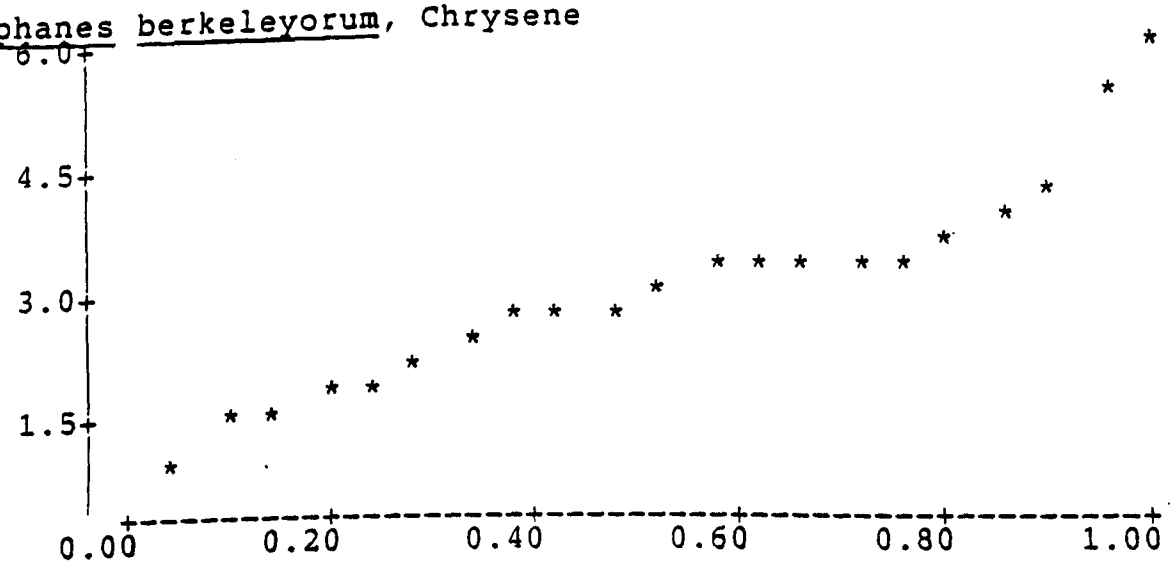
Platynereis bicanaliculata, Benzo(a)anthracene



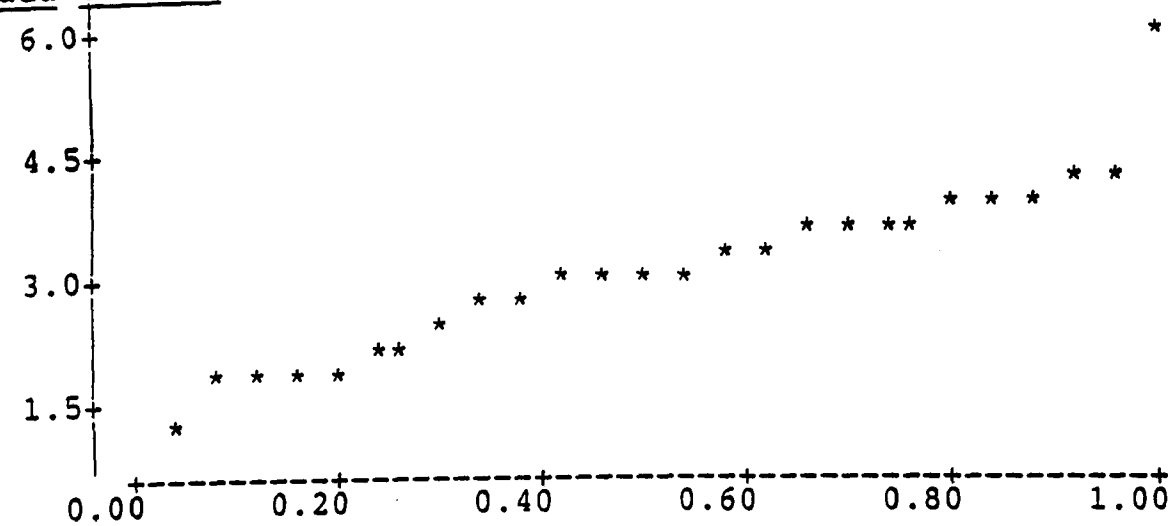
Prionospio cirrifera, Chrysene



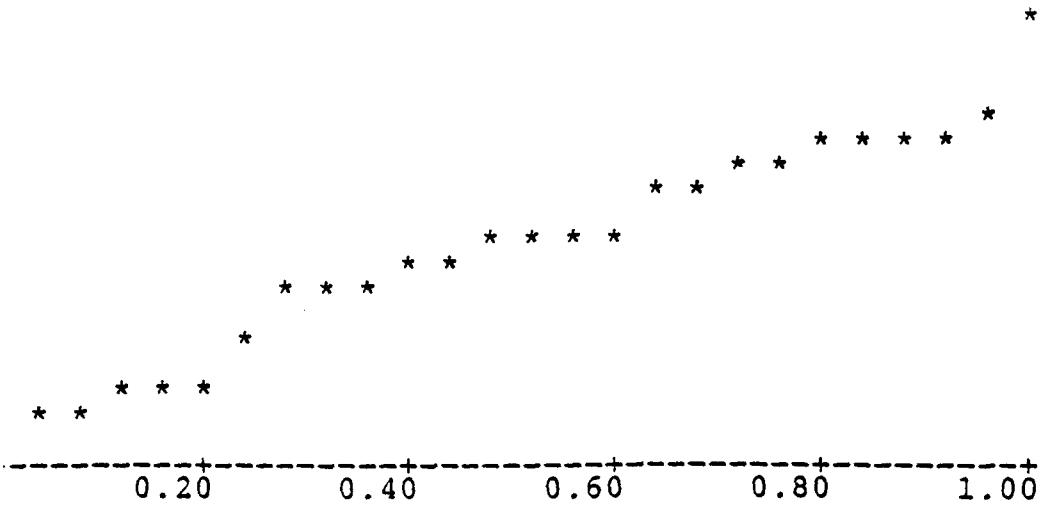
Spiophanes berkeleyorum, Chrysene



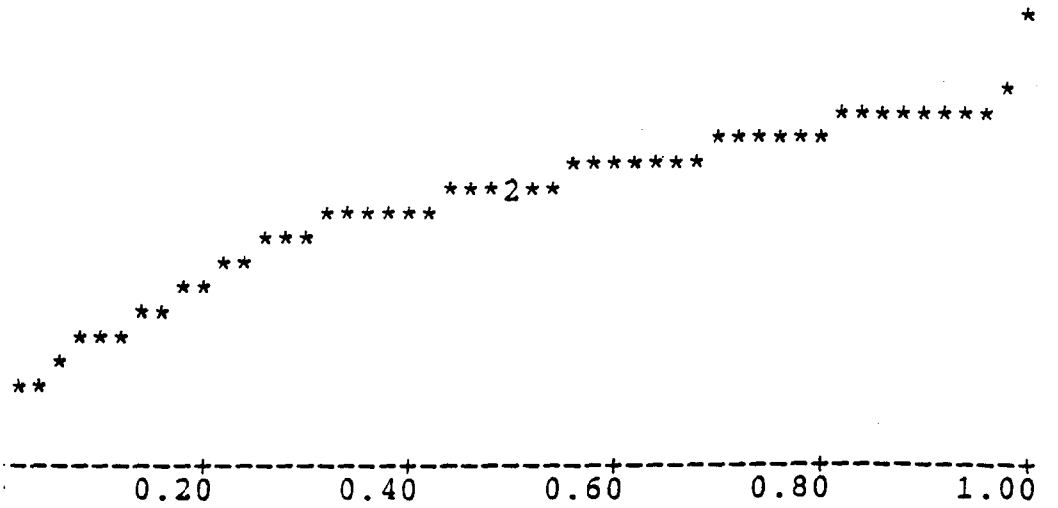
Goniada brunnea, Chrysene



evis, Chrysene



sericata, Chrysene



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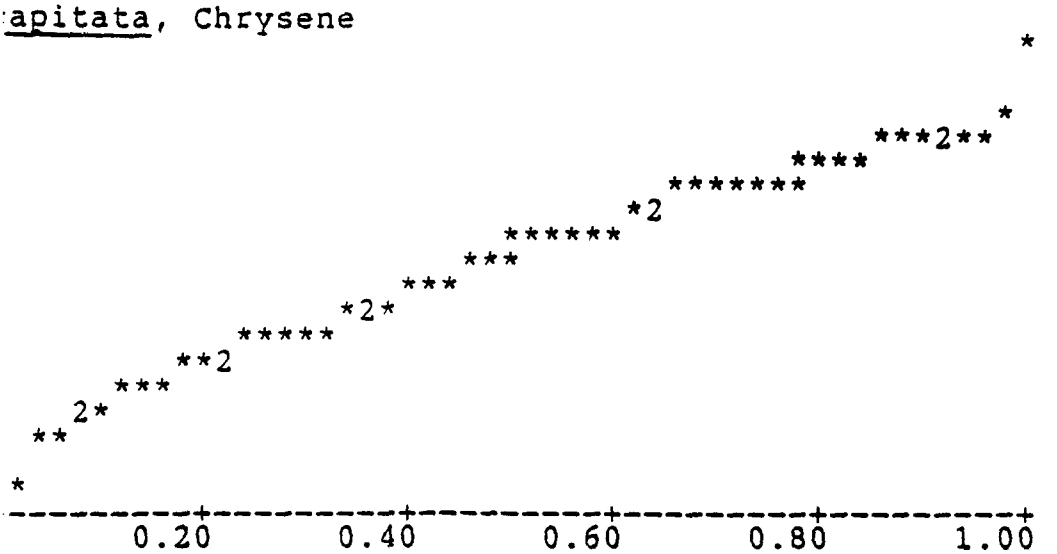
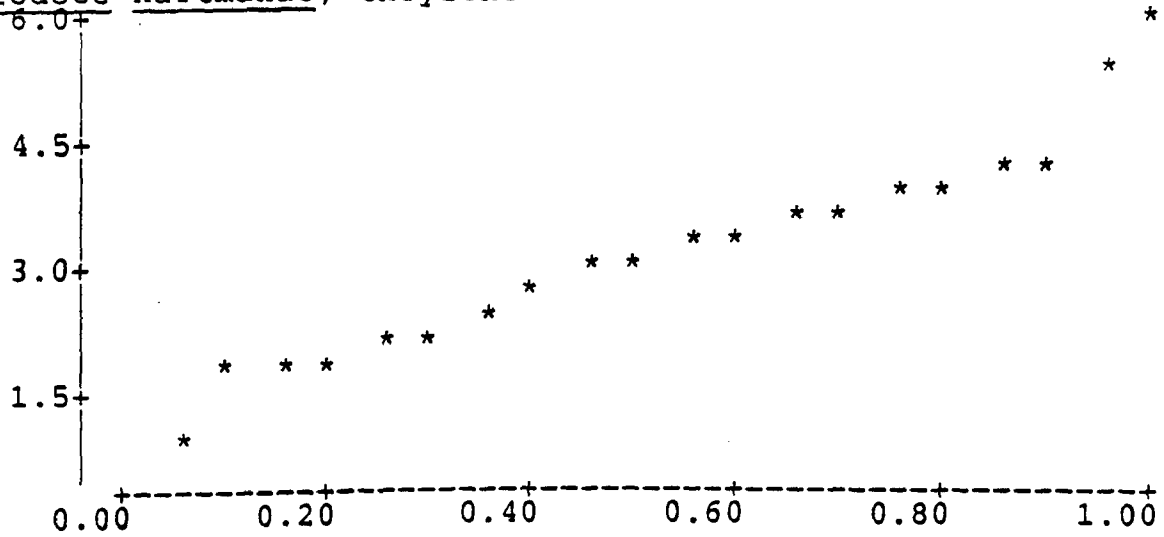
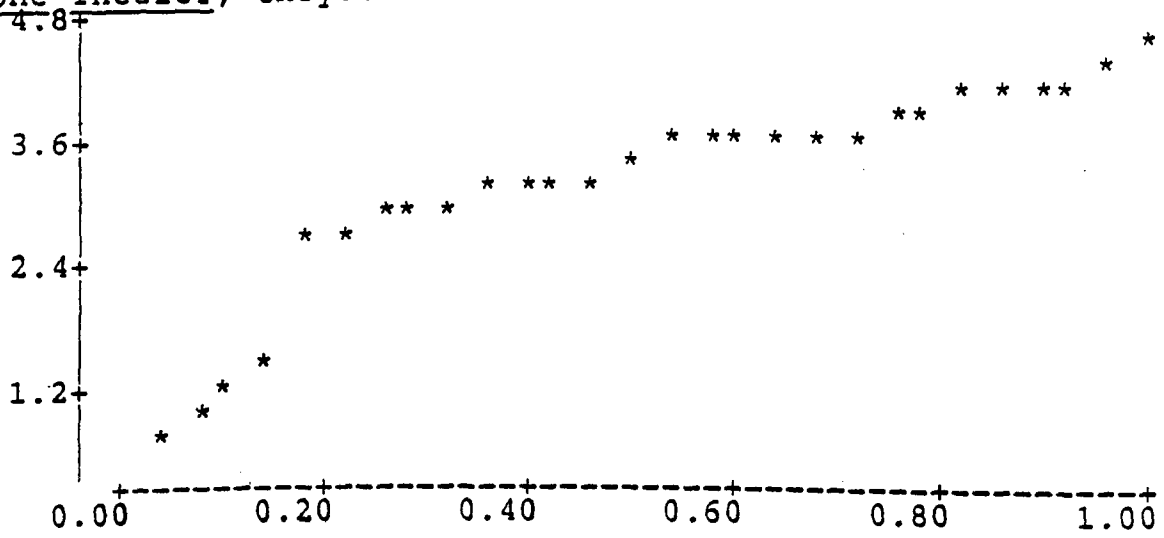


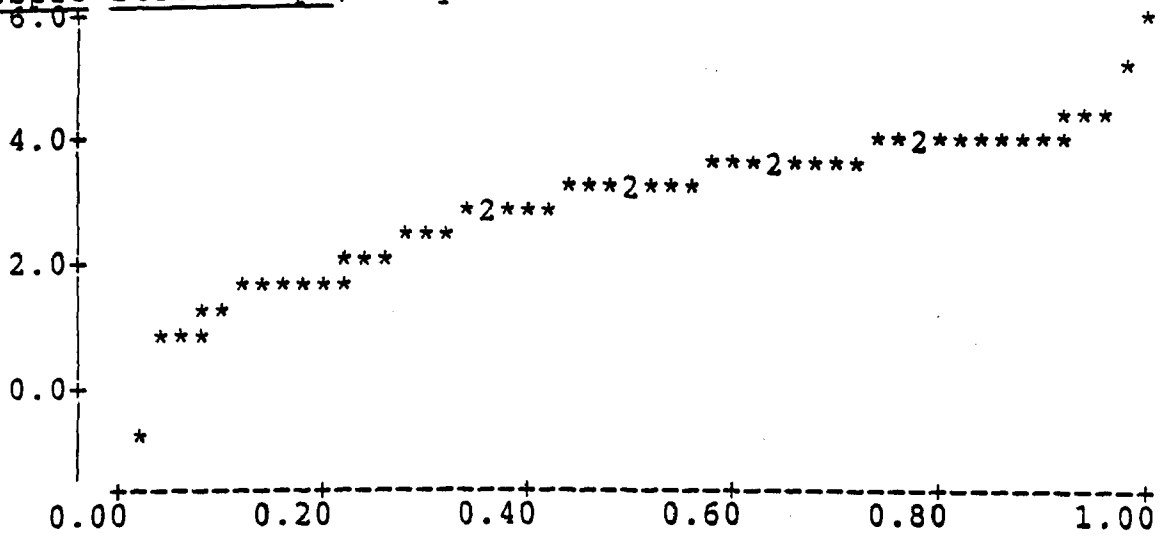
Phyllodoce hartmanae, Chrysene



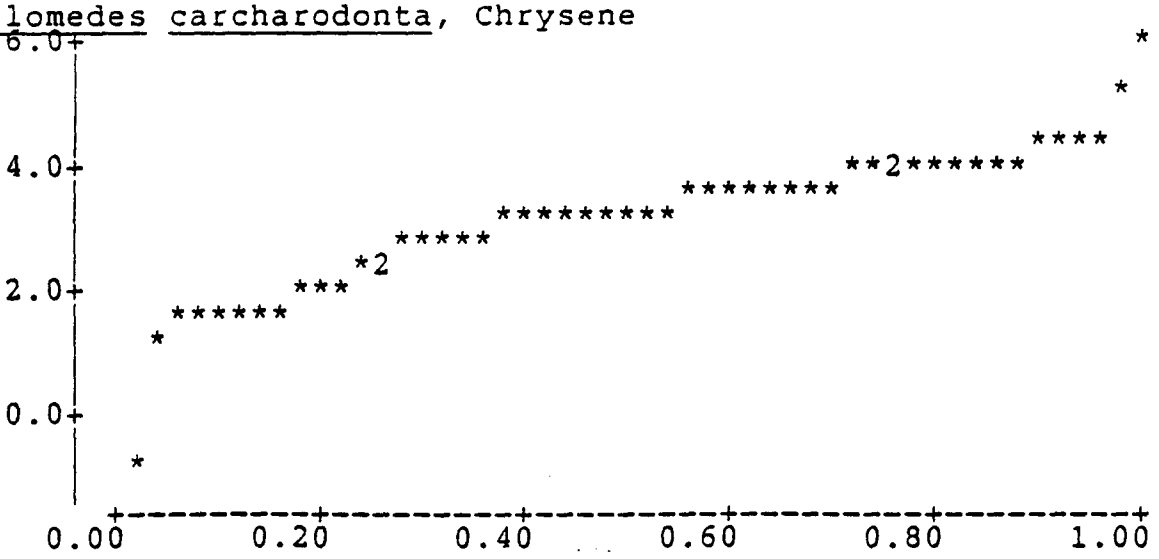
Euchone incolor, Chrysene



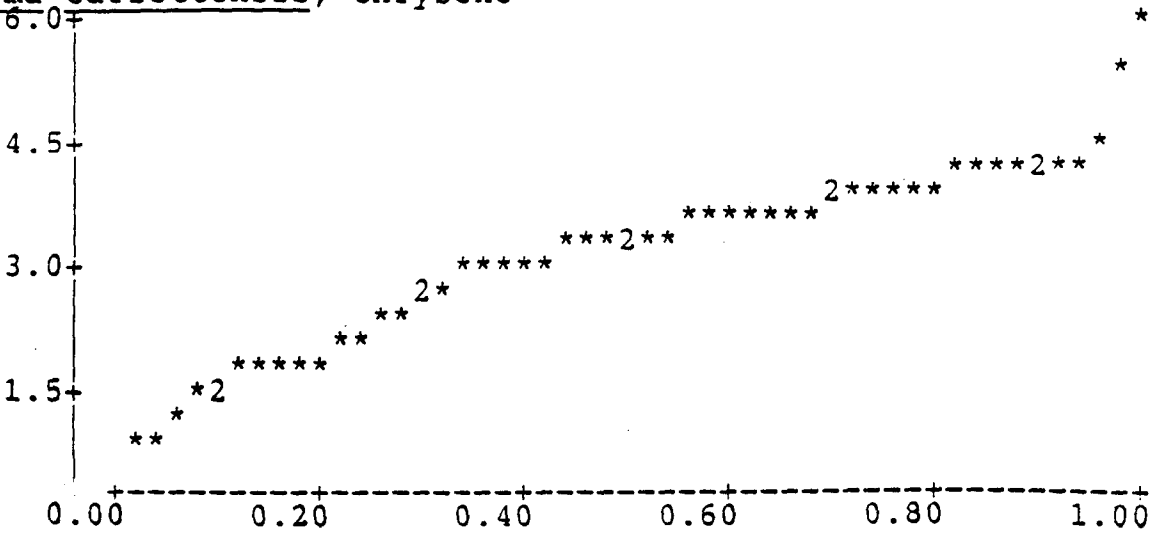
Prionospio steenstrupi, Chrysene



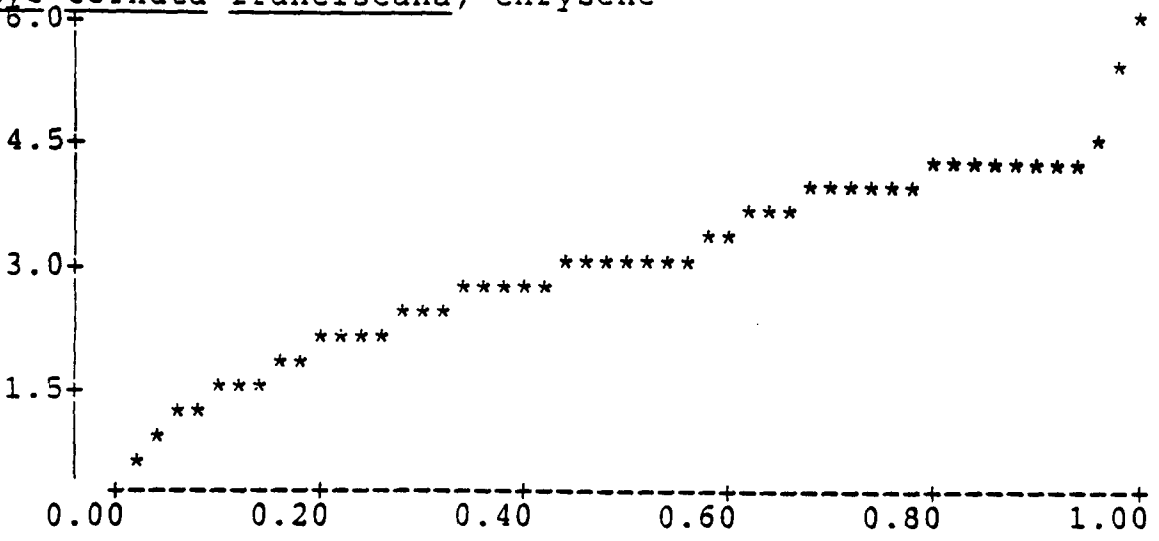
Euphilomedes carcharodonta, Chrysene



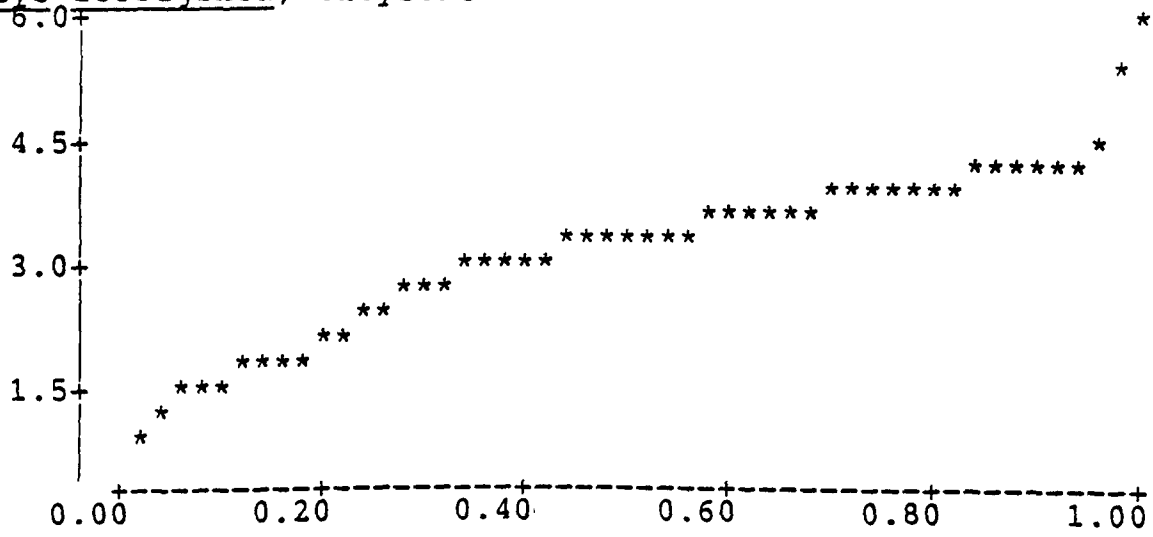
Macoma carlottensis, Chrysene



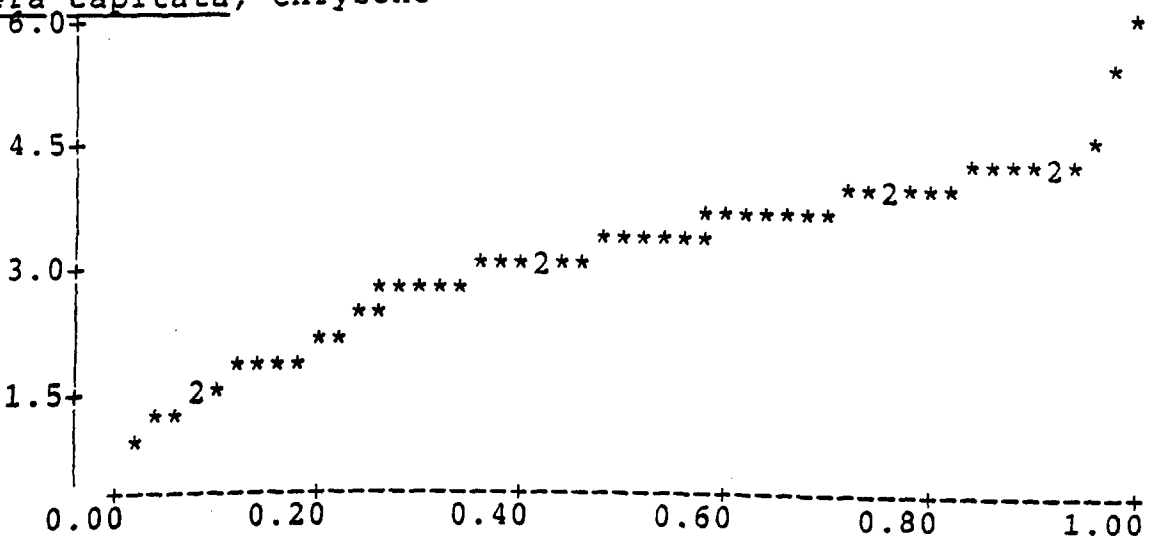
Nephtys cornuta franciscana, Chrysene



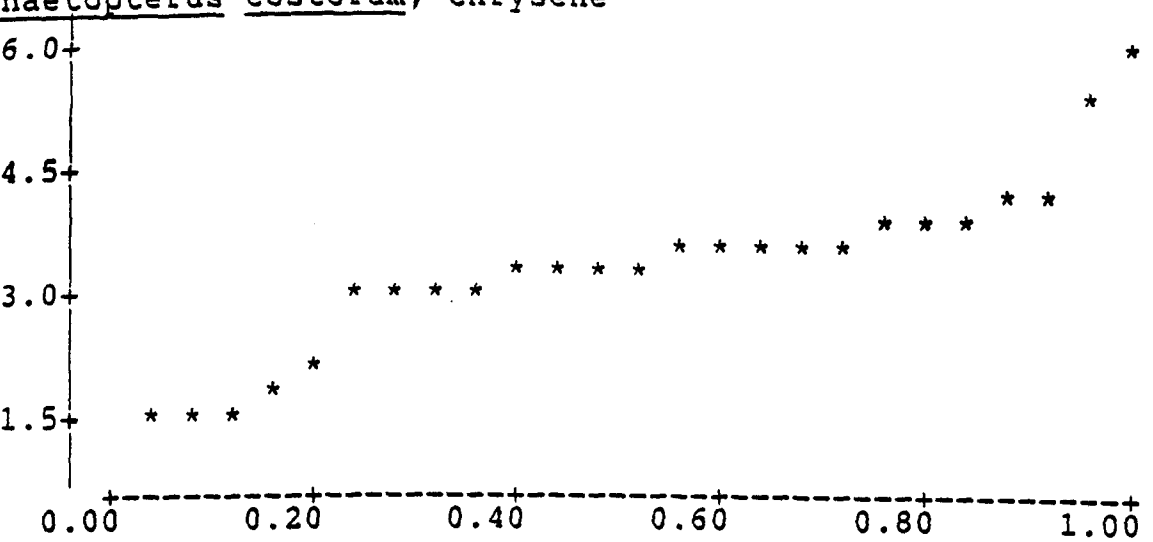
Nephtys ferruginea, Chrysene



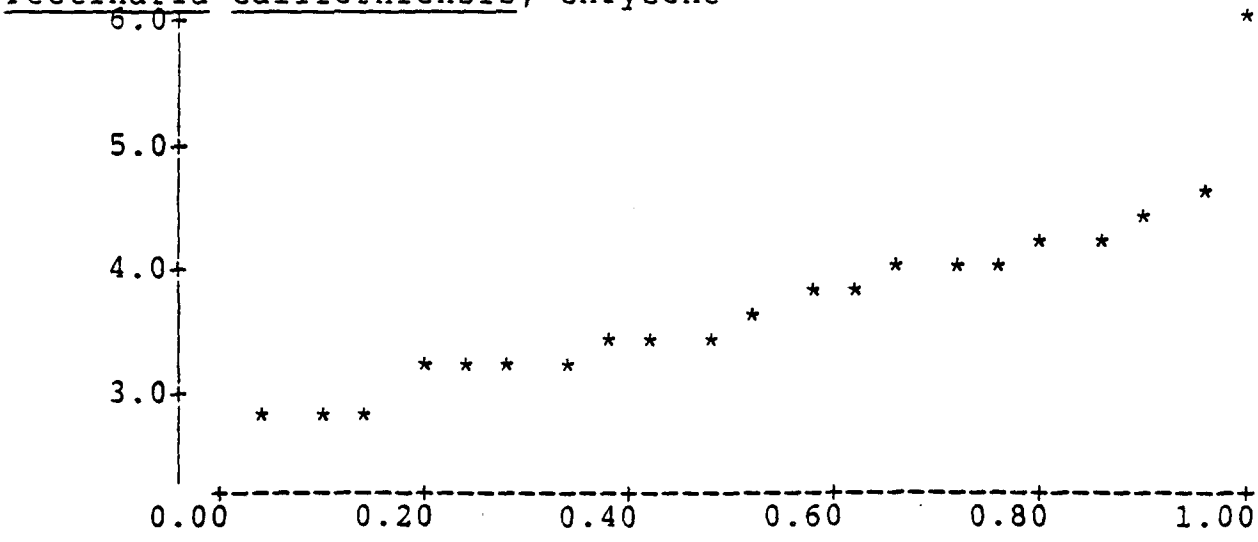
Glycera capitata, Chrysene



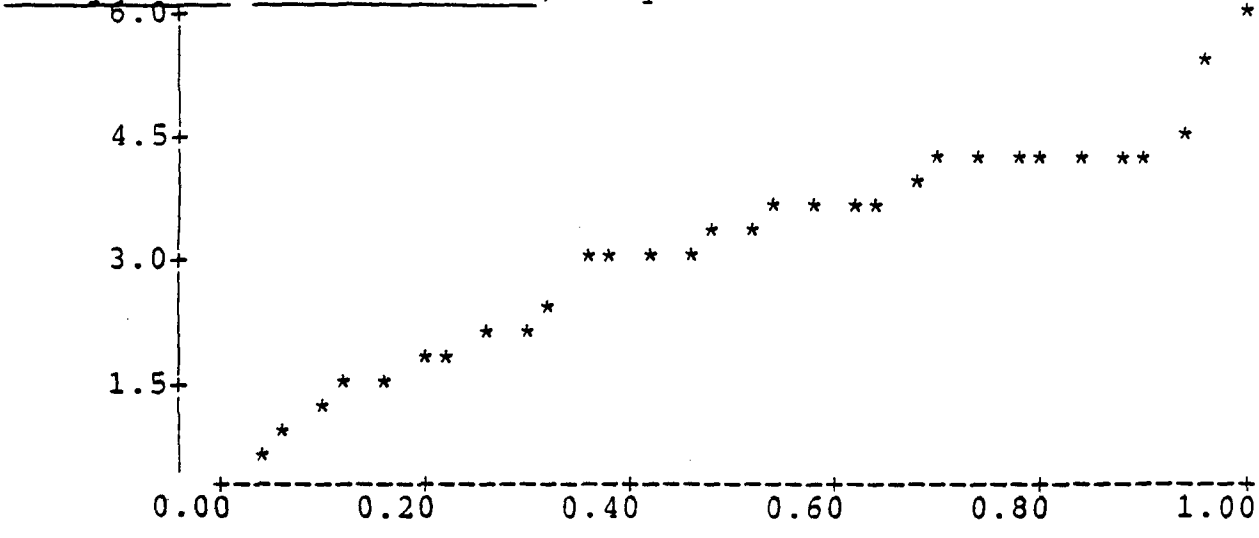
Spiochaetopterus costorum, Chrysene



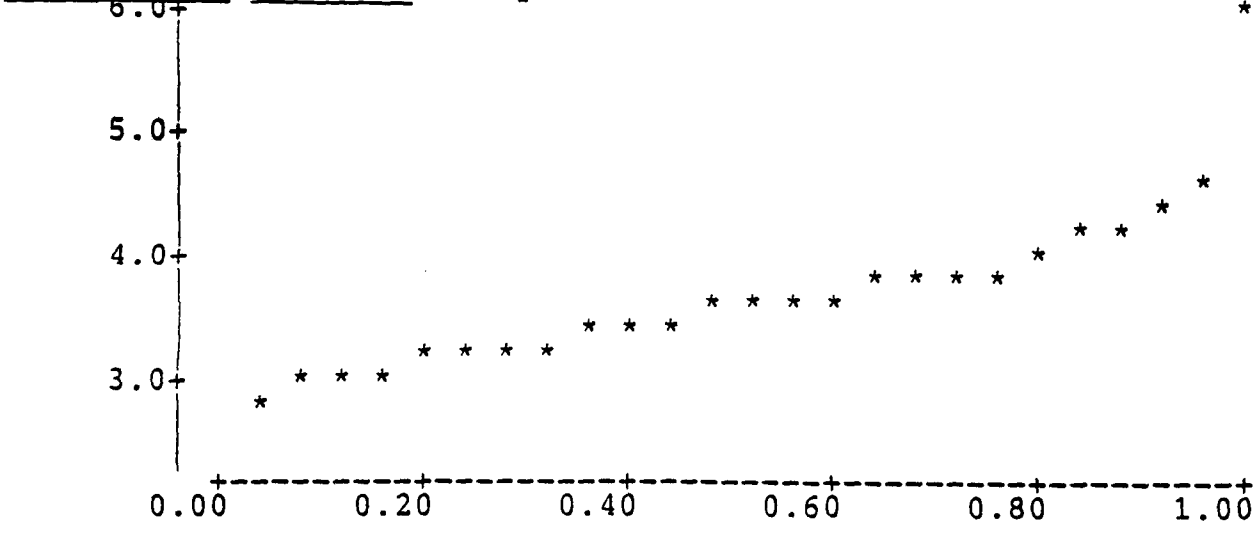
Pectinaria californiensis, Chrysene



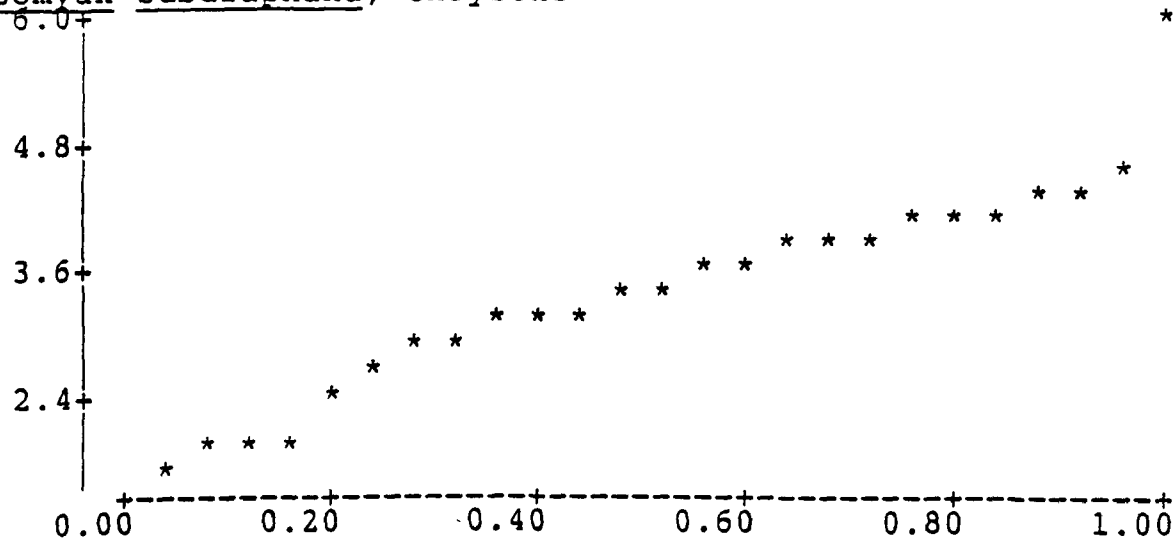
Platynereis bicanaliculata, Chrysene



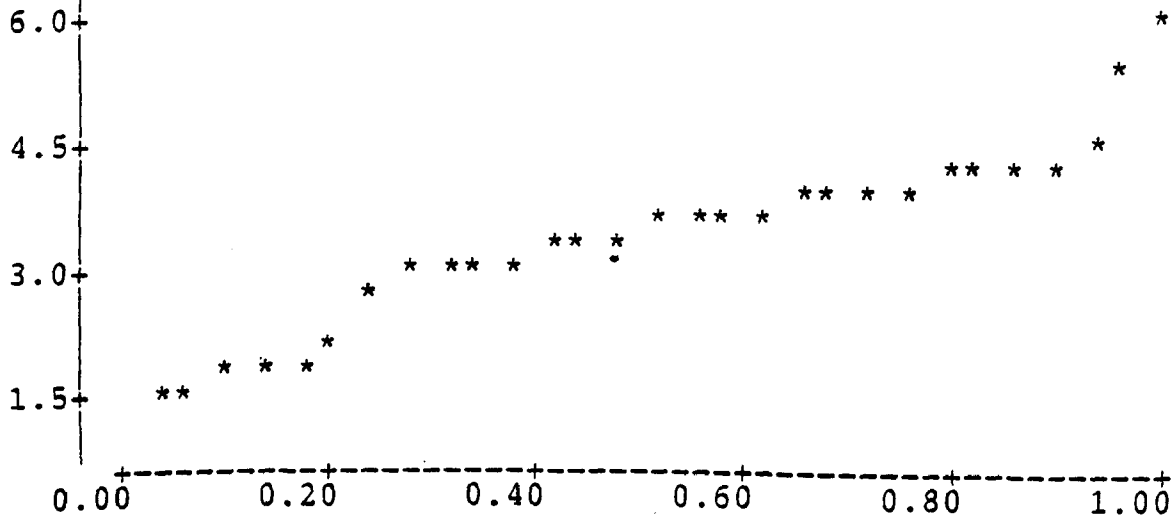
Praxillella gracilis, Chrysene



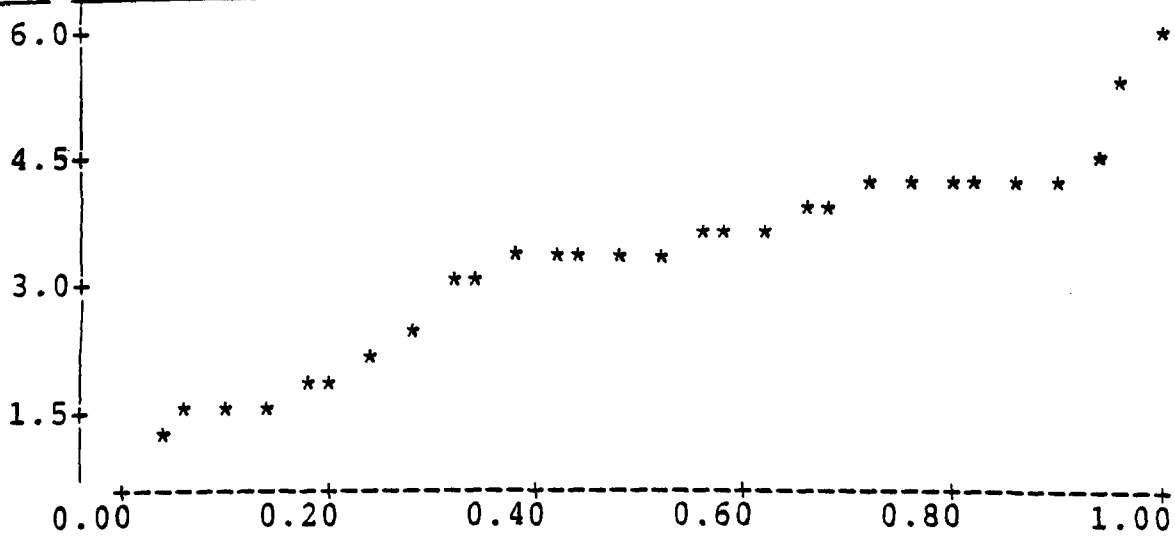
Compsomyax subdiaphana, Chrysene



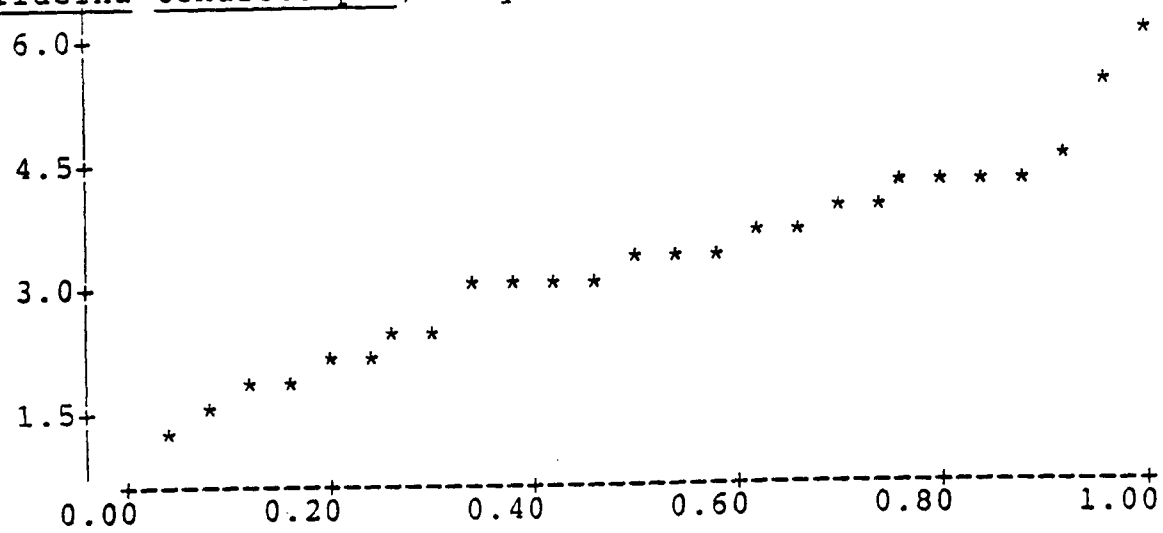
Amphioda (amphispina) urtica, Chrysene



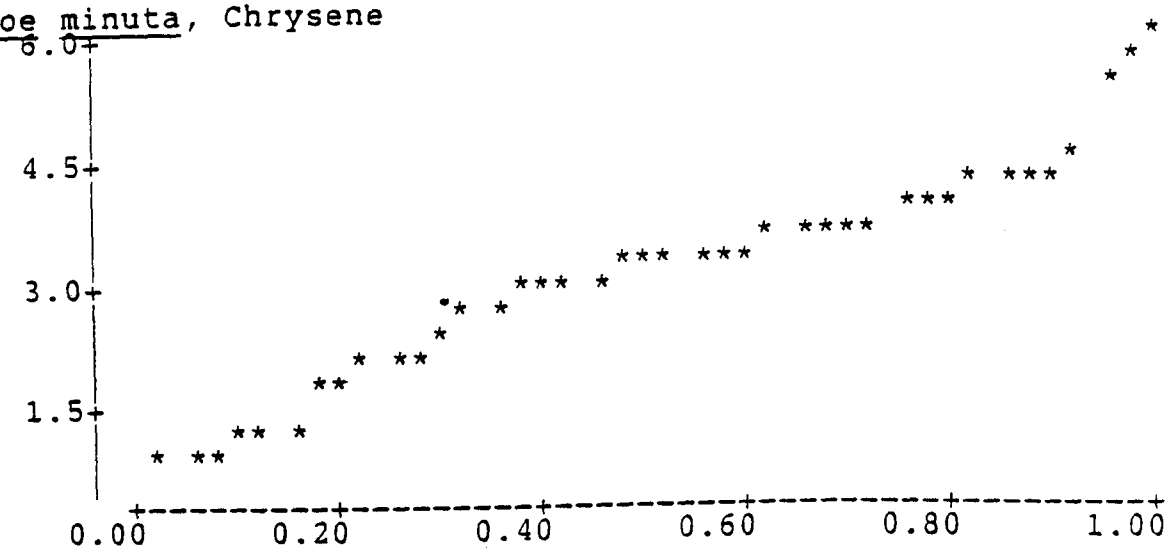
Glycera americana, Chrysene



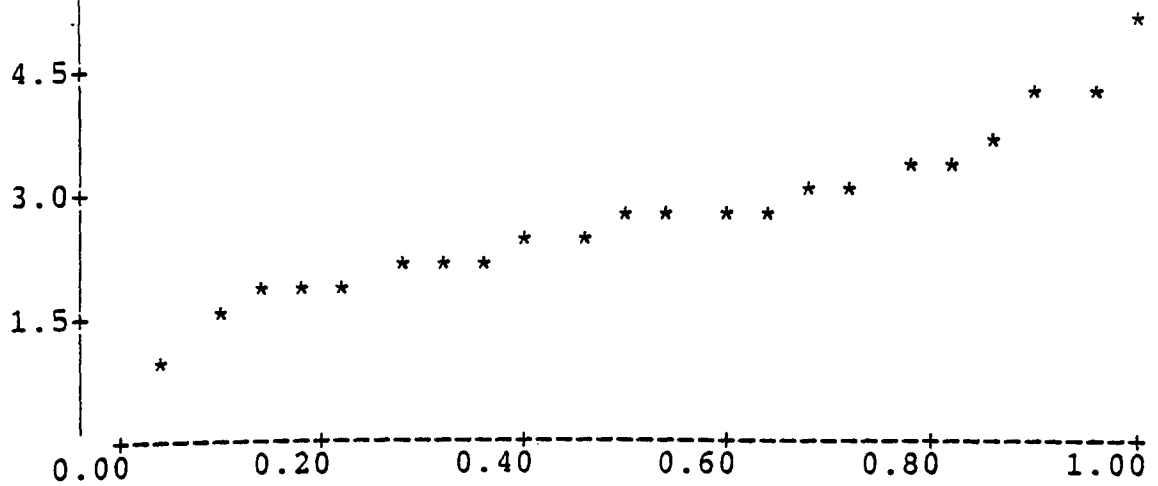
Parvilucina tenuisculpta, Chrysene



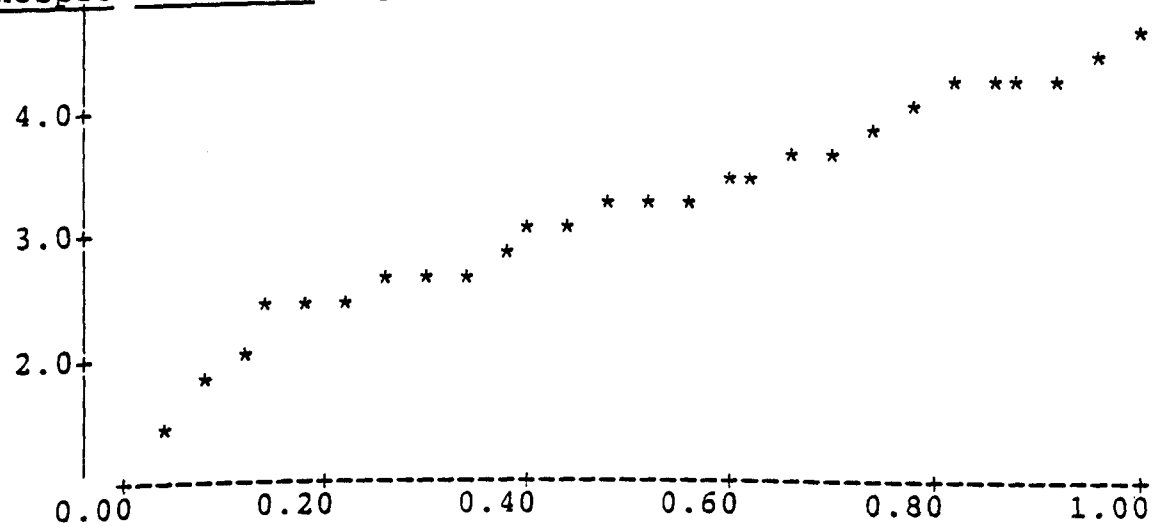
Pholoe minuta, Chrysene



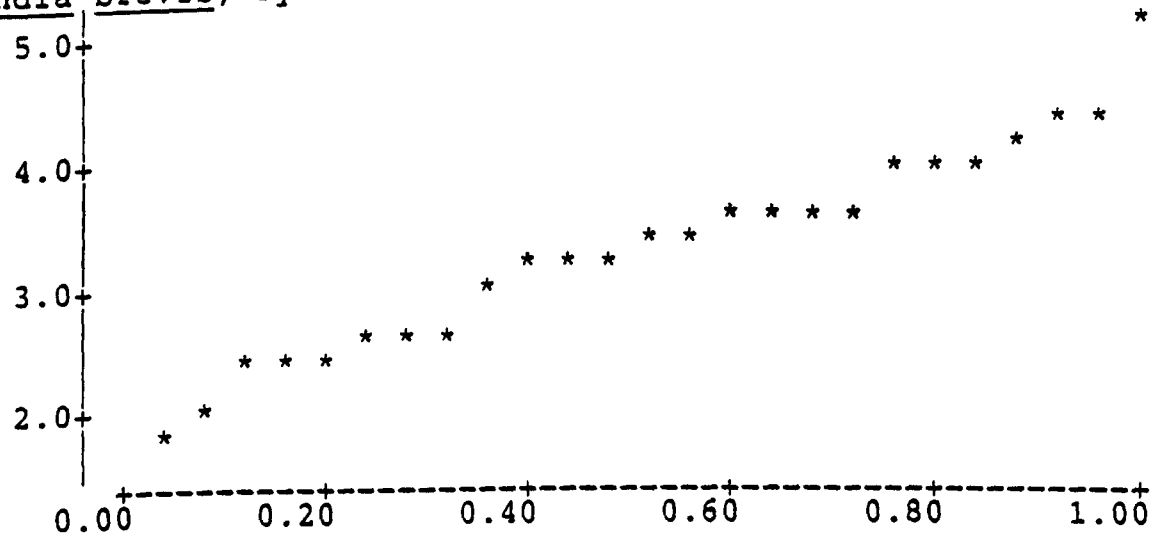
Glycinde armigera, Pyrene



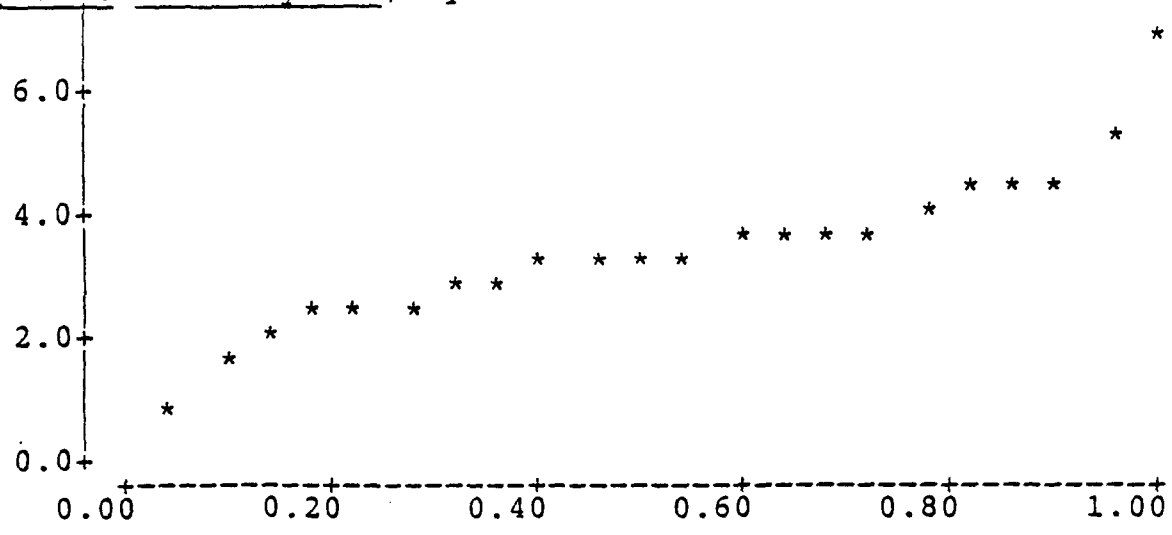
Prionospio cirrifera, Pyrene



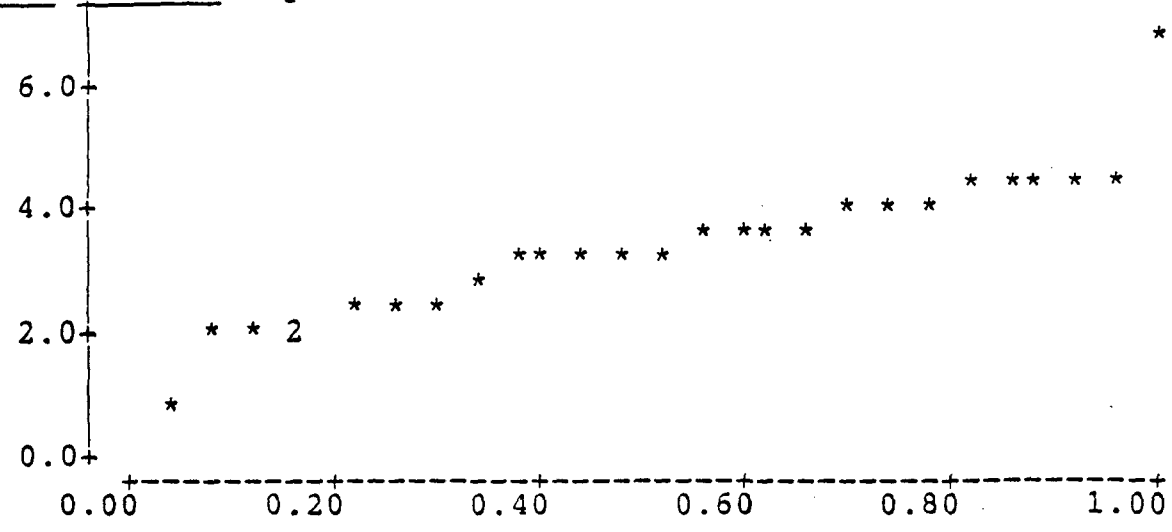
Armandia brevis, Pyrene



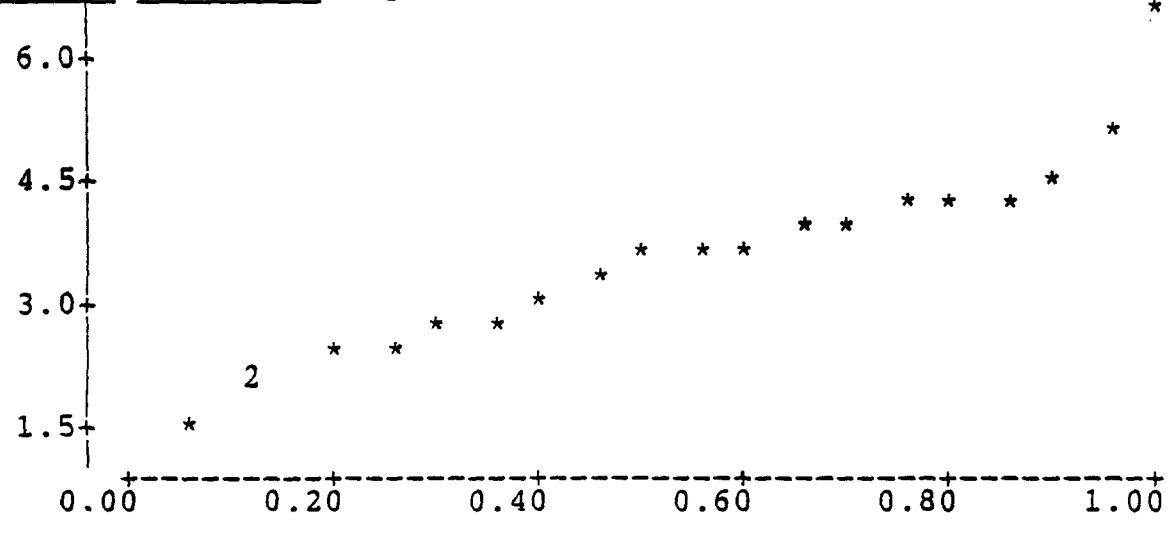
Spiophanes berkeleyorum, Pyrene



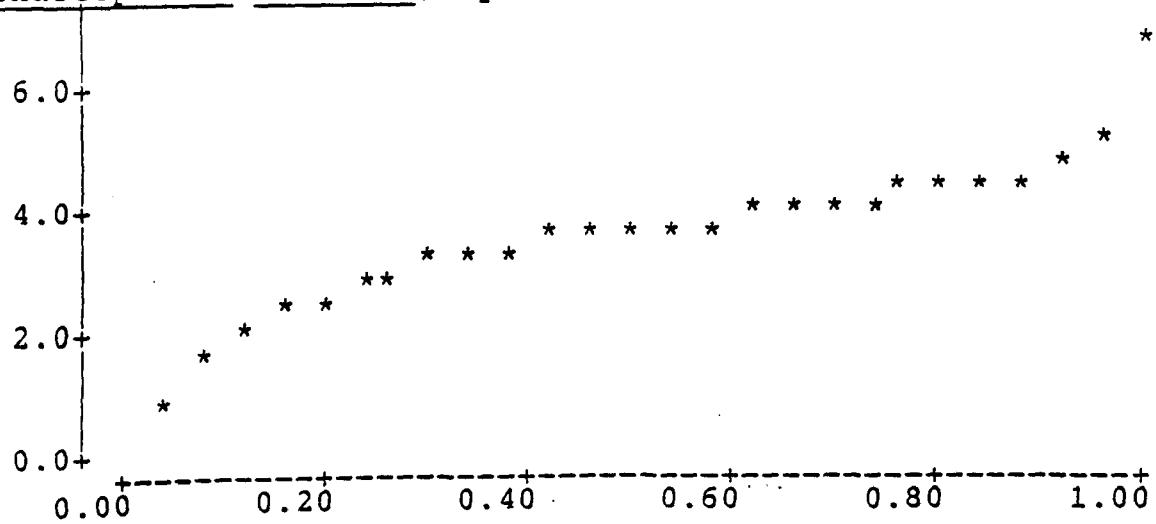
Goniada brunnea, Pyrene



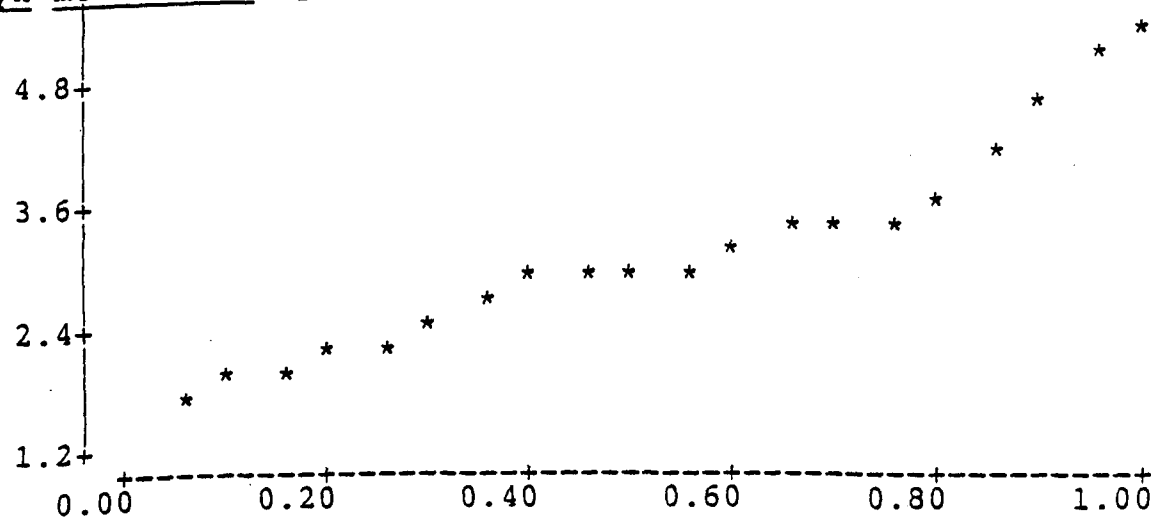
Phyllodoce hartmanae, Pyrene



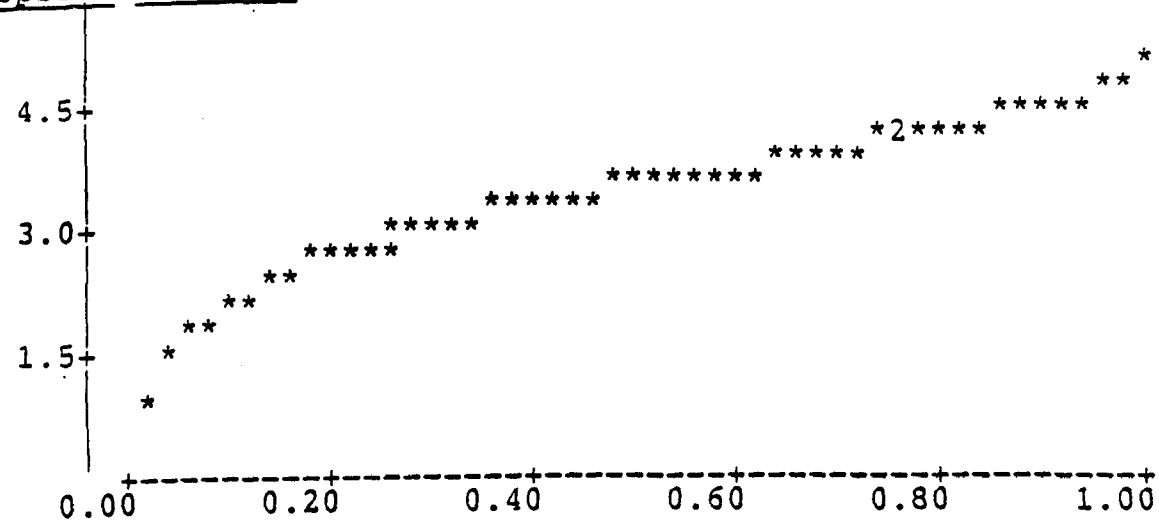
Spiochaetopterus costorum, Pyrene



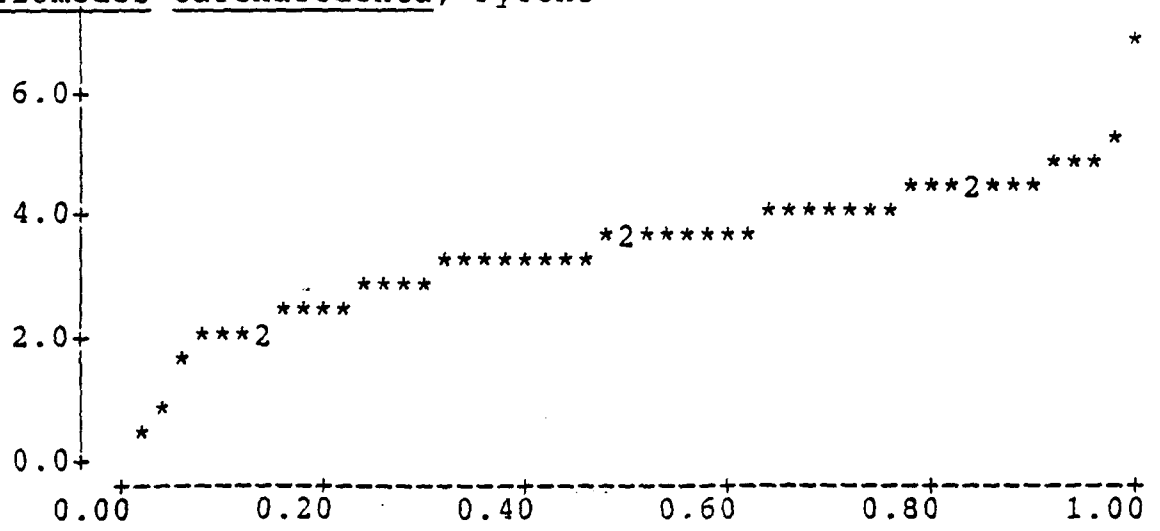
Tharyx monilaris, Pyrene



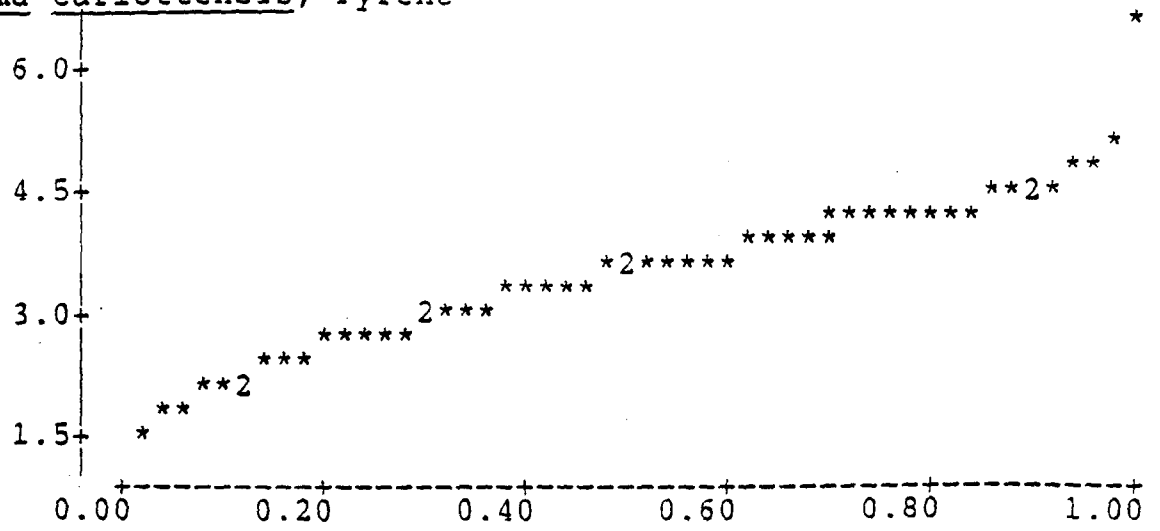
Axinopsida sericata, Pyrene



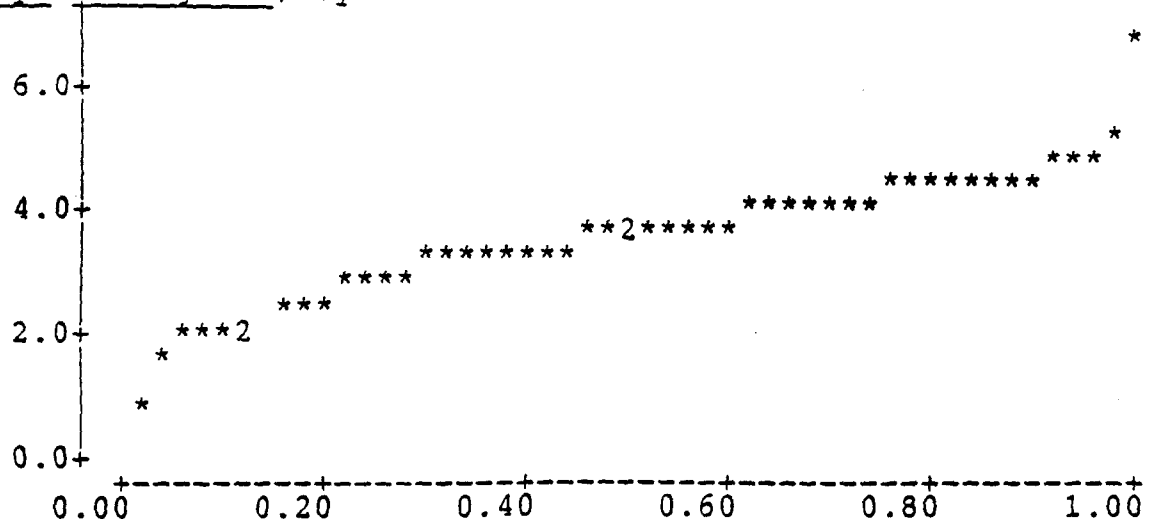
Euphilomedes carcharodonta, Pyrene



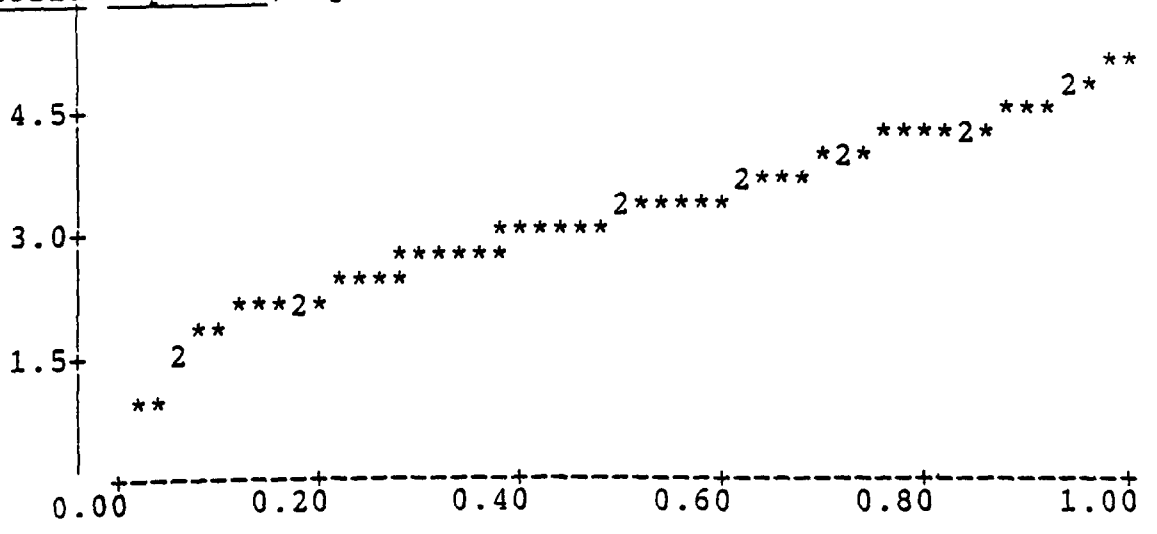
Macoma carlottensis, Pyrene



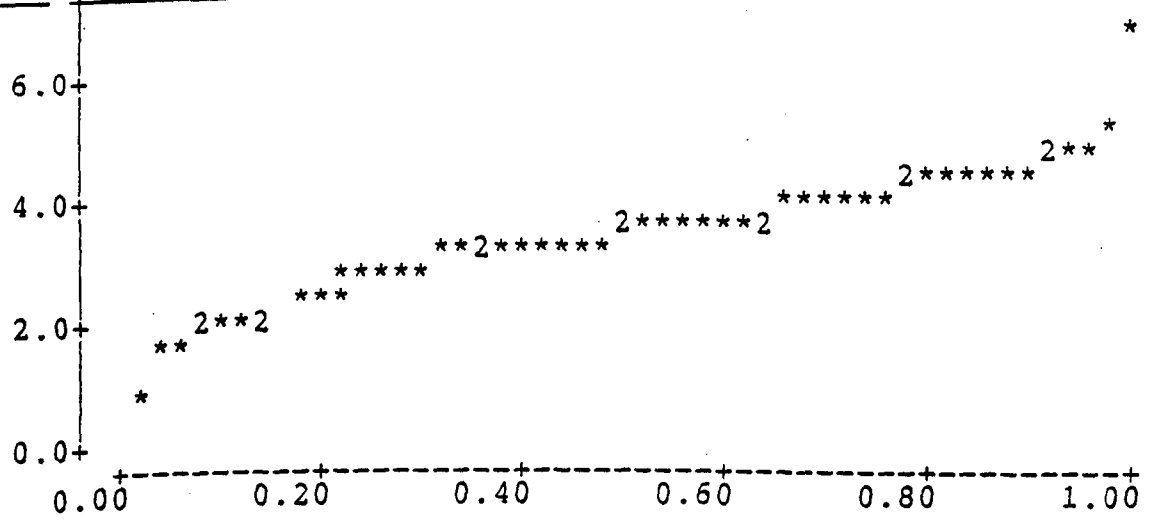
Nephtys ferruginea, Pyrene



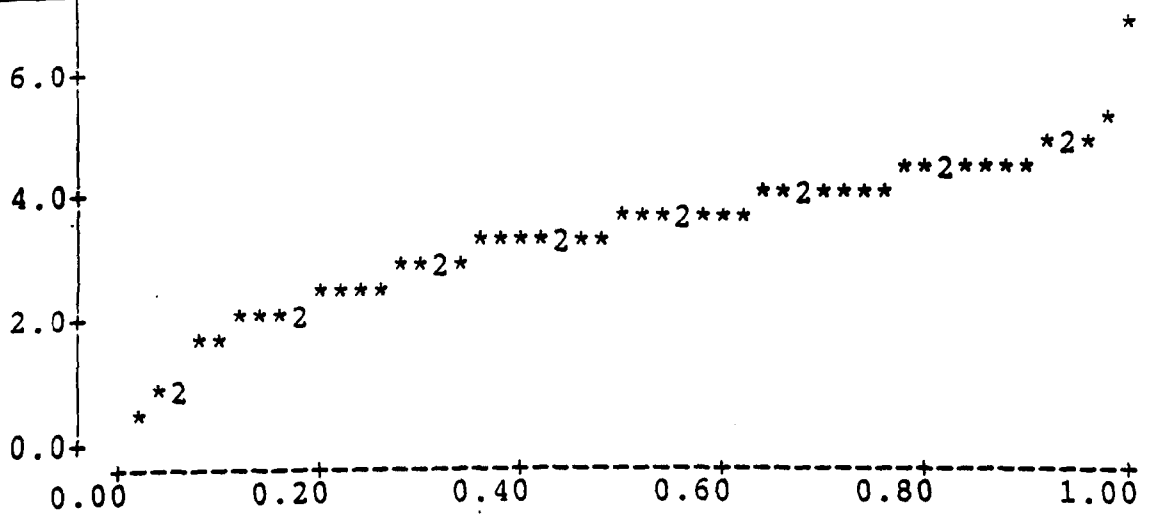
Capitella capitata, Pyrene



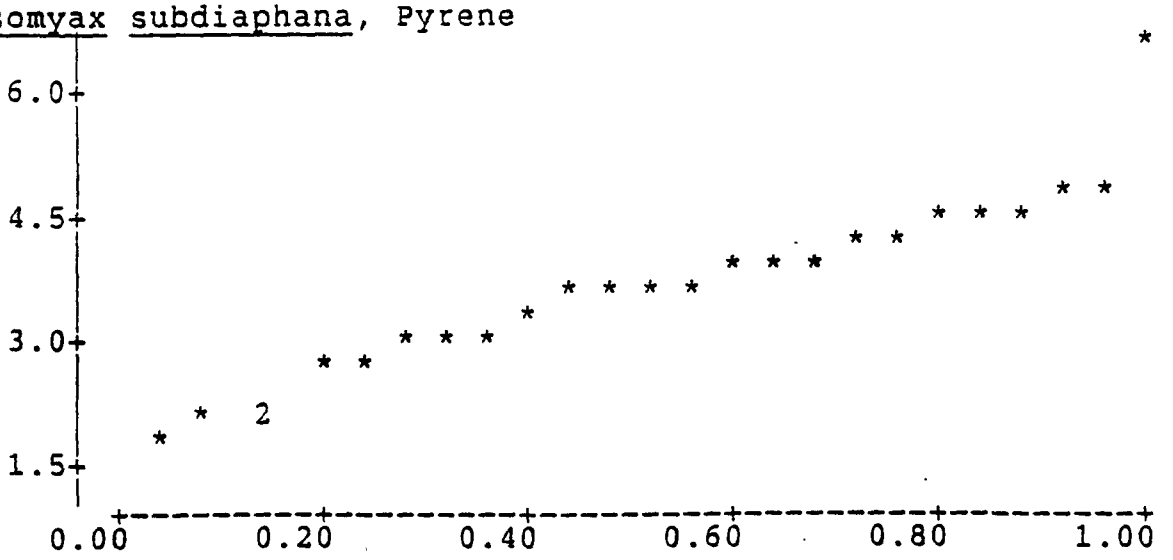
Glycera capitata, Pyrene



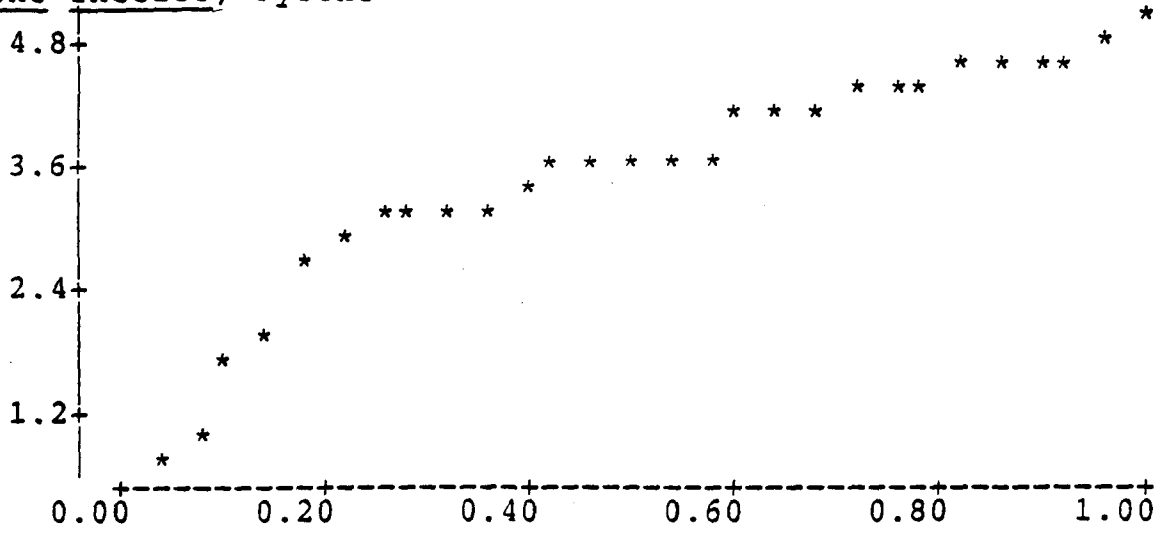
Prionospio steenstrupi, Pyrene



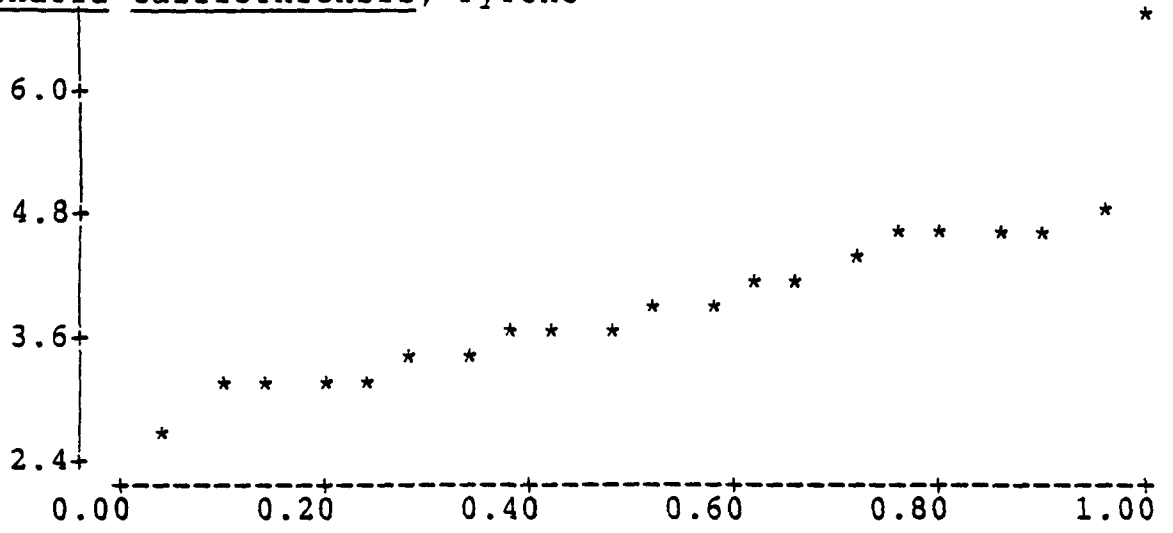
Compsomyax subdiaphana, Pyrene



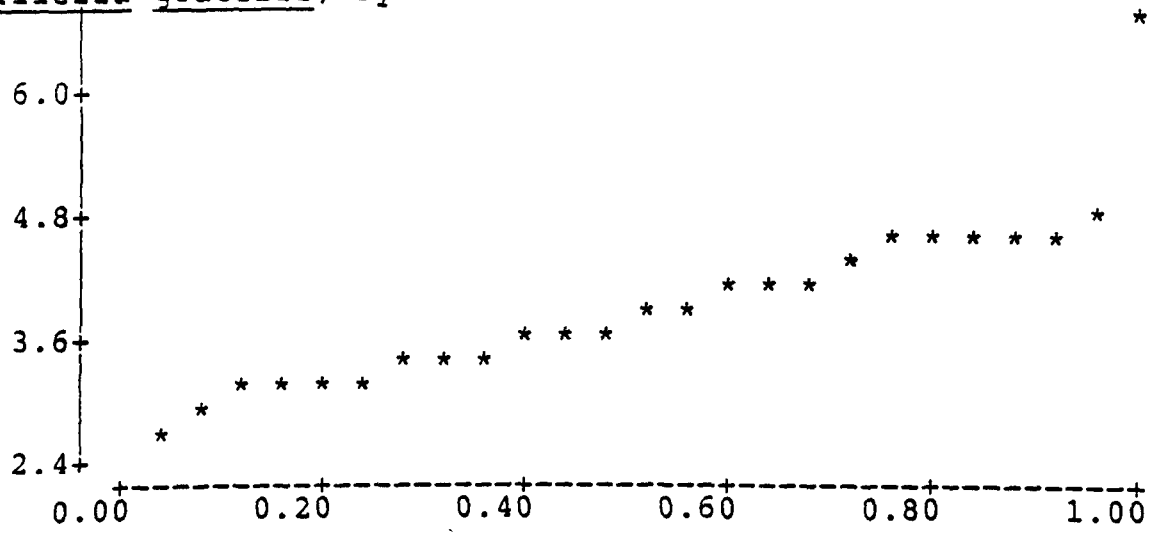
Euchone incolor, Pyrene



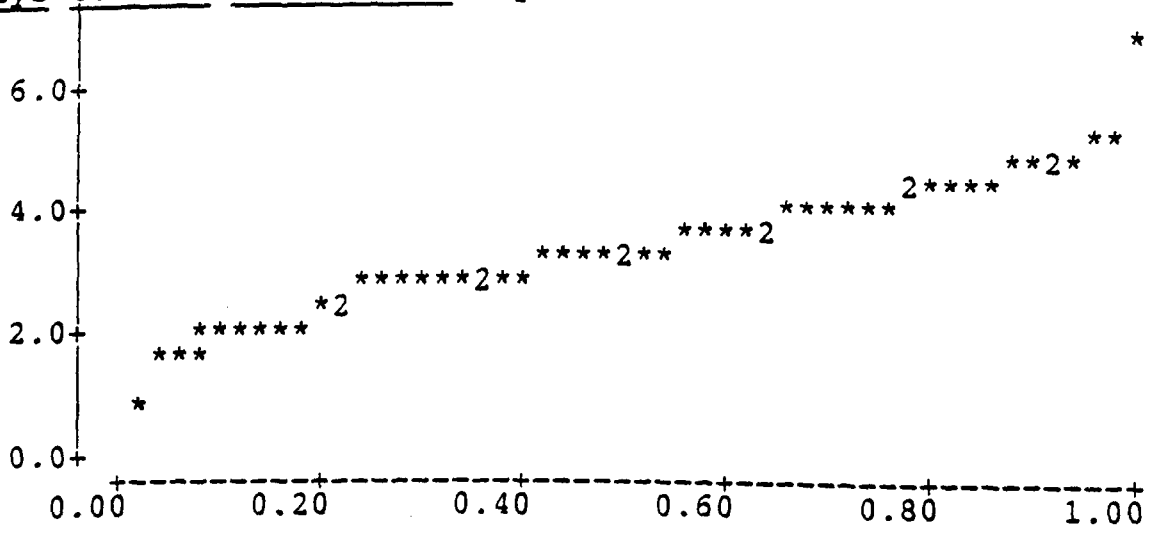
Pectinaria californiensis, Pyrene



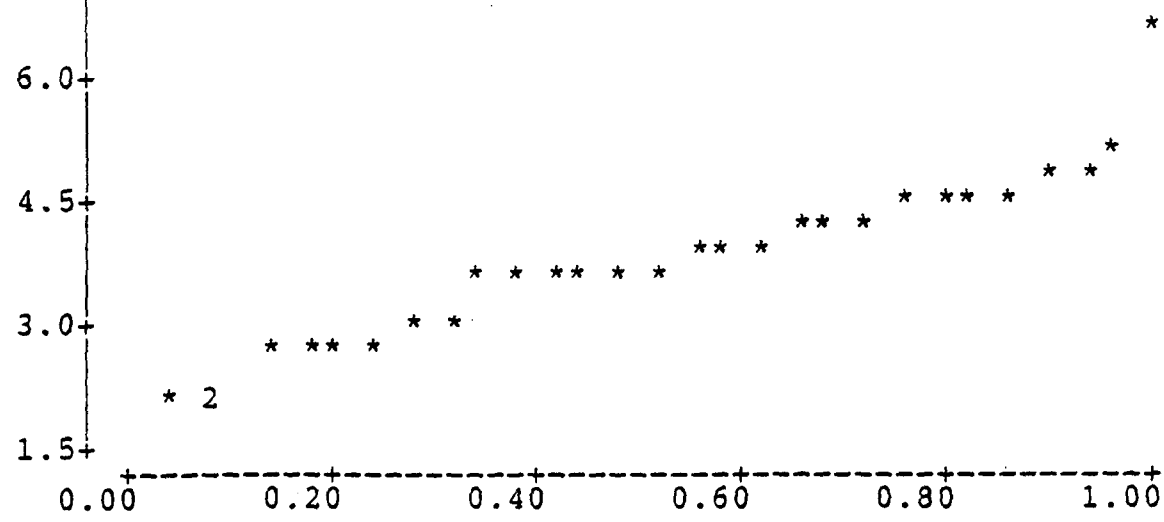
Praxillella gracilis, Pyrene



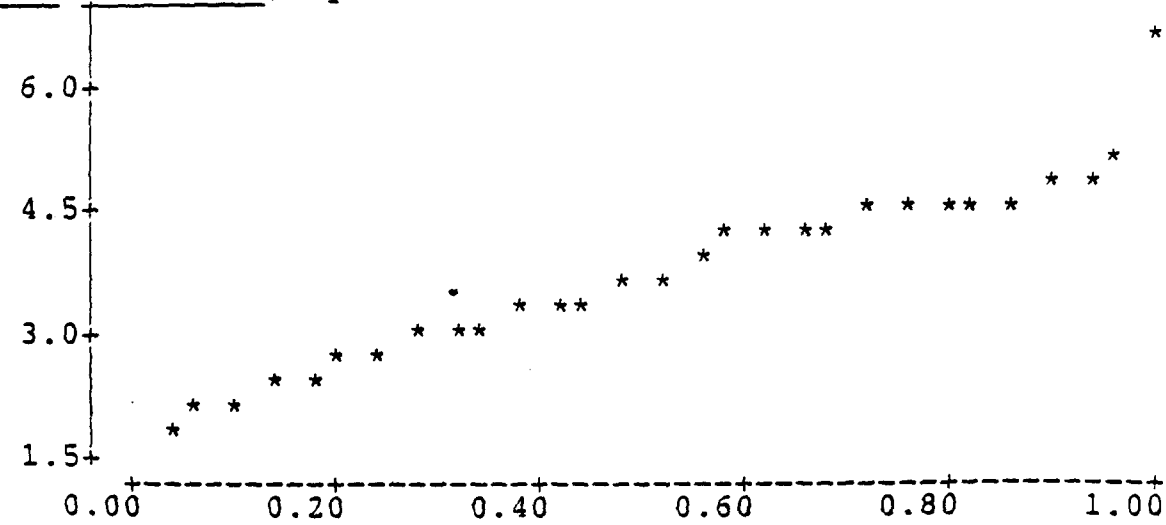
Nephtys cornuta franciscana, Pyrene



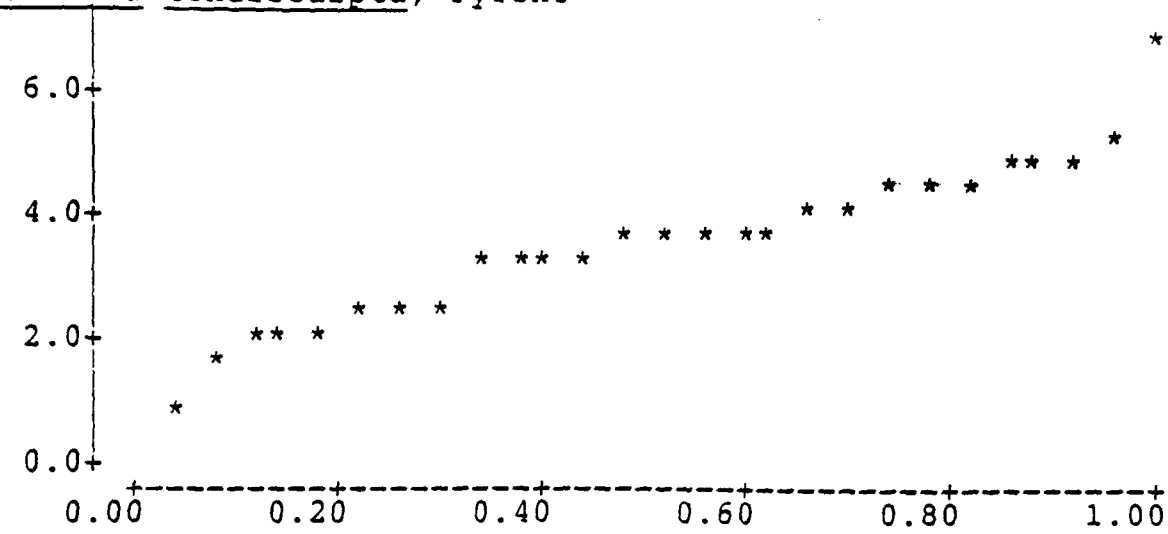
Amphioda (amphispina) urtica, Pyrene



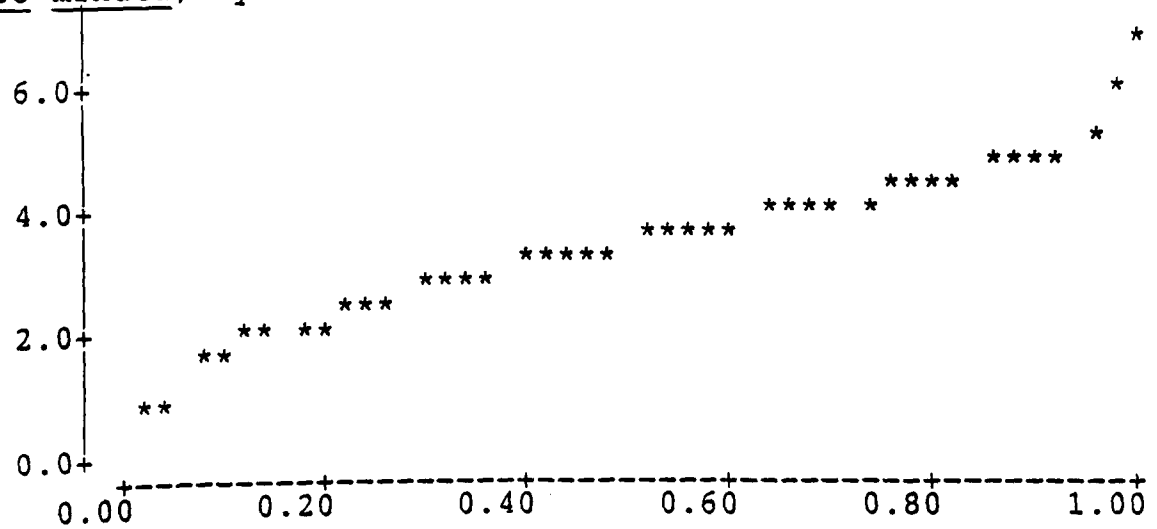
Glycera americana, Pyrene



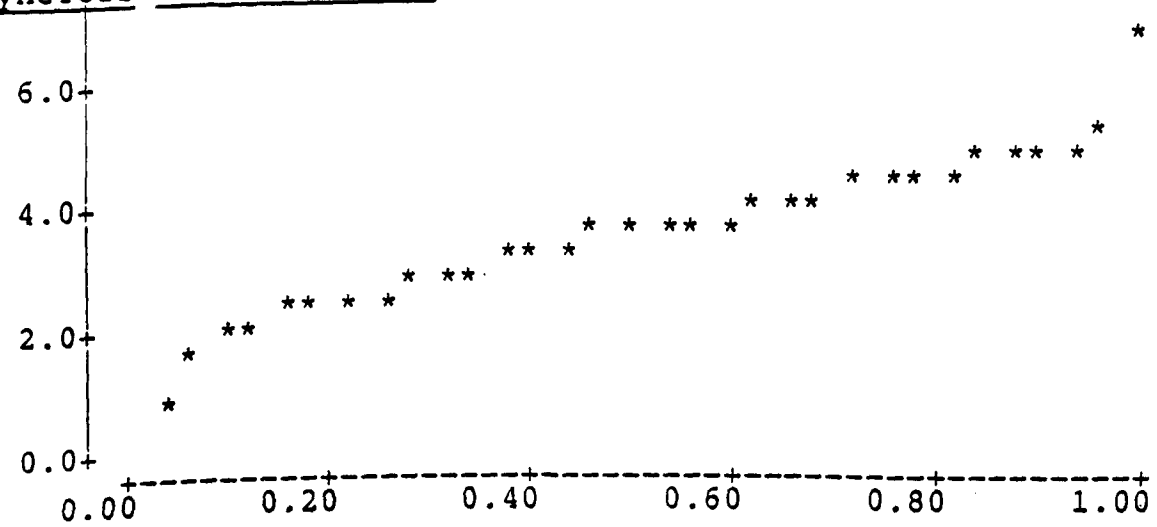
Parvilucina tenuisculpta, Pyrene



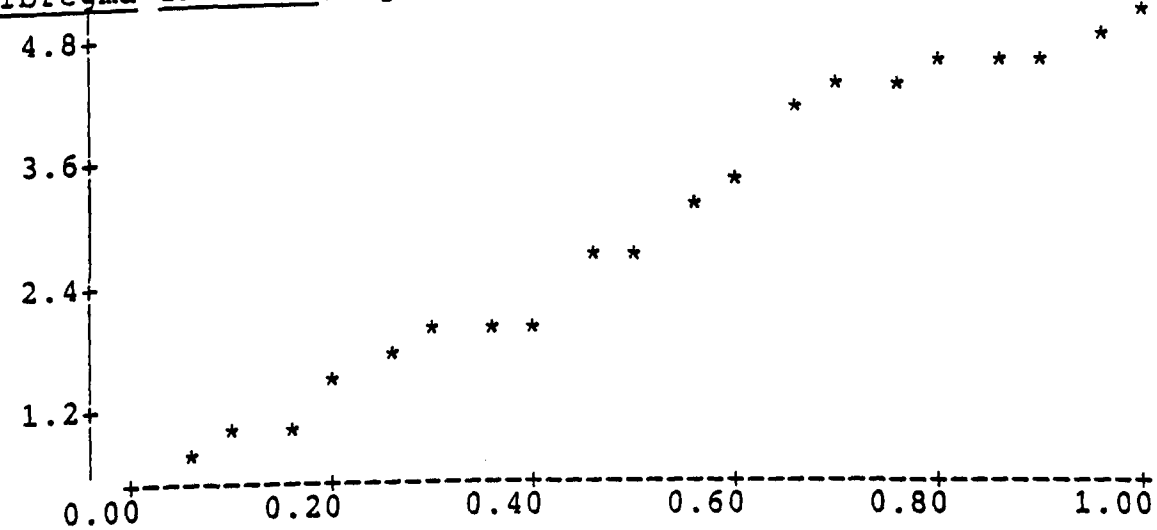
Pholoe minuta, Pyrene



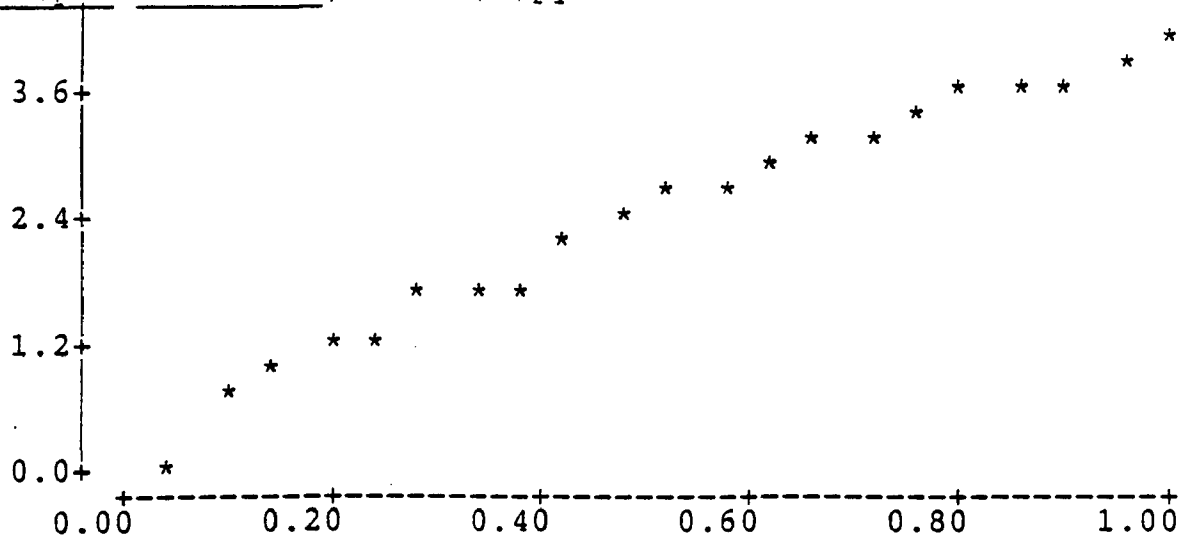
Platynereis bicanaliculata, Pyrene



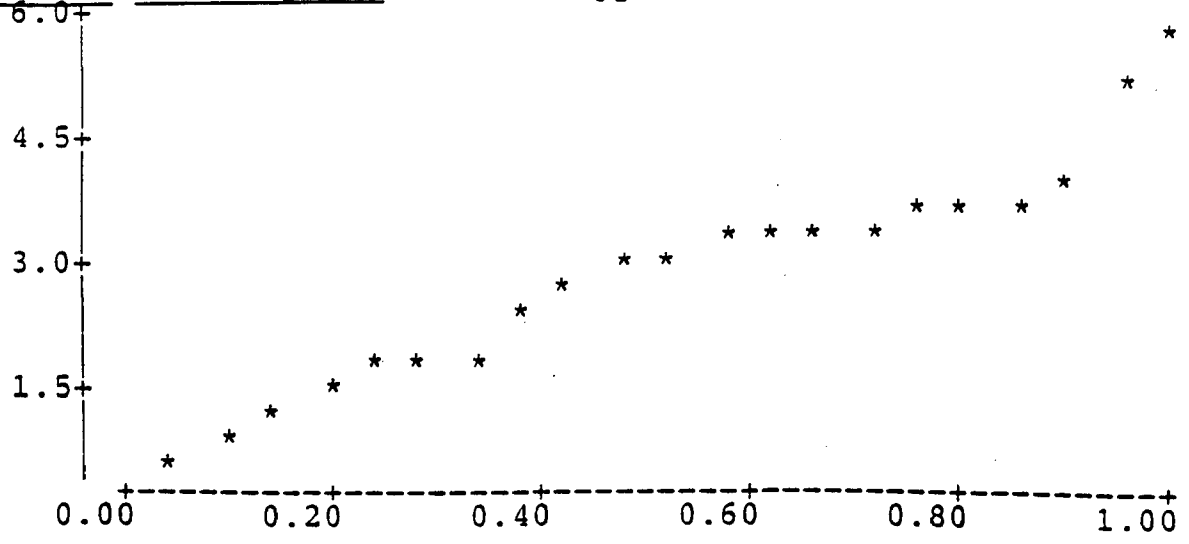
Scalibregma inflatum, Pyrene



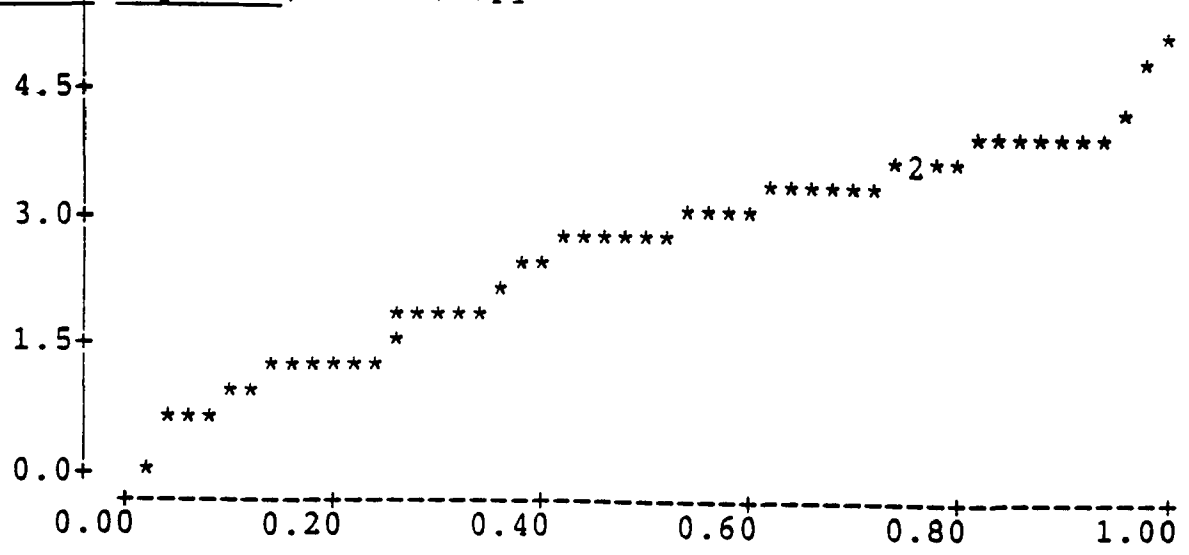
Prionospio cirrifera, Benzo(a)pyrene



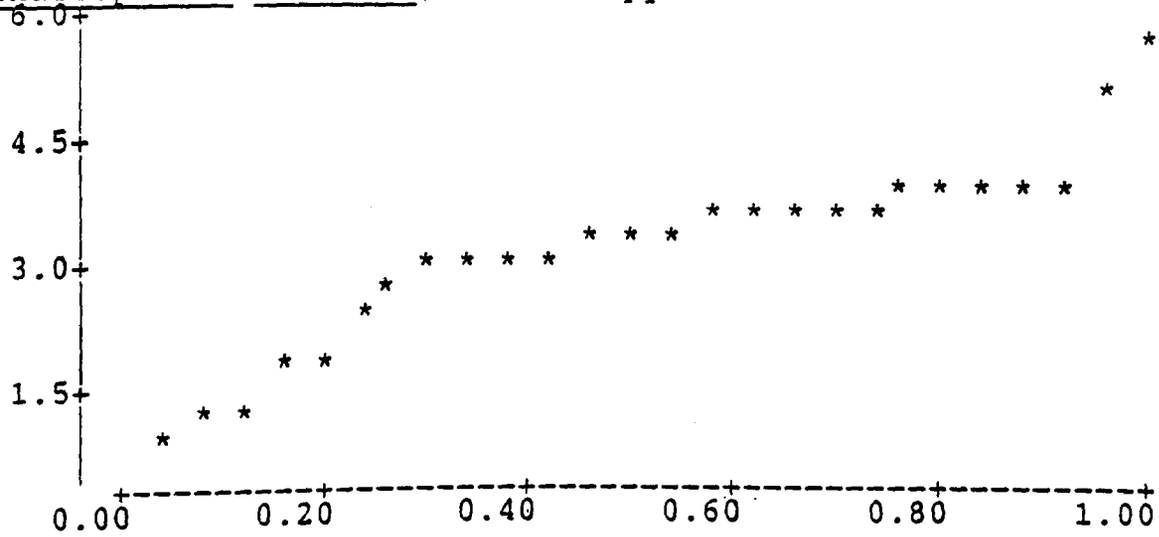
Spiophanes berkeleyorum, Benzo(a)pyrene



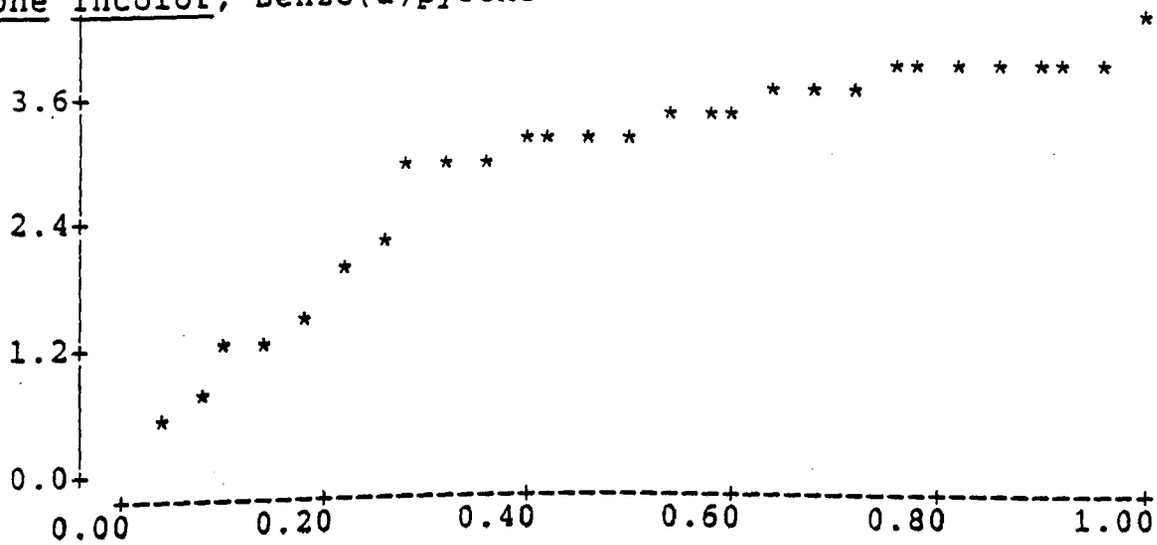
Capitella capitata, Benzo(a)pyrene



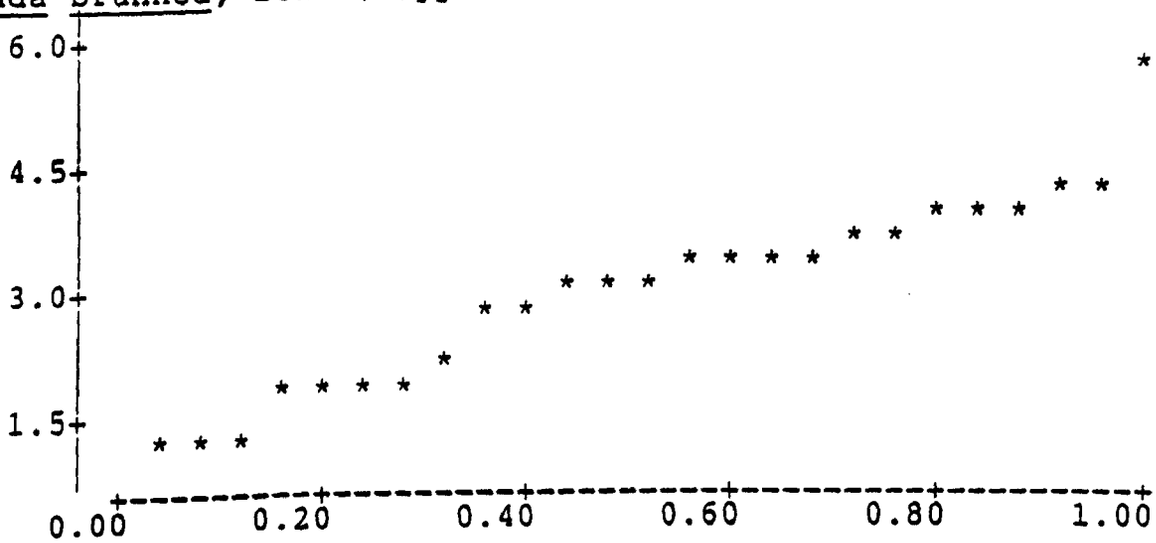
Spiochaetopterus costorum, Benzo(a)pyrene



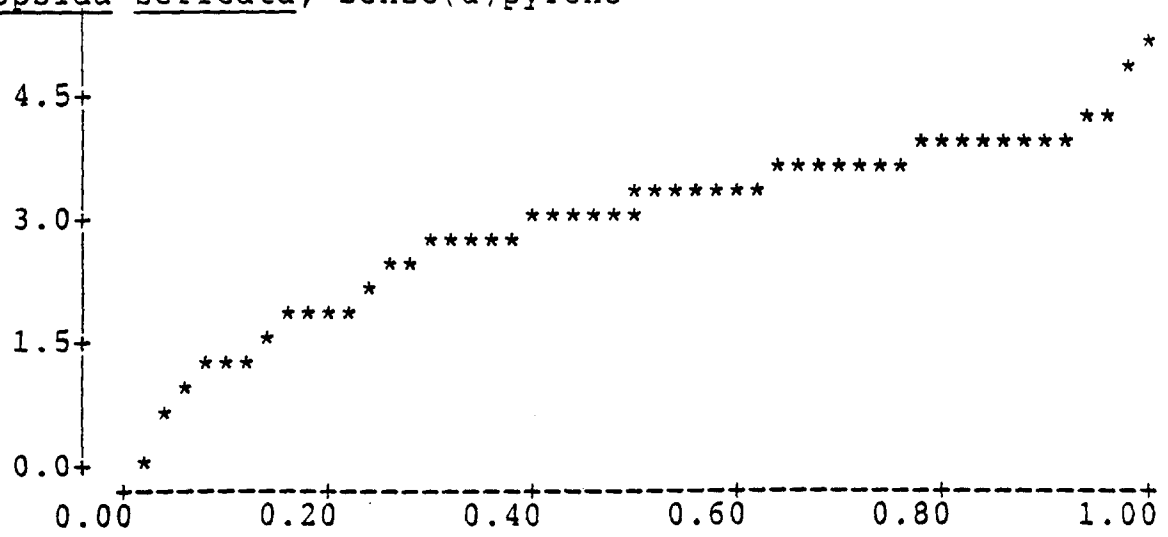
Euchone incolor, Benzo(a)pyrene



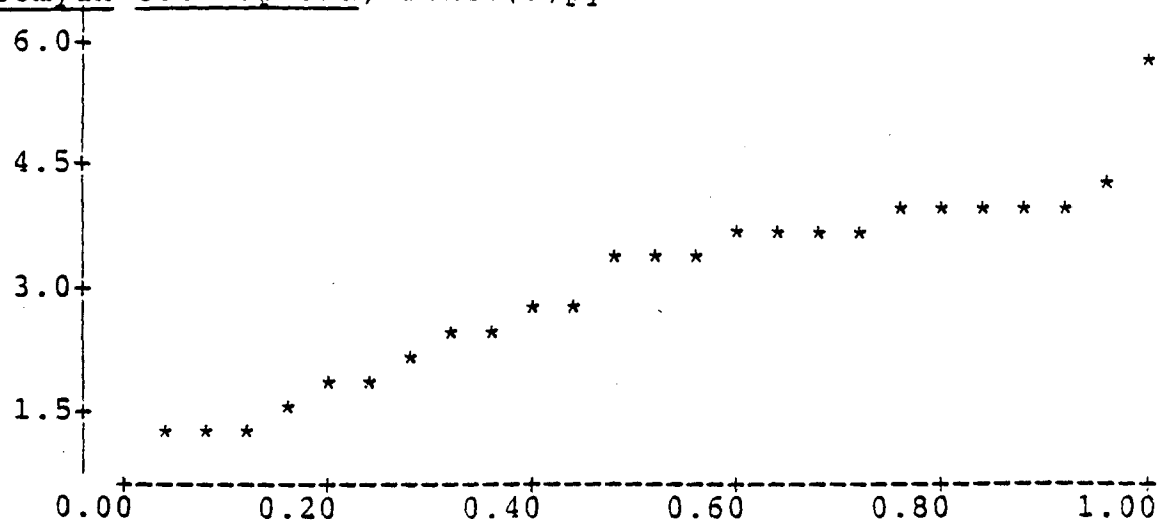
Goniada brunnea, Benzo(a)pyrene



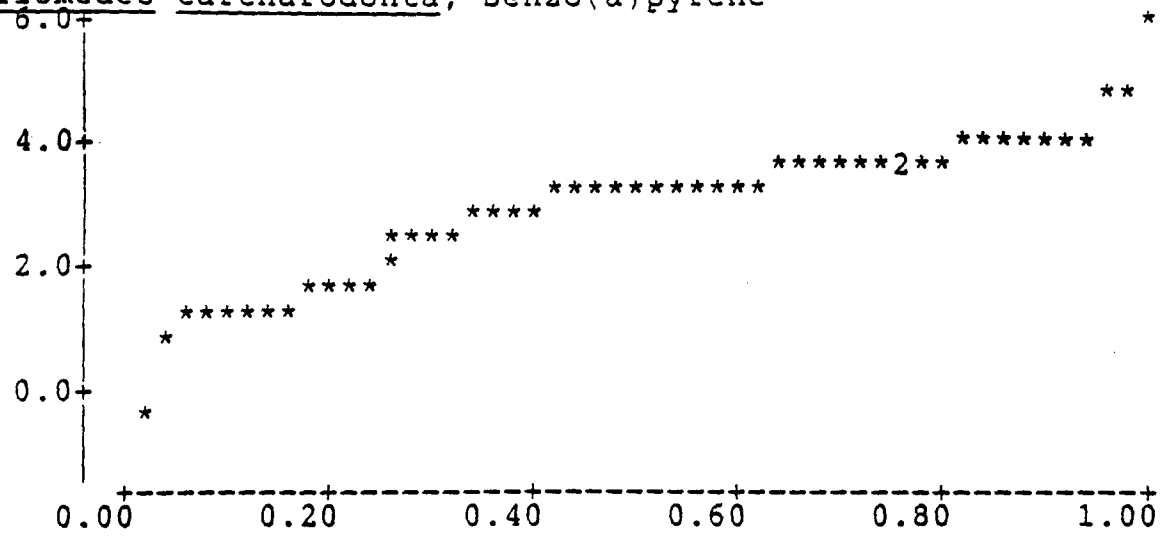
Axinopsida sericata, Benzo(a)pyrene



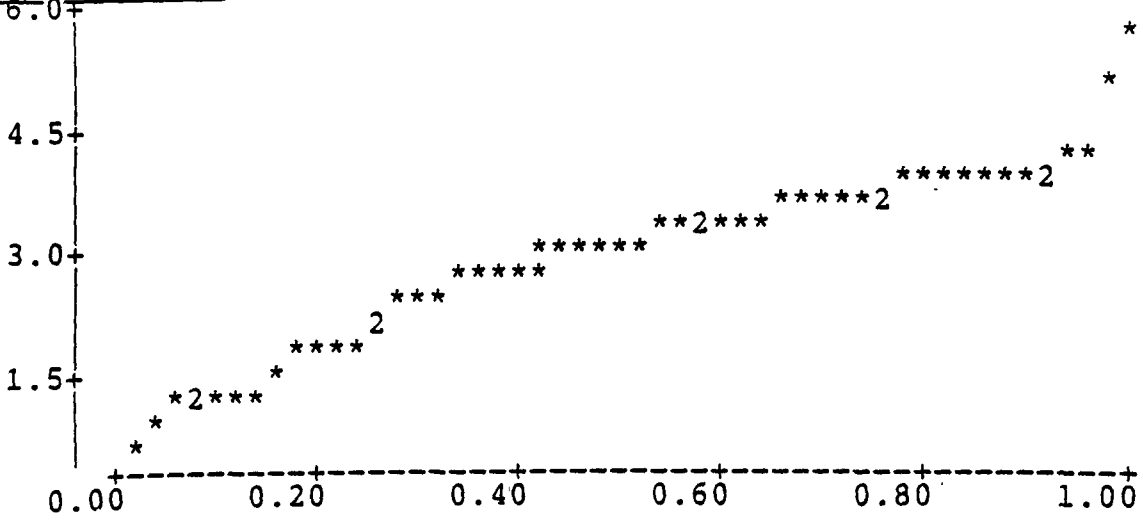
Compsomyax subdiaphana, Benzo(a)pyrene



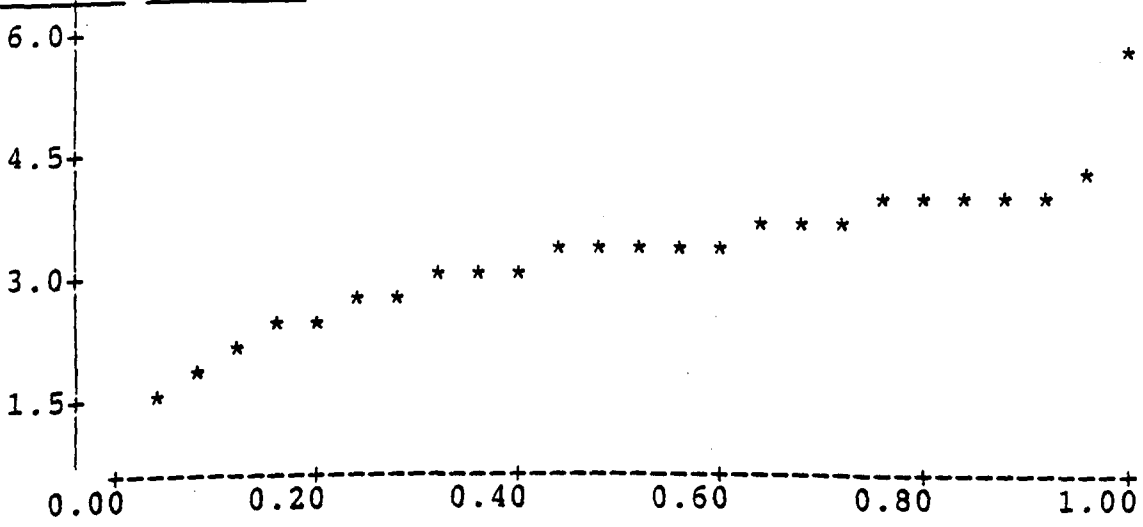
Euphilomedes carcharodonta, Benzo(a)pyrene



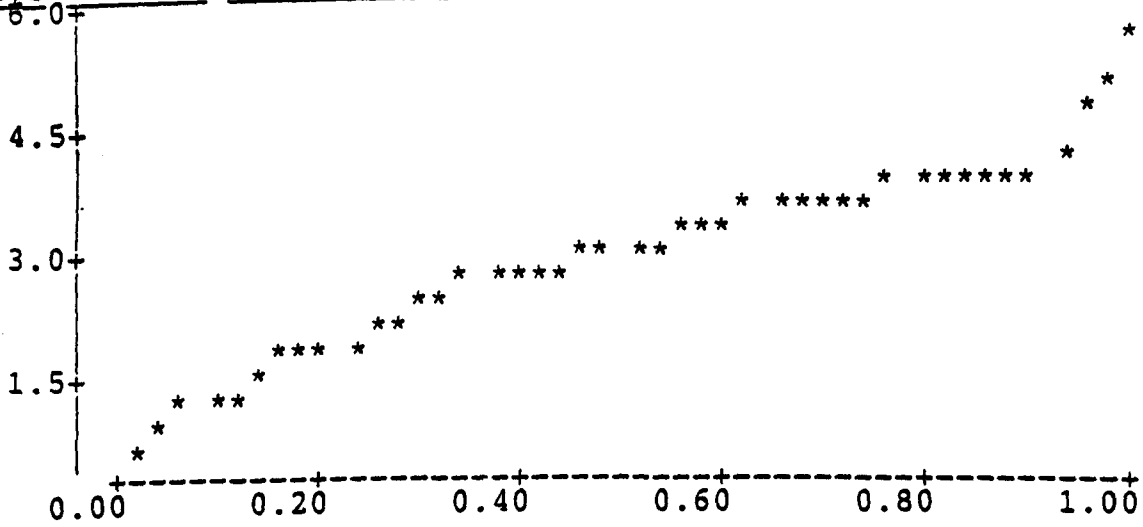
Glycera capitata, Benzo(a)pyrene



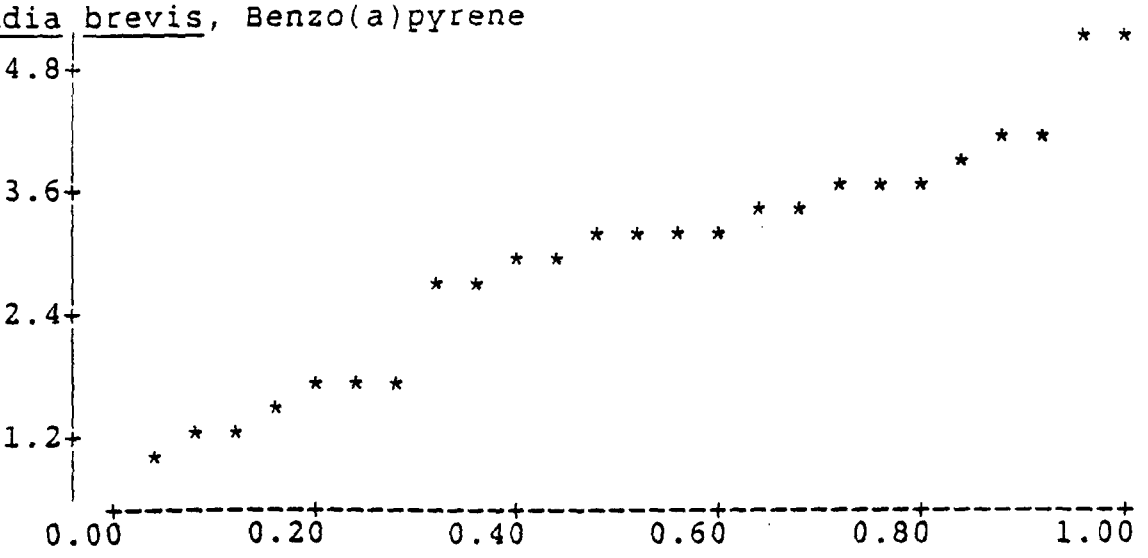
Praxillella gracilis, Benzo(a)pyrene



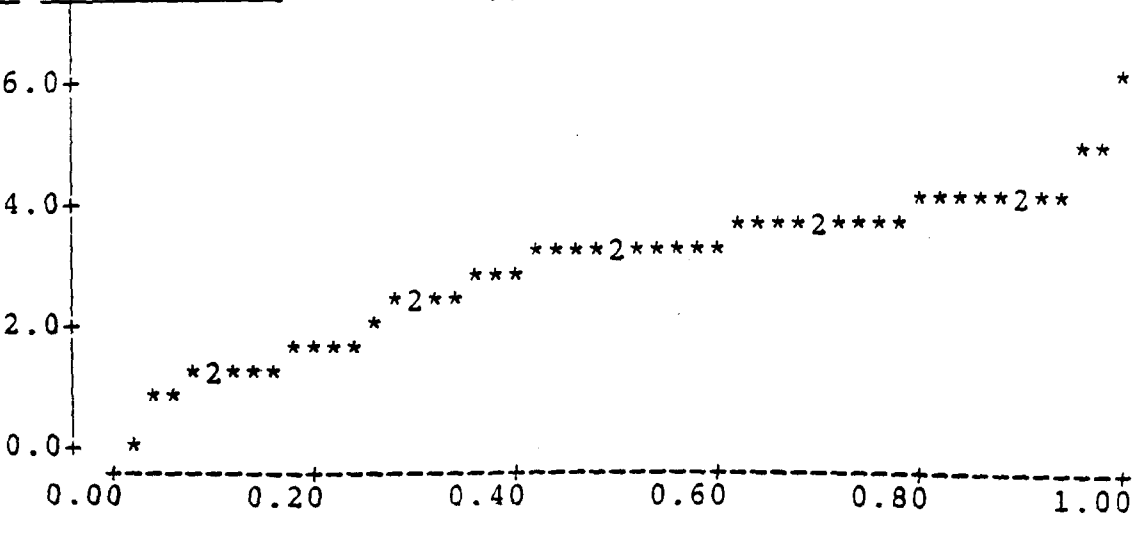
Nephtys cornuta franciscana, Benzo(a)pyrene



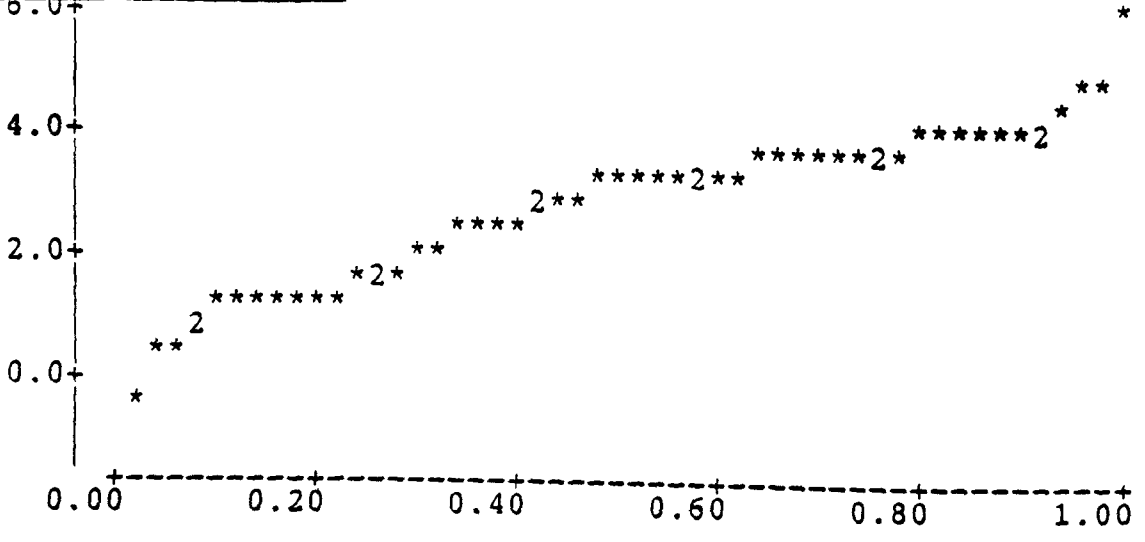
Armandia brevis, Benzo(a)pyrene



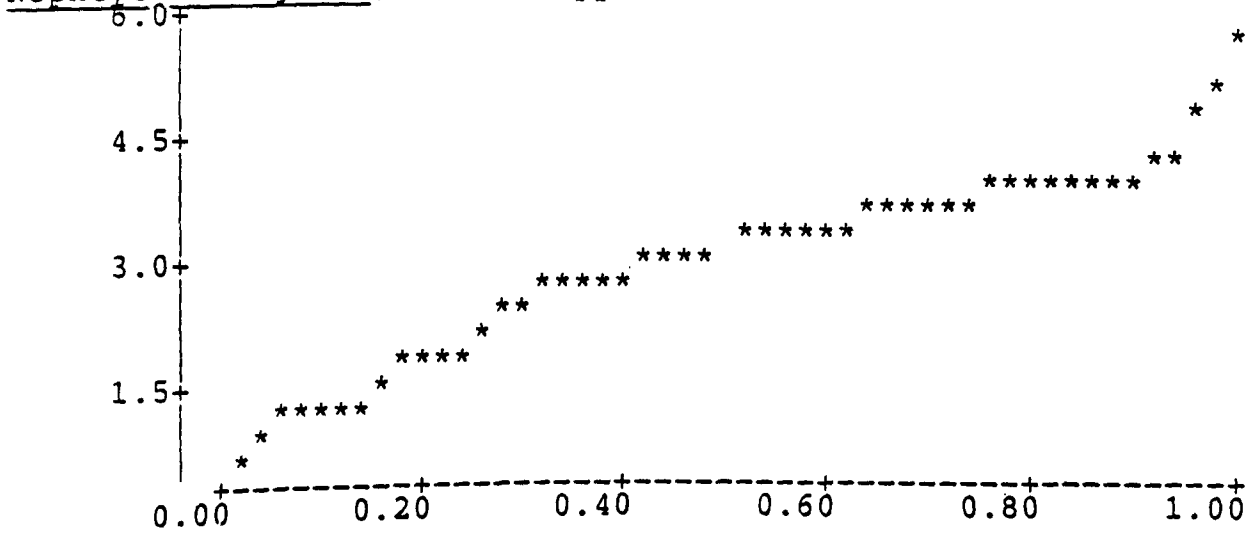
Macoma carlottensis, Benzo(a)pyrene



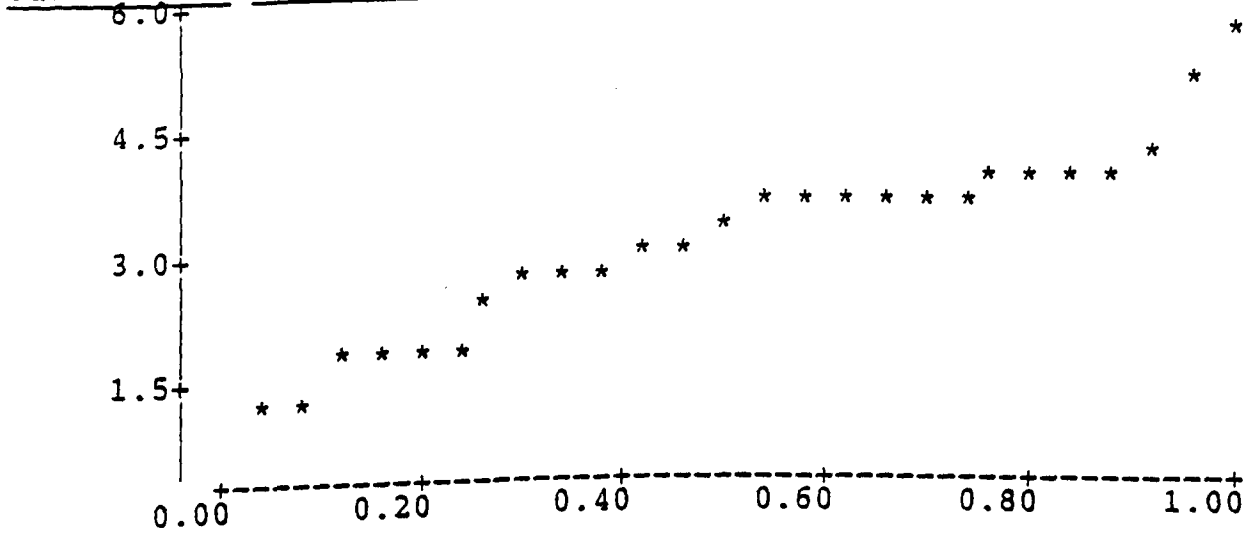
Prionospio steenstrupi, Benzo(a)pyrene



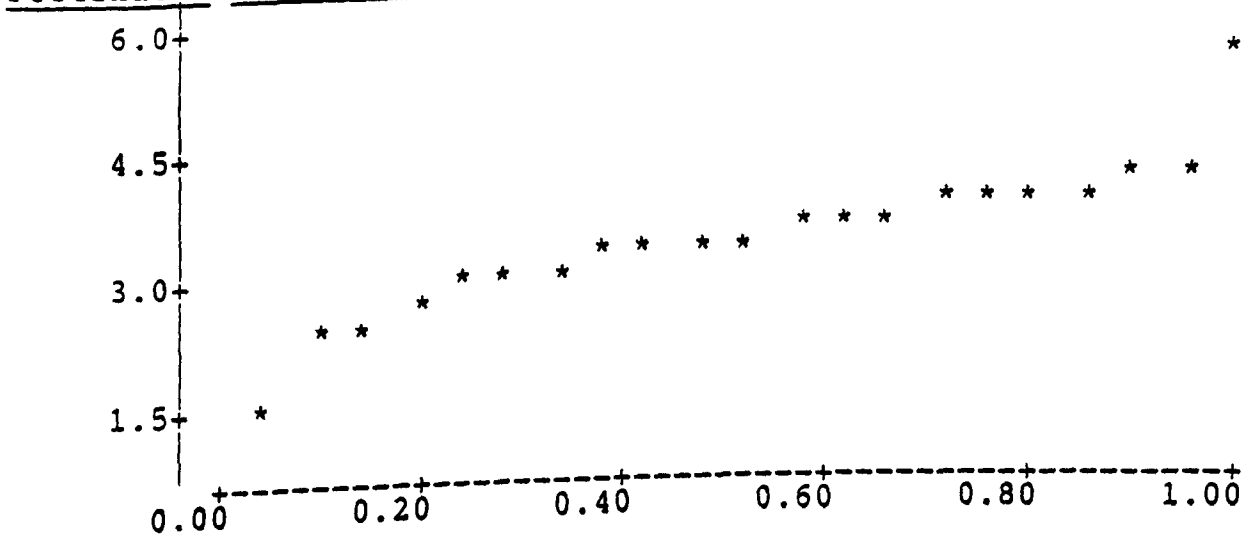
Nephtys ferruginea, Benzo(a)pyrene



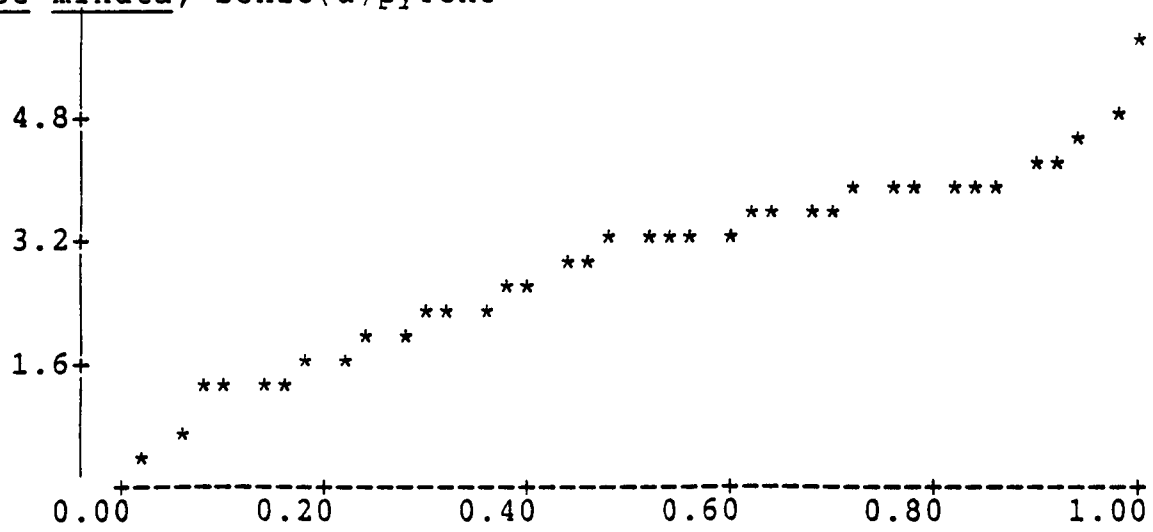
Parvilucina tenuisculpta, Benzo(a)pyrene



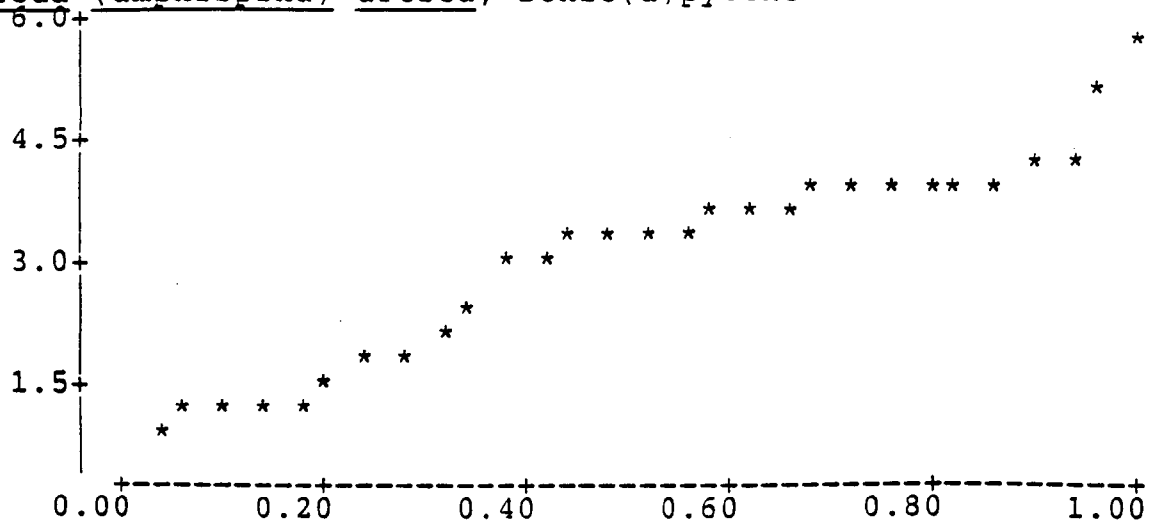
Pectinaria californiensis, Benzo(a)pyrene



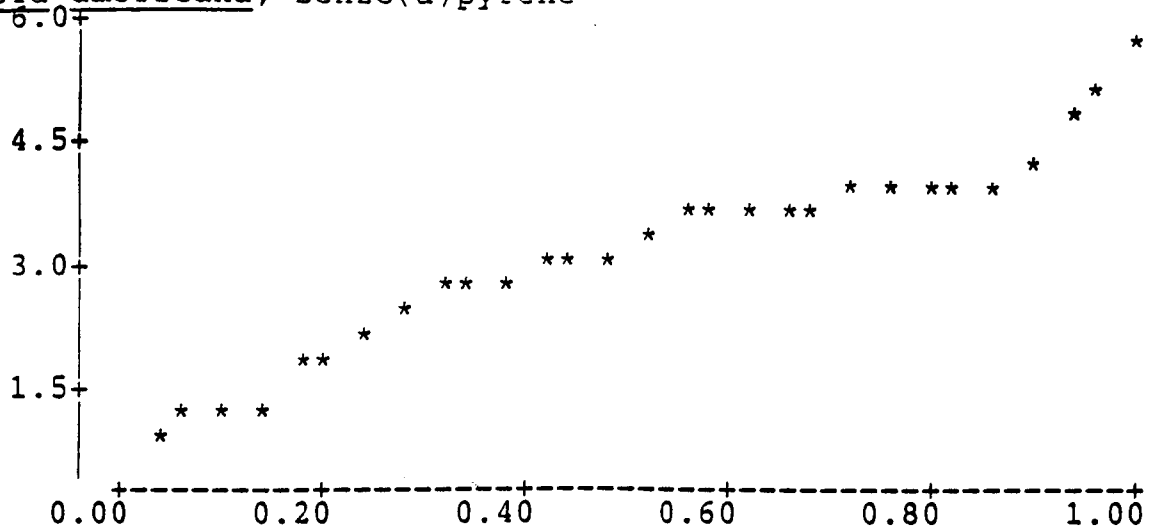
Pholoe minuta, Benzo(a)pyrene



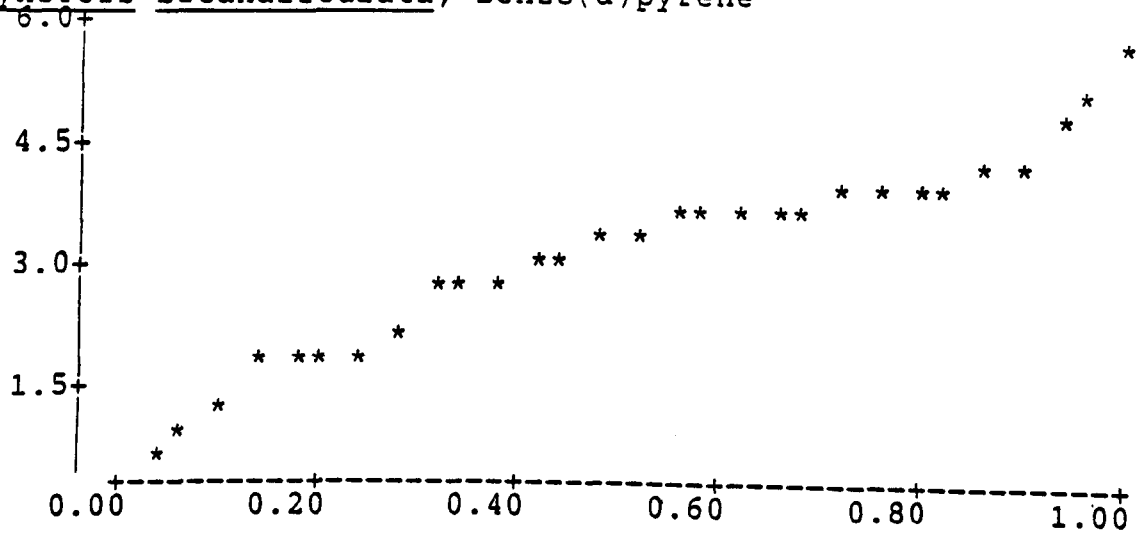
Amphioda (amphispina) urtica, Benzo(a)pyrene



Glycera americana, Benzo(a)pyrene



Platynereis bicanaliculata, Benzo(a)pyrene



Phyllodoce hartmanae, Benzo(a)pyrene