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Restoring a Northeast Coastal Forest Community on the Fresh Kills Landfill: Survival, Growth and Recruitment of trees and shrubs in an Experimental Plantation.

A report to the City of New York, Department of Sanitation, Waste Management and Facilities Development

Prime Contractor: SCS Engineering

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ABSTRACT:

There is growing interest in converting closed landfills to native woodlands, which would be both attractive and productive wildlife habitats. This would be an appealing ecological alternative to current management practices, which consist of installing grasses which require long-term maintenance. To help understand how this might be accomplished, 18 species of trees and shrubs were installed by the New York City Department of Sanitation in 1989-90, on fresh soil above an inactive section of the Fresh Kills Landfill, Staten Island, New York. In June-July 1991, we censused this experimental plantation to determine: the relative success of each species; how the entire installation was functioning as a seed source and as a site for seed attraction (via animal dispersers); and the character of the developing plant community. These latter functions are key components in the eventual success of restoration programs. The planted species, many from coastal scrub forests native to this region, generally performed well, with respect to their survival and growth, but contributed almost no seedlings to the area, in part because only 20% of the installed trees or shrubs produced seeds. 94% of the 1071 recruiting woody seedlings came from sources outside the plantation, and largely represented berry-bearing, bird-dispersed plants. Thus, although the restoration planting had not begun spreading, it did function as a site for attracting birds or other dispersers, who enriched the biodiversity of the site with 25 additional woody species from nearby woodlands. It is noteable that this increase occurred after only one year. The presence of a fruit reward did not seem to influence the level of recruitment, although locations with high ratios of trees to shrubs had proportionately more recruits. We offer recommendations to enhance future landscaping at Fresh Kills and similar areas undergoing restoration.

Introduction

Restoration ecologists face a number of challenges, not the least of which is the need to anticipate environmental change in areas under restoration. Evidence is mounting that complete *de novo* restoration programs have limited chances for success, given the meager financial resources typically available, and especially given the fact that long-term monitoring and evaluation rarely follow a restoration or mitigation project. All vegetation, whatever its origin, undergoes change. Species are lost and gained; some increase, while others decrease. Restoration efforts must include a measure of anticipation of such changes in vegetation, both long- and short-term. Furthermore, when change is anticipated as part of restoration planning, natural processes that regulate such change can be manipulated to some extent, and the "natural' outcome of a restoration can be directed in favorable ways.

Plant succession (the directional change in vegetation from shorter- to longer-lived species) is a process with considerable potential as a tool in restoration (Majer, 1989; Luken, 1990). The forces that drive succession are many and complex, but there is clear evidence that animal seed dispersers are key to the rate and direction of forest succession, since they continuously transport seeds of woody species into open areas (Johnston and Odum, 1956; Smith, 1975; Hoppe, 1988). There is further evidence that visits by these dispersers, especially birds, increase with the presence of even a few trees and shrubs (Debussche, Escarré, and Lepart, 1982; McDonnell and Stiles, 1983; McDonnell, 1985; McClanahan and Wolfe, 1987), which provide perching sites for birds and food for a variety of animals. Succession, as driven by seed dispersers, is an exponential process: as more woody plants arrive, the vegetation becomes more complex, attracting ever more dispersers. The reason so many abandoned landfills fail to undergo natural succession (Stalter, 1984; Robinson, Handel and Schmalhoffer, 1991) is probably tied to the lack of a first "pulse" of woody recruitment. That is, the exponential succession curve simply doesn't get started. The few woody plants found in most local abandoned landfills are wind-dispersed, primarily *Populus deltoides* and *Ailanthus altissima*, neither of which provide a substantial food reward to fruit eaters.

Our working hypotheses for this study were:

1) Native woody species can survive and grow on restored landfills and similar recovering sites, and their absence reflects, a lack of natural dispersal.

2) A moderate planting of woody species can stimulate natural succession to a diverse woodland, provided native seed sources are nearby.
3) Some species will better stimulate succession than others, based on their capacity to grow, to reproduce, and to attract seed dispersers.

To examine these hypotheses empirically, we conducted a census and a statistical survey of a young woodland restoration, recently installed over a closed landfill, near a natural woodland community. In this paper, we present direct evidence that supports our first and second hypotheses, and indirect evidence that is consistent with the third. We conclude with general recommendations that follow from the results.

Methods

In fall 1989 and spring 1990, 3.75 ha (= 9.3 acres) of an approximately 6 ha (= 14.8 acres) site on the Fresh Kills Landfill (Staten Island, New York) was designated for restoration, and planted with 18 species of trees and shrubs (Figure 1). The plants were commercial nursery stock from four sources, located in the states of New York and New Jersey. The species, all of which are native to Northeastern North America, were chosen as representative of a coastal scrub forest, once found on Staten Island, and still occurring on Long Island, New York (Olsvig et al., 1979), and coastal New Jersey (Robichaud and Buell, 1973). Prior to planting, the site was covered with 30 cm (= 12") of compacted till mix (to prevent gas and water exchange between the landfill contents and the atmosphere, in accordance with local regulations), and then overlain by 60 cm (= 24") of sandy mineral soil, into which approximately 15 cm (= 6") of composted leaf mulch was incorporated. This material was graded from one to three feet deep on the site to create an undulating topography, characteristic of natural coastal sites.

Three separate vegetation mixes were installed in three different portions of the site: 1) a predominantly oak-shrub mix planted on a south-facing slope, approximately 25 m (= 80') upland from a tidal inlet of the Fresh Kills waterway; 2) a predominantly pine-shrub mix planted on a shallow, north-facing upland swale, 30 to 90 meters (100-300') inland from the oak-shrub group; 3) an ericaceous shrub mix planted upslope from the two other areas, on a predominantly east-facing slope. In analyses that follow, these are referred to as the Oak, Pine, and Ericaceous sites. [Note: For statistical purposes, the transition zone boundary between the oak and pine groups was split in half.]

We conducted our evaluation of this restoration in summer, 1991, a full growing season after all plants were installed.

To measure plant size and estimate annual growth, we sampled all planted individuals within one meter of 16 randomly-located, transects each 20 to 50 m long (≈ 65 to 160'), depending on location. We measured height, diameter (for trees), number of stems (for shrubs), and reproductive state (flowering, fruiting, or non-reproductive). For trees, diameters are reported as dbh (diameter at breast height), the forestry standard, as well as basal diameter (db), the nursery trade standard. Basal diameters are reported for the larger shrub species, as well. We compared size parameters with rough estimates of size at installation (based on nurserymen's standard sizes) for each species as available. All sampled individuals were marked for future reference.

To study survival and reproductive status of the planted stock, we censused all trees, shrubs, and woody vines within the three sites. To estimate recruitment, we censused all seedlings of woody plants, identified by species. Living individuals were counted, and categorized according to one of four sources:

1) installed as part of the restoration;
2) a seedling derived from one of the restoration plants;
3) a seedling derived from a nearby source outside the restoration site;
4) a seedling or sprout that arrived in a root ball of a planted individual (a species other than the installed plant, presumably part of the natural vegetation of the source nursery).

In some cases, the precise number of plants of each species was not always recorded at the time of installation (e.g., *Pinus rigida* and *P. virginiana* were grouped together in a single heading in the landscaper's contract). In these cases, we estimated the number installed to prepare relative survival data.

Results

a. survival, growth, and reproduction

The majority of plants, and 17 of the 18 species, survived the first season after installation (Table 1). Growth estimates indicate that most trees had moderate increases in girth (0 to 50%) over the first season, whereas most shrubs grew substantially in height, about 60% on average. Some trees and several shrubs were planted during an exceptionally cold period in late fall, 1989, and climatic stresses during transplanting may have accounted for the relatively lower survival of some species. More notable is the rather low proportion of reproductive plants. Lack of reproduction in this case is generally attributable to the young age of many of the plants, although it may also reflect some amount of transplant shock. However, it gave us an opportunity to examine the relative value of dsiplaying fruits and nuts for attracting dispersers to the site.

b. recruitment

After one year, the woody species complement of the restoration had increased from 18 to 48, with the addition of thirteen tree, ten shrub, and seven vine species (Table 2). Seven of the 31 recruiting species were probably carried in by wind, 21 by birds or other animals. The soil around roots of installed plants was another source of recruits, and three recruiting species (*Crataegus sp.*, *Eleagnus commutata,* and *Quercus velutina*) were found only in a root ball. Of great interest is the fact that almost none of the seedlings found were attributable to the planted stock, i.e., only four seedlings were counted that were potentially derived from the "as built" species.

Recruitment via clonal growth was found in a single species, *Rhus glabra,* which produced five additional stems in the vicinity of planted individuals. Although some specimens of *R. glabra* were fruiting, no seedlings occurred near planted individuals, and we surmised that the installed plants had not produced seeds the previous season. This species also recruited naturally, and most individuals found were considered volunteer seedlings from nearby wooded areas.

We counted 2929 installed plants, and 1028 new seedlings. Thus, for every three installed plants, natural dispersal mechanisms added a new individual to the community. 46 additional seedlings and saplings were growing in root balls of the planted stock, and these we counted as artificial recruits, transported from the nurseries. Additional seedlings were probably lost to herbivory. We have unpublished evidence from several other former landfill sites that herbivores, especially rabbits, can have a severe impact on seedlings of many susceptible species.

Although 14 of the 18 planted species had some reproduction, only 564 (19%) of individuals produced flowers or fruits. To examine in detail the relative value of the presence of fruits, we compared the number of recruiting seedlings with the proportion of fruiting plants in each transect. A plant was judged as having provided a fruit reward if a) it bore remnant winter or spring fruits; b) it was currently in flower or in fruit and was large enough to have borne fruit the previous season. There was no apparent relationship between variation in local recruitment and the proportion of installed plants that were fruiting (Figure 2). Consequently, the main attractive feature of the restoration plants appeared to be their structural presence.

Plant size did appear to be a general factor in attracting dispersers. The installed trees averaged about 3 m in height, and the shrubs 1 to 1 1/2 m. Among the transects, we compared the size ratio of planted trees to shrubs (within the Oak and Pine mixtures only, since no trees were planted in the Ericaceous mix) with the number of "volunteer" recruits. A positive correlation was evident (Figure 3). Although statistically significant, this result needs a more direct test for confirmation.

Recruitment rates varied little among the three species mixes, which had similar ratios of recruits to installed species (Oak mix: 312/908; Pine mix: 443/1310; and Ericaceous mix: 229/710) A non-parametric test for differences in ratios, the *G* test, indicated no differences. This is technically expressed as: $G_{2d.f.} = 0.42$, $p = 0.81$. The proportion of installed plants that produced seed did vary significantly among the three sites (Oak mix: 199/908; Pine mix: 261/1310; and Ericaceous mix: 109/710; $G_{2d.f.} = 7.99$, $p = 0.02$). Since recruitment was similar among sites, this result adds fuels to the argument that, under these conditions, disperser attraction was not influenced by a fruit reward.

Discussion

Severely disturbed lands offer an opportunity for ecologists to apply theory in very fundamental ways, because such degraded sites represent relatively "clean slates" — i.e. simple systems at early stages of development with few residual effects from past communities (Ashby, 1987; Cairns, 1986). Restoring a natural vegetation involves a number of decisions, however — some practical, others philosophical, and still others scientific. Included in the latter category are choosing appropriate species (Flower et al., 1978; Parmenter et al., 1985; Robinson, Handel and Schmalhofer, 1991; Robinson and Handel 1989), determining a schedule of species introductions (Buckley and Knight, 1989; Malcom 1990), and learning the potential contributions of nearby vegetation as both a seed source (Gibson, Johnson, and Risser, 1985;

Guevara, Purata and Van der Maarel, 1986), and as habitat for seed dispersers and herbivores (McClanahan,1986; McClanahan and Wolfe, 1987).

We are particularly interested in the role of nearby remnant vegetation in promoting the rehabilitation of disturbed sites, through the process of natural succession. This is a new, but growing theme in restoration ecology, and one of potentially great interest to engineers and landscapers charged with rehabilitating damaged lands. What we have learned thus far from our studies at the Fresh Kills Landfill confirms our hypotheses that woody plants can grow in such areas, and that succession can be stimulated by planting woody species to promote the invasion of others. Of great interest are the rates of such invasions. In previous work (Robinson, Handel and Schmalhofer, 1991), we found that a small (800 m^2, or 0.2 acre), tightly-grouped planting of 180 trees and shrubs attracted many new species, and after 14 years, the densities of volunteers were approximately 660 trees and shrubs per hectare, and 24,000 stems of viny plants per hectare (1670 per acre, and 69,000 per acre, respectively). The densities at Fresh Kills, after only one year, were 220 new tree and shrub seedlings, and 60 new vines per hectare (560 and 150 per acre). Thus, recruitment may take place relatively quickly for some species. Comparisons between these two restorations should be drawn with care, however, since the plants installed in the two studies were of very different sizes and they were planted in very different arrangements. Nonetheless, the results of this current study are encouraging for workers who desire a rapid development of biodiversity.

Some landfills present special problems for woodland restoration. When landfill gases (primarily methane and carbon dioxide generated by decomposition) are present in the soil at high concentrations, many plants are stressed. Under those conditions, selection of woody plants for landscaping must be done with care (Flower et al., 1978). There are, however, native plants that can grow well under those conditions (Gilman, Flower and Leone, 1985).

We anticipated that most recruitment of new species would be in the vicinity of berry-bearing and seed-bearing trees and shrubs, but this did not occur. There are several possible reasons for this. First, the fruits may have not been sufficiently apparent to attract dispersers (Sargeant, 1990). A greater number of fruiting plants, or perhaps a tighter clustering of those in fruit, might have have led to a different pattern of recruitment. Second, it appears that, in many locations, migrating birds perform most of the fruit removal and dispersal

(Willson 1988). During the single season of recruitment, migrants may have simply missed the site, or remained on the periphery. Third, seedlings under fruiting plants may have been removed by herbivores, which are known to limit succession and recruitment of woody plants on forest edges (Myster and McCarthy,1989) as well as in restoration sites (Anderson, 1989). If herbivores (in this case, probably rabbits) were more attracted to clumped seedlings, and preferentially removed them in areas of higher seedling density, this could also account for the generally uniform distribution of seedlings that we found.

Several of the newly-arrived species (e.g., *Ailanthus altissima, Rosa multiflora, and Lonicera japonica*) are serious weeds of northeast woodlands, and represent undesirable additions to the community (Hu, 1979; Decker and Enck, 1987). These species should be expected to rapidly colonize in urban areas, and a management scheme for their control, should be part of any restoration project. Our research has shown that these undesirable species appear within the first year, so control measures should be swift.

Our third hypothesis, that some plant species will provide a better attractive function than others, gained some support in this study, since those plant groups that included trees had somewhat higher recruitment in their vicinity. The simple conclusion is that some tall species ought to be included in restoration plantings. The evidence is weak here, but other research (Mark McDonnell, pers. com.) indicates that most birds will not perch on plants below a minimum height (1.5 to 2 m, or 4' to 6').

The choice of appropriate species for restoring woodland-shrub communities cannot be a simple matter. In addition to ecological criteria are landscape installation protocols: the manner in which plants are installed; how species are mixed; when they are installed; whether bare root or balled and burlapped; and how plantings are spatially arranged. We have seen that mixtures of trees and shrubs could be an effective combination. Another potentially useful ecological approach is to mix species that produce fruit at different times, so that some fruit reward is always present throughout most of the growing season. We have taken this latter approach in an experiment on a former landfill in the New Jersey Meadowlands, where we are testing several other factors. In that study, we are setting out tight clusters of mixed trees and shrubs, rather than installing plants in even arrays. In addition, we are testing the effect of plant size (clusters include either large or small individuals) and the presence or absence of nitrogen-fixing species. In future work, we plan to test the role of cluster size (ranging from 7 to 56 plants per cluster) in succession. and soil development. These are the types of ecological questions that must be addressed for efficient restorations.

Many issues in restoration techniques need to be resolved (Cairns, 1986; Buckley, 1989), but several important points emerge from the current literature. First, a more complex vegetation, one that includes woody plants, has great value in increasing the pace of restoration and the development of wildlife habitat (Gibson, Johnson, and Risser,1985; Parmenter et al., 1985; Schuster and Hutnick,1987; McKell, 1989). The natural value of revegetated former landfills could be greatly enhanced by landscaping with attention to this need for the complexity provided by trees and shrubs. The prospects for using restored lands to enhance biodiversity are sufficiently strong to deserve attention (OTA, 1988). In great Britain, for example, over 75 nature reserves now occupy what were once highly-degraded lands (Bradshaw and Chadwick, 1980).

We recognize that the process of closing a landfill involves many environmental and engineering problems, and that revegetation often takes a back seat to more pressing concerns. However, the opportunity to convert these highly unpopular and unsightly areas to natural or semi-natural habitats is there. Under the proper circumstances, it is possible that a relatively inexpensive, low-maintenance restoration can lead to a healthy, complex habitat. To that end, we have several <u>recommendations for future landscaping and test plantings at Fresh Kills</u> and similar areas, based on this study and previously cited work:

First, woody species should be well-mixed and clustered, not spread in even arrays over a site, to increase their potential for attracting seed dispersers.

Second, species mixtures should include some relatively tall (over 1.5 m) individuals, to further enhance their attractiveness.

Third, whenever possible, woody plants for installation should be at or near reproductive ages, to increase their immediate potential to colonize and spread into open areas.

Fourth, substrate throughout the area should be appropriate quality for the native species that can quickly appear.

Fifth, management plans for controlling detrimental exotics ahould be in place.

Implementing these rather simple recommendations should substanti[al] improve the capacity of future installations to develop and spread, and to eventually produce diverse, low-maintenance, woodland habitat.

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Table 1. Summary of survival, growth, and reproduction data, for the 18 installed woody species in the Fresh Kills dune installation.

SURV = estimated relative survival rate (survivors/number planted).

% = percent survival.

HT = height (cm) from ground to tallest bud.

DB = stem diameter (cm) of the largest stem at ground level for small trees.

DBH = diameter at breast height (cm) for taller single-stemmed species.

STEMS = average number of stems at ground level.

FRT = the proportion of individuals sampled bearing fruit.

GROWTH = estimated % increase in girth (for trees) and height (for shrubs) since planting.

	SPECIES	COMMON NAME	SURV	%	HT	DB	DBH	STEMS	FRT	GROWTH
1	*Amelanchier stolonifera*	shadbush	178/190	93	133			8.9	0.85	120%
2	*Arctostaphylos uva-ursi*	bearberry	21/1980	1	22			2.6	0.09	
3	*Aronia arbutifolia*	chokeberry	215/312	69	120			6.9	0.90	100%
4	*Kalmia angustifolia*	sheep laurel	0/100	0						
5	*Leiophyllum buxifolium*	sandmyrtle	4/21	19						
6	*Lyonia mariana*	staggerbush	12/90	13	32			6.0	0.00	60%
7	*Myrica pensylvanica*	bayberry	781/975	80	74			10.0	0.34	65%
8	*Pinus rigida*	pitch pine	87/92	95	148	4.6		2.4	0.00	0%
9	*Pinus virginiana*	scrub pine	78/80	98	167	7.2		1.0	0.29	0%
10	*Prunus maritima*	beach plum	523/735	71	66	2.0		3.0	0.12	40%
11	*Quercus ilicifolia*	scrub oak	65/873	78	113	3.3		4.3	0.33	30%
12	*Quercus marilandica*	blackjack oak	54/55	99	152	3.7		2.1	0.21	50%
13	*Quercus palustris*	pin oak	4/4	100	275	5.0	3.0	1.0	0.00	0%
14	*Quercus phellos*	willow-lvd oak	59/75	79	416	7.1	5.3	1.0	0.00	25%
15	*Quercus stellata*	post oak	28/29	98	220	4.0	3.1	1.0	0.29	30%
16	*Rhus glabra*	smooth sumac	14/14	100	105			3.2	0.25	75%
17	*Vaccinium angustifolium*	l.b. blueberry	564/600	94	12			9.8	0.04	0%
18	*Vaccinium corymbosum*	h.b. blueberry	240/640	38	42			4.0	0.06	40%
	MEAN PER SPECIES			71%	111	4.2	3.8	6.6	0.28	42%

Table 2. Census data for woody species in the Fresh Kills dune installation. (Note: since no *Kalmia* survived, that species is not included in this table)

TSV = type of plant: T = tree; S = shrub; V = vine.
NAT = 1 = native; 0 = introduced; 2 = native to the U.S., but not this region.
COUNT = total number of individuals censused.
FRT = number of plants with fruit.
SDLGS = number of seedlings produced by planted stock.
BALL = seedlings recruiting from root balls of installed plants.
DISP = main type of dispersal for each species (W = wind-dispersed; B = bird and/or mammal dispersed).

PLANTED SPECIES	TSV	NAT	COUNT	FRT	SDLGS	BALL	DISP
1 *Amelanchier stolonifera*	S	1	178	145	1	0	B
2 *Arctostaphylos uva-ursi*	S	1	21	0	0	0	B
3 *Aronia arbutifolia*	S	0	219	160	0	0	B
4 *Eleagnus commutata*	S	1	5	5	0	0	B
5 *Leiophyllum buxifolium*	S	1	4	0	0	0	B
6 *Lyonia mariana*	S	1	12	6	0	0	B
7 *Myrica pensylvanica*	S	1	781	86	0	0	B
8 *Pinus rigida*	T	1	87	0	0	0	B
9 *Pinus virginiana*	T	1	78	1	0	1	B
10 *Prunus maritima*	S	1	523	43	1	0	B
11 *Quercus ilicifolia*	T	1	65	33	2	1	B
12 *Quercus marilandica*	T	1	47	9	0	0	B
13 *Quercus palustris*	T	1	4	0	0	0	B
14 *Quercus phellos*	T	1	59	0	0	0	B
15 *Quercus stellata*	T	1	28	8	0	0	B
16a *Rhus glabra*	S	1	14	13	0	1	B
17 *Vaccinium angustifolium*	S	1	564	12	0	1	B
18 *Vaccinium corymbosum*	S	1	240	43	0	14	B
Total			2929	564	4	18	

VOLUNTEER SPECIES	TSV	NAT	COUNT	FRT	SDLGS	BALL	DISP
19 *Acer rubrum*	T	1	14	0	0	0	W
20 *Ailanthus altissima*	T	0	65	0	0	0	W
21 *Albizzia julibrissin*	T	0	47	0	0	0	W
22 *Baccharis halimifolia*	S	1	64	0	0	0	W
23 *Campsis radicans*	V	0	19	0	0	4	B
24 *Celastrus scandens*	V	1	77	0	0	5	B
25 *Comptonia peregrina*	S	1	22	14	0	2	B
26 *Cornus stolonifera*	S	1	2	0	0	0	B
27 *Crataegus sp.*	T		1	0	0	1	B
28 *Eleagnus commutata*	S	2	6	2	0	6	B
29 *Juglans nigra*	T	1	1	0	0	0	B
30 *Juniperus virginiana*	T	1	1	0	0	0	B
31 *Liquidambar styraciflua*	T	1	37	0	0	4	B
32 *Lonicera japonica*	V	0	2	0	0	0	B
33 *Parthenocissus quinquefolia*	V	1	40	0	0	2	B
34 *Paulownia tomentosa*	T	0	1	0	0	0	W
35 *Populus tremuloides*	T	1	29	0	0	0	W
36 *Prunus serotina*	T	1	108	0	0	0	B
37 *Quercus prinus*	T	1	1	0	0	0	B
38 *Quercus velutina*	T	1	1	0	0	1	B
39 *Rhus aromatica*	S	1	1	0	0	0	B
40 *Rhus copallina*	S	1	276	0	0	8	B
16b *Rhus glabra*	S	1	86	0	0	1	B
41 *Robinia pseudoacacia*	T	1	34	0	0	0	B
42 *Rosa multiflora*	S	0	5	0	0	1	B
43 *Rosa sp.*	S	1	2	0	0	0	B
44 *Rubus sp.*	V	1	87	0	0	2	B
45 *Salix discolor*	T	1	1	0	0	0	W
46 *Sassafras albidum*	S	1	8	0	0	8	B
47 *Smilax sp.*	V	1	6	0	0	0	B
48 *Toxicodendron radicans*	S	1	26	0	0	1	B
49 *Vitis sp.*	V	1	4	0	0	0	B
Total			1074	16	0	46	

Figure 1. Diagrammatic map of the Fresh Kills dune restoration planting. P = Pine-shrub mix; T = transition pine-oak-shrub mix; O = oak-shrub mix; E = ericaceous shrub mix. Reduced from 'as built' drawing by Frederick Harris, Inc., for Briar Contracting Corp. and W. Young, R.L.A. Reduced scale: 1" = 200'.

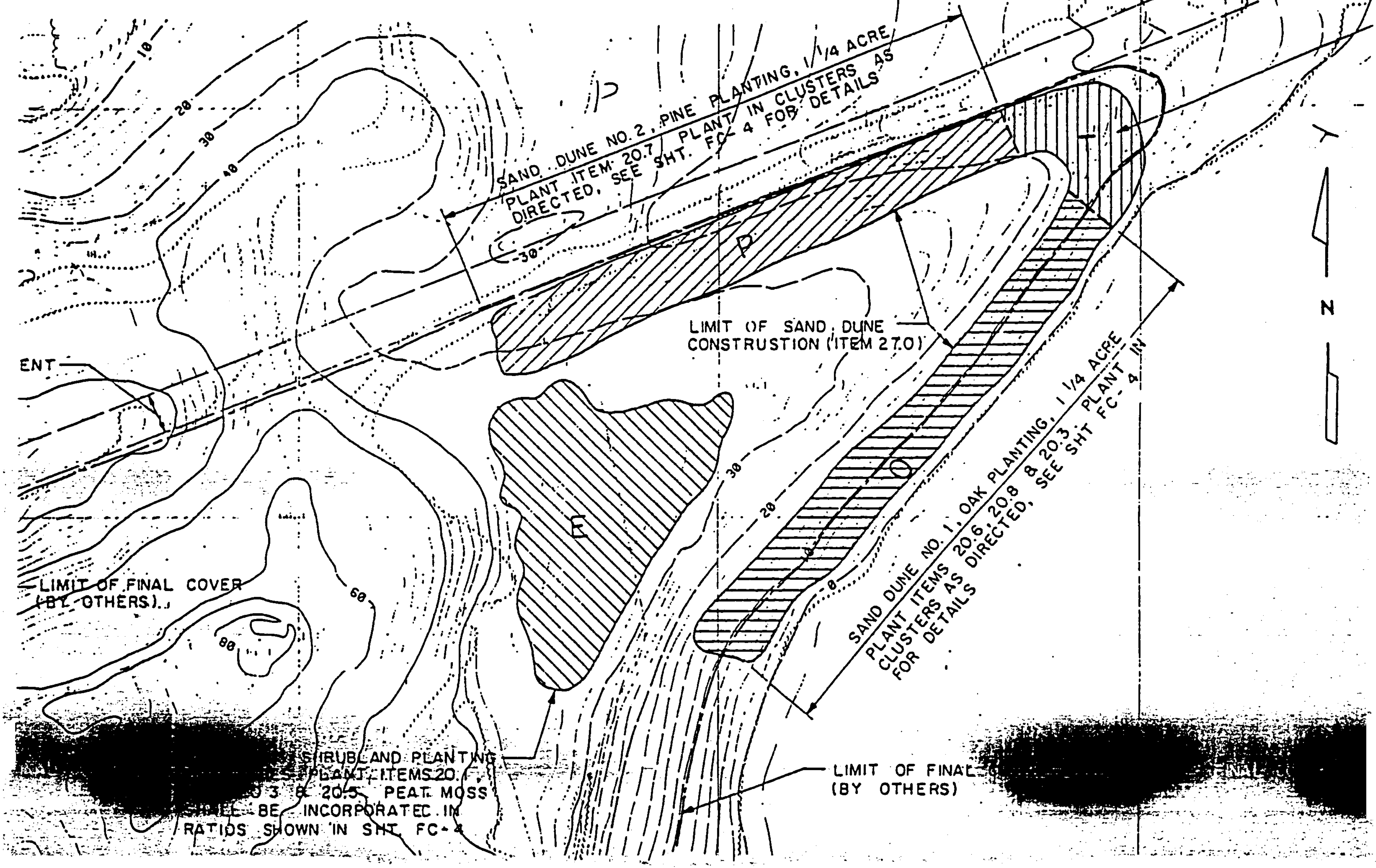

Figure 2. Relationship between the number of new invading seedlings and the proportion of installed plants that produced fruits.

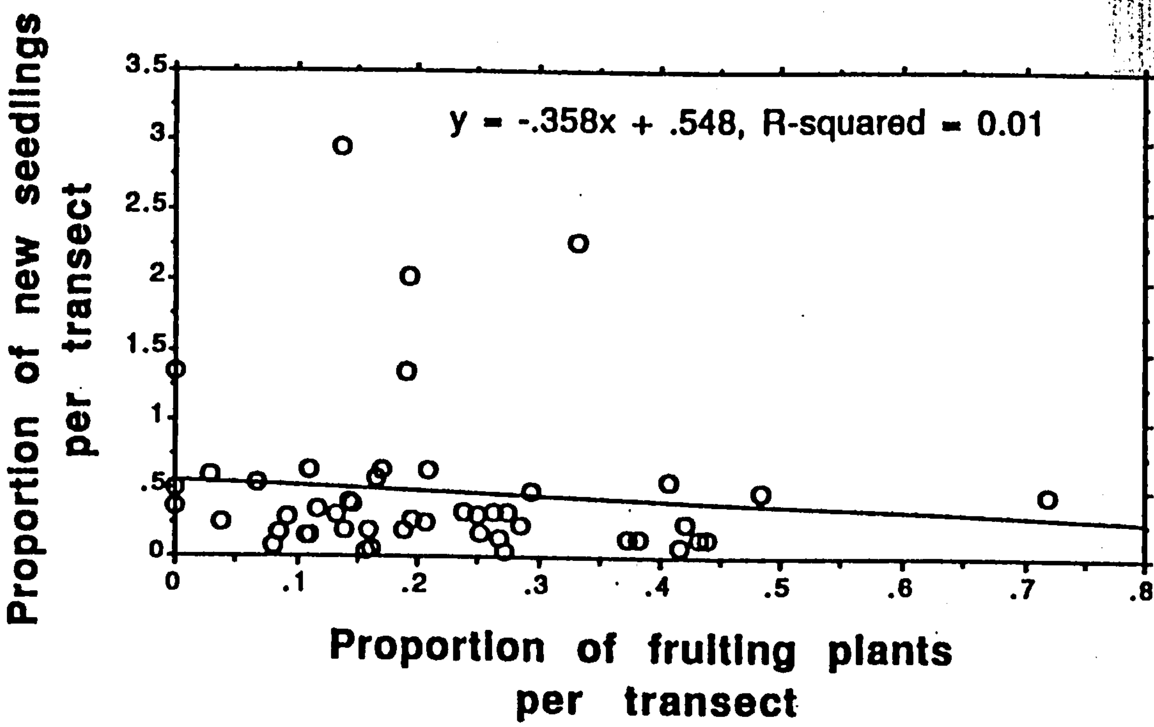

Figure 3. Relationship between the number of new invading seedlings and the ratio of installed trees to shrubs in the recruitment vicinity.