Arch. Environm. Contam. Toxicol. 10, 393–426 (1981)

Archives of Environmental Contamination and Toxicology

Long-Term Effects of Intensive Pesticide Applications on the Aquatic Community in Orchard Drainage Ditches near Hamburg, Germany

Charles W. Heckman

Institut für Hydrobiologie und Fischereiwissenschaft, Universität Hamburg, Zeiseweg 9, 2000 Hamburg 50, Germany

Abstract. The results of an ecological investigation carried out to determine the structure of an aquatic community in orchard drainage ditches were compared with the results of a similar study conducted about 25 years earlier, before the full impact of modern pesticides had been felt. Comparisons of the community structures and abundances of the various species indicate that many species have become completely resistant to the agricultural chemicals to which they are exposed, while others have been completely eliminated from the habitat. Certain species have apparently benefited from the disappearance of predators and competitors and are now present in great abundance. Herbicides have had little, if any, effect on the floral species diversity. Insecticides have taken the greatest toll on predatory species, while acaricidal compounds have completely eliminated all species of water mite. Only one predatory eugamasid mite species was found in the ditches among a large population of collembolans on the water's surface. The individual substances now used in the largest amounts to protect the orchards are discussed, and their properties are listed. The simultaneous use of several toxic substances seems to make the development of resistance more difficult because the probability that one individual will be naturally insensitive to two toxic substances is much less than that it will be resistant to one. The sequential application of different pesticides, on the other hand, allows species to develop populations resistant to each, in turn.

Relatively little is known about the long-term effects of intensive pesticide treatments on aquatic habitats. There are several reasons for this; first, pesticides are applied directly to such habitats on a regular basis in only a few instances. Mosquito control and the treatment of rice fields are examples. Other than these special cases, the amount of chemical treatments for pest control that directly affect water bodies is small compared to those directed at terrestrial farmland. Although a great deal of substances applied to fields reach

0090–4341/81/0010–0393 $06.80

water courses indirectly, the bulk of the research on their effects has been directed toward terrestrial enviornments. A second reason is that judging long-term effects requires a detailed knowledge of the *status quo ante,* which means that studies are carried out only at locations that were investigated ecologically before the pesticides were first applied on an intensive basis. Third, the habitat must be in a stable state. That is, during the period that elapsed between the comparative studies, the entire water body did not advance to another stage of eutrophication or undergo a similar significant change. Partial changes will of course occur, but all important kinds of habitat within the ecosystem must still be present. Thus, effects observed can be related to conditions other than a normal succession of species that occurs with a change in trophic conditions. The necessary stability is found in large standing or flowing water bodies or in places where the habitat is artificially kept in the desired state. Furthermore, the investigations must be carried out for at least a full year to rule out effects associated with the normal seasonal succession of species. A fourth reason is that there is the practical need of supporting the research. A particular institute with facilities for carrying out the investigations must maintain interest in a habitat long enough to follow up studies made decades earlier with a thorough comparative research program. In practice, most researchers and institutions prefer to carry out well controlled short-term projects for which funding is more easily obtained.

Naturally, long-term studies could not have been made two decades ago, because the chemical-intensive form of agriculture is a relatively new phenomenon. It was not until the 1950s, after DDT and other substances had been developed and proven to be extremely effective, that agriculture began to depend on the chemical protection of crops. From the time it takes for resistances to develop and unbalanced ecological equilibria to restabilize, it could be assumed that a minimum of 10 to 20 years would be necessary before any long-term pattern could be established.

An excellent opportunity to study the effects of a 25 year intensive pesticide application program was found in the Altes Land, a fruit-growing region to the southeast of Hamburg, Germany. During the 1950s, at the start of the modern pesticide era, Garms (1961) made a thorough investigation of the aquatic biotic community in the drainage ditches beneath the fruit trees, listing the chief components of the macrofauna and flora. Since he completed this study, great amounts of insecticides, acaricides, fungicides, and herbicides have been applied to the orchards, their direct fall-out landing in the waters of the drainage system. Individual ditches are occasionally dredged, reversing the effects of eutrophication and returning them to clear, open waterways. As a result, ditches in all eutrophic states typical of the region are available for study.

In 1978, an investigation was initiated to provide a qualitative and quantitative characterization of the presently existing biotic community of the orchard ditches so that a comparison could be made with that which existed 25 years ago. The information provides evidence to test the accuracy of several hypotheses regarding the ecological consequences of long-term pesticide use.

Based on numerous short-term studies and observations of unexpected effects produced by applications of certain pesticides, ecologists were able to forecast specific results of intensive pesticide application programs, should they be continued for a long period of time. Such forecasts were generally predictions of extensive biotic destruction or shifts in the ecological equilibrium, resulting in an actual increase of the pest populations, which in the meantime would have developed an effective resistance to the pesticides applied.

The study undertaken was designed to find out what actually happens to a biotic community after years of exposure to a variety of toxic substances applied on a regular schedule. These substances include representatives of several broad chemical groups, and the location of the ditches makes it inevitable that some of each pesticide reaches the aquatic habitat.

Location

The Altes Land is a region of alluvial deposits to the south of the Elbe near Hamburg. Its geological, soil, and hydrological characteristics are described by Köhler and Riediger (1970). The study by Garms (1961) provided a list of species found in the drainage ditches during the 1950s, and his report included quantitative data on many of the taxa. A full ecological characterization of the biotic community was presented by Caspers and Heckman (1980).

One important modification of the habitat was made in the interval between the two studies: a new system of dikes was constructed along the south bank of the Elbe after a disastrous flood in 1962. This system provides a more complete separation between the water in the orchards and that in the river. Thus, several migratory potamal species have been excluded from the ditches.

The site of this investigation, between Cranz (Hamburg) and Hinterbrack (Niedersachsen), was designated the "*Hauptuntersuchungsgebiet*" by Garms (Figure 1). In the orchards, apple, pear, plum, and cherry trees are cultivated, and a few fields have been cleared for strawberry plants. The spraying schedule used is typical of that used throughout the Altes Land (Tiemann 1979). Recently, fish culture in the ditches has also been undertaken on a small scale.

Material and Methods

This analysis of the effects produced by pesticides on aquatic biota is based on data obtained during a thorough ecological investigation that included regular measurements of physical and chemical parameters and detailed study of the biotic community. The methods used and complete ecological characterization of the biocoenosis are reported by Caspers and Heckman (1980). Through this investigation, it was determined that habitats in every eutrophic state still exist in the orchards. Thus, comparisons with the data of Garms (1961) do not reveal changes based solely on the elimination of any one kind of habitat through advancing eutrophication. The results are here analyzed to determine which structural changes in the community have most probably been the result of intensive pesticide use.

Specimens were collected in dip nets for identification. Quantitative data were obtained by counting specimens captured in a 1/3 m × 1/3 m plexiglas device that could be dropped into the ditches to isolate a column of water from the surface to the sediment. The sample was filtered through a 1 mm × 1 mm screen that could be inserted beneath the device through the soft sediment. The device worked very well in clear water, but where dense beds of submerged plants were present, some of the specimens were lost because the device could not be completely closed. The distribution of the fauna was not random, so quantitative data are applicable only to the ditches from which the samples were obtained and to the corresponding season.

Fig. 1. A typical orchard drainage ditch in an intermediate stage of eutrophication—late autumn

To account for the many species that inhabit the ditches for only part of their life cycles, sampling was carried out for over a year at about weekly intervals, except when the ditches were covered by a thick ice coat. Analyses were made to determine dissolved O_2 content by the Winkler method; chlorosity by titration with a standard $AgNO_3$ solution; and concentrations of NO_3^-, NO_2^-, NH_4^+, PO_4^{3-}, SiO_2 were recorded using a Technicon Autoanalyzer. Temperature and pH of the water were measured in the field. Merck *Spezialindikatorstäbchen* were used to determine pH, and the appropriate Merck field test kits were employed for the analyses of total and CO_3 hardness, sulfide, and Fe^{2+}. Diurnal and seasonal changes in these parameters were recorded. The results were discussed by Caspers and Heckman (1980), and it is sufficient for the analysis of pesticide effects to outline the significance of the water quality in the development of the biotic communities.

Based on the age of the ditches, the diurnal oxygen regime, the presence of H_2S, and the plant associations present, definite seral stages could be distinguished. The climax of the sere is terrestrial, and without the continual efforts of the fruit growers, a newly dredged ditch would transition to the terrestrial phase in about 10 to 15 years. During the aquatic phase, five distinct eutrophication stages could be described. These were inhabited by distinct species aggregations. Many species of both macro and microbiota were restricted to only one or two aquatic stages, and only a few were found in ditches of all stages.

The extent of the ditches in the orchards between Cranz and Hinterbrack was determined using aerial photos. Habitats in each of the five aquatic stages were selected for intensive investigation. Even within each individual stage, local peculiarities bring about differences in the structure of the biotic community. For example, ditches fed by upwelling ground water contain a very high concentration of Fe^{2+}, which is rapidly oxidized to Fe^{3+} and precipitated as $Fe(OH)_3$. The growth of iron bacteria is encouraged, while the ferric hydroxide flakes inhibit the development of many species. A detailed program was developed for the balanced sampling of each micro-habitat so that no species with specialized requirements would be overlooked. The study by Garms (1961) confirmed that the same habitat conditions had prevailed during the 1950s.

The sere stages were designated as follows:

1a—Newly dug ditches containing only that biota which happened to drift in with the water. No littoral flora.

1b—Old ditches newly dredged but still containing much organic enrichment, and generally covered by a thick coating of *Lemna minor* and other lemnids.

2—Open ditches with submerged vegetation just beginning to develop and bordered by a pioneer littoral flora. The oxygen concentration shows only minor diurnal variation, and the habitat is therefore suitable for fish populations. The benthos is supplied by much detritus, but aerobic conditions prevail.

3—Ditches filled with submerged vegetation and coated by some floating plants. The species diversity is greatest during this stage. Fishes are rare, but amphibians are abundant. The sediment is anaerobic, but the O_2 concentration among the plants in the overlying water is often well above 100% saturation during the day. A dense littoral flora is present.

4—During most of the year, the water remains anaerobic, and it usually contains much H_2S. Sulfur bacteria are abundant, and so are several species of small arthropods. The surface of the water is generally coated with much *Lemna minor*. The littoral plants begin to invade the entire ditch.

5—The transition stage to the terrestrial phase. The ditches are filled with *Glyceria maxima* and *Typha latifolia*. The anaerobic water is covered by the mass of plants and detritus.

The ecological study of Caspers and Heckman (1980) provided a qualitative and quantitative description of the biota inhabiting each stage. For the analysis of the long-term pesticide effects, however, it is only important that all abundant species be collected and identified. This enables the comparison of the biotic community present from 1978 to 1980 with that found in the ditches during the 1950s.

A case by case evaluation of the changes that have occurred requires a knowledge of the life cycles and feeding habits of the species concerned. Only a few members of the biotic community migrated regularly between the Elbe and the adjacent orchard drainage ditches, so the new dike system could be ruled out as a factor in most cases. The properties of the various pesticides must also be known, as well as their distribution in the orchard drainage system. This information was provided by the fruit growers and through the courtesy of Dr. K.-H. Tiemann of the Obstbauversuchsanstalt der Landwirtschaftskammer Hannover at Jork. The analyses of animals for chlorinated hydrocarbons were performed on specimens quick-frozen shortly after collection in the laboratory of the Bundesforschungsanstalt für Fischerei through the courtesy of Dr. E. Huschenbeth. The methods used were those of Holden and Marsden (1969).

The identification of the specimens collected was performed in the manner outlined by Caspers and Heckman (1980). For those groups which are particularly difficult to identify or which have undergone recent taxonomic revisions, specialists were consulted. They are listed in the "Acknowledgments" section.

For the purpose of comparison, only those species found in the *Hauptuntersuchungsgebiet* by Garms (1961) are included. Because several phyla were not investigated during the 1950s, nothing can be concluded about changes in their representation or abundance. The species now present, however, can be assumed resistant or immune to the pesticides regularly applied to the orchards, at least in the form in which they occur in the water of the ditches. A list of important algae and protozoans can be found in Caspers and Heckman (1980). In the evaluation, only those changes are considered significant where a species that was abundant and wide-spread in the 1950s has disappeared completely from the ecosystem. A possible significance can be attached to the disappearance of a formerly uncommon species or to the near elimination of an abundant one. No significance can be attached to a failure to find a species reported as rare by Garms. A separate judgment is made in the case of each species.

Results

No comprehensive list of flora was compiled by Garms (1961), but he did mention a large number of vascular plant species. Of the 24 angiosperms reported for the region inside of the dikes, only *Potamogeton natans* and *Phragmites communis* were not observed during this investigation. Both species were uncommon in the habitat during the 1950s, so little significance can be attached to their absence. Table 1 presents a list of aquatic and littoral plants occurring now and those reported by Garms (1961). The fact that Garms made only incidental mention of the flora explains the absence of the rarer species from his list. It seems doubtful that any of the tracheophytes have suffered noticeable damage from the pesticide application program. A moderate quantitative reduction of a few species, most notably *Stratiotes aloides*, has occurred, but this is almost certainly because the number of ditches regularly dredged has decreased in recent years eliminating much of the suitable habitat. The present

Table 1. Aquatic and littoral flora observed in the orchard ditches from 1978 to 1980 and reported by Garms (1961) as occurring inside the dikes. Probable synonyms in Garms's paper are reported in brackets. ++ = Abundant, + = Sporadic, 0 = Not observed or not reported

Species	1951-57	1978-80
Riccia fluitans L.	0	+
Ricciocarpus natans L.	0	++
Fontinalis antipyretica L.	0	++
Equisetum fluviatile L.	0	++
Equisetum palustre L.	+	+
Ceratophyllum demersum L.	++	++
Cardamine pratensis L.	0	++
Epilobium palustre L.	0	++
Myriophyllum verticillatum L.	+	+
Callitriche cophocarpa Sendtner (*C.* sp.)	++	++
Oenanthe aquatica (L.) Poiret	0	+
Polygonum amphibium L.	+	+
Rumex aquaticus L.	0	++
Stellaria palustris Retzius	0	+
Myosotis palustris (L.) Nathhorst	++	++
Lycopus europaeus L.	0	++
Solanum dulcamara L.	0	+
Galium palustre L.	0	++
Bidens cernua L. (*B.* sp.)	++?	+
Bidens tripartita L.	?	+
Alisma plantago-aquatica L.	++	+
Sagittaria sagittifolia L.	+	+
Elodea canadensis Michaux	++	++
Hydrocharis morsus-ranae L.	++	++
Stratiotes aloides L.	++	+
Potamogeton crispus L.	+	++
Potamogeton natans L.	+	0
Potamogeton rutilus Wolfgang (*P.* sp.?)	+?	+
Iris pseudacorus L.	+	+
Juncus conglomeratus L.	0	++
Juncus cf. *subnodulosus* Schrank	0	+
Carex (*Carex*) *acuta* L.	0	++
Carex (*Carex*) *hirta* L.	0	+
Carex (*Carex*) *pseudocyperus* L.	0	++
Carex (*Vignea*) *elongata* L.	0	++
Carex (*Vignea*) *otrubae* Podpěra	0	++
Scirpus silvaticus L.	0	+
Alopecurus geniculatus L.	0	++
Glyceria fluitans (L.) Robert Brown	++	+
Glyceria maxima (Hartman) Holmberg (*G. aquatica*)	++	++
Phalaris arundinacea L.	0*	++
Poa palustris L.	0	++
Phragmites communis Trinius	+	0
Lemna minor L.	++	++
Lemna gibba L.	0	+
Lemna trisulca L.	++	++
Spirodela polyrrhiza (L.) Schleiden	++	+
Typha latifolia L. (*T.* sp.?)	+?*	+
Sparganium erectum L. (*S.* sp.)	++	+

* Reported outside of the dikes.

trend is to increase the number of open ditches, because of their beneficial effects on the soil hydrology (Quast 1977, 1979).

The aquatic macrofauna was thoroughly investigated by Garms; therefore, a detailed set of comparisons is possible. An interesting pattern along taxonomic lines is presented with some phyla fully intact and others missing large groups of species that were formerly abundant. Table 2 shows the macrofauna list of Garms (1961) and the status of those species today. Changes considered significant are recorded, and the reason for each change is discussed below.

PORIFERA: The freshwater sponge, *Ephydatia fluviatilis,* was not found, but its distribution in the ditches was patchy during Garms's study, so its absence was not of great significance, and no harmful effect of the pesticides on this animal is suspected.

TURBELLARIA: It is quite certain that the species found by Garms are still abundant in the ditches. Taxonomic revisions of the flatworm species, however, make many identifications based on older literature doubtful. Whitehead (1922), for example, listed *Polycelis tenuis* as a variety of *Polycelis nigra,* and the two species can still not reliably be distinguished on the basis of external anatomy alone (Reynoldson 1978). Cytological proof of the distinctness of these two species was not provided until after Garms's results were published (Benazzi 1963). It is, therefore, not surprising that only *P. nigra* was mentioned in the report of Garms, and it is likely that at least some of the flatworms he found were actually *P. tenuis*. Only *P. tenuis* was identified during 1978-80. A similar problem exists with the species *Dugesia lugubris* and *D. polychroa*. The latter species was not recognized for many years (Reynoldson and Bellamy 1970), so it is not surprising that Garms reported only the former from the orchard ditches. Both species actually occur. All of the triclads are abundant in places, and no harmful effects of pesticides on this group could be detected.

ECTOPROCTA: Of the two species reported by Garms, one is still present and very abundant in summer. The other was not seen in 1978-80. The disappearance of *Lophopus crystallinus* may not be a result of pesticide applications, because it was formerly not abundant enough for its disappearance to be considered significant. In contrast, *Plumatella fungosa* is abundant in all open, oxygen-rich ditches. In late summer, the surfaces of those ditches are covered by vast numbers of floatoblasts.

OLIGOCHAETA: Apparently, all of the species found by Garms still occur in the ditches. He reported that dense populations of tubificids were found in the newer ditches, but the species was not identified. During the investigation of 1978-80, a moderate number of *Tubifex tubifex* were collected in one of the ditches. One of the reasons for their present scarcity may be the abundance of fishes, now raised in habitats suitable for these worms. Three naidids and one aelosomatid occur in the orchard ditches, probably the same species observed in the 1950s. *Stylaria lacustris* occurs chiefly among detritus, while *Chaetogaster diaphanus, Nais* sp. and *Aelosoma hemprichi* occur in masses of submerged angiosperms and filamentous algae. Harmful effects of the pesticide applications on these organisms can be ruled out. *Lumbriculus variegatus* was rather abundant in very eutrophic sections of the drainage system where the water contained much H_2S. Another lumbriculid, *Rhynchelmis limosella,* was found twice in open, oxygen-rich ditches. The decrease in abundance of this last species is not significant, and the oligochaete species have all survived 25 years of intensive pesticide applications.

HIRUDINEA: All of the leeches found by Garms in the main investigation area were not collected in 1978-80. The two species that live on fishes were not found. *Piscicola geometra* and *Hemiclepsis marginata* had formerly been at least moderately abundant in the 1950s. Their disappearance was confirmed when a farmer who cultures fishes in the ditches found none on over 100 fishes harvested in 1979. No substances have ever been applied specifically against leeches, and the presence of all other species, that do not prey on fishes, raises the question of why only these two have disappeared. *Dina lineata* was found only once by Garms, and not in the orchards, so it is not surprising that it was not found again. *Erpobdella testacea* is rare, showing a significant decrease in its population. *E. octoculata* is present in massive numbers throughout most of the ditches, and it is perhaps the most abundant invertebrate predator of all. *Haemopsis sanguisuga* and *Helobdella stagnalis* are abundant during the spring, but they cannot be found in late summer and autumn. Apparently, they feed early in the year, then remain concealed. The other glossiphoniid leeches are at least as common as they were in the past. An effect of pesticides is considered possible only in the case of the two fish leaches.

GASTROPODA: In this taxon, there is a great likelihood that specific damage has resulted from agricultural chemicals. Operculate snails seem to have been more negatively influenced than the pulmonates. The genus *Viviparus* was formerly well represented in the ditches. During the study in 1978-80, only one living example was found. Taxonomic confusion within this genus (Watson 1955, Forcart 1960) makes it difficult to know which species authors referred to in earlier papers. The *Viviparus viviparus* mentioned by Garms is almost certainly *V. contectus*, a species very rare in the ditches at this time. Another operculate, *Valvata piscinalis*, has apparently completely disappeared since the 1950s, but a small population of *V. cristata*, a species not reported by Garms, was found in one of the ditches. A snail normally found in the river, *Potamopyrgus crystallinus*, occurred in some of the ditches during the 1950s. Its absence during 1978-80 is most probably due to the isolation of the orchard drainage system from the river by the new dikes. The other three species that have disappeared in the last 25 years were not very abundant during Garms's investigation. *Anisus leucostomus* may not have been in the orchard ditches at all, and *Gyraulus albus* and *Acroloxus lacustris* were among the least numerous snails. No conclusions can be drawn from their absence at this time. The most likely species to have been a victim of the pesticides is *Viviparus contectus*. These snails were characteristic of detritus-rich *Stratiotes* ditches, and occasionally their shells rise to the surface with aquatic spiders inside. The collection of only one living individual in 18 months demonstrates a great population reduction, and because a suitable habitat is still available, agricultural chemicals offer the most plausible explanation for their decline.

BIVALVA: The feeding habits of bivalves make them particularly susceptible to exposure to toxic substances in the water or adsorbed to particulate matter on the sediment surface. One of the species, *Sphaerium corneum*, is at least as common and widely distributed as it was in the 1950s. The other species reported by Garms are no longer found. The absence of the ubiquitous *Pisidium* species is notable.

CRUSTACEA: Some changes have occurred in the crustacean fauna since the 1950s, but the significance is difficult to judge, because many of the species characteristically appear for short times in great numbers, then disappear. Such "boom or bust" behavior was observed among the cladoceran populations, in particular. The species *Scapholeberis mucronata*, *Daphnia longispina*, and *Eurycercus lamellatus*, which had been found during the 1950s, could not be found. Garms (1961) provided no quantitative data for this group, except to say that *Simocephalus vetulus* was the most common and that *S. exspinosus* occurred much less frequently. Populations of both were found regularly throughout the orchards in waters where aerobic conditions prevailed from 1978 to 1980. *Daphnia pulex* can be found, but infrequently. In place of the three species no longer found, three others, *Daphnia hyalina*, *Ceriodaphnia laticaudata*, and *Chydorus sphaericus*, were found during our investigation. Of these, only *C. sphaericus* was wide-spread and abundant. Thus, the same number of species as Garms found still live in the ditches, indicating that ascribing a destructive role to pesticides in the case of cladocerans would not be justified. Nevertheless, the ecological relationships within this group require further study, particularly since they are important prey for many fish species. Most of the copepod populations showed regular seasonal and regional distribution patterns, in contrast to the cladocerans. Of the species found by Garms, all are still present, except for *Mesocyclops leuckarti*, *Acanthocyclops robustus*, and *Attheyella trispinosa*. Not reported by Garms but found in the ditches were specimens tentatively identified as *Cyclops furcifer*. This species is not always distinguishable from *C. strenuus* by external characteristics (Kiefer 1978). Specific quantitative changes have occurred within this group. Garms reported the three species of *Macrocyclops* to be the most abundant copepods within the dikes, while *Megacyclops viridis* and *Canthocamptus staphylinus* were the most common outside the dikes. Recently, the *Macrocyclops* species have become rather rare, whereas the other species have periods of great abundance, each during a particular season and in ditches in a specific stage of eutrophication. For example, *Megacyclops gigas*, another species not found by Garms, occurred in great numbers during early spring among dense vegetation and much detritus, but it was never seen at any other time. The ostracods were not identified by Garms, who reported that they were found everywhere both inside and outside the dikes. Ostracods are still represented by massive populations. By far, the commonest species is *Cypria ophthalmica*, which is the dominant species of macrofauna in the oxygen-free sections of the most eutrophic ditches. It is found in lesser numbers throughout the rest of the orchard drainage system. Garms (1961) found *Argulus foliaceus* occasionally during 1957 on *Gasterosteus aculeatus* and swimming free in the open ditches of the fruit orchards. None have been found recently, but because of their past sporadic occurrence, their absence is not significant. However, these fish parasites are combatted by aquaculturists with specific pesticides; the fish farmers in the area of investigation have not found it necessary to employ these substances. The amphipod, *Gammarus pulex pulex*, was never common in the orchard ditches, although it occurred elsewhere in the Altes Land. *Gammarus zaddachi* was found near Cranz only in waters with at least a partial contact with the Elbe. It is therefore not surprising that these amphipods were not encountered during 1978-80 in the orchards. The isopod, *Asellus aquaticus*, was extremely abundant during the 1950s, just as it is today. *Eriocheir sinensis*, the Chinese full-hand crab, occurred in the orchards within the dikes as well as along the banks of the Elbe before the floods of 1962. It is common along the Elbe, but no longer found in the orchards. This is undoubtedly because of the new dike system, which provides a fairly complete separation between the waters of the Elbe and those of the orchard drainage system. *E. sinensis* can only reproduce in marine or brackish water, so it appears in freshwater only as a transient, and it can be assumed that the physical barrier rather than pesticides is responsible for the disappearance of the full-hand crab.

ARANEAE: Ill effects due to pesticides are not shown by the two common aquatic spiders. Both *Argyroneta aquatica* and *Pirata piraticus* are extremely abundant in most of the ditches. Although its habit of remaining under water allows *A. aquatica* to avoid direct contact with the chemical sprays, *P. piraticus* normally remains on the surface tension of the water or in the littoral zone of the ditches, where a full dose of the pesticide fog is unavoidable; one may assume that these spiders are not very sensitive to the substances used. The large *Dolomedes fimbriatus* was reported to occur in the Altes Land, but it was not seen during the 1978-80 investigation. It is apparently not very abundant, and Garms gave no details of its former distribution.

ACARI: More than 18 species of water mite were reported by Garms to occur in the main investigation area. Most were abundant; the others, rare. During this study, not one single water mite was collected. This was the largest taxon to have completely disappeared since the start of the pesticide application program. Since acaricides are used regularly, a relationship between the disappearance of the water mites and the pesticides can be assumed. Furthermore, several insects that normally serve as hosts to the parasitic mite larvae have also disappeared from the orchards. One semi-aquatic mite that normally lives on damp soil, *Pergamasus crassipes*, was occasionally found on the surface of the water in ditches choked with *Glyceria maxima*. Garms did not investigate this group of mites and his report makes no mention of it. Its prey is collembolans (Karg 1971).

COLLEMBOLA: Massive numbers of springtails are present in the nearly terrestrial ditches choked with *Glyceria maxima*, on small temporary puddles of rainwater, and along the edges of several other ditches. The species present, however, are not all the same as those reported by Garms. *Podura aquatica*, which was present in massive numbers during the 1950s, and *Isotoma viridis* were not found. *Isotomurus palustris*, which was found only once by Garms far from the Cranz-Hinterbrack region, is now the most abundant species throughout the orchards. Massive numbers of *Hypergastrura armata* occurred during late autumn and early spring on pools of rainwater as well as on some of the overgrown ditches. *Sminthurides aquaticus* occurs in limited numbers as it formerly did. Associated with the massive numbers of *I. palustris* are usually a few *Lepidocyrtus cyaneus*, another species not found by Garms. The rearrangement of the collembolan fauna is somewhat puzzling, and little can be concluded about the effects of pesticides in bringing about the changes that have occurred. Of course, the epineustonic habitat occupied by these insects places them in the most exposed position during the pesticide fogging operations. Obviously, some are surviving quite well.

EPHEMEROPTERA: Two of the five species of mayfly identified by Garms were found during the recent investigation. The most abundant, *Cloeon dipterum*, is relatively abundant during late summer, autumn, and winter. *C. rufulum* was commonly encountered in the autumn. The other three species had not been particularly numerous in the 1950s, and great significance cannot be attached to their absence.

ODONATA: This insect order seems to have been particularly hard-hit by the pesticides. The larvae of two damselflies, *Coenagrion puella* and *C. pulchellum*, are still very abundant in the more open ditches. Adults of these species and *Lestes sponsa*, as well as the dragonflies, *Aeschna cyanea* and *Sympetrum sanguineum*, were found flying near or spawning in some of the ditches.

Larvae of these species, however, were never collected, indicating that development in the orchard ditches does not occur on a large scale, if at all. *S. sanguineum* was not one of the species reported by Garms, but eleven other species he observed were never found. Because the adults, especially the dragonflies, are strong fliers, their appearance in the orchards should not be surprising, even if the waters of the ditches are unsuitable for larval development. It should also not be surprising if these insects re-established themselves rapidly should suitable conditions return. Ecologically, this insect order is important, because its members are effective predators that consume larvae of mosquitoes and other harmful aquatic insects.

HETEROPTERA: This insect order shows few ill effects that might be ascribable to pesticides. The commonest species, as reported by Garms, are still very abundant in the ditches, with the notable exceptions of *Hydrometra stagnorum, Cymatia coleoptrata,* and *Corixa punctata. H. stagnorum* is epineustonic and is directly exposed to the sprays. Two species of *Gerris* are still very abundant in this habitat. *Ranatra linearis* was not found, but this is not considered a significant change, since the species was rare during Garms's study. The species *Plea leachi, Notonecta glauca, Nepa rubra,* and *Ilyocoris cimicoides* have maintained their populations since the 1950s, and after direct entry of fungicide fogs into the ditches, they were observed to remain active without any apparent ill-effects.

The most diverse hemipteran family, Corixidae, has undergone some redistribution in the Altes Land since Garms's study. The two most abundant species outside the dikes in the 1950s were found to be the most abundant in the orchard ditches. These were *Sigara striata* and *S. falleni. Hesperocorixa linnei,* formerly the most abundant species inside the dikes, was only moderately abundant. As a replacement for the two species that were no longer found in the orchards, *Callicorixa praeusta* must be added to the corixid list. Apparently the majority of species can continue to exist in areas of intensive pesticide use.

NEUROPTERA: *Sialis flavilatera* was reported by Garms to be a typical representative of the benthic fauna in the newer ditches of the region within the dikes. These insects are now completely absent from the habitat, and even the adults were never observed. The influence of pesticides, particularly insecticides, is strongly suspected.

TRICHOPTERA: Of the 12 caddisflies mentioned by Garms, 7 were found abundantly in the main area of investigation. No member of this insect order, adult or larva, was found anywhere in the orchards during the recent study. It is also significant that two of the species, *Helocentropus stagnalis* and *Limnephilus rhombicus,* were abundant during the first years of Garms's study, 1953 through 1955, and then disappeared from the area. The modern insecticides were then first coming into intensive use in the orchards, suggesting that these insects were not able to develop an immunity to them. That pesticides played a major role in the disappearance of these insects from the region is very likely.

LEPIDOPTERA: The habits of the adult moths that skim over the surface of the ditches or hide in the littoral vegetation place them in direct contact with any pesticides distributed by fogging operations. Insecticides against the apple moths, also lepidopterans, might be expected to decimate the harmless aquatic species as well. It is apparent that at least two of the three species reported by Garms, *Cataclysta lemnata* and *Nausinoe nymphaeata,* are fully immune to the substances sprayed during their periods of activity. Both species are abundant; *C. lemnata,* extremely so. Garms's third species, *Parapoynx stratiotata,* was not particularly common, and one of its host plants, *Stratiotes aloides,* is now relatively restricted in distribution within the area, which may explain why none of this species were found in 1978–80. Pesticide applications have not been effective in eliminating members of the Lepidoptera from the ditches. An immunity to the substances sprayed, natural or acquired, is the suggested explanation.

COLEOPTERA: This order was represented by the most species during the study carried out in the 1950s. A total of 62 occurred in the area within the dikes. Most of these could be found in the orchards between Cranz and Hinterbrack, and 25 could be described as abundant. From 1978 to 1980, a total of 14 species were collected, including one not found in the area by Garms, namely, *Hydroporus planus* (Table 2). Only one of these, *Haliplus ruficollis,* was wide-spread and abundant most of the year. *Hydroporus palustris* had an abundant adult population only during the spring. Most of the species were found only once or twice.

It is noted that quantitative data for this group are only reliable when samples are taken regularly throughout the year. Adults of *Graptodytes pictus,* for example, were found as adults only in the spring. The life cycles of many beetles seems to be timed to the seasons, and when larvae are secretive and hard to identify, only an investigation lasting throughout the entire year can provide a complete picture of the faunal structure.

The disappearance of such a large number of beetle species indicates that only a few have succeeded in producing pesticide-resistant populations. Those that occur in the ditches now are those that have been able to develop an immunity, as evidenced by the fact that they show no ill effects after pesticide applications. The other species are completely gone. Because the adults often fly considerable distances before spawning, the changes of water flow created by the dike system can be ruled out as a factor in their elimination. In fact, those species found only rarely are very likely immigrants from elsewhere and not part of a local breeding population. One example deserves special mention, because it illustrates a very specific structural change that has occurred since the 1950s. Two of the largest aquatic beetles found by Garms, *Dytiscus dimidiatus* and *D. marginalis,* were found together. *D. dimidiatus* was more abundant then, but during the recent investigation, only *D. marginalis* was found. It was present only in moderate numbers, as it was 25 years ago. These beetles are so large that they can scarcely escape notice, so it is fairly certain that the most abundant species of the genus has been completely eliminated. The fact that the less common one has experienced no change in its population density suggests that a factor is involved that affected one species and not the other. A natural or acquired immunity to a frequently used insecticide in *D. marginalis* would provide the explanation for this phenomenon. A selective effect on the beetle species by one or more of the pesticides seems highly likely. Insecticides are applied each year, and it would be expected that they would have an effect on the aquatic beetles.

DIPTERA: If the list by Garms is reasonably complete, the Diptera has undergone a massive increase in species diversity since the 1950s. A few of the species reported by Garms were not found, but a total of several times as many species as he reported were collected and identified. The reason *Culex* sp. has disappeared is apparently because the household waste water is no longer collected in open channels. In such polluted water, the *Culex* larvae lived in massive numbers. They did not develop in the orchard ditches. It is possible that *Stratiomys* sp., formerly abundant, has been killed off by the pesticides, but other flies show no ill effects whatever during the pesticide applications. Adult syrphids occur in enormous numbers on the littoral vegetation, and larvae are common in the waters of hypereutrophic ditches. Many species appear as adults only during certain seasons. Petauristids are specialized to life in winter. Tipulids also show a clear seasonal pattern of activity, with adults of some species appearing once a year and others, twice a year. *Tipula paludosa* is an example of the former; the adults appeared in August and September. *T. oleracea* is common in May and in late summer, providing an example of the latter. Larvae occur in semiterrestrial locations, including densely overgrown ditches. Chironomids are common in the open, oxygen-rich waters in the early stages of eutrophication. A massive population of *Glyptotendipes gripekoveni* larvae built their tubes on the bottom of one large ditch. In May, a massive emergence of adults took place, and the surface of the water was fully covered with pupal casts. Among water plants, a great many *Cricotopus sylvestris* developed. Such massive populations are probably due to the elimination of so many insect predators, that are normally able to keep the chironomid populations rather small. Predatory diptera larvae, such as the species of *Chaoborus,* benefit both from the overabundance of suitable prey and from the elimination of many natural enemies. Three species of this genus were abundant: *C. crystallinus, C. flavicans,* and *C. obscuripes;* only one was reported by Garms. The total number of Diptera species was quite large (Table 2) and included some species which are common in wet places, the development of which is unknown.

VERTEBRATA: No direct effects of pesticides on the vertebrates are suspected. The species of fish no longer found have very likely been excluded by the isolation of the orchard drainage system from the Elbe. This is almost certainly the case with *Perca fluviatilis. Esox lucius* is not a fish normally found in great numbers, so not much significance can be attached to its absence during the recent study. In addition to the fishes found during the 1950s, tench (*Tinca tinca*) and carp (*Cyprinus carpio*) have been stocked in some ditches. During the first harvest in the autumn of 1979, about one-half of the stocked fishes were still present. Eel (*Anguilla anguilla*) were also released, but none were recaptured. This is not surprising, because eels can migrate overland. Fishes adapted to eutrophic waters thrive in the ditches. The stocked tench spawned during the summer of 1979, and the harvested fishes showed that growth had been satisfactory, indicating that conditions in the ditches did not place the fishes under any unusual stress. Because more fishes were stocked

Table 2. Species of macrofauna reported by Garms (1961), their status in the 1950s and today. Synonyms are placed in parentheses beside currently accepted names. Where there is some question about which species was referred to, the probable equivalent is placed below the name used by Garms. ++ = Abundant, + = Sporadic (+? Present, no further information), ± = Rare, 0 = Not observed, S = Significant reduction or elimination of the species

Species	1951-57	1978-80	Species	1951-57		1978-80
Spongillidae			Valvatidae			
Ephydatia fluviatilis (L.)	+	0	*Valvata piscinalis* (O. F. Müller)	++	S	0
Dendrocoelidae			Hydrobiidae			
Dendrocoelum lacteum (O. F. Müller)	++	++	*Potamopyrgus crystallinus carinatus* (J. T. Marshall)	+		0
Planariidae			Bithyniidae			
(*Polycelis nigra* Ehrb.) *P. nigra* (O. F. Müller)	++		*Bithynia tentaculata* (L.)	++		++
Polycelis tenuis Ijima		++	*Bithynia leachi* Sheppard	++		++
(*Planaria torva* M. Schultze) *P. torva* (O. F. Müller)	++	++	Viviparidae			
			Viviparus viviparus (L.)	+		
Dugesiidae			*Viviparus contectus* (Millet)			±
(*Planaria lugubris* O. Schn.)	++	++	Succineidae			
Dugesia lugubris (O. Schmidt)			*Succinea putris* (L.)	++		++
Plumatellidae			Sphaeriidae			
Plumatella fungosa (Pallas)	±	++	*Sphaerium corneum* (L.)	++		++
Lophopodidae			*Sphaerium (Musculium) lacustre* (O. F. Müller)	+		0
Lophopus crystallinus (Pallas)	+	0				
Tubificidae			*Pisidium* sp.	++	S	0
Unidentified sp.	++		Argyronetidae			
Tubifex tubifex (O. F. Müller)		+	*Argyoneta aquatica* (L.)	++		++
Aelosomatidae			Lycosidae			
Aelosoma sp.	++		*Pirata piraticus* (Clerck)	++		++
Aelosoma hemprichi Ehrenberg		+	Pisauridae			
Naididae			(*Dolomedes fimbriatus* [L.])	+		0
Nais sp.	++		*D. fimbriatus* (Clerck)			
Nais sp.		++	Hydrachnidae			
Chaetogaster sp.	++		*Hydrachna globosa* (De Geer)	++	S	0
Chaetogaster diaphanus (Gruithuisen)		++	*Hydrachna cruenta* (O. F. Müller)	±		0
Stylaria lacustris L.	++	++	Eylaidae			
Lumbriculidae			*Eylais undulosa* Koenike	++	S	0
Lumbriculus variegatus (O. F. Müller)	+?	+	Hydrodromidae			
Rhynchelmis limosella Hoffmeister	+	±	(*Diplodontus despiciens* [Müll.])	+		0

Piscicolidae			
Piscicola geometra L.	++	S	0
Glossiphoniidae			
Helobdella stagnalis (L.)	+		++
Hemiclepsis marginata (O. F. Müller)	+		0
(*Protoclepsis tesselata* [Müll.])	±		±
Theromyzon tessulatum (O.F.M.)			
Glossiphonia complanata (L.)	++		++
Glossiphonia heteroclita (L.)	++		++
Hirudinidae			
Haemopsis sanguisuga (L.)	+		++
Erpobdellidae			
(*Herpobdella lineata* Müll.) *Dina lineata*	±		0
(O. F. Müller)			
(*H*)*Erpobdella octoculata* (L.)	++		++
(*H*)*Erpobdella testacea* (Savigny)	++		±
Lymnaeidae			
Lymnaea stagnalis (L.)	+		++
Radix ovata (Draparnaud)	++		++
Lymnaea (*Stagnicola*) *palustris*	++		++
(O. F. Müller)			
Planorbidae			
(*Planorbis corneus* [L.])	++		++
Planorbarius corneus (L.)			
(*Tropidiscus planorbis* [L.])	++		++
Planorbis planorbis (L.)			
(*Tropidiscus carinatus* [Müll.])	++		++
Planorbis carinatus (O.F.M.)			
(*Spiralina vortex* [L.]) *Anisus vortex* (L.)	++		++
Anisus leucostomus (Millet)	±		0
Gyraulus albus (O. F. Müller)	+		0
Bathyomphalus contortus (L.)	++		++
Hippeutis complanatus (L.)	±		±
Segmentina nitida (O. F. Müller)	++		++
Acroloxidae			
Acroloxus lacustris (L.)	+		0
Physidae			
Physa fontinalis (L.)	++		++
Hydrodroma despiciens (O.F.M.)			
Limnesiidae			
Limnesia maculata (O. F. Müller)	++	S	0
Limnesia fulgida Koch	++	S	0
Limnesia undulata (O. F. Müller)	+		0
Hydryphantidae			
Hydryphantes ruber (De Geer)	+?		0
Unionicolidae			
Neumania vernalis (O. F. Müller)	±		0
Pionidae			
Hydrochoreutes krameri Piersig	+		0
Piona variabilis Koch	±		0
Piona coccinea (Koch)	++	S	0
Piona carnea (Koch)	±		0
(*Acerus* sp.) *Tiphys* sp.	++	S	0
Arrenuridae			
Arrenurus spp.	+?		0
Arrenurus bruzelii Koenike	+		0
Arrenurus bifidicodulus Piersig	±		0
Arrenurus scutiformis Piersig	±		0
Daphniidae			
Scapholeberis mucronata (O. F. Müller)	+?		0
(*Daphnia pulex* De Geer) *D. pulex* Leydig	+?		++
Daphnia longispina O. F. Müller	+?		0
Simocephalus vetulus Schødler	++		++
Simocephalus exspinosus (Koch)	+		++
Chydoridae			
Eurycercus lamellatus (O. F. Müller)	+?		0
Cyclopidae			
Macrocyclops albidus (Jurine)	++		±
Macrocyclops fuscus Jurine	++		±
Macrocyclops distinctus (Richard)	++		±
Mesocyclops leuckarti (Claus)	+?		0
Cyclops insignis Claus	+?		±
Cyclops strenuus Fischer	+?		++
(*Cyclops viridis* Jurine)	++		++
Megacyclops viridis (Jurine)			
(*Cyclops bicuspidatus* Claus)	++		++
Diacyclops bicuspidatus (Claus)			

Table 2. (cont'd)

Species	1951-57	1978-80	
(*Cyclops robustus* O. O. Sars)	+?		0
Acanthocyclops robustus (G. O. Sars)			
Eucyclops serrulatus (Fischer)	+?		++
Eucyclops macruroides Lilljeborg	+?		0
Canthocamptidae			
Canthocamptus staphylinus (Jurine)	++		++
Attheyella trispinosa (Brady)	+?		0
Argulidae			
Argulus foliaceus (L.)	+		0
Asellidae			
Asellus aquaticus (L.)	++		++
Grapsidae			
Eriocheir sinensis Milne-Edwards	++	S	0
Poduridae			
Podura aquatica (L.)	++	S	0
Sminthuridae			
Sminthurides aquaticus (Bourlet)	++		+
Isotomidae			
Isotoma viridis Bourlet	+		0
Baetidae			
Cloeon dipterum (L.)	++		++
Cloeon rufulum (O. F. Müller)	++		++
Leptophlebiidae			
Leptophlebia vespertina (L.)	+		0
Caenidae			
Caenis horaria (L.)	+		0
Ephemeridae			
Ephemera vulgata L.	±		0
Coenagriidae			
Ischnura elegans (Van der Linden)	++	S	0
(*Agrion pulchellum*) *Coenagrion pulchellum* (Van der Linden)	++		++
(*Agrion puella*) *Coenagrion puella* (L.)	++		++
(*Agrion mercuriale*) *Coenagrion mercuriale* (Charpentier)	±		0
Pleidae			
Plea leachi McGregor & Kirkaldy	++		++
Sialidae			
(*Sialis flavilatera* L.)	++	S	0
Sialis lutaria (L.)			
Pyralidae			
Cataclysta lemnata (L.)	++		++
(*Nymphula nymphaeata* L.)	++		++
Nausinoe nymphaeata (L.)			
Parapoynx stratiotata (L.)	±		0
Polycentropodidae			
Holocentropus stagnalis Albarda	+		0
Phryganeidae			
Phryganea grandis L.	++	S	0
Leptoceridae			
(*Leptocerus aterrimus*)	++	S	0
Athripsodes aterrimus Stephens			
(*Leptocerus fulvus*)	++	S	0
Athripsodes fulvus Rambur			
Triaenodes bicolor Curtis	++	S	0
Limnephilidae			
Limnephilus rhombicus L.	++	S	0
Limnephilus flavicornis Fabricius	++	S	0
Haliplidae			
Haliplus ruficollis De Geer	++		++
Haliplus fluviatilis Aubé	±		0
Haliplus apicalis Thomson	±		0
Haliplus fulvus Fabricius	+		0
Peltodytes caesus (Duftschmidt)	++	S	0
Dytiscidae			
(*Hyphidrus ferrugineus* L.)	++		+
Hyphidrus ovatus L.			
Hygrotus inaequalis (Fabricius)	++	S	0
Coelambus impressopunctatus (Schaller)	±		±
(*Bidessus geminus* F.)	±		0
Guignotus pusillus (Fabricius)			

Pyrrhosoma nymphula (Sulzer)	+		0
Erythromma naias (Hansemann)	++	S	0
Lestidae			
Lestes sponsa Hansemann	++		+
Lestes viridis (Van der Linden)	±		0
Agriidae			
(*Calopteryx virgo* L.) *Agrion virgo* (L.)	±		0
Aeschnidae			
Aeschna cyanea (O. F. Müller)	++		±
Aeschna grandis (L.)	±		0
Brachytron hafniense (O. F. Müller)	+		0
Libellulidae			
Libellula quadrimaculata L.	+		0
Sympetrum danae (Sulzer)	±		0
Hydrometridae			
Hydrometra stagnorum (L.)	++	S	0
Gerridae			
Gerris lacustris (L.)	++		++
Gerris thoracicus Schummel	++		++
Gerris gibbifer Schummel	+		0
Corixidae			
Cymatia coleoptrata (Fabricius)	++	S	0
Corixa punctata (Illiger)	++	S	0
(*Sigara linnei* Fieb.)	++		+
Hesperocorixa linnei (Fieber)			
(*Sigara sahlbergi* Fieb.)	++		+
Hesperocorixa sahlbergi (Fieber)			
Sigara fossarum (Leach)	++		+
Sigara falleni (Fieber)	++		++
Sigara striata (L.)	++		++
Naucoridae			
(*Naucoris cimicoides* L.)	++		+
Ilyocoris cimicoides (L.)			
Nepidae			
Nepa rubra L.	++		++
Ranatra linearis (L.)	±		0
Notonectidae			
Notonecta glauca L.	++		++

Hydroporus dorsalis (Fabricius)	±		0
Hydroporus palustris (L.)	++		++
Hydroporus angustatus Sturm	±		0
Hydroporus obscurus Sturm	±		0
Hydroporus erythrocephalus (L.)	+		0
Hydroporus umbrosus (Gyllenhal)	+		0
(*Graptodytes lineatus* F.)	++	S	0
Porhydrus lineatus (Fabricius)			
Graptodytes pictus (Fabricius)	++		+
(*Deronectes elegans* Panz.)	±		0
Potamonectes depressus (Fabricius)			
Noterus crassicornis (O. F. Müller)	++	S	0
(*Laccophilus obscurus* Panz.)	++		+
Laccophilus minutus (L.)			
Laccophilus hyalinus (De Geer)	+		0
Agabus bipustulatus (L.)	++	S	0
Agabus sturmi (Gyllenhal)	++	S	0
Agabus undulatus (Schrank)	++	S	0
Ilybius obscurus (Marsham)	++	S	0
Ilybius ater (De Geer)	+		0
Ilybius fenestratus (Fabricius)	±		0
(*Copelatus ruficollis* Schall.)	±		0
Copelatus haemorrhoidalis (Fabr.)			
Nartus grapei (Gyllenhal)	+		0
(*Rhantus punctatus* Foucr.)	++		±
Rhantus pulverosus (Stephens)			
Colymbetes fuscus (L.)	±		+
Hydaticus seminiger (De Geer)	++	S	0
Hydaticus transversalis (Pontopp)	++		+
Graphoderes cinereus (L.)	±		0
Acilius sulcatus (L.)	+		0
Acilius canaliculatus (Nicolai)	++	S	0
Dytiscus dimidiatus Bergstrom	++	S	0
Dytiscus marginalis L.	+		+
Dytiscus circumcinctus Ahrens	±		0
Gyrinidae			
Gyrinus marinus Gyllenhal	++	S	0

Table 2. (cont'd)

Species	1951-57	1978-80
Helophorus aquaticus (L.)	+	0
(*Helophorus viridicollis* Steph.)	+	0
Helophorus flavipes (Fabr.)		
Helophorus granularis (L.)	±	0
Hydrochus elongatus Schaller	±	0
Spercheidae		
Spercheus emarginatus (Schaller)	±	0
Hydrophilidae		
Hydrous piceus (L.)	++	S 0
Hydrophilus caraboides (L.)	++	S 0
Hydrobius fuscipes (L.)	++	±
Anacaena limbata (Fabricius)	++	+
Enochrus melanocephalus (Olivier)	+	0
(*Phylidrus coarctus*)	±	0
Enochrus coarctatus (Gredler)		
(*Phylidrus testaceus*)	++	+
Enochrus testaceus (Fabricius)		
Cymbiodyta marginella (Fabricius)	±	0
(*Helochares griseus* F.)	+	0
Helochares obscurus (O. F. Müller)		
Laccobius sp.	++	S 0
Helodidae		
Helodes minuta (L.)	+	0
Scirtes sp.	+	0
Curculionidae		
Bagous binodulus Herbst	+	0
Chrysomelidae		
Prasocuris phellandrii (L.)	+	0
Hydrothassa marginella (L.)	+	0
Galerucella nymphaeae (L.)	±	0
Donacia spp.	+	0
Tipulidae		
Unidentified spp.	++	++
Stratiomyidae		
Stratiomys sp.	++	0
Syrphidae		
Eristalis sp.	+	
Eristalis spp.		+

Species	1951-57	1978-80
Hydraenidae		
Ceratopogonidae		
Unidentified sp.	++	0
Chironomidae		
Unidentified spp.	+?	
Several spp.		++
Culicidae		
Dixa sp.	++	
Dixa amphibia De Geer		++
Chaoborus crystallinus De Geer	++	++
Anopheles sp.	+	0
Culex sp.	+	0
Theobaldia annulata Schrank	++	++
Cyprinidae		
Carassius carassius (L.)	++	++
Leucaspius delineatus (Heckel)	++	++
Gasterosteidae		
Gasterosteus aculeatus L.	++	+
Pygosteus pungitius (L.)	+	±
Percidae		
Perca fluviatilis L.	++	S 0
Salamandridae		
Triturus vulgaris (L.)	++	++
Ranidae		
Rana temporaria L.	++	++
Rana esculenta L.	+?	0
Rana arvalis Nilsson	+?	+
Bufonidae		
Bufo bufo L.	+?	++
Soricidae		
(*Crossopus fodiens* Pallas)	+?	+
Neomys fodiens (Pennant)		
Muridae		
(*Mus decumanus* Pallas)	++	++
Rattus norvegicus (Berkenhout)		
Cricetidae		
(*Arvicola amphibius* [L.])	++	+
Arvicola terrestris (L.)		
(*Fiber zibethicus* L.)	++	++
Ondatra zibethica (L.)		

than the natural habitat could support, supplemental feeding was required. A natural population of *Carassius carassius*, the Crucian carp, shares the ditches with the cultured fishes and are very abundant. Small sticklebacks, *Gasterosteus aculeatus* and *Pygosteus pungitius*, and the small cyprinid, *Leucaspius delineatus*, also survive in the habitat. Among the amphibia, *Triturus vulgaris* and *Rana temporaria* are still the most abundant species. Massive numbers of larvae belonging to both species are present in the ditches during the spring. *Bufo bufo* and *Rana arvalis* are observed rather often, as well. *Rana esculenta*, a frog reported by Garms, was never collected for identification, but its presence in the large collecting canals is strongly suspected.

Wild ducks, *Anas platyrhynchos*, and moorhens, *Gallinula chloropus*, were observed in the ditches. A brood of the rails lived in the orchard drainage system during the summer of 1979. Terrestrial birds abounded in the area, as well. Raptors were common. Pesticides have apparently not eliminated the birds, but many are inadvertently killed in mechanical traps meant for rodents.

Several mammals are extremely numerous in the orchard ditches. The rodents, *Rattus norvegicus* and *Arvicola terrestris* are pests usually combatted by annual applications of endrin, a substance normally forbidden in the Federal Republic of Germany (Perkov 1971). *Ondatra zibethicus*, the muskrat introduced from North America, is considered dangerous, because of its habit of undermining the banks of the ditches, causing them to collapse when tractors are driven too close to the edge. They are trapped, but the population is probably increasing. The water shrew, *Neomys fodiens*, occurs in the orchards now, as it did in the 1950s. Two juvenile specimens were found dead near the ditches. In spite of measures undertaken against them, the mammals in the habitat are not endangered.

Discussion

The evaluation of the results requires great caution, because the nature of the field investigations with their many uncontrolled factors is prohibitive to the establishment of clear-cut cause and effect relationships. Nevertheless, these studies are necessary to determine if the results obtained in the laboratory actually reflect the real situation in the natural ecosystem.

This investigation was designed to provide data that can be directly compared with those presented by Garms (1961), and which were obtained in a way that eliminated as many uncontrolled variables as possible. A set of possible factors, other than those related to the pesticides, that might be responsible for changes in the structure of the aquatic community was considered in evaluating the data. The most obvious of these factors is the degree of eutrophication which the ditches have reached. Certainly, 25 years is sufficient time to have effected a complete change in the state of the ditches. The digging and dredging of the ditches, however, return a sufficient number to the original state to ensure that each habitat is preserved. Although there was a decrease in the number of ditches kept open during the 1960s, enough were maintained to prevent the disappearance of any biotic community. The evidence for this is provided by the aggregations of vascular plants found in the various ditches. Many of these species are confined to only one stage of eutrophication. The fact that all aggregations are still found in suitable parts of the orchard drainage system demonstrates that all of the former habitats are still in existence. By sampling every kind of aquatic species aggregation, it was possible to compensate for the factor of advancing eutrophication.

A problem that could also lead to misinterpretation is that of determining which species belong in the habitat and which are simply occasional visitors. Insects, particularly, often make long flights and stray into all kinds of aquatic habitats in which they do not normally develop. A reduction in the number of open ditches could certainly have lessened the chances of occasional appearances by non-characteristic insect species. It is, therefore, necessary to eliminate the species that have always been rare from consideration.

Quantitative reduction of any particular species cannot be considered evidence of harm due to pesticides. Rather this is a reflection of a reduction of the space occupied by ditches in a particular stage of the sere. For example, the number of ditches containing extensive beds of *Stratiotes aloides* has been significantly reduced since the 1950s. As a result, associated fauna could also be expected to show a numerical decline. Only the complete elimination of a formerly abundant species is indicative of some destructive factor with a specific effect on that organism. Table 2 shows that decreases in the populations of individual species were infrequent. Most of the fauna either maintained their population densities or disappeared completely from the ecosystem. This is different from the results usually obtained during short-term investigations, where great fluctuations in the populations of susceptible species are nearly always encountered. As expected, the development of immunity over a long period of time results in a stabilization of the ecological balance, apparently with some compensation for species that do not develop immunity and are completely eliminated. Increases in the populations of certain species give evidence that they are compensating for the loss of some formerly abundant biotic component in the community.

Assignment of "blame" for the disappearance of formerly abundant species is very difficult, since even laboratory experiments cannot reflect the true situation in the field. Many substances have been and are still being applied regularly to the orchards, and to test the effectiveness of each one on each aquatic species would be a monumental undertaking. Furthermore, the substance with the most acute lethal toxicity is not always the one with the most pronounced long-term effect on the species. Finally, a species may be affected by the toxicity of a substance applied, or the effect may be due to elimination of an important prey organism on which one developmental stage of the species depends. Thus, a distinction must be made between the direct and indirect effect of the pesticides.

Undoubtedly, the best investigated of the modern pesticides is DDT. Originally, extreme toxicity was demonstrated for this insecticide when it was applied against the common insect pests. After a few years, DDT no longer showed effectiveness against many of the pests, and the resistance of the species was inheritable (Brown 1978). Furthermore, the elimination of many predatory insects allowed the harmful arthropod populations to increase far beyond their previous sizes (Reynolds *et al.* 1975). A great many economically or ecologically important species have suffered great reductions in their populations or extinction over parts of their former ranges as a result of indiscriminate use of certain pesticides over a long period of time, particularly when persistent chemicals, such as DDT, were applied. As a result of the many disadvantages associated with the use of DDT, its use in the orchards was discontinued in 1969 or thereabouts (Tiemann, pers. comm.). Nevertheless, specimens collected during the investigation from 1978 to 1980 contained measurable amounts of DDT and its breakdown products (Table 3). Although it cannot be definitely ruled out that some farmers are still using DDT privately, the probable explanation is that the DDT has remained in the soil and water for

Table 3. Chlorinated hydrocarbon content (ppm) of selected species

Species	Fat (hexane extracted) %	DDT	DDD	DDE	Lindane	Dieldrin	HCB	Aroclor 1254 (PCB)
Erpobdella octoculata								
spring	0.84	<0.001	0.009	0.004	0.017	0.008	0.002	0.132
autumn	1.02	0.016	0.008	0.012	0.018	0.008	0.002	0.170
Planorbis planorbis								
spring	0.22	0.006	0.004	0.002	0.008	0.002	—	0.021
autumn	0.55	0.007	0.002	0.004	0.012	0.002	0.001	0.043
Planorbis corneus								
spring	0.38	<0.001	0.002	0.001	0.002	0.001	0.001	0.030
autumn	0.42	0.002	0.001	0.002	0.004	0.001	0.001	0.013
Asellus aquaticus								
spring	1.30	0.046	0.029	0.011	0.035	0.018	0.004	0.353
autumn	0.42	0.008	0.004	0.004	0.011	0.004	0.001	0.250
Sigara falleni								
spring	6.00	<0.001	<0.001	0.025	0.131	0.035	0.010	1.765
Sigara striata								
autumn	4.53	0.019	0.008	0.008	0.021	0.004	0.001	0.147
Carassius carassius								
spring	0.44	<0.001	0.017	0.007	0.001	0.007	0.001	0.205
autumn	3.98	0.014	0.003	0.018	0.058	0.003	0.002	0.192
Tinca tinca								
spring	1.51	<0.001	0.010	0.010	0.043	0.003	0.002	0.183

the last ten years, and it can be expected to persist in measurable quantities for at least several more years. Edwards (1973) reported that 5 to 10% of the original DDT application could still be detected in the ecosystem 10 years later, and fruit orchards tend to maintain higher concentrations in the upper soil layer than any other kind of habitat tested (Kuhr *et al.* 1974).

Not only is DDT toxic, its degradation products are also poisonous to many arthropods. This is also true of many other pesticides (Brown 1978). A complete scheme of DDT breakdown was provided by Klein and Korte (1970), and much is now known about the toxicity of the various degradation products (Brown 1978, McEwen and Stephenson 1979). Certainly, DDT and its metabolic descendants have played a large role in the past to shape the present ecological situation in the orchard drainage system. The residues still remaining, however, are relatively insignificant, although enough was detected in the fauna tested to inhibit very sensitive species from recolonizing the orchards from uncontaminated regions.

As DDT represented an improvement over the primitive arsenates used in earlier years, so the newer chemicals used are an improvement over DDT. At the present time, fungicides, acaricides, insecticides, herbicides, and rodenticides are used in the orchards. Not all the substances mentioned are used in every orchard, but each of these substances is currently used in various parts of the Altes Land. Instructions for the farmers about which substances to use during each season and about plant pests that are locally prevalent at the time are provided by booklets and newsletters issued by the Obstbauversuchsanstalt in Jork, Niedersachsen. An approximate annual spraying schedule would include fungicides 16 times per year, insecticides 5 times, and herbicides, acaricides, and a rodenticide once each (Tiemann, pers. comm.).

A bewildering number of different chemicals are currently on the market today as fungicides. The ecological effects of most of them are still poorly known, but a great many individual reports are available about specific effects of each one on various organisms. The chief fugicides currently in use throughout the Altes Land are sulfur, copper oxychloride, captan, folpet, dithianon, mancozeb, propineb, ferbam, bupirimate, dichlofluanid, pyrazophos, benzimidazole, fenarimol, triadimefon, and vinclozolin. Each of these is applied only during a particular season against a specific fungus disease. In the damp, cool summers of Hamburg, diseases caused by fungi can spread very rapidly and cause great damage. Thus, the variety of fungicides and the amount used are greater than those of any other pesticide class.

Sulfur and copper oxychloride are fungicides from the pre-DDT era. While sulfur is applied over a very limited area, the copper mixture is still used in large quantities throughout the Altes Land (Tiemann, pers. comm.). The use of compounds containing copper over a period of many years causes a build-up of high concentrations in the soil (McEwen and Stephenson 1979). In water, copper is poisonous to algae and snails, in particular, but in a short time, it is deposited in the sediment (Brown 1978). Typical of the primitive pesticides, these substances are not highly toxic to the pests, but they have sublethal detrimental effects on a broad spectrum of organisms.

The other fungicides used are all complex organic compounds which have come into use during the last 30 years. Most of them contain sulfur. Two rather similar substances that have been in use for many years and are still widely used in the orchards, captan and folpet, are both recommended for prevention of apple scab, *Venturia inaequalis* (Cook) Aderh. Captan has a half-life as short as 3½ days in moist soil but as long as 50 days in dry earth. On breakdown, it may release the very active thiophosgene gas. The toxicity of captan and folpet for mammals and birds is very low, but some fishes are very sensitive to captan (Brown 1978). A compound related to the trichloromethylthio fungicides is the more recently developed dichlofluanid, which is sold under the name Euparen®. It is designated for use against *Botrytis cinerea* Pers. in strawberry fields. Hence, its use in the Altes Land is limited to these habitats. A quinone derivative employed against the apple scab fungus is dithianon, sold under the name Delan®. The LD_{50} for rats given oral doses is 1015 mg/kg, but it can cause skin irritation (Schlör 1970). Very little is known about its ecological effects. Mancozeb and propineb are two alkylene bisdithiocarbamate compounds recommended for use against scab fungi. Mancozeb is usually applied together with captan in a mixture called Pomuran®. Propineb is sold under the name Antracol®. Significant quantities of both are used in the Altes Land. Brown (1978) discussed what is known about their ecological effects, mentioning that several important predators are not harmed. Ferbam is another substance employed to control apple scab, and is also used to protect foliage, but it has the disadvantage of blackening the leaves (McEwen and Stephenson 1979). The LD_{50} for rats given ferbam orally is extremely high: greater than 17,000 mg/kg (Brown 1978). It is relatively harmless to most arthropods, but it is toxic to a few mite predators that feed on the red spider mite, *Panonychus ulmi* (Koch). *Podosphaera leucotricha* (Ell. & Ev.) Salm, the fungus that causes powdery mildew disease of apple trees, is combatted with bupirimate, sold under the name Nimrod®. It is absorbed through the leaves and transported through the plants, where it kills the fungus. Its decomposition is rapid in water under illumination. An organophosphorus fungicide called pyrazophos, sold under the name Afugan®, is applied against the powdery mildew disease of apple trees and against the disease of the same name that causes damage to strawberry plants, which has as its causative agent *Sphaerotheca humuli* (DC.) Burr. Like ferbam, it is absorbed by the plant and acts against the fungus in the tissues. Benzimidazoles are antibiotic substances with herbicidal and fungicidal properties, which are derivatives of the basic formula shown in Table 4. Because of their undesirable ecological properties, they are not suitable for use in the open, but they can be effective in protecting stored fruit. In the Altes Land, some may find their way into the water in the ditches when the farmers wash their storage rooms out. Nevertheless, the benzimidazoles cannot be considered important contaminants of the orchard drainage system. Another substance that is absorbed into the apple trees, through the leaves or the roots, to combat powdery mildew is triadimefon, sold under the name Bayleton®. It is applied often over a large area in the Altes Land. Fenarimol is used against both apple scab and powdery mildew. It is sold under the name Rubigan®. Little is known about its ecological effects, but it is not acutely toxic to mammals and birds. The LD_{50} for rats fed fenarimol is 2500 mg/kg. The toxicity for fishes, however, is high: LC_{50} is 0.91 mg/l for *Lepomis macrochirus* Rafinesque (Centrarchidae), the bluegill sunfish, and 1.8 to 2.4 mg/l for *Salmo gairdneri* Richardson (Salmonidae), the rainbow trout (Elanco 1979). Another chlorine-containing fungicide used as a powder on strawberry fields is vinclozolin, sold under the name

Table 4. Pesticides used extensively in the Altes Land during the investigation

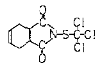
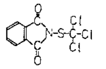
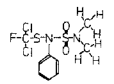
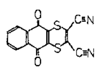
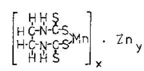
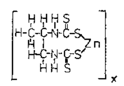
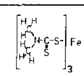
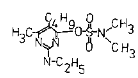
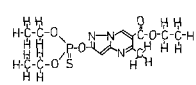
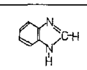
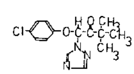
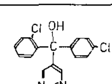
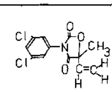
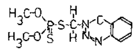
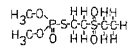
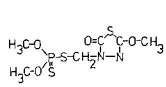
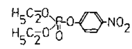
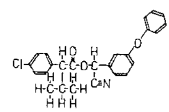
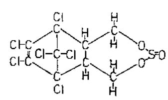
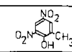
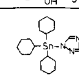
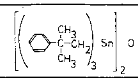
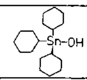
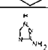
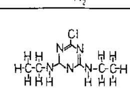
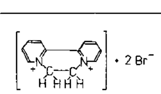
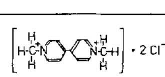
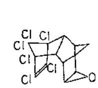
Pesticide	Chemical name	
Sulfur	S_6 and S_8	
Copper oxychloride	$3\ Cu(OH)_2 + 1\ CuCl_2$	
Captan	N-(trichloromethylthio)-4-cyclohexene-1,2-dicarboximide	
Folpet	2-[(trichloromethyl)thio]-1-*H*-isoindole-1,3(2*h*)-dione	
Dichlofluanid	N-[(dichlorofluoromethyl)-thio]-N′N′-dimethyl-N-phenylsulfamide	
Dithianon	5,10-dihydro-5,10-dioxo-naphthol(2,3*b*)-1,4-dithin-2,3-dicarbonitrile	
Mancozeb	[[1,2-ethanediylbis[carbamo-dithioate]] (2-)]manganese mixt. with [[1,2-ethanediylbis [carbamodithioate]](2-)]zinc	
Propineb	[[1-methyl-1,2-ethanediyl) bis[carbamodithioate]](2-)] zinc homopolymer	
Ferbam	tris(dimethyl carbamodithioate *S*, *S*′) iron	
Bupirimate	2-ethylamino-5-butyl-6-methyl-4-yl-dimethyl-sulfamate	
Pyrazophos	ethyl-2-[(diethoxyphos-phinothioyl)oxy]-5-methylpyrazolo[1,5-*a*] pyrimidine-6-carboxylate	
Benzimidazoles	Several compounds of same basic formula	
Triadimefon	1-(4-chlorophenoxy)-3,3-dimethyl-1-(1,2,4-triazol-1-yl)-butan-2-one	
Fenarimol	α(2-chlorophenyl)-α-(4-chlorophenyl)-5-pyrimidine methanol	
Vinclozolin	3-(3,5-dichlorophenyl)-5-methyl-5-vinyl-1,3-oxazolidin-2,4-dione	

Table 4. (cont'd)

Azinphos-methyl	*O,O*-dimethyl *S*-[(4-oxo-1,2, 3-benzotriazin-3(4*H*)-yl) methyl] phosphorodithioate	
Demeton-S-methylsulfone	*S*-[2-(ethylsulfonyl) ethyl] *O,O*-dimethyl phosphorothioate	
Methidathion	*S*-[(5-methoxy-2-oxo-1,3,4-thiadazol-3 (2*H*) methyl] *O,O*-dimethyl phosphorodithioate	
Parathion	*O,O*-diethyl-*O*-(4-nitrophenyl) phosphorothioate	
Fenvalerate (one of several pyrethroids)	cyano(3-phenoxyphenyl) methyl 4-chloro-alpha-(1-methylethyl) benzeneacetate	
Endosulfan	6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzo(e)-dioxathiepin-3-oxide	
Dinitrocresol	2,4-dinitro-*o*-cresol	
Peropal® (an azocyclotin)	1-(tricyclohexylstannyl)-1*H*-1,2,4-triazole	
Fenbutatin oxide	Hexakis-(β,β-dimethyl-phenylethyl)-distannoxan	
Cyhexatin	Tricyclohexyl-stannic hydroxide	
Amitrole	3-amino-*s*-triazole	
Simazine	6-chloro-*N,N'* diethyl-1,3,5-triazine-2,4-diamine	
Diquat dibromide	6,7-dihydropyridol 1[2-*a*:2',1'c]pyrazine-diium dibromide	
Paraquat dichloride	1,1'-dimethyl-4,4'-bipyridinium dichloride	
Endrin	(1aα,2β,2aβ,3a,6a,6aβ,7β,7aα) -3,4,5,6,9,9-hexachloro-1a, 2, 2a, 3,6,6a-octahydro-2,7:3,6-dimeth-anonaphth[2,3-b] oxirene	

Ronilan®. It acts against grey mold, *Botrytis cinerea* Pers. After its application to a strawberry field beside a ditch in which fish were being cultured, no negative effects on the aquatic organisms could be observed. The fungicides are generally regarded as ecologically benign. Only a few of them are rather toxic to vertebrates, but many kill mites and other arthropods. Some are advertised as also being effective against red spider mites, particularly the old standby, sulfur. No evidence was found to indicate that fungicides alone were responsible for any negative ecological effects.

The variety of insecticides employed is much less than that of fungicides. Like the fungicides, the modern insecticides generally are not persistent in the environment. Fruit trees require insects for pollination, and residual insecticides during the blooming period could seriously reduce the harvest. Sprays against codling moths, *Carpocapsa pomonella* (L.), and other pests must be used in the evening and should become inactive by morning before the bees start their work. Bees are kept commercially for honey production, so the fruit growers must make sure that they are not killed even after the blooming season of the trees is over. For this purpose, organophosphorus insecticides are currently popular. Three preparations currently widely used in the Altes Land are Gusathion MS®, Ultracide®, and E 605. The first of these is a mixture of azinphosmethyl and demeton-S-methylsulfone. Azinphosmethyl is toxic to rats, for which the oral LD_{50} is 15 mg/kg. It is relatively non-toxic when applied to the skin. Apparently, applications of this insecticide are dangerous to aquatic life as some fish kills have resulted from its use (McEwen and Stephenson 1979). Demeton-S-methylsulfone is less toxic to fishes, but both substances are broad spectrum insecticides, killing predators as well as pests. This particular combination must not be sprayed until after the trees have finished blooming, because both substances are harmful to bees. The toxicity of azinphosmethyl to aquatic invertebrates is rather high compared to other organophosphorus insecticides, and it is persistent enough to be a factor throughout the entire growing season (Brown 1978). The active ingredient of Ultracide is methidathion. It is the least toxic of the three preparations to mammals, the LD_{50} for the rat being 25 to 48 mg/kg (Fest and Schmidt 1970). It is a relatively new product; hence, its ecological effects are not yet well known. Parathion is the active ingredient in E 605. It has the lowest LD_{50} for rats: 10 mg/kg when administered either orally or to the skin. Inactivation is rapid on foliage, but it persists for a long time in the soil. It is probably less dangerous to aquatic life than azinphosmethyl (McEwen and Stephenson 1979). It should be noted that the organophosphorus insecticides are also toxic to mites and are recommended for use against the red spider mites. Nevertheless, pesticides designated specifically as acaricides are also sprayed in the orchards, as discussed below.

Another group of insecticides used in the orchards are the pyrethroids; synthetic compounds similar to the natural pyrethrins. Their toxicity to mammals is very low, the LD_{50} for the rat ranging from 920 to 40,000 mg/kg, depending on the substance (McEwen and Stephenson 1979), but they are toxic to aquatic arthropods (Brown 1978). The persistence of pyrethroids is rather low, but some decompose more slowly than the natural pyrethrins. One such substance available for use against biting and sucking insects, fruit maggots, and red spider mites in the Altes Land is fenvalerate, sold under the name Sumicidin 30®.

Only one organochlorine compound is still used primarily as an insecticide in the orchards: endosulfan—trade name Thiodan®. Fortunately for the fish culturists, it is used over a smaller area in the Altes Land than the other compounds. It is sometimes used as a piscicide since it has a high toxicity to fishes, but its effects do not last long because it decomposes rapidly in water (McEwen and Stephenson 1979). On foliage, it is somewhat more persistent. The LD_{50} for rats given oral doses is about 75 mg/kg. Only one pre-DDT insecticide is in general use in the Altes Land. It goes under the name yellow carbolineum, but it is simply dinitrocresol, used as an insecticide since 1892 (Wegler and Eue 1970); it finds more use as a herbicide than as an insecticide. It is unsuitable for use on crops during the growing season. It is safe to assume the insecticides are chiefly responsible for the disappearance of the pesticide-sensitive arthropods. This is not to say that other substances do not have an effect in individual cases, but because of their toxicity and frequent applications, insecticides certainly play the leading role. In addition, acaricidal compounds are used to control the population of red spider mites in the orchards. They supplement the acaricidal properties of the insecticides and work against resistant strains of mites. The use of acaricides in orchards was made necessary in many locations around the world by the elimination of predators through the use of insecticides. This is one of the first ecological disasters shown to have resulted from the application of the modern pesticides. Collyer (1953) reported that DDT was responsible for the elimination of predators that normally controlled the population of red spider mites, *Panonychus ulmi* (Koch), in British orchards. The situation repeated itself around the world, and a list of occurrences was provided by Brown (1978). In untreated orchards, the predators are effective in keeping the numbers of red spider mites very small, but when they are removed, massive populations of the prolific pests quickly develop. This requires the farmers to add acaricides to their list of sprays. Three acaricides are in general use in the Altes Land at the present time: azocyclotin, fenbutatinoxide, and cyhexatine. They are sold under the names Peropal®, Torque®, and Plictran 25®, respectively. The acaricides are designed to be narrow spectrum pesticides that kill harmful mites but spare predatory species. They are also advertised to be harmless to honey bees and insect predators. Torque is toxic to fishes, and Peropal can be dangerous to mammals: LD_{50} for the rat is 76 mg/kg or more when given orally (Perkov 1971). Thus, they cannot be viewed as ideal pesticides, although they are a great improvement over the substances used in the past. These substances in combination with the acaricidal insecticides are very likely responsible for the absence of water mites in the ditches. Because they are not harmful to most arthropods, they are designed to be rather persistent. In most cases, a different gene is involved in the resistance to each pesticide (Plapp 1976). A wild population normally contains few individuals with a resistance to a particular toxic substance. If acaricidal compounds had been applied in sequence, time would have been sufficient for resistant populations to develop against each chemical, in turn. The fact that during each year, several substances, applied for different purposes, find their way into the orchard drainage ditches explains why the aquatic mites did not have the chance to develop resistances. Toxicity tests on these species are not normally carried out. The predatory species, however, are viewed as desirable, and the chemical manufacturers search for substances that spare them. This explains the relative abundance of *Pergamasus crassipes* (L.), a eugamasid, among the beds of *Glyceria maxima,* where it apparently feeds on the springtails (Karg 1971). Other chelicerates, the spiders, are apparently not affected by the acaricides at all. Another factor might be involved with the disappearance of some aquatic mite species. Several of the genus *Arrenurus* are parasitic during their immature stages on damsel and dragonflies. It thus cannot be completely ruled out that their disappearance is related to the elimination of their host species. Münchberg (1938) gave detailed information about the parasitic habits of the larvae. A secondary effect of a similar nature is not a factor in the disappearance of other water mite species, however, since the larvae are parasitic on members of the Hemiptera, which are still numerous in the ditches, and the adults can feed on a variety of organisms (Böttger 1970, 1972).

The herbicides have apparently not been responsible for the elimination of any aquatic plant species since the 1950s. The two aquatic species mentioned by Garms (1961) that were not observed during 1978–80 were formerly of seldom occurrence (Table 1); hence, little can be concluded from their absence. The chief purpose of the herbicides is the eradication of terrestrial species that grow beneath the fruit trees. Dense thickets of nettles are also sometimes sprayed. The use of yellow carbolineum (dinitrocresol) as a herbicide was discussed above. Amitrole is non-persistent in water; it disappears from soil in less than one month, degrading to urea and cyanamid. As an herbicide, it is non-selective and readily translocated in the plants, the foliage of which is bleached white. Aquatic vegetation is also killed. Amitrole has an extremely low toxicity to mammals. The LD_{50} for the rat is 24,600 mg/kg, but it induces thyroid swelling (Carter 1975), and it is forbidden on crop lands in the United States (Matsumura 1975). Simazine is intended for use as a non-selective herbicide on non-crop land and against aquatic plants. It is the least soluble of the triazine pesticides and acts very slowly against submerged plants. Because the half-life of simazine is relatively long, it remains effective in the soil for about six months, giving "full season control." Significant reductions in aquatic arthropod populations and some toxicity to fish fry are attributed to this compound (Brown 1978). Diquat and paraquat are bipyridyliums used as non-selective contact herbicides. Because the plant tissue is killed on contact, there is no transport, and hardy weeds can survive the treatment. The substances lose their herbicidal activity almost immediately on contact with the soil, but they break down slowly and persist from one to four weeks in water. Phytoplankton may be killed, but invertebrates survive the direct effects. Paraquat is harmless to fish, but diquat may kill some fry. The dead vegetation, however, decomposes and reduces the dissolved oxygen concentration, thereby presenting a danger to the aquatic fauna (Brown 1978). Paraquat is often used in orchards, while diquat is applied chiefly as an aquatic herbicide (McEwen and Stephenson 1979). Paraquat is more dangerous to mammals than diquat, with an LD_{50} for the rat of 100 to 150 mg/kg. Many fatalities have resulted in cases where it was ingested by humans (Staiff *et al.* 1973). The harm to the fauna caused by herbicides is probably not significant. The chief danger of such substances is the oxygen deficiency that they cause as the poisoned plants decompose in the water. One bed of *Elodea canadensis* died shortly after the application of herbicides beneath the fruit trees in the spring of 1979. The water developed a brown slick on the surface, and some snails and aquatic arthropods died. A massive population of hypotrich ciliates appeared among the detritus, and many insects that breathe atmospheric oxygen at the surface thrived. After several weeks, the water had cleared, and the *Elodea* grew up again. The normal macrofauna also returned as individuals from unaffected parts of the ditch recolonized the temporarily disrupted habitat. Since the herbicidal effects are local and not of long duration, the community can rapidly recover.

Endrin is applied once annually with special permission to reduce the rodent populations. According to Perkov (1971), endrin is forbidden in the Federal Republic of Germany because of its effects as a general ecosystem poison. Endrin is persistent and relatively insoluble in water. It has a half-life of 2.2 years in soil, and its isomer, dieldrin, has been found nine years after application. It is highly toxic to mammals and has caused some large fish kills (McEwen and Stephenson 1979). A broad spectrum of aquatic invertebrates are also affected (Brown 1978). Perkov (1971) reported that the oral LD_{50} for the rat is 7 mg/kg, and when applied to the skin, 10 mg/kg. It was also found to be toxic to *Daphnia* spp. in various concentrations from 50 to 352 ppb. In spite of the bad ecological characteristics of endrin, it is not considered likely that it has been responsible for any of the observed changes in the aquatic community. First, its limited use in the orchards would guarantee that the amounts entering the ditches remain small. Second, the fact that no fish kills at all were observed show that this subtance is not a factor in the habitat. Even small concentrations should be sufficient to cause the death of some fishes. It might be added that rodents still abound in the orchards, and muskrats occur in great numbers beneath the banks of the ditches. This makes the value of endrin questionable from an economic viewpoint, since mechanical traps seem to eliminate many more rodents and can be used the year round.

Obviously, with so many substances and species involved, the analysis of the events that have taken place in the last 25 years does not yield clear-cut answers. Nevertheless, studies that show what actually happens to biotic communities in areas of intensive use are absolutely necessary to test the theoretical assumptions concerning the impact of modern, intensive agriculture on natural ecosystems. While the myriad of short-term studies under controlled conditions in the laboratory are necessary to understand the individual effects of each compound on selected species, the results often do not agree with what is observed in the field. There is an enormous amount of evidence concerning the development of resistance to toxic substances by populations of individual species (Brown 1978). It is obvious that the carefully calculated LD_{50} and LC_{50} values from countless investigations become meaningless as soon as the resistant genotypes assume a different proportion of the total population. An LD_{50} value for a resistant strain would normally be from about ten to several thousand times greater than that of a susceptible one. Six different methods are known by which an organism may resist a pesticide, and one population sometimes develops more than one of these methods by a genetic selection process. The details of these methods and their development are discussed in detail by Corbett (1974).

A further problem with laboratory experiments is that the carefully controlled conditions do not allow the test organisms freedom to carry out their natural behavior patterns. Furthermore, there is a certain amount of stress associated with the conditions of captivity that most certainly lowers the resistance strength, at least of arthropods and vertebrates. Pesticides in water are normally adsorbed on particulate matter to various degrees, and some are bound tightly to solid materials. It is difficult to match such conditions in the laboratory with any degree of precision.

A great deal is still unknown about the chemistry of the pesticides in relation to the biota on which they work. Corbett (1974) lists most of the insecticides used in the orchards as inhibiting acetylcholinesterase, but how this is done in each case is still a mystery. Since pesticide functions are scarcely known, little exact information about the chemistry of resistance can be provided. Furthermore, half-lives calculated under carefully controlled conditions can often be far from the values actually encountered in the field. A relatively large amount of information is available about DDT, but its half-life value in nature cannot be accurately estimated. In anaerobic habitats with many bacteria and yeasts present, it can be expected to decompose years before similar amounts in dry, aerobic soils (Guenzi and Beard 1968). Food chain accumulations in the case of each individual pesticide will only be revealed by hundreds of separate research projects.

It is essential to emphasize that the subject of ecological changes brought about by pesticide use is an extremely complex one. There are no simple, easily obtained answers to the problem of how to preserve natural biotic communities and at the same time to maximize agricultural yields. Besides the chemical approach, several other pest control techniques are now under consideration. Most are still in the developmental stage. Roelofs (1976) discussed the future prospects of pheromones. By attracting the pests to one place, the toxic pesticides can be kept in traps and need not be broadcast over the entire ecosystem. Other control methods that have been widely discussed include the culture and release of large numbers of predators or parasites, the culture of sterile males to control species that mate only once, and the use of pathogenic organisms to cause epizootics among the pests. All of these methods have proven successful in individual cases. Since these techniques are species specific, however, each has to be developed based on a thorough knowledge of the habits and ecological requirements of the individual pest. This requires much research and development effort, usually more than is required to develop chemical pesticides. Thus, for the present, the farmers will continue to depend on chemical controls to ensure a satisfactory harvest.

From the results of this study, it is possible to provide support for several theoretical principles that had been proposed before modern pesticides had been in use for very long. It is clear that the species surviving in the pesticide-rich environment of the fruit orchards are those that have the greatest potential for developing an effective resistance. This is based on a preadaptation of individuals within a population and not on any form of acquired immunity (Brown 1971). Some species do not develop resistances against certain pesticides at all, and are displaced in contaminated habitats by species with resistance (Brown 1978).

Many studies have concentrated on sub-lethal effects of pesticides. These may be obvious over a short-term, perhaps for several years, but after restabilization of the biotic community under continuous influence of pesticides has occurred, sub-lethal effects should no longer be a factor for populations that have developed resistance, and those species that cannot cope with the toxic substances would be completely eliminated. Among the many populations of macrofauna observed from 1978 to 1980, none were found to be undersized or obviously affected by diseases. On the contrary, a great many of the animals were unusually large and numerous. This has very likely resulted from the productivity of the waters and the elimination of many competitors and predators that did not successfully develop resistance to the pesticides in use.

It is not possible to define "long-term" in an absolute sense. In a study of sub-lethal effects from small amounts of an herbicide, atrazine, on three invertebrates, and of lethal effects on eggs and developmental stages of the same species, Streit and Peter (1978) used the phrase "long-term effects" to refer to a period of time that did not exceed six weeks. Long-term in an ecological sense, of course, would refer to many generations and not just a small portion of one. In the case of bacteria, a few days are sufficient to determine changes that affect the population dynamics. Flies with several generations per season can show a stabilization after a disturbance, such as an application of an insecticide, within a period of two or three years. To determine the effects on raptors, however, several decades would certainly be required. It would seem, for example, from the information now available on relatively short-lived species, that raptors with the ability to produce hard-shelled eggs in the presence of DDT would survive and produce DDT resistant populations. Rather than dealing with averages and increased mortality during embryological development from thin-shelled eggs, conservationists must concern themselves with finding out if individual birds can produce normal eggs in spite of DDT contamination. If such individuals cannot be found, it is likely that the species is doomed to extinction. DDT will be around for many years to come in spite of the ban in some countries. Obviously, a great many formerly sensitive insect species now live in strongly contaminated habitats without showing any lethal or sub-lethal effects. There are also many formerly abundant species that are now missing from much of their former range, including many of the useful predators. The scarcity of most odonatans in the Altes Land orchards shows that they no longer develop in the ditches in which they were formerly abundant.

In addition to DDT, which under certain circumstances may persist in substantial quantities at least 17 years after application (Nash and Woolson 1967), the whole spectra of modern pesticides enters into the analysis of ecological changes that have been observed. The effects of certain insecticides and acaricides should be severe to many species, but even many herbicides that are harmless in most cases, may have unexpected effects on certain developmental stages of various species, as Streit and Peter (1978) pointed out. Under the circumstances, it is not surprising that so many arthropod species have disappeared from the orchard drainage ditches, but rather that so many are still there.

The taxonomic groups most influenced by the introduction of agricultural chemicals into the orchard drainage ditches since Garms's study are readily discernible in Table 5. These quantitative data do not reflect displacements of one species by another. Certain species are notable for being resistant to pollution and are therefore generally associated with foul waters. Organisms that live in the presence of H_2S and a variety of organic chemicals produced by the

Table 5. The absolute number of species, including those reported as rare, belonging to the major taxa investigated from 1951 through 1957 and from 1978 to 1980

Major taxon	1951-57	1978-80	Change
Porifera	1	0	−1
Platyhelminthes			
Tricladida	4	4	+1
Ectoprocta	2	1	−1
Annelida			
Oligochaeta	7	7	0
Hirudinea	10	7	−3
Mollusca			
Gastropoda	20	20	0
Bivalva	3	1	−2
Arachnida			
Acari	18+	1	−17
Araneae	3	4	+1
Crustacea			
Cladocera	6	6	0
Copepoda	13	11	−2
Branchiura	1	0	−1
Isopoda	1	1	0
Decapoda	1	0	−1
Insecta			
Collembola	3	4	+1
Ephemeroptera	5	2	−3
Odonata	14	5	−9
Heteroptera	16	12	−4
Neuroptera	1	0	−1
Lepidoptera	3	2	−1
Trichoptera	7	0	−7
Coleoptera	62+	14	−48
Diptera	10+	41	+31
Chordata (except Aves)	14	15	+1

breakdown of detritus are likely to have integuments particularly impenetrable to toxic substances and metabolic systems particularly well suited to the detoxification of a variety of harmful materials. The great variety of syrphids in the orchards, for example, attests to the ability of the larvae to live in the foulest possible habitats. One method of resistance is avoiding the uptake of the toxic compound (Corbett 1974), and certainly some species are able to isolate themselves from the chemical environment better than others.

Protection of the aquatic habitat in the orchard drainage ditches by forbidding the use of pesticides cannot be seriously considered. The habitat is an artificial one that exists solely to meet the needs of the fruit growers. It is through their efforts that the ditches are kept open. With the advent of fish culture in the ditches, however, there is a likelihood that problems will arise because of pesticide spraying. First, some of the substances applied to the fruit trees are harmful to fish and are therefore not used near the ditches used for aquaculture. A second and more serious problem is that the fish may contain traces of organic compounds not approved for human consumption. No trace of endrin, for example, is permitted in food. When polyculture is substituted for monoculture, it must be expected that additional care is necessary in applying agricultural chemicals.

The extremely complex situation presented by actual crop protection programs and their effects on natural and cultivated environments cannot be revealed by routine, superficial investigations. Each case must be investigated on an individual basis. This study confirms that significant changes do take place among non-target communities exposed to agricultural chemicals for a long enough time to allow an equilibrium to be reestablished.

A pesticide spraying program to protect agricultural crops can be viewed from several aspects: ecological, agricultural, economic, and public health. This study concerned itself chiefly with ecological aspects of the pesticide applications, and in addition to a great many individual examples of long-term changes, it revealed several general principles, the existence of which had long been predicted on the basis of theoretical considerations. It is evident that a restabilization of the biotic community occurs after it has been long exposed to toxic substances. Species that succeed in producing resistant populations usually return to at least their former abundance, while others are never sensitive to the chemicals and remain unharmed. Some species do not succeed in developing a tolerance to one or more of the pesticides and disappear completely from the habitat. The species that disappear are normally those most closely related to the pests, the target organisms for the pesticides. Certain species, however, may show no ill effects, even though they belong to a group that is particularly hard-hit. *Coenagrion pulchellum* and *C. puella,* for example, were very abundant, even though most other odonatans had been completely eliminated from the ditches. Organisms sensitive to several pesticides applied simultaneously are more likely to be eliminated than those exposed to only one toxic substance at a time. For instance, the mites, that were sensitive to both the acaricides and the insecticides, were completely absent from the ditches, while the aquatic insect species were only partially eradicated. The acaricides were chosen for use because of their relative harmlessness to predatory insects; hence, the insects were only exposed to one kind of lethal organic compound at a time.

Predatory species seem generally to be more likely victims of the pesticides than herbivorous or saprobic ones. Particularly hard-hit in the orchard drainage ditches were the odonatans, several families of predatory beetles, and the water mites. Apparently increasing in importance were members of the Diptera, mostly saprobic species. There is a theoretical reason for this. In an undisturbed ecosystem, plants must maintain a larger biomass than the herbivores, and the herbivores must outnumber the carnivores. If this were not the case, one group would quickly exhaust its food supply and starve. Since herbivorous species have larger populations and usually higher reproduction rates, they are more likely to be able to develop a resistance and return to their former abundance more rapidly after a pesticide application. Their temporary scarcity immediately after the pesticide is first introduced, however, may cause the few naturally resistant predators to starve before they have the chance to reproduce. Because of the availability of the crop, the pest will have the best food supply, assuring it the best chance of producing a resistant population. Because of the elimination of some species from the habitat, others have a chance to develop large populations unchecked by predation or competition. In the orchard ditches, massive populations of chironomid larvae were able to develop without undergoing decimation by predatory beetles or odonatan larvae.

The development of biological controls should be a primary goal of agricultural research. Species specific control measures ensure maximum control of the pest population and protection of non-target species, including important predators.

Although the pesticides do not represent ideal solutions to the pest control problems in the orchards, there has been a steady improvement in the substances used. Less persistent pesticides not only do less harm to non-target organisms ''downstream'' from the agricultural regions, they also delay the formation of strongly resistant populations by permitting sensitive individuals to migrate from unsprayed areas and mix with the resistant ones during the time between the sprayings.

The economic aspects of crop protection programs are intimately linked with the cost of pesticides and the amounts required. The new products are generally more expensive than the older ones. As the older ones become less effective, however, the more expensive ones become necessary even without consideration of environmental protection. Increasing the dosage of substances that are no longer effective can result in severe distortions of the ecological balance, leading to massive population growth of very destructive organisms (Reynolds *et al.* 1975, Vaughan and Leon 1976).

As polyculture is introduced in the form of combined culture of fruit and fish, greater caution will be required to prevent losses of fishes from substances sprayed to protect the fruit. This leads to a consideration of the public health aspect of pesticide use. In order to avoid contamination of food meant for human consumption, more attention will have to be paid to concentrations of pesticides in the food chains which supply nourishment for the fish. Since many organisms are obviously very resistant to a variety of pesticides, it can be considered likely that some of them would contain these substances just as they contain DDT and its breakdown products (Table 3). A monitoring of the fish flesh will be necessary to determine if any contaminants are present in dangerous concentrations. It may then be necessary to remove certain substances from the list approved for use on the fruit trees in regions where fish culture is practiced.

Diptera may be taken as an example of an insect order that has benefited from the application of modern pesticides. This group of insects includes many species with very short generation times, giving them the chance to develop immunity to insecticides by selection rather rapidly; that many do develop immune populations rapidly is well established (Brown 1978). Habitats in which the agricultural chemicals have decimated the predatory beetles and odonatan larvae are ideal places for massive populations of flies, mosquitoes, and midges to develop.

Acknowledgments. Special thanks are due to Prof. Dr. H. Caspers of the Institut für Hydrobiologie und Fischereiwissenschaft der Universität Hamburg for material support and encouragement during this investigation, and to Dr. K.-H. Tiemann of the Obstbauversuchsanstalt der Landwirtschaftskammer Hannover, Jork, for providing information about the pesticide application schedule followed by the fruit growers in the Altes Land. Thanks also to the following taxonomic experts for identifying specimens collected during this study: Dr. Rolf Brandt, Wentorf, Germany (Gastropoda); Prof. Dr. M. Dzwillo (Oligochaeta), Dr. D. Keyser (Ostracoda) and Mr. G. Kraft

(Tardigrada) of the Zoologisches Institut und Zoologisches Museum der Universität Hamburg; Dr. F. Reiss, Zoologische Sammlung des Bayerischen Staates, Munich (Chironomidae); Dr. T. B. Reynoldson, University College of North Wales, Bangor (Planariidae and Dugesiidae); Dr. F. Riemann, Institut für Meeresforschung, Bremerhaven (Nematoda); and Dr. R. Wagner, Limnologische Flußstation des Max-Planck-Instituts für Limnologie, Schlitz (Psychodidae). Dr. E. Huschenbeth, Bundesforschungsanstalt für Fischerei, Hamburg, was kind enough to provide analyses of the specimens for DDT and its degradation products.

This investigation was supported by the Forschungsbereich Umweltschutz und Umweltgestaltung, Universität Hamburg.

References

Benazzi, M.: Il Problema Sistematico delle *Polycelis* del Gruppo *nigra tenuis* alla luce Ricerche Citologiche e Genetiche. Monitore Zoologico Italiano **70**, 288 (1963).

Böttger, K.: Die Ernährungsweise der Wassermilben (Hydrachnellae, Acari). Int. Revue ges. Hydrobiol. **55**, 895 (1970).

———: Vergleichend biologisch-ökologische Studien zum Entwicklungszyklus der Süßwassermilben (Hydrachnellae, Acari). I. Der Entwicklungszyklus von *Hydrachna globosa* und *Limnochares aquatica*. Int. Revue ges. Hydrobiol. **57**, 109 (1972).

Brown, A. W. A.: Pest resistance to pesticides. In R. White-Stevens (ed.): Pesticides in the environment. Vol. 1. Part 2, p. 457. New York: Marcel Dekker (1971).

———: Ecology of pesticides. New York: J. Wiley and Sons (1978).

Carter, M. C.: Amitrole. In D. C. Kearney and D. D. Kaufman (eds.): Herbicides: Chemistry, degradation and mode of action. 2 ed. Vol. 1, p. 377. New York: Marcel Dekker (1975).

Caspers, H., and C. W. Heckman: Ecology of orchard drainage ditches along the freshwater sections of the Elbe Estuary. Arch. Hydrobiol. Suppl. 43 (Elbe Estuary 4). in press (1980).

Collyer, E.: Biology of some predatory insects and mites associated with the fruit tree red spider mite [*Metatetranychus ulmi* (Koch)] in South-Eastern England. IV. The predator–mite relationship. J. Hortic. Sci. **28**, 246 (1953).

Corbett, J. R.: The Biochemical mode of action of pesticides. London: Academic Press (1974).

Edwards, C. A.: Persistent pesticides in the environment. 2 ed. Cleveland: Chemical Rubber (1973).

Elanco: Technische Information Rubigan. Eli Lilly and Co., Bad Homburg.

Fest, C., and K.-J. Schmidt: Insektizide Phosphorsäureester. In R. Wegler (ed.): Chemie der Pflanzenschutz- und Schädlingsbekämpfungsmittel. Vol. 1, p. 246. Berlin: Springer-Verlag (1970).

Forcart, L.: Zur Nomenklatur der in Deutschland lebenden Arten von *Viviparus*. Arch. Moll. **89**, 111 (1960).

Garms, R.: Biozönotische Untersuchungen an Entwässerungsgräben in Flußmarschen des Elbe-Aestuars. Arch. Hydrobiol. Suppl. 26 (Elbe-Aestuar 1): 344 (1961).

Guenzi, W. D., and W. E. Beard: Anaerobic conversion of DDT to DDD and aerobic stability of DDT in soil. Soil Sci. Soc. Am., Proc. **32**, 522 (1968).

Holden, A. V., and K. Marsden: Single-stage clean up of animal tissue for organochlorine residue analysis. J. Chromatog. **44**, 481 (1969).

Karg, W.: Acari (Acarina), Milben. Unterordnung Anactinochaeta (Parasitiformes). Die freilebenden Gamasina (Gamasides), Raubmilben. Die Tierwelt Deutschlands. Part 59. Gustav Fischer Verlag, Jena. (1971).

Kiefer, F.: Freilebende Copepoda. Das Zooplankton der Binnengewässer. Part 2. E. Schweizerbart'sche Verlagsgesellschaft, Stuttgart, p. 1. (1978).

Klein, W., and F. Korte: Metabolismus von Chlorkohlenwasserstoffen. In: R. Wegler (Ed.), Chemie der Pflanzenschutz- und Schädlingsbekämpfungsmittel. Vol. 1, p. 199. Berlin: Springer-Verlag (1970).

Köhler, B., and H. Riediger: Das Alte Land. Perten-Druck, Reinbek, Hamburg. (1970).

Kuhr, R. J., A. C. Davis, and J. B. Bourke: DDT residues in soil, water, and fauna from New York apple orchards. Pesticide Monit. J. **7**, 200 (1974).

Matsumura, F.: Toxicology of insecticides. New York: Plenum Press (1975).
McEwen, F. L., and G. R. Stephenson: The use and significance of pesticides in the environment. New York: John Wiley and Sons (1979).
Münchberg, P.: Über den Larvenparasitismus der *Arrenurus*-Arten. Abhandlungen und Berichten der Naturwiss. Abteilung der Grenzmärkischen Gesellschaft zur Erforschung und Pflege der Heimat, Schneidemühl **12**, 49 (1938).
Nash, R. G., and E. A. Woolson: Persistence of chlorinated hydrocarbon insecticides in soils. Science **157**, 924 (1967).
Perkov, W.: Wirksubstanzen der Pflanzenschutz- und Schädlingsbekämpfungsmittel. Hamburg: Verlag Paul Parey (1971–79).
Plapp, F. W.: Biochemical genetics of insecticide resistance. Ann. Rev. Entomol. **21**, 179 (1976).
Quast, P.: Die Zusammenhänge zwischen den Luft- und Wassergehalten der verschiedenen Böden im niederelbischen Obstbaugebiet und deren Bedeutung für den Obstbau. Mitteilungen des Obstbauversuchsringes des Alten Landes **32**, 130 (1977).
———: Weitere Ergebnisse von Bodenfeuchtemessungen mit Tensiometern in Obstanlagen auf Marsch- und Geestböden aus den Vegetationsperioden 1977 und 1978 und die Schlußfolgerungen daraus. Mitteilungen des Obstbauversuchsringes des Alten Landes **34**, 306 (1979).
Reynolds, H. T., P. L. Adkisson, and R. F. Smith: Cotton insect pest management. In R. L. Metcalf and W. Luckmann (eds.): Introduction to insect pest management, p. 379. New York: John Wiley and Sons (1975).
Reynoldson, T. B.: A key to British species of freshwater triclads. Freshwater Biological Assoc. Sci. Pub. No. 23. 2 ed. Kendal: Titus Wilson and Son (1978).
Reynoldson, T. B., and L. S. Bellamy: The status of *Dugesia lugubris* and *D. polychroa* (Turbellaria, Tricladida) in Britain. J. Zool. **162**, 157 (1970).
Roelofs, W. L.: Pheromones. In R. L. Metcalf and J. J. McKelvey Jr. (eds.): The future for insecticides. Needs and prospects, p. 445. New York: John Wiley and Sons (1976).
Schlör, H.: Chemie der Fungizide. In R. Wegler (ed.): Chemie der Pflanzenschutz- und Schädlingsbekämpfungsmittel. Vol. 2, p. 44. Berlin: Springer-Verlag (1970).
Staiff, D. C., G. K. Irle, and W. C. Felsenstein: Screening of various absorbents for protection against paraquat poisoning. Bull. Environ. Contam. Toxicol. **10**, 193 (1973).
Streit, B., and H.-M. Peter: Long-term effects of atrazine to selected freshwater invertebrates. Arch. Hydrobiol. Suppl. 55 (Falkau-Arbeiten 11):62 (1978).
Tiemann, K.-H.: Vorschläge für den Pflanzenschutz und die Sortenwahl mit Hinweisen für sonstige Pflegemaßnahmen im Obstbau verbunden mit einem Tagebuch. Führer durch das Obstjahr 1979. Obstbauversuchsring des Alten Landes e. V., Jork, Niedersachsen. (1979).
Vaughan, M. A., and G. Leon: Pesticide management on a major crop with severe resistance problems. Trans. 15th Internat. Congress Entomology (1976).
Watson, H.: The names of the two common species of *Viviparus*. Proc. Malac. Soc. London **31**, 163 (1955).
Wegler, R., and L. Eue: Herbizide. In R. Wegler (ed.): Chemie der Pflanzenschutz- und Schädlingsbekämpfungsmittel. Vol. 2. Berlin: Springer-Verlag (1970).
Whitehead, H.: The British Freshwater Planarians (Tricladida). Essex Nat. **20**, 1 (1922).

Manuscript received May 7, 1980; accepted July 7, 1980.