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PATTERNS OF SUCCESSION IN MAN-MADE AND NATURAL WETLANDS

Report to

Texasgulf Chemicals, Incorporated

Aurora, North Carolina 27896

by

William G. Ambrose, Jr.
Institute for Coastal and Marine Resources
East Carolina University

Greenville, NC 27858

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ABSTRACT

The response of estuarine benthos to disturbance was investigated to test the hypotheses that season, sediment, composition, and location significantly affect patterns of recolonization. The study was conducted in two creeks, one natural and one mad-made, located in the Pamlico River estuary. Defaunated sediment was exposed 4 times in a temporally overlapping design and sampled after 15, 30, 60, 90, 120, and 210 days. Both site and exposure time and the interactions between these two factors caused highly significant differences in the densities of colonists. With the exception of *Hydrobia* and chronomid insect larvae, common colonists were more abundant in the natural than in the man-made creek. Differences in patterns of colonization between natural and man-made wetlands may be one factor causing differences in the structure of their invertebrate fauna. The community structure of the disturbed community quickly resembled the ambient community and thereafter temporal patterns of specie's densities in the ambient and disturbed communities were similar. Gross sediment characteristics had little or no effect on recolonization patterns. These results are preliminary and based on the analyses of only one set of recolonization experiments.

INTRODUCTION

Succession can be considered the change in species composition and community structure occurring in an ecological community following a disturbance (sensu Connell and Slayter 1977). It is a fundamental process in ecological systems and has been studied extensively in soft-sediment environments following a variety of types and scales of disturbance (Grassle and Grassle 1974, McCall 1977, Simon and Dauer 1977, Pearson and Rosenberg 1978, Rhodes et al. 1978, Saunders et al. 1980, Woodin 1981, Zajac and Whitlatch 1982a, 1982b, Ambrose 1984, Homziack 1985). Similar successional patterns have been observed in distinct soft-sediment systems, but the influence of spatial and temporal differences in abiotic and biotic factors within an environment on successional patterns have only begun to be investigated.

Recent studies have demonstrated a number of physical and biological processes which appear to be important determinants of estuarine succession: 1) timing of disturbance, 2) habitat where disturbance occurs, 3) reproductive periodicity of infauna 4) population dynamics of ambient community generating colonists, 5) proximity of adult populations to disturbed area, 6) composition of initial colonists, and 7) abiotic and biotic factors that affect the preceding 6 factors (Zajac and Whitlatch 1982a, 1982b, Ambrose 1984, Levin 1984, Homziak 1985, Smith and Brumsickle 1989). Patterns of succession can therefore be expected to vary significantly in environments such as estuaries where abiotic and biotic factors often display tremendous temporal and spatial variability.

Given the factors known to influence succession in marine communities, different successional patterns might be expected between natural and mitigated or man-made habitats. Most studies comparing natural and man-made habitats follow the developmental trajectory of faunal abundance and composition in man-made habitats and compare these patterns of distribution and abundance to those in natural communities (Fonseca et al. 1989, Smith et al. 1989). These descriptive studies furnish important information concerning faunal utilization of natural and mitigated habitats, but mechanisms that control the observed patterns of faunal abundance and composition remain largely unknown.

Colonization by larvae and adults is recognized as one of the most important processes controlling the structure of marine soft-sediment communities (Woodin 1976, Peterson 1979). In the present study I follow patterns of colonization and succession in newly exposed sediment located in a natural and a man-made wetland to test the hypotheses that season, sediment composition, and location significantly affect recolonization. Differences in patterns of colonization between natural and man-made wetlands would offer one explanation for differences in the structure of their invertebrate fauna.

METHODS

Colonization of defaunated sediment was followed in the shallow subtidal of two creeks on the north side of South Creek which opens into the Pamlico River, North Carolina. One of these creeks, Project Area 2 , was created by Texas Gulf Inc. in 1983 while the other, Drinkwater, is relatively undisturbed. Sediment was exposed in both creeks for varying lengths of time between April 1989 and January 1990.

All sediment used to follow recolonization was collected in March 1989 from adjacent creeks using a .1 m^2 ponar grab. This sediment was frozen (-20^o C) for at least one month prior to exposure to kill all existing fauna. Azoic sediment was placed in 30 cm x 35 cm x 15 cm plastic trays which were then set in the field. Trays were located in approximately 1 m water depth, within 2 m of shore, and in the upper reaches of both creeks.

Sediment was exposed on 4 different dates for 6 different lengths of time. Sediment was exposed during the spring (4 April), summer (7 July), fall (10 October,) and winter (24 January) and sampled after 15, 30, 60, 90, 120 and 210 days. Consequently, sediment was exposed for overlapping periods of time (Figure 1). Trays of sediment exposed on the same date were evenly arrayed in a matrix with trays 1 m apart. Replicate trays were randomly selected for sampling.

To sample colonization trays, I located the appropriate trays within the matrix, covered each tray with a plastic cover to prevent loss of sediment and organisms during handling, and removed the trays from the water. One 0.018 m^2 by 12 cm deep core was taken from the center of each tray and the enclosed sediment sieved through a 0.5 mm mesh in the field. The residue retained on the sieve was stained with a 0.1% solution of Rose Bengal and preserved in 5% formalin. Four smaller cores (5.7 cm^2 x 10 cm deep) were also taken from each tray. Their contents were immediately fixed with 5% formalin and later sieved through a .1 mm mesh sieve. The larger cores were sorted by eye and the smaller ones with a dissecting microscope at 15X magnification. Four replicate large and small cores were taken from the surrounding ambient community each time trays were sampled.

The effect of sediment composition on recolonization patterns was also tested by exposing different type sediments. The sediment in the man-made creek is fine sand rather than silt-clay which is found in the nearby creeks. In addition, the natural creeks often have sections of bottom covered with large pieces of terrigenous plant material ('chips'). Trays containing silt-clay ('mud') were exposed in both creeks and 3 replicates collected on each sample date. Trays containing a mixture of mud and chips were exposed in Drinkwater and 4 replicates sampled at 30, 90, and 210 days. Fine sand was collected from and exposed at Project Area. Four replicate trays of sand were sampled at 210 days.

Two-way analyses of variance (ANOVA) were used to test for differences between creeks and sampling periods in total infaunal densities and individual densities of common taxon (greater than an average of 3 individuals per core in any sampling period) colonizing mud. When these were significant ($p<0.05$), between site differences within a time period and temporal differences within a site were compared using one-way ANOVAs and the *a posteriori* Duncan's Multiple Range test. Differences between sand and mud in Project Area were compared using a one-way ANOVA and differences between chips and mud in Drinkwater were compared using a two-way ANOVA with time and substrate as the two independent variables.

All data were tested for homogeneity of variances using the F-max test (Sokal and Rohlf 1981) and where necessary the data were transformed, $\log_{10}$ (X+1), prior to analyses. These analyses were conducted separately for each set of trays exposed on the same date.

RESULTS

All of the taxa which colonized defaunated sediment, their feeding type, and mobility/ microhabitat are listed in Table 1. No species exotic to the two creeks settled in the experimental containers. Statistical analyses were carried out for the polychaetes *Laeonereis culveri* and *Hobsonia florida*, the gastropod *Hydrobia* sp., chronomid insect larvae, all crustaceans combined, all polychaetes combined, and total infauna. Analyses have been so far limited to the trays exposed in April because samples from the other series have not been fully processed. In addition, only data from the large cores are included because in the instances when large and small cores have both been analyzed, they sampled the same fauna.

Both site and exposure time and the interactions between these two factors caused highly significant differences in the fauna colonizing mud (Table 2). All taxonomic groups except *Hydrobia* exhibited significant temporal variability in colonization. In general, densities tended to peak after 60 days with a second and smaller peak after 120 or 210 days (Table 3, Figures 2-8). The one-way ANOVAs analyzing temporal variability in colonization at each site separately indicate that while temporal changes in the density of individual taxa are not identical between creeks, the general patterns are similar (Tables 4 and 5).

With the exception of crustaceans and total fauna, densities of colonizers were significantly different between sites (Table 3). Chironomids and hydrobia were significantly more abundant in Project Area while *L. culveri*, *H. florida*, and total polychaetes were more abundant in Drinkwater. The one-way ANOVAs comparing densities between sites for each time period separately indicate that except for chironomids which were much more abundant in Project Area compared to Drinkwater for all time periods except 90 and 210 days, there was no significance difference in densities of individual taxa between sites at the end of 15 days of recolonization (Figures 2-8). *L. culveri* and *H. florida* were more abundant in Drinkwater but not until after 60 and 30 days of recolonization respectively. *Hydrobia* was more abundant in Project Area than in Drinkwater for all exposure periods but its abundance was extremely variable and only after 90 days of exposure was there a significant difference between creeks. Total polychaetes generally followed the pattern of the two most abundant polychaetes, *L. culveri* and *H. florida*, and were significantly more abundant in Drinkwater after 60 days of colonization with the densities at the two sites converging after 210 days.

Temporal changes in the ambient communities reflected recolonization patterns (Figures 9 and 10). Densities of most groups were highest in April, declined to a mid-Summer low, and increased slightly in the Fall. The exception to this pattern was *L. culveri* which reached its highest densities in Drinkwater in early summer.

Recolonization trays had significantly ($p<0.05$, one-way ANOVA) fewer taxa compared to the ambient community in both Drinkwater and Project Area after 15 days of exposure (Figure 11). After 15 days, however, there was, with one exception, no significant difference in the number of taxa which colonized the sediment in trays and the number of taxa collected from

the ambient communities. The one exception occurred at 120 days when the trays in Drinkwater had significantly more taxa than the ambient community.

The pattern of recolonization of sand and chips did not differ greatly from the pattern observed in mud. Densities were greater in sand compared to mud for all taxa except *H. florida* but these differences were only significant for *L. culveri* (Table 11). One of the replicate trays containing sand was lost making it difficult to detect significant differences between treatments for chironomids, polychaetes, and total fauna despite large differences in density. There was no significant difference in the densities of fauna colonizing chips compared to mud in Drinkwater (Table 12).

DISCUSSION

Benthos in the two creeks exhibited temporal and spatial variation in ambient community structure, a pattern which has been noted in other studies of estuarine soft-substrate communities (Sanders et al. 1965, Santos and Simon 1974, Zajac and Whitlatch 1982a). The response of organisms to the initial disturbance of exposing defaunated sediment also varied among taxa and between creeks. The differential response of benthic species to disturbance has long been recognized, but the scheme of classifying organisms on their recolonization ability (McCall 1977) has been questioned (Zajac and Whitlatch 1982a, Ambrose 1984, Homziak 1985). Rather, patterns of recolonization are often related to the dynamics of the ambient community supplying potential colonists (Zajac and Whitlatch 1982, Ambrose, 1984, Homziak 1985). This appeared to be the case in the present study. With the exception of *Laeonereis culveri*, densities of all colonists were low when ambient densities were low. A true test of the importance of the ambient community to recolonization rates will have to wait until samples of sediment exposed in the summer, fall, and winter are analyzed. If recolonization does track changes in the ambient community, then recolonization should be low initially in the sediment exposed in July and slightly higher in the sediment exposed in October.

Given the apparent importance of the ambient community in determining recolonization patterns, it is perhaps not surprising that there were differences in recolonization patterns between the two creeks because their ambient communities are different. On the other hand, many of the colonists have larval periods of several days to weeks, so because of their proximity the two creeks might be considered to have the same larval pool. Spatial variability in recolonization and successional patterns has been recorded in other estuaries, but over a larger scale than studied here (Zajac and Whitlatch 1982b).

A variety of factors other than differences in ambient community structure might have contributed to differences in recolonization between the two creeks. The importance of hydrodynamics in invertebrate settlement is well recognized (see review by Butman 1987) and even though the trays were placed at similar water depth and distance from shore, water flow in Project Area is not likely to be the same as in Drinkwater which is a much larger creek. The quantity and quality of food resources available to colonists has also been suggested as an important determinant of juvenile survival and successional patterns (Grassle and Grassle 1974, Zajac and Whitlatch 1982a, Olaffson 1989). Rates of sedimentation and resuspension in the two creeks are not known, but are likely to be different and result in different amounts of food available to the benthos, particularly surface feeding deposit feeders which make up a large

number of the colonists (Table 1). The dominant vegetation surrounding Project Area and Drinkwater is different, composed of *Spartina* sp. and *Juncus* sp. respectively, and may cause differences in the quality of food available. Resident infauna can affect the survival of colonists (Ambrose 1984). Chironomid insect larvae are predators on other infauna and were much more abundant in Project Area than in Drinkwater beginning with the first sampling (Figure 6). This difference in chronomid density may have contributed to the lower densities of other colonists in Project Area compared to Drinkwater. The importance of these factors in determining patterns of recolonization and succession require manipulative experiments and cannot be determined based on the data collected in this study.

Gross sediment characteristics had little effect on recolonization. It was initially hypothesized that large pieces of woody material, 'chips', on and in the sediment might function like seagrass roots which have been demonstrated to reduce predation by epibenthic predators (Peterson 1982). The absence of such a substrate in Project Area and its presence in Drinkwater might then explain some of the differences in infaunal densities between these two creeks. Densities of colonists in mud and chips in Drinkwater were nearly identical, however, (Table 7) and if this pattern persists for the other recolonization periods these replicates will be combined in further analyzes. Densities of fauna colonizing sand and mud were different but lack of replication hindered statistical tests of significance (Table 6). One other study also failed to detect significant differences in recolonization patterns between sand and mud (Zajac and Whitlatch 1982a), but the differences recorded in the present study indicate further investigation with better replication is warranted.

The benthic community which developed in the defaunated mud underwent large temporal changes, but these changes largely mimicked the dynamics of the ambient communities. This is because ambient community structure was quickly reestablished following the disturbance of introducing defaunated mud. Densities of most taxa reached ambient levels within 30 to 60 days following exposure and after 15 days there was very little difference in species diversity between the ambient communities and the communities in the trays (Figure 11). Consequently, when a tray was sampled was a more important determinant of its community structure than how long it had been exposed; densities of organisms in trays exposed 15 days often more closely resembled densities in trays exposed 120 days than those exposed 30 or 60 days.

A full evaluation of rates of recolonization and successional patters in Project Area and Drinkwater must await the analyses of the three remaining recolonization series. Other studies have demonstrated that the timing of a disturbance can have a significant effect on species responses and subsequent community development (Zajac and Whitlatch 1982a, 1982b, Ambrose 1984, Homziak 1985). The same result is expected in Project Area and Drinkwater because of the large seasonal fluctuations in temperature and salinity they experience. As discussed above, the results from these other settlement periods will allow a test of the importance of ambient community dynamics to colonization of defaunated sediment and may further elucidate the factors causing differences in recolonization between the two creeks. The design of overlapping periods of sediment exposure (Figure 1) allows two additional comparisons: 1) comparison of communities occupying sediment exposed the same length of time but sampled on different dates and 2) comparison of sediment sampled on the same date but exposed for different lengths of time. These comparisons will be made between and within the two creeks and reveal the importance of abiotic and biotic factors in controlling successional patterns.

Finally, the entire overlapping design will be repeated for at least a second year. While there have been studies which monitored the recovery of a marine benthic community for several years following a disturbance (e.g. Sanders et al. 1980), to the best of my knowledge, no study of marine soft-substrate succession has monitored rates of colonization for more than 16 months. In estuaries experiencing large annual differences in abiotic factors, there may be large differences in patterns of colonization and succession. Consequently, differences between mitigated and natural habitats may vary from year to year.

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Table 1. Feeding type and mobility/microhabitat of all taxa which colonized defaunated sediment in Drinkwater and project area.

Taxon*	Feeding Type**	Mobility/Microhabitat
(A) Oligochaeta	DF	mobile, surface-subsurface
(A) Hirudinea	C	mobile, surface
(A) *Capitella capitata*	DF	tube dweller, surface
(A) *Heteromastus filiformis*	DF	tube dweller, surface
(A) *Hobsonia florida*	DF	tube dweller, surface
(A) *Laeonereis culveri*	O	mobile, surface-subsurface
(A) *Mediomastus* sp.	DF	tube dweller, surface
(A) *Polydora ligni*	DF	tube dweller, surface
(A) *Streblospio benedicti*	DF, FF	tube dweller, surface
(I) Chironomids	C	mobile, subsurface
(I) Cerat apogonidae	?	mobile, subsurface
(C) Copepod	DF	mobile, surface
(C) *Cyathura polita*	DF, C	mobile, surface-subsurface
(C) *Corophium lacustra*	DF	tube dweller, surface
(C) *Edotea* sp.	DF, O	mobile, surface
(C) *Gammarus mucronatus*	O	mobile, surface-subsurface
(C) *Gammarus tigrinus*	O	mobile, surface-subsurface
(C) *Leptocheris plumulosus*	O, DF	tube dweller, surface
(C) Mysid	O	mobile, surface
(C) Ostracoda	O, C, FF	mobile, surface-subsurface
(C) Paleomonetes pugio	O	mobile, surface
(C) Tanaid *Hargeria rapax*	C	mobile, surface
(M) *Macoma balthica*	DF, FF	mobile, sursurface
(M) *Hydrobia* sp.	DF	mobile, surface
(CN) Anemore *Edwardsia* sp.	C	sedentary, surface

*(A) - Annelida, (C) - Crustacea, (M) - Mollusca, (CN) - Cnidaria

**(DF) - deposit feeder, C - carnivore, O - omnivore, FF - filter feeder

Table 2. Summary of the significant main effects from 2-way ANOVAs testing the influence of site (S) and time (T) on densities of common taxonomic groups and total fauna in recolonization trays containing mud [NS = $p>0.05$, ** = $p<0.01$, *** = $p<0.001$].

	Main Effects		Interaction
Taxon	T	S	T x S
Laeonereis culveri	***	***	***
Hobsonia florida	***	**	**
Chironomids	**	***	***
Hydrobia sp.	NS	**	NS
Polychaetes	***	***	**
Crustaceans	**	NS	NS
Total fauna	***	NS	***

Table 3. Results of Duncan's multiple range tests comparing exposure periods (time) and site (PA = project area, DW = Drinkwater) shown by the ANOVAs to have significantly different densities. Treatments are ordered with the highest to lowest densities arranged from left to right; those that do not differ significantly share a common underline. ANOVAs which did not indicate a significant difference ($p>0.05$) are indicated by NS.

Taxon	Site		Time					
Laeonereis culveri	DW	PA	60	90	120	210	30	15
Hobsonia florida	DW	PA	60	210	30	90	120	15
Chironomids	PA	DW	210	30	15	60	120	90
Hydrobia sp.	PA	DW	NS					
Polychaetes	DW	PA	60	90	210	30	120	15
Crustaceans	NS		30	120	60	15	90	210
Total fauna	NS		60	30	210	90	120	15

Table 4. Comparison of densities of common taxonomic groups and total fauna colonizing mud during 6 time periods of exposure in Drinkwater. Each value represents the mean number of individuals per 0.018 m^2 replicate core. Significance level of one-way ANOVAs are indicated. When an ANOVA was significant, Duncan's multiple range test was used to determine significant differences between means. Means with common underline are not significantly different ($p>0.05$).

Taxon	Days						
	15	30	60	90	120	210	Sig.
Laeonereis culveri	0.0	15.7	141.7	52.3	41.0	13.3	.0001
Hobsonia florida	4.0	19.3	44.3	27.3	20.7	27.0	.0003
Chironomids	3.7	5.7	5.7	3.0	23.3	19.7	NS
Hydrobia sp.	0.0	2.0	1.7	.3	3.0	.3	NS
Polychaetes	8.7	45.0	201.0	83.0	63.3	43.3	.0002
Crustaceans	2.3	3.6	3.3	2.0	7.3	.3	NS
Total fauna	16.7	58.0	214.0	90.3	100.7	68.0	.0004

Table 5. Comparison of densities of common taxonomic groups and total fauna colonizing mud during 6 time periods of exposure in project area. Each value represents the mean number of individuals per 0.018 m^2 replicate core. Significance level of one-way ANOVAs are indicated. When an ANOVA was significant, Duncan's multiple range test was used to determine significant differences between means. Means with common underline are not significantly different ($p>0.05$).

Taxon	Days						
	15	30	60	90	120	210	Sig.
Laeonereis culveri	0.0	13.3	37.7	8.0	6.6	6.5	.0100
Hobsonia florida	4.0	7.3	54.3	2.6	1.0	34.0	.0040
Chironomids	45.7	58.7	44.7	3.6	0.7	15.0	.0002
Hydrobia sp.	4.0	206.3	6.7	5.0	23.3	0.0	NS
Polychaetes	6.7	26.3	93.3	12.0	7.7	40.5	.0002
Crustaceans	1.0	9.3	3.0	0.3	0.0	0.0	NS
Total fauna	57.3	307.7	148.3	21.0	31.7	57.0	.0100

Table 6. Comparison of densities of common taxonomic groups and total fauna colonizing sand and mud substrata after 210 days of exposure in project area. Each value represents the mean number of individuals per 0.018 m^2 replicate core. Significance levels of one-way ANOVA are indicated (NS = $p>0.05$).

Taxon	Mud	Sand	Sig.
Laeonereis culveri	6.5	39.0	.05
Hobsonia florida	34.0	33.0	NS
Chironomids	15.0	45.6	NS
Polychaetes	40.5	77.3	NS
Total fauna	57.0	131.3	NS

Table 7. Comparison of densities of common taxonomic groups and total fauna colonizing mud (M) and chip (C) substrata after 30, 90, and 210 days of exposure. Each value represents the mean number of individuals per 0.018 m^2 replicate core. Two-way ANOVAs were used to test for time and substrate treatment effects. Significance levels for substrate treatment effects are indicated. Substrate x time treatment interaction was not significant ($p>0.05$) for any group.

Days:	30		90		210		
Treatment:	M	C	M	C	M	C	Sig.
Taxon							
Laeonereis culveri	15.7	12.8	52.3	55.8	13.3	12.3	NS
Hobsonia florida	19.3	17.5	27.3	22.5	27.0	30.8	NS
Chironomids	5.7	9.0	3.0	1.3	19.7	32.8	NS
Polychaetes	45.0	39.8	83.0	82.8	43.3	55.3	NS
Crustaceans	3.6	7.6	2.0	1.3	0.0	1.3	NS
Total fauna	58.0	60.3	90.3	87.5	68.0	94.0	NS

FIGURE LEGENDS

Figure 1. Experimental design of recolonization experiment. Roman numerals indicate the 4 sets of defaunated sediment exposed on different dates. Numbers indicate length in days of each exposure.

Figure 2. Mean number (+/- S.E.) of *Laeonereis culveri* per 0.018 m^2 core from trays of defaunated mud sampled after 15, 30, 60, 90, 120 and 210 days of exposure. Sediment was exposed in April in Drinkwater and Project Area.

Figure 3. Mean number (+/- S.E.) of *Hobsonia Florida* per 0.018 m^2 core from trays of defaunated mud sampled after 15, 30, 60, 90, 120 and 210 days of exposure. Sediment was exposed in April in Drinkwater and Project Area.

Figure 4. Mean number (+/- S.E.) of *Hydrobia sp.* per 0.018 m^2 core from trays of defaunated mud sampled after 15, 30, 60, 90, 120 and 210 days of exposure. Sediment was exposed in April in Drinkwater and Project Area.

Figure 5. Mean number (+/- S.E.) of Chironomid insect larvae per 0.018 m^2 core from trays of defaunated mud sampled after 15, 30, 60, 90, 120 and 210 days of exposure. Sediment was exposed in April in Drinkwater and Project Area.

Figure 6. Mean number (+/- S.E.) of crustaceans per 0.018 m^2 core from trays of defaunated mud sampled after 15, 30, 60, 90, 120 and 210 days of exposure. Sediment was exposed in April in Drinkwater and Project Area.

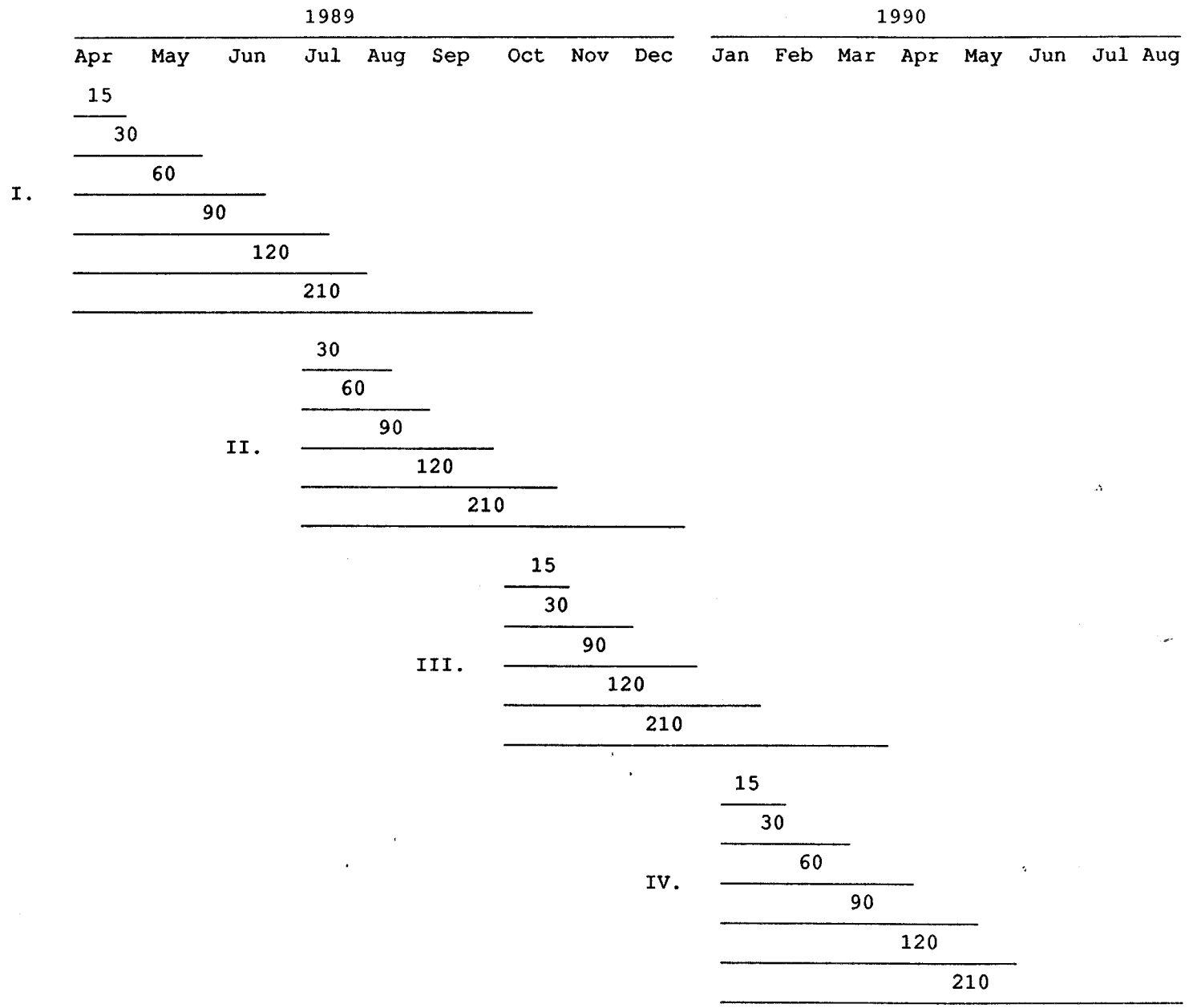
Figure 7. Mean number (+/- S.E.) of polychaetes per 0.018 m^2 core from trays of defaunated mud sampled after 15, 30, 60, 90, 120 and 210 days of exposure. Sediment was exposed in April in Drinkwater and Project Area.

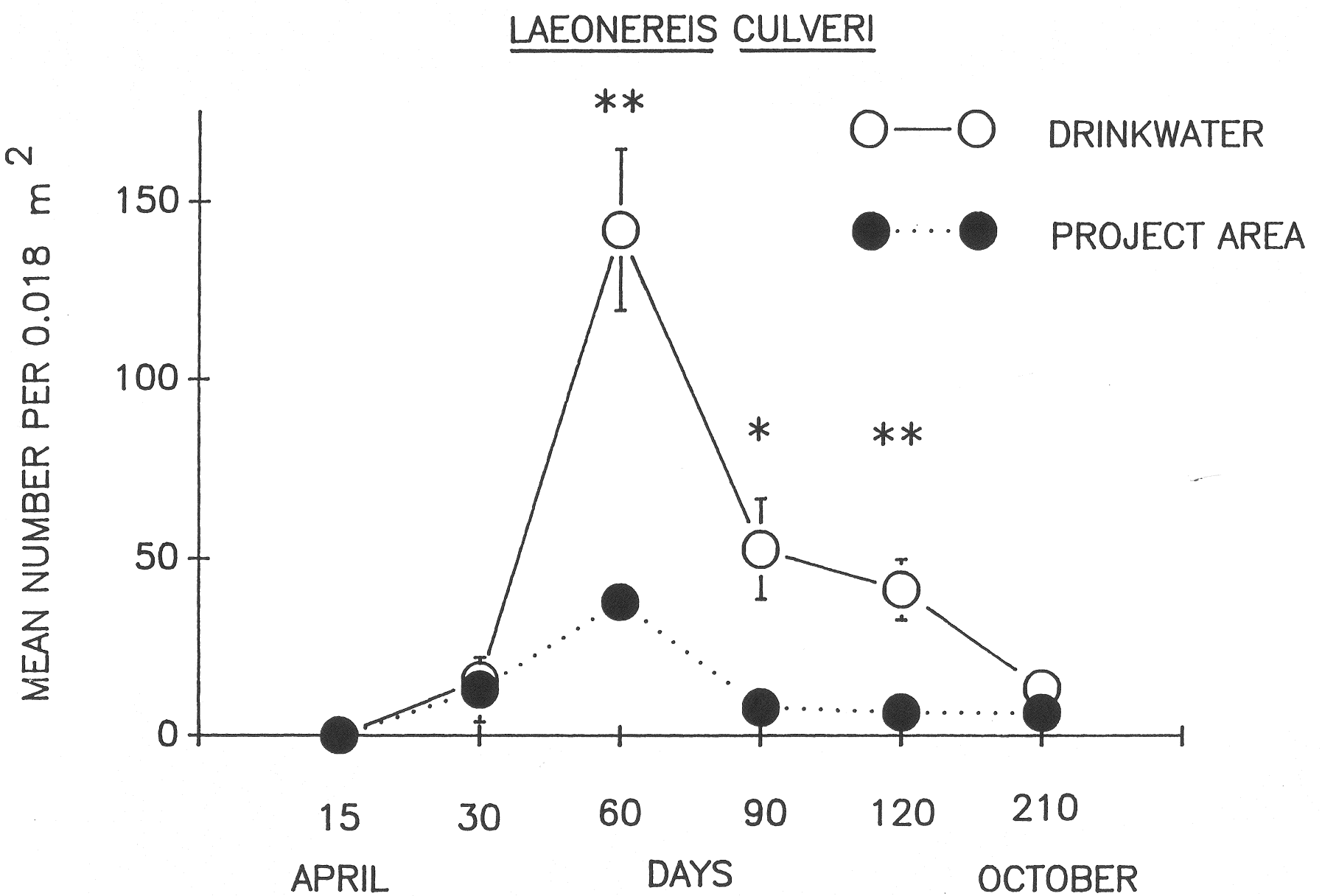
Figure 8. Mean number (+/- S.E.) of all fauna per 0.018 m^2 core from trays of defaunated mud sampled after 15, 30, 60, 90, 120 and 210 days of exposure. Sediment was exposed in April in Drinkwater and Project Area.

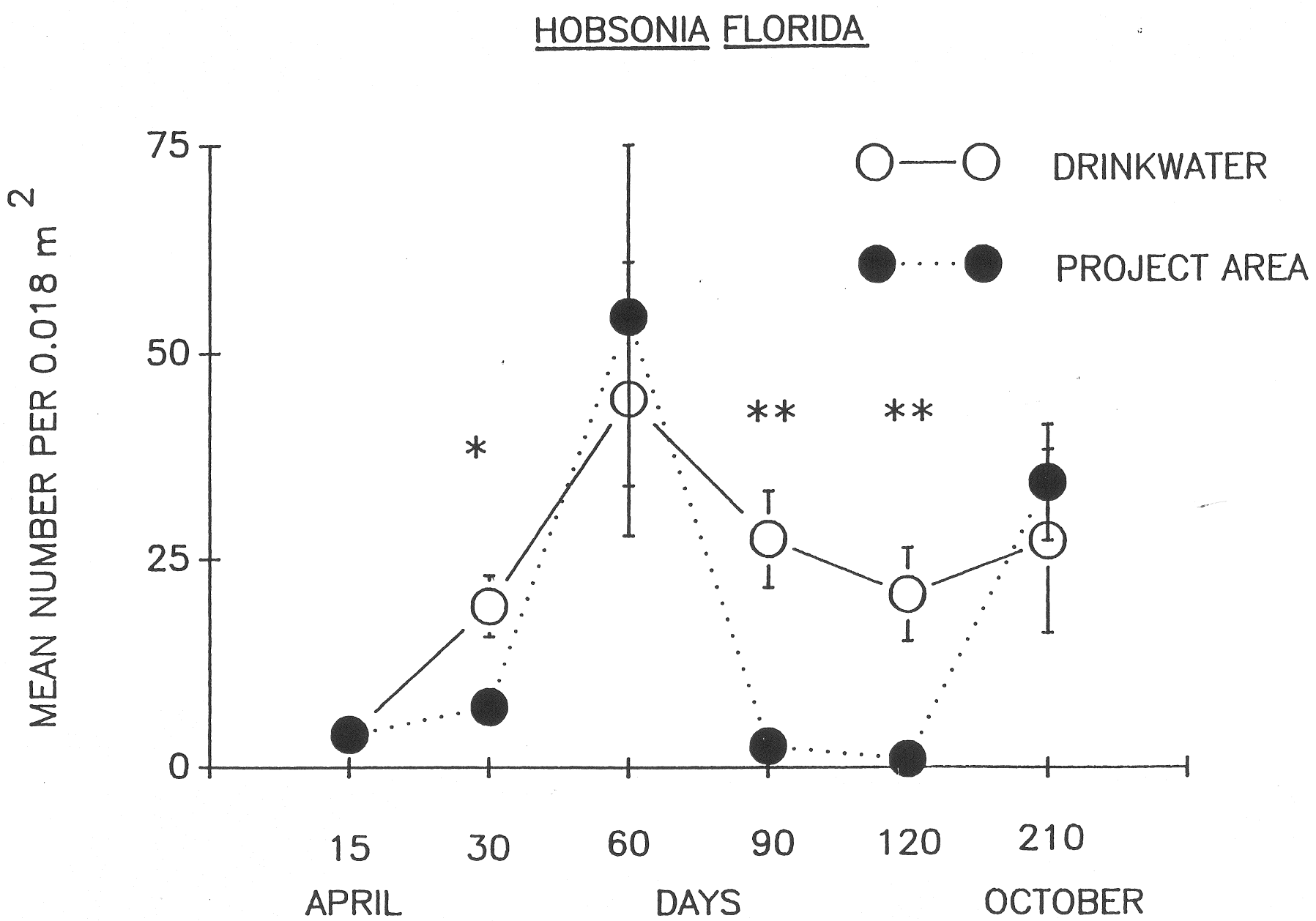
Figure 9. Mean number (+/- S.E.) of *Laeonereis culveri*, chironomid insect larvae, polychaetes, and crustaceans per 0.018 m^2 core from the ambient community adjacent to the recolonization trays in Drinkwater.

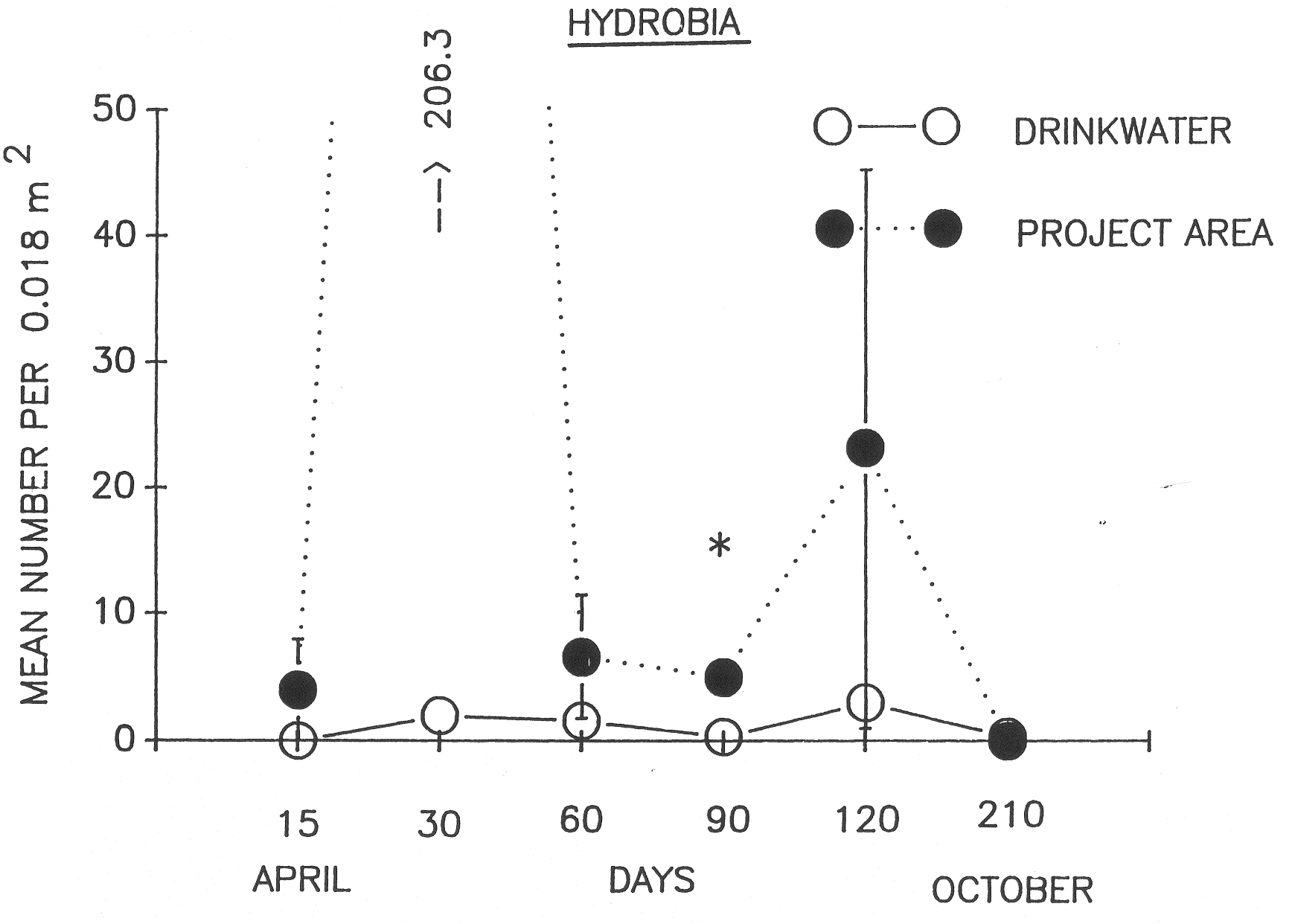
Figure 10. Mean number (+/- S.E.) of *Laeonereis culveri*, chironomid insect larvae, polychaetes, and crustaceans per 0.018 m^2 core from the ambient community adjacent to the recolonization trays in Project Area.

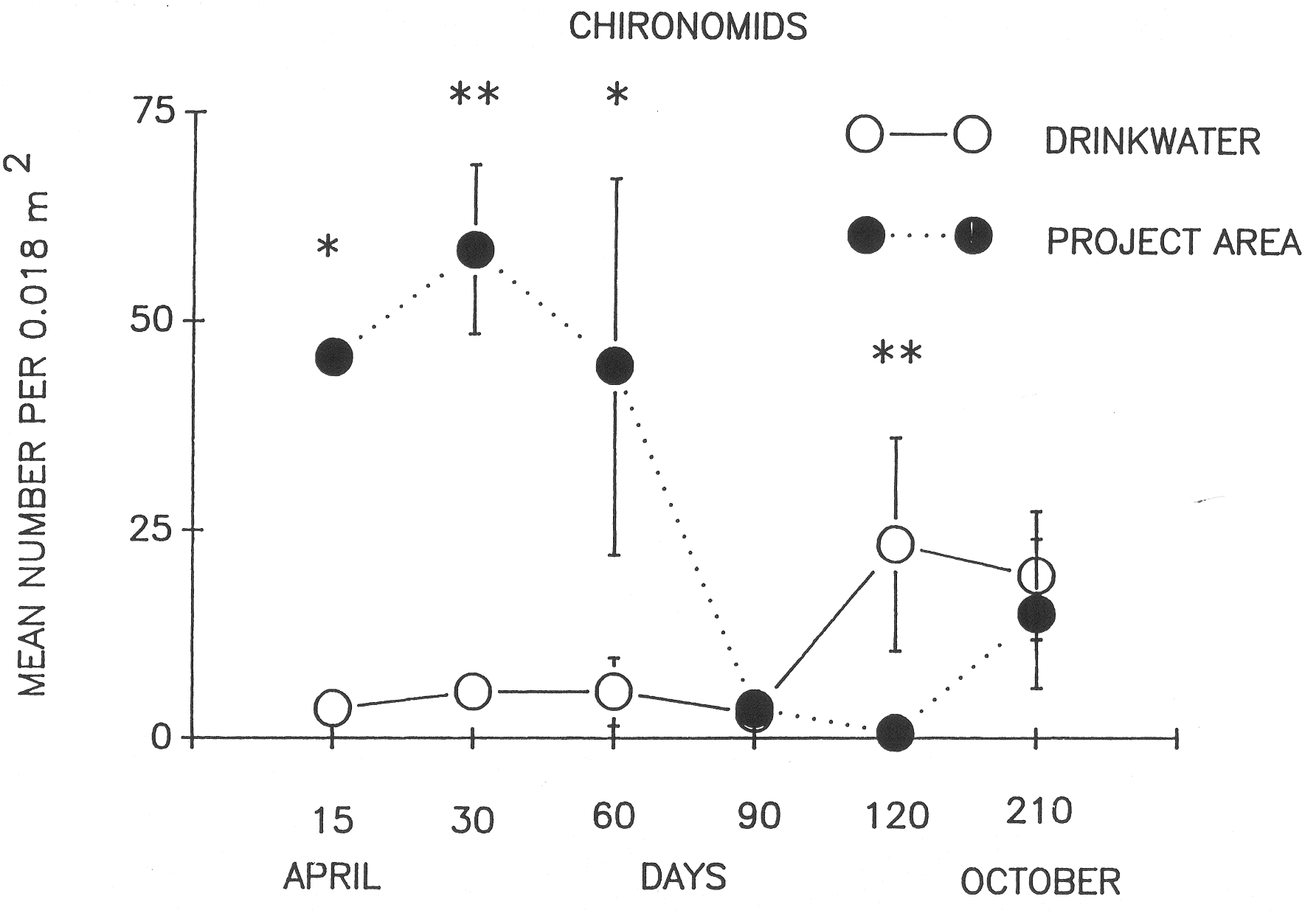
Figure 11. Mean number (+/- S.E.) of taxa per 0.018 m^2 core from trays of defaunated mud and the surrounding ambient community in Drinkwater and Project Area.

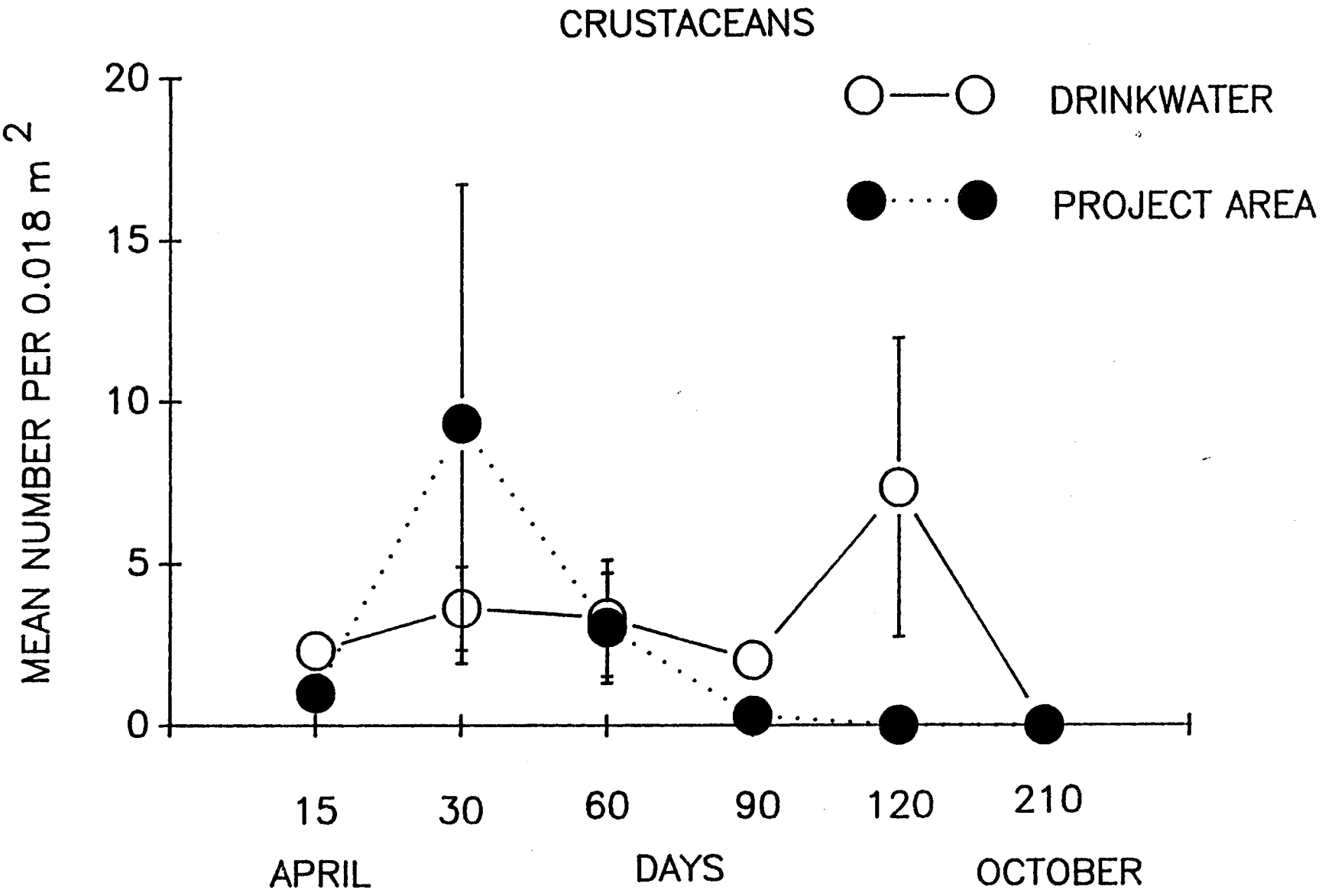

1989
1990
Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug
I.
15
30
60
90
120
210
II.
30
60
90
120
210
III.
15
30
90
120
210
IV.
15
30
60
90
120
210

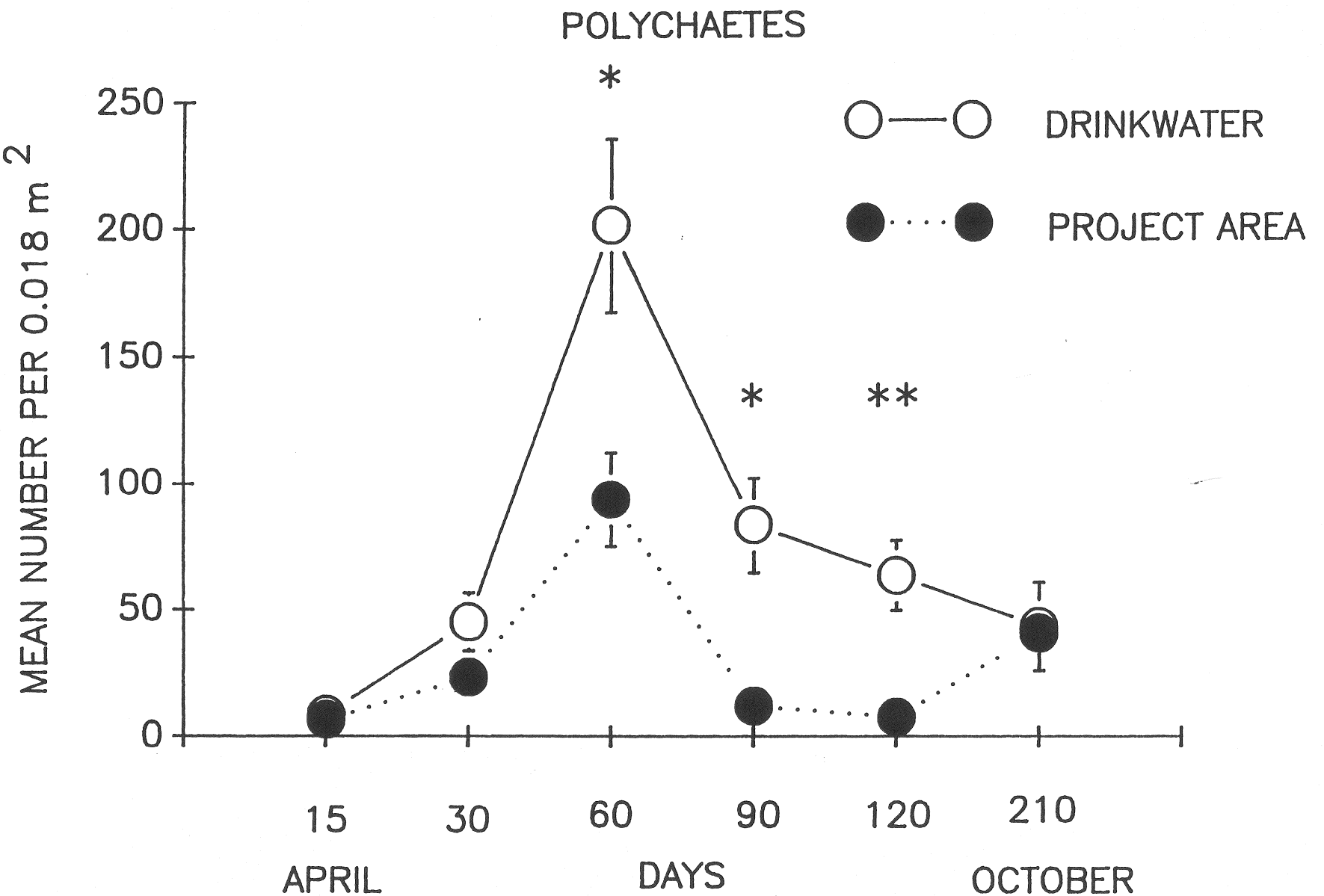

LAEONEREIS CULVERI
MEAN NUMBER PER 0.018 m 2
150
100
50
0
**
*
**
DRINKWATER
PROJECT AREA
15
30
60
90
120
210
APRIL
DAYS
OCTOBER

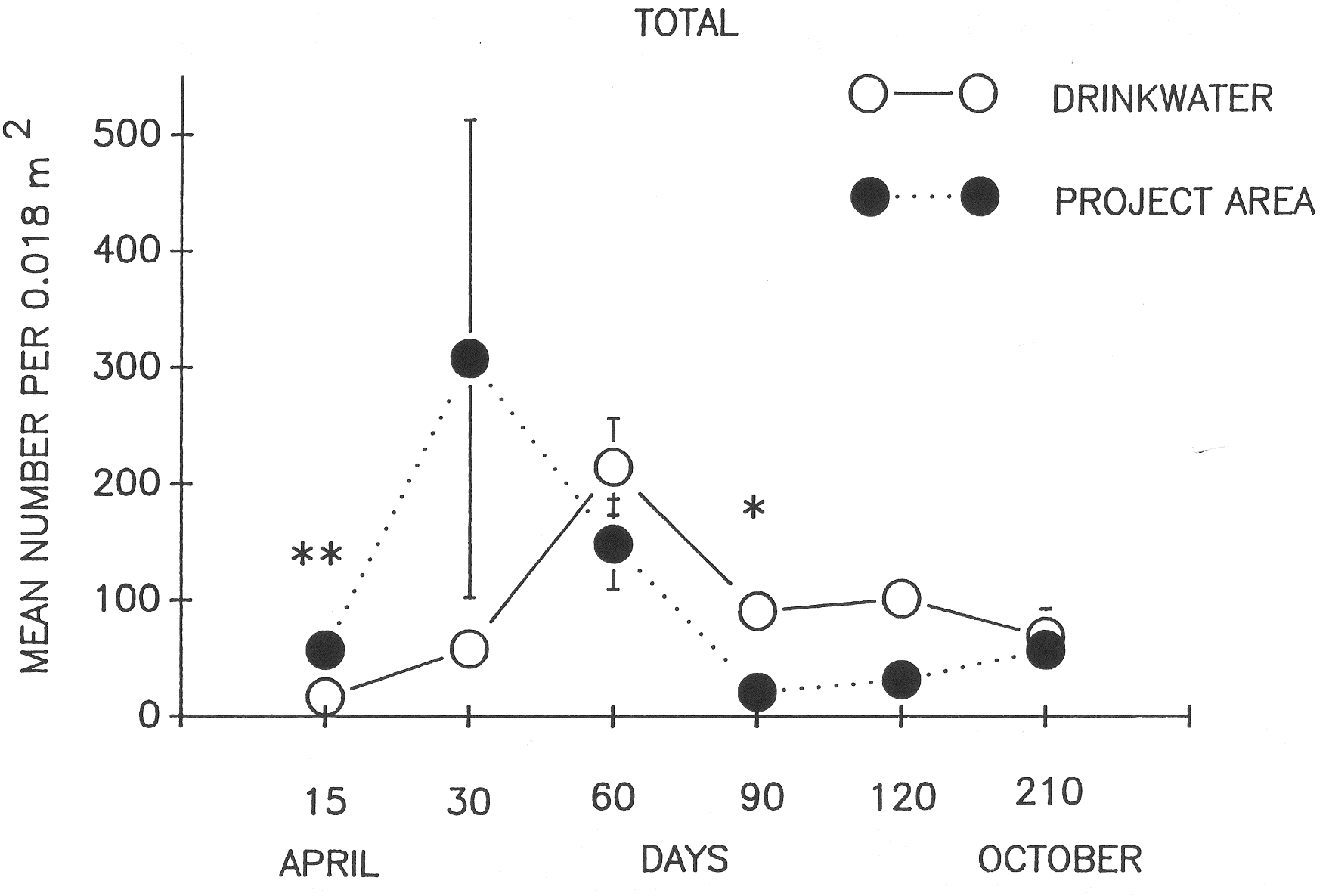

HOBSONIA FLORIDA
MEAN NUMBER PER 0.018 m 2
75
50
25
0
DRINKWATER
PROJECT AREA
*
**
**
15
30
60
90
120
210
APRIL
DAYS
OCTOBER

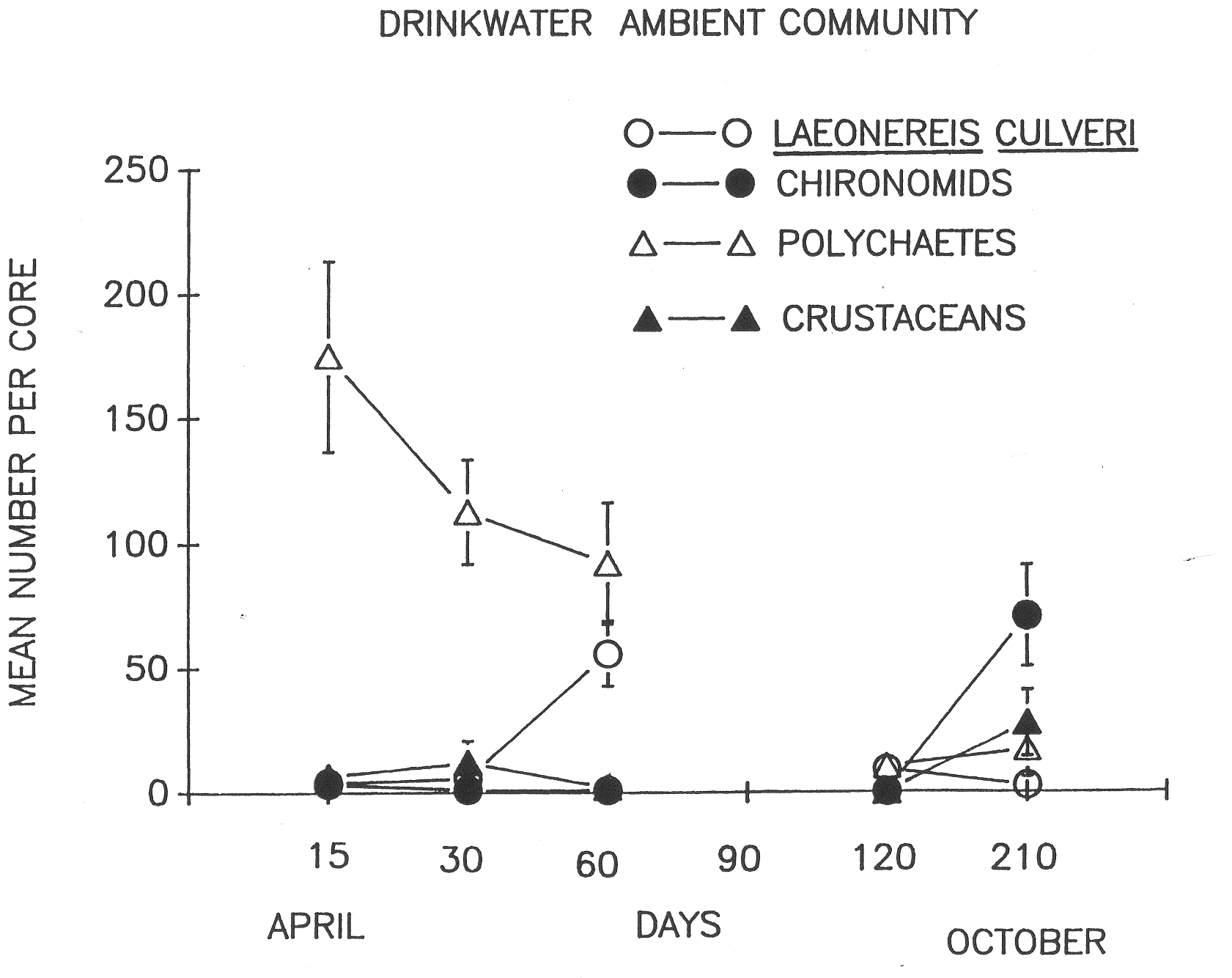

HYDROBIA
206.3
DRINKWATER
PROJECT AREA
MEAN NUMBER PER 0.018 m 2
50
40
30
20
10
0
*
15
30
60
90
120
210
APRIL
DAYS
OCTOBER

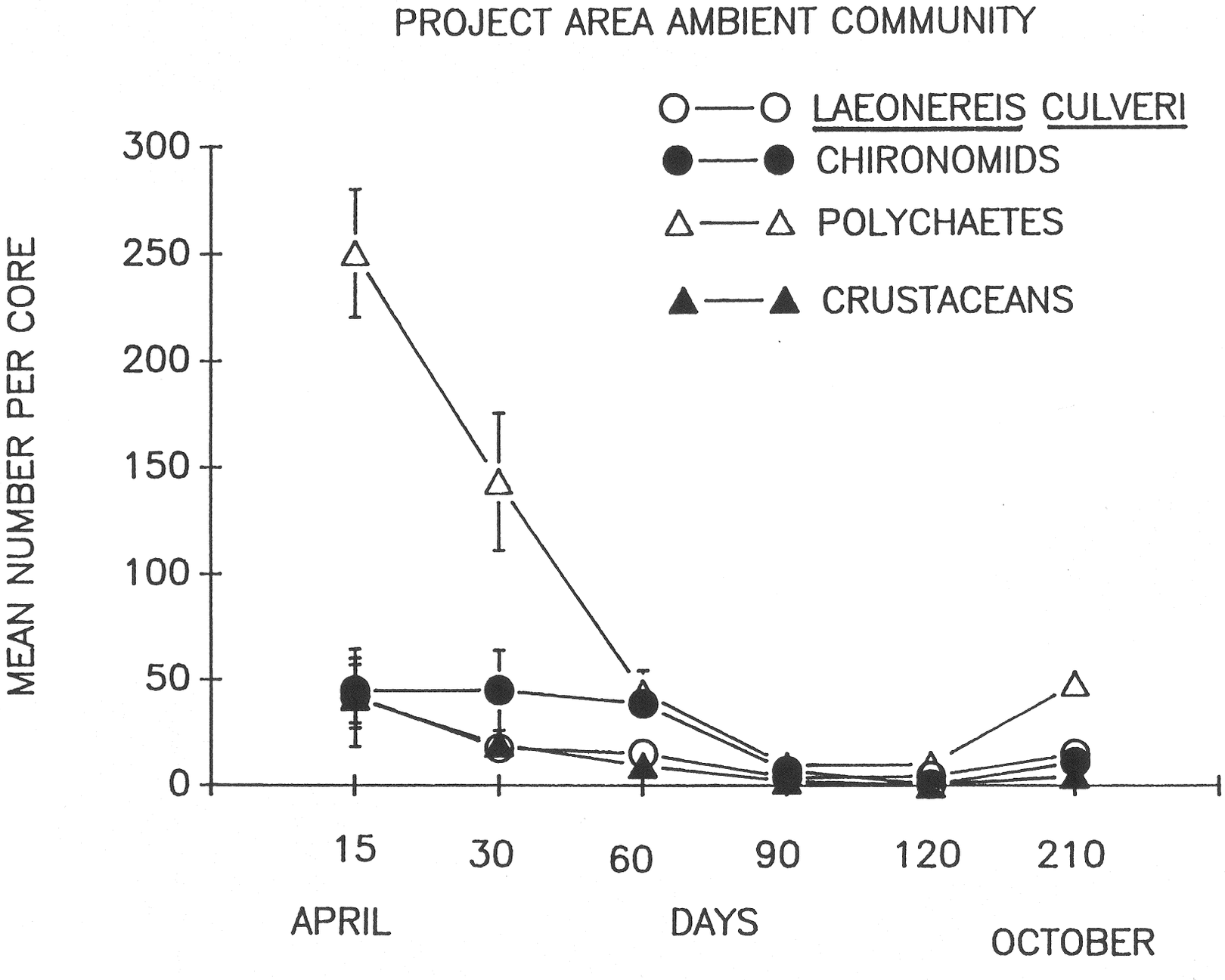

CHIRONOMIDS
MEAN NUMBER PER 0.018 m 2
75
50
25
0
**
*
*
*
**
DRINKWATER
PROJECT AREA
15
30
60
90
120
210
APRIL
DAYS
OCTOBER

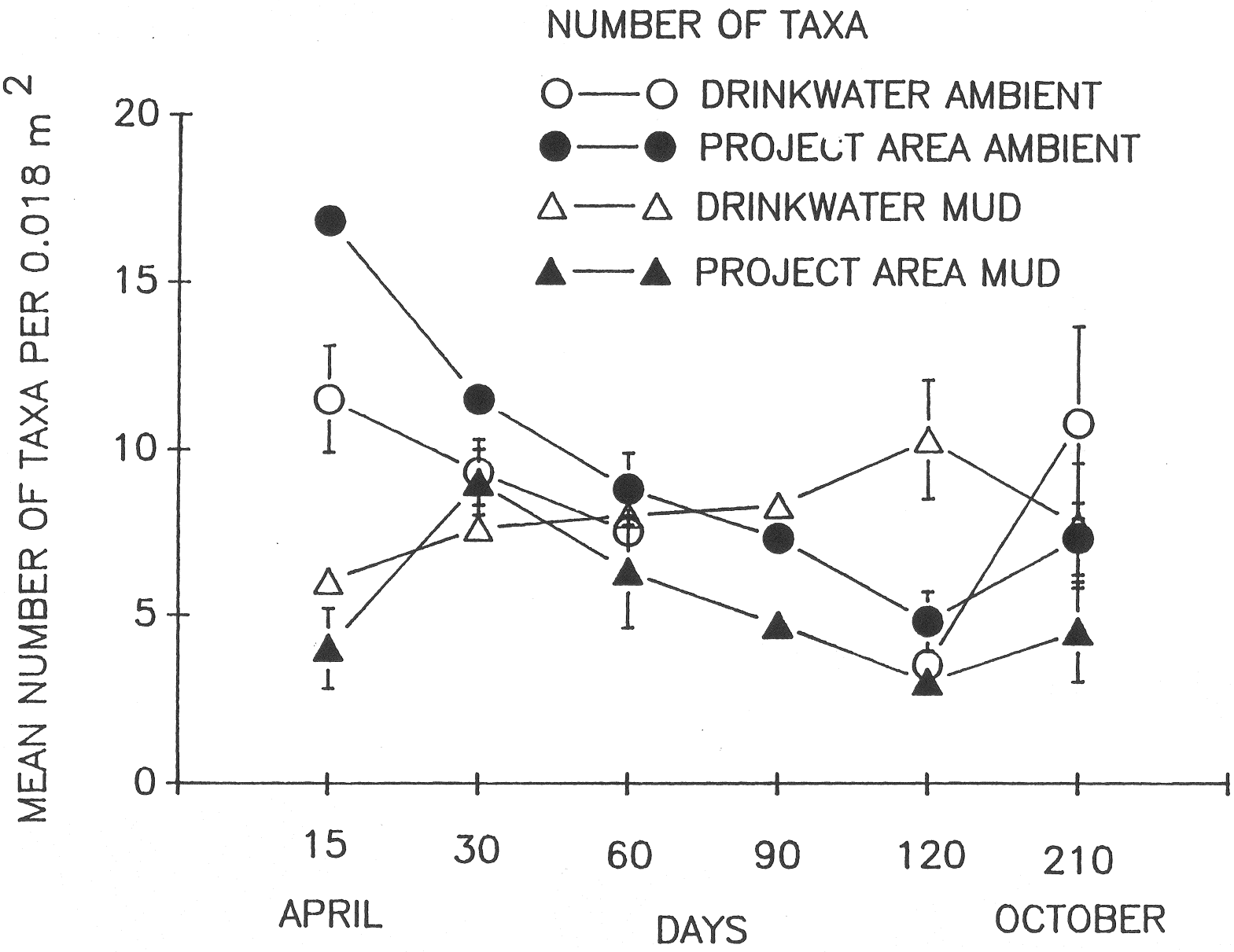

CRUSTACEANS
DRINKWATER
PROJECT AREA
MEAN NUMBER PER 0.018 m 2
20
15
10
5
0
15
30
60
90
120
210
APRIL
DAYS
OCTOBER


POLYCHAETES
*
250
200
150
100
50
0
MEAN NUMBER PER 0.018 m 2
DRINKWATER
PROJECT AREA
*
**
15
30
60
90
120
210
APRIL
DAYS
OCTOBER


TOTAL
DRINKWATER
PROJECT AREA
MEAN NUMBER PER 0.018 m 2
500
400
300
200
100
0
**
*
15
30
60
90
120
210
APRIL
DAYS
OCTOBER


DRINKWATER AMBIENT COMMUNITY
LAEONEREIS CULVERI
CHIRONOMIDS
POLYCHAETES
CRUSTACEANS
MEAN NUMBER PER CORE
250
200
150
100
50
0
15
30
60
90
120
210
APRIL
DAYS
OCTOBER


PROJECT AREA AMBIENT COMMUNITY
LAEONEREIS CULVERI
CHIRONOMIDS
POLYCHAETES
CRUSTACEANS
MEAN NUMBER PER CORE
300
250
200
150
100
50
0
15
30
60
90
120
210
APRIL
DAYS
OCTOBER


NUMBER OF TAXA
O—O DRINKWATER AMBIENT
●—● PROJECT AREA AMBIENT
△—△ DRINKWATER MUD
▲—▲ PROJECT AREA MUD
MEAN NUMBER OF TAXA PER 0.018 m 2
20
15
10
5
0
15
30
60
90
120
210
APRIL
DAYS
OCTOBER