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# FROGS CAPTURED IN GREEN BEAN HARVEST:ANALYSIS OF A PEST PROBLEM

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# FROGS CAPTURED IN GREEN BEAN HARVEST:ANALYSIS OF A PEST PROBLEM

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## ABSTRACT

In southern New Jersey a new agricultural pest problem has seriously impacted production of green beans for plant processing. Newly acquired harvesters inadvertently capture frogs, which are difficult and expensive to remove from harvested beans. Goals of this project were to (1) define the biological properties of the pest problem, and (2) identify biologically sound and effective methods to manage the problem.

Fowler's toad (*Bufo woodhousei fowleri*) was the most numerous (82%) of 9 species sorted from harvested beans, and it was also the most common in field censuses (76%). Density estimates based on field censuses were higher than when based on samples sorted from harvested beans. Harvesters selectively captured large frogs. Relatively few fields produced most problems; only 17% (74 of 433) produced more than 4 frogs, while 83% (359) produced less than 4 (44.8 % had none). Continuing research will develop quantitative models using features of habitat and environment to predict the "pest potential" of fields so that these can be managed individually.


## INTRODUCTION

The rich diversity of vegetable crops grown in southern New Jersey is a major strength of the local agricultural industry. Green beans are an important part of this diversity, contributing significantly to the economic base.

In an effort to increase harvest efficiency green bean growers began to commit large sums of money in 1983 for replacement of their aging bean harvesters. They bought newly designed, highly efficient models (Chisholm Ryder multi-row pickers). The new harvesters use a large counter-rotating brush to stand plants up and remove beans. Bean fields, like many agricultural habitats, provide a high quality environment for many species of frogs. The ample cover of maturing plants and frequent irrigation are near ideal. Unfortunately the same brushes that are so efficient at removing beans are also very effective at dislodging and capturing frogs at or near the soil surface.

Because a satisfactory management approach is not available, this emerging problem holds the potential for seriously affecting the long term viability of this important, but economically fragile crop. At present management involves simple removal of the animals during plant processing. Sorting must be carried out with near absolute certainty, otherwise there is the potential for seriously affecting the quality of the product. Implementing and maintaining these methods with such high standards is difficult and expensive. A better approach would avoid contamination of the crop at the time of harvest.

The overall goal of this study was to examine this pest situation in an

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effort to identify preharvest management techniques that would prevent contamination of the bean crop. The immediate objectives were to (1) define the biological properties of the pest situation, and (2) identify biologically sound and effective methods to manage the pest problem.

## METHODS

The study was conducted on the outer coastal plain of southern New Jersey (Salem and Cumberland Co.). Bordered by the Delaware Bay on the south, the area is characterized by a high water table, little topographic relief and sandy unconsolidated soils. Combined with a 193 day growing season and 113cm annual precipitation, these features provide an excellent environment for a large variety of vegetable crops.

Two permanent study sites were established near the northeast and southwest extremes of the study area. The northeastern site (Site 4 on Lawrence Corner Road) was inland, having somewhat heavier soils and much less direct coastal influence than the southwestern site (Site 3, Route 40 and Pointers Auburn Road).

The pest population was identified directly by examining animals captured in bean fields during harvesting, and subsequently sorted from beans at the processing plant (plant samples). In 1986 plant personnel froze animals in groups according to the truck load from which they were removed. Truck loads were numbered sequentially as they arrived at the plant, and could be traced to specific bean fields. Each week frogs were collected from the plant, identified, counted, and measured. Normal accounting practices at the processing plant included records of the number of animals removed from each truck load. Counts of animals recorded by the accounting department were verified in 1986 by comparing them to numbers of frogs removed by sorting. For 1985 estimates of animals removed from harvested beans were based entirely on the accounting department's records.

Field estimates of population size were made by strip censuses conducted after sundown. After measuring field size, a sample strip 200 meters long was randomly selected along each of 5 randomly selected rows. Sampling involved searching the area between adjacent rows (from row center to center) for frogs. A total of 116 censuses of 21 plantings were made.

We made 64 pre-harvest censuses, between 25 June and 18 September usually on the day of harvest, however several were run 1-3 days prior to harvest. Pre-harvest censuses provided estimates of population size independent of plant samples.

Repeated strip census were conducted weekly at 6 locations from 20 May-11 September. In addition to the 2 permanent sites, 2 sites were selected within 1 km of Site 4, and two within 5 km of Site 3.

At the two permanent sites drift fences (Gibbons and Bennett 1974) were constructed to capture frogs moving to and from breeding ponds. They were fabricated from 6mm plastic mesh fencing reinforced with 2.54cm poultry wire. The fences were buried 15-20cm below ground and extended about 50cm above ground. Pitfall traps were made by sinking plastic potting buckets (diameter = 36cm) 46cm into the ground along both sides of fences.

At Site 4 five drift fences (two

15m, one 26m, and two 30m) had 42 pitfall traps. Traps were located near a pond among fields normally used to grow green beans. At Site 3, 80 traps were set along eight fences (six 15m, one 30, and one 518m fence encircling a pond). All traps were checked daily from 20 April-19 September. Frogs were removed from traps, identified, measured, marked and released.

## RESULTS AND DISCUSSION

### Pest Population Sizes

The frog problem was acute in 1985 with as many as 63 frogs removed from individual truck loads (about 9,100kg beans/load). In 1986 the overall problem was less severe with smaller weekly catches (Figure 1) and far fewer total frogs for the season (4027 and 1168 respectively).

In 1986 the maximum weekly average for frogs per load (Figure 2) was only about half (2.3 mean frogs per load) the maximum for 1985 (5.4). The mean values per week appear low because most loads were not contaminated. For example in 1986 frogs were found in only 55.2% of all loads processed at the plant.

Overall numbers were low in 1986 because of unusually dry weather in spring and early summer (-34% departure from normal, NOAA 1986). The period of below normal precipitation began in early spring when many local species normally migrate from wintering sites to breeding areas (Conant 1975). Dry conditions persisted through the summer months, resulting in a greatly abbreviated breeding season (see below).

Weekly values in Figure 2 reflect seasonal patterns of activity for frogs because they are independent of harvesting activity. The seasonal peak during Aug. 1985 is probably more typical than the bimodal pattern in 1986 (Blair 1953), and so provides an unambiguous measure of the seasonal pattern in magnitude of the pest problem.

Low numbers in 1986 may have been due in part to drought induced mortality of adults, but more likely the main effects came from changes in activity patterns (Einem 1956). For example, dry conditions in spring may have delayed normal spring dispersion from wintering sites. And, although overall population sizes may have been approximately the same as in 1985, the frogs may have not been able to move into agricultural habitats in as great numbers. Also, when conditions are dry, frogs spend less time on the soil surface, reducing the likelihood of being captured by harvesters.

### Species Causing the Pest Problem

We found 10 species of frogs among the 1046 indentifiable specimens removed from beans at the processing plant (Table 1). Of these Fowler's toad (*Bufo woodhousei fowleri*) com-

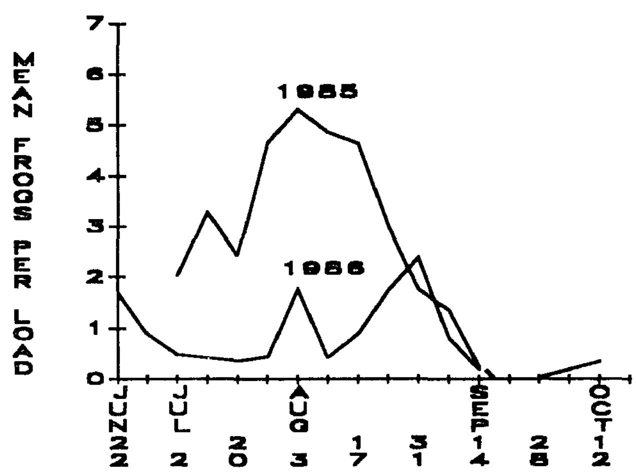


Figure 1. Number of frogs captured by harvesters and removed at the processing plant during 1985 and 1986.

prised nearly 82%. Two other toads (spadefoot [*Scaphiopus holbrooki holbrooki*] and American toad [*Bufo americanus* ]) were relatively uncommon in plant samples, although the spadefoot was quite common in field samples (see below).

Five species of true frogs (*Rana*) made up 14.3% of plant samples. The leopard (*R. retricularia*) and pickerel frog (*R. palustris*) were most abundant (4.8% each) while the green frog (*R. clamitans*) and the bullfrog (*R. catesbeiana*) each made up only about 2% of the total. Least abundant was the wood frog (*R. sylvatica*) (<1%). The remaining two species were tree frogs; the spring peeper (*Hyla crucifer*) and gray frog (*H. versicolor*); both were uncommon (together <0.5%).

We identified six species of frogs in field samples (Table 2). This was four fewer than in plant samples. Two of the missing species were uncommon in plant samples (gray and wood frog), so their absence in field samples was

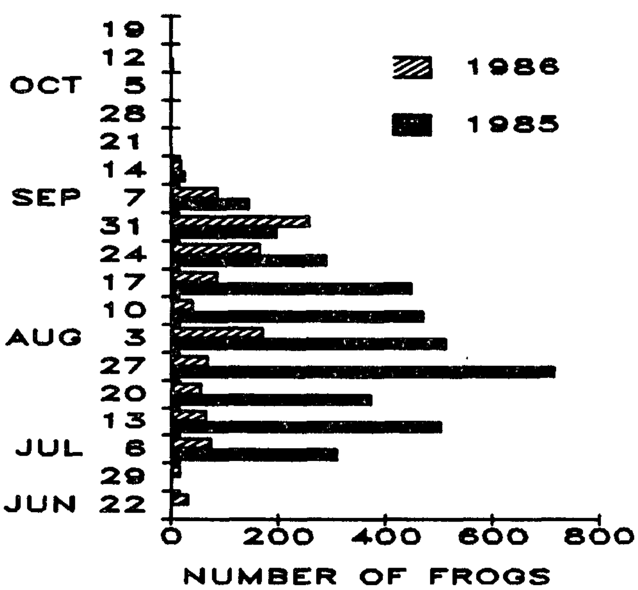


Figure 2. Mean number of frogs per truck load of harvested beans for 1985 and 1986.

Table 1. Frogs removed from harvested beans at the processing plant (1986 data).

| SPECIES | NUMBER | PERCENT |
|---|---|---|
| *B. americanus* | 15 | 1.4 |
| *B. w. fowleri* | 852 | 81.5 |
| *H. crucifer* | 5 | 0.5 |
| *H. versicolor* | 1 | 0.1 |
| *R. species* | 4 | 0.4 |
| *R. catesbeiana* | 20 | 1.9 |
| *R. clamitans* | 22 | 2.1 |
| *R. palustris* | 50 | 4.8 |
| *R. retricularia* | 50 | 4.8 |
| *R. sylvatica* | 3 | 0.3 |
| *S. h. holbrooki* | 24 | 2.3 |
| Total | 1046 | 100.0 |

likely due to rarity. The other two missing species (green frog and leopard frog) were relatively abundant in plant samples, and therefore were under represented in field samples. Both species are small, cryptic, and very fast, providing an explanation for why they were not detected during field sampling. Similarly, pickerel frogs were relatively abundant in plant samples (4.8%), but were much less common in field samples (0.4%). Like the green and leopard frogs, pickerel frogs are difficult to detect and are also likely under represented in field samples.

Fowler's toad was the most common species (76%) in field samples just as it was in plant samples (82%). The similarity in both samples suggest that bean harvesters captured Fowler's toads in proportion to their abundance in fields.

This contrasts sharply with the situation for spadefoot toads. In field samples spadefoot toads comprised 21%, while at the plant they made up only 2.3%. This suggests that spadefoot toads were captured by harvesters far less frequently than they were encountered. This may be due to the spadefoot's propensity for burying itself in sandy soils where it is most common (Pearson 1955). Their burrows may be deep enough to avoid dislodgement by the harvesters' brushes.

Breeding Season

Fowler's and spadefoot toads were the 2 most commonly trapped species at breeding ponds. In southern New Jersey these species emerge from wintering sites and move to breeding areas when it rains. In 1986 breeding began relatively late and remained infrequent throughout spring and early summer. Locally, Fowler's toad breeds as early as the end of March (Gibbons and Coker 1978). However, in 1986 first signs of breeding occurred near the end of April (Figure 3). The spadefoot normally begins breeding later than Fowler's, and in 1986 we first detected breeding spadefoot toads in late May.

Breeding activity for Fowler's and spadefoot toads was concentrated in 1986 around the 3 periods of moderate to heavy precipitation (Figure 3). Because the spadefoot began breeding activity so late in the season, we recorded only one major breeding influx. It occurred in early June during the only wet weather of the normal breeding season. Breeding data were not available from 1985. However, the heavier rainfall likely resulted in a greater level of breeding activity with more bouts lasting longer than those measured under the dry conditions of 1986 (Aronson 1944).

Table 2. Frogs censused during field sampling.

| SPECIES | NUMBER | PERCENT |
|---|---|---|
| *B. americanus* | 3 | 1.3 |
| B. *w. fowleri* | 181 | 76.1 |
| *H. crucifer* | 1 | .4 |
| *R. catesbeiana* | 2 | 0.8 |
| *R. palustris* | 1 | 0.4 |
| *S. h. holbrooki* | 50 | 21.0 |
| Total | 238 | 100.0 |

Body Size Distributions

I separately analyzed sizes of frogs obtained from (1) pitfall traps along the drift fences, (2) field censuses, (3) sorting at the processing plant. Ordinarily in a stable population, there would be fewer individuals in each progressively older age cohort (i.e., size class) (Blair 1943). Nevertheless, none of my samples assumed such a distribution (Figure 4), suggesting that each was a biased sample of the actual populations.

The strip census came closest to the expected age structure (Figure 4), however, the smaller size classes were still under represented. This may have been partly due to a seasonal effect, since sampling started weeks before young of the year emerged. Small frogs are difficult to see at night, and were probably missed more often than larger animals. Also, their small size would restrict mobility and increase susceptibility to desication, limiting them to areas relatively close to water sources.

Pitfall traps captured only the breeding population as they moved towards ponds. Absence of smaller size classes biases the sample, but the largest 3 size categories are probably representative. The pattern for plant

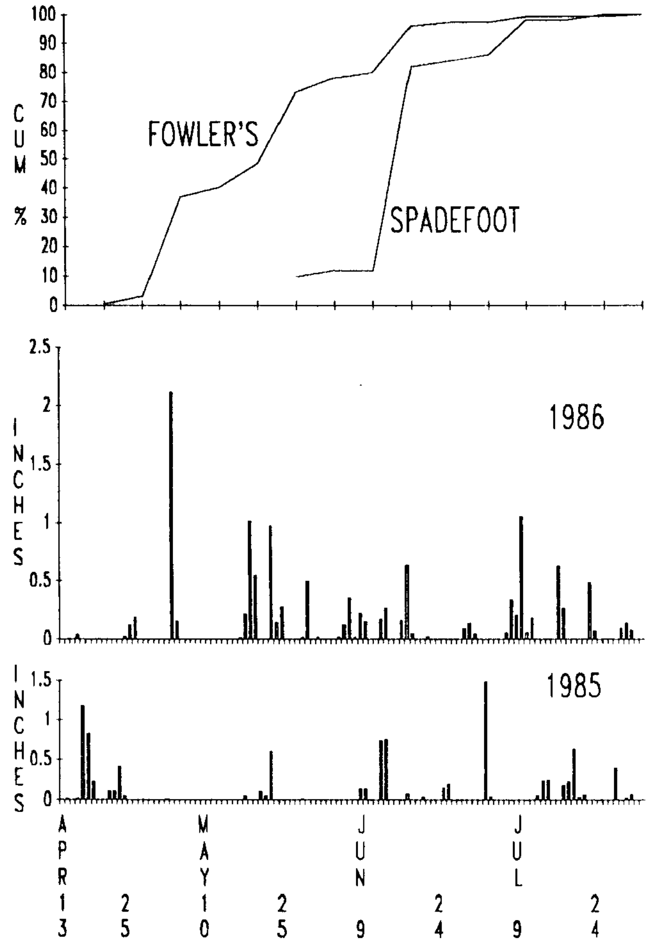


Figure 3. Breeding activity (cumulative %) for Fowler's and spadefoot toads during 1986 (top) and daily mean rainfall for corresponding periods during 1985 and 1986 (bottom and middle).

samples was similar to trap samples, but with proportionately fewer frogs in the 50-59mm category (Figure 4).

In plant samples both Fowler's and spadefoot toads had fewer individuals in smaller size classes than in larger classes (Table 3). However, from the census sample it is clear that smaller size categories were far more abundant than plant data suggest. Therefore, harvesters must be disproportionately capturing animals in larger size categories.

For the spadefoot 90% of all frogs captured by harvesters ranged in size from 40-59mm (snout-vent length), although frogs in these size categories were likely much less abundant in bean fields than individuals in smaller size classes. Spadefoot toads smaller than 40mm were rare in plant samples indicating that smaller individuals were relatively immune to harvesting. Similarly for Fowler's toad, individuals in 40-59mm size classes were most abundant. However the 30-39mm class was also abundant, and at 21% of the total, Fowler's in this category were much more common than spadefoot toads (4%) of the same size. Smaller Fowler's are evidently much more susceptible to capture by harvesters than small spadefoot toads.

<u>Estimates of Population Densities</u>

Density estimates of frogs captured by harvesters ranged from 0 to 7.8 animals/ha. The overall average for

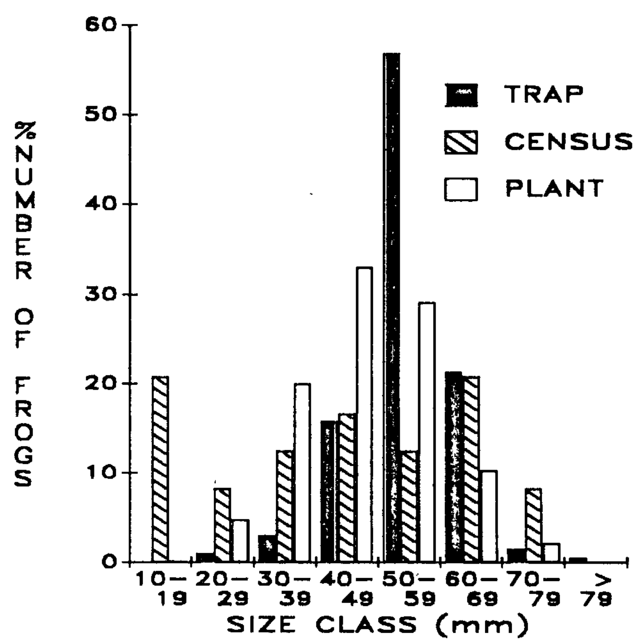


Figure 4. Size distributions of frogs from the 3 types of census.

Table 3. Size classes (mm) of amphibians removed from harvested beans at the processing plant. Values represent percent of total for each species with sample sizes shown in parentheses.

| | SPECIES | | |
|---|---|---|---|
| | Bwf | Shh | Other |
| SIZE CLASS | | | |
| <20 | 0.3(2) | 0.0 | 0.0 |
| 20-29 | 4.8(34) | 0.0 | 5.8(9) |
| 30-39 | 21.0(150) | 4.8(1) | 17.4(27) |
| 40-49 | 30.9(221) | 71.(15) | 38.1(59) |
| 50-59 | 30.9(221) | 11.0(4) | 22.6(35) |
| 60-69 | 10.4(74) | 4.8(1) | 11.0(17) |
| 70-79 | 1.8(13) | 0.0 | 4.5(7) |
| >80 | 0.0 | 0.0 | 0.6(1) |

fields that produced at least one animal was 1.23 frogs/ha. Estimates of population density based on field censuses were as high as 33 animals/ha (Table 4).

Field censuses yielded consistently higher values than estimates based on plant samples. This was, at least in part, due to the absence of small size categories in plant samples, as these only included the larger "harvestable" portion of the population. Field censuses also underestimated smaller size categories, but the error was much smaller than for plant samples, so field censuses provided a much better estimate of actual numbers.

Our estimates of population densities were least precise in low density fields. This was due largely to underlying statistical properties requiring greater sampling intensities (at a given level of precision) when densities are low. This problem was compounded by lower than expected frog densities in 1986. The sampling scheme was based on relatively high population densities estimated from 1985 plant samples. As a result the number of samples per field was less than optimum for the reduced 1986 population sizes. Future censuses should include more individual samples per field in order to lower the statistical variation of each estimate and to increase precision at low population densities.

A second, and we believe unrelated, problem developed in 3 plantings (harvest dates - 24 July, 30 Aug, 1 Aug) for which we obtained vastly different population estimates for plant samples and field censuses. For example, we paid especially close attention to the 1 Aug field because we knew that it had produced many frogs in previous years. We censused it 7 times through the season (including the night before harvest) in order to determine when and from where the frogs originated. We were quite unsuccessful in detecting any frogs. They were either absent when we performed our censuses, implying that the population can be highly mobile, or they were buried so completely that they were undetectable. Nonetheless, 36 frogs were picked up by the harvesters.

I am unable to explain these discrepancies, but I believe they were not directly related to the overall sampling program. Rather the discrepancies seem to have originated from an unidentified feature of natural history or perhaps the physical environment (soil moisture, timing of irrigation, etc.) in these particular fields about which we were unaware.

Table 4. Estimated frog density, based on harvested frogs and field censuses, for fields at permanent sampling sites. Table does not include fields where no toads were detected during field censuses.

| FIELD | HARV DATE | NUM TOADS HARV | EST. FROGS/HA HARV | EST. FROGS/HA CENSUS |
|---|---|---|---|---|
| 1 D | 8/11 | 3 | 1.4 | 11.1 |
| 1 E | 8/11 | 3 | 0.7 | 11.1 |
| 2 A | 7/7 | 16 | 4.0 | 11.1 |
| 3 J | 8/4. | 2 | 0.2 | 25.0 |
| 3 K | 8/5 | 31 | 2.7 | 33.3 |
| 3 L | 8/5 | 31 | 7.8 | 33.3 |
| 3 F | 8/22 | 6 | 0.4 | 33.3 |
| 3 G | 8/22 | 6 | 0.7 | 25.0 |
| 3 H | 8/27 | 19 | 2.0 | 16.7 |
| 3 I | 9/2 | 12 | 0.6 | 16.7 |
| 4 CA | 9/2 | 0 | 0 | 11.1 |
| 4 A | 7/5 | 0 | 0 | 11.1 |
| 4 B | 7/5 | 0 | 0 | 11.1 |
| 4 C | 7/21 | 6 | 0.7 | 22.2 |
| 4 E | 8/29 | 5 | 0.8 | 11.1 |
| 4 F | 9/12 | 0 | 0 | 22.2 |
| 4 G | 9/18 | 1 | 0.1 | 14.8 |
| 4 H | 9/18 | 1 | 0.1 | 18.5 |

## AN EXAMINATION OF MANAGEMENT APPROACHES

Current problems with frogs in harvested green beans were precipitated by the purchase of new highly efficient harvesters. Returning to older less efficient designs might seem the simplest solution, but this is not practical. Economic demands for higher productivity required the purchases in the first place. Aside from large capital outlays already made, growers reverting to older, less efficient techniques would not be competitive with growers able to use newer harvesters.

Rarely, if ever, have vertebrate pest problems found universal solutions, broadly applicable to a wide range of situations. Rather, management strategies are generally customized to the requirements of specific situations. Approaches to frog problem will likely face these same limitations, with success coming largely on a site by site basis.

### Population Reduction

In many pest situations population reduction is the first approach considered, but this is often impractical or undesirable. Impractical because costs to remove an animal are high relative to amount of damage an individual causes; undesirable because the damage caused is only one small part of an animals's overall role in the ecosystem. Nonetheless, there are 3 general approaches to reducing populations of frogs associated with green bean production that might be considered.

Lethal control of adults in bean fields--Lethal control of adults is not likely to be a viable approach to the problem. Densities of frogs are low (10-20 animals per ha) in bean fields making impractical any methods based on removal of individuals (e.g., trapping). Labor and material costs per animal for any conceivable program of removal would simply be too high.

The use of chemical pesticides is the only other lethal method having practical labor requirements. There are no materials currently labeled for this purpose, nor are there, to my knowledge, any materials in any stage of development. Development of chemical solutions to the problem would, at best, be expensive and would require many years. In addition, successful labeling of a pesticide for use against a vertebrate that is generally considered beneficial is fraught with difficulties and likely would not be possible with current regulations.

Lethal control of immatures at breeding sites--Development of chemically based methods for lethal control of immatures faces similar obstacles, but with the added complications of labeling a material for use in aquatic systems. Another difficulty is that any lethal control of immatures is quite indirect in that the young cohorts killed in ponds would be up to three years away from being large enough to be picked up by the harvesters. In situations where limited breeding sites can be identified and treated, larvicides might be practical (assuming labeling was possible). In the more usual situation where many breeding sites would remain untreated, and where the opportunity existed for immigration of adults from other areas, lethal control of immatures would not likely be effective.

Reproduction inhibition--Use of chemosteralents to lower reproductive success offers no immediate opportunities since materials are not currently available, and are unlikely to become available in the near future. Nevertheless, there are other ways to reduce or prevent reproduction in frogs. Since some frogs hibernate during winter in upland sites (e.g., bean fields) exclusion fencing around breeding ponds can prevent them from returning to breeding sites in spring. When drift fences are equipped with pitfall traps breeding adults, as well, can be removed from the population. However, in some states frogs are protected so local regulations should be consulted. Only when frogs come to breeding ponds in the spring are they sufficiently aggregated to employ non-chemical means of control. The materials are inexpensive, but considerable manpower is needed to erect and maintain fences.

Another way to physically inhibit reproduction is through management of pond habitats. Species of frogs causing the greatest problem prefer calm shallow water for egg deposition. Water is warmer than at deeper sites allowing development to proceed at a faster rate, and perhaps more importantly, these areas are safe from large predacious fish. To minimize breeding success, edges of ponds should be very steep with no emergent vegetation. Shallow wet areas that are often associated with ponds should be eliminated. Such steps are time consuming and expensive, but can have a substantial effect on reproductive success.

The effectiveness of population management at breeding sites is dependent on the number and distribution of breeding sites in the general area of problem bean fields. In areas where breeding sites are limited, size of the local frog population can be reduced, particularly if habitat modification is combined with an effort to trap breeding adults.

## Cultural Practices

Our results suggest two places where modifications in current cultural practices might influence capture rate of frogs by harvesters.

(1) We found important differences in frequency of capture between Fowler's toad and spadefoot toad. The spadefoot has a much greater propensity

for burying itself in soil during periods of inactivity. It was also captured by the harvesters at frequencies far lower than its actual abundance. Fowler's toad, the most serious pest, tends to remain at or near the soil surface. This suggests that Fowler's toads might avoid capture, as does the spadefoot, if it could be induced to bury itself deeper at time of harvest. One possible approach might closely manage moisture at the soil surface by adjusting irrigation schedules near time of harvest. This approach might be most useful in fields with a propensity for frog problems, however additional research is necessary.

(2) Our results indicate that smaller frogs are relatively immune from capture by harvesters. This suggests the possibility that if, by what ever mechanism, the harvesters avoid some size categories perhaps minor mechanical modifications might extend this to include slightly larger animals as well. Although this approach may not eliminate the problem as larger animals will likely remain susceptible, it might be possible to at least ameliorate the problem to some small degree.

## CONTINUING RESEARCH

My current research is focused on developing methods to evaluate , *a priori*, the "pest potential" of perspective green bean fields. Variation in numbers of animals captured by the harvesters comes primarily from two sources. (1) The likelihood of a site having frog problems varies from day to day because behavior of frogs changes in response to very immediate and local conditions. For example, when its dry

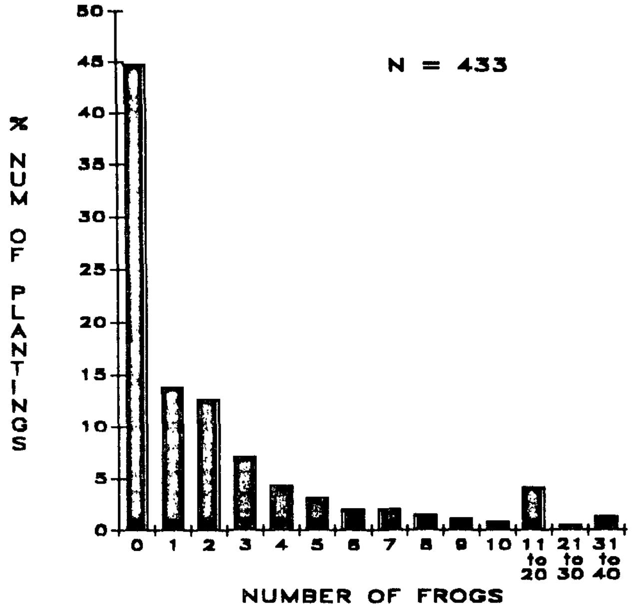

Figure 5. Frequency of plantings categorized by the total number of frogs harvested.

they burrow, or when there is no food they disperse. Either response can have a significant impact on the number of frogs picked up by a harvester. (2) Variation also comes from dispersion of amphibian populations over the landscape. This regional dispersion is fixed by larger, relatively permanent habitat features.

We are analyzing plant samples from fields over a large area to provide measures of dispersion. These are being combined with measurements of physical features and time-of-harvest characteristics in an effort to produce predictive models that will indicate the pest potential of individual bean fields anywhere in the growing region. If our models are adequately predictive growers will be able to make informed decisions on how best to select fields for physical management of local frog habitats, or which fields might be better used for alternate crops.

The justification for this approach comes mainly from our analysis of 1986 plant samples. We found that most bean fields did not have any frog problems, and many fields had only minor problems (Figure 5). Only 74 plantings (17%) of 433 total produced more than 4 frogs, while 359 (83%) produced less than 4 (44.8% produced no frogs). Thus, relatively few fields experienced a majority of the problems. This being the case then, the management strategy does not attempt to broadly manage frog populations, but rather identifies specific fields that have the potential for developing frog problems. Once identified, troublesome fields can be managed individually according to methods outlined above, or when these approaches are not practical such fields could be reserved for alternate crops.

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