TABLE 2.—*Comparison of differences in fecundity of lobsters as calculated from regression equations derived from Herrick's data and from the Rhode Island analysis*

Carapace length (mm)	Total length (inches)	Fecundity: Herrick's regression (1)	Fecundity: Rhode Island regression (2)	Difference (1)–(2)	Percent of (2)
70	8.00	5474	5210	+264	5.06
76	8.75	7213	6112	+1101	18.01
85	9.75	10500	8424	+2076	24.64
92	10.50	13695	10569	+3126	29.57
98	11.25	16920	12597	+4323	34.31
103	11.75	19958	14602	+5356	36.27
107	12.25	22725	16263	+6462	39.73
110	12.50	24934	17631	+7303	41.42
114	13.00	28110	19530	+8580	43.93
120	13.75	33390	22628	+10762	47.56
127	14.50	40418	26615	+13803	51.86
133	15.25	47110	30360	+16750	55.17
137	15.75	52050	33060	+18990	57.44
144	16.50	61548	38150	+23398	61.33
149	17.00	68990	42068	+26922	63.99
153	17.50	75408	45378	+30030	66.17
158	18.00	84030	49761	+34269	68.86

that the variance of the new data is considerably greater than that obtained from Herrick. This is probably due to the fact that only average values of fecundity are available from Herrick's data, and individual values were used for the new study. A test of the hypothesis $\beta_1 = \beta_2$ clearly demonstrated significant differences in the two sample regression coefficients. As stated previously, the difference is apparently due to a bias introduced by Herrick's method of estimating fecundity.

The derived regression equations for the carapace length—fecundity relationships of the American lobster are as follows:

Herrick's data:

$$\log_{10} Y(\text{Fecundity}) = -2.4505 + 3.3542 \log_{10} \times (\text{carapace length mm})$$

New data:

$$\log_{10} Y(\text{Fecundity}) = 1.6017 + 2.8647 \log_{10} \times (\text{carapace length mm})$$

The above equations were utilized to calculate fecundity for a range of sizes and to make comparisons of the differences obtained (Table 2). It is clear from an examination of this table that there is a consistent positive difference in the estimated average fecundity for given lengths and that the magnitude of this difference increases with increasing size.

It is suggested from this study that the equation derived from the new estimates of lobster fecundity is more realistic than the one previously utilized based on Herrick's data. The latter estimates of average fecundity are apparently biased in a positive direction due to the estimation method since the samples were compared at approximately the same period of egg development, and it is assumed that fecundity has not changed since the original samples were taken.

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The Effects of a Rotenone Treatment on the Insect fauna of a California Stream

In the late summer of 1963, the California Department of Fish and Game embarked upon a "rough fish" control program of the major tributaries of the Russian River, north coastal California. The major objective of this project was to remove the non-salmonid component of the fish fauna from the warmer, lower gradient sections of these tributary streams in the hope that once competing non-game species were removed, these zones would provide trout habitat. Although a five-year follow-up evaluation of this project from a fisheries standpoint was planned by the Department, nothing has yet appeared in print to indicate its success or failure.

Although chemical treatment of streams to remove unwanted fish species is a common fisheries management practice (see Burns 1966, and Meyer 1966 for reviews), this practice has been subject to justifiable criticism (Hubbs, 1963). One question that has been raised concerns the possible adverse effects of these treatments on the non-target invertebrate fauna of the streams so affected. It is this point that forms the basis for this report.

One of the streams selected for treatment under this project was Robinson Creek, Mendocino County. Robinson Creek is about 10 miles in length and drains a fairly extensive mountainous watershed from the eastern slope of the central Coast Range. As is typical of most streams in this region, water volume varies from several thousand cubic feet per second during winter storms to mere trickles in the summer; sections of many of the streams go dry or underground during the dry season.

In the general area of concern here, the creek flows through a canyon for about 3 miles. The upper part of the canyon is steep sided and narrow, gradually opening out as it approaches the valley floor of the Russian River. This is accompanied by a decrease in the stream gradient. The substrate varies locally with the stream gradient from bedrock to silty gravel in the quiet pools. Water-worn rocks and boulders characterize much of the stream bed. The canyon walls are well vegetated with many of the trees and shrubs characteristic of the broad sclerophyll association in this region.

The treatment plan for Robinson Creek was to apply rotenone to the stream below a point 4½ miles above its mouth. It was at approximately this point where visual observation indicated an upstream predominance of trout and a downstream predominance of suckers, western roach, sculpins, squawfish, and larval lampreys. It was also at approximately this point where the canyon began to open up gradually and the stream gradient decreased.

The data presented here represent an attempt to determine the overall effect of the rotenone treatment of Robinson Creek on the predominant insect groups. Neither time nor facilities permitted identification of these organisms beyond the ordinal of familial level.

METHODS AND PROCEDURES

The procedural plan that appeared best adapted to the objectives of this study was to follow the population levels of the major insect groups subsequent to treatment in the treated and untreated zones. Consequently, sampling stations were established within a few hundred yards above and below the point where the treatment began.

Two major habitat types were sampled: the pools and the riffles. Although the pools appeared fairly similar throughout, the riffles varied in gradient from what might be typically regarded as a riffle of fairly low gradient to small cascades where the water flowed over, around, and between boulders in the stream bed. Between 2 and 4 samples were taken at irregular intervals from each of the habitat types from both the treated and untreated zones as water conditions permitted from 3 days after the treatment until the following spring.

The sampling method originally considered for use in this study was based upon the Surber sampler. Due, however, to the rocky character of the stream bed, and the limited amount of water in the creek during the late summer, this method proved generally unsatisfactory for purposes of this study. Instead, a method was employed which took advantage of the rocks that formed so much of the substrate. At each station 5 rocks were carefully removed from the stream bed and washed into a fine-mesh (32 squares/inch) sieve. The organisms and other residue so obtained were then washed into pint jars. Every attempt was made to sample rocks of roughly the same size from all stations. Although this was not possible in all cases, most

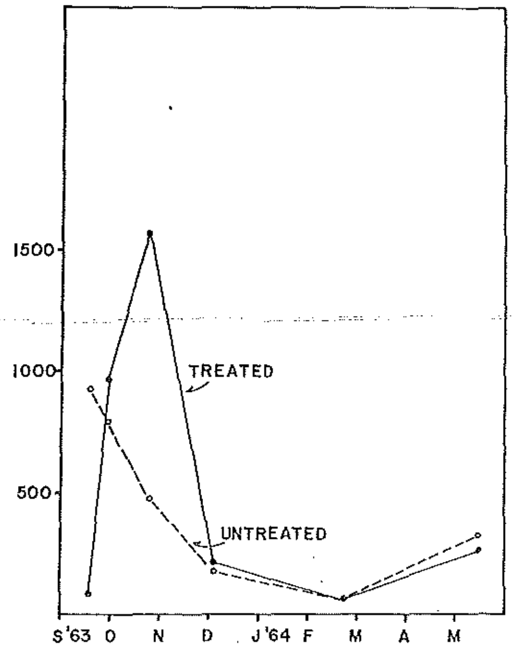

FIGURE 1.—Total insect fauna: riffle samples.

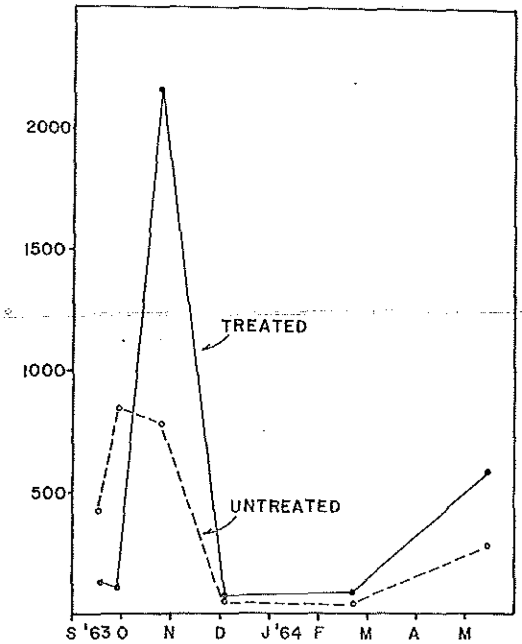

FIGURE 2.—Total insect fauna: pool samples.

of the rocks sampled were in the 2 to 3 pound range. When it became necessary to sample larger or smaller sizes, compensations were made to adjust for significant differences in surface area.

Robinson Creek was treated on September 12, 1963, by the California Department of Fish and Game with the authors as observers. The project plan called for dispensation into the water of *Pronoxfish* "at a concentration level of not less than 0.050 active ingredient rotenone."

RESULTS

The predominant groups of insects encountered in Robinson Creek during the course of this study were representatives of the orders Trichoptera, Ephemeroptera, and Diptera. Although the caddisflies and mayflies were not broken down in this report beyond the ordinal level, they were primarily represented in the samples by leptocerids and rhyacophilids, and heptageniids respectively. The Diptera were broken down to the family with simuliids and chironomids (tendipedids) predominating in this group.

As would be expected, the effects of the treatment became apparent within a few minutes after the material was applied to the water. A small mesh net placed below a riffle yielded large numbers of dead and dying aquatic invertebrates as well as fish. The first sample recorded was taken on September 15, 1963, 3 days following the treatment.

The effects of the poisoning and the subsequent recovery of the total insect fauna in the treated portion of Robinson Creek can be compared with the control, or untreated zone, in Figures 1 and 2. As can be seen in both of these figures, there was a rapid and explosive resurgence of the insect fauna in both the habitat types sampled in the treated zone following initial near annihilation. With the onset of winter, however, population levels in the treated zone of the stream had declined to a point commensurate with population levels in the untreated zone. This trend continued with the riffle fauna until the next spring (Figure 1). The pool fauna (Figure 2), however, appeared to carry populations in the treated zone approximately double to that in the untreated zone.

The major components of the riffle fauna were found to be larvae of blackflies (Figure

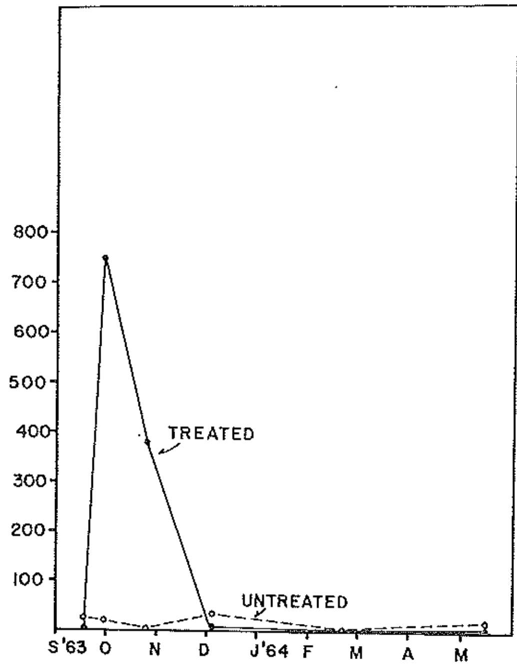

FIGURE 3.—Diptera: Simuliidae: riffle samples.

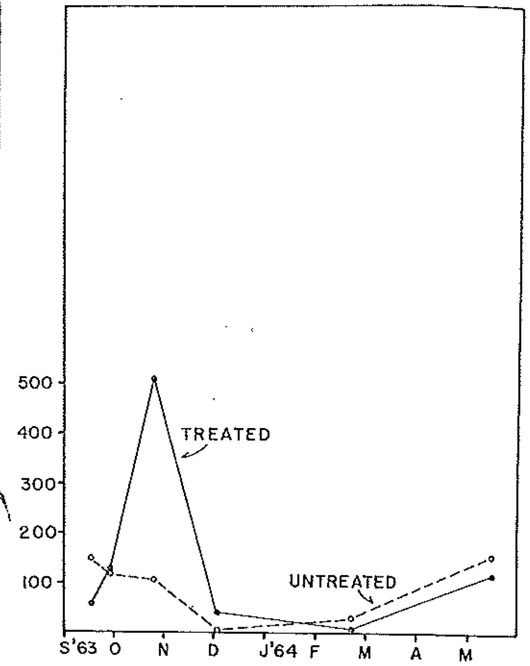

FIGURE 4.—Trichoptera: riffle samples.

3), caddisflies (Figure 4), and mayflies (Figure 5). Chironomid midges by far predominated in the pools (Figure 6), with trichopters and ephemerids contributing approximately 10% to the total insect fauna in this habitat.

The first major group to make a comeback in the treated riffles was the simuliids (Figure 3). Within two weeks subsequent to treatment, these organisms had virtually taken over all the available attachment space in the moving water. Although in streams blackfly larvae are most generally associated with fast moving water, they were everywhere at this time. Significantly, they were all early instars, indicating recent reproduction rather than drift from the untreated zone above. Within six weeks after the treatment, the simuliid population had dropped significantly. The caddisfly and mayfly larval populations, however, had erupted by this time (Figures 4 and 5). These were also represented by early instars, although a few large individual caddisfly larvae indicated an incomplete kill or drift from the upstream untreated zone.

In the pools, the chironomid midge larvae also erputed in the treated zone approximately 6 weeks after the treatment (Figure 6). These were also almost exclusively early instars.

There were several other major insect groups encountered during this study, although collectively they represented less than 5% of the total insect fauna sampled. Of these, the Plecoptera were found to be most abundant. These were also virtually annihilated in the treated zone, but had attained densities commensurate with those of the untreated zone by the following spring. Of the remaining groups, too few individuals were collected to evaluate. These included species of Odonata, Coleoptera (Psephenidae), Lepidoptera (Pyralidae: Nymphulinae), and Diptera (Tipulidae, Stratiomyidae, Ceratopogonidae, Tabanidae, and Blephariceridae). Other organisms included aquatic mites, copepods, ostracods, nematodes, *Planaria*, leeches, annelid worms, and snails.

CONCLUSIONS

From an entomological standpoint, the most interesting aspect of this study concerned the great resurgence of the insect fauna shortly after their initial near annihilation in the treated zone. This was particularly interesting

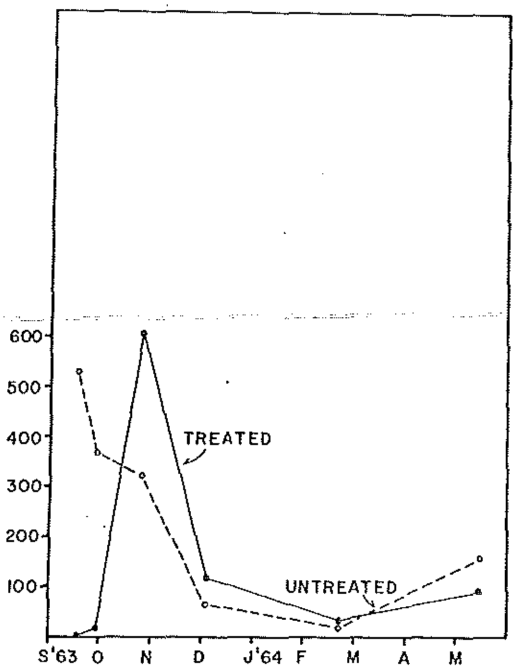

FIGURE 5.—Ephemeroptera: riffle samples.

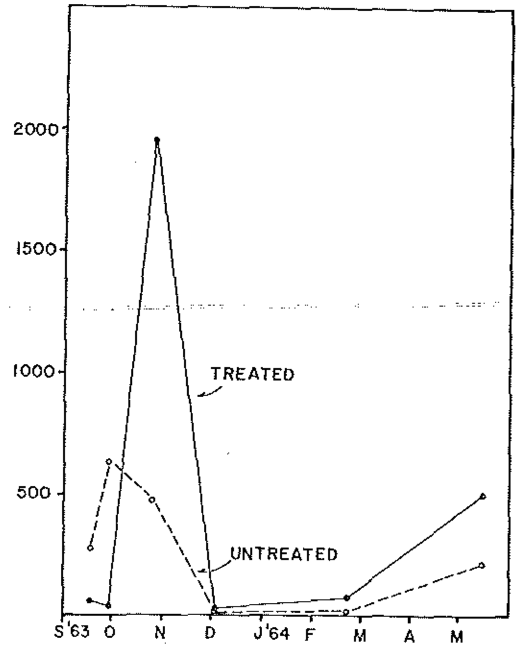

FIGURE 6.—Diptera: Chironomidae: pool samples.

in the case of the simuliids. As alluded to above, in environments such as Robinson Creek, these organisms are associated with the swiftest moving water. In view of the observations made here, it would appear that blackfly larvae may be limited in their ecological distribution by predation pressure rather than by any highly specific environmental needs, such as particularly fast moving water. As mentioned previously, when the Simuliidae returned after the treatment, they were attached to rocks, twigs, leaves, aquatic vegetation, and any other stationary objects in the stream bed. A few were even found in the pools. The elimination of the fish and other potential predators from this portion of the stream may account in part for the unusual abundance and survival of these organisms during the several weeks subsequent to the treatment.

On the basis of the information obtained in this limited study, it would appear that the application of rotenone to a stream for the purpose of reducing unwanted fish species has little lasting effect upon the non-target insect fauna of significance as fish forage. Caution, however, should be used in projecting these results to other instances of stream poisoning. In the case of Robinson Creek, only a portion of the stream was treated; this permitted repopulation from the untreated zone. Also, the timing of such a treatment could be very important in the case of those species that produce but one generation per year, or those with highly synchronous emergence times. If the treatment occurred during that time when the entire population was in the larval stage, repopulation could be significantly delayed.

Other points to be considered in the evaluation of these results concern possible biases due to the sampling methods, and possible species shifts that went undetected due to the broad identification procedures. It was unfortunate that a more detailed study was not possible in this case. It is entirely possible that had the identifications been carried to the specific level, that species shifts in predominance might have been detected.

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