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with Special Reference to Migratory Birds:

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North and South Dakota Fish and Wildlife Enhancement Offices
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South Dakota State University

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Impact of Agricultural Chemicals on Wetland Habitats and Associated Biota with Special Reference to Migratory Birds:

A Selected and Annotated Bibliography

Prepared for the U.S. Fish and Wildlife Service
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by

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This bibliography documents the impact of pesticides and other agricultural chemicals on northern prairie wetlands and the migratory birds using the wetlands. It also recommends various practices or techniques which could mitigate, ameliorate, or prevent such impacts.

Such a subject covers a variety of topics. Included are papers from basic laboratory research to determine the acute, and sometimes chronic, toxicity of a variety of chemical pesticides. Also included are papers covering alternative pest control and agricultural methods and various bioassay techniques.

Generally, only those reports published since 1970 are included, thus excluding those dealing with many chemicals no longer in use. For the same reason, many papers reporting organochlorine contamination were not included unless the research was performed during the past 10 years.

Comments or terms added for clarification or explanation are in []. Editorial comments are those of the author and do not necessarily reflect the views of the Fish and Wildlife Service (Service) or of South Dakota State University (SDSU).

Scientific names of birds and fish are listed in the appendix. Both common and scientific names of birds are in accordance with the sixth edition of the AOU Check List of North American Birds. Common and scientific names of fish are as listed in *Fishes of Missouri* by W. L. Pflieger (Missouri Dept. of Conservation, 1975) or as listed in the source.

The index on page 62 groups all papers on a particular subject. The numbers under each heading refer to the citation numbers and not to page numbers.

The bibliography was produced under a cooperative agreement between the North and South Dakota field offices of the Service and the Fish and Wildlife Cooperative Research Unit at SDSU. Primary resources included the H.M. Briggs Library at SDSU and various online databases.

It is hoped that this bibliography will not only benefit Service Environmental Contaminant Specialists, for whom it was primarily intended, but all others who are interested in the effects of agricultural chemicals on the environment.

Abbreviations

These abbreviations have been used throughout the text to conserve space.

AI	active ingredient
BChE	butyrylcholinesterase
ChE	cholinesterase
DDD	1,1-dichloro-2,2-bis(p-chlorophenyl)ethane
DDE	dichlorodiphenyldichloro-ethylene
DDT	1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane
EC₅₀	concentration at which some behavioral or physiological end point is noted in 50% of the organisms tested
GI	gastrointestinal
LC₅₀	concentration at which 50% of the organisms tested die
LD₅₀	dose at which 50% of the organisms tested die
OC	chlorinated hydrocarbon or organochlorine
OP	organophosphate
PCB	polychlorinated biphenyl

This bibliography and its associated index are available on either 5 1/4- or 3 1/2-inch disks. The file is in WordPerfect 5.1 and is compatible with all MS/DOS hardware. To receive a copy of this software, contact Dr. Walter G. Duffy, U.S. Fish and Wildlife Service, Cooperative Research Unit, South Dakota State University, Box 2206, Brookings, SD 57007-1696. Requests must be in writing and specify the disk size desired. Phone orders will not be honored.

1. A.A. AQUATIC RESEARCH Ltd. 1985. Implications of reduced and no-tillage systems on chemical use in the prairie provinces. EPS 4/AG/1. Environmental Protection Service, Environment Canada, Ottawa. 20 pp.

Very few reduced and no-tillage systems existed in 1985 in the prairie provinces. The high cost of herbicides and the need for more intensive farm management were given as major limiting factors. Although the southern regions of the prairie provinces have the greatest potential for reduced and no-tillage farming, the change from conventional farming would favor the growth of perennial weeds and a concomitant increase in the need for herbicide control. Reduced and no-tillage systems substantially reduce soil erosion, however. As a result, the transport of nutrients and herbicides to nearby surface waters is greatly reduced as compared to conventional tillage.

2. ABEL, P.D. 1980. Toxicity of gamma-hexachloro-cyclohexane (lindane) to *Gammarus pulex*: mortality in relation to concentration and exposure. Freshwater Biol 10:251-259.

In standard acute toxicity tests, the median survival time ranged from 0.57 h at a concentration of 2 mg/L to 116 h at a concentration of 0.01 mg/L.

3. AHLF, W., W. Calmano, J. Erhard, and U. Förstner. 1989. Comparison of five bioassay techniques for assessing sediment-bound contaminants. Hydrobiol 188/189:285-289.

Many pollutants are preferentially associated with sediments in aquatic systems. The relative sensitivities of five different bioassay techniques were compared. The Neubauer phytoassay, which evaluates seed germination and plant growth of *Lolium multiflorum* and *Lepidium sativum* in serially diluted sediment concentrations, was the most sensitive. Tests involving microbial biomass and algal growth, however, were good indicators of contaminant and nutrient availability. The authors recommended using a variety of bioassays in toxicity testing of contaminated sediments to increase the information gained.

4. AHMAD, N., D.D. Walgenbach, and G.R. Sutter. 1979. Comparative disappearance of fonofos, phorate and terbufos soil residues under similar South Dakota field conditions. Bull Environ Contam Toxicol 23:423-429.

Granular formulations of fonofos, terbufos, and phorate (used to control corn rootworm) were applied to silty clay loam experimental plots under drought conditions at rates of 19.0 and 1.1 kg (the recommended application) AI/ha. Fonofos was the most persistent of the three insecticides. At 84 days post-treatment, 47% of the compound remained in the 19 kg/ha plot; 27% remained at 70 days post-treatment in the plot receiving 1.1 kg/ha. Dissipation of terbufos and phorate was much more rapid. More than 62

and 84% of the terbufos and 67 and 70% of the phorate was lost from the two treatment areas, respectively. Concentrations of the oxidized products of terbufos and phorate (terbufoxon and phoratoxon sulfones) increased in the soil concomitant with the decrease of the parent product and were more persistent than the parent product. The half life of phorate and terbufos did not change significantly with application rate; the half life of fonofos increased with increased application rate. [Correspondence from one of the authors (DDW to J. Cooper, March 14, 1990) stated "that an at-planting application of phorate at labeled rates would not present a hazard to waterfowl and most certainly [would] be in insufficient concentration for secondary poisoning."]

5. ALEXANDER, H.C., F.M. Gersich, and M.A. Mayes. 1985. Acute toxicity of four phenoxy herbicides to aquatic organisms. Bull Environ Contam Toxicol 35:314-321.

The acute toxicities of 2,4-D, 2,4-D dimethylamine salt (2,4-DD), 2,4-D isooctyl ester, and MCPA isooctyl ester to three fish species and *Daphnia magna* were determined. MCPA was non-toxic at concentrations up to 1500 times its water solubility of 0.003 mg/L. Likewise, 2,4-D in the isooctyl ester form was not toxic to the aquatic organisms at 1000 times its water solubility of 0.006 mg/L. *D. magna* was most sensitive to the other two phenoxyacids. The 48-h LD₅₀s were 25.0 and 184 mg/L to 2,4-D and 2,4-DD, respectively. Of the three fish species tested, bluegill were most sensitive to 2,4-D (96-h LD₅₀, 263 mg/L). Rainbow trout were most sensitive to 2,4-DD (96-h LD₅₀, 250 mg/L). The 96-h acute toxicity of both compounds to fathead minnows was >300 mg/L.

6. ALLEN, J.D., and R.E. Daniels. 1980. Sublethal effects of pollutants: test of the usefulness of life tables for evaluating the impact of chronic toxicity. U.S. NTIS PB Rep PB80-216, 674:1-69.

To test the usefulness of the intrinsic rate of population increase, r , as a chronic bioassay statistic, estuarine copepods (*Eurytemora affinis*) and freshwater daphnids (*Daphnia pulex*) were exposed to dieldrin. For *E. affinis*, r declined sharply at 5 ppb (<20% of the LC₅₀ of 23 ppb), due to increased time to reproductive maturity, increased time between broods, and increased mortality of pre- and post-reproductive females. For *D. pulex*, r declined at 200 ppb (80% of the EC₅₀ of 251 ppb), due to increased mortality of reproductive females. The authors concluded that r is a better predictor of the sensitivity of *E. affinis* to dieldrin than the LC₅₀, whereas r and the EC₅₀ are approximately equal in predicting toxicity to *D. pulex*. They suggested that *E. affinis*-and copepods in general-may be more suitable chronic bioassay organisms than *D. pulex*.

7. ANDERSON, D.W., D.G. Raveling, R.W. Risebrough, and A.M. Springer. 1984. Dynamics of low-level organochlorines in adult cackling geese over the annual cycle. J Wildl Manage 48:1112-1127.

OC concentrations were monitored in cackling Canada geese over the annual cycle (1973-1974) to study pollutant acquisition patterns during migration from Alaska's Yukon-Kuskokwim river deltas to the Klamath Basin of Oregon and California and California's Central Valley. Concentrations for all OCs detected were in the ppb range and were not believed to be overtly detrimental. Variations in acquisition patterns suggested slightly different exposures to different compounds during migration but could only be related to reported OC use in a qualitative manner. Concentrations of toxaphene, the most-used OC insecticide in California, were below detection limits. Occurrence of several banned compounds suggested illegal use in some areas. With the exception of PCBs and DDE, the authors believed that the geese should eliminate all residues acquired during annual migration.

8. ANONYMOUS. 1979. Leptophos. FAO Plant Prod Prot Paper 15:165-168.

Exposure of 1-week-old mallards to 260 ppm leptophos resulted in clinical signs of ataxia and subsequent paralysis within 17-23 days.

9. ASZTALOS, B., J. Nemcsok, I. Benedeczky, R. Gabriel, and A. Szabo. 1989. Comparison of effects of paraquat and methidation on enzyme activity and tissue necrosis of carp, following exposure to the pesticides singly or in combination. Environ Pollut 55:123-135.

Under aquarium conditions, treatment with paraquat and methidathion resulted in cell damage and stress in carp, indicated by glutamate dehydrogenase, glutamate oxaloacetate transaminase and lactate dehydrogenase activities, and by blood sugar levels. Paraquat was synergistic with methidathion in certain cases, resulting in dilated extracellular spaces (light microscope) and cell autolysis (electron microscope) in the liver.

10. AZEVEDO, J.A. 1973. Pesticide investigations: pesticide residue monitoring of wildlife. Calif FW-1-R-10/Wk Pl 2/Job 4. California Department of Fish and Game. 13 pp.

Eggs from nests of fish-eating waterbirds and raptors were analyzed for OC content. The highest residues were found in herons and egrets. DDT and associated metabolite concentrations mirrored use patterns from 1969 to 1972: the average concentration ranged from 28 ppm in 1972 to 45 ppm in 1970. PCB concentrations ranged from <0.01 to 3050 ppm (mean = 118 ppm). Highest dieldrin residues (mean = 2.4 ppm, range 0.6 to 4.7 ppm) were found in red-tailed hawk egg yolk. Great blue heron egg yolk contained dieldrin residues ranging from 0.2 to 3.8 ppm,

average 1.7 ppm. DDT and DDT metabolite concentrations in Brandt's cormorant tissue samples collected in 1971 increased with age from 1.6 ppm in 1-year-old birds to 12.6 ppm in adults (>3 years of age). Concentrations also varied seasonally, being highest (15.8 ppm) during May and June and lowest (5.2 ppm) from August to December.

11. BABCOCK, K.M., and E.L. Flickinger. 1977. Dieldrin mortality of lesser snow geese in Missouri. J Wildl Manage 41:100-103.

In March and April 1974, 157 lesser snow geese died from dieldrin poisoning during northern migration through western Missouri. Sick geese showed a lack of awareness followed by an inability to fly. Nervous pecking, uncontrolled head jerking, and violent body tremors with rapid wing movement were observed prior to death. Necropsies showed no evidence of infectious disease or significant parasitic infection. Dieldrin residue concentrations ranged from 13.0 to 24.5 ppm wet weight. The evidence suggested that mortality was due to aldrin-treated rice ingested on Texas wintering grounds.

12. BALCOMB, R. 1983. Secondary poisoning of red-shouldered hawks with carbofuran. J Wildl Manage 47:1129-1132.

Two red-shouldered hawks, one near death and one partially paralyzed, were collected from a Maryland cornfield. The more seriously impaired bird was sacrificed for necropsy. Shrew and grackle remains were recovered from the gut. Carbofuran was found in the gut contents and body tissue at concentrations of 3.1 and 0.07 ppm, respectively. Several small vertebrates from the cornfield had carbofuran concentrations, expressed as percent of published LD₅₀ values, from 30 to 994.

13. BALCOMB, R., C.A. Bowen, D. Wright, and M. Law. 1984. Effects on wildlife of at-planting corn applications of granular carbofuran. J Wildl Manage 48:1353-1359.

A search conducted within 96 h of application of granular carbofuran (applied at time of planting) in a cornfield in Frederick County, Md., yielded six dead songbirds (Passeriformes). Five contained carbofuran residues from 1.6 to 17.0 ppm (GI tract and liver combined). A dead white-footed mouse (*Peromyscus leucopus*) found 24 h post-treatment contained 15.1 ppm carbofuran. Laboratory tests on house sparrows and red-winged blackbirds revealed that doses as low as a single granule caused death in both species.

14. LIN, B., J. Jin, and S.F. Dowdle. 1988. Soil fertility and the transition from low-input to high-input agriculture. Better Crops International, June 1988:1-4.

In China, the switch from total organic farming to high use of chemical fertilizers produced dramatically increased yields only initially. Severe adverse effects are now seen, including increasing incidence

of certain diseases, declining soil fertility, and stagnation in the increase of agricultural production. The authors encourage the use of organic and inorganic fertilizers. Studies have shown that the balanced use of both, under certain conditions, leads to greater yields than when either was used separately.

15. BART, J. 1979. Effects of acephate and sevin on forest birds. J Wildl Manage 43:544-549.

Acephate was applied to two 200-ha mixed hardwood plots in New York aerially at a rate of 0.55 kg/ha. Sevin was applied in water at a normal rate of 1.1 kg/ha, and subsequently in an oil carrier at the same rate, and later at five times the normal rate (5.5 kg/ha). Modified singing-male surveys indicated a significant decline in red-eyed vireo populations after acephate treatment. Although not significant, declines also occurred in the number of rose-breasted grosbeaks and scarlet tanagers on the same plots. No Sevin treatment had any apparent effect on bird numbers or on growth rate of nestlings.

16. BART, J., and L. Hunter. 1978. Ecological impacts of forest insecticides: an annotated bibliography. New York Cooperative Wildlife Research Unit, Cornell University, Ithaca, NY. 128 pp.

Part 1 summarizes and evaluates studies; Part 2 is an annotated bibliography of studies completed before 1977. Only papers concerning direct aerial application of insecticides to forests and laboratory studies regarding toxicity and persistence (but which permit inferences to be drawn) were treated. [Note: Some of the studies cited are also included in this bibliography.]

17. BATT, B.D.J., J.A. Black, and W.F. Cowan. 1980. Effects of glyphosate herbicide on chicken egg hatchability. Can J Zool 58:1940-1942.

Hatchability and length of incubation period of domestic chicken eggs were unaffected by glyphosate at three different concentrations and at four embryo ages. The data suggest that the use of glyphosate in zero-tillage farming should not affect the hatchability of upland nesting bird eggs.

18. BECHARD, M. 1981. DDT and hexachlorobenzene residues in Southeastern Washington Swainson's hawks (*Buteo swainsoni*). Bull Environ Contam Toxicol 26:247-253.

Tissue samples from Swainson's hawk, ferruginous hawk, and American kestrel carcasses were relatively free of OC residues. Eggs contained an average of 0.65 ppm *p,p'*-DDE and were free of other metabolites. Only trace levels of heptachlor epoxide, dieldrin, oxylchlorodane, and PCB were found. Hexachlorobenzene concentrations were greatest (5.2 ppm) in Swainson's hawk. There was no apparent relationship between pesticide concentrations and clutch size or survivorship.

19. BENNETT, R.S., J.K. Bennett, S.M. Meyers, B. Marden, and A. Fairbrother. 1990. Effects of organophosphorus compounds on avian reproductive success. Pp 25-26 in Proceedings: environmental contaminants and their effects on biota of the Northern Great Plains. North Dakota Chapter, The Wildlife Society, Bismarck.

Mallard hens were exposed to methyl parathion (400 ppm in feed) during egg laying. A significant reduction in egg production resulted. Seventeen of 23 birds exposed during incubation did not complete incubation: four died, seven abandoned their nests, and the remaining six birds exhibited reduced nest attentiveness for at least 2 days. Nest abandonment was correlated with reduced serum levels of prolactin, indicating the behavior was the result of chemically induced physiological alteration. Free-living red-winged blackbirds orally gavaged during the incubation period did not experience reduced nest success, as measured by the number of birds fledged, even though the adult females were ataxic, lacrimose, and lethargic to varying degrees. Direct exposure of red-winged blackbird and European starling nestlings to organophosphorus insecticides resulted in significant mortality and decreased growth rates at doses non-lethal to adults. Adverse behavioral changes were observed in 5-day-old mallard ducklings gavaged orally with 4 mg/kg methyl parathion. Treated broods spent more time on land preening and loafing than did their control counterparts. Hens remained with their broods and kept all ducklings together even when treated young were too sick to move. Forty percent of treated ducklings (and no control ducklings) died the first day of the experiment. Exposure to methyl parathion can potentially impact recruitment in avian populations throughout all aspects of the reproductive cycle.

20. BERGER, D., G. Craig, and J. Enderson. 1978. Nesting performance of peregrine falcons in Colorado. Colorado W-124-R/Wk. Pl. 5/Job 1. Colorado Division of Wildlife. 14 pp.

Egg shells from 11 occupied peregrine falcon nest sites showed approximately 20% thinning. Pesticide analysis of nine eggs showed DDE concentrations from 10.9 to 43.0 ppm. PCB concentrations ranged from 0.70 to 9.70 ppm. From analysis of remains found in nests, the major sources of contamination were thought to be violet-green swallows, white-throated swifts, and American robins, with concentrations of 5.81, 1.75, and 2.07 ppm DDE and 0.31, 0.12, and 0.12 ppm PCB in fat, respectively.

21. BERKMAN, H.E., C.F. Rabeni, and T.P. Boyle. 1986. Biomonitoring of stream quality in agricultural areas: fish versus invertebrates. Environ Manage 10:413-419.

Fish and invertebrate communities were evaluated for their ability to reflect habitat quality of sedi-

ment-impacted streams. Habitat quality was defined by a combination of substrate composition, riparian type, buffer strip width, and land use. Invertebrates were most sensitive to differences in habitat when various community parameters (e.g., species diversity) were used. Information gained from fish communities was increased by use of the Index of Biotic Integrity. The authors believed the more direct impact of sediments to invertebrate communities probably accounted for the differences noted.

22. BEYER, W.N., and C.D. Gish. 1980. Persistence in earthworms and potential hazards to birds of soil applied DDT, dieldrin and heptachlor. J Appl Ecol 17:295-307.

Bioconcentration factors for DDT, dieldrin, and heptachlor epoxide were 5, 8, and 10, respectively. Heptachlor applied at 2.2 kg/ha yielded concentrations still hazardous to earthworm-eating birds 3 years post spray. Application at 9.0 kg/ha remained hazardous for 11 years.

23. BISCHOFF, A.I. 1967. Waterfowl losses from suspected diazinon poisoning, Imperial Valley, January-February, 1967. Calif FW-1-R-4/Wk Pl 1/Job 4. California Department of Fish and Game. 9 pp.

Approximately 300 wigeon and 4 Canada geese were found dead in California alfalfa fields after diazinon application. The field where the geese were found had received 0.57 L diazinon in 46.7 L of water per ha the morning of the previous day. Alfalfa samples collected from this field 7 h post-application contained 38 ppm diazinon. Diazinon residues in alfalfa samples from wigeon proventriculi and gizzards were at concentrations of 10 and 2.7 ppm, respectively. Proventriculus samples from the geese indicated 6.2 ppm diazinon. Laboratory toxicity tests showed an LD₅₀ for wigeon of approximately 2.5 ppm diazinon.

24. BLUS, L.J., and R.M. Prouty. 1979. Organochlorine pollutants and population status of least terns in South Carolina. Wilson Bull 91:62-71.

Least tern eggs on the Cape Romain National Wildlife Refuge, South Carolina, from 1972 through 1975 contained low concentrations of DDE (0.33-0.63 ppm), PCBs (0.40-1.08 ppm), and other OC pollutants. Eggshell thickness, although less than the pre-1947 mean, was not significantly different from the earlier mean. OCs were determined to pose no identifiable threat to least tern populations in South Carolina.

25. BLUS, L.J., C.J. Henny, D.J. Lenhart, and T.E. Kaiser. 1984. Effects of heptachlor- and lindane-treated seed on Canada geese. J Wildl Manage 48:1097-1111.

Heptachlor-treated wheat was said to have caused a decline in resident western Canada geese due to lowered reproductive success and increased

mortality of adult birds. Heptachlor epoxide (HE) concentrations in goose brain tissue ranged from below detection limits to 22.0 ppm, well above the 8-9 ppm known to be lethal to passerines. HE concentrations in eggs were highly correlated with nest success. Only 17% of nests containing eggs with >10.0 ppm HE were successful, as opposed to 80 to 83% nest success when concentrations were <10.0 ppm. Lindane-treated seed caused no apparent effects under normal circumstances, however.

26. BLUS, L.J., O.H. Pattee, C.J. Henny, and R.M. Prouty. 1983. First records of chlordane-related mortality in wild birds. J Wildl Manage 47:196-198.

Two adult male red-shouldered hawks and an adult female great horned owl, all found dead, had lethal concentrations of heptachlor epoxide (3.4-5.8 ppm) and oxychlordane (1.9-5.2 ppm) in brain tissue. These are both metabolites of technical chlordane. Dieldrin levels (3.4 and 4.7 ppm) in the hawks were also near or within the lethal range of 4-5 ppm (obtained using experimental birds). Body condition of the birds was indicative of OC poisoning.

27. BOGACKA, T., and J. Groba. 1980. Toksycznosc i biodegradacja chlorfenwinfosu, karbarylu oraz propoksuru w srodowisku wotnym [Toxicity and biodegradation of chlorfenwinphos, carbaryl and propoxur in water environment]. Bromatol Chem Toksykol 13:151-158.

Pesticide degradation decreased with water temperature, thus compounds remained toxic for longer periods in colder than in warmer water. Carbaryl degraded more rapidly than propoxur, which degraded more rapidly than chlorfenwinphos.

28. BORGMANN, U., and M. Munawar. 1989. New standardized sediment bioassay protocol using the amphipod *Hyalella azteca* (Saussure). Hydrobiol 188/189:425-531.

A bioassay procedure for testing the chronic toxicity of sediments to *Hyalella azteca* is described. The authors suggest a 4-week exposure of young (0-1 week old) amphipods should provide a suitable standardized chronic toxicity test for sediments.

29. BORTHWICK, S.M. 1988. Impact of agricultural pesticides on aquatic invertebrates inhabiting prairie wetlands. M.S. thesis, Colorado State University, Fort Collins. 90 pp.

Survival of invertebrates within enclosures was monitored after aerial application of selected pesticides. 2,4-D had no acute effects on survival. Survival of conchostracans and odonates was reduced significantly by fenvalerate. Ethyl parathion was more toxic than methyl parathion and caused complete mortality of amphipods and odonates within 1 day of application. Survival of the same taxa was <30% when subjected to methyl parathion. The most

sensitive invertebrate was the amphipod *Hyaella azteca*; gastropods were least sensitive.

30. BOYLE, T.P. 1980. Effects of the aquatic herbicide 2,4-D DMA on the ecology of experimental ponds. Environ Pollut (Ser A) 21:35-49.

Growth of rooted macrophytes and fish was stimulated by the dimethylamine salt of 2,4-D at rates of 5 and 10 kg/ha, respectively. Gross production in treated ponds was more highly related to planktonic chlorophyll *a* and dissolved nutrients than in treated ponds.

31. BOYLE, T.P. 1983. Role and application of semicontrolled ecosystem research in the assessment of environmental contaminants. Pp 406-413 in W.E. Bishop, R.D. Cardwell, and B.B. Heidolph (eds), Aquatic toxicology and hazard assessment: Sixth Symposium, ASTM STP 802. American Society for Testing and Materials, Philadelphia, Pa.

Procedures for assessing toxic effects of potential environmental contaminants are hierarchical and consist of the following steps: (1) single-species acute and chronic toxicity tests; (2) tests in laboratory microcosms to assess ecological interactions in simple communities; (3) studies to determine chemical-induced changes in ecosystem structure or function, using replicate semi-controlled pond and stream ecosystems; and (4) development and use of techniques for assessment of the actual impact of chemicals on natural ecosystems. Experiments using semi-controlled artificial ecosystems in ponds and streams must cover a period of time (1 to 2 years) that allows identification of the magnitude of both primary direct and secondary indirect effects at the community and ecosystem levels. Results from such studies are invaluable in assessing the applicability of laboratory bioassays, examining ecosystem qualities that enable resistance to and recovery from contaminant stress, and in answering questions regarding the effect of long-term stress associated with the use of herbicides or insecticides.

32. BOYLE, T.P. 1984. Effect of environmental contaminants on aquatic algae. Pp 237-256 in L.E. Shubert (ed), Algae as ecological indicators. Academic Press, London.

[A review paper; only the highlights are presented here.] Algal response to toxic contaminants is greatly dependent on many physical and chemical factors including temperature, water hardness, pH, and nutrient conditions. Organophosphorus insecticides are more toxic than OCs (both inhibit photosynthesis), but are less persistent in the environment, thus do not present a chronic problem unless continuously added to the environment. Some mosquito larvicides, including methoprene, propoxur, temephos, and methoxychlor, cause an increase in nitrogen fixation by blue-green algae. Diflubenzuron reduced nitrogen fixation. Indirect effects of contam-

inants to the algal community include the release of nutrients from mature macrophyte communities treated with herbicides. Releases of nutrients sufficient to cause an algal bloom, however, do not seem to occur without severe deoxygenation of the water due to increased BOD from rapid macrophyte decay. On the other hand, the suppression of macrophyte growth by herbicides applied at concentrations not toxic to the algae resulted in an increase in the oxidation-reduction potential of the bottom mud. This prevented the solubilization of usable forms of nitrogen and phosphorus. The resultant lack of nutrients in the water column significantly decreased planktonic algae. [As algae are a major food item for aquatic invertebrates, a reduction in algal biomass would lead to a reduction in invertebrate biomass and less food for waterfowl.] A reduction in the number of aquatic invertebrates after insecticide treatment led to increased phytoplankton production and abundance. Algae have been noted to bioconcentrate environmental contaminants. Bioconcentration factors (BCF) were extremely high for some species/pesticide combinations. For example, *Skeletonema costatum*, after a 2-h exposure to 1.7 $\mu\text{g/L}$ dieldrin, had a concentration of 27.0 ppm, a BCF of 15,882. *Nostoc muscorum* showed a similar response to dieldrin with a BCF of 18,484, but the same species did not bioconcentrate aldrin at all. Algae have been implicated in the degradation of organic chemicals and may be an important factor in the mitigation of contaminant effects on other organisms.

33. BRACH, J. 1989. Agriculture and water quality: best management practices for Minnesota. Minnesota Pollution Control Agency, St. Paul. 64 pp.

This handbook is divided into two parts: (1) a description of major non-point source pollutants in Minnesota, and (2) descriptions of agricultural practices that can protect and enhance water quality. Each section in the practice portion contains a short description, an explanation of the benefits, and a discussion on planning considerations. A resource directory lists organizations that can provide information, technical and financial assistance, and other services related to the application of best management practices for agriculture.

34. BRADBURY, S.P., and J.R. Coats. 1989. Comparative toxicology of the pyrethroid insecticides. Rev Environ Contam Toxicol 108:133-177.

[A review paper; only those data applicable to avian and aquatic species are presented here.] Acute oral LD₅₀ values for most synthetic pyrethroids were generally >1000 ppm. Deltamethrin and tefluthrin LD₅₀ values for mallards were >4000 and 4190 ppm, respectively. Chronic effects were only detectable at very high (15,000-27,000 ppm) concentrations. One study using deltamethrin showed some indication of embryotoxicity; otherwise, reproductive function

seemed to be unimpaired. Field studies have failed to show any harmful direct effects on birds. All synthetic pyrethroids tested were highly toxic to fish. LC₅₀ values for fathead minnows ranged from 0.22 µg/L flucythrinate to 15.6 µg/L permethrin. The median for all species and chemicals was generally >10.0 µg/L. Effects of temperature and body weight seemed to be inversely proportional to pyrethroid toxicity. Under field conditions, pyrethroid toxicities appeared greatly reduced, probably due to adsorption of the toxicant to suspended solids. Little is known concerning chronic toxicity, but those data that are available indicate acute-chronic ratios for fenvalerate, flucythrinate, and permethrin to range from <1 to about 40. Bioconcentration studies conducted at the conclusion of chronic tests indicate BCFs for the fathead minnow of 3200, 2800, and 4000 for fenvalerate, permethrin, and flucythrinate, respectively. Highly toxic to aquatic insects, 24-h LC₅₀ values for deltamethrin, cypermethrin, fenvalerate, and permethrin in mosquito and midge larvae ranged from 0.02 to 13.0 µg/L. Deltamethrin was generally reported as the most toxic. Twenty-eight-day flow-through exposures indicated LC₅₀ values of fenvalerate and permethrin to four benthic species in the range of 0.03 to 0.17 µg/L. Mayfly (*Ephemera* sp) and Rhaginoid fly (*Atherix* sp) larvae experienced 80 and 30% mortality at the lowest concentration of 0.02 µg/L. Crustaceans were particularly sensitive to pyrethroids with LC₅₀ values generally well below 1.0 µg/L. The 96-h LC₅₀ for some estuarine species has been reported to be as low as 0.003 µg/L. Again, deltamethrin was most toxic, and fenvalerate was least harmful. Molluscs were relatively tolerant to pyrethroids.

35. BREWER, L.W., C.J. Driver, R.J. Kendall, C. Zenier, and T.E. Lacher, Jr. 1988. Effects of methyl parathion in ducks and duck broods. Environ Toxicol Chem 7:375-379.

Nesting mallards, blue-winged teal, and wood ducks inhabiting two agricultural fields bordered by waterways were fitted with radio transmitters and their activities monitored daily. One field was treated with methyl parathion at a rate of 1.4 kg AI/ha. The other was untreated. Brood abandonment by hens and nesting hen mortality were observed only on the treated field. Brain ChE levels were significantly depressed in two of three nesting hens. In the untreated field, 58% of 37 ducklings survived to day 22 post-spray, but only 16% of 24 ducklings in the treated field survived to day 22. The average daily rate of duckling loss was greater in the treated than untreated field. Nest abandonment rates did not appear to be correlated with pesticide application.

36. BROWN, P.W., and M.L. Hunter, Jr. 1985. Potential effects of insecticides on the survival of dabbling duck broods. J Minnesota Acad Sci 50:41-44.

Black duck and mallard ducklings raised on wetlands treated with carbaryl took 5 days longer to reach the normal 14-day body weight. Behavioral changes were also noted. Ducklings on treated ponds increased time in searching and moving about and reduced time in resting when compared to ducklings on control ponds. The reduction in growth rate and the behavioral changes seemed to relate to reductions in invertebrate numbers and biomass due to spraying. As most mortality in normal broods occurs during the first 14 days of life, the authors concluded that depressed growth rates, which would increase the amount of time that ducklings were most vulnerable, should lead to increased mortality.

37. BUHL, K.J., and N.L. Faerber. 1989. Acute toxicity of selected herbicides and surfactants to larvae of the midge *Chironomus riparius*. Arch Environ Contam Toxicol 18:530-536.

Eight commercial herbicides (Eradicane (EPTC), Fargo (trallate), Lasso (alachlor), ME4 Brominal (bromoxynil), Ramrod (propachlor), Rodeo (glyphosate), Sencor (metribuzin), and Sutan + (butylate)) and two surfactants (Activator N.F. and Ortho X-77) were tested for acute toxicity to midge (*Chironomus riparius*) larvae under static conditions. Technical grade alachlor, metribuzin, propachlor, and triallate were also tested for comparison with the formulated products. EC₅₀ values ranged from 1.23 mg/L (Fargo) to 5,600 mg/L (Rodeo). Fargo, ME4 Brominal, and Ramrod were moderately toxic; Lasso, Sutan +, and Eradicane were slightly toxic; and Sencor and Rodeo were essentially non-toxic to the midge larvae. EC₅₀ (48 h) values of the two surfactants were nearly identical (8.6 and 8.9 mg/L) and were considered moderately toxic. In some cases the inert ingredients had a significant effect on the toxicity of the AI. Fargo was twice as toxic as technical grade triallate, but Sencor was nearly three times less toxic than technical grade metribuzin. A comparison with other published data regarding the toxicity of these compounds indicated that the relative order of toxicity to *C. riparius* was similar to those obtained for fish and other aquatic invertebrates. Acute test results indicated Ramrod, ME4 Brominal, and Lasso would pose the greatest threat to midge larvae from runoff during a storm.

38. BULL, D.L. 1979. Fate and efficacy of acephate after application to plants and insects. J Agric Food Chem 27:268-272.

After a foliar application of acephate, cotton leaves absorbed >50% in 24 h. Unabsorbed residues were depleted in 48 h. Of the amount absorbed, approximately 9% of the dose was metabolized by the plant to methamidophos. Absorbed material and the metabolites were rapidly translocated throughout the

plant, including the fruit. With normal application methods, translocated toxicant concentrations appeared to be insufficient to cause mortality of plant pests feeding on new growth or fruit.

39. BUNCH, T.D., and J.B. Low. 1973. Effects of dieldrin on chromosomes of semi-domestic mallards. *J Wildl Manage* 37:51-57.

Juvenile mallards from parents which had received long-term doses of dieldrin were given 0, 4, 10, or 30 ppm dieldrin for approximately 60 days. The level of treatment of each juvenile matched that received by its parent. Examination of femoral bone marrow cultures at the end of the 60-day period showed no significant chromosome abnormalities at any treatment level. In those ducks receiving 30 ppm dieldrin, however, the mitotic index was reduced >5 times when compared with control birds. Lymphocytic cultures from adult, non-treated ducks were treated with dieldrin at concentrations varying from 0.1 to 100 ppm. Chromosome aberrations in cultures treated with 30 ppm or less did not differ from controls, but cultures receiving 100 ppm dieldrin exhibited at least a twofold increase in chromosome structural abnormalities over that of control animals. Significant reductions in the mitotic index were noted at all treatment levels and were proportional to treatment level. The authors concluded that levels of dieldrin commonly found in free-living waterbirds are probably too low to cause chromosome aberrations.

40. BUSBY, D.G., P.A. Pearce, and N.R. Garrity. 1981. Brain cholinesterase response in songbirds exposed to experimental fenitrothion spraying in New Brunswick, Canada. *Bull Environ Contam Toxicol* 26:401-406.

Trials determined the efficacy of a fenitrothion formulation containing a low-drift additive. Aerial application to half of 12 40-ha treatment plots was by boom and nozzle (BN), and to the other half by rotary atomizer (RA). Untreated control plots were at least 10 km from treatment areas. Application rates were 280 g/ha on all treatment plots. Five to 23 individuals from each of the five most dominant species (Tennessee, magnolia, Blackburnian, and bay-breasted warblers and white-throated sparrow) were collected from control and treatment plots (bay-breasted warblers were not found on the RA plots and Blackburnian warblers were not found on the BN plots) within 48 h post-spray. All species from treatment plots showed some degree of ChE inhibition when compared with birds from control plots. BN application caused the most ChE depression, inhibiting 30% of the samples by >20%. More than 50% inhibition was found in three birds for each method of application. Whereas bay-breasted warblers from BN plots showed the most pronounced depression, the greatest ChE reduction (59%) was observed from a white-throated sparrow collected from a BN plot. There was no significant difference in ChE values between any of the species from the control plots.

41. BUSBY, D.G., P.A. Pearce, and N.R. Garrity. 1982. Brain cholinesterase inhibition in forest passerines exposed to experimental aminocarb spraying. *Bull Environ Contam Toxicol* 28:225-229.

Five to 48 individuals of five species of forest-dwelling birds (Tennessee warbler, yellow-rumped warbler, Blackburnian warbler, bay-breasted warbler, and American redstart) were collected 2-48 h post-spray from fir-spruce control plots and from plots treated with Matacil 180F (aminocarb) and an emulsifier (Atlox) by rotary atomizer at an application rate of 70 g/ha of AI. Treated plots were sprayed twice: in the evening and again 6 days later in the morning. None of the sampled species showed ChE depression as a result of pesticide application, and only four individuals from sprayed plots exhibited ChE depression of >20% below the mean value. No birds had ChE activity >50% of the mean. The authors concluded that aerial application of aminocarb at the rate indicated had no significant inhibitory effects on ChE activity in exposed songbirds.

42. BUSBY, D.G., P.A. Pearce, and N.R. Garrity. 1983. Brain ChE response in forest songbirds exposed to aerial spraying of aminocarb and possible influence of application methodology and insecticide formulation. *Bull Environ Contam Toxicol* 31:125-131.

Selected spruce-fir forest plots were sprayed twice with two different formulations of Matacil 180F. One formulation used Atlox as an emulsifier; the other was an oil-based formulation. Both were applied at the same dosage and application rate by TBM aircraft rigged with boom and nozzle sprayers. Adult male Tennessee warblers, bay-breasted warblers, magnolia warblers, American redstarts, and white-throated sparrows were collected from control plots 1-2 days pre-spray and from sprayed plots 0 to 48 h post-spray. Most species samples from the emulsion-sprayed plots showed some ChE inhibition. Tennessee and bay-breasted warblers (both foraging in the canopy) and magnolia warblers were most affected; bay-breasted warblers showed the most consistent reduction. White-throated sparrows (foraging on the ground and in the understory) were least affected. Birds from oil-sprayed plots were affected less than those from emulsion-sprayed plots. Some birds from this plot, collected after the first application, had increased, rather than inhibited, ChE activity. After the second application, brain ChE activities were similar in birds from both treatment areas due to a general increase in ChE activity in birds from the emulsion plots and a general decrease in activity in those individuals collected in the oil plots. Neither treatment block contained species-samples which were inhibited >20% below the control mean. Comparison with a previous study [entry 41] indicates a possible difference in toxicity due to application method.

43. BUSBY, D.G., P.A. Pearce, and N.R. Garrity. 1987. Effect of ultra ULV fenitrothion spraying on brain cholinesterase activity in forest songbirds. Bull Environ Contam Toxicol 39:304-311.

Aerial application of ULV fenitrothion at a rate of 0.4 L/ha on spruce-fir forest caused ChE inhibition in exposed songbirds. The amount of inhibition was dependent on species and feeding location within the canopy. Upper canopy foragers were most affected and ground foragers were least affected. Results suggest a cumulative impact with time post-spray. As ChE depression was considerably <50% below mean control activity, it is unlikely that any mortality occurred. Effects of sub-lethal ChE inhibition on behavior, reproductive success, and survival are poorly understood, but unpublished data collected by the senior author showed reduced singing activity and nest desertion and decreased growth rate of nestlings by white-throated sparrows exposed to twice the normal fenitrothion application rate.

44. BUSBY, D.G., S.B. Holmes, P.A. Pearce, and R.A. Fleming. 1987. Effect of aerial application of zectran on brain cholinesterase activity in forest songbirds. Arch Environ Contam Toxicol 16:623-639.

Individuals of seven songbird species were collected from two 300-ha blocks of coniferous forest after application of Zectran (mexacarbate). One block was sprayed at a dosage rate of 70 g AI/ha; the other at 140 g/ha. Brain ChE activity was similar among all species from a control plot. Among exposed birds, ChE activity was lowest in individuals from the plot receiving the highest dosage; however, between-plot differences were not significant. As in previous studies cited, the Tennessee warbler (an upper-canopy forager) was most affected, and white-throated sparrows (foraging on the ground and in the understory) were least affected. Other differences were noted between warblers and sparrows, however. Cholinesterase inhibition in warblers from the high-dosage block was greater and longer lasting than in those from the low-dosage block. The opposite was true for sparrows. Although brain weight explained most of the variation in ChE inhibition, inhibition was also significantly correlated with dosage in warblers.

45. CAIRNS, J., Jr. 1986. Myth of the most sensitive species. BioScience 36:670-672.

The probability of actually selecting the most sensitive species for any given toxicity test is rather remote. Current toxicity test methods make four assumptions: (1) selecting the most sensitive species from an array of test organisms means that the responses of the selected species will at least partly correspond to those of a much larger array of exposed organisms in natural systems, (2) there will be no responses at any level of organization that are more sensitive than the end points chosen for the most sensitive species, (3) savings resulting from using the

most sensitive species are not offset by the costs of bad management decisions, and (4) a species shown to be most sensitive to a limited array of toxic substances will also be most sensitive to a much larger array of toxic substances. The author illustrates the weak points inherent in each assumption. He concludes that although multispecies tests, including the use of micro- and mesocosms, are not common [at the time of writing], they should provide valuable information not gained from single-species tests. [Not mentioned is another assumption made in single-species toxicity tests: that the test organism, whatever the species, will echo the response of the same or similar organisms in nature. Many of the species used in standard acute toxicity tests are from laboratory strains with little genetic variability. Research has shown that some genotypes are much more sensitive than others to a given pollutant. Thus, not only would we have to select the most sensitive species but also the most sensitive genotype within the population. Doing this by chance alone would be highly improbable.]

46. CALL, D.J., L.T. Brooke, R.J. Kent, M.L. Knuth, C. Anderson, and C. Moriarity. 1983. Toxicity, bioconcentration, and metabolism of the herbicide propanil (3',4'-dichloropropionanilide) in freshwater fish. Arch Environ Contam Toxicol 12:175-182.

Fathead minnows were exposed to technical grade propanil in a series of acute toxicity tests. LC₅₀ values were 11.5, 10.2, 8.6, and 3.4 mg/L at 24, 48, 96, and 120 h respectively. Eggs, newly hatched fry, and juvenile fish exposed for 58 days showed no adverse effects at concentrations from 0.4 to 0.6 µg/L, dependent upon length and dry weight of juvenile fish. Bioconcentration of propanil in fathead minnows was insignificant. The herbicide was readily metabolized by rainbow trout, with at least ten metabolites formed.

47. CARSEL, R.F., and C.N. Smith. 1987. Impact of pesticides on groundwater contamination. Pp 70-84 in G.J. Marco, R.M. Hollingworth, and W. Durham (eds), Silent spring revisited. American Chemical Society, Washington, D.C.

In an evaluation of past and present pesticide use, the authors draw several conclusions: (1) pesticide characteristics have changed from nearly water-insoluble, strongly sorbed, non-mobile compounds to more water-soluble, slightly sorbed, mobile compounds, (2) ground water contamination by current pesticides is a much greater problem than any contamination resulting from pesticides produced and used through the 1960s, (3) chronic effects of low-level pesticide residues in ground water are of greater concern than acute effects, (4) ground water contamination from pesticide use is only a serious health problem if the contaminated ground water is the source of supply; thus, privately owned, shallow wells in unconfined aquifers are probably at greater

risk than large municipal wells in deeper, confined aquifers, and (5) ground water contamination by pesticides involves some human health risk which will probably have to be carefully evaluated. The combination of current pesticide application technologies, land management practices, and pesticide properties are cause for increasing environmental concern. For example, chemigation (a technology that mixes pesticides in irrigation water) increases the likelihood of ground water contamination. Conservation tillage (which leaves crop residue on the soil) retards runoff and surface water contamination, but promotes infiltration of pesticides into the soil profile. As new pesticides are developed in response to new agricultural practices and needs and as pest resistance changes and pesticide chemistry makes technical advances, the strategies for protection of ground water must keep pace.

48. CHARNETSKI, W.A. 1976. Organochlorine insecticide residues in ducklings and their dilution by growth. Bull Environ Contam Toxicol 16:138-144.

DDT, DDD, DDE, and dieldrin residues were measured in seven species of ducklings from Alberta, Canada. DDT and associated metabolite levels ranged from 0 to 36.48 ppm in fatty tissues of 96% of the birds and from 0 to 0.97 in muscle from 67% of the birds. Dieldrin residues were considerably lower, ranging from 0 to 2.62 ppm in fat and 0 to 0.11 ppm in muscle in 43 and 19% of the ducklings, respectively. Dilution due to growth was considered the most significant factor in the reduction of pesticide levels. DDT and metabolites decreased significantly with increased weight of pintail, baldpate [wigeon] and gadwall.

49. CHARNETSKI, W.A., and W.E. Stevens. 1974. Organochlorine insecticide residues in preen glands of ducks: possibility of residue excretion. Bull Environ Contam Toxicol 12:672-676.

The authors suggest that any species with a well-developed preen gland can excrete lipid soluble insecticides and their metabolites through the gland, and that during preening the same compounds or their metabolites could be reingested. The ducklings could have received their contaminant load only from the hen through the egg, and the hen probably became contaminated on the wintering grounds or during migration. DDT and dieldrin concentrations (2.29 and 3.77 ppm, respectively) in the preen gland of the lesser scaup were an order of magnitude higher than in any of the other species (American wigeon, blue-winged teal, gadwall, northern pintail).

50. CHERWONOGRODZKY, J.W. 1980. Microbial agents as insecticides. Residue Rev 76:73-96.

The author suggests that microbial agents may approach the ideal for an insecticide. Essentially non-toxic and highly specific, they would not upset

the ecological balance. Some may persist for several years, alleviating annual applications. He states that all are not equally beneficial, however, and that more research is needed before making them available as living insecticides.

51. CHYKALIUK, P.B. 1980. Bibliography of glyphosate. Texas AES Misc Publ 1443, Texas A & M University, College Station. 87 pp.

The bibliography contains 1,026 references to the Roundup formulation of glyphosate. Arranged alphabetically, the papers deal with a variety of subjects. Less than 1% of the entries address effects on aquatic organisms or other wildlife.

52. COOK, M.G. 1988. Impacts of current U.S. agricultural policy on land use. INTECOL Bull 16:29-34.

Conservation aspects of the 1985 U.S. Farm Bill are given. The author estimated that in excess of 500 million tons of topsoil are saved annually as a result of the Conservation Reserve Program.

53. COURTEMANCH, D.L., and K.E. Gibbs. 1980. Short-term and long-term effects of forest spraying of carbaryl (Sevin-4-oil) on stream invertebrates. Can Entomol 112:271-277.

Invertebrate communities in three streams in untreated (control) coniferous forest areas, three streams in areas treated with a single dose of carbaryl at an application rate of 840 g AI/ha, and three streams in areas which were treated twice (1120 g AI/ha and then 840 g AI/ha a year later) were compared. In treated areas, the drift response was up to 170 times that of control area streams. Plecoptera, Ephemeroptera, and Trichoptera populations in treated area streams showed significant declines. Plecoptera populations were still depressed after 60 days. In streams subjected to two annual treatments, pre-spray Plecoptera population levels were significantly lower than controls in the second year. Oligochaetes and dipteran populations, with the exception of *Microtendipes* (Chironomidae), showed no apparent response to treatment.

54. COWAN, W.F. 1982. Waterfowl production on zero tillage farms. Wildl Soc Bull 10:305-308.

Nest success on zero tillage farmland (cropland and native cover combined) was more than three times greater than that observed from nests on conventional tillage farms. Sixty percent of nests in cropland on zero tillage farms were successful compared to 0% in cropland subject to conventional tillage. Total duck production was 3.8 times greater on zero tillage farms.

55. COWARDIN, L.M., A.B. Sargeant, and H.F. Duebbert. 1983. Low waterfowl recruitment in the prairies: the problem, the reasons, and the challenge to management. Pp 16-18 in H. Boyd (ed), First Western Hemisphere Waterfowl and Waterbird Symposium.

Nest success estimates for the northern U.S. generally range from 5 to 15%, and recent data from a central North Dakota study reported only 8% nest success for the mallard. Nest success was lowest in cropland and highest in grassland. Hen success, the likelihood that an individual hen will have a successful nest during the season, averaged 15% during 1977-80 and was dependent upon overall nest success, age of the hen, and water conditions. At least 70% of nest losses was due to predation. When predators were removed from a 259-km² area of pot-hole habitat, nest success was observed to range between 70 and 98%. The authors recommended the development of managed breeding habitats as a way to increase duck production.

56. COWARDIN, L.M., D.S. Gilmer, and C.W. Shaiffer. 1985. Mallard recruitment in the agricultural environment of North Dakota. Wildl Monogr 92:1-37.

Recruitment of a mallard population was assessed on a large (>10,000 km²) study area in central North Dakota during 1977-80. Data were from 235 hens fitted with radio transmitters. Nest initiation was negatively correlated with mean temperature in April or May. Cropland generally was rejected for nest sites. Grassland was preferred, and hens distinctly preferred road right-of-ways and odd areas of cover. Hen success (defined in 55, above) averaged 15% and varied between years, depending on water availability. Nest success was 8%. On average, hens in the spring population recruited only 0.27 young females to the fall population. Based upon these data, the authors predict an annual population decline of 20%.

57. CUSTER, T.W., and C.A. Mitchell. 1987. Organochlorine contaminants and reproductive success of black skimmers in south Texas, 1984. J Field Ornithol 58:480-489.

Although DDE concentrations found in black skimmer eggs during this study (mean = 3.2 ppm) were one third less than in eggs from the same colony in 1979-81, nesting success was still apparently affected by OC residues. DDE concentrations were significantly higher in eggs from nests where none of the remaining eggs hatched (mean = 5.9 ppm) than in nests where all of the remaining eggs hatched (mean = 1.9 ppm). Concentrations in eggs from nests where some of the remaining eggs hatched were intermediate (mean = 3.6 ppm). There was no significant difference between PCB concentrations in 1981 and those in 1984. DDE (max = 28.4 ppm) and PCB (max = 9.1 ppm) residues were found in 98.5 and 72.6% of the eggs, respectively. Other OC compounds

found were toxaphene, dieldrin, oxychlordane, and trans-nonachlor.

58. CUSTER, T.W., E.F. Hill, and H.M. Ohlendorf. 1985. Effects on wildlife of ethyl and methyl parathion applied to California rice fields. Calif Fish Game 71:220-224.

Mammalian and avian species collected from rice fields were analyzed for ChE inhibition after application of either ethyl or methyl parathion (0.11 or 0.84 AI/ha, respectively). Mice (*Mus musculus*) and ring-necked pheasant ChE activity was significantly inhibited, when compared to controls, by methyl parathion. Ethyl parathion application caused significant ChE inhibition in 43, 33, and 37% of ring-necked pheasants, American coots, and mice, respectively. Although neither chemical appeared to be acutely hazardous to wildlife in or near treated rice fields, the authors advised cautious use of these chemicals, especially methyl parathion.

59. DABI, R.K., H.C. Gupta, and S.K. Sharma. 1980. Bio-efficacy of *Bacillus thuringiensis* Berliner against *Euproctis lunata* Walker on pearl millet. Indian J Agric Soc 50:356-358.

A kill of greater than 80% was achieved using the equivalent of 1120 g/ha of Dipel HD-1.

60. DAVIES, J.E., and R. Doon. 1987. Human health effects of pesticides. Pp 113-124 in G.J. Marco, R.M. Hollingworth, and W. Durham (eds), Silent spring revisited. American Chemical Society, Washington, D.C.

The exact number of pesticide poisonings is not known, but estimates based upon data gathered by the World Health Organization indicate that 500,000 poisonings may occur each year with a 1% fatality rate. Others have argued that the actual number is probably closer to 21,000 fatalities annually. Pesticides are often used for suicides. Over 1,000 suicides during 1978 in Sri Lanka were attributable to pesticides. The most pressing problem, however, is disposal of pesticide containers. For example, aldicarb and ethylene dibromide residues have been found in some Florida ground water systems.

61. DAVISON, K.L., and J.L. Sell. 1972. Dieldrin and *p,p'*-DDT effects on some microsomal enzymes of livers of chickens and mallard ducks. J Agric Food Chem 20:1198-1205.

Some mixed-function oxidases of hepatic microsomes of mallards and white leghorn chickens were examined. Dieldrin at concentrations of 10 and 20 µg/g of diet and DDT at 100 and 200 µg/g of diet increased cytochrome P₄₅₀ concentration and estradiol metabolism in both species, but increases were greater in ducks. DDT increased aniline hydroxylase activity in duck microsomes and had the opposite effect in chickens.

62. DELAUNE, R.D., R.P. Gambrell, W.H. Patrick, and J. Pardue. 1987. Fate and effect of petroleum hydrocarbons and toxic organics on Louisiana coastal environments. Pp 83-84 in Preprints of papers presented at the 194th American Chemical Society Meeting, v. 27 no 2. Division of Environmental Chemistry, American Chemical Society, Washington, D. C.

Oxidation-reduction potential and pH were important factors governing the activity of hydrocarbon-degrading microorganisms and subsequent mineralization rates in sediments of Louisiana's Barataria Basin. Because the herbicides 2,4-D and trifluralin are mineralized at slower rates under anaerobic conditions, surface runoff of residues of these chemicals and subsequent incorporation into anaerobic sediments will retard their degradation when compared to degradation rates in aerobic upland soils. Other chemicals and various petroleum compounds are also discussed.

63. DE SMET, K.D. 1987. Organochlorines, predators and reproductive success of the red-necked grebe in southern Manitoba. Condor 89:460-467.

Red-necked grebe eggs from Turtle Mountain Provincial Park, Manitoba, Canada, showed OC residues of eight different compounds at concentrations above 1 ppm liquid weight. PCB (Arochlor 1254/1260) and DDE residues averaged 194.8 and 74.3 ppm, respectively. Nesting losses approached 80% of 697 eggs in 179 nests. Eggshell thinning was greater than that noted in studies in 1947 and 1971-73. Clutch abandonment appeared to be linked to the presence of pesticide residues and to egg inviability.

64. DE SMET, K.D., and M.W. Shoesmith. 1988. Levels of organochlorines and PCB's in fish-eating and raptorial birds in Manitoba. Manitoba Department of Natural Resources, Winnipeg. 33 pp.

OC and PCB residue concentrations were examined in the eggs of 28 piscivorous and raptorial species in Manitoba during 1986 and 1987. DDE residues were present in all samples. Although concentrations in pooled homogenates rarely exceeded 4 ppm (wet weight), individual eggs from five species (red-necked grebe, western grebe, double-crested cormorant, great blue heron, and caspian tern) had concentrations ranging from 8 to 15 ppm. PCB residues were generally higher (from 10 to 31 ppm); a third of individual samples from red-necked grebes, western grebes, double-crested cormorants, and herring gulls exhibited 10 to 38 ppm PCB. Dieldrin, heptachlor epoxide, mirex, DDD, β -BHC, and cis-chlordane concentrations rarely exceeded 0.5 ppm in pooled homogenates and 1.0 ppm in individual eggs. Organochlorine residues (includes PCBs) in eggs of the common loon, red-necked grebe, western grebe, great blue heron, merlin, herring gull, Bonaparte's gull, caspian tern, and loggerhead shrike were suffi-

ciently elevated to adversely affect recruitment. Nevertheless, data obtained in this study indicated a downward trend in OC levels during the past decade.

65. DeWEESE, L.R., L.C. McEwen, L.A. Settini, and R.D. Deblinger. 1983. Effects on birds of fenthion aerial application for mosquito control. J Econ Entomol 76:906-911.

Aerial application of fenthion at 47 g AI/ha in a low-volume formulation resulted in sickness or death for 99 birds and 15 mammals. Mean brain ChE activity in dead birds ranged from 6.9 (Wilson's phalarope, $n = 3$) to 23.0% (horned lark, $n = 1$) of activity in control animals. Cholinesterase activity in sick birds ranged from 9.4 to 20.6%, as measured in a killdeer and two savannah sparrows, respectively. Census data indicated that avian population declines were greatest in areas with greatest mortality.

66. DeWEESE, L.R., L.C. McEwen, G.L. Hensler, and B.E. Petersen. 1986. Organochlorine contaminants in Passeriformes and other avian prey of the peregrine falcon in the western United States. Environ Toxicol Chem 5:675-693.

Composite samples of bird carcasses (less beak, tarsi, GI tract, and feathers) collected from eight western states in 1980 were analyzed for OC pesticide content. Chemicals detected at concentrations greater than 0.05 ppm were (in order of frequency) DDE, PCBs, hexachlorocyclohexane, heptachlor epoxide, oxychlordane, dieldrin, and toxaphene. DDE and PCBs accounted for 72 and 3% of total OC concentrations, respectively. Geometric mean concentrations of DDE were 12.0, 5.9, and 2.7 in tree swallows, killdeer, and Brewer's blackbirds. Eight migratory species showed DDE concentrations 13 times higher than four resident species, but PCB residues were similar in both groups. DDE, PCB, and total OC concentrations were greatest in insectivores. Males of some species showed higher residues than did females. Residue concentrations in killdeer, Brewer's blackbirds, and violet-green swallows were significantly related to latitude and longitude of origin. DDE concentrations in the fat of some individual tree swallows and killdeer were in the lethal range if 15 to 20% of the stored DDE were rapidly mobilized to the brain. Samples of 13 species contained DDE concentrations greater than 3 ppm, sufficient to inhibit normal reproduction of any avian predators which might feed on them.

67. DEWEY, S.L. 1986. Effects of the herbicide atrazine on aquatic insect community structure and emergence. Ecology 67:148-162.

Atrazine was applied to experimental ponds at concentrations of 0, 20, 100, and 500 $\mu\text{g/L}$. Physical, chemical, and biological variables were measured. Aquatic insect community structure was monitored using partially submerged funnel submergence traps. Atrazine had no effect on water temperature or dissolved oxygen concentrations but did cause a signifi-

cant increase in turbidity. Turbidity, however, could not be correlated with emerging insect species richness or abundance. Macrophyte production was inversely correlated with atrazine concentration, but the alga (*Chara* sp) showed resistance up to 100 µg/L. At atrazine concentrations of 20 µg/L, emergence of the chironomid *Labrundinia pilosella* was significantly reduced. Three other species (*Dicrotendipes modestus*, *Parachironomus chaetoalvus*, *Cricotopus* cf. *sylvestris*) emerged earlier from atrazine-treated ponds than from control ponds. Benthic insect species richness, species equitability (evenness), and total emergence all declined significantly with the addition of atrazine. In general, predator species showed no response to atrazine treatment, and non-predatory species declined in abundance. The lowest concentration at which atrazine affected aquatic insects (20 µg/L) was one order of magnitude lower than the lowest concentration shown to have a toxic effect on *Chironomus tentans* in an earlier laboratory study. The results indicate that insect community effects were indirect, probably due to reductions of nonpredatory food and habitat resources.

68. DIAZ-COLON, J.D., and R.W. Bovey. 1980. Selected bibliography of the phenoxy herbicides. IX. Toxicological and physiological effects of 2,4-D. Texas AES Misc Publ 1454, Texas A & M University, College Station. 92 pp.

A listing of 810 references deals with the toxicological and physiological effects of 2,4-D on animals, humans, plants, and microorganisms. Acute, subacute, and chronic toxicity effects (including reproductive, cytogenic, and carcinogenic responses) are listed.

69. DICKERMAN, J.A., A.J. Stewart, and J.C. Lance. 1985. Impact of wetlands on the movement of water and nonpoint pollutants from agricultural watersheds. USDA Rep., Water Quality and Watershed Research Laboratory, Durant, Okla. 92 pp.

[Pages 59-64 address the fate of pesticides in wetlands. A synopsis of these pages follows.] Of some 200 million kg of pesticides used annually for agriculture, some 1 to 4 million kg are lost to surface waters yearly in agricultural runoff. Pesticides are more likely to enter run-off water if they sorb to surface soil particles, are applied as wetttable powders, or have solubilities greater than about 10 ppm. Run-off losses typically decline exponentially with time post-application; they are much greater if a critical run-off event occurs within 2 weeks of application; and they typically exceed 2% of the applied amount during a catastrophic run-off event, regardless of timing or intensity of rainfall. Erosion control methods can reduce the runoff of many hydrophobic pesticides such as aldrin, dieldrin, DDT, chlordane, and arachlor, but are less effective for relatively soluble pesticides such as atrazine, alachlor, carbofuran, propachlor, and metribuzin. Pesticides entering an aquatic system, either adsorbed to sediment particles

or in solution, may be permanently or temporarily tied up by sedimentation, lost to the atmosphere by volatilization, chemically changed as a result of hydrolysis, microbial action, or photolysis, or pass through the wetland unaltered. The fate of each is governed by the chemical characteristics of the pesticide and by physicochemical conditions in the wetland. Several generalities may be made concerning pesticide persistence in wetland habitats. OC pesticides are most persistent and frequently sorb strongly to soil particles. The best predictor of the sorptive tendency of a pesticide is its octanol-water partition coefficient (P_{ow}). OP insecticides, on the other hand, tend to hydrolyze rapidly in water and sediments at neutral pH. Parathion is an exception as it is resistant to chemical hydrolysis but is degraded by microbial action, both in aerobic and anaerobic conditions. Carbamates are more persistent at low pH than at alkaline conditions. Phenoxyherbicides are decomposed mainly by microbes, and although temperature sensitive, decomposition rates are generally faster in sediments. Generally, the more efficient a wetland is at trapping sediment particles from runoff, the more efficient it will be at locking up the more hazardous or persistent pesticides due to permanent sedimentation.

70. DUNKER, P.N. 1989. Ecological effects monitoring in environmental impact assessment: what can it accomplish? Environ Manage 13:797-805.

The author holds that monitoring environmental impacts is impossible [which is likely true]. He then states that the only reason to incur the expense in time and money of monitoring any environmental change would be to reduce uncertainty in predictions. Several objectives or reasons for monitoring in environmental impact assessment studies are presented. They include (1) detecting effects, (2) testing impact forecasts and forecasting models, (3) testing mitigation effectiveness, (4) improving the knowledge base for future assessments, (5) providing evidence for compensation, (6) providing an early warning of adverse change, and (7) establishing baseline knowledge. In any case, the data will provide a single time series. To make any determination of their meaning, another time series will be required for comparison. Methods of obtaining this second data set are discussed.

71. DWERNYCHUK, L.W., and D.A. Boag. 1973. Effect of herbicide-induced changes in vegetation on nesting ducks. Can Field Nat 87:155-165.

A reduction of broad-leaved plants from application of 2,4-D ester caused a reduction in the numbers of nests of lesser scaup, gadwall, and white-winged scoter. The number of nesting ducks increased with cessation of herbicide treatment.

72. EDWARDS, W.M., G.B. Triplett, Jr., and R.M. Kramer. 1980. Watershed study of glyphosate transport in runoff. J Environ Qual 9:661-665.

Roundup as a pre-seeding herbicide in no-tillage establishment of fescue and corn, was applied at 1.1, 3.36, and 8.96 kg/ha. The highest concentration (5.2 ppm) and greatest percentage (1.85%) of the amount applied was found in runoff 1 day after application. Runoff still contained 2 ppb 4 months after treatment. On one watershed, 99% of total transport occurred in the first run-off event after treatment.

73. EISLER, R. 1985. Carbofuran hazards to fish, wildlife, and invertebrates: a synoptic review. Biol Rep 85(1.3). U. S. Fish and Wildlife Service, Washington, D.C. 36 pp.

Carbofuran at recommended rates has caused sporadic and extensive kills of fish, wildlife, and invertebrates. Laboratory studies have shown that acute toxicities (96-h LC₅₀) for aquatic organisms ranged from 2.5 ppb for larval dungeness crabs (*Cancer magister*) to 125,000 ppb for a clam (*Rangia cuneata*). Other than for the crab larvae, all LC₅₀ values were above 130 ppb. In tests longer than 96 h, safe concentrations for fish were generally found to be between 15 and 23 ppb. Of birds tested, the fulvous whistling-duck was the most sensitive (14-day LD₅₀, 238 ppb), but an aerosol containing 40 ppb killed all ring-necked pheasants within 5 minutes. The most resistant avian species was the domestic chicken (LD₅₀, 25,000 to 38,900 ppb). Mammals were less sensitive than most birds, having acute oral LD₅₀ values generally greater than 2 ppm. However, the 6-h LD₅₀ for rhesus monkeys, from an aerosol, was only 2 ppb. Dermal toxicity to birds and mammals is comparatively low. LD₅₀ values ranged from about 1,000 ppm for cattle down to 100 ppm in birds. Secondary poisoning of raptors has been reported frequently in recent years. [Several entries in this bibliography address this phenomenon; see index]. Many non-target invertebrate species are killed, as might be expected. Honeybees (*Apis* spp) are extremely sensitive to carbofuran (LD₅₀, 0.16 µg/bee). Earthworms in soils treated with commercial applications of carbofuran developed fatal lesions within 72 h. At sublethal levels, carbofuran reportedly disrupts enzyme and lipid metabolism in fishes. Most investigators argue that, under current application rates, accumulation in aquatic systems is not significant and that degradation is rapid under field conditions. There are some studies, however, that indicate degradation rates may be retarded by the presence of other pesticides in the system.

74. EISLER, R. 1986. Diazinon hazards to fish, wildlife, and invertebrates: a synoptic review. Biol Rep 85(1.9). U.S. Fish and Wildlife Service, Washington, D.C. 37 pp.

At recommended rates of application, diazinon has caused the deaths of songbirds, waterfowl, and honeybees. Among aquatic organisms, 96-h LC₅₀

values ranged from <2 µg/L for some cladocerans (*Daphnia magna* and *Simocephalus serrulatus*) to over 2 million µg/L for bullfrogs (*Rana catesbeiana*). Turkeys were the most sensitive avian species tested (LD₅₀, 2.5 mg/kg body weight), and European starlings were the least sensitive (LD₅₀, 213 mg/kg). Ingestion of five granules of Diazinon 14G killed 80 and 100% of all house sparrows and red-winged blackbirds, respectively. Mammalian acute toxicities ranged from 224 mg/kg body weight for female rats (*Rattus rattus*; Diazinon 50W) to over 1,000 mg/kg for sheep (*Ovis aries*). Sublethal effects reported include spinal deformities (lordosis and scoliosis) in fathead minnows and yearling brook trout after 19 weeks in water containing 3.2 and 4.8 µg/L, respectively. Mayfly, damselfly, caddisfly, and amphipod populations were reduced (mayflies and caddisflies only) or absent from the aquatic macroinvertebrate communities after 3 and 12 weeks of exposure to 0.3 µg/L diazinon.

75. EISLER, R. 1989. Atrazine hazards to fish, wildlife, and invertebrates: a synoptic review. Biol Rep 85(1.18). U.S. Fish and Wildlife Service, Washington, D.C. 53 pp.

More than 50 million kg of atrazine are applied annually to more than 25 million ha in the U.S., primarily to control weeds in corn and sorghum. Phytotoxic concentrations have been found in ground water, lakes, and streams as a result of agricultural runoff. The half-time persistence in soils is approximately 4 days; but in dry, sandy, alkaline soils, the half-time may be as long as 385 days with low temperatures and low microbe density. In freshwater, half-time persistence is about 3 days. Sensitive aquatic plant species may experience temporary, reversible adverse effects at concentrations from 1 to 5 µg/L. Indirect effects on aquatic fauna have been recorded at concentrations of 20 µg/L and higher. Direct adverse effects to aquatic invertebrates and fish have been reported at concentrations equal to or greater than 94 µg/L. Bioaccumulation is limited and biomagnification through the foodchain is negligible in aquatic systems. Known acute oral LD₅₀ values for birds are greater than 2,000 ppm; thus, avian species are relatively immune to normal concentrations found in the environment.

76. EISLER, R. 1989. Pentachlorophenol hazards to fish wildlife, and invertebrates: a synoptic review. Biol Rep 85(1.17). U.S. Fish and Wildlife Service, Washington, D.C. 72 pp.

Used primarily as a wood preservative and only secondarily as a herbicide, insecticide, fungicide, molluscicide, or bactericide, pentachlorophenol (PCP) residues have been detected in air, precipitation, ground and surface water, fish, aquatic invertebrates, and human urine, blood, and milk. Extremely toxic, it has been the cause of numerous human occupational illnesses and deaths and significant adverse impacts on domestic animals. It is fet-

toxic and teratogenic, but evidence for mutagenicity and carcinogenicity is either incomplete or negative. The toxicity of commercial preparations is often enhanced by variable amounts of toxic impurities including chlorophenols, hexachlorobenzene, and dioxins. In living organisms it is rapidly accumulated and rapidly excreted and is degraded in the environment by chemical, microbial, and photochemical processes. Growth, survival, and reproduction may be affected in sensitive aquatic species at concentrations of 8, 3, and <1 µg/L in algae, invertebrates, and fish, respectively. Avian fatalities have been reported for oral doses of 380 to 580 mg/kg body weight and >285 mg/kg in contaminated nest materials; however, adverse sublethal effects have been reported at dietary levels as low as 1 mg/kg ration. Acute toxicosis has been noted in birds with residue concentrations >11 mg/kg fresh weight.

77. EISLER, R. 1989. Tin hazards to fish, wildlife, and invertebrates: a synoptic review. Biol Rep 85(1.15). U.S. Fish and Wildlife Service, Washington, D.C. 83 pp.

Triorganotin compounds, especially tricyclohexyltin and triphenyltin, are used extensively in agricultural pesticides. Although neither of these is as toxic to aquatic invertebrates as is tributyltin, they are both more toxic than mono-, di-, or tetraorganotin compounds. Growth of two species of marine diatoms was inhibited by 50% in 72-h exposures by triphenyltin concentrations as low as 0.6 µg/L. Acute toxicity values for triphenyltin ranged from 4.3 µg/L (72-h LC₅₀) for the marine diatom *Skeletonema costatum* to 1,000 µg/L (24-h LC₅₀) for the snail *Biomphalaria glabrata*. No data are presented regarding triphenyltin toxicity in avian species, but the acute oral LD₅₀ for tricyclohexyltin hydroxide for Japanese quail and domestic chickens was reported as 255 to 390 and 654 mg/kg body weight, respectively.

78. EISLER, R., and J. Jacknow. 1985. Toxaphene hazards to fish, wildlife, and invertebrates: a synoptic review. Biol Rep 85(1.4). U.S. Fish and Wildlife Service, Washington, D.C. 26 pp.

[Although its use was discontinued in 1989, there still may be some stocks of toxaphene, so this report was included.] Toxaphene does not appear to constitute a major threat to warm-blooded animals (acute oral LD₅₀ values ranged from 11.9 to 794 ppm in birds and from 139 to 240 ppm in the two mammals tested). It is, however, extremely toxic to freshwater and marine biota. Acute toxicities (96-h LC₅₀) ranged from 0.05 ppb in a marine crab (*Sesarma cinereum*) to 1,120 ppb for quahaug clam (*Mercenaria mercenaria*) embryos. Fifty percent of most freshwater arthropod species, however, suffered mortality at concentrations <20 ppb. Exceptions were midge larvae (*Chironomus* sp; 30 ppb), snipeflies (*Atherix* sp; 40 ppb), amphipods

(*Gammarus fasciatus*; 26 ppb), and glass shrimp (*Palaemonetes kadiakensis*; 28 ppb). The LC₅₀ for leopard frogs (*Rana sphenocephala*) ranged from 32 to 54 ppb. Maximum acceptable toxicant concentration values (based on exposure for the entire or most of the life cycle) ranged from 0.025 ppb for fathead minnows to 3.2 ppb for midge larvae (*Chironomus plumosus*).

79. ELDRIDGE, J.L., and G.L. Krapu. 1988. Influence of diet quality on clutch size and laying pattern in mallards. Auk 105:102-110.

Lack of animal protein in the diet of wild-strain mallards resulted in reduced clutch size, egg size, laying rate, number of nesting attempts, and total eggs laid when compared with siblings fed an enriched diet. Diet had no apparent effect on initiation of laying, duration, or the seasonal pattern of change in clutch and egg size with each re-nest. The authors believed the variation and pattern observed was an adaptation to a highly variable environment. Such an environment on the northern prairies decreases the probability of reproductive success as the season progresses. [A pesticide-induced reduction of aquatic invertebrates theoretically would have the same effect.]

80. ESTENIK, J.F., and W.J. Collins. 1979. In vivo and in vitro studies of mixed-function oxidase in an aquatic insect, *Chironomus riparius*. Pp 349-370 in M.A.Q. Khan, J.J. Lech, and J.J. Menn (eds), Pesticide and xenobiotic metabolism in aquatic organisms. American Chemical Society, Washington, D.C.

Chironomus riparius larvae were exposed to *p,p'*-DDT, lindane, parathion, paraoxon, malathion, malaoxon, propoxur, carbaryl, Landrin (trimethylphenyl methylcarbamate), aminocarb, mexacarbate, allethrin (90%), piperonyl butoxide (PBO), and sesamex. Short-term (24 h) acute toxicity tests were conducted for each chemical as well as for each chemical plus PBO or sesamex (DDT only). Synergistic ratios (SR; insecticide LC₅₀/insecticide-synergist LC₅₀) were calculated in addition to standard LC₅₀ values. LC₅₀ values ranged from 0.3 µg/L (dieldrin+PBO) to 1,172.2 µg/L (aminocarb+PBO). SRs for aldrin, parathion, malathion, aminocarb, and mexacarbate (+PBO in each case) were <1, indicating that the synergist was antagonistic to the action of the pesticide and that the mixture was thus less toxic than the pesticide alone. DDT+sesamex and PBO plus dieldrin, paraoxon, malaoxon, carbaryl, Landrin, propoxur, or allethrin all had SRs >1. The largest SR (102.1) was noted for allethrin+PBO; the mixture was two orders of magnitude more toxic than the pesticide alone. The presence of PBO prevented larvae from converting aldrin to dieldrin via metabolic processes. All insecticides affected the mobility of midge larvae similarly.

81. ETO, M. 1981. Structure and avian teratogenicity of organophosphorus compounds. Nippon Noyaku Gakkaishi (J Pestic Sci) 6:95-106.

Dicrotophos, diazinon, parathion, esterine, and carbaryl were strongly teratogenic to avian species. Carbaryl caused only type-I malformations. Parathion generally caused type-II malformations. The other pesticides caused both types at high dosages but generally only type I at low dosage. [Dosages were not specified in the abstract.]

82. EWEN, A.B., and M.K. Mukerji. 1980. Evaluation of *Nosema locustae* (Microsporida) as a control agent of grasshopper populations in Saskatchewan. J Invert Pathol 35:295-303.

Fifty percent of all *Melanoplus sanguinipes*, *M. packardii*, and *Camnula pellucida* populations were infected within 4-5 days after exposure to the pathogen *Nosema locustae*. Maximum numbers were infected by the 12th week. *M. sanguinipes* populations were reduced by 20, 50, and 60% by weeks 4, 9, and 12, respectively. *Melanoplus* egg production was also lowered considerably.

83. FACEMIRE, C.F. 1989. Comparison of the sensitivity of electrophoresis and ecological indices for the detection of stress in aquatic ecosystems. Ph.D. dissertation, Miami University, Oxford, Ohio. 188 pp.

Caution is advised in using species diversity indices as indicators of water quality. Data illustrate that species richness and species diversity may be greatest in areas highly impacted by contaminants. This opposes accepted theory. Analysis of selected enzyme systems of individuals from indigenous vertebrate and invertebrate populations proved to be a sensitive indicator of environmental stress due to industrial contaminants.

84. FAIRBROTHER, A., S.M. Meyers, and R.S. Bennett. 1988. Changes in mallard hen and brood behaviors in response to methyl parathion-induced illness of ducklings. Environ Toxicol Chem 7:499-503.

Mallard ducklings gavaged orally with 4 mg/kg methyl parathion and then released with their mother and untreated siblings exhibited abnormal behavior within 4 h after treatment. Untreated ducklings spent significantly more time on water feeding and swimming than did treated ducklings, which spent nearly all their time preening and loafing on land. Hens remained with their broods and kept all the ducklings together even when treated young were too sick to move. Forty percent of treated ducklings and no untreated ducklings died the first day. Generally, dosed ducklings surviving the first day survived the second day also. None of the dead ducklings nor any survivors captured at the end of the 2-day observation period had any food in their proventriculus or gizzard at the time of recovery. Results indicate that

methyl parathion exposure can affect the brood-rearing phase either by direct mortality or through behavioral changes.

85. FAN, A.M.M. 1981. Effects of pesticides on immune competency: influence of methyl parathion and carbofuran on immunologic responses to *Salmonella typhimurium* infection. Dissert Abstr Int B 41:2962.

Immunologic competence (correlated with resistance to infectious disease) in mice exposed to *Salmonella typhimurium* decreased with exposure to methyl parathion or carbofuran. However, pesticide exposure of <2-week duration did not significantly increase mortality in mice exposed to the bacterium. The results of this and other studies cited in the text indicate that environmental toxicants have a deleterious effect upon the resistance and immune competence of experimental animals.

86. FERRARO, S.P., F.A. Cole, W.A. DeBen, and R.C. Swartz. 1989. Power-cost efficiency of eight macrobenthic sampling schemes in Puget Sound, Washington, USA. Can J Fish Aquat Sci 46:2157-2165.

Power-cost efficiencies ($PCE_j = (n \times c)_{\min} / (n_j \times c_j)$), where j = sampling scheme, n = minimum number of replicate samples needed to detect a difference between locations with a probability of Type I or II errors of 0.05, c = the mean cost in time or money per replicate sample, and $(n \times c)_{\min}$ = the minimum value of $(n \times c)$ among the j sampling schemes, were determined for eight macrobenthic sampling schemes. The 0.06-m², 0- to 8-cm deep sample unit size and 1.0-mm sieve mesh size was determined to be the overall optimum sampling scheme of those studied, ranking first in PCE on 8 and second on three of 11 measures of community structure. Considering statistical power, the authors ranked the 11 measures from greatest to least as Infaunal Index, $\log_{10}(\text{mollusc biomass} + 1)$, species richness, $\log_{10}(\text{numerical abundance})$, $\log_{10}(\text{polychaete biomass} + 1)$, $\log_{10}(\text{total biomass} + 1)$, $\log_{10}(\text{crustacean biomass} + 1)$, McIntosh's Index, 1 - Simpson's Index, Shannon's Index, and Dominance Index.

87. FERREL, C.M. 1963. Detection of wildlife losses caused by pesticides. Calif W-52-R-7/Wk Pl 03/Job 02. California Department of Fish and Game. 4 pp.

Drainwater from rice fields treated with DDT caused mortality in fish, coots, and mallards. Most (approximately 95%) of the dead fish were carp.

88. FIKES, M.H., and R.A. Tubb. 1972. Dieldrin uptake in the three-ridge naiad. J Wildl Manage 36:802-809.

The three-ridge naiad (*Amblema plicata*: Pelecypoda) was evaluated as a biological indicator for dieldrin in surface water. At concentrations of 20 ppb and 20 ppt, dieldrin concentrations in naiad gills

stabilized at 17 ppm and 55 ppb, respectively, after 2 weeks of exposure. Release rates for the two treatment groups were one sixth and one fourth of the respective rates of uptake. The authors concluded that the species appeared to be an acceptable biomonitor of dieldrin.

89. FLEMING, W.J. 1981. Recovery of brain and plasma cholinesterase activities in ducklings exposed to organophosphorus pesticides. Arch Environ Contam Toxicol 10:215-229.

Brain ChE recovery rates in mallard ducklings exposed to dicrotophos and fenthion administered as a single dose vs. a 2-week dietary exposure did not differ significantly. Recovery to about 50% of normal ChE activity was rapid and followed the general model $Y = a + b(\log X)$. Further recovery was slower and followed the same model. Brain ChE activity was found to be superior to plasma ChE activity for environmental monitoring, due to a high degree of variation in plasma ChE between individuals. Recovery of brain ChE activity can be modeled to facilitate interpretation of sublethal inhibition of brain ChE activities in wild birds following exposure to OP [and carbamate] insecticides.

90. FLEMING, W.J., B.P. Pullin, and D.M. Swineford. 1984. Population trends and environmental contaminants in herons in the Tennessee Valley, 1980-81. Colonial Waterbirds 7:63-73.

Concentrations of OC and PCB residues in great blue heron and black-crowned night-heron eggs collected in 1980 were generally below those associated with decreased productivity. Green-backed heron eggs collected in 1981 near a former DDT manufacturing site, however, contained the highest DDE concentrations ever reported for the species (mean = 3.9 ppm; range 1.3 to 12 ppm). Effects on reproductive success were not assessed. Stable or increasing populations of all three species, coupled with the above, indicate that OC compounds are not adversely affecting Tennessee Valley heron populations.

91. FLEMING, W.J., G.H. Heinz, J.C. Franson, and B.A. Rattner. 1985. Toxicity of Abate 4E (temephos) in mallard ducklings and the influence of cold. Environ Toxicol Chem 4:193-199.

Mallard ducklings were fed a diet containing <0.5, 0.89, 6.0, and 59 ppm temephos for a 7-day period. Mortality in all dietary groups was greater for ducklings maintained in unheated (10 to 18 C) than in heated (39 to 41 C) brooders. Mortality due to temephos ingestion was noted only in the group receiving 59 ppm and maintained in an unheated brooder. [Although the authors say in the text that ducklings in this group exhibited brain ChE inhibition (range in dead birds from <10 to 48%), elevated plasma corticosterone concentration, and elevated creatine phosphokinase activity, the tabular data are unclear regarding these phenomena. It does appear,

however, that diets containing 6.0 ppm temephos or less do not affect duckling survival and that the toxicity of this chemical may be increased by decreasing temperatures.]

92. FLEMING, W.J., H. de Chacin, O.H. Pattee, and T.G. Lamont. 1982. Parathion accumulation in cricket frogs and its effect on American kestrels. J Toxicol Environ Health 10:921-927.

An American kestrel, fed five adult cricket frogs (*Acris crepitans*) which had been maintained in water containing 10 ppm parathion for a 96-h period, died within 3 h. The frogs had accumulated an average 4.6 ppm parathion. There was no mortality of kestrels fed frogs from groups exposed to <10 ppm.

93. FLICKINGER, E.L., and A.J. Krynitsky. 1987. Organochlorine residues in ducks on playa lakes of the Texas Panhandle and eastern New Mexico. J Wildl Dis 23:165-168.

To determine the cause of death of 1,291 ducks at playa lakes in the Texas Panhandle during January 1981 and January 1982, 23 dead ducks were necropsied and 48 adult ducks were shot for OC analysis. No OC residues were found in 46% of the ducks. Forty-four, 31, and 10% of the ducks contained DDE (0.09-1.2 ppm), heptachlor epoxide (HE; 0.13-9.3 ppm) and oxychlordan (0.11-0.38 ppm) residues, respectively. Of those containing HE residues, 94% were pintails or green-winged teal. Oxychlordan residues were found in only teal. HE residues were highest in those birds collected from feedlot-agricultural lakes, but exposure was determined to be from harvested corn fields. Pintails and teal had the highest OC residue concentrations; the two species comprised only 24 and 11% of dead birds. The authors found most mortality was probably caused by avian cholera and concluded that it was unlikely that contaminants contributed to the annual winter duck mortality in playa lakes.

94. FLICKINGER, E.L., and K.A. King. 1972. Some effects of aldrin-treated rice on Gulf Coast wildlife. J Wildl Manage 36:706-727.

Dead waterfowl, shorebirds, and passerines were collected from three gulf-coast counties in Texas from 1967 through 1971. Aldrin residues were found in samples of the dead birds and in all eggs, scavengers, predators, invertebrates, fish, frogs, and soils from the area. Whole-body dieldrin residues were highest (16-17 ppm) in fulvous tree [whistling-] ducks, but brain residues were low (<0.1-1.6 ppm). Brain residues in other waterfowl species averaged 10 ppm. Some birds were exposed by eating treated rice seed, but most were contaminated by ingestion of invertebrates. Snails and crayfish contained aldrin and dieldrin residues sufficient (average = 9.5 ppm) to account for deaths in birds using these species as a major food item. A controlled study using fulvous tree [whistling-] ducks penned in fields aerially planted with treated rice seed resulted in deaths of 3

of 10 birds. Brain residues in the dead birds were 2.5, 2.9, and 6.8 ppm.

95. FLICKINGER, E.L., C.A. Mitchell, and A.J. Krynitsky. 1986. Dieldrin and endrin residues in fulvous whistling-ducks in Texas in 1983. J Field Ornithol 57:85-90.

Analysis of adult and juvenile fulvous whistling-ducks for OC residues was conducted to determine origin of contamination. Seven of 15 and 4 of 15 adult birds collected just after arrival on the breeding grounds contained detectable (>0.1 ppm) residues of dieldrin and endrin, respectively. None of the flightless juveniles contained OC residues. Pesticide concentration levels in adult birds were higher than would be expected in birds arriving from Mexico (the mean half life of dieldrin in bird tissue is 47 d. Migration from Mexico occurs in somewhat less than 47 d, but concentrations were such that birds would have to have contained lethal concentrations prior to leaving Mexico for them to contain the concentrations measured). Consequently, results indicate that some rice farmers in Texas were probably illegally treating rice seed with aldrin or dieldrin.

96. FLICKINGER, E.L., C.A. Mitchell, D.H. White, and E.J. Kolbe. 1986. Bird poisoning from misuse of the carbamate Furadan in a Texas rice field. Wildl Soc Bull 14:59-62.

Rice seed treated illegally with Furadan 4F [carbofuran] led to the mortality of more than 100 passerine birds, mostly dickcissels and savannah sparrows. Brain ChE activity was depressed between 32 and 85% in 44% of the birds. Carbofuran residues in the gut of dead birds ranged from 0.54 to 10 ppm (mean = 3.4 ppm). Mortality continued for approximately 2 weeks after planting.

97. FLICKINGER, E.L., D.H. White, C.A. Mitchell, and T.G. Lamont. 1984. Monocrotophos and dicrotophos residues in birds as a result of misuse of organophosphates in Matagorda County, Texas. J Assoc Off Anal Chem 67:827-828.

The ingestion of rice seed bait illegally treated with either monocrotophos or dicrotophos resulted in the deaths of some 1,100 birds during March and May 1982. Brain ChE inhibition of those birds examined averaged 87% (range 82-89%). GI tracts contained residues of dicrotophos (5.6-14.0 ppm) and monocrotophos (2.1-13.0 ppm). Rice seed collected on-site contained 950 and 210 ppm monocrotophos and dicrotophos, respectively.

98. FOLEY, R.E., and G.R. Batcheller. 1988. Organochlorine contaminants in common goldeneye wintering on the Niagara River. J Wildl Manage 52:441-445.

Detectable concentrations of PCB, DDE, dieldrin, hexachlorobenzene (HCB), oxychlorane, mirex, and heptachlor epoxide (HE) were found in adult and

hatching-year common goldeneyes arriving on the wintering grounds. Adults were also collected just prior to spring migration. PCB, dieldrin, HCB, and HE concentrations in fat increased significantly between the two sampling periods. The major source of exposure was believed to be invertebrate and vertebrate prey.

99. FOLMAR, L.C. 1977. Acrolein, dalapon, dichlobenil, diquat, and endothal: bibliography of toxicity to aquatic organisms. Tech Paper 88. U.S. Fish and Wildlife Service, Washington, D.C. 16 pp.

In addition to a bibliography, toxicity tables (indicating the test organism, test type, experimental conditions, and test results) are included for the herbicides listed. Each table includes a list of references. Of the five pesticides tested, acrolein was most toxic. Acute toxicities for fish species were generally <0.25 ppm, and brown trout were most sensitive (24-h LC₅₀, 0.046 ppm). Dichlobenil was least toxic. For freshwater species, LC₅₀ values ranged from 7.0 ppm (96-h) for a stonefly, *Peteronarcys californica*, to over 22,000 ppm (48-h EC₅₀) for rainbow trout.

100. FOLMAR, L.C., H.O. Sanders, and A.M. Julin. 1979. Toxicity of the herbicide glyphosate and several of its formulations to fish and aquatic invertebrates. Arch Environ Contam Toxicol 8:269-278.

Studies to determine the acute toxicity of technical grade glyphosate, the isopropylamine salt of glyphosate, Roundup, and the Roundup surfactant were conducted. Four species of aquatic invertebrates (*Daphnia magna*, *Gammarus pseudolimnaeus*, *Chironomus plumosus*, *Ephemera walkeri*) and four species of fish (fathead minnow, channel catfish, bluegill, and rainbow trout) were used. Acute toxicities for Roundup ranged from 2.3 mg/L (96-h LC₅₀, fathead minnow) to 43.0 mg/L (48-h EC₅₀, *G. pseudolimnaeus*). Toxicities of the surfactant were similar to the herbicide. Technical grade glyphosate was less toxic than Roundup or the surfactant. The toxicity of Roundup to rainbow trout and bluegill was directly proportional to water temperature and was greater at pH 7.5 than at pH 6.5 but did not increase at pH values greater than 7.5. Toxicity increased with development stage. Eyed eggs were least sensitive. Data regarding fecundity and gonadosomatic index are presented. The authors concluded that Roundup applications at label-recommended rates along ditchbank areas of irrigation canals should not adversely affect resident populations of fish or invertebrates, but they advised caution for spring applications in lentic systems where dissolved oxygen levels are depressed or temperatures are elevated. Under these conditions, Roundup applications could be hazardous to young-of-the-year fishes.

101. FOX, G.A., P. Mineau, B. Collins, and P.C. James. 1989. Impact of the insecticide carbofuran (Furadan 480F) on the burrowing owl in Canada. Tech Rep Ser No 72. Canadian Wildlife Service, Ottawa.

During 1985, some 1.2 million ha in Saskatchewan and 420,000 ha in Alberta were treated at least once with carbofuran for grasshopper control. The authors estimated that, at the recommended rate, each square meter of treated area received 27 to 86 median lethal doses (for a 3-4 month-old mallard) of carbofuran (a median lethal dose is the quantity of chemical necessary to kill half the test population; = LD₅₀). The use of alternative chemical control agents was strongly recommended.

102. FREED, V.H. 1987. Pesticides: global use and concerns. Pp 145-158 in G.J. Marco, R.M. Hollingworth, and W. Durham (eds), Silent spring revisited. American Chemical Society, Washington, D.C. 214 pp.

This paper documents the growing global dependency upon chemical pesticides and estimates an average annual increase in pesticide use of 4 to 5% with the current level of use (more than 4 billion pounds AI annually). Western Europe and North America use about 57% of the total. Latin America, Eastern Europe, Japan, and the remaining countries use approximately 15, 11, 11, and 6%, respectively. The four foremost problems associated with pesticide use are (1) human and animal poisoning, (2) residues in foods, (3) the development of resistance by insects, and (4) safe disposal of pesticide wastes and containers.

103. FREMLING, C.R., and W.L. Mauck. 1980. Methods for using nymphs of burrowing mayflies (Ephemeroptera, *Hexagenia*) as toxicity test organisms. Pp 81-97 in A.L. Buikema, Jr., and J. Cairns, Jr. (eds), Aquatic invertebrate bioassays. ASTM STP 715.

Burrowing mayflies (*Hexagenia*) are widespread in the Western Hemisphere and are important members of the detrital foodchain. Changes in distribution and abundance due to pollution episodes indicate that they are sensitive to contaminants. Their biology is well known and they are easily cultured, handled, and observed. Thus, they offer distinct advantages over fish as toxicity test organisms. In addition to their use in monitoring contaminant impacts in a field situation, *Hexagenia* nymphs, when supplied with inert artificial substrates, are useful in a variety of static and flow-through acute and chronic bioassay procedures. Culture and test methods are described.

104. FRENZEL, R.W., and R.G. Anthony. 1989. Relationship of diets and environmental contaminants in wintering bald eagles. J Wildl Manage 53:792-802.

Bald eagles fed largely on cholera-killed waterfowl and on microtine rodents during mid- to late

winter. OC pesticide residues in prey items were low, and no elevated pesticide levels were noted in wintering eagles. Contaminant residues in prey items have caused reproductive problems for eagles resident in the Klamath Basin.

105. FRIEND, M., and D.O. Trainer. 1974. Experimental dieldrin-duck hepatitis virus interaction studies. J Wildl Manage 38:887-895.

Dieldrin exposure significantly increased mortality in ducks subsequently exposed to duck hepatitis virus (DHV) under some conditions. In one experiment, however, dieldrin was antagonistic to the effects of DHV, with reduced mortality. There were, however, physiological indications of synergism in all species and ages, even in the absence of mortality.

106. FRIEND, M., and D.O. Trainer. 1974. Experimental DDT-duck hepatitis virus interaction studies. J Wildl Manage 38:896-902.

DDT altered the response to duck hepatitis virus, and was either antagonistic or synergistic, depending on conditions. Synergistic effects were evident, however, even where no mortality occurred.

107. FRIEND, M., M.A. Haegele, D.L. Meeker, R. Hudson, and C.H. Baer. 1979. Correlations between residues of dichlorodiphenylethane, polychlorinated biphenyl, and dieldrin in the serum and tissues of mallard ducks. Pp 319-326 in F. Peter (ed), Animals as monitors of environmental pollutants. National Academy of Sciences, Washington, D.C.

Mallard ducks were studied to determine the efficacy of determining OC residue concentrations by using blood rather than tissue samples. The correlation between blood serum and fat samples was highly significant and supports the use of blood for sampling OC residues in birds.

108. GEORGHIOU, G.P. 1980. Insecticide resistance and prospects for its management. Residue Rev 76:131-145.

The increased use of pesticides has resulted in increased numbers of resistant organisms. By the end of 1978, at least 414 species had developed strains resistant to one or more pesticides.

109. GIESY, J.P., and R.A. Hoke. 1989. Freshwater sediment toxicity bioassessment: rationale for species selection and test design. J Great Lakes Res 15:539-569.

The relative merits of a variety of sediment toxicity assays are discussed. A battery of assays is recommended over any single assay method. Assays recommended for inclusion in the screening battery are Microtox, an algal assay, the *Chironomus tentans* 10-d growth assay, and the 48-h acute assay using *Daphnia magna*.

110. GIESY, J.P., C.J. Rosiu, R.L. Graney, and M.G. Henry. 1990. Benthic invertebrate bioassays with toxic sediment and pore water. Environ Toxicol Chem 9:233-248.

Five bioassay techniques and three dilution methods were compared for their utility in assessing toxicity of sediments. Lethality of *Daphnia magna* in pore water was similar to that of *Hexagenia limbata* in whole sediment. Further, the 48-h LC₅₀ for *D. magna* was approximately equal to the 10-d EC₅₀ for *C. tentans* and was similar to the toxicity that restricts benthic macroinvertebrate colonization of contaminated sediments. Although the three dilution techniques gave similar results for some assays, very different results were obtained in others; hence, dose-response relationships derived from each technique should be interpreted carefully.

111. GIESY, J.P., R.L. Graney, J.L. Newsted, C.J. Rosiu, A. Benda, R.G. Kreis, Jr., and F.J. Horvath. 1988. Comparison of three sediment bioassay methods using Detroit River sediments. Environ Toxicol Chem 7:483-498.

Three bioassays indicated that some sediments were toxic, and all were able to identify the most and least toxic sediments. However, Microtox assay of pore water was most sensitive, and the 48-h acute toxicity assay using *Daphnia magna* was least sensitive and least discriminatory. Based only on lethality, 10-d growth reduction of *Chironomus tentans* was less sensitive than the 48-h *D. magna* assay. Some locations were deemed highly toxic by one or two assays, but not by the others. Although the results of all assays were correlated, none could accurately predict the results of the other two. The authors concluded that results of the 48-h *D. magna* assay could be used to predict which sediments were sufficiently toxic to preclude benthic insects. Furthermore, based upon results of this study, they suggest that the Microtox assay should be included in those studies designed to accurately classify sediment toxicities.

112. GILMER, D.S., M.R. Miller, R.D. Bauer, and J.R. LeDonne. 1982. California's Central Valley wintering waterfowl: concerns and challenges. Trans 47th N Am Wildl Nat Res Conf 1982:441-452.

This paper evaluates the Central Valley of California as a wintering area for waterfowl, identifies problems confronting wintering waterfowl, discusses efforts in the resolution of these problems, and recommends actions to improve waterfowl management. Only the second of these, the identification of problems facing wintering waterfowl, is addressed here. Some disease data are presented, but perhaps of greatest importance within the context of this document is the statement that approximately 17% of all pesticides used in the U.S. (as of 1982) was applied in California. This amounted to some 55 million kg in 1980, with about 55% of it applied in Central Valley counties. The authors recommended that research

be conducted to determine, among other things, the physical condition and reproductive potential of waterfowl relative to winter habitat conditions.

113. GOLDSBOROUGH, L.G., and D.J. Brown. 1988. Effect of glyphosate (Roundup formulation) on periphytic algal photosynthesis. Bull Environ Contam Toxicol 41:253-260.

Photosynthetic activity of periphyton communities from three of five experimental ponds was not significantly affected at glyphosate concentrations \leq 0.89 mg/L. Threshold levels for communities from two other ponds were 8.9 to 18.0 mg/L. Between 8.9 and 1800 mg/L, photosynthesis decreased with increasing herbicide concentration. Carbon fixation was not completely inhibited at the higher concentration, but varied from 11 to 27% of the control. EC₅₀ values varied from 35.4 mg/L to 69.7 mg/L.

114. GOLDSBOROUGH, L.G., and G.G.C. Robinson. 1983. Effect of two triazine herbicides on the productivity of fresh water marsh periphyton. Aquat Toxicol 4:95-112.

Varying concentrations of simazine and terbutryn were added to in situ enclosures of marsh water. Algal periphyton colonization on artificial strata was monitored relative to herbicide exposure. Compared to an untreated control, chlorophyll *a* accumulation and carbon assimilation varied from no difference from the control at a concentration of 0.1 mg/L simazine to approximately 95% inhibition at 5.0 mg/L. The two processes were reduced >90% at a concentration of 0.01 mg terbutryn per L. Factor analysis indicated that periphytic productivity was correlated with water chemistry, light availability, and time, in addition to the experimental herbicide treatment. These results suggest that herbicidal effect resulted from a complex interaction of several parameters rather than herbicide concentration alone. Periphyton community recovery began within 1 week following decreased herbicide application. As the post-application growth rate was equal to or greater than that of the control, the long-term impact of a single dosage of these herbicides may have been minimal.

115. GOLDSBOROUGH, L.G., and G.G.C. Robinson. 1985. Effect of an aquatic herbicide on sediment nutrient flux in a freshwater marsh. Hydrobiol 122:121-128.

Addition of simazine to in situ macrophyte-free enclosures at concentrations of 0.1, 1.0, and 5.0 mg/L caused proportional increases in sediment releases of NH₃, total reactive phosphorus, and silicon. Results suggest that increases of dissolved nutrients commonly observed following herbicide treatment of shallow waters may not be attributable solely to macrophyte decay but may involve a complex interaction of biotic and abiotic sediment nutrient exchange processes.

116. GOLDSBOROUGH, L.G., and G.G.C. Robinson. 1986. Changes in periphytic algal community structure as a consequence of short herbicide exposures. *Hydrobiol* 139:177-192.

Application of the triazine herbicides simazine and terbutryn to in situ marsh enclosures resulted in total biovolume inhibition greater than 98% at all terbutryn concentrations (0.01, 0.1, and 1.0 mg/L). Similar inhibition was noted at only the highest simazine concentration (5.0 mg/L). Post-treatment recolonization patterns indicated that periphyton successional processes, which normally lead to the development of a complex three-dimensional mat, may be prevented by short herbicide exposures.

117. GOLDSBOROUGH, L.G., and G.G.C. Robinson. 1988. Functional responses of freshwater periphyton to short simazine exposures. *Int Verein Theor Ang Lim Verhand* 23:1586-1593.

The authors suggest that freshwater periphyton communities may develop partial resistance to herbicide exposure but that such resistance may not persist at herbicide levels of <0.8 mg/L.

118. GOLLEY, F.B., and L. Ryszkowski. 1988. How can agroecology help solve agricultural and environmental problems? *INTECOL Bull* 16:71-75.

The major theme is that only the individual farmer can ultimately make the changes necessary to solve current ecological problems wrought by agricultural practices. The establishment of sound farm policy will not work if, for one reason or another, the farmer is unwilling to change current practices or to take private risks for the common good. The authors suggest that farmers of the future must be highly educated, provided with the most modern tools and sources of information, provided with better methods of natural pest control, and finally, must be aware that they are, individually, natural resource managers. As such, the farmer must be employed in nature conservation, in the administration of the rural landscape, in the distribution of rural health and education, and in the creation of rural culture. Lastly, the authors suggest more research, tied to the needs of farmers, neighborhoods, and regions. Most of all, research must have practical applications and not be driven by the needs of the research community.

119. GOODRICH, M.S., and J.J. Lech. 1990. Behavioral screening assay for *Daphnia magna*: a method to assess the effects of xenobiotics on spatial orientation. *Environ Toxicol Chem* 9:21-30.

This paper describes a method that may be used in screening surface water samples for pesticides or other environmental contaminants. The migration of *Daphnia magna* along a light gradient was used to determine effects. Effects were observed with lindane concentrations as low as 50 ppb. Analysis and statistical techniques are also discussed.

120. GOPAL, K., R.N. Khanna, M. Anand, and G.S.D. Gupta. 1981. Acute toxicity of endosulfan to fresh-water organisms. *Toxicol Lett* 7:453-456.

Fish, insect nymphs, and frog tadpoles were used to assess the acute toxicity of endosulfan. Exposure (96 h) was at concentrations of 0.001-0.004 ppm for tadpoles and 0.005-0.04 ppm for catfish and invertebrates. Fish exhibited jumping, erratic movement, and convulsions accompanied by rapid opercular movement and occasional gulping of air. Loss of equilibrium and death followed. Hyperglycemia was maximum at 48 h at all concentrations, suggesting that endosulfan may interfere with carbohydrate metabolism. Similar symptoms were observed in nymphs and tadpoles, including severe reduction in free swimming and reduced physical stamina. Frog tadpoles appeared to be the most sensitive species tested.

121. GRABER, D.A. 1987. Survey of agricultural cropping systems and wetland management practices on selected Missouri Department of Conservation wildlife areas. *Missouri W-13-R-41/Study 03/Job 01, Missouri Department of Conservation*. 20 pp.

A range of farming and wetland management activities occurred on wetland management areas. The lack of readily available information about some aspects of farming and wetland programs indicated a need for more formal and standardized record keeping of routine management operations. Further research is needed regarding waterfowl nutrient requirements, nutrient content of waterfowl foods, impacts of agricultural chemicals, the utility of conventional versus biological farming, no-till farming, and goose browse production.

122. GRUE, C.E., and B.K. Shipley. 1981. Interpreting population estimates of birds following pesticide applications - behavior of male starlings exposed to an organophosphate pesticide. *Stud Av Biol* 6:292-296.

Male European starlings exposed to a single oral dose of 2.5 mg dicotophos/kg body weight spent significantly more time perching and less time flying, foraging, and singing and displaying than did control birds. Results suggest that conventional censusing or population estimating techniques which are dependent upon bird activity may be inadequate in assessing bird populations after pesticide applications.

123. GRUE, C.E., and B.K. Shipley. 1984. Sensitivity of nestling and adult starlings to dicotophos, an organophosphorus pesticide. *Environ Res* 35:454-465.

Toxicity (24-h LD₅₀) of dicotophos was age dependent. Free-living 5-day-old nestlings (LD₅₀, 4.92 mg/kg body weight) were approximately twice as sensitive to the chemical as free-living 15-day-old nestlings (LD₅₀, 9.59 mg/kg) and captive adult birds (LD₅₀, 8.37 to 8.47 mg/kg). Brain ChE activity was

severely depressed in all dead birds, but ChE inhibition was not age dependent. Weight loss varied inversely with age and dosage but directly with time to death.

124. GRUE, C.E., and C.C. Hunter. 1984. Brain cholinesterase activity in fledgling starlings: implications for monitoring exposure of songbirds to ChE inhibitors. Bull Environ Contam Toxicol 32:282-289.

ChE activity in the European starling increases rapidly with age to the time of fledging. After fledging, the rate of increase in ChE activity dropped sharply. The authors suggest that age must be considered when diagnosing exposure of nestling and fledgling songbirds to ChE inhibitors.

125. GRUE, C.E., G.V.N. Powell, and C.H. Gorsuch. 1982. Assessing effects of organophosphates on songbirds: comparison of a captive and a free-living population. J Wildl Manage 46:766-768.

There were no significant differences in brain ChE activity or in body weight change between captive and free-living populations of European starlings exposed to dicrotophos (single oral dose, 2.5 mg/kg body weight).

126. GRUE, C.E., L.R. DeWeese, G.A. Swanson, S.M. Borthwick, and C.M. Bunck. 1990. Effects of aerial applications of 2,4-D, fenvalerate, and ethyl and methyl parathion on waterfowl inhabiting prairie-pothole wetlands. Pp 34-35 in Proceedings of a symposium: environmental contaminants and their effects on biota of the Northern Great Plains. North Dakota Chapter, The Wildlife Society, Bismarck.

2,4-D (0.3 kg AI/ha), 2,4-D contaminated with fenvalerate (0.009 kg AI/ha), ethyl parathion (0.6 kg AI/ha), and methyl parathion (0.3 kg AI/ha) were applied aerially to several small wetlands in south-central North Dakota in June 1986. Growth and survival of several groups of 3-week-old mallard and blue-winged teal ducklings released on treated and control wetlands were monitored. No overt toxicity was observed in any waterfowl exposed to the pesticides. Brain ChE activity was depressed in <30% of juvenile blue-winged teal collected 2 days post-spray and was still detectable 30 days post-spray in those teal exposed to ethyl parathion. Maximum depression ($\leq 69\%$) occurred 2 days post-spray. Body weights of mallard and teal ducklings on treated wetlands were equal to or greater than those on control wetlands. Although 2,4-D did not pose either a direct or indirect impact on waterfowl, fenvalerate and methyl and ethyl parathion were acutely toxic to the aquatic invertebrates which are essential foods for laying females and young ducklings.

127. GRUE, C.E., L.R. DeWeese, P. Mineau, G.A. Swanson, J.R. Foster, P.J. Arnold, J.N. Huckins, P.J. Sheehan, W.K. Marshall, and A.P. Ludden. 1986. Potential impacts of agricultural chemicals on waterfowl and other wildlife inhabiting prairie wetlands: an evaluation of research needs and approaches. Pp 357-383 in Trans 51st N Amer Wildl Nat Res Conf.

The potential for agricultural chemical impact on prairie pothole wetlands and the wildlife dependent on them for survival and reproduction appears to be great, but the assessment of actual risk is hindered by a lack of data. Those data that are available regarding pesticide use and toxicity suggest that insecticides pose the greatest threat to wetland wildlife, particularly birds. The impact of agricultural chemicals on the quality of the remaining wetland habitat in the northern prairie and on the observed declines in waterfowl populations is of particular concern. Existing data indicate that adult and juvenile waterfowl may not be more sensitive to pesticides than other wetland wildlife. However, their food habits and feeding behaviors may make them more vulnerable to direct toxic effects or chemical-induced changes in the abundance of aquatic invertebrates. Further laboratory and field studies are required to adequately assess potential impacts.

128. GRUE, C.E., M.W. Tome, and G.A. Swanson. 1988. Agricultural chemicals and the quality of waterfowl habitat within the prairie pothole region: what are the research needs? Unpublished issue paper prepared for Patuxent Wildlife Research Center, Laurel, MD.

Additional studies are needed to quantify agricultural chemical inputs and assess their impact on the quality of prairie wetlands. To determine the extent of chemical inputs into non-target habitats, the effects of these chemicals on non-target habitats and waterfowl productivity, and the chemicals and management strategies that minimize risks to waterfowl and other wildlife, the following research topics must be addressed:

- (1) The extent of contamination of non-target habitats by normal uses of agricultural chemicals.
- (2) The seasonal and cumulative effects of agricultural chemicals on the productivity of waterfowl utilizing wetlands and nesting habitat within intensively farmed areas.
- (3) The effect on quality of seasonal wetlands for waterfowl under intermittent tillage and haying.
- (4) Differences in and effects of exposure of waterfowl to agricultural chemicals on conventional and conservation-tillage fields.
- (5) Effectiveness of buffer zones and other strategies in minimizing inputs of agricultural chemicals into non-target habitats.
- (6) Contribution of exposure to agricultural chemicals, directly or indirectly, to mortality of waterfowl from botulism or other diseases.

129. GRUE, C.E., M.W. Tome, G.A. Swanson, S.A. Borthwick, and L.R. DeWeese. 1988. **Agricultural chemicals and the quality of prairie-pothole wetlands for adult and juvenile waterfowl: what are the concerns?** Natl Symp, Protection of Wetlands from Agricultural Impacts. Colorado State University, Ft. Collins, CO, April 25-29, 1988.

A review of the literature and results of ongoing studies indicate the potential great impact of agricultural chemicals, particularly aerially applied insecticides, on prairie pothole wetlands and the waterfowl using them. Aerial application of ethyl parathion at a rate of 1.1 kg/ha to sunflower fields surrounding wetland areas, but with no direct application to the wetlands, resulted in death of aquatic invertebrates and a 23% reduction of brain ChE activity in blue-winged teal ducklings collected 2 days post-spray. In other studies, 100 of 104 (96.2%) mallard ducklings died within 3 days after application of ethyl parathion (1.1 kg/ha) to adjacent sunflower fields. Duckling mortality on nearby unexposed control wetlands ranged between 35 and 68% (mean = 48%). Brain ChE activity in all but one of the dead birds from the treated wetland was depressed greater than 50% compared to controls. 2,4-D application (0.6 kg AI/ha) to wetlands and surrounding cropland had no apparent impact on the majority of aquatic plants, aquatic invertebrate populations, or mallard ducklings. A coordinated effort by farmers, wildlife managers, and regulatory agencies is needed to minimize these impacts.

130. GRUE, C.E., M.W. Tome, G.A. Swanson, S.M. Borthwick, and L.R. DeWeese. 1988. **Aerial application of insecticides may be contributing to declines in waterfowl production with the prairie pothole region.** Unpubl ms.

This paper presents the results from the mallard duckling and aquatic invertebrate (amphipod: *Hyalella azteca*) study referenced in entry 129.

131. GRUE, C.E., M.W. Tome, T.A. Messmer, D.B. Henry, G.A. Swanson, and L.R. DeWeese. 1989. **Agricultural chemicals and prairie-pothole wetlands: Meeting the needs of the resource and the farmer, U.S. perspectives.** Trans 54th N Amer Wildl Nat Res Conf 43-58.

This paper is very similar to entries 128, 129, and 130, and essentially is a synthesis of them. Some data relating to Russian wheat aphid (*Diuraphis noxia*) infestation, previously unpublished, are presented.

132. HALL, R.J., and E. Kolbe. 1980. **Bioconcentration of organophosphorus pesticides to hazardous levels by amphibians.** J Toxicol Environ Health 6:853-860.

Bullfrog (*Rana catesbeiana*) tadpoles concentrated parathion and fenthion by factors of 64 and 62, respectively. Tadpoles exposed to 1 and 2.2 ppm

parathion and fenthion and fed to mallard ducklings resulted in significant bird mortality. Animals that prey regularly on amphibians may ingest lethal doses of ChE inhibitors.

133. HALL, J.K., N.L. Hartwig, and L.D. Hoffman. 1983. **Application mode and alternate cropping effects on atrazine losses from a hillside.** J Environ Qual 12:336-340.

External drainage losses of atrazine were evaluated at two application rates (2.2 and 4.5 kg AI/ha), applied pre-emergence and preplant-incorporated. Application was on a hillside (14% slope) where corn (*Zea mays*) was planted with and without a 6-m wide oat (*Avena sativa*) buffer strip at the base of the slope. Over 11 erosion events, the buffer strip reduced water and soil losses by 66 and 76%, respectively, compared with nonstripped areas, and atrazine losses were reduced by 91% at the 2.2 kg/ha application rate. At the higher application rate, herbicide losses were 65% less in stripped areas compared with non-stripped areas. Regardless of cropping pattern, minimal preplant incorporation reduced total atrazine loss by 91 and 87% at the two application rates, allowing a total loss of only 7 g/ha at each rate. The results indicate that a conventional-tillage management system, minimal mechanical incorporation of the herbicide into the topsoil, and a buffer strip provided soil, water, and herbicide residue retention equivalent to that achieved in reduced-tillage cropping.

134. HALL, R.J. 1987. **Impact of pesticides on bird populations.** Pp 85-111 in G.J. Marco, R.M. Hollingworth, and W. Durham (eds), *Silent spring revisited.* American Chemical Society, Washington, D.C. 214 pp.

This is a review of the literature dealing with pesticide impacts on avifauna from the introduction of DDT through the mid-1980s. Several papers regarding antagonistic and synergistic effects are cited. Wildlife threats from chemicals other than pesticides are also discussed. The author concludes that studies on impacts of pesticides at an ecosystem level are lacking. Several studies are suggested including the effects of reduction of food supply, disruption of predator-prey relationships, and habitat alteration due to herbicide use.

135. HAMELINK, J.L., D.R. Buckler, F.L. Mayer, D.U. Palawski, and H.O. Sanders. 1986. **Toxicity of fluridone to aquatic invertebrates and fish.** Environ Toxicol Chem 5:87-94.

The acute toxicity of fluridone to aquatic invertebrates ranged from 1.3 mg/L (48-h EC₅₀) for midge (*Chironomus plumosus*) larvae to 36.2 mg/L (96-h LC₅₀) for blue crabs (*Callinectes immunis*) with a mean of 4.3 mg/L. Acute toxicity in fish was somewhat pH dependent and ranged from 4.2 mg/L (96-h LC₅₀) for rainbow trout to 22.0 mg/L for fathead minnows with a mean value of 10.4 mg/L. Toxicity

appeared to be greater in softer than in harder water. The liquid formulation (Sonar) was generally more toxic to invertebrates than was technical grade fluridone. Survival and reproduction of daphnids (*Daphnia magna*) and amphipods (*Gammarus pseudolimnaeus*) were similar to controls at concentrations of 0.2 mg/L for 21 days and 0.6 mg/L for 60 days, respectively. Emergence of adult midges was not significantly reduced when exposed to 0.5 mg/L for 30 days. After 60 days exposure, channel catfish bioconcentration factors ranged from 2 to 9; a metabolite accounted for 15 to 23% of the total fluridone residue detected. At concentrations greater than 0.95 mg/L, survival of second-generation fry was reduced within 30 days after hatch. The results of this study indicate that a favorable safety margin exists between the fluridone concentration that affects non-target organisms and the concentration needed (approximately 0.1 mg/L) to control aquatic weeds.

136. HAMILTON, P.B., G.S. Jackson, N.K. Kaushik, K.R. Solomon, and G.L. Stephenson. 1988. Impact of two applications of atrazine on the plankton communities of in situ enclosures. Aquatic Toxicol 13:123-140.

Compared to single atrazine applications, two applications 35 days apart at nominal concentrations of 0.1 mg/L resulted in a more gradual killing of the phytoplankton, a longer period of recovery for the green algal community, and a distinct shift in the taxonomic composition of the affected communities. The rotifer community was not significantly affected. However, two crustaceans (*Bosmina longirostris*, *Diaptomus oregonensis*) experienced significant short-term reductions in numbers after the second application. As these reductions were not observed after the first exposure, it is suggested that population declines were the result of changes in other populations within the community and not directly due to pesticide exposure.

137. Takayuki, H., and Y. Masayuki. 1990. Influence of time of application of an insecticide on recovery patterns of a zooplankton community in experimental ponds. Arch Environ Contam Toxicol 19:77-83.

Zooplankton communities in outdoor concrete ponds were exposed to carbaryl at a final concentration of 0.5 mg/L. Pesticide applications were made at different times relative to the population trend. Chemical applications markedly reduced the cladoceran and copepod populations, but the rotifer population was unaffected. After the treatments, *Bosmina fatalis* recovered earlier than *Daphnia* spp and dominated until *Daphnia* recovery was complete. The reappearance of *Daphnia* was delayed when carbaryl was applied later in community development. Thus, the treatment induced *Bosmina* dominance with the period of dominance extended by delayed pesticide application. *Daphnia* recovery was probably retarded by the seasonal decline in water temper-

ature. When carbaryl was applied during the increasing phase of the *Keratella valga* population, population density increased more than normal. If exposed during the decreasing phase, the *Keratella* population did not recover even with the disappearance of competitors. Applications of the insecticide at different times thus induced different recovery patterns of the zooplankton communities.

138. HANSON, W.R. 1952. Effects of some herbicides and insecticides on biota of North Dakota marshes. J Wildl Manage 16:299-308.

Effects of 2,4-D amine and water, 2,4-D ester and oil, chlordane, DDT, and toxaphene treatment on marsh plants and animals are reported. Results of two herbicide treatments were similar, resulting in a heavy kill of dicotyledonous plants and damage to most monocots, especially from the ester and oil formulation. The only animals killed were a few insects, presumably from the oil alone. Chlordane and toxaphene both affected recruitment in bird populations. In chlordane-treated areas, 34 birds were produced from 25 nests; only 6 birds were reared from 21 nests in the toxaphene area. Adult birds fed heavily on DDT-poisoned insects with apparent immunity. All insecticides eradicated most insects for at least 5 weeks; the greatest destruction was caused by DDT and oil.

139. HARTMAN, W.A., and D.B. Martin. 1984. Effect of suspended bentonite clay on the acute toxicity of glyphosate to *Daphnia pulex* and *Lemna minor*. Bull Environ Contam Toxicol 33:355-361.

The calculated 48-h EC₅₀ for *Daphnia pulex* was 3.2 mg/L glyphosate with suspended sediment present in the water column and 7.9 mg/L without suspended sediment. Conversely, the EC₅₀ for *Lemna minor* was greater with suspended sediment (>10.0 mg/L) than without (2.0 mg/L). It is possible that the presence of suspended sediment enhanced the bioavailability of glyphosate to *D. pulex* via adsorption to the clay particles. The same action may have rendered the chemical unavailable to *L. minor*.

140. HARTMAN, W.A., and D.B. Martin. 1985. Effects of four agricultural pesticides on *Daphnia pulex*, *Lemna minor*, and *Potamogeton pectinatus*. Bull Environ Contam Toxicol 35:646-651.

The acute toxicities of alachlor, atrazine, and carbofuran to *Daphnia pulex* and *Lemna minor* with and without suspended sediment (in water) were assessed. Only slight differences were noted in the EC₅₀ values for *D. pulex*. With the exception of alachlor (9.0 and 10.4 mg/L with and without sediment), toxicities were greater without than with suspended sediment (45.0 and 35.0 µg/L and 46.5 and 36.5 mg/L for carbofuran and atrazine with and without sediment, respectively). For *L. minor*, no growth effects were noted with carbofuran concentrations up

to 10.0 mg/L. The EC₅₀ values for atrazine with and without suspended sediment were 10.1 and 14.5 µg/L. Atrazine was ineffective against *L. minor* below a threshold of approximately 100 µg/L regardless of sediment presence or absence. Sprouting and growth rate of sago pondweed (*Potamogeton pectinatus*) were measured in the presence of the three pesticides and glyphosate. None of the chemicals had an effect on sprouting, and neither carbofuran nor glyphosate produced inhibitory effects on growth rate at concentrations up to 10.0 mg/L; however, glyphosate stimulated growth at 1.0 mg/L and atrazine inhibited growth at concentrations as low as 0.1 mg/L. Alachlor inhibited growth at 10.0 mg/L, showed no effect at 1.0 mg/L, and stimulated growth at 0.1 mg/L.

141. HARTWIG, N.L., and J.K. Hall. 1980. Influencing the action of herbicides - runoff losses. Crops Soils 33:14-16.

Herbicide loss due to runoff is dependent on a number of soil and climatic factors. Soil factors include texture, porosity, pH, organic matter content, percent saturation, and slope. The proximity of rainfall to the area of herbicide application and to other rainfall events, the intensity and duration of rainfall, and total rainfall amounts are major climatic factors. Herbicide loss is also dependent upon herbicide formulation, solubility, and method of application. Water soluble herbicide formulations allow the herbicide to percolate into the top soil and become less vulnerable to surface loss. If the herbicide of choice has low solubility in water, a light mechanical incorporation significantly reduces run-off losses. Adsorption to soil particles is enhanced if the herbicide is applied to a dry, well-prepared soil surface. The best method, however, is to prevent erosion in the first place. The authors recommend the use of terraces, contour farming, strip cropping, and other conservation practices that reduce water flow and soil loss. Grass waterways reduce pesticide concentrations in runoff by as much as 70%. No-tillage and minimum tillage were also recommended, including a living mulch of, for example, crownvetch or birdsfoot trefoil. The use of the latter system was reported to reduce water runoff 93 to 98% and soil loss by 98 to 100% compared to conventionally planted corn on plowed ground. Surface losses were less than 0.1 inch of water and 0.01 to 0.03 tons of soil per acre per year in each of 2 years.

142. HILL, I.R. 1989. Aquatic organisms and pyrethroids. Pestic Sci 27:429-465.

A large number of field studies on the impact of pyrethroids on aquatic systems are reviewed extensively. [A table to show the low toxicity of cypermethrin to birds is missing from the paper.] Laboratory studies have shown some invertebrates and fish to be extremely susceptible to synthetic pyrethroids. Normal field use of the chemicals, however, did not affect most fish. Although larval stage numbers of some aquatic insects were greatly reduced with direct application of either permethrin or cyperme-

thrin to pond surfaces, most insects demonstrated some or complete recovery. Mesocosm studies using permethrin, cypermethrin, and lambda-cyhalothrin suggest that effects due to normal agricultural use will be minor and transient with no overall adverse impacts on aquatic ecosystem populations or productivity. The apparent reduction of toxicity of pyrethroids in field situations is probably due to the rapid adsorption of these chemicals to particulate matter. Acute toxicity data are presented for permethrin, cypermethrin, fenvalerate, deltamethrin, lambda-cyhalothrin, and flucythrinate.

143. HAVERA, S.P., and R.E. Duzan. 1986. Organochlorine and PCB residues in tissues of raptors from Illinois, 1966-1981. Bull Environ Contam Toxicol 36:23-32.

Brain, fat, liver, breast muscle, and heart tissues from 68 raptors collected in Illinois during 1966-1981 as dead or dying birds were analyzed for DDE, dieldrin, heptachlor epoxide (HE), and PCBs. Results are presented in tabular form. Of 68 birds collected, 17 were considered migrants in Illinois. Of the 68 birds analyzed, 76.5% were contaminated with at least one of the chemicals. DDE concentrations were found in a greater percentage of migrants than in residents (88.2 vs. 72.5%). The other four contaminants were more frequently found in resident birds. Brain tissue analysis revealed that five birds had dieldrin levels that approached or exceeded the 4-5 ppm diagnostic lethal level. Only one of these, a sharp-shinned hawk with 4.01 ppm, was considered a migrant. None of the birds had lethal levels of any of the other contaminants. Of all migratory species collected, goshawks were least contaminated, although DDE residues were found in at least one tissue of the seven collected. The highest concentrations were in resident species: 781.1 ppm DDE and 195.3 ppm dieldrin in fat from a red-shouldered hawk, 10.2 ppm HE in fat from a barred owl, and 487.8 ppm from fat of another barred owl.

144. HELLING, C.S., W. Zhuang, T.J. Gish, C.B. Coffman, A.R. Isensee, P.C. Kearney, D.R. Hoagland, and M.D. Woodward. 1988. Persistence and leaching of atrazine, alachlor, and cyanazine under no-tillage practices. Chemosphere 17:175-187.

Persistence and mobility of atrazine, alachlor, and cyanazine were determined in soil subjected to a no-till cropping regime during a 3-year period (1983-85). Up to 6 weeks after application, atrazine was most, and alachlor least, persistent. The order changed somewhat after 6 weeks. Atrazine was still most persistent, and cyanazine persistence was least. Relative mobility did not change over time. Atrazine was most, and cyanazine least, mobile. Atrazine was found deep (0.3-0.5 m) in the soil profile, but there was no direct evidence that movement was deeper with no-till than with conventional tillage as comparisons were not available.

145. HENNY, C.J. 1972. Analysis of the population dynamics of selected avian species with special references to changes during the modern pesticide era. Wildl Res Rep 1, U.S. Fish and Wildlife Service, Washington, D.C. 99 pp.

Population dynamics of 16 species of non-game birds (great horned owl, red-shouldered hawk, American kestrel, osprey, barn owl, Cooper's hawk, red-tailed hawk, great blue heron, black-crowned night-heron, brown pelican, barn swallow, chimney swift, blue jay, black-capped chickadee, northern cardinal, and American robin) during 1947 to 1972 were studied to determine the impact of pesticides on recruitment and mortality. Comparison to similar data collected from 1925 to 1945 showed no significant differences in post-fledgling mortality rates. Evidence of decreased recruitment rates was found in five species (brown pelican, osprey, Cooper's hawk, red-shouldered hawk, and sparrow hawk). Recruitment for an additional four species (red-tailed hawk, great horned owl, great blue heron, and barn owl) was unchanged over time. Recruitment data for the other seven species were not available. Differences in recruitment rates were associated with feeding habits. Those species feeding primarily on mammals were stable; those species which fed mainly on fish, amphibians, reptiles, and other birds had decreased reproductive success, which was also correlated with decreased eggshell thickness. Although those data reflect the impact of OC pesticides, they provide an excellent source of baseline data for future comparison.

146. HENNY, C.J. 1987. Field methods to evaluate effects of pesticides on wildlife of the north-western United States. Pp 54-68 in P. Kacmár and J. Legáth (eds), Collected reports from the Czechoslovak-American Symposium on toxic effects of chemical environmental contaminants upon production and reproduction ability in free-living animals. University of Veterinary Medicine, Košice, Czechoslovakia. 273 pp.

The paper reviews basic methodology that may be used by field biologists conducting pesticide studies. Five case histories involving four species of birds are cited for reference. When investigating the effects of OC pesticide contamination, the author recommended a comparison of reproductive success, on a nest-by-nest basis, with OC residue concentrations in an egg collected at random from the nest. First used with the peregrine falcon, this technique has been reliable. This technique has often been used with the measurement of brain or plasma ChE activity to assess the impact of OP and carbamate pesticides in avian populations. Examination of GI tract contents is also used extensively when pesticide poisoning is the suspected cause of death and brain ChE activity is depressed by 50% or more.

147. HENNY, C.J., E.J. Kolbe, E.F. Hill, and L.J. Blus. 1987. Case Histories of bald eagles and other raptors killed by organophosphorus insecticides topically applied to livestock. J Wildl Dis 23:292-295.

From several case histories, the authors concluded that secondary poisoning of raptors following topical application of various organophosphorus insecticides to cattle is widespread. Mortality in the cases cited was due to ingestion of animals either treated with or containing lethal concentrations of famphur or fenthion. One case of tertiary poisoning is cited. In this instance, a great horned owl apparently ate a portion of a red-tailed hawk that had died as a result of secondary poisoning. Brain ChE activity in the owl was depressed 85% and GI tract contents contained 15 ppm famphur.

148. HENNY, C.J., L.J. Blus, and C.J. Stafford. 1983. Effects of heptachlor on American kestrels in the Columbia Basin, Oregon. J Wildl Manage 47:1080-1087.

This paper documents the effects of heptachlor epoxide (HE) on productivity and survival of American kestrels in the Columbia Basin. Reduced productivity and adult mortality was observed in kestrels exposed to HE through the foodchain (treated wheat -> mice -> kestrel). The kestrel was found to be more sensitive to HE residues in eggs than the Canada goose, as reduced productivity occurred at >1.5 ppm in kestrel eggs vs. >10 ppm in goose eggs. No eggshell thinning due to HE contamination was evident.

149. HENNY, C.J., L.J. Blus, A.J. Krynetsky, and C.M. Bunck. 1984. Current impact of DDE on black-crowned night-herons in the intermountain west. J Wildl Manage 48:1-13.

A study of OC contamination in black-crowned night-heron populations in 1978-1980 in Washington, Oregon, and Nevada revealed DDE residues in all eggs (n = 220) sampled. Eggshell thickness was inversely correlated with DDE and PCB residue concentrations. A strong north-south clinal pattern was evident, with southern colonies more contaminated than northern ones. Concentrations above 8.0 ppm DDE resulted in reduced clutch size and productivity, and the incidence of cracked eggs increased. With the exception of those breeding grounds along the Columbia River, no breeding-ground DDE-DDT contamination was found.

150. HENNY, C.J., and G.B. Herron. 1989. DDE, selenium, mercury, and white-faced ibis reproduction at Carson Lake, Nevada. J Wildl Manage 53:1032-1045.

A study of a white-faced ibis population nesting at Carson Lake, Nevada, in 1985 and 1986 revealed that the number of young produced per nesting attempt, the number of young produced per successful nest, and eggshell thinning were directly related

to DDE residue concentration in eggs. The relationship between DDE contamination (ppm wet weight) and eggshell thickness (mm) was $\hat{Y} = 0.286 - 0.028 \log_{10} X$. As DDE concentrations increased beyond 4.0 ppm, productivity decreased and the incidence of cracked eggs increased. If 4.0 ppm DDE is the critical residue level, 40% of the nesting population in the 2-year period was adversely affected, resulting in a net loss of approximately 20% of the population's expected production. Most eggs with high levels of DDE also had high levels of DDT, indicating recent DDT exposure. However, no DDE or DDT contamination was found on the breeding grounds.

151. HENNY, C.J., and L.J. Blus. 1986. Radiotelemetry locates wintering grounds of DDE-contaminated black-crowned night-herons. *Wildl Soc Bull* 14:236-241.

Radiotelemetry was successfully used to determine the wintering grounds and source of DDE contamination in a population of black-crowned night-herons nesting at Ruby Lake, Nevada. Elevated DDE concentrations in the heron colony appeared to originate on the wintering grounds in the Imperial Valley, California, and along the Gila River east of Yuma, Arizona.

152. HENRY, M.G., and R.A. Schoettger. 1988. Aquatic toxicity test methodologies: an update for the 1980s. Pp 137-145 in R.C. Ryans (ed), Protection of river basins, lakes, and estuaries: fifteen years of cooperation toward solving environmental problems in the USSR and USA. American Fisheries Society, Bethesda, MD.

This paper reviews toxicity tests used in the USSR and USA prior to 1975 and discusses new approaches for toxicity testing developed since that time. The newer methods include microbiological, physiological-biological, behavioral, and laboratory-field approaches. The authors stated that the more recent test methods, in addition to offering standardized procedures, are ecologically relevant and broadly applicable across chemical classes. Future research interests, according to the authors, will address resistance, reversibility of effects, and further development of test methodologies that use fish and invertebrate species indigenous to broad areas of the USSR and USA, with particular emphasis on laboratory-field verification.

153. HENRY, M.G., B.A. Flerov, V.T. Komov, and T.A. Heming. 1988. On-site toxicity testing: applications in the United States and Soviet Union. Pp 70-77 in R.C. Ryans (ed), Fate and effects of pollutants on aquatic organisms and ecosystems: Proceedings of USA-USSR Symposium, Athens, Ga., October 19-21, 1987, EPA/600/9-88/001. U.S. Environmental Protection Agency, Athens, Ga.

On-site toxicity tests were conducted in the U.S. and USSR using *Ceriodaphnia dubia* as a test organ-

ism. Although the U.S. test involved non-point source contaminated water from the Detroit River and the test in the USSR used water contaminated by a point source spill in the Rybinsk Reservoir, results were comparable and the approach was compatible with both situations. The use of this methodology should allow comparison of future data sets.

154. HERNANDEZ, L.M., M.J. Gonzalez, M.C. Rico, M.A. Fernandez, and A. Aranda. 1988. Organochlorine and heavy metal residues in falconiforme and ciconiforme eggs. *Bull Environ Contam Toxicol* 40:86-93.

Sixty-nine infertile bird eggs collected at Doñana National Park and Castile Plateau, Spain, in 1985 and 1986 were analyzed for OC and heavy metal residues. The eggs were from nests of five species of raptors and two species of the order Ciconiformes. Residues of DDE and PCBs were found in each of the 69 eggs (range 0.06 to 65.86 ppm and 0.14 to 18.75 ppm, respectively). DDT and gamma-HCH (hexachlor) residues were detected in 87 and 61% of the eggs. The mean total OC concentrations in raptor and ciconiform eggs was 3.4 and 0.9 ppm. Differences were thought to result from differences in feeding habits. DDE and PCB mean concentrations were greatest in Castile Plateau peregrine falcon (9.752 ppm DDE) and Doñana Park black kite (2.882 ppm PCB) eggs and least in Castile Plateau black kite (0.167 ppm DDE) and Castile Plateau royal eagle (0.206 ppm PCB) eggs.

155. HERSCH, C.M., and W.G. Crumpton. 1989. Atrazine tolerance of algae isolated from two agricultural streams. *Environ Toxicol Chem* 8:327-332.

Green algae (*Chlorella* sp and other species of Chlorococcales) collected from two Iowa streams, one contaminated with atrazine and the other uncontaminated, showed similar responses to atrazine exposure during 5-min bioassays. Based on oxygen evolution, EC₅₀ values for the two streams ranged from 42 to 125 µg/L and 35 to 162 µg/L, respectively. A species of *Franceia*, however, proved to be resistant to atrazine (EC₅₀, 430 to 774 µg/L). This is near the high end of the range of EC₅₀ values reported for green algae.

156. HILL, E.F. 1988. Brain cholinesterase activity of apparently normal wild birds. *J Wildl Dis* 24:51-61.

A reference file of [assumed] normal brain ChE activity is provided for 48 species of North American birds representing 11 orders and 23 families. These data are suggested for use in emergency situations when controls from local populations may not be available. Although ChE activity was usually similar for closely related species, some congeners differed by as much as 50%. Overall, ChE activity varied nearly threefold among the 48 species represented.

157. HILL, E.F., and M.B. Camardese. 1984. Toxicity of anticholinesterase insecticides to birds: technical grade versus granular formulations. *Ecotoxicol Environ Safety* 8:551-563.

A comparison of the acute toxicities of 13 granular insecticides with their technical grade AIs using adult Northern bobwhite quail as a test organism showed that, when significant differences between the granular formulation and the technical grade material existed, the granular formulation was less toxic. Interspecific differences were evaluated by exposing ringed turtle-doves to five of the granular formulations. The 13 chemicals tested were: Amaze 15G (isofenphos), Counter 15G (terbufos), Dasanit 15G (fensulfothion), Diazinon 14G, Di-Syston 15G (disulfoton), Dyfonate 20G (fonofos), Furadan 10G (carbofuran), Lorsban 15G (chlorpyrifos), Nemacur 15G (fenamiphos), Parathion 10G, Tattoo 10G (bendiocarb), Temik 15G (aldicarb), and Thimet 15G (phorate). Fenamiphos, fensulfothion, and aldicarb were the most toxic. Northern bobwhite LD₅₀ values ranged from 1.0 mg AI/kg body weight for technical grade fenamiphos to 2.5 mg/kg for Temik 15G. Lorsban 15G was least toxic to quail (LD₅₀, 108 mg/kg). Ringed turtle-doves were 1.7 times more sensitive than bobwhites to carbofuran but 1.5 times less sensitive to chlorpyrifos. The two species were equally sensitive to fensulfothion, parathion, and phorate. Ingestion of a single granule of aldicarb was found to be life threatening to a quail-sized bird, and less than five grains of fensulfothion, diazinon, fonofos, carbofuran, or fenamiphos in the formulations tested could be lethal to sparrow-sized birds.

158. HILL, E.F., and W.J. Fleming. 1982. Anticholinesterase poisoning of birds: field monitoring and diagnosis of acute poisoning. *Environ Toxicol Chem* 1:27-38.

This paper describes the collection and preservation of vertebrates to be analyzed for ChE inhibition, as well as the analysis and interpretation of analytical data. Both post-mortem and live sampling methods are discussed as is the analysis of both brain and plasma ChE activity. Several case studies are included.

159. HILL, E.F., R.G. Heath, J.W. Spann, and J.D. Williams. 1975. Lethal dietary toxicities of environmental pollutants to birds. *Spec Sci Rep - Wildl* 191. U.S. Fish and Wildlife Service, Washington, D.C. 61 pp.

Eight-day (5 days of toxic diet followed by 3 days of untreated diet) dietary toxicities of 131 pesticidal and industrial compounds to three species of upland game birds and mallards were determined. Results are presented in tabular form. OCs, OPs, and organometallics generally were most toxic. Mallards were generally the most tolerant species tested. Eight compounds (Azodrin [monocrotophos], Bidrin [dicrotophos], Ceresan MR [ethylmercury chloride], Dasanit [fensulfothion], endrin, famphur, Morsodren

[cyano(methylmercury)guanidine], and parathion) were most toxic (LD₅₀ <100 ppm AI) to mallards. Monocrotophos was most toxic (5-day-old duckling LD₅₀, 9.6 ppm). Tolerance was positively correlated to body mass at time of testing in most cases.

160. HOFFMAN, D.J. 1988. Effects of krenite brush control agent (fosamine ammonium) on embryonic development in mallards and bobwhite. *Environ Toxicol Chem* 7:69-75.

The embryotoxic and teratogenic potential of fosamine ammonium (FA; Krenite) was determined for mallard ducks. After 96 h of development, eggs were dipped in distilled water or distilled water and Krenite at concentrations of 1.5, 6.5, or 30% FA. At 6.5% FA, hatching success was reduced by 33%, and at the highest concentration, 100% of the embryos died by time of hatching compared to 37 and 30% mortality for untreated and distilled water-treated controls. Only 23% of the eggs exposed to 6.5% FA hatched. Teratogenic effects noted in these hatchlings included severe edema with stunting, hypoplasia of the liver, heart aberrations, gastroschisis, and hydrocephaly. Two embryos from the low-dose group had curled toes. Three ducklings from the control groups exhibited abnormalities. Several blood plasma aberrations were found in low- and intermediate-dose ducklings. Brain ChE activity was unimpaired.

161. HOFFMAN, D.J., and P.H. Albers. 1984. Evaluation of potential embryotoxicity and teratogenicity of 42 herbicides, insecticides, and petroleum contaminants to mallard eggs. *Arch Environ Contam Toxicol* 13:15-27.

A variety of contaminants, including 29 pesticides, were tested for toxicity to mallard embryos. Eggs were either immersed in an aqueous emulsion or dosed with pesticides in a non-toxic oil vehicle by pipet. In aqueous emulsion, paraquat was most toxic (LC₅₀, equivalent of 1.7 kg/ha application rate), followed by trifluralin, propanil, bromoxynil with MCPA, and diclofop-methyl, all of which exhibited LC₅₀ values <10.0 kg/ha. When the LC₅₀ was calculated as a percentage of the field level of application, however, trifluralin was most toxic (LC₅₀, 0.8) with paraquat, prometon, toxaphene, malathion, methyl diclofop, propanil, and bromoxynil with MCPA being less toxic in the order presented. 2,4-D, glyphosate, atrazine, carbaryl, dalapon, dicamba, methomyl, and phosmet in an aqueous emulsion were only slightly toxic or non-toxic (LC₅₀ values, 199 to 560 kg/ha). Pesticides applied in a non-toxic oil vehicle were up to 18 times more toxic than when applied in a water vehicle. Paraquat was most toxic (EC₅₀, 0.5 µg/g egg). Reduced growth and physical abnormalities resulted upon exposure to most of the pesticides tested, often at levels less than the appropriate LC₅₀. Abnormalities appeared as edema, stunted growth, scoliosis, gastroschisis, internal hemorrhage, lordosis, and aberrations of the eye, brain, limbs, neck, bill, joints, and internal organs.

162. HOFFMAN, D.J., and W.C. Eastin, Jr. 1981. Effects of malathion, diazinon, and parathion on mallard embryo development and cholinesterase activity. Environ Res 26:472-485.

External exposure of mallard eggs to malathion, diazinon, or parathion in either an aqueous emulsion or a non-toxic oil vehicle resulted in embryotoxicity and inhibition of plasma and brain ChE activity. Formulations and concentrations used were similar to those used in field applications. On a kg/ha basis, parathion was most, and malathion least, embryotoxic with either vehicle. Malathion, however, may present the greatest potential for impact, due to the high application rates permissible for certain crops. Parathion was more toxic in an oil vehicle than in water, as reflected by an LC₅₀ of approximately 2.2 kg/ha, stunted growth, and frequent distortions of the axial skeleton. Cholinesterase inhibition due to parathion exposure was more pronounced and of longer persistence than with the other two pesticides.

163. HOFFMAN, D.J., and W.C. Eastin, Jr. 1982. Effects of lindane, paraquat, toxaphene, and 2,4,5-trichlorophenoxyacetic acid on mallard embryo development. Arch Environ Contam Toxicol 11:79-86.

Concentrations and formulations of lindane, paraquat, toxaphene, and 2,4,5-T were applied externally to mallard eggs in either an aqueous emulsion or a non-toxic oil vehicle. Paraquat was the most toxic regardless of the vehicle used, but was 15 times more embryotoxic in oil than in water. Both paraquat and toxaphene caused mortality at approximately half the field application rate. Although lindane was teratogenic, effects were noted only at levels five times the normal field application rate. Overall, with either water or oil, paraquat was most, and 2,4,5-T least, toxic. During the course of the 16-day study, mortality due to lindane poisoning was <7%, and no mortality was caused by 2,4,5-T.

164. HOFFMAN, D.J., L. Sileo, and H.C. Murray. 1984. Subchronic organophosphorus ester-induced delayed neurotoxicity in mallards. Toxicol Appl Pharmacol 75:128-136.

Eighteen-week-old female mallards fed 0, 10, 30, 90, or 270 ppm technical grade EPN over a 90-day period developed ataxia after 16 to 38 days depending on dose. Concentrations of 10 ppm or less failed to produce ataxia. All birds receiving 270 ppm developed ataxia or paralysis by the end of the 90-day period. Five of six birds in the 90-ppm group and two of six birds in the 30-ppm group showed visible effects. Decreased body weights were observed at the three higher treatment rates. Average brain neurotoxic esterase activity depression was 16, 69, 73, and 74% in the 10-, 30-, 90-, and 270-ppm groups, respectively. Demyelination and degeneration of spinal cord axons were observed in ducks receiving 30, 90, or 270 ppm. Ducks exposed to 60, 270, or 540 ppm leptophos exhibited similar symptoms.

165. HOLCOMBE, G.W., G.L. Phipps, A.H. Sulaiman, and A.D. Hoffman. 1987. Simultaneous multiple species testing: Acute toxicity of 13 chemicals to 12 diverse freshwater, fish, and invertebrate families. Arch Environ Contam Toxicol 16:697-710.

Five to nine vertebrate and invertebrate species were tested simultaneously for sensitivity to each of 12 chemicals. The method described not only satisfies the freshwater acute toxicity requirements for setting water quality criteria, but also allows more accurate comparisons of species sensitivity with a tested chemical. The authors suggest that use of this method can also produce the minimum acute data set for the derivation of a water quality standard in less time and with a substantial cost saving for labor, materials, and chemical analyses when compared with the more standard single species tests.

166. HOLMES, S.B., and P.T. Boag. 1990. Inhibition of brain and plasma cholinesterase activity in zebra finches orally dosed with fenitrothion. Environ Toxicol Chem 9:323-334.

Zebra finches given single oral doses of fenitrothion dissolved in soya bean oil at rates of 1.04, 3.80, and 11.36 mg AI/kg body weight exhibited maximum brain ChE inhibitions of 50, 70, and 75%, respectively. Plasma ChE inhibition at the three dosage rates was 78, 82, and 89%. Recovery was at an exponential rate, with plasma ChE recovering more rapidly than brain ChE activity. At the two lower dosages, plasma ChE activity returned to normal in 1 to 2 days, and brain ChE activity continued to be inhibited for up to 10 days at the lowest dosage rate. Four of 40 birds died at the intermediate rate and 12 of 40 died at the highest rate. Birds that died lost, on average, 12.6% of their initial body weight. Body temperatures of birds receiving 11.36 mg/kg were 6 to 15% below normal up to 12 h after treatment. No temperature changes were noted in other control and treated birds. Brain ChE inhibition in those birds that died ranged between 3 and 84%.

167. HOWARD, E.B., G.N. Esra, and D. Young. 1979. Acute foodborne pesticide toxicity in cormorants (*Phalacrocorax* sp) and seagulls (*Larus californicus*). Pp 290-296 in F. Peter (ed), *Animals as monitors of environmental pollutants*. National Academy of Sciences, Washington, D.C.

Two Brandt's cormorants, three guanay, and 16 California gulls at the Los Angeles City Zoo were poisoned by a diet of bottom-feeding fish harvested near the San Pedro Harbor. Bird tissue analyses revealed average concentrations of 3,057.0 and 746.0 ppm DDE in gull and cormorant liver, respectively. Mean concentrations in brain tissue were 428.0 ppm for gulls and 217.0 ppm for cormorants. Tissue analysis from various food-fish species showed a mean DDE concentration of 3.06 ppm in queenfish. A gull would have to consume 24 kg of queenfish to accumulate

over 3,000 ppm DDE in the liver. However, given that the half life of DDE is approximately 250 days in a gull-sized bird and that the birds ingested some 149 to 225 g of food daily, the lethal level (200 to 300 ppm in brain tissue) could easily have been reached in 12 to 15 months or less. The results of this study indicate a need for monitoring pesticide levels in food items consumed by avian species.

168. HUCKINS, J.N., J.D. Petty, and D.C. England. 1986. Distribution and impact of trifluralin, atrazine, and fonofos residues in microcosms simulating a northern prairie wetland. *Chemosphere* 15:563-588.

Wetland microcosms, consisting of sediments from a representative wetland, biota associated with the sediments, seeded populations of *Daphnia magna* and *Chironomus riparius*, and reconstituted water, were separately exposed to atrazine (20 µg/L), trifluralin (4 µg/L), and fonofos (22 and 94 µg/L) in sediment-water mixtures simulating edge-of-field runoff. All pesticides were labelled with ¹⁴C. Data collected at the end of a 6-week exposure period indicated that approximately 45 and 72% of the trifluralin and fonofos was in the sediment. About 27% of the trifluralin and 13% of the fonofos was found in the water. More atrazine was in the water (approx. 49%) than in the sediment (approx. 38%). Pesticide concentrations in biota varied among chemicals. Daphnid concentrations of ¹⁴C-trifluralin residues were more than three times those of any other biotic component. Algae concentrated more ¹⁴C-atrazine residues than any other biotic group. Macrophytes and midge larvae, however, contained only slightly lower atrazine concentrations. ¹⁴C-fonofos residue concentrations in biota were generally proportional to application rate. Plants and ostracods showed highest concentrations. Daphnid mortality due to fonofos was significantly different from controls at both application rates, but no differences were noted in daphnid mortality due to either atrazine or trifluralin exposure. Survival of midge larvae was not significantly affected by exposure to any of the three chemicals. Analysis of plant biomass data failed to detect any significant differences between control and treatment microcosms; however, dissolved oxygen was significantly lower in atrazine microcosms than in controls.

169. HUDSON, R.H., R.K. Tucker, and M.A. Haegele. 1972. Effect of age on sensitivity: acute oral toxicity of 14 pesticides to mallard ducks of several ages. *Toxicol Appl Pharmacol* 22:556-561.

Mallard ducks aged 36 h, 7 days, 30 days, and 6 months were used to assess differential toxicity to 13 commonly used pesticides. Four of the pesticides were nervous system stimulants, and the remaining 10 were ChE inhibitors. Birds aged 36 h were more sensitive than older ones to Baygon [propoxur], Dasanit [fensulfothion], Furadan [carbofuran], and

Temik [aldicarb]. Six-month-old birds were more sensitive to Azodrin [monocrotophos], Bidrin [dicrotophos], and Systox [demeton] than were birds of other ages. Dursban [chlorpyrifos], endosulfan, parathion, and toxaphene were most toxic to 7-day-old birds, and endrin was most toxic to 30-day-old birds. 1080 [sodium fluoroacetate] was more toxic to 7- and 30-day-old birds than to birds either younger or older. The toxicity of Zectran [mexacarbate] was evaluated with birds aged 48 h, 7, 14, 30, and 60 days. Relative sensitivity for the various age groups was in the order of 60 days > 48 h > 30 days > 14 days > 7 days. The extremes between age groups for all compounds were generally less than threefold. The four central nervous system stimulant LD₅₀ values decreased from 36 h- to 7- or 30-day-old animals, and increased for birds aged 7 or 30 days to 6 months. Eight of the ten ChE inhibitors produced LD₅₀ values that increased for birds aged 36 h to 7 or 30 days, and decreased with age for older ducks. Thus, young animals are not always more susceptible to pesticides than are adults. Such factors must be considered in the development of both laboratory and field studies.

170. HUDSON, R.H., R.K. Tucker, and M.A. Haegele. 1984. Handbook of toxicity of pesticides to wildlife (2nd ed.). Res Publ 153, U.S. Fish and Wildlife Service, Washington, DC. 90 pp.

This book provides acute oral and, in some cases chronic, toxicity data (LD₅₀ values) of some 93 chemical and biological pesticides for several avian, mammalian, and amphibian species. Signs of intoxication and comments regarding physiological effects are given.

171. HUFFAKER, C.B. 1980. Use of predators and parasitoids in biological control. Pp 173-199 in R.C. Staples (ed), *Linking research to crop production*. Plenum Press, New York.

This is a review of the use of predators and parasitoids for biological control of pest species. A large number of cases of successful biological control are cited. Several of these cases which illustrate sound ecological principles are discussed in detail, as are many cases involving integrated pest management. Most cases involved restoration of biological control in systems which were disrupted by chemical pesticides.

172. HUNT, E.S. 1967. Detection and investigation of fish and wildlife losses caused by pesticides. Calif FW-1-R-4/Wk Pl 1/Job 1. California Department of Conservation. 6 pp.

Mortality of a number of individuals representing several upland game, waterfowl, and fish species due to pesticide exposure is reported. Several hundred American wigeon and four Canada geese were found dead on Ramer Lake (ducks) and Imperial Valley alfalfa fields (geese). Alfalfa was found in the proventriculi of both species, and mortality was due

to diazinon poisoning. Diazinon residue concentrations of 10 and 2.7 ppm were found in wigeon proventriculus and gizzard samples, and a goose ventriculus sample contained 6.2 ppm diazinon. Both alfalfa fields involved had been treated with diazinon (approx 0.5 kg/ha) within 24 h of wildlife loss. Alfalfa collected from the field where the geese were found contained 38 ppm diazinon. Fish kills were associated with agricultural runoff contaminated with Thiodan [endosulfan]. Concentrations of 1.3 and 1.4 ppm Thiodan were sufficient to cause mortality. Illegal disposal of pesticide containers resulted in a fish kill near Crescent City, Calif. Dinitro-o-sec-butyl phenol [dinoseb] was found in the water at a concentration of 640 ppm.

173. IRWIN, R.J. 1988. Impacts of toxic chemicals on Trinity River fish and wildlife. U.S. Fish and Wildlife Service, Fort Worth Field Office, Fort Worth, Texas. 82 pp.

This report does not directly address toxic effects of pesticides to migratory birds, but data of interest are presented. Included are pesticide concentrations in a variety of fish, amphibians, and mammals; FDA action levels for human and animal food; and recommendations for predator protection levels. Pesticides and associated organic compounds discussed include PCBs, chlordane and metabolites, dieldrin, lindane, mirex, DDT and metabolites, and a variety of aliphatic and polycyclic aromatic hydrocarbons. Metallic contaminants are also addressed, and data are presented relative to metal concentrations in mosquitofish.

174. ISENSEE, A.R., C.S. Helling, T.J. Gish, P.C. Kearney, C.B. Coffman, and W. Zhuang. 1988. Groundwater residues of atrazine, alachlor, and cyanazine under no-tillage practices. *Chemosphere* 17:165-174.

Detectable concentrations of atrazine, alachlor, and cyanazine were found in 75, 18, and 13% of ground water samples from test wells in no-till cornfield plots in Maryland. Maximum residue concentrations were 5.9, 3.6, and 1.0 µg/L, respectively. Results indicated rapid vertical transport to the shallow, unconfined ground water (approx 1 m depth), as well as substantial lateral subsurface flow.

175. JARVIS, R.L., and S.W. Harris. 1971. Land-use patterns and duck production at Malheur National Wildlife Refuge. *J Wildl Manage* 35:767-773.

Number of mated pairs, nesting species, earlier and later nests, and nesting success were directly correlated with the amount of residual cover. [Although cover loss in this study was not pesticide-related, removal of broad-leaved weeds and other herbaceous species as a result of pesticide application should produce similar effects.]

176. JEFFERIES, D.J., and M.C. French. 1972. Changes induced in the pigeon thyroid by p,p'-DDE and dieldrin. *J Wildl Manage* 36:24-30.

Pigeons were force-fed dieldrin or p,p'-DDE in olive oil at rates of 4, 2, or 1 mg/kg and 72, 36, or 18 mg/kg, respectively, daily for 56 days. Controls were fed olive oil only. Thyroid glands of treated birds increased in weight and showed loss of colloid from the follicles associated with hyperplastic epithelia when compared with control birds. The changes were similar to those observed in pigeons after ingestion of p,p'-DDT and were indicative of either hyper- or hypothyroidism. Further investigation indicated hyperthyroidism at low dosages and hypothyroidism at high doses of p,p'-DDT. Hypothyroidism was proposed as a possible mechanism responsible for eggshell thinning. In addition to thyroid effects, liver and adrenal weights increased and heart weights decreased with ingestion of p,p'-DDE, but similar responses were not noted in birds fed dieldrin. Higher-than-expected mortality in birds treated with p,p'-DDE indicated that pigeons may be more sensitive to DDE than to DDT.

177. JOHNSON, B.T. 1971. Pesticides in the freshwater ecosystem. Pp 59-62 in D.R. Scoby (ed), *Environmental ethics: studies of man's self-destruction*. Burgess Publishing Co., Minneapolis, Minn. 239 pp.

This paper was taken in part from an address to college biology teachers. It addresses three specific areas: the influence of pesticides on primary productivity, the biological magnification of pesticides by consumers, and the interaction of pesticides and decomposers. The only pesticide discussed is DDT, but perhaps rightly so. Some worthwhile historical data are presented.

178. JOHNSON, B.T. 1986. Potential impact of selected agricultural chemical contaminants on a northern prairie wetland: a microcosm evaluation. *Environ Toxicol Chem* 5:473-485.

The potential effects of carbofuran, fonofos, phorate, atrazine, triflan, and triallate were assessed using aquatic, multicomponent microcosms designed to simulate northern prairie wetland habitat. Pre-exposure of the wetland sediments to either triallate or fonofos did not appear to change the relative toxicological persistence of either compound in the water column. Changes in pH, alkalinity, conductivity, dissolved oxygen, total nitrogen, and total phosphorus were observed with different pesticide treatments. Atrazine significantly reduced gross primary productivity and inhibited algal and macrophytic growth. In general, however, there was no evidence of significant inhibition of microbial functions in the water or hydrosol of the treated microcosms. Standard acute 48-h toxicity tests of the six pesticides using *Daphnia magna* and *Chironomus riparius* indicated that carbofuran, fonofos, phorate, and triallate were very toxic to aquatic invertebrates. Forty-eight-hour EC₅₀ values

ranged from 15.5 µg fonofos/L for *D. magna* to 108.0 µg phorate/L for *C. riparius*. EC₅₀ values for atrazine and treflan were 3,600 and 560 µg/L, respectively, for *D. magna* and 1,000 µg/L for *C. riparius*. With the exception of atrazine, *D. magna* was more sensitive (approx two times) to the pesticides tested than was *C. riparius*. Carbofuran and phorate were less persistent in the microcosms than were triallate and fonofos. There was no detectable evidence that atrazine or treflan influenced daphnid growth, survival, or reproduction. Algal growth was reduced >40% by atrazine and by triallate at concentrations greater than 10 µg/L. It was unaffected by treflan and phorate and was stimulated by carbofuran concentrations above 100 µg/L. Fonofos at a concentration of 1,000 µg/L reduced algal growth >50%. Over the 30-day test period, both producers and consumers were affected by atrazine, triallate, and fonofos at concentrations of 10 µg/L or less.

179. JOHNSON, W.W., and F.L. Mayer. 1972. Pesticides and the aquatic environment. Pp 21-37 in T. Hinckley (ed), Proc, Symposium of Pests and Pesticides. Southeast Missouri State University, April 28, 1972.

Effects of a number of pesticides upon the aquatic environment are discussed in relation to pesticide type and method of application. Effects on aquatic organisms are reviewed, and acute and chronic toxicity data are presented for a variety of vertebrate and invertebrate species. Other topics include mode of action, synergism, and the development of resistance. The authors conclude that detailed attention must be given to potential effects of pesticides prior to their release into the aquatic environment if such environments are to be preserved.

180. JOHNSON, W.W., and M.T. Finley. 1980. Handbook of acute toxicity of chemicals to fish and aquatic invertebrates. Res Publ 137. U.S. Fish and Wildlife Service, Washington, D.C. 98 pp.

This handbook presents summary data from toxicity tests conducted at the Columbia National Fisheries Research Laboratory from 1965 to 1978. Data are presented for 197 chemicals and are arranged alphabetically by chemical.

181. JULIN, A.M., and H.O. Sanders 1977. Toxicity and accumulation of the insecticide imidan in freshwater invertebrates and fishes. Trans Am Fish Soc 106:386-392.

Toxicity tests used Imidan [phosmet] with a variety of freshwater fishes and aquatic invertebrates. Invertebrate 48-h EC₅₀ or LC₅₀ values ranged from 2.4 µg/L for amphipods (*Gammarus pseudolimnaeus*) to 3,200 µg/L for larval midges (*Chironomus plumosus*). The most sensitive fish tested were chinook salmon and smallmouth bass; 96-h LC₅₀ values for both were 150 µg/L. Channel catfish were most resistant (LC₅₀, 11,000 µg/L). Toxicities to fishes of the AI, technical grade material

and the 50% wettable powder were similar, and increased with increasing temperature and decreasing pH. Toxicity was unaffected by water hardness. Eyed eggs and yolk-sac fry of rainbow trout were more resistant than were fingerlings. Imidan toxicity in water decreased rapidly over time (water temperature maintained at 20 C at pH 7.2). Four-day-old solutions were less than 0.04 as toxic as fresh solutions. Bioaccumulation factors (24-h exposure at 1.2 µg/L of ¹⁴C-Imidan) ranged from 1 in the damselfly (*Ishnura verticalis*) to 10 in fathead minnows, channel catfish, and bluegill.

182. JULIN, A.M., and H.O. Sanders. 1978. Toxicity of the IGR, diflubenzuron, to freshwater invertebrates and fishes. Mosquito News 38:256-259.

Technical grade material and wettable powder formulations of the insect growth regulator diflubenzuron and three of its degradation products were tested for toxicity to three species of aquatic invertebrates (*Daphnia magna*, *Gammarus pseudolimnaeus*, *Chironomus plumosus*) and four fish species (rainbow trout, fathead minnows, channel catfish, and bluegills). The acute toxicities of the wettable powder ranged from a 48-h EC₅₀ of 0.015 mg/L for daphnids to a 96-h LC₅₀ of 660 mg/L for bluegills. The 96-h LC₅₀ of technical grade diflubenzuron exceeded 100 mg/L for all fishes. The most toxic degradation product, 4-chloroaniline, had a 96-h LC₅₀ of 2.4 mg/L to bluegills and a 48-h EC₅₀ of 43 mg/L to early fourth-instar midge larvae. The 48-h EC₅₀ for midge larvae and 96-h LC₅₀ for three of the four fish species for two other degradation products, 4-chlorophenyl urea and 2,6-difluorobenzoic acid, exceeded 100 mg/L. Rainbow trout were most sensitive to 4-chlorophenyl urea (LC₅₀, 72 mg/L) and fathead minnows were most affected by 2,6-difluorobenzoic acid (LC₅₀, 69 mg/L).

183. JUTSUM, A.R. 1988. Commercial application of biological control: status and prospects. Phil Trans Royal Soc Lond B 318:357-373.

This paper examines the suitability of different types of biological control agents (BCAs) for research and commercialization. Biological control includes obligate parasites and pathogens, facultative parasites and pathogens, competitors (e.g., weeds), toxin-producing pathogens, toxins produced by pathogens, and non-toxic behavior-modifying chemicals (e.g., pheromones). BCAs may ultimately be used to advantage in virtually any market, if they are as good as or better than existing control agents in terms of cost and efficiency or if they have a significant toxicological or environmental advantage. The authors state that only four exploitable market niches currently (as of 1988) exist: (1) Outlets where conventional chemical agents give insufficient levels of control (e.g., insect strains resistant to chemical pesticides). (2) Outlets where conventional chemical control agents are too expensive.

(3) Outlets where the application of chemical control agents is restricted by government agencies.

(4) Outlets where the environment is contained and controlled (e.g., greenhouses).

Several cases are cited where BCAs were used successfully: the cactus moth (*Cactoblastis cactorum*) to control prickly pear (*Opuntia* spp) in Australia, and *Bacillus thuringiensis* for the control of lepidopterans and dipterans. Several failures are also cited. In some cases the BCA failed to become established, became a pest itself after failing to control the target organism, or failed due to human error or lack of foresight (e.g., difficulties in handling, storage, etc.). Overall, only about 5% of all deliberate releases actually achieved their aim. The authors concluded that although the future of BCAs looks bright, the agrochemical industry expects them to complement, and not replace, chemicals.

184. KAHN, M.A.Q. (ed). 1977. Pesticides in aquatic environments. Plenum Press, New York, NY. 257 pp.

Proceedings of a symposium for the International Congress of Entomology in 1976, this book includes papers on a wide variety of topics including the nature and origin, dynamics, and fate of pesticides in aquatic environments. All families of pesticides are discussed, and some excellent models to predict pesticide distribution and fate are presented.

185. KEILTY, T.J., D.S. White, and P.F. Landrum. 1988. Sublethal responses to endrin in sediment by *Stylocdrilus heringianus* (Limbriculidae) as measured by a ¹³⁷Cs marker layer technique. *Aquat Toxicol* 13:251-270.

A microcosm study to determine possible sublethal responses of earthworms to endrin was conducted. Endrin concentrations ranged from 3.1 to 42,000 ng/g dry sediment, well below the LC₅₀ of 1,650 µg/g. At lower concentrations, earthworm activity seemed to be stimulated for the first 300 to 600 h of observation, followed by significant decreases relative to controls. At higher endrin concentrations, activity was equal to or less than that of controls during the first 600 h, then decreased dramatically. Worm mortality ranged from 9.3 to 28% for higher concentrations; at lower concentrations (including controls), it ranged from 0 to 6.7%. Post-experimental worm dry weights were inversely correlated with endrin concentration. Bioaccumulation factors ranged from 34 to 67 on a g dry organism to g dry sediment basis. Data implied that worms mediated upward transport of the chemical.

186. KEILTY, T.J., D.S. White, and P.F. Landrum. 1988. Sublethal responses to endrin in sediment by *Limnodrilus hoffmeisteri* (Tubificidae), and in mixed-culture with *Stylocdrilus heringianus* (Lumbriculidae). *Aquat Toxicol* 13:227-250.

Sediment reworking by *Limnodrilus hoffmeisteri* alone and with *Stylocdrilus heringianus* was measured in sediments dosed with endrin by monitoring the burial of a ¹³⁷cesium marker layer. Endrin concentrations ranged from 16.1 to 81,400 ng/g dry sediment weight. Alterations in re-working rates were noted at sediment concentrations two to five orders of magnitude below LC₅₀ values. *L. hoffmeisteri* activity did not appear to be stimulated at low endrin concentrations as previously [see preceding paper] noted for *S. heringianus*. At higher concentrations, both species were affected adversely. Re-working rates with both species present (1:1 ratio) suggested that the presence of *S. heringianus* enhanced the re-working response of *L. hoffmeisteri*. Worm dry weights at the end of the experiment were inversely correlated with sediment endrin concentrations. Fewer *L. hoffmeisteri* mortalities occurred with *S. heringianus* present than when tested alone. In addition, *L. hoffmeisteri* post-treatment dry weights were greater in the two-species experiments than when tested alone. The reverse did not seem to be true. As in previous studies, upward transport of contaminants was mediated by the worms. *S. heringianus* bioaccumulation factors ranged from 9.7 to 43.8 and were consistently three to four times greater than bioaccumulation factors for *L. hoffmeisteri*.

187. KING, K.A., D.H. White, and C.A. Mitchell. 1984. Nest defense behavior and reproductive success of laughing gulls sublethally dosed with parathion. *Bull Environ Contam Toxicol* 33:499-504.

Adult laughing gulls of both sexes were orally intubated with parathion (5 mg/kg body weight). This dosage was previously determined to inhibit brain ChE activity by an average of 46%, a level at which no overt signs of pesticide poisoning were noted. This dose had no effect on nest defense behavior or on hatching success.

188. KIRSCHENMANN, F. 1988. Switching to a sustainable system - strategies for converting from conventional/chemical to sustainable/organic farming systems. Northern Plains Sustainable Agriculture Society, Windsor, ND. 18 pp.

This booklet describes the advantages (and some of the pitfalls) of a sustainable agriculture system. Step-by-step directions, somewhat simplified, are given for switching from conventional (chemical dependent) to sustainable (organic) agriculture.

189. KLINGHAUF, F., U. Stein, H.-J. Bestmann, O. Vostrowsky, B. Classen, and U. Kobold. 1988. Pflanzliche Insektizide VI. Wirkung eines ethanolschen Blattextraktes aus Essigbaum (*Rhus typhina* L.) auf verschiedene Schadinsekten. J Appl Ent 105:41-47.

This paper describes the use of an ethanolic leaf-extract of Buck's horn (*Rhus typhina*) for control of a variety of insect pests. Mortality rates of 76.3, 71.2, and 62.0% were observed in three aphid species at 24 h post-application. Mortality of *Metopolophium dirhodum* was 77% within 5 min after application. The extract was also toxic to larvae of the mustard beetle (*Phaeodon cochleariae*), and delays were noted in larval and pupal development. An increase in molting defects was also observed. Of some 70 Buck's horn leaf compounds identified, hexahydrofarnesylacetone (as a 1% solution in 96% ethanol) was highly toxic to the beetle larvae when applied to plant foliage. From first larval stage to adult emergence, 92% mortality was observed.

190. KOZLOVSKAYA, V.I., and F.L. Mayer, Jr. 1984. Brain acetylcholinesterase and backbone collagen in fish intoxicated with organophosphate pesticides. J Great Lakes Res 10:261-266.

This paper presents the rationale for using brain ChE inhibition in fish as an indicator of OP pesticide contamination. Cyprinids and percids were exposed to trichlorfon (80% technical formulation of Dylox) and malathion (50% emulsion). Cholinesterase was completely inhibited in those fish that died during the study. Some of the perch died when ChE inhibition due to trichlorfon exposure was decreased by 50% (48-h LC₅₀, 0.62 mg/L). In 2-h exposures at 5 mg/L, however, mortality was 100% and occurred when ChE was inhibited by 75%. Only 11% of carp exposed to 100 mg malathion/L (= 2-h LC₁₀₀) died at 75% ChE inhibition, and all died when enzyme activity was depressed to 87% of normal. The authors suggested that ChE inhibition was not the direct cause of death, but was the first step leading to further complications. Further, they observed that the level of ChE activity at which death occurred was dependent upon the physiological condition of the organism as well as the degree of exposure to the toxicant. Survival was noted in longer, less acute exposures at ChE levels which proved fatal in more acute exposures.

191. KREUTZWEISER, D.P., P.D. Kingsbury, and J.C. Feng. 1989. Drift response of stream invertebrates to aerial applications of glyphosate. Bull Environ Contam Toxicol 42:331-338.

A stream invertebrate community was exposed to an aerial application of Roundup (glyphosate). Glyphosate application (2.0 kg AI/ha) on or adjacent to small tributaries of the stream did not appear to unduly disturb stream invertebrate communities. Drift densities of most aquatic invertebrates did not increase in response to the herbicide application.

Only two organisms, an amphipod (*Gammarus* sp) and a mayfly nymph (*Paraleptophlebia* sp), seemed to exhibit a slight ephemeral herbicide-induced response in and downstream of treated areas. Post-spray drift of these taxa was not significantly different from pre-spray levels, but a measurable alteration in the drift patterns of both genera was seen. Although there seemed to be a definite increase in drifting amphipods, residual glyphosate in integrated water samples did not exceed 162 µg/L and was <50 µg/L within 10 h after over-spray. These levels are well below the 48-h EC₅₀ of 43,000 µg/L for *Gammarus* sp. The mean number of mayflies collected on the evening of the glyphosate application was not significantly different from that of the previous evening, but drift was approximately ten times greater than the pre-spray peak. Peak glyphosate concentrations were 1/90 to 1/3,000 the reported concentration required to induce movement of *Ephemerella* sp mayflies in an avoidance chamber. Overall, glyphosate application in accordance with label recommendations did not appear to impose any significant impact on stream invertebrate communities.

192. LAGERHÖF, J., and H. Wallin. 1988. Cropping systems, field margins and invertebrate fauna in Swedish agriculture. INTECOL Bull 16:55-59.

Four types of field margins were investigated for their potential as hibernation and propagation sites for predators of insect pests. Of the four, field margins--with their naturally high diversity of plant species--had the highest diversity and abundance of insects and other arthropods (25 carabid beetle species, for example). The greatest number of parasitoids was found in field margins of almost entirely coach grass (*Agropyron repens*) (21 carabids). Coach grass margins plowed and sown in legumes or left to vegetate naturally from the seed bank proved to be less valuable (16 and 19 carabid species, respectively). The number of hibernating predatory beetles was greatest in the coach grass margin. None of the margin types was an important hibernation site for blossom beetle or any other pest insect.

193. LEIGHTON, F.A., and G.A. Wobeser. 1990. Occurrences of poisoning of wild birds by pesticides in Saskatchewan, 1984-1989. Pp 11-12 in Proceedings of a symposium: environmental contaminants and their effects on biota of the Northern Great Plains. North Dakota Chapter, The Wildlife Society, Bismarck.

Very few deaths of wild birds from pesticide poisoning have been reported or investigated in Canada. The first such incident, the death of approximately 60 lapland longspurs due to carbofuran poisoning, occurred in May 1984. Granular carbofuran, applied during seeding, was present in the gizzard. Brain ChE activity was markedly depressed. Carbofuran was also the cause of death of some 45 California gulls in June 1986. Exposure was facilitated by

grasshopper ingestion. Grasshoppers eaten by the gulls contained 4.2 to 7.2 ppm carbofuran. Brain ChE activity was normal. Death was likely the result of paralysis of the respiratory system due to ChE inhibition at the peripheral nerve endings. Diazinon used in a Regina city park led to the death of some 66 Canada goose goslings in June 1989. Brain ChE was very low. No adult mortality was observed. Fensulfothion and associated metabolites were the source of death of approximately 60 herring and California gulls in and around Prince Albert in May 1986. The presence of fensulfothion metabolites suggests the gulls may have fed on other birds or mammals that had ingested the pesticide.

194. LEININGER, W.C. 1988. Non-chemical alternatives for managing selected plant species in the western United States. U.S. Fish Wildl Serv and Colorado State U CES Rep XCM-118. 48 pp.

Identification, ecology, and methods for biological and cultural control of 14 aquatic and terrestrial plants are presented.

195. LINDUSKA, J.P., and H.M. Reeves. 1974. Direct mortality and related factors affecting waterfowl in North America. Pp 437-443 in Proceedings of an International Conference for the Conservation of Wetlands and Waterfowl.

Pesticides are listed with other non-hunting mortality factors which tend to limit waterfowl production and recruitment in North America. Dieldrin and DDT were cited as causes of mortality and egg shell thinning in snow geese and black ducks, respectively. Aldrin-treated rice seed was connected with a sharp decline in the fulvous whistling-duck population in coastal regions of Texas and Louisiana. The authors expressed concern about the increased use of chemical pesticides, particularly aldrin and dieldrin.

196. LIPCIUS, R.N., C.A. Coyne, B.A. Fairbanks, D.H. Hammond, P.J. Mohan, D.J. Nixon, J.J. Staskiewicz, and F.H. Heppner. 1980. Avoidance response of mallards to colored and black water. J Wildl Manage 44:511-518.

In a series of experiments, captive mallards, which had been deprived of food for 24 to 48 h, were placed in a pen consisting of a habituation section connected by a ramp to a small artificial pool. Food in feeders was freely available on the far side of the pool. Results indicated that orange-colored water was the most effective aversive stimulus. No other color (red, yellow, green, blue, indigo, violet, black) produced consistent avoidance. Black water was possibly attractive to mallards. [This paper was included in case it should be necessary to discourage waterfowl from utilizing a highly contaminated pond or pothole. It would appear that avoidance could be achieved by placing orange dye (100:1, FDC yellow #5;repoline red; 0.077 g/L) in the water.]

197. MACEK, K.J., D.F. Walsh, J.W. Hogan, and D.D. Holz. 1972. Toxicity of the insecticide Dursban to fish and aquatic invertebrates in ponds. Trans Am Fish Soc 101:420-427.

Bluegills and largemouth bass were exposed to two applications of Dursban [chlorpyrifos] at the recommended rates for mosquito control of 0.056 or 0.011 kg AI/ha in 0.04-ha experimental ponds. Dursban residues in water 1 day post-treatment were 2.39 ppb and 0.97 ppb for the two treatments, respectively. Cumulative mortality in control ponds during the 63-day observation period was approximately 1% of the total population for each species of fish. During the same period, mortality in ponds receiving 0.011 kg/ha was 3 and 10% for bluegills and bass, respectively, whereas the corresponding mortalities due to the high application rate were 55% and 46%. Both species bioaccumulated the pesticide. One to 3 days after treatment, the mean residue concentration was 3.2 ppm in bluegills and 2.55 ppm in bass at the higher application rate. Residue loss was rapid. At 2 weeks post-treatment, residue concentrations were <0.4 ppm. They were undetectable 2 weeks later. Both species exhibited greater than 80% inhibition in brain ChE activity when exposed to the highest application. Histological examination did not show conclusive evidence for pesticide-induced pathological effects. The high treatment rate reduced colonization of artificial substrate samplers by 75%, eliminated caddisfly larvae, and reduced mayfly populations by about 90%. Significant reductions in the number of insects colonizing the samplers were also observed at the lower application rate. Again, caddisflies were the most sensitive group. The lower application rate did not appear to have any effect on the number of emergent midges; but at the higher rate, the number of midges emerging was <1/3 the number emerging from control ponds.

198. MACHBUB, M., H.F. Ludwig, and D. Gunaratnam. 1988. Environmental impact from agrochemicals in Bali (Indonesia). Environ Monitor Assess 11:1-23.

With an increasing demand for food for a growing population and limited land, the agricultural community of Bali sought to increase productivity through intensified agricultural practices including use of high-yield rice varieties and agricultural chemicals. Data show the kinds and amounts of pesticides used since 1963 and fertilizer use since 1970. As in the U.S., pesticide and chemical fertilizer use increased over time, as has the number of pest species. Total insecticide use increased from 1,677 kg in 1963 to 390,283 kg (about 2.5 kg/ha) in 1978. Nearly 70% of the paddy land area was treated with chemical fertilizer in 1979. Fertilizer application rates averaged 144 kg of urea and 5.6 kg phosphate per ha. The use of chemical fertilizers had not caused any known significant adverse environmental effects as of 1980. Nutrients lost to the environment from irrigated paddies represented only a small part

of the total nutrient input to surface waters. The past use of 'hard' OC pesticides (mainly endrin and dieldrin, 1963-1973) has resulted in serious and persistent impairment of the aquatic ecosystems on Bali. Residual concentrations of those OCs measured (aldrin, DDT, dieldrin, lindane, benzene hexachloride, and DDE) are considerably greater than USEPA recommended limits. Total accumulation in the soil ranged from an average of about 9 µg/kg for lindane and benzene hexachloride to 321 µg/kg for dieldrin. The average total accumulation for all pesticides was about 100 µg/kg. Prawns sampled in 1980 contained residue concentrations of dieldrin, aldrin, lindane, and benzene hexachloride of 4.2, 18.0, 4.3, and 3.3 µg/kg, respectively. Residue concentrations in some river bottom sediments were extremely high: 3,470 and 6,490 ppb in the Palasari and Mertagangga rivers, respectively. Palasari River sediment concentrations of aldrin (245 ppb) and lindane (1,210 ppb) were also much higher than might be expected based on surface soil samples. [Conditions similar to those noted in this paper may be prevalent in many developing countries. Thus, elevated concentrations of OC residues currently noted in many migratory bird species may be traceable to contamination of breeding, wintering, or resting areas, as appropriate.]

199. MADDER, D.J., and W.L. Lockhart. 1980. Studies on the dissipation of diflubenzuron and methoprene from shallow prairie soils. *Can Entomol* 112:173-179.

Studies conducted to characterize the dissipation of diflubenzuron and methoprene from shallow Manitoba prairie pools indicated the rapid disappearance of both from the water, but diflubenzuron degraded more slowly than methoprene. Results indicated that the use of methoprene for mosquito control should not pose a long-term persistence hazard in water.

200. MAGUIRE, R.J., and R.J. Tkacz. 1989. Potential underestimation of chlorinated hydrocarbon concentrations in fresh water. *Chemosphere* 19:1277-1287.

Chlorinated hydrocarbons are usually extracted from fresh waters at neutral pH; however, the authors found significant concentrations of PCBs and other OC compounds in dichloromethane extracts of filtered Niagara River water at pH 12 after a thorough extraction had been performed at pH 1. The basic fraction accounted for 40 to 48% of the total concentrations of all OC compounds. These results suggest that OC concentrations in surface water when extractions were made at neutral pH may have been significantly underestimated.

201. MAGURRAN, A.E. 1988. Ecological diversity and its measurement. Princeton Univ. Press, Princeton, NJ. 179 pp.

This book provides perhaps the most complete treatise available regarding species diversity and many of the indices which may be used to measure

this ecological parameter. Examples illustrate the calculation of each index; guidance is given to help in choosing and interpreting the results of the proper index for a given situation.

202. MAHONEY, J.J. 1975. DDT and DDE effects on migratory condition in white-throated sparrows. *J Wildl Manage* 39:520-527.

The onset of the spring migratory condition, as measured by Zugunruhe, and weight increase were delayed at least 1 week in caged white-throated sparrows fed diets containing either 5 or 25 ppm technical DDT. Migratory fat stores were inversely correlated with dose. [Although this paper discusses the effects of DDT, now banned in the U.S., other pesticides have been observed to cause anorexia in birds. This condition would result, presumably, in effects similar to those observed in the white-throated sparrow.]

203. MARTIN, D.B. 1985. Accumulation of sediment, nutrients, and cesium-137 in prairie potholes in cultivated and noncultivated watersheds. Pp 274-275 in *Perspectives on nonpoint source pollution: proceedings of a national conference*. USEPA, Washington, D.C.

An attempt was made to measure sedimentation rates in prairie potholes surrounded by cultivated (at least partially) or non-cultivated land by using ¹³⁷cesium as a tracer. The average accumulation rate of cesium in the pothole sediments was the same in grassed and cultivated watersheds. This was believed to be due to differences in the vertical distribution of the contaminant. In the grasslands, the cesium was all found on the soil surface; in cultivated watersheds, it was incorporated throughout the tillage layer. Thus, similar rates of accumulation was indicative of greater erosion in the cultivated watersheds. The author encouraged increased use of conservation tillage practices to reduce overall sedimentation rates and incorporation of pesticides into the soil to reduce the amount transported to wetland sediments.

204. MARTIN, D.B., and W.A. Hartman. 1985. Organochlorine pesticides and polychlorinated biphenyls in sediment and fish from wetlands in the north central United States. *J Assoc Off Anal Chem* 68:712-717.

The data indicated that contamination by OC pesticides or PCBs in the wetland habitats of the north-central U.S. was minimal. Sediment concentrations were above the minimum detection limits of 5 ng/g for OCs and 20 ng/g for PCBs in <4% of the samples taken. Detectable amounts of contaminants were found more often in fish than in sediments; 51% of the fish sampled contained DDE. The maximum concentration was 512 ng/g. Alpha-benzene hexachloride and DDD were detected in 36 and 14% of the fish samples; DDT, dieldrin, PCBs, and trans-nachlor were found in less than 10%.

205. MARTIN, D.B., and W.A. Hartman. 1987. Effect of cultivation on sediment composition and deposition in prairie pothole wetlands. Water Air Soil Pollut 34:45-53.

This is a longer version of entry 203. The average specific activity of ¹³⁷cesium in the top 10 cm of soil was 0.92 and 0.44 pCi/g for non-cultivated and cultivated land, respectively. As the average accumulation rate of cesium in recent pothole sediments was equal for both cultivated and non-cultivated watersheds, it may be assumed that sedimentation rates in potholes surrounded by cultivated watersheds were approximately twice those noted in potholes in grassland watersheds. The authors concluded that information regarding the movement of ¹³⁷cesium may be useful in assessing the movement of many non-point source pollutants.

206. MARTIN, P.A. 1990. Effects of carbofuran, chlorpyrifos and deltamethrin on hatchability, deformity, chick size and incubation time of Japanese quail (*Coturnix japonica*) eggs. Environ Toxicol Chem 9:529-534.

Japanese quail eggs were immersed in aqueous emulsions of carbofuran, chlorpyrifos, and deltamethrin at three potential field concentrations and at three stages of incubation. Hatchability was not affected by exposure to any of the three pesticides, nor did carbofuran cause any significant effects on rate of hatching deformity, incubation time, chick mass, or tarsal length. Chlorpyrifos at two times the recommended field application concentration was teratogenic to eggs treated immediately prior to incubation. Incubation was also delayed relative to controls. Deltamethrin exposure at two times field application rates at the pre-incubation stage resulted in longer incubation rates and in, at incubation day 14, significantly lighter chicks relative to controls. As overall effects were small, the author concluded that the three pesticides do not represent a significant hazard to quail embryos at application rates up to two times the recommended rate.

207. MARTIN, P.A., and K.R. Solomon. 1990. Potential effects of carbofuran during the initial upland brood movement of mallard ducklings. Pp 38-39 in Proceedings of a symposium: environmental contaminants and their effects on biota of the Northern Great Plains. North Dakota Chapter, The Wildlife Society, Bismarck.

Groups of 16-20 ducklings imprinted on humans were led for varying distances up to 300 m through plots of upland vegetation that had been sprayed with a flowable formulation of carbofuran at rates of 0, 132, or 264 g AI/ha (control, 1x, and 2x recommended application rate). No mortality occurred during the study, but many birds in the 2x exposure group and a single bird in the 1x exposure had difficulty in completing the 300-m trial. In most 1x spray treatment and in all 2x treatments, some birds exhibited symptoms of carbamate poisoning.

Distressed birds vocalized excessively and were unable to keep pace with the rest of the group. Inhibition of brain ChE activity was directly related to both application rate and distance travelled. Birds receiving maximum exposure (2x and 300 m) had mean ChE activities only 29% of controls. Previous studies by the senior author indicated carbofuran-induced mortality was associated with ChE inhibition of 75 to 85%. Plasma ChE was depressed at higher application rates, but was not affected by distance traveled and appeared to buffer brain ChE against carbamate binding. Growth rates were not affected by exposure. The magnitude of brain ChE depression suggested that many of the exposed birds were at risk of dying. In addition, observed behavioral alterations, if manifested among wild birds, could disrupt brood cohesiveness and result in high duckling mortality during upland brood movements.

208. MATTES, K. 1989. Kicking the pesticide habit. Amicus Journal, Fall 1989:10-17.

Quoting David Pimentel, the author notes that during the past 45 years, pesticide use has increased by a factor of ten, and during the same time period, crop loss from insects has increased from 7 to 13%. She then reviews current studies and trends in agriculture including integrated pest management, organic and low-input sustainable agriculture, and the use of biotechnology (genetic engineering) to produce herbicide resistant crop strains. She concludes that learning to love dandelions, spiders, and imperfect apples may be the hardest and most urgent task we must face in kicking the pesticide habit.

209. MATSUMURA, F., and E.G. Esaac. 1979. Degradation of pesticides by algae and aquatic microorganisms. Pp 371-387 in M.A.Q. Khan, J.J. Lech, and J.J. Menn (eds), Pesticide and xenobiotic metabolism in aquatic organisms. American Chemical Society, Washington, D.C.

Small-weight flavoproteins were found to be instrumental in the photodegradation of DDT, lindane, dieldrin, toxaphene, parathion, and mexacarbate by blue-green algae. In addition, reductive degradation of mexacarbate, DDT, and toxaphene was enhanced in anaerobic conditions when the same flavoproteins were present. The authors concluded that due to the biomass, large surface area, and relative abundance of algae in many aquatic systems, these algae-derived flavoproteins may play an important role in pesticide degradation in an aquatic environment.

210. MAYER, F.L. 1974. Pesticides as pollutants. Pp 405-418 in B.G. Liptak (ed), Environmental engineers handbook. Chilton Book Co., Radnor, PA.

Although somewhat dated, this review paper covers many topics including mode of action, exposure routes, and acute and chronic toxicity of the different classes of pesticides to aquatic organisms.

Biomagnification, synergism, antagonism, and the development of resistance are also discussed. Tables showing acute toxicity (herbicides; OC, OP, carbamate and botanical insecticides; and a variety of other pesticides) and biomagnification (OCs only) are included.

211. MAYER, F.L., and M.R. Ellersieck. 1986. Manual of acute toxicity: interpretation and data base for 410 chemicals and 66 species of freshwater animals. Res Publ 160, U.S. Fish and Wildlife Service, Washington, D.C. 506 pp.

This book contains all acute toxicity data developed by the Columbia National Fisheries Research Laboratory, U.S. Fish and Wildlife Service, since 1965 that were deemed to be quality data. Covered are 4,901 acute toxicity tests involving 410 chemicals, mostly pesticides, and 66 species of aquatic animals. A synopsis of the data is also presented. As a group, insects were most sensitive, followed by crustaceans, fishes, and amphibians. Among the four most commonly tested forms, daphnids were most sensitive 58% of the time, followed by rainbow trout (35%), bluegills (5%), and fathead minnows (2%). Testing of three species (*Daphnia*, *Gammarus*, and rainbow trout) provided the lowest toxicity (EC or LC₅₀) values 88% of the time. Toxicity of aged solutions increased (11%), decreased (22%), or remained the same (69%) dependent upon the chemical tested. Although pH affected the toxicity of only 20% of the chemicals tested, pH changes resulted in greater changes in toxicity than did any other factor. Generally, toxicity increased with increasing temperature, but the toxicity of DDT, dimethrin, and methoxychlor decreased with increasing temperature. Toxicity values for most chemicals increased by a factor of 3.1 per 10 C rise in temperature; however, the factor was 5.1 for OP insecticides. This was probably due to contaminant increases in ChE activity and inhibition with increasing temperature. The fish diets fish altered test results and could increase toxicity up to 5.7x. The authors concluded that precise information can only be obtained by testing the chemical and species of concern under the environmental conditions of interest.

212. McBRIDE, D.K. 1989. Managing pesticides to prevent groundwater contamination. NDSU CES E-979. North Dakota State University, Fargo. 12 pp.

This publication summarizes the potential for pesticide contamination of groundwater as influenced by water, pesticide, and soil characteristics. Various management practices to minimize this potential are presented.

213. McBRIDE, D.K., D.E. Peterson, and H.A. Lamey. 1988. Persistence and mobility of pesticides in soil and water. NDSU CES Bull 49. North Dakota State University, Fargo. 7 pp.

Basic information about factors involved in movement of pesticides from surface to groundwater

is presented. The relative persistence and mobility of pesticides registered for use in North Dakota are presented in tabular form. From the data, the applicator should be able to select the pesticide that presents the least potential for movement into the groundwater.

214. McEWEN, L.C., T.L. George, and B.E. Petersen. 1990. Response of wildlife to current range grasshopper IPM practices and to former control methods. Pp 43-44 in Proceedings of a symposium: environmental contaminants and their effects on biota of the Northern Great Plains. North Dakota Chapter, The Wildlife Society, Bismarck.

Aldrin, dieldrin, chlordane, heptachlor, and other pesticides formerly used in wide-area grasshopper control programs were highly toxic to many non-target species. Due to the nature of OC pesticides, all except toxaphene were phased out during the 1970s. Research by the USDA in cooperation with the U.S. Fish and Wildlife Service and other agencies to find more acceptable grasshopper pesticides led to the registration of malathion (in an ultra low volume formulation), carbaryl (Sevin-4-Oil) and acephate (Orthene) for large aerial spray operations. The only other materials registered for use are bait formulations of carbaryl and a biological control agent, *Nosema locustae* spores. Field studies showed that none of these caused direct mortality of terrestrial vertebrates. Malathion and carbaryl, accounting for over 90% of total use, can cause fish kills and are very damaging to aquatic ecosystems. Caution must therefore be used when these two chemicals or acephate are used for grasshopper control to assure that wetland habitat is not over-sprayed and to prevent aerial drift into these sensitive habitats. Carbaryl bait and bait treated with *N. locustae* have the least impact on wildlife.

215. McMULLEN, M. 1985. Survey of pesticide usage by aerial applicators. NDSU CES, North Dakota State University, Fargo. 19 pp.

The magnitude of aerial application of pesticides on all North Dakota crops, the magnitude of use on individual crops, regional differences throughout the state, the differences among crops per pesticide category, and the major target pests are presented. The author also states that survey information will help in assessing any impact resulting from actions taken against pesticides by regulatory agencies.

216. McMULLEN, M.P., A.G. Dexter, J.D. Natewaja, W. Hamlin, and K. Davison. 1985. Pesticide uses on major crops in North Dakota 1984. NDSU and North Dakota Crop and Livestock Rep Serv Agron Rep 3. North Dakota State University, Fargo. 31 pp.

This booklet presents the results of the second survey conducted to determine pesticide use by the agricultural community in North Dakota and is

based upon data received from 3,039 respondents. The first such survey was conducted in 1978. North Dakota ranked 6th in the nation in acreage of principal crops harvested and first in production of durham and hard red spring wheats, barley, flax, and sunflower in 1978. By 1984, the state ranked 4th in the nation in acreage of principal crops harvested, with no change in the production of the other crops listed for 1978. Some 5.7, 0.3, and 0.5 million ha were treated with herbicides, insecticides, and fungicides, respectively, during 1978. During 1984, herbicide and insecticide use increased (7.1 and 1.0 million ha treated, respectively), but fungicide use decreased (0.2 million ha treated). The greatest change reported was the increased use of insecticides on sunflower fields: from 5.6% of the total number of ha in 1978 to 64.8% in 1984. A significant increase in the use of insecticides for corn was also reported: from 4.2% in 1978 to 17.9% in 1984. Sugarbeets and potatoes were the major crops treated with fungicides. The top three herbicides used during 1984 (as determined from the number of acres treated) were 2,4-D amine (2.1 million ha), trifluralin (1.8 million ha), and 2,4-D ester (1.2 million ha). 2,4-D (all formulations), trifluralin, and MCPA (all formulations) were the top three in 1978. Among insecticides, fenvalerate, parathion, and carbofuran were most favored (0.57, 0.20, and 0.17 million ha, respectively) in 1984. Azinphos-methyl, toxaphene, and aldicarb were the three most used insecticides during 1978. Mancozeb, maneb and zinc, and triphenyl tin hydroxide (0.08, 0.05, and 0.05 million ha, respectively) were the three most used fungicides during 1984. During 1978, mancozeb, thiabendazole, and maneb were most often used.

217. McMULLEN, M., and A. Dexter. 1985. Survey of pest management practices used by farm producers in North Dakota. NDSU CES Serv Agron Rep 2. North Dakota State University, Fargo. 11 pp.

This publication presents the results of a survey of North Dakota farmers to determine pest management practices used in 1984 and covers not only chemical pest control methods but also information regarding alternative pest control methods used. Results (242 respondents) indicated that herbicides were applied to 89.2% of the reported acreage. Fungicide use was greatest on sugarbeets (91.8% of sugarbeet acres treated), and insecticide use was greatest on sunflowers (75.7%) and potatoes (100.0%). The most frequently reported non-chemical methods of pest control were planting clean seed, crop rotation, summer fallow, conventional tillage, and use of resistant varieties. Biological control was reported least often, and 20.9% of the respondents did not know whether they used biological control methods. When asked what the term 'Integrated Pest Management' meant, 38.0% did not respond and 19% indicated that they did not know. Only 9.0% provided a definition that was acceptable.

218. MEHRLE, P.M., M.T. Finley, J.L. Ludke, F.L. Mayer, and T.E. Kaiser. 1979. Bone development in black ducks as affected by dietary toxaphene. Pestic Biochem Physiol 10:168-173.

Black ducks were exposed to dietary toxaphene concentrations of 0, 10, or 50 $\mu\text{g/g}$ for 90 days prior to laying and through the reproductive season. Toxaphene did not seem to affect reproduction or survival, but bone growth was reduced and backbone development was impaired in ducklings. In ducklings fed 50 $\mu\text{g/g}$, the collagen content of cervical vertebrae was significantly decreased. Ducklings receiving either 10 or 50 $\mu\text{g/g}$ exhibited increased calcium concentrations in vertebrae. These effects were observed only in female ducklings. In contrast to vertebral effects, tibia development was unaltered. Toxaphene residues in duckling carcasses averaged slightly less than the dietary levels.

219. MILLER, H.W. 1971. Relationships of duck nesting success to land use in North and South Dakota. Trans, 10th Congr Internat Union Game Biologists 133-141.

Duck nesting success was determined relative to land use in North and South Dakota. Study plots consisted of fields or tracts under a single land use for one year. Four classifications were recognized: (1) idled - unused land with the previous growth remaining on the plot, (2) grazed - domestic livestock were present or had removed a noticeable portion of the previous growth, (3) mowed - the previous and sometimes the current growth had been removed by mowing, and (4) cultivated - tillage during the previous or current year. The number of nests found per ha of area searched was 0.51, 0.36, 0.35, and 0.05, respectively, and nesting success for the four land use types was 44, 27, 29, and 14%.

220. MINEAU, P., and D.B. Peakall. 1987. Evaluation of avian impact assessment techniques following broad-scale forest insecticide sprays. Environ Toxicol Chem 6:781-791.

Methods for assessing the impact of forest insecticide spray programs on forest songbirds are reviewed, and the applicability of various census techniques are discussed. As a result of re-analysis of brain ChE levels in live birds collected post-spray (most data related to exposure to either fenitrothion or acephate), the authors concluded that a severe collection bias exists in favor of birds with a low (<30%) degree of ChE inhibition. Three options are suggested to alleviate this problem: (1) the recognition of the limitations of the technique and use of the proportion of individuals that were "exposed" as a measure of impact, (2) the adoption of exact criteria of acceptability with respect to the intensity and duration of the cholinergic response followed by an intensive search of the spray area to collect individuals with maximum inhibition, or (3) lower the range of acceptable inhibition to the level generally found in sampling (e.g., 30-35% as indicated from the data presented in the

paper) provided that an impact can be demonstrated at the selected level of inhibition. Finally, the authors suggest that multiyear impact assessment studies involving a number of reproductive parameters are needed to adequately evaluate the effects of non-persistent insecticides on forest [or any other group of] songbirds.

221. MISHRA, S.K., C.J. Whitenack, and A.R. Putnam. 1988. Herbicidal properties of metabolites from several genera of soil microorganisms. *Weed Sci* 36:122-126.

Metabolites from 906 microbial isolates were evaluated for their effectiveness as selective herbicides. Metabolites from 72 isolates significantly inhibited germination of cress (*Lepidium sativum*) seeds. About 18% of all *Streptomyces* and *Nocardiosis* isolates and 13% of *Actinoplanes* isolates were toxic to cress. Several other genera also inhibited cress germination. About half the isolates were also toxic to barnyardgrass (*Echinochloa crus-galli*).

222. MOORE, J.A. 1987. Not so silent spring. Pp 15-22 in G.J. Marco, R.M. Hollingworth, and W. Durham (eds), *Silent spring revisited*. American Chemical Society, Washington, D.C. 214 pp.

This chapter reviews current pesticide registration criteria. Recent amendments to FIFRA led to the development of criteria closely attuned to some of Rachel Carson's demands. EPA now reviews chemicals by examining experimental data on their effects on soil, water, wildlife, and humans. These needs are clearly detailed in the recently issued Pesticide Registration Requirements. The requirements for the registration of a new chemical for use on land crops grown for human consumption span five major categories: product chemistry, residue chemistry, environmental fate, wildlife effects, and toxicology. In addition, data from two other categories, re-entry and spray-drift characteristics, are also commonly required. Specific needs in toxicology include acute toxicity data by three routes of exposure, eye and dermal irritancy, dermal sensitization, delayed neurotoxicity, repeat dose 90-day study in rodent and non-rodent species, chronic feeding study (usually 1 year in duration), oncogenicity studies in two species, teratogenicity in two species, two-generation reproduction study, gene mutation studies, structural chromosome effects, and general metabolism effects. In 1962, only acute toxicity studies using two or three exposure routes plus eye and dermal irritation studies were required. A chronic test was sometimes performed if residue concentrations in excess of 1 part in 100,000 (the detection limit) were found. Environmental effects were not addressed. Alternatives to chemical pesticide use are briefly discussed.

223. MORA, M.A., D.W. Anderson, and M.E. Mount. 1987. Seasonal variation of body condition and organochlorines in wild ducks from California and Mexico. *J Wildl Manage* 51:132-141.

Significant seasonal variation in the body weights and extractable lipid levels of northern pintails did not appear to be correlated with OC content. The authors concluded that, whereas OC pesticide residues were found in all birds examined, levels noted were insufficient to cause adverse effects on reproduction or survival.

224. MORRISON, M.L., and E.C. Meslow. 1984. Effects of the herbicide glyphosate on bird community structure, western Oregon. *Forest Sci* 30:95-106.

An aerial application of glyphosate to two clear-cut areas of western Oregon resulted in a modification of the density and habitat use of birds. Although bird density and diversity were similar, several species declined in relative density on the glyphosate site 1 year after treatment and others increased in density. All species that declined in density during the first year post-spray increased during the second year. Use of shrub cover on the treated site decreased and use of deciduous tree cover increased relative to the control during the first year post-spray. With the exception of the rufous-sided towhee, all species showed increased use of shrub cover during the second year.

225. MORRISON, M.L., and E.C. Meslow. 1984. Response of avian communities to herbicide-induced vegetation changes. *J Wildl Manage* 48:14-22.

This study in the Douglas fir (*Pseudotsuga menziesii*) region of the Oregon Coast Range examined the relationships between avian communities and herbicide (2,4-D and 2,4,5-T) modification of early-growth clear-cuts. Areas were sprayed 1 or 4 years previous to the study. For both 1 and 4 year post-spray sites, vegetation development was greater in the third height interval (>3.0 m) on untreated sites. Overall density and diversity of birds were similar between treated and untreated sites; however, several species altered their foraging behavior on treated sites (i.e., species using deciduous trees, which were largely removed as a result of herbicide application, increased use of shrubs on treated sites). The authors concluded that small patches of deciduous trees scattered in clear-cut areas could maintain an avian community similar to that of untreated sites.

226. MURIHEAD-THOMSON, R.C. 1971. Pesticides and freshwater fauna. Academic Press, New York, NY. 248 pp.

The book presents a review of the literature to 1981 about effects of pesticides on both vertebrate and invertebrate target and non-target species as well as the influence of chemical and physical factors on the impact of pesticides in freshwater ecosystems.

227. NAQVI, S.M., T.S. Leung, and N.Z. Naqvi. 1980. Toxicities of paraquat and diquat herbicides to freshwater copepods (*Diatomus* sp and *Eucyclops* sp) Bull Environ Contam Toxicol 25:918-920.

Copepods (*Diatomus* and *Eucyclops* spp) were exposed to various concentrations of paraquat (0-100 ppm) and diquat (0-140 ppm). Mortality was recorded at 24 and 48 h. LC₅₀ values for paraquat were 10 and 5.3 ppm at 24 and 48 h, respectively. Corresponding diquat LC₅₀ values were 74 and 19 ppm.

228. NEMCSÓK, J., L. Orbán, B. Asztalos, Z. Buzás, A. Németh, and L. Boross. 1985. Investigations on paraquat toxicity in fishes. Water Internat 10:79-81.

The effect of different concentrations of paraquat on three fish species with different feeding habits was investigated. Carp, silver carp, and sheatfish were exposed to concentrations of 1, 10, and 100 mg/L paraquat for 2 h. All species died within the first 15 minutes at the highest concentration. Paraquat significantly increased transaminase and lactate dehydrogenase activity and blood glucose level, concomitant with a decrease in ChE activity. Results suggest that paraquat causes liver and kidney damage, reduces O₂ uptake by injuring gill epithelia, and inhibits ChE activity.

229. NEIDERLEHNER, B.R., K.W. Pontasch, J.R. Pratt, and J. Cairns, Jr. 1990. Field evaluation of predictions of environmental effects from a multispecies-microcosm toxicity test. Arch Environ Contam Toxicol 19:62-71.

The predictive validity of a multispecies-microcosm toxicity test was evaluated. Predictions of biological response to a complex effluent were made from dose-response curves obtained from laboratory tests. These predictions were compared to effects observed in the receiving system. No effects on the protozoan or macroinvertebrate communities were observed at the field site with effluent concentrations less than the chronic value of 1.7% effluent determined in laboratory tests. The microcosm test accurately predicted the magnitude of decreases in species richness in protozoan and macroinvertebrate communities in the receiving system at the first site downstream of the effluent outfall. Predictions of environmental effects for stations farther downstream were generally less accurate and too high. This was perhaps due to lack of persistence in the toxicity of the effluent. Stimulation of total biomass and algal growth was observed in both laboratory and field tests, but laboratory tests greatly over-estimated the magnitude of enrichment responses in the receiving system.

230. NIETHAMMER, K.R., and T.S. Baskett. 1983. Cholinesterase inhibition of birds inhabiting wheat fields treated with methyl parathion and toxaphene. Arch Environ Contam Toxicol 12:471-475.

Red-winged blackbirds and dickcissels, two species with similar food habits, had significantly different degrees of brain ChE inhibition as a result of inhabiting wheat fields treated with 0.67 kg AI/ha methyl parathion and 1.35 kg/ha toxaphene. Maximum inhibition of 40 and 74% for red-winged blackbirds and dickcissels, respectively, occurred approximately 5 days post-spray. Barn swallows reached maximum ChE inhibition (42%) 3 days post-spray. Enzyme activity approached normality 10 days post-spray. The authors postulated that the difference in ChE activity between dickcissels and red-winged blackbirds may have been due to physiological differences between the species.

231. NIMMO, D.R., D.L. Coppage, Q.H. Pickering, and D.J. Hansen. 1987. Assessing the toxicity of pesticides to aquatic organisms. Pp 49-69 in G.J. Marco, R.M. Hollingworth, and W. Durham (eds), Silent spring revisited. American Chemical Society, Washington, D.C. 214 pp.

The authors estimated the value of aquatic resources by citing the following statistics for the continental U.S.:

- 34,259,813 ha of freshwater
- 28,328,611 ha of wetlands
- 59,894,779 ha of continental shelf and estuarine waters
- 53,900,000 persons participating in fishing
- 25,400,000 persons participating in shellfishing and shell collecting
- \$17.3 billion spent per annum on consumer goods related to recreational activities
- \$7 billion contributed to the Gross National Product per annum from harvesting, processing and marketing commercial fish stocks
- \$2.2 billion per annum income from commercial landings

Several case studies are cited regarding pesticide contamination of aquatic resources including pesticide residues in fish on the Rocky Mountain Arsenal, elevated DDE and toxaphene concentrations in birds and fishes in the Lower Rio Grande Valley, Texas, endrin residues in Central Flyway ducks as a result of pesticide use on Montana grasslands, heptachlor in milk in Hawaii as a result of fire ant control on pineapple plantations, and the continuing presence of PCBs. DDT and associated metabolite residues are declining, however, in both the environment and in biota. Since the publication of Carson's *Silent spring*, pesticide use has increased and will probably continue to increase for some time. Current testing procedures may not be sufficient to assure protection of aquatic habitats.

232. NIPPER, M.G., D.J. Greenstein, and S.M. Bay. 1989. Short- and long-term sediment toxicity test methods with the amphipod *Grandidierella japonica*. Environ Toxicol Chem 8:1191-1200.

The methods were designed for conducting flow-through sediment toxicity tests using the marine amphipod *Grandidierella japonica*. They would be equally applicable for use with freshwater amphipods (e.g., *Hyaella azteca*). The exposure time is relatively short (10 days), and tests may be conducted in 1-liter beakers.

233. ODENKIRCHEN, E.W., and R. Eisler. 1988. Chlorpyrifos hazards to fish, wildlife, and invertebrates: a synoptic review. Biol Rep 85(1.13). U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, Md. 34 pp.

Chlorpyrifos is used extensively in a variety of formulations to control a broad spectrum of agricultural and other insects, including mosquitos and turf-destroying insects on golf courses. Domestic use in 1982 was about 3.6 million kg. Accidental or careless applications have resulted in mortality of many non-target organisms including fish, aquatic invertebrates, birds, and humans. Applications at recommended rates (0.028 to 0.056 kg/surface ha) for mosquito control have led to mortality, bioaccumulation, and various deleterious sublethal effects of aquatic plants, zooplankton, insects, rotifers, crustaceans, waterfowl, and fish. Adverse effects have also been noted in bordering terrestrial invertebrate populations. Degradation rates in abiotic substrates vary from about 1 week in seawater to >24 weeks in soils of low moisture content, low temperature, reduced microbial activity, and low organic content. In fishes, degradation has been reported to occur in <9 h. Similar rates could be expected in birds and invertebrates. Chlorpyrifos is acutely toxic to some species of aquatic invertebrates and teleosts at nominal water concentrations. LC₅₀ values for aquatic invertebrates are as low as 0.035 µg/L for *Mysidopsis bahia* to a high of 2,710 µg/L for the snail *Lanistes carinatus*. Among fish species, the fathead minnow was most sensitive of those species tested with an LC₅₀ of 0.13 µg/L. The gulf toadfish (LC₅₀, 520 µg/L) was least sensitive. Acute single-dose oral LD₅₀ values for avian species ranged from 5 mg/kg for the European starling to 157 mg/kg for the ringed turtle-dove. Bioaccumulation factors (BCFs) in fish varied with the mean concentration in the medium and the duration of exposure. For example, the BCF for California grunion varied from <1 for a 26-day exposure at a concentration of 0.13 µg/L to 1,000 for a 35-day exposure at essentially the same concentration. BCFs for the gulf toadfish, on the other hand, varied from 100 at 1.4 µg/L to 650 at 46.0 µg/L during 49-day exposure tests. Sublethal effects included ChE inhibition in brain and hematopoietic tissues, reduced growth, impaired reproduction including

sterility and developmental abnormalities, motor incoordination, convulsions, and depressed aquatic invertebrate population densities. The authors recommended restricted use of chlorpyrifos for mosquito control in wetlands, curtailed agricultural use in watershed areas, and the development of more environmentally safe replacements with greater specificity for target organisms.

234. ODUM, E.P. 1985. Trends expected in stressed ecosystems. BioScience 35:419-422.

Certain well-defined developmental trends may be observed in ecosystems which are not suffering from unusual external perturbations. As disturbance may arrest or even reverse these autogenic developments, we should be able to anticipate and measure some ecosystem responses to stress. Trends expected in stressed ecosystems are discussed and include changes in energetics, nutrient cycling, and community structure and function.

235. OHLENDORF, H.M., and M.R. Miller. 1984. Organochlorine contaminants in California waterfowl. J Wildl Manage 48:867-877.

Wings and carcasses of northern pintails, canvasbacks, lesser scaups, and northern shovelers were collected from the Pacific Flyway survey and from the Sacramento Valley. Concentrations of all OC compounds were <1 ppm in pintail wings, but residues were higher in wings from pintails shot late in the season than early in the season, suggesting that pintails were accumulating chemicals while on the wintering grounds. Highest concentrations were found in pintails from southern California, and DDE was significantly higher in males than in females. Wings of diving ducks were too few to permit evaluation. Carcasses of shovelers contained significantly higher concentrations of DDE (0.68 ppm) than observed in pintails (0.12 ppm) collected at the same time and place. On a wet-weight basis, pintail wing concentrations were about half of carcass concentrations. Although some individuals were contaminated with possibly harmful levels of some chemicals, concentrations of OCs were relatively low in all species and probably would have no adverse effect on survival or reproduction.

236. OHLENDORF, H.M., F.C. Schaffner, T.W. Custer, and C.J. Stafford. 1985. Reproduction and organochlorine contaminants in terns at San Diego Bay. Colonial Waterbirds 8:42-53.

Caspian tern eggs were found to contain significantly higher concentrations of DDE (9.30 ppm) than elegant tern eggs (3.79 ppm). Although the relationship between hatching success and DDE concentration was not clear, shells from eggs that broke during incubation or that contained chicks that died while hatching were significantly thinner than shells from pre-1947 eggs. OC concentrations in the brains of dead chicks were not sufficient to indicate OC poisoning as the cause of death.

237. OLSON, L.J. 1986. Immune system and pesticides. J Pestic Reform (Summer 1986):20-25.

A properly functioning, intact immune system is essential for protection against diseases, cancer, autoimmunity, and certain allergic reactions. However, tests using standard laboratory strains are least likely to show effects as they are maintained in an atmosphere designed to promote health and minimize stress. In a normal wild population, the individuals most likely to be affected are the aged, very young, pregnant, sick, or those otherwise stressed. Although a broad spectrum of non-pesticide compounds affects the immune system (including lead, mercury, cadmium, nickel, NO₂, SO₂, volatile organic compounds, halogenated hydrocarbons, asbestos, and others), this review concerns only pesticides. It is important to understand that different chemicals will affect some segments of the immune system more than others. DDT lowered the antibody titer to the bacterium *Salmonella typhi* by a significant amount and decreased the gamma globulin serum fraction to ovalbumin in rabbits after a 35-day exposure to 200 ppm DDT in drinking water. Mortality of young mice infected with encephalomyocarditis was significantly increased with exposure to DDT when compared to infected mice not so exposed. Increased susceptibility to duck hepatitis virus was found in ducks given DDT. Tests using carbamate insecticides showed that methyl carbamate and pyrimidol carbamate had little or no effect on selected immune responses in mice or rabbits; however, carbofuran fed to mice was associated with decreased nitrogen activity, reduced immunoglobins, and increased mortality following challenge by *Salmonella typhimurium*. Several other carbamate insecticides have also been shown to affect the immune system. For example, primacarb has induced immune hemolytic anemia (damage to the bone marrow sufficient to affect the production of white or red blood cells or both) in dogs; ethyl carbamate caused severe bone damage, depressed killer T-cell activity, reduced humoral immunity, and increased susceptibility to tumor cell challenge in one strain of laboratory mice. Carbaryl increased the susceptibility of quail to a protozoan parasite, reduced spleen antibody-producing cell numbers in mice, and enhanced in vitro infectivity of viruses to human lung cells and green monkey kidney cells. Aldicarb significantly reduced the splenic plaque-forming cell response in outbred mice fed 1, 10, 100, and 1000 ppb in the drinking water. The effect was greatest at the lowest dose. Triphenyl tin acetate (TPTA), a fungicide, was associated with atrophy of the thymus and reduced plasma cell populations and decreased immunological response to tetanus toxoid in guinea pigs fed 12 ppm TPTA for several weeks. Methyl parathion increased mortality of mice exposed to *S. typhimurium*, decreased the mouse antibody response to *S. typhimurium*, reduced the mouse mitogenic response, and suppressed the tuberculin delayed hypersensitivity reaction in rabbits. Many other pesticides (including dieldrin, hexachlorobenzene, pen-

tachlorophenol, maleic hydrazide, cyclohexamide, and dinoseb) also affect the immune system of various vertebrate organisms. Thus, it is evident that the potential exists for serious damage to human and non-human populations through immunosuppression due to pesticide exposure. Further, research has demonstrated that subtle immune system defects can have serious or fatal consequences to both animals and humans.

238. PAPENDICK, R.I., L.F. Elliott, and R.B. Dahlgren. 1986. Environmental consequences of modern production agriculture: how can alternative agriculture address these issues and concerns? Am J Alternative Agricult 1:3-10.

The authors propose various alternatives to large-scale conventional agriculture as a means of curbing soil erosion and runoff, such as conservation tillage, organic farming, and crop rotation. Use of some or all of these agricultural alternatives would greatly reduce the input of sediments into surface waters as well as dependence upon chemical pesticides.

239. PATTEE, O.H., M.R. Fuller, and T.E. Kaiser. 1985. Environmental contaminants in eastern Cooper's hawk eggs. J Wildl Manage 49:1040-1044.

Cooper's hawk eggs were collected from nests located in five eastern and midwestern states. Egg shells, but not contents, were also collected from two other states. Shell thickness, Ratcliffe thickness index, shell weight, and lipid level data were compared with pre-1946 data. Shell thickness was not significantly different between the 1980 and 1946 eggs, but there was a significant difference in the Ratcliffe indices for the two time periods, indicating 9% thinning in 1980 egg shells. Mean OC residue concentrations ranged from <0.05 ppm (wet weight) *p,p'*-DDT, in Pennsylvania and Wisconsin eggs, to 17 ppm *p,p'*-DDE in a single egg from Connecticut. DDE and oxychlorane residue concentrations were correlated with the Ratcliffe index but not with egg shell thickness. There was no relationship between embryo development stage and residue concentration or shell thickness.

240. PAULOV, S. 1981. Rizikovost fungicidu afaganu (pyrazofos) pre vyvin obojzivelnikov (*Rana temporaria* L.). [Hazards of the fungicide Afagan (pyrazophos) for the development of amphibians (*Rana temporaria* L.).] Biologia (Bratislava) 36:135-140.

Examination of the effect of the fungicide Afagan [pyrazophos] on development and on the activities of glutamate oxaloacetate transaminase (GOT) and glutamate pyruvate transaminase (GPT) of 22-day-old amphibian tadpoles (*Rana temporaria*) showed that concentrations greater than 1 mg/L resulted in lethality. A concentration of 0.1 mg/L pyrazophos stimulated growth (front leg development, atmospheric respiration, and tail resorption

were accelerated by 2 days). However, all animals died prior to metamorphosis. GOT activity increased and GPT activity decreased. The author concluded that the use of pyrazophos represents a potential risk for natural ecosystems and that the chemical should only be used within the framework of integrated pest management where it cannot contaminate useful surface and groundwater resources.

241. PAYNE, C.C. 1988. Pathogens for the control of insects: where next? Phil Trans R Soc Lond B 318:225-248.

The narrow host-range of many pathogenic microorganisms makes them natural candidates for integrated pest management programs. However, many microbial pathogens currently available do not meet the expectations of an agricultural industry used to the rapid and broad-spectrum pest knock-down achieved by many chemical pesticides. Much recent attention has focused on the improvement of strains by genetic manipulation. For example, the environmental persistence of the insect-pathogenic toxin of *Bacillus thuringiensis* has been extended by inserting the toxin gene into other bacterial hosts and plants. Although future opportunities for biological control may be created by the use of such strategies, we must understand more about their long-term impact on insect populations and the environment. The author suggests that such information should come not only from detailed ecological studies of the host-pathogen interaction but also from laboratory and field studies of the frequency and consequences of the exchange of genetic information between modified strains and naturally occurring microorganisms.

242. PETERSEN, B.E., and L.C. McEwen. 1990. Use of American kestrels as bioindicators of environmental contaminant effects. Pp 45-46 in Proceedings of a symposium: environmental contaminants and their effects on biota of the Northern Great Plains. North Dakota Chapter, The Wildlife Society, Bismarck.

American kestrels were evaluated as bioindicators of environmental contaminant stress at point source locations and on large-scale grasshopper control IPM management areas. The species can be readily attracted to nest boxes, is tenacious to its nests, and will tolerate periodic examination of eggs and young. Data collected bi-weekly (more frequently after incubation was complete) were clutch size, nestling growth rate, hatching success, fledging success, and food habits. Nest box utilization was affected by distance between nest boxes, nest entrance orientation, location in respect to other trees, and height of the box. Percent utilized ranged from 21 (Dinosaur National Monument, Colorado) to 58 (Rocky Mountain Arsenal, Denver). At the Rocky Mountain Arsenal, where OC pesticides were manufactured and released for many years prior to this study, data collected during 1982, 1983, and 1986, showed a significant increase in number of young fledged (1.1 in 1982 to 2.2

in 1986). Mean fledging success on grasshopper IPM management areas in Idaho and North Dakota during 1988 and 1989 was approximately 2.2 and 1.7 young per nest, respectively. The mean number of young fledged from a group of nests (used for comparison) located along the front range of Colorado from 1982 to 1989 was approximately 2.5.

243. PHILLIPS, J.D. 1988. Nonpoint source pollution and spatial aspects of risk assessment. Annals Assoc Am Geog 78:611-623.

As pollution has significant off-site impacts which are often more severe than local impacts, it is necessary that we consider the cumulative impacts of spatially distributed pollution sources rather than consider each source as a separate case. In this context, spatial risk assessment for a wide variety of air, water, and cross-media pollutions will become more urgent, and hopefully, more common.

244. PHILLIPS, J.D. 1989. Fluvial sediment storage in wetlands. Water Resources Bull 25:867-873.

The ecological and hydrological roles of wetlands are widely recognized, but their geomorphic functions are often overlooked. An analysis of fluvial sediment budget studies shows that wetlands typically serve as short-term sediment sinks or, over the long term, sediment storage sites. In ten drainage basin studies, 14 to 58% of the total upland sediment production was stored in alluvial wetland or other aquatic environments, and 29 to 93% of sediments reaching streams was stored in wetland or channel environments. The author suggested that wetlands should be managed in the context of drainage basins, rather than as discrete, independent units and that any attempts to control sedimentation rates or erosion of wetlands to achieve ecological goals might have serious repercussions throughout the entire drainage basin.

245. PHILLIPS, J.D. 1989. Nonpoint source pollution control effectiveness of riparian forests along a coastal plain river. J Hydrol 110:221-237.

A detention-time model of water quality buffer zones was used to evaluate the non-point source pollution control effectiveness of riparian forests in a North Carolina river basin. All typical riparian forests provided significant water quality protection, but there was a wide variation in buffer effectiveness due to soil type, topography, and vegetation characteristics. Effective buffer width varied from 5.07 m for the best soil under optimum conditions to 73.25 m for the worst-case scenario. Buffer widths of 60 m or less are generally adequate to filter nitrates from agricultural runoff.

246. PICKETT, J.A. 1988. Integrating use of beneficial organisms with chemical crop protection. *Phil Trans R Soc Lond B* 318:203-211.

Of the four groups of insecticides currently used in crop protection (OCs, OPs, carbamates, and pyrethroids), pyrethroids are rapidly replacing the others. This paper addresses the selectivity of some pyrethroids and proposes possibilities for development of even greater selectivity. The relative toxicity of bioresmethrin, permethrin, and deltamethrin to house flies and honeybees is used to illustrate advances in selectivity. Bioresmethrin was equally toxic to both species, permethrin was 12x more toxic to house flies than to honeybees, and the relative toxicity of deltamethrin is 1,700 (house fly) to 11 (honeybee). Several other possibilities for minimizing pesticide impact are also discussed. Genes from pest species which confer resistance to the host have been cloned, and it seems only a matter of time until these genes may be successfully transferred to beneficial insects. Semiochemicals (chemicals which control behavior) such as insect pheromones are being developed for agricultural use. These chemicals have been used to bring the target species into contact with various biological control agents either through attracting them to the agent, as in the use of moth sex pheromones, or by causing them to disperse, illustrated by the use of the aphid alarm pheromone to increase the likelihood of contact with pathogenic organisms. Beneficial insects may also be manipulated by use of semiochemicals. For example, the Nasonov pheromone can be used to attract honeybees away from crops recently sprayed with insecticides, or alternatively, sting gland and mandibular gland pheromones mixed with the pesticides could serve as an effective repellent, again reducing the hazard to foraging bees. It may also be possible to attract natural predators of some insect pests to crop plants using genetic engineering techniques. Thus, many alternatives to chemical pesticide use may be available.

247. PIMENTEL, D. 1987. Is *Silent spring* behind us? Pp 175-187 in G.J. Marco, R.M. Hollingworth, and W. Durham (eds), *Silent spring revisited*. American Chemical Society, Washington, D.C. 214 pp.

Some pesticides may actually increase pest problems. For example, 2,4-D used at recommended application rates on corn increased the susceptibility of corn to both insects and plant pathogens. Sublethal doses of parathion increased egg production of the Colorado potato beetle by 65%. Highly toxic materials at low dosage can achieve mortality similar to larger doses of low-toxicity materials and be less damaging to the environment, but risks to humans handling these highly toxic chemicals are far greater. Even though more pesticides and non-chemical controls are being used today than ever before, an estimated 37% of all crops is lost annually to pest species. Losses to weeds and pathogens have remained relatively constant since 1942, but crop losses to insects have nearly dou-

bled in spite of a tenfold increase in insecticide use. Reasons for this seeming anomaly are discussed.

248. PIMENTEL, D., D. Andow, R. Dyson-Hudson, D. Gallahan, S. Jacobson, M. Irish, S. Kroop, A. Moss, I. Schreiner, M. Shepard, T. Thompson, and B. Vinzant. 1980. Environmental and social costs of pesticides: a preliminary assessment. *Oikos* 34:126-140.

Indirect costs of pesticide use in the U.S. are 45,000 fatal and non-fatal human pesticide poisonings annually; \$12 million in livestock losses; \$287 million due to reductions in natural enemies and increased pesticide resistance in pest species; \$135 million due to honeybee poisonings and reduced pollination; \$70 million in losses of crops and trees; \$11 million in fish and wildlife losses; and \$140 million in miscellaneous losses. The authors believed that the \$839 million total annual loss attributed to environmental and social costs of pesticide use represented only a fraction of the total cost, and that a more complete accounting would probably result in a figure several times that obtained in this study.

249. PINOWSKI, J. 1988. Effect of liquid manure on the environment. *INTECOL* 16:61-70.

The deposition of large amounts of liquid manure from Polish livestock farms on fields and in waste areas since 1970 has caused several adverse environmental impacts, including an excessive accumulation of nitrogen and an increase in salinity. Nitrogen above standard levels was found in 74% of the wells on the test area. Vegetational changes included the development of large populations of nitrogenphilous species. Faunal changes included a reduction in the number of species of nematodes and saprophagous acarina.

250. PONTASCH, K.W., E.P. Smith, and J. Cairns, Jr. 1989. Diversity indices, Community comparison indices and canonical discriminant analysis: interpreting the results of multi-species toxicity tests. *Wat Res* 23:1229-1238.

Canonical discriminant analysis, diversity indices, and community similarity indices were evaluated for their utility in measuring invertebrate response to a complex effluent in laboratory microcosms. All measures tested indicated that microcosms receiving the high dose (10% effluent) were significantly different from the controls. The canonical discriminant analysis, however, was mainly influenced by decreased mayfly densities in the high-dose microcosms. The Shannon and Simpson diversity indices indicated that both the medium- (1.0% effluent) and high-dose microcosms were significantly different from controls, but this was solely dependent upon high numbers of chironomids. Diversity indices calculated excluding chironomid numbers failed to discriminate between medium-dose and control microcosms. The most meaningful condensation of data was provided by the Bray-Curtis community similarity index.

251. POWELL, G.V.N. 1984. Reproduction by an altricial songbird, the red-winged blackbird, in fields treated with the organophosphate insecticide fenthion. J Appl Ecol 21:83-95.

Fenthion (Baytex), an OP chemical used for mosquito control, was applied aerially at a rate of 52 g AI in 3.2 L of No. 2 diesel oil/ha. One study area received a single application; another received two applications 35 days apart. Red-wing behavior was studied both before and after the application(s). The insecticide application(s) had no significant effect on frequency of nest abandonment, clutch size, hatching success, or fledging success. Growth rates of 0-3 day-old nestlings were lower in nests on the area receiving two treatments, but overall growth rates of survivors did not differ significantly from those of controls. There were no significant differences in brain ChE activity of birds from the treatment sites when compared with control site birds. Cholinesterase activity was not significantly depressed in six large nestlings found dead 2 to 11 days post-spray. Spatial distribution of territorial males was not affected by the application of fenthion. Although a single application of fenthion eliminated approximately 50% of the dominant larvae (a noctuid) in nestling food 1 to 2 days post-spray, nestling growth and fledging success was not affected.

252. POWELL, G.V.N., and D.C. Gray. 1980. Dosing free-living nestling starlings with an organophosphate pesticide, famphur. J Wildl Manage 44:918-921.

European starling nestlings were dosed perorally with 0, 0.3, 1.0, or 3.0 mg famphur/kg body weight each day from age 4 to 18 days. Nine of 11 4-day-old birds given a single dose of 3.0 mg/kg died within 8 h. Of the remaining two birds, one died after the second dose and the other was killed by a predator. Only one bird receiving 1.0 mg/kg died as a result of the treatment, and two birds receiving 0.3 mg/kg died during the study. Growth rates of surviving treated birds were independent of dosage level; however, nestlings receiving 1.0 mg/kg reached lower pre-fledging weights than did controls.

253. PROUTY, R.M., and C.M. Bunck. 1986. Organochlorine residues in adult mallard and black duck wings, 1981-1982. Environ Monitor Assess 6:49-57.

Although ten OC compounds were detected in black duck and mallard wings collected during the 1981-82 hunting season, most occurred very infrequently, and, with the exception of PCBs, were generally less than observed concentrations in 1979. DDE concentrations differed among collections, flyways, and regions, although PCB concentrations differed only between flyways and regions.

254. RATTNER, B.A. 1982. Diagnosis of anti-cholinesterase poisoning in birds: effects of environmental temperature and underfeeding on cholinesterase activity. Environ Toxicol Chem 1:329-335.

The effects of underfeeding and increased temperature on ChE activity were studied to determine whether such non-contaminant related phenomena might confound diagnosis of pesticide poisoning. Only slight reductions in ChE activity were noted in Japanese quail subjected to either stress. The amount of inhibition was considerably less than 50% (the criterion generally employed in the diagnosis of insecticide-induced mortality). However, it did approach 20% and thus could be confused with levels generally construed to indicate sublethal exposure to pesticides.

255. RATTNER, B.A., and J.C. Franson. 1984. Methyl parathion and fenvalerate toxicity in American kestrels: acute physiological responses and effects of cold. Can J Physiol Pharmacol 62:787-792.

Methyl parathion and fenvalerate were administered to American kestrels by stomach gavage at dosages of 0.375 to 3.0 and 1,000 to 4,000 mg/kg body weight, respectively. Birds were maintained at ambient temperatures of 22 and -5 C. Methyl parathion was highly toxic (estimated LD₅₀, 3.08 mg/kg) and produced dose-dependent inhibition of brain and plasma ChE activity, hyperglycemia, and elevated plasma corticosterone concentration. Fenvalerate, on the other hand, caused only mild intoxication and elevated alanine aminotransferase activity at doses far exceeding those encountered in the environment. Cold increased toxic response to methyl parathion but not fenvalerate. Thus, far greater impacts may be expected from OP insecticides than from pyrethroids.

256. RATTNER, B.A., J.M. Becker, and T. Nakatsugawa. 1987. Enhancement of parathion toxicity to quail by heat and cold exposure. Pestic Biochem Physiol 27:330-339.

High temperatures (37 C) increased and low temperatures (4 C) decreased plasma ChE inhibition in Japanese quail exposed to 4 mg technical grade parathion/kg body weight relative to those reared at 26 C. These results and limited field observations indicate that the hazards imposed by ChE inhibitors may be substantially influenced by environmental temperature regimes.

257. REBEIZ, C.A., J.A. Juvik, and C.C. Rebeiz. 1988. Porphyrin insecticides. 1. Concept and phenomenology. Pest Biochem Physiol 30:11-27.

Modulators of the porphyrin-heme biosynthetic pathway, used singly or in combination with δ -aminolevulinic acid, induced massive accumulation of protoporphyrin IX in the treated insect, causing death whether in darkness or in light. In light, death appeared to be photodynamic in nature. Photodynamic damage was also induced by treating

the insect with exogenous protoporphyrin or Mg-protoporphyrin. The authors proposed that the term "porphyric insecticides" be used to designate such insecticides. They suggested that the appeal of such insecticides might reside in the potential to design a large number of totally biodegradable formulations of selective photodynamic insecticides and herbicides and in the anticipated difficulty for insects to develop resistance to such compounds.

258. REIMER, G.J., and G.R.B. Webster. 1980. Loss of chlorpyrifos in pond water: examination of results using three simple mathematical models. J Environ Sci Health (B) 15:559-569.

[From abstract] The half lives of an emulsified and a slow-release formulation were 5 and 14 h, respectively.

259. RENNER, K.A., W.F. Meggitt, and R.A. Leavitt. 1988. Influence of rate, method of application, and tillage on imazaquin persistence in soil. Weed Sci 36:90-95.

Preplant-incorporated applications of 280 g AI/ha of imazaquin had significantly greater persistence than pre-emergence surface applications throughout the 1985 growing season; however, there was no significant between-treatment difference in persistence in 1984. No explanation for observed between-year differences was found.

260. RESH, V.H., and D.M. Rosenberg. 1989. Spatial-temporal variability and the study of aquatic insects. Can Ent 121:941-963.

Many researchers have attempted to determine the quality of an aquatic system by studying its invertebrate community. This paper discusses the spatial and temporal variability inherent within aquatic invertebrate communities and suggests that, rather than trying to reduce this variability through various homogenization processes, a "variance" approach, in which the data are disaggregated and fluctuation extremes considered, may provide more information and elucidate underlying mechanisms.

261. RIZVI, S.J.H., D. Mukerji, and S.N. Mathur. 1980. New report on a possible source of natural herbicide. Indian J Exper Biol 18:777-778.

An extract from seed of *Coffea arabica* was effective in preventing germination of *Amaranthus spinosus*.

262. ROBERTSON, J.B., and C. Mazzella. 1989. Acute toxicity of the pesticide diazinon to the freshwater snail *Gillia altilis*. Bull Environ Contam Toxicol 42:320-324.

The 4- and 96-h LC₅₀ values for snails exposed to diazinon were 93 and 11 ppm, respectively. A 96-h static renewal test was also conducted to compensate for possible diazinon losses over time. The results of this test indicated that the 96-h LC₅₀ for a flow-through system would be even <11 ppm. *Gillia*

altilis was less sensitive to diazinon than some other species previously tested. For example, the 24-h LC₅₀ values reported for bluegill and rainbow trout were 0.05 and 0.38 ppm.

263. SANDERS, H.O. 1969. Toxicity of pesticides to the crustacean *Gammarus lacustris*. U.S Fish Wildl Serv Tech Pap 25. 18 pp.

The results of a series of acute toxicity tests of 70 pesticides using the amphipod *Gammarus lacustris* indicated that the species was generally more sensitive to OP than to OC pesticides. Twenty-four-hour LC₅₀ values ranged from 0.32 µg/L for coumaphos, a parasiticide, to 56,000 µg/L for aldrin. Herbicides and fungicides were less toxic than most insecticides. Toxicity increased with time of exposure. DDT toxicity was positively correlated with water temperature.

264. SANDERS, H.O. 1970. Pesticide toxicities to tadpoles of the western chorus frog *Pseudacris triseriata* and Fowler's toad *Bufo woodhousii fowleri*. Copeia 1970:246-251.

Although dated [many of the pesticides studied are no longer registered for use], this paper contains several data of interest. Static bioassays lasting from 24 to 96 h were conducted using *Pseudacris triseriata* and *Bufo woodhousii fowleri* tadpoles. Tadpoles were exposed to 16 and 18 pesticides, respectively. Tolerance limits (TL₅₀) were determined for each pesticide and species. Endrin [discontinued in 1987] was most toxic to *Pseudacris* tadpoles and second-most toxic to *Bufo* tadpoles (trifluralin was most toxic to this species; 24-h TL₅₀, 0.18 mg/L). Overall, herbicides were generally less toxic than insecticides. Lindane was the least toxic insecticide to both species. One-week-old *Pseudacris* tadpoles were more sensitive to the pesticides tested than were 4- to 5-week-old *Bufo* tadpoles.

265. SANDERS, H.O. 1970. Toxicities of some herbicides to six species of freshwater crustaceans. J Water Pollut Control Fed 42:1544-1550.

Of 37 herbicides tested, dichlone was most toxic to all six crustaceans. The 48-h tolerance limits (TL₅₀) ranged from 0.025 mg/L for *Daphnia magna* to 3.2 mg/L for the crayfish *Orconectes nais*. Silvex [discontinued in 1984], 2,4-D, and trifluralin were generally the next three most toxic chemicals tested; however, crayfish were resistant to 2,4-D and silvex (TL₅₀, >100 mg/L). Of those herbicides tested which are still registered for use, dicamba was least toxic. The other four species tested were seed shrimp (*Cypridopsis vidua*), amphipods (*Gammarus fasciatus*), isopods (*Asellus brevicaudus*) and glass shrimp (*Palaemonetes kadiakensis*).

266. SANDERS, H.O. 1972. Toxicity of some insecticides to four species of malacostracan crustaceans. Tech Paper 66, U.S. Fish and Wildlife Service, Washington, D.C. 19 pp.

Acute and chronic (20-day) toxicities of 40 insecticides to amphipods (*Gammarus fasciatus*), crayfish (*Orconectes nais*), glass shrimp (*Palaemonetes kadiakensis*), and isopods (*Asellus brevicaudus*) were determined in static and intermittent-flow bioassays. Median tolerance limits (96-h TL₅₀) ranged from 0.1 µg azinphos-methyl/L for *Gammarus* to 100,000 µg malathion/L for *Orconectes*. Amphipods were generally the most sensitive species; 96-h TL₅₀ values for 17 of the 40 pesticides tested were <10 µg/L; of these, seven were below 1.0 µg/L. The next most sensitive species were glass shrimp, isopods, and crayfish, in that order. Azinphos-methyl was most toxic to amphipods and glass shrimp; crayfish were most sensitive to parathion; and isopods were most affected by endrin. Malathion was generally least toxic; however, the 96-h TL₅₀ was 1.3 µg/L for *Gammarus*. *Gammarus* was more sensitive to OP insecticides than to OC compounds. Glass shrimp were equally sensitive to both groups. Isopods were generally more sensitive to OCs than to OPs and carbamates. Younger crayfish were more sensitive to pesticides than were older ones. A progressive reduction in TL₅₀ values occurred when animals were continuously exposed to insecticides for 20 days.

267. SANDERS, H.O. 1980. Sublethal effects of toxaphene on daphnids, scuds and midges. USEPA Rpt EPA-600/3-80-006. 17 pp.

Daphnids (*Daphnia magna*), amphipods (*Gammarus pseudolimnaeus*), and midge larvae (*Chironomus plumosus*) were exposed to various concentrations of toxaphene in a flow-through system. Concentrations greater than 0.07 µg/L reduced the number of young daphnids produced when compared to controls. Amphipod growth rate was reduced at concentrations exceeding 0.13 µg/L, and concentrations in excess of 1.0 µg/L reduced midge emergence. When exposed to toxaphene at a water concentration of 0.06 µg/L for a 7-day period, the bioconcentration factor for *Daphnia* was 4,000.

268. SANDERS, H.O., and J.B. Hunn. 1982. Toxicity, bioconcentration, and depuration of the herbicide Bolero 8EC in freshwater invertebrates and fish. Bull Japanese Soc Sci Fish 48:1139-1143.

Acute toxicity of Bolero [thiobencarb], an herbicide used in rice culture, to four species of aquatic invertebrates and three freshwater fish species was moderate. The 48- or 96-h LC₅₀ values ranged from 1.0 to 6.5 mg/L for amphipods (*Gammarus pseudolimnaeus*), daphnids (*Daphnia magna*), juvenile crayfish (*Orconectes nais*), and mature crayfish (*Procambarus clarkii*) and from 1.2 to 2.3 mg/L for rainbow trout, bluegills, and channel catfish. Bioconcentration factors during a 5-day exposure

ranged from 10 to 168 for the invertebrate species and from 48 to 471 for the four species of fish. More than half of the herbicide was eliminated by all organisms other than *Procambarus* within 24 h when placed in fresh water. In the case of *Procambarus*, tail residue half time was 10 days.

269. SANDERS, H.O., and J.H. Chandler. 1972. Biological magnification of a polychlorinated biphenyl (Aroclor 1254) from water by aquatic invertebrates. Bull Environ Contam Toxicol 7:257-263.

Four species of crustacea and four species of immature aquatic insects were exposed to ³⁶C-labeled Aroclor 1254. Rapid uptake and bioconcentration was noted in several species. *Daphnia magna* exposed for 4 days to water containing 1.1 ppb of 1254 accumulated body concentrations 48,000 times greater than those in the water. Late-instar mosquito (*Culex tarsalis*) larvae exposed to 1.5 ppb 1254 for 24 h accumulated 19 ppm, a 12,600-fold magnification. Amphipods (*Gammarus pseudolimnaeus*) were exposed to 1.6 ppb 1254 until equilibrium was achieved at 14 days. Body residues were 27,500x the water concentration.

270. SANDERS, H.O., D.F. Walsh, and R.S. Campbell. 1981. Abate: effects of the organophosphate insecticide on bluegills and invertebrates in ponds. Tech Paper 104, U.S. Fish and Wildlife Service, Washington, D.C. 6 pp.

Abate [temephos] was applied three times (at monthly intervals) to duplicate 0.4-ha ponds at 18 g/ha (recommended application) or 180 g/ha. No bluegill mortality was observed at either treatment rate, however, fewer fry were produced in ponds receiving 18 g/ha than in control ponds, and growth of both fry and adults was accelerated. This appeared to be due to intense feeding on dead or moribund dipteran larvae resulting from the pesticide application. Bluegill ovarian development was initially accelerated in ponds receiving 180 g/ha when compared with control pond fish. In addition, when compared to controls, the number of fry per female was lower, brain ChE activity was inhibited by as much as 40% after the second and third treatments, and dipteran biomass was reduced about 40% in ponds receiving the higher treatment. The routine use of Abate at the recommended rate should have little adverse affect on fishery resources. [Temephos is registered for control of mosquito, black fly, and midge larvae. As midge larvae are a major food item of several species of waterfowl during breeding and brood rearing, the timing of application should be carefully considered.]

271. SANDERS, H.O., J. Huckins, B.T. Johnson, and D. Skaar. 1989. Biological effects of kepone and mirex in freshwater invertebrates. Arch Environ Contam Toxicol 10:531-539.

The acute and chronic toxicity of Kepone (chlordecone [discontinued]) and mirex [discontinued] for daphnids (*Daphnia magna*), amphipods (*Gammarus pseudolimnaeus*), and midge larvae (*Chironomus plumosus*) was determined. Acute toxicities of chlordecone ranged from a 48-h EC_{50} of 350 $\mu\text{g/L}$ for midges to a 96-h LC_{50} of 180 $\mu\text{g/L}$ for amphipods. The acute toxicity of mirex exceeded 1,000 $\mu\text{g/L}$ for all three species. Maximum acceptable toxicant concentrations (MATCs) for chlordecone and mirex were based on daphnid reproduction, amphipod growth, midge emergence, and survival of all three species. The MATC for chlordecone was estimated to be between 9 and 18 $\mu\text{g/L}$ for daphnids, between 1 and 2 $\mu\text{g/L}$ for amphipods, and between 8.4 and 18 $\mu\text{g/L}$ for midges. The MATC for mirex exceeded 34 $\mu\text{g/L}$ for daphnids and midges, but was <2.4 $\mu\text{g/L}$ for amphipods. Bioconcentration factors for chlordecone and mirex by daphnids were 760 and 8025. Estimated half times by daphnids were 141 and 12 h for chlordecone and mirex, respectively.

272. SANDERS, H.O., M.T. Finley, and J.B. Hunn. 1983. Acute toxicity of six forest insecticides to three aquatic invertebrates and four fishes. Tech Paper 110, U.S. Fish and Wildlife Service, Washington, D.C. 5 pp.

Technical grade and field formulations of six experimental forest insecticides (methomyl, carbaryl, aminocarb, trichlorfon, fenitrothion, and acephate) were tested for acute toxicity using three aquatic invertebrate species (*Daphnia magna*, *Gammarus pseudolimnaeus*, and *Chironomus plumosus*) and four piscine species (bluegill, rainbow trout, fathead minnow, and channel catfish). Methomyl, carbaryl, aminocarb, trichlorfon, and fenitrothion were highly toxic (EC_{50} , 100-1,000 $\mu\text{g/L}$) or extremely toxic (EC_{50} <100 $\mu\text{g/L}$) to the invertebrate species depending upon species and formulation. The field formulation of aminocarb (17% AI; EC_{50} , 19-30 $\mu\text{g/L}$) was at least an order of magnitude more toxic to all three invertebrate species than was the technical grade material (EC_{50} , 145-320 $\mu\text{g/L}$). The methomyl field formulation (24% AI) was also more toxic than the technical grade, but differences were slight. Methomyl and carbaryl were most toxic to *Daphnia* (EC_{50} , 7.6 and 5.6 $\mu\text{g/L}$, respectively) and least toxic to *Gammarus* (EC_{50} , 920 and 16 ppm). The relative toxicity of aminocarb to invertebrates was dependent upon the species and formulation. Daphnids were most sensitive to the field formulation (EC_{50} , 19 $\mu\text{g/L}$) and gammarids to the technical grade (EC_{50} , 145 $\mu\text{g/L}$). Daphnids and midge larvae were equally sensitive to trichlorfon, either as technical grade or as 80% wettable powder; the EC_{50} ranged from 0.08 to 0.12 $\mu\text{g/L}$ for the two species. Gammarids were least sensitive to the technical grade material; EC_{50}

values were 17 and 43 $\mu\text{g/L}$ for field formulation and technical grade material, respectively. Gammarids were most sensitive to the fenitrothion field formulation (87.7% AI; EC_{50} , 2.0 $\mu\text{g/L}$), and midge larvae were most affected by technical grade (EC_{50} , 2.6 $\mu\text{g/L}$), however only 4.0 $\mu\text{g/L}$ of the field formulation was required to cause immobilization or death of half the test population of midge larvae, and the difference may not have been significant. The EC_{50} for acephate was greater than 50,000 $\mu\text{g/L}$ for all three invertebrate species. Five of the insecticides ranged from highly toxic (methomyl, to channel catfish; 96-h LC_{50} , 0.32-0.50 mg/L for all formulations tested) to relatively non-toxic (trichlorfon, to fathead minnows; LC_{50} >100 mg/L); the sixth, acephate, was only slightly toxic to the four species tested (LC_{50} >50 mg/L). Rainbow trout were generally the most sensitive species and highly so to methomyl, carbaryl, trichlorfon, and fenitrothion (96-h LC_{50} values ranged from 0.7 mg/L field grade trichlorfon to 2.2 mg/L technical grade carbaryl). In tests with bluegill and rainbow trout, the toxicity of methomyl and fenitrothion was little influenced by temperature, pH, or water hardness, but that of carbaryl, aminocarb, and trichlorfon generally increased with increasing temperature or pH, or both.

273. SANTILLO, D.J., P.W. Brown, and D.M. Leslie. 1989. Response of songbirds to glyphosate-induced habitat changes on clearcuts. J Wildl Manage 53:64-71.

Vegetation complexity was reduced on clear-cut areas treated with glyphosate (Roundup). Total numbers of birds, common yellowthroats, Lincoln's sparrows, and alder flycatchers were reduced on treated clear-cuts as compared to control areas. Songbird densities were correlated with habitat complexity, especially hardwood regeneration, foliage height diversity, and vegetation height. The authors suggested that leaving untreated patches of vegetation and staggering herbicide treatments on large clear-cuts should help to maintain bird populations similar to those on untreated areas.

274. SCHAFER, E.W. 1971. Acute oral toxicity of 369 pesticidal, pharmaceutical and other chemicals to wild birds. Toxic Applied Pharmacol 21:315-330.

The acute oral toxicity of 369 chemicals was determined for one or more species of wild birds. Red-winged blackbirds or European starlings were always included to allow comparison. Of the total number of chemicals tested, 180 (many of which are pesticides) were toxic to one or more species at a concentration of 100 mg/kg or less. Bay 25141 [fensulfothion] was most toxic to both red-winged blackbirds and European starlings. LD_{50} values were 0.24 and 0.56 mg/kg, respectively. Red-wings were more sensitive to chemicals than starlings, and both were more sensitive than rats.

275. SCHOETTGER, R.A., and J.L. Ludke. 1980. Research strategy for anticipating contaminant threats to aquatic resources. Pp 1-17 in W.R. Swain and V.R. Shannon (eds), Proceedings of the Third USA-USSR Symposium on the Effect of Pollutants upon Aquatic Ecosystems: Theoretical Aspects of Aquatic Toxicology. EPA-600/9-80-034. U.S. Environmental Protection Agency, Duluth, Minn. 241 pp.

The number of potential chemical contaminants that may pollute U.S. lakes and streams has been estimated to be in excess of 87,000. There are 129 priority toxic substances listed by the EPA for immediate assessment of production, distribution, disposal, toxicity, environmental fate, and ecological impact. Hundreds more are awaiting ecological hazard evaluation. As manpower and scientific resources are limited, members of the environmental research community must recognize and emphasize the necessity of not only placing priorities on fish and wildlife resources, but also in increasing efforts in determining which of the many pollutants are reaching or may reach these resources. To accomplish this task, the U.S. Fish and Wildlife Service is developing its research priorities so that (1) emphasis may be placed on those resources that can least afford to be lost, and (2) valuable time is not lost studying a contaminant or polluting activity unlikely to affect a priority resource. Research should be designed to provide information on the real or potential effects a contaminant may have on priority resources. The authors suggest that such results should enable the researcher to make remedial recommendations which could include one or more of the following:

- (1) legislative action to regulate or prohibit the manufacture, use, or disposal of a chemical,
- (2) modification of management techniques or practices to protect fish or other aquatic resources from the contaminant,
- (3) changes in the development, use, or application of certain chemicals,
- (4) suggested substitute chemicals which prove less harmful, or,
- (5) selection of a less harmful activity or process over one that is proven deleterious.

276. SCHOETTGER, R.A., and W.L. Mauck. 1978. Toxicity of experimental forest insecticides to fish and aquatic invertebrates. Pp 11-27 in W.R. Swain and N.K. Ivanikiw (eds), Proc, 1st and 2nd USA-USSR Symp on the Effects of Pollutants Upon Aquatic Ecosystems, Borok, Jaroslavl, Oblost, USSR, June 22-26, 1976, Vol. II. Spec Publ EPA-600/3-78-076. U.S. Environmental Protection Agency, Environmental Research Laboratory, Duluth, Minn. 158 pp.

The acute toxicities of six experimental forest insecticides (Sumithion [fenitrothion], carbaryl, Dylox [trichlorfon], Matacil [aminocarb; discontinued 1989], Dimilin [diflubenzuron] and Orthene [acephate]) for

two species of fish (brook trout and Atlantic salmon) and two invertebrate species (*Gammarus pseudolimnaeus* and a stonefly, *Peteronarcys californica*) were determined. The three chemicals most toxic to the fish species tested were Matacil, Dylox, and Sumithion. The 96-h LC₅₀ values (pH 7.5; temperature 17 C) were 0.13, 0.50, and 1.8 mg/L, respectively. All three were more toxic at higher than lower temperatures. The toxicity of Matacil and Dylox increased with increased pH. Technical grade Dylox and Sumithion were more toxic than field formulations, but the field formulation of Matacil (17% AI) was as much as seventy times more toxic than the technical grade. Carbaryl and Dylox toxicities increased with increased water hardness. Orthene and Dimilin were least toxic to fish (LC₅₀, >100 mg/L). With the exception of Orthene (LC₅₀, >100 mg/L), all chemicals tested were acutely toxic to the two invertebrate species. Stoneflies were generally more sensitive than amphipods; 96-h LC₅₀ values ranged from 0.002 mg carbaryl/L to 0.035 mg Dylox/L for the former and from 0.012 mg Matacil/L to 0.040 mg Dylox/L for the latter. Brook trout eggs and sac-fry were exposed to Sumithion at a concentration of 0.1 mg/L with no significant effects on either life stage. The two fish species were also exposed to paired mixtures of the six insecticides and to a Dylox/Guthion [azinphos-methyl] mixture. The toxicities of all combinations were additive with the exception of the Dylox/Guthion mixture which was synergistic. Carbaryl and Matacil were about two times more toxic to brook trout containing Aroclor 1254 (PCB) residues of 2.3 µg/g than to trout with lower PCB concentrations.

277. SCHUYTEMA, G.S., D.F. Krawczyk, W.L. Griffis, A.V. Nebeker, and M.L. Robideaux. 1990. Hexachlorobenzene uptake by fathead minnows and macroinvertebrates in recirculating sediment/water systems. Arch Environ Contam Toxicol 19:1-9.

Fathead minnows, earthworms (*Lumbricus variegatus*), and amphipods (*Hyalella azteca* and *Gammarus lacustris*) were exposed to hexachlorobenzene (HCB) in water with and without an HCB-spiked sediment bed. HCB concentrations in water were maintained by recirculation through HCB-packed columns. Significant bioaccumulation (bio-concentration factors ranged from 6,700 to 95,400) was observed in water-only and water-sediment exposures. With the exception of the two amphipod species, bioaccumulation was greater in water-only systems than in water-sediment systems. No significant increase in rate of uptake of HCB by the exposed organisms when exposed to water-sediment concentrations occurred; however, HCB sediment concentrations did increase over time. Higher tissue HCB levels in water-only systems suggest that sediments were a more efficient sink for HCB than were the organisms, and that sediments thus ameliorated the effects of HCB on the organisms.

278. SCHWAZBACH, S.E., L. Shull, and C.R. Grau. 1988. Eggshell thinning in ring doves exposed to p,p'-dicofol. Arch Environ Contam Toxicol 17:219-227.

Ringed turtle-doves fed diets containing either 33.4 ppm dicofol or 37 ppm p,p'-DDE produced eggs with shells 7.2 or 5.6% thinner than birds receiving no toxicant. In addition, birds receiving the dicofol- and DDE-treated diets produced an average of 1.88 and 1.79 eggs per clutch, compared with 1.97 eggs per clutch from control birds. The proportion of eggs found cracked in the nest were 16.9, 7.9, and 5.7% for birds treated with dicofol, DDE, and no toxicant. Dicofol residues in eggs ranged from 2.62 to 22.58 ppm. Only eggs from dicofol-treated birds showed any significant correlation between residue concentrations and percent shell thinning.

279. SHEEHAN, P.J., A. Baril, P. Mineau, D.K. Smith, A. Harfenist, and W.K. Marshall. 1987. Impact of pesticides on the ecology of prairie-nesting ducks. Tech Rep Ser 19. Canadian Wildlife Service, Environment Canada, Ottawa. 625 pp.

This report is perhaps the most comprehensive treatise currently available regarding the impacts of pesticides on waterfowl. Begun in 1983, it presents a review of most of the literature through the summer of 1985. Detailed information is presented regarding the ecology of prairie sloughs and waterfowl, the overlap between waterfowl nesting and pesticide use, and the main threats associated with both insecticides and herbicides as well as the problem of off-site contamination. An executive summary is presented in the final chapter.

280. SHUTAIN, G., and H. Chunru. 1988. Problems of the environment in Chinese agriculture and a strategy for its ecological development (an overview). INTECOL Bull 16:5-16.

The authors list seven major problems that have arisen due to rapid changes in agricultural practices in China. These are (1) the conversion of forest and grassland to agriculture which leads to soil erosion, desertification, and frequent natural disasters, (2) a general decrease of soil fertility and land quality due to intensive agricultural use, (3) pollution (e.g., fertilizer pollution, more than 80% of which was nitrogen, averaging 208 kg/ha annually, more than twice the world average; pesticide pollution of 13 million ha, which, coupled with urban and industrial pollution, resulted in decreased food grain production of >5 million tons annually), (4) water resource depletion, (5) a decrease in the amount of cultivated land relative to population numbers, (6) increasing costs of food production, and (7) a slowdown in agricultural production. The authors propose that the solution to these problems will require the application of ecological agricultural practices. Ecological agriculture, which combines the rationale of traditional farming with modern science and technology, takes a systems

approach to the entire rural environment, society and economy. The goals of this approach are to increase biological productivity, improve farm income, protect the environment, and to assure sustainable development by allowing more effective adaptation to market trends, the climate, and other extraneous conditions. Implementation of this approach in various areas of China has shown measured success.

281. SIERRA, M., M.T. Teran, A. Gallego, M.J. Diez, and D. Santiago. 1987. Organochlorine contamination in three species of diurnal raptors in Leon, Spain. Bull Environ Contam Toxicol 38:254-260.

OC residue concentrations in tissues and organs of the kestrel, sparrow hawk, and red kite were determined. The sparrow hawk was the most contaminated; DDE concentrations were high in all organ and tissue samples and averaged 48.6 ppm in fat. The least contaminated species was the red kite; liver and muscle tissue samples contained only 0.69 ppm total organochlorines.

282. SMITH, A.E. 1980. Analytical procedure for bromoxynil and its octanoate in soils: persistence studies with bromoxynil octanoate in combination with other herbicides. Soil Pestic Sci 11:341-346.

In a laboratory study, 90% of an original treatment of 3 µg bromoxynil/g soil disappeared within 7 days after application. On field test plots treated with 1 kg/ha in combination with asulam and MCPA, residues were absent from the top 10 cm of soil at 10 weeks post-treatment.

283. SMITH, G.J. 1987. Pesticide use and toxicology in relation to wildlife: organophosphorus and carbamate compounds. Res Publ 170, U.S. Fish and Wildlife Service, Washington, D.C. 171 pp.

This publication presents data relating to regional use of OP and carbamate pesticides throughout the U.S. and data on the chemical properties, acute toxicity, and persistence of 108 compounds. Acute toxicity data are presented for a variety of non-target mammalian, avian, and amphibian species.

284. SMITH, G.J., J.W. Spann, and E.F. Hill. 1986. Cholinesterase activity in black-crowned night-herons exposed to fenthion-treated water. Arch Environ Contam Toxicol 15:83-86.

The black-crowned night-heron was used to assess the effects of fenthion, a mosquito control agent, on wading birds. Birds were exposed in an experimental chamber which contained water treated with 1 and 10 times the recommended field application rate of 112 g AI/ha. Results suggested that the birds received only a dermal exposure. No mortality was observed during the study, and brain ChE activity was not significantly inhibited. Plasma BChE was

inhibited relative to controls in the birds exposed to the higher dosage. Butyrylcholinesterase levels in birds from the lowest treatment group did not differ significantly from those of the control group birds. The authors concluded that mortality of birds under field conditions is likely due to ingestion of treated water or of poisoned invertebrate fauna.

285. SOLBERG, K.L. 1989. Chemical treatment of monodominant cattail stands in semipermanent wetlands: duck, invertebrate, and vegetation response. M.S. thesis, South Dakota State Univ., Brookings.

Glyphosate [Roundup] treatment of wetlands for cattail control seemed to enhance the habitat for use by breeding ducks. Aquatic invertebrate abundance was neither enhanced nor adversely affected by the treatment; however, aquatic invertebrate diversity (as determined from activity trap samples) was greater in treated wetlands 1 year post-treatment. Benthic macroinvertebrate populations were not directly monitored.

286. SOMASUNDARAM, L., J.R. Coats, K.D. Racke, and H.M. Stahr. 1990. Application of the Microtox system to assess the toxicity of pesticides and their hydrolysis metabolites. Bull Environ Contam Toxicol 44:254-259.

Twenty-one chemicals, including 2,4-D, 2,4,5-T, carbaryl, fonofos, parathion, carbofuran, chlorpyrifos, isofenphos, diazinon, and several of their respective hydrolytic metabolites, were tested for toxicity to the marine bioluminescent bacterium, *Photobacterium phosphoreum*, using the Microtox system. Acute toxicities (EC₅₀ values) of the pesticides ranged from 5.0 and 5.2 µg/ml for carbaryl and fonofos, respectively, to 100.7 µg/ml for 2,4-D. Hydrolytic metabolite toxicities ranged from 1.8 µg/ml for 2,4,5-trichlorophenol, a metabolite of 2,4,5-T (approximately 25 times more toxic than 2,4,5-T), to 886.4 µg/ml for hydroxypyrimidine, which was about 80 times less toxic than its parent product, diazinon. Although 2,4-D was least toxic, its hydrolysis metabolite 2,4-dichlorophenol was among the most toxic (EC₅₀, 5.0 µg/ml). Isofenphos results were similar. This insecticide (EC₅₀, 97.8 µg/ml) was nearly 20 times less toxic than one of its metabolites, isopropyl salicylate (EC₅₀, 5.6 µg/ml).

287. SPALDING, R.F., and D.D. Snow. 1989. Stream levels of agrichemicals during a spring discharge event. Chemosphere 19:1129-1140.

During spring runoff, atrazine, cyanazine, alachlor, and metolachlor maximum concentrations in Shell Creek, Nebraska, were 89, 76, 46, and 3 µg/L, respectively. Peak concentrations occurred prior to the maximum discharge rate of 781 cfs. Other residues were detected at low levels (<2 µg/L) during the run-off event. These included butylate, EPTC, metolachlor, metribuzin, propachlor, trifluralin, and disulfoton. Total dissolved pesticide levels

ranged from 9 to 220 µg/L. Suspended sediment levels were correlated with pesticide levels, but nitrate-N concentrations were not.

288. SPRAY, C.J., H.Q.P. Crick, and A.D.M. Hart. 1987. Effects of aerial applications of fenitrothion on bird populations of a Scottish pine plantation. J Appl Ecol 24:29-47.

Application of fenitrothion at 300 g/ha from helicopters using ultra-low-volume techniques had no apparent effect on breeding bird density or the number of singing birds pre- and post-treatment. The number of coal tits breeding in nest boxes, the proportion of broods hatched and fledged, clutch size, and brood size were not significantly different from the same parameters noted in control areas. Although nest visiting rates by parent coal tits and nestling diets were different between treated and untreated areas, such differences were complex and could have been caused by factors other than spraying.

289. STADNYK, L., R.S. Campbell, and B.T. Johnson. 1971. Pesticide effect on growth and 14C assimilation in a freshwater alga. Bull Environ Contam Toxicol 6:1-8.

The effects of diuron, carbaryl, 2,4-D, DDT, dieldrin, toxaphene [discontinued 1989], and diazinon on subcultures of the algal species *Scenedesmus quadricaudata* were evaluated under static conditions. Initial concentrations in each test were either 0.1 or 1.0 mg/L. The most conspicuous effects were found with the herbicide diuron and the insecticide carbaryl. Following the second day of treatment with diuron, there was a significant reduction in cell numbers which continued through the remainder of the 10-day test. Final dry-weight biomass was 0.05 mg/L in treated subcultures as opposed to 46.8 mg/L in the controls. Carbon assimilation was also significantly suppressed (up to 90%) in the treated cultures. In contrast, carbaryl stimulated cell growth (44 to 57% more biomass in the two treated subcultures) concomitant with an increase in carbon assimilation. Cell numbers were reduced with all other pesticides tested except diazinon, which showed no effect on cell number, photosynthesis, or biomass.

290. STARY, P., J.P. Lyon, and F. Leclant. 1988. Biocontrol of aphids by the introduced *Lysiphlebus testaceipes* (Cress.) (Hym., Aphidiidae) in Mediterranean France. J Appl Ent 105:74-87.

This paper reports the success of efforts aimed at the biological control of two aphids (*Toxoptera aurantii* and *Aphis citricola*) exotic to southern France. A parasitoid, *Lysiphlebus testaceipes*, introduced from Cuba proved to be extremely successful throughout the Mediterranean region in controlling these citrus pests.

291. STONE, W.B. 1979. Poisoning of wild birds by organophosphate and carbamate pesticides. New York Fish Game J 26:37-47.

This paper documents eight instances of bird mortality due to OP or carbamate poisoning. Three of the eight cases appeared to be intentional. Diazinon used to treat a lawn was the cause of death of some 200 mallards and black ducks near Rochester, New York, during the fall of 1970. Diazinon and Dursban [chlorpyrifos] applied to a golf course in May 1974 resulted in the death of eight Canada geese in Suffolk County, New York. Gizzard contents contained 0.99 and 0.38 ppm diazinon and chlorpyrifos, respectively. A similar incident, again in Suffolk County, occurred in October 1976; 24 Canada geese were poisoned by diazinon. Liver concentrations for two samples were 0.018 and 0.014 ppm, and the gizzards contained 0.34 and 5.3 ppm diazinon. Some 25 geese were poisoned by Dasanit [fensulfothion] applied to a golf course in Rockland County in June 1977. Crop and gizzard contents contained 4.0 and 25.0 ppm, and sod samples contained 13 ppm of the insecticide. Individuals of several species were found dead at an industrial lagoon near Middleport. The cause of death was determined to be carbofuran. Of the three intentional cases reported, carbofuran granules mixed with wheat (2,000 ppm carbofuran), parathion-treated corn, and bread soaked in diazinon (14,300 ppm diazinon) were used as avicides.

292. STROMBORG, K.L., C.E. Grue, J.D. Nichols, G.R. Hepp, J.E. Hines, and H.C. Bourne. 1988. Postfledging survival of European starlings exposed as nestlings to an organophosphorus insecticide. Ecology 69:590-601.

Sixteen-day-old European starlings were orally dosed with 6 mg dicrotophos in corn oil/kg body weight. Controls, receiving only corn oil, all fledged successfully, but 18.5% of the treated birds died prior to fledging. Weight loss of survivors was significantly less than controls after treatment, but only slightly so at fledging. Brain ChE activity was depressed an average of 93% in birds dying prior to fledging (day 18) and was depressed 46% in survivors at day 18. Regular observations of treated and control birds after for 10 to 14 weeks after treatment indicated no significant differences in age at fledging, post-fledging survival, flocking behavior, or habitat use. The effects on nestlings appeared to be rapid but readily reversible in survivors. There was no apparent relationship between body mass at fledging and post-fledging survival.

293. STROMBORG, K.L., L.C. McEwen, and T. Lamont. 1984. Organophosphate residues in grasshoppers from sprayed rangelands. Chem Ecol 2:39-45.

Grasshoppers (Orthoptera) collected from pastures sprayed with malathion or acephate were used to assess adverse effects on insectivorous birds.

Based upon the presence of 3-5 ppm of methamidophos, an acephate metabolite, at 4 h post-spray, the authors suggest that although malathion may not be hazardous, acephate may pose a threat to insectivorous species.

294. STUBER, P.J. (coord). 1988. Proceedings of the national symposium on protection of wetlands from agricultural impacts. Biol Rep 88(16), U.S. Fish and Wildlife Service, Washington, D.C. 221 pp.

This report contains 27 papers covering four major topics: agricultural impacts on wetlands, national legislative wetland protection strategies, state and regional wetland protection strategies, and wetland and agriculture management strategies. Little definitive information regarding agricultural chemical impacts on wetland habitats was presented; however, many of the papers provide excellent overviews of the general problem as well as some methods which may be used to remedy many of the more specific problems associated with wetland preservation and management.

295. SULLIVAN, D.S., T.P. Sullivan, and T. Bisalputra. 1981. Effects of Roundup herbicide on diatom populations in the aquatic environmental of a coastal forest. Bull Environ Contam Toxicol 26:91-96.

Roundup (356 µg/L glyphosate) was applied to experimental areas at the recommended application rate of 2.2 kg AI/ha. Although some differences were noted between treatment and control areas, the authors generally concluded that variation in abundance of diatoms was mainly determined by habitat and seasonal factors.

296. TOME, M.W., and C.E. Grue. 1990. Spray deposit in the wetland emergent zone following an aerial application of ethyl parathion to sunflowers in North Dakota. Pp 27-28 in Proceedings of a symposium: environmental contaminants and their effects on biota of the Northern Great Plains. North Dakota Chapter, The Wildlife Society, Bismarck.

Measurement of spray deposit from an aerial application of ethyl parathion in sunflower fields and in the emergent vegetation zone of adjacent seasonal and semipermanent wetlands was performed in two separate experiments during 1987. The insecticide was applied under optimal conditions and at the normal recommended rate of 1.12 kg AI/ha. During the first trial, the applicator over-sprayed the wetland areas. Spray deposit in three sunflower fields ranged from a mean of 0.06 to 0.12 kg/ha, and mean concentrations in wetland margins ranged between 0.21 and 0.40 kg/ha. In two of four wetlands adjacent to sunflower fields, spray deposit in the emergent zone immediately adjacent to the sunflower field was greater than the deposit in the emergent zone on the opposite side of the wetland. When the entire wet-

land was surrounded by sunflowers, no such differences were observed. During the second trial, wetlands were not over-sprayed. Deposit in two sunflower fields averaged 0.22 and 0.34 kg AI/ha. Average spray deposit in emergent vegetation zones ranged from 0.07 to 0.25 kg/ha. These data indicate that aerially applied pesticides are deposited into prairie potholes, even when meteorological conditions are excellent and when the applicator attempts to keep the spray out of the wetland.

297. TOME, M.W., C.E. Grue, S. Borthwick, and G.A. Swanson. 1990. Effects of an aerial application of ethyl parathion on selected aquatic invertebrate populations inhabiting prairie pothole wetlands. Pp 31-33 in Proceedings of a symposium: environmental contaminants and their effects on biota of the Northern Great Plains. North Dakota Chapter, The Wildlife Society, Bismarck.

Seven macroinvertebrate populations (Coleoptera adults, Coleoptera larvae, Amphipoda, Gastropoda, Odonata, Corixidae, and Notonectidae) indigenous to prairie pothole wetlands were monitored to detect pre- and post-spray differences after treatment of adjacent sunflower fields by aerial application of ethyl parathion. Applications were made under optimal weather conditions and at the recommended rate. In addition to monitoring the status of these seven wild populations, survival of amphipods (*Hyalella azteca*), waterboatmen (Corixidae), damselfly nymphs (*Lestes* sp) and snails (*Stagnicola elodes*) was measured in in situ enclosures. Of the seven populations monitored, only two (Coleoptera larvae and Amphipoda) did not exhibit significant differences. Adult coleopterans decreased 83.3 and 76.8% from pre-spray numbers on days 1 and 2 post-spray as compared to decreases of 18.5 and 24.7% in control wetlands. No differences were noted between treatment and control wetlands after 35 days post-spray. After 2 days post-spray, significantly more gastropods were found on treated wetlands. This appeared to be because snails in treated wetlands tended to float on the surface with the foot extended. Cholinesterase levels were significantly lower in snails from treated wetlands than from control wetlands. Odonates were virtually eliminated from treated wetlands; however, a sixfold increase in numbers was observed in control wetlands. Notonectids reacted similarly. Corixid numbers decreased significantly 1-2 days post-spray, but then increased over pre-spray numbers. The increase seemed to be due to immigration of adult corixids. Similar results were obtained on a second treatment area with the exception of the amphipod population which generally experienced a significant decrease in treated wetlands. In the enclosures, all treated populations except snails experienced significant mortality when compared to control populations.

298. TURNBULL, R.E., F.A. Johnson, M. de los A. Hernandez, W.B. Wheeler, and J.P. Toth. 1989. Pesticide residues in fulvous whistling-ducks from south Florida. J Wildl Manage 53:1052-1057.

Thirty fulvous whistling-ducks were collected from Everglades Agricultural Area of south Florida and analyzed for OC and OP pesticide residues. Liver tissue from all 30 birds contained contaminants as did 14 of 15 breast muscle samples. A total of 18 contaminants was found, but all were at levels below those known to pose direct threats to birds or humans. DDE, dieldrin, and heptachlor epoxide residues occurred most frequently in breast muscle, whereas livers most frequently contained aldrin (19 of 30 livers; geometric mean = 9.4 ppb), dieldrin, heptachlor epoxide, heptachlor, and DDE, indicating recent illegal use of aldrin and heptachlor. DDT was found in 4 of 15 breast muscles; the highest concentration was 95.9 ppb. Sources of contamination may have been from areas outside the U.S.

299. WEIS, J.S., and P. Weis. 1989. Tolerance and stress in a polluted environment. BioScience 39:89-95.

Populations of organisms chronically exposed to chemical pollutants may develop increased tolerance to those pollutants. Increased tolerance may also be induced by pre-exposure to organic pollutants. Development of tolerance does not appear to be without cost, however. Resistance to a specific chemical pollutant (methylmercury) in the mummichog, for example, decreased the tolerance of eggs and embryos to salinity and HgCl₂ and resulted in slower growth and weakness as adults. The effects noted in adults, including early reproduction, diminished growth and regeneration rate, reduced longevity, and less feeding, probably reflect the stress associated with living in a contaminated environment. [One could perhaps expect similar reactions to pesticide induced stress.]

300. WHITE, D.H., and E.J. Kolbe. 1985. Secondary poisoning of Franklin's gulls in Texas by monocrotophos. J Wildl Dis 21:76-78.

Secondary poisoning from monocrotophos contaminated cicadas was determined to be the cause of death of 45 Franklin's gulls. Brain ChE activity was 95 to 98% inhibited in dead gulls. A sugarcane field adjacent to the refuge where the gulls were found had been treated for sugarcane beetles coincident with cicada emergence a few days prior to discovery of the gulls.

301. WHITE, D.H., and J.T. Seginak. 1990. Brain cholinesterase inhibition in songbirds from pecan groves sprayed with phosalone and disulfoton. J Wildl Dis 26:103-106.

Phosalone had little effects on ChE activity of birds from treated (0.83 kg AI/ha) groves. Eleven of 15 blue jays from groves treated with disulfoton,

however, had moderate (32%) to severe (72%) ChE inhibition. Although no direct mortality was observed in disulfoton-treated pecan groves, other studies have shown rapid disappearance of bird carcasses from agricultural areas. Additional research is needed, especially since disulfoton is the pesticide of choice to control the Russian wheat aphid (*Diuraphis noxia*) in the western great plains.

302. WHITE, D.H., C.A. Mitchell, and E.F. Hill. 1983. Parathion alters incubation behavior of laughing gulls. Bull Environ Contam Toxicol 31:93-97.

Incubating laughing gulls treated orally with 6 mg parathion/kg body weight spent significantly less time on the nest the first and second days post-treatment than did controls.

303. WHITE, D.H., C.A. Mitchell, E.J. Kolbe, and J.M. Williams. 1982. Parathion poisoning of wild geese in Texas. J Wildl Dis 18:389-391.

Seventy-two geese were found dead as a result of parathion poisoning in the Hagerman National Wildlife Refuge, Texas, during February 1981. From 6 to 20 ppm parathion (wet weight) were found in the proventriculi of six of the dead birds. Brain ChE activity ranged from 78 to 85% of normal in Canada and snow geese, respectively.

304. WHITE, D.H., C.A. Mitchell, E.J. Kolbe, and W.H. Ferguson. 1983. Azodrin poisoning of waterfowl in rice fields in Louisiana. J Wildl Dis 19:373-375.

Azodrin (monocrotophos) was responsible for the death of approximately 100 birds (mostly waterfowl) near Sweet Lake, Louisiana. Rice soaked in the insecticide was broadcast aerielly over an already-planted rice field, apparently to kill birds feeding in the field. Monocrotophos was found in the proventricular contents of all snow geese and in three of five blue-winged teal analyzed, ranging from 0.65 to 110 ppm. Rice seed samples collected on-site contained 160 to 720 ppm monocrotophos wet weight. Brain ChE inhibition in dead birds ranged from 82% in green-winged teal to 89% in great-tailed grackles.

305. WHITE, D.H., C.A. Mitchell, L.D. Wynn, E.D. Flickinger, and E.J. Kolbe. 1982. Organophosphate insecticide poisoning of Canada geese in the Texas Panhandle. J Field Ornithol 53:22-27.

Parathion and methyl parathion were the cause of some 1,600 waterfowl deaths at a Texas playa lake. The GI tracts of those geese examined were packed with winter wheat leaves and stems. Parathion residues in the birds examined ranged from 0.8 to 17.0 ppm wet weight, and methyl parathion residues ranged from 0.5 to 6.3 ppm. Brain ChE activity in the dead birds was about 75% below normal.

306. WHITE, D.H., K.A. King, C.A. Mitchell, E.F. Hill, and T.G. Lamont. 1979. Parathion causes secondary poisoning in a laughing gull breeding colony. Bull Environ Contam Toxicol 23:281-284.

Parathion contamination of insects in Texas cotton fields apparently caused the death of over 200 laughing gull chicks and adults. Brain ChE activity was depressed by 57 to 89% and 75 to 90% in dead adults and chicks, respectively. Parathion residues in the GI tracts of dead birds ranged from <0.02 to 10 ppm wet weight.

307. WHITE, D.H., W.J. Fleming, and K.L. Ensor. 1988. Pesticide contamination and hatching success of waterbirds in Mississippi. J Wildl Manage 52:724-729.

During 1984, waterfowl wintering on the Yazoo National Wildlife Refuge were contaminated with DDT and DDE, but at levels below those known to affect waterfowl. Higher than expected levels of DDE were found in the eggs of some nesting birds. This was especially noticeable in green-backed heron eggs where residue levels ranged from 0.60 to 43.0 ppm wet weight. Hatching success and eggshell thickness in green-backed herons and anhingas were negatively correlated with DDE residue concentrations in the eggs. The threshold level necessary for reduced hatching success of green-backed heron eggs was 5.1 to 10.0 ppm DDE wet weight.

308. WILKINSON, C.F. 1987. Science and politics of pesticides. Pp 25-46 in G.J. Marco, R.M. Hollingworth, and W. Durham (eds), Silent spring revisited. American Chemical Society, Washington, D.C. 214 pp.

This paper provides a good overview of past and present procedures in the regulation of pesticides as well as some basic information regarding the sciences of toxicology and risk assessment.

309. WINGER, P.V., D.P. Schultz, and W.W. Johnson. 1985. Organochlorine residues in fish from the Yazoo National Wildlife Refuge. Proc Ann Conf Southeast Assoc Fish Wildl Agencies 39:125-131.

All samples of fish collected from nine locations on the Yazoo National Wildlife Refuge, Mississippi, contained at least 10 ppm toxaphene and DDT (including metabolites). Endrin, PCB, dieldrin, and benzene hexachloride residues were also detected in some of the samples, but at concentrations generally <1 ppm. The major exception was 5.68 and 2.06 ppm dieldrin and endrin, respectively, found in gizzard shad at one site sampled in 1982. DDT and toxaphene residues were greatest in fish from sites receiving agricultural runoff. Gizzard shad from upper Swan Lake contained 280.33 and 23.49 ppm toxaphene and DDT (plus metabolites).

310. WOODWARD, D.F., and W.L. Mauck. 1980. Toxicity of five forest insecticides to cutthroat trout and two species of aquatic invertebrates. Bull Environ Contam Toxicol 25:846-854.

Cutthroat trout and two species of aquatic invertebrates, a stonefly (*Pteronarcella badia*) and an amphipod (*Gammarus pseudolimnaeus*), were exposed to technical grade and field formulations of acephate, fenitrothion, trichlorfon, aminocarb, and carbaryl. Cutthroat were most sensitive to aminocarb (field formulation, 17% AI), carbaryl, fenitrothion, and trichlorfon (96-h LC₅₀ values ranged from 88 µg aminocarb/L to 6.7 mg field formulation carbaryl/L). The LC₅₀ for acephate was greater than 100 mg/L. The toxicity of aminocarb, carbaryl, and trichlorfon to cutthroat trout increased with increasing pH and to some extent, with increasing temperature. Stoneflies were more sensitive to acephate, aminocarb, and trichlorfon than were amphipods, but amphipods were more sensitive to carbaryl. The toxicity of trichlorfon to stoneflies at pH 7.5 was 10 times greater than at pH 6.5, and two times greater at 8.5 than at 7.5. Acephate toxicity to stoneflies increased with decreasing pH, but the differences were not as great. The 96-h LC₅₀ values ranged from 4.3 µg/L (amphipod; fenitrothion; pH 6.5) to >25,000 µg/L (amphipod; acephate; pH 6.5-8.5). From the standpoint of impact on non-target aquatic organisms, acephate was the most acceptable insecticide tested.

311. ZINKL, J.G., C.J. Henny, and P.J. Shea. 1979. Brain cholinesterase activities of passerine birds in forests sprayed with cholinesterase inhibiting insecticides. Pp 356-365 in F. Peter (ed), Animals as monitors of environmental pollutants. National Academy of Sciences, Washington, D.C.

Carbaryl (Sevin-4-oil), trichlorfon (Dylox), and acephate (Orthene) were sprayed aerially on several 128- to 800-ha forest plots in southwestern Montana and northeastern Oregon during a pilot test for control of western spruce budworm (*Choristoneura occidentalis*). Application rates were 0.56, 1.13, or 2.26 kg/ha for acephate, 1.13 or 2.26 kg/ha for carbaryl, and 1.13 kg/ha for trichlorfon. Birds were collected 0, 1, 2, and 3 or more days post-spray. The effect of trichlorfon application on brain ChE activity was evaluated for 10 passerine species. Two of 28 birds collected on day 0 (western tanagers; 21 and 27% depression) and one of 21 collected on day 3 (evening grosbeak; 19.7% depression) had depressed ChE activity when compared to controls. As a result of the 1.13 kg/ha carbaryl application, only one (mountain chickadee; 21% inhibition) of 48 birds representing 10 species collected on day 0 was affected by the insecticide. The 2.26 kg/ha carbaryl spray resulted in ChE inhibition of two Cassin's finches collected on day 1. None of the other 57 birds collected had ChE inhibition. Acephate caused much more ChE inhibition than either trichlorfon or carbaryl. Although

only one of seven birds collected on day 0 exhibited ChE depression (American robin; 23%), all birds from days 1, 2, and 6 from the areas sprayed with 2.26 kg/ha were inhibited. The degree of inhibition in these birds ranged from 21 (American robin; day 6) to 54% (one dark-eyed junco and one golden-crowned kinglet; both collected on day 6). Results from the 1.13 kg/ha applications were similar but not as severe; one of 14 birds from day 0 (a MacGillivray's warbler) was inhibited by 23%. The majority of birds collected after day 0 showed some ChE depression ranging from 21% in two birds (a golden-crowned kinglet and a chipping sparrow), both collected on day 2 (Fall 1976) to 65% (dark-eyed junco collected on day 15, Summer 1976). Results were less severe from the 0.56 kg/ha carbaryl application. Cholinesterase activity was not inhibited in most birds, and none from day 1 showed ChE depression. Inhibition ranged from 18 to 43% in two dark-eyed juncos collected 5 days post-spray. Dark-eyed juncos were most affected by acephate. Of all species collected from the acephate-sprayed areas, only pine siskins did not show ChE inhibition. Inhibition was generally greater as a result of summer rather than fall acephate application.

312. ZINKL, J.G., R.B. Roberts, P.J. Shea, and J. Lasmanis. 1981. Toxicity of acephate and methamidophos to dark-eyed juncos. Arch Environ Contam Toxicol 10:185-192.

The acute oral LD₅₀ of acephate and methamidophos (a metabolite of acephate) to dark-eyed juncos was 106 and 8 mg/kg, respectively. Birds dying after exposure to acephate had brain ChE levels 80% below those of control birds. Cholinesterase depression in birds dying from methamidophos poisoning was 60% below controls. The 5-day feeding LC₅₀ for acephate was 1,485 mg/kg. Brain ChE activities of birds which died early in this part of the study were less depressed (51.5%) than those dying later (69.6%), and brain residues of the two chemicals were lower than in the birds of the acute oral LD₅₀ studies. Brain ChE activity returned to normal within 3 days of receiving a single sublethal dose of acephate.

313. RUIQUIN, X., X. Yongxiang, and G. Shirong. 1989. Toxicity of the new pyrethroid pesticide, deltamethrin, to *Daphnia magna*. Hydrobiol 188/189:411-413.

Deltamethrin was highly toxic to both neonate (6- to 24-h age) and juvenile (48- to 72-h age) cladocerans. Overall, neonates were most sensitive to the chemical. The 24- and 48-h EC₅₀ (immobilization) values were 0.113 and 0.031 µg/L, respectively. Although there was no significant difference between the 48-h EC₅₀ values for neonates and juveniles, 96-h tests indicated neonates were six times more sensitive than juveniles (EC₅₀ values, 0.003 and 0.018 µg/L) for this exposure period. The concentration at which no effects were observed was 0.01 µg/L for both age groups.

314. BENNETT, R.S., E.E. Klaas, J.R. Coats, and E.J. Kolbe. 1986. Fenvalerate concentrations in the vegetation, insects, and small mammals of an old-field ecosystem. Bull Environ Contam Toxicol 36:785-792.

Fenvalerate (Pydrin) was applied to three 1-ha old-field test plots at a rate of 0.112 kg AI/ha twice in 1980 and twice in 1981. Immediately after application, fenvalerate concentrations were as high as 12.1 ppm on vegetation, but this declined to <1 ppm by day 24 post-spray. Degradation was more rapid after the second application each year than after the first (half life 6-7 days and 11 days, respectively). Insect samples contained <0.5 ppm. The highest mean values were found in short-horned grasshoppers (Acrididae; 0.33 ppm). In small mammals, the highest concentration (1.0 ppm) was from a meadow vole (*Microtus pennsylvanicus*).

315. BENNETT, R.S., Jr., E.E. Klaas, J.R. Coats, M.A. Mayse, and E.J. Kolbe. 1983. Fenvalerate residues in nontarget organisms from treated cotton fields. Bull Environ Contam Toxicol 31:61-65.

Organisms were collected 5 days after an aerial application of 0.112 kg AI/ha. Fenvalerate residues were detected in 10 of 39 samples. Concentrations ranged from 0.01 ppm in the house mouse (*Mus musculus*) to 0.55 ppm in a ground beetle (*Calosoma* sp). Snails [species not stated], golden shiners, and mosquitofish ranked second, third, and fourth with concentrations of 0.53, 0.47, and 0.32 ppm, respectively. Concentrations in all other samples were <0.25 ppm. Ground beetles were trembling when found. It is likely that 0.55 ppm is near the lethal concentration for this species.

316. DANIELS, S.A., M. Munawar, and C.I. Mayfield. 1989. Improved elutriation technique for the bioassessment of sediment contaminants. Hydrobiol 188/189:619-631.

The mixing efficiency of the rotary tumbler was compared to that of compressed air, wrist-action shaker and reciprocal shaker methods. Results indicated that the rotary tumbler method produced the most consistent bioassay-supportable data and was also the most efficient procedure when used for 1 h with 1:4 sediment-water mixtures.

317. ANDRUSCH, T. 1989. Core sampler for soft bottom sediments with lower closing mechanism. Acta Hydrochem Hydrobiol 17:699-700.

A core sampler for soft and liquid sediment sampling from either shallow or deep water is described in detail sufficient to allow construction of the device.

318. KENNEDY, H.D., and D.F. Walsh. 1970. Effects of malathion on two warmwater fishes and aquatic invertebrates in ponds. Tech Paper 55, U.S. Fish and Wildlife Service, Washington, D.C. 13 pp.

Test ponds were treated biweekly with either 0, 0.002, or 0.020 ppm malathion. Bluegill and channel catfish losses during the experiment could not be correlated with malathion concentration; greatest losses were observed in untreated ponds. In addition, bluegill growth rates were highest in the ponds receiving 0.020 ppm malathion. Likewise, catfish growth was greatest in the ponds receiving the highest dosage; however, length gain in catfish was greatest in untreated ponds. Macroinvertebrate densities were determined from artificial substrate sampler data. Although there were no significant differences between control and low-treated ponds, the total number of organisms were significantly lower in high- than in low-treated or control ponds. About 70% of the total number of benthic species were from the family Chironomidae. Compared to control ponds, there were significant reductions of chironomids in both the low- and high-treated ponds after the third application of malathion. Mayflies (Baetidae), comprising about 24% of the total benthos, were also significantly reduced in treated ponds after the third treatment; heptageniid mayflies, originally low in numbers, did not recover after three applications of the pesticide.

319. KENNEDY, H.D., L.L. Eller, and D.F. Walsh. 1970. Chronic effects of methoxychlor of bluegills and aquatic invertebrates. Tech Paper 53, U.S. Fish and Wildlife Service, Washington, D.C. 18 pp.

Bluegills exposed to methoxychlor at concentrations of 0, 0.01, or 0.04 ppm in ponds for a period of 13 weeks exhibited pathologic changes in various tissues and organs (mainly liver and circulatory system). The mortality observed during the experiment could not be correlated with methoxychlor concentrations. No differences in growth were noted between fishes from the treatment and control ponds. Some bioaccumulation occurred. Fish in the high-treated ponds contained 21 ppm methoxychlor by day 3, which was metabolized or excreted by day 56. Chironomids made up 74% of the total benthos in the high-treated ponds as opposed to 43 and 42% from the low-treated and control ponds, respectively. Heptageniid mayflies were scarce in the high-treated ponds. Methoxychlor residues were not detected in bottom sediments.

320. OBERHEU, J.C., R.D. Soule, and M.A. Wolf. 1970. Correlation of cholinesterase levels in test animals and exposure levels resulting from thermal fog and aerial spray applications of Dursban insecticide. Down Earth 26:12-16.

Dursban [chlorpyrifos] was applied to two test sites in Brevard County, Florida, by two different methods. Rats, domestic chicks, mullet (*Mugil* sp),

blue crabs (*Callinectes sapidus*), and shrimp (*Penacus* sp) were exposed in cages located within 22.9 m of the fog generator or spray plane. There were no significant differences in either mortality or cholinesterase activity in test animals from either experiment when compared with controls or with each other. The authors concluded that when used in accordance with label instructions, Dursban concentrations in the environment should be less than those required to cause an adverse impact, at least upon those species tested.

321. SHEA, K.P. 1970. Dead stream. Environment 12:12-15.

Careless dumping of a mixture of chlordane and malathion in xylene into a Missouri stream resulted in the mortality of large numbers of fish, frogs, snakes, and aquatic insects. It was estimated that some 349,000 fish were lost due to pesticide poisoning. Thirty days after the incident, residue concentrations in fish were still at a level of 8.5 ppm, a level deemed unsafe for human consumption.

322. EDWARDS, C.A. 1973. Persistent pesticides in the environment (2nd ed). CRC Press, Cleveland, Ohio. 170 pp.

In this review, the author attempts to bring together many of the comparative data regarding the amounts of residues in the environment. Biomagnification, where substantiated, is discussed. DDT, aldrin, chlordane, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, methoxychlor, toxaphene, 2,4-D, and 2,4,5-T residues in soil, air, and water are presented in tabular form with references. Data are also presented for pesticide residue concentrations in soil fauna and flora, aquatic invertebrates, fish and aquatic mammals, plants, birds, terrestrial mammals, food, feed, and man. One chapter addresses ways to minimize pesticide residues in the environment.

323. MARSHALL, C.D., and C.W. Rutschky, III. 1974. Single herbicide treatment: effect on the diversity of aquatic insects in Stone Valley Lake, Huntingdon Co., Pa. Proc Pennsylvania Acad Sci 48:127-131.

The application of a granular form of 2,4-D (butoxyethanol ester) to a 1.6-ha cove at a rate of 43.7 kg AI/ha resulted in no overall change in benthos diversity. Aquatic invertebrate species reacted differently with some (chironomid larvae, tabanid larvae, and oligochaetes) increasing and some (damselfly nymphs) decreasing in numbers after application. The dissolved oxygen concentration dropped to 0 ppm 6 days after treatment and remained low throughout the summer. This was apparently due to the increased biological oxygen demand required for decomposition of the plant biomass destroyed by the 2,4-D application. Overall, the short-range effect on macroinvertebrate community structure seemed to be minimal.

324. EISELE, P.J. 1975. Effects of methoxychlor on aquatic invertebrate populations and communities. Diss Abstr Int 36:1118-1119B.

Continuous-flow acute and chronic bioassays and continuous dosing of a small stream were used to assess the effects of methoxychlor on aquatic invertebrates. Acute 96-h bioassays indicated a tenfold difference between species. An amphipod (*Gammarus pseudolimnaeus*) was most sensitive (EC₅₀, 0.75 µg/L) and a crayfish (*Orconectes virilis*) was least susceptible (EC₅₀, 7.05 µg/L) to the pesticide. Agreement between laboratory and field methods was good as an amphipod indigenous to the stream, *Hyallolela azteca*, was more sensitive to methoxychlor than were other benthic or aquatic invertebrate species. Species considered to be tolerant were generally not affected by the treatment. Caddisfly larvae (*Chimarra* sp) and the larvae of a dipteran (*Hemerodromia* sp) both increased in number as a result of treatment.

325. CAMPBELL, B.C., and R.F. Denno. 1976. Effect of temephos and chlorpyrifos on the aquatic insect community of a New Jersey salt marsh. Environ Entomol 5:477-483.

Species richness and diversity of the non-target salt marsh aquatic community were not changed significantly as a result of four bi-weekly applications (recommended rate for mosquito control) of temephos and chlorpyrifos.

326. DEJOUX, C., and J.M. Elouard. 1978. Action dl l'Abate sur les invertébres aquatiques Cinetique de décrochement a court et moyen terme. [Action of Abate on aquatic invertebrates. Detachment kinetic in the short and medium term.]. Cah ORSTROM Ser Hydrobiol 11:217-239.

Various concentrations of Abate (temephos) applied at weekly intervals resulted in detachment of non-target invertebrates, especially larvae, from their substratum. Drift rate also increased. The response of the insects and larvae was rapid, with detachment occurring almost immediately after the appearance of the chemical in the water. All invertebrate groups reacted similarly, but baetids and caenids (Ephemeroptera), chironomids, and trichopterans appeared to be more sensitive to the pesticide than other taxa. Biota not previously exposed to temephos were extremely sensitive. Greater than 50% mortality of non-target organisms often occurred in such communities when temephos was applied at concentrations recommended for control of blackflies (*Simulium* sp).

327. KINGSBURY, P., and D.P. Kruetzweiser. 1980. Permethrin in streams. For Pest Manage Inst Rep FPM-X 27. Canadian Forest Service, Sault Ste. Marie, Ontario. 42 pp.

The most evident result of two applications of permethrin (17.5 g AI/ha) 5 to 6 days apart for the control of spruce budworms was a decrease in the

number of aquatic insects. Consequently, fish food habits were greatly altered. However, fish mortality was not observed. One and one-half months after spraying, insect numbers recovered, and fish food habits returned to normal 4 months post-spray. Pesticide concentrations in water were below detection limits within 12 and 48 h post-spray in streams and ponds, respectively.

328. BUIKEMA, A.L., E.F. Benfield, and B.R. Niederlehner. 1981. Effects of pollution on freshwater invertebrates. J Water Pollut Control Fed 53:1007-1015.

In addition to reviewing literature regarding pollutant effects on freshwater invertebrates, the authors also provide a comprehensive bibliography (105 references) of the then-current literature. Specific studies relating to the toxicity of various pesticides including glyphosate, DDT, simazine, trifluralin, toxaphene, fenvalerate, lindane, mirex, and dieldrin are cited.

329. ANDERSON, R.L. 1983. Toxicity of fenvalerate and permethrin to several nontarget aquatic invertebrates. Environ Entomol 11:1251-1257.

Several species of aquatic invertebrates were exposed to fenvalerate or permethrin in a flow-through system for up to 28 days. The LC_{50} values decreased with increased exposure time. Behavior changes or mortality were observed at concentrations as low as 0.022 and 0.030 $\mu\text{g/L}$ for fenvalerate and permethrin, respectively. Amphipods were most sensitive to fenvalerate. As a result of exposure to permethrin, behavioral changes were generally noted within a few hours, but mortality did not exceed 50% until at least 14 days of exposure. Bioconcentration factors (concentration in organism/concentration in water) ranged from 177 to 1,286 for fenvalerate in snails, and from 43 to 570 for permethrin in stoneflies.

330. MULLER, H.D. 1971. Reproductive responses of the mallard duck to subtoxic pesticide ingestion. Poultry Sci 50:1610.

Beginning approximately 30 days prior to the onset of egg production, mallard hens were fed subtoxic levels of either dieldrin (4 ppm) or parathion (10 ppm) in food for 90 days. Although no differences in egg production or fertility were noted when compared to controls, hatchability of eggs from dieldrin-treated hens was significantly reduced to less than half that in parathion-treated or control birds. Egg shell thickness was significantly reduced as a result of both treatments; thus hatchability of eggs from dieldrin-treated hens was likely due to factors influencing embryo survival rather than to egg shell thinning.

331. FINK, R.J. 1975. Effect of simazine on the reproductive capability of mallard ducks. Toxicol Appl Pharmacol 33:188-189.

Mallard hens were exposed to simazine at dietary levels of either 2.0 or 20.0 ppm from prior to onset of egg production through the normal production cycle. Analysis of seven reproductive parameters revealed that simazine caused no adverse effects on mallard reproduction.

332. MEYERS, S.M., and J.D. Gile. 1986. Mallard reproductive testing in a pond environment: a preliminary study. Arch Environ Contam Toxicol 15:757-761.

Mallards were exposed to either 8.0 or 80.0 ppm (mg/kg of feed) chlorpyrifos. No significant reproductive effects were noted at the lower rate. Birds receiving 80.0 ppm, however, hatched significantly fewer ducklings per successful nest (5.8) than controls (10.2). None of the ducklings on treatment ponds survived to age 7 days. Control birds produced an average of 8.4 ducklings per successful nest surviving 7 days or longer. Birds in the high dose group ate less prepared food than did control birds, but weight loss was less than expected, indicating that these birds must have supplemented their diets with natural foods.

APPENDIX

Common and scientific names of fishes mentioned in the text.

Atlantic salmon	<i>Salmo salar</i>
Bigeye shiner	<i>Notropis boops</i>
Blackspotted topminnow	<i>Fundulus olivaceus</i>
Bluegill.....	<i>Lepomis macrochirus</i>
Brook trout	<i>Salvelinus fontinalis</i>
Brown trout	<i>Salmo trutta</i>
California grunion	<i>Leuresthes tenuis</i>
Carp	<i>Cyprinus carpio</i>
Channel catfish	<i>Ictalurus punctatus</i>
Chinook salmon	<i>Onchorhynchus tshawytscha</i>
Cutthroat trout.....	<i>Salmo clarki</i>
Fathead minnow.....	<i>Pimephales promelas</i>
Gizzard shad	<i>Dorosoma cepedianum</i>
Golden shiner.....	<i>Notemigonus crysoleucas</i>
Gulf toadfish	<i>Opsanus beta</i>
Largemouth bass.....	<i>Micropterus salmoides</i>
Mosquitofish	<i>Gambusia affinis</i>
Mummichog.....	<i>Fundulus heteroclitus</i>
Perch.....	<i>Perca fluviatilis</i>
Rainbow trout	<i>Salmo gairdneri</i>
Sheatfish	<i>Silurus glanis</i>
Silver carp	<i>Hypophthalmichthys molitrix</i>
Smallmouth bass	<i>Micropterus dolomieu</i>
Yellow perch	<i>Perca flavescens</i>

Common and scientific names of birds mentioned in the text.

Alder flycatcher	<i>Empidonax alnorum</i>
Anhinga	<i>Anhinga anhinga</i>
American coot	<i>Fulica americana</i>
American kestrel	<i>Falco sparverius</i>
American redstart.....	<i>Setophaga ruticilla</i>
American robin.....	<i>Turdus migratorius</i>
American wigeon (baldpate)	<i>Anas americana</i>
Bald eagle	<i>Haliaeetus leucocephalus</i>
Barn owl	<i>Tyto alba</i>
Barn swallow	<i>Hirundo rustica</i>
Barred owl.....	<i>Strix varia</i>
Bay-breasted warbler.....	<i>Dendroica castenea</i>
Black duck.....	<i>Anas rubripes</i>
Black kite	<i>Milvus migrans</i>
Black skimmer	<i>Rynchops niger</i>
Blackburnian warbler.....	<i>Dendroica fusca</i>
Black-capped chickadee.....	<i>Parus atricapillus</i>
Black-crowned night heron ...	<i>Nycticorax nycticorax</i>
Blue jay	<i>Cyanocitta cristata</i>
Blue-winged teal	<i>Anas discors</i>
Bonaparte's gull	<i>Larus philadelphia</i>
Brandt's cormorant	<i>Phalacrocorax penicillatus</i>
Brewer's blackbird	<i>Euphagus cyanocephalus</i>
Brown pelican	<i>Pelecanus occidentalis</i>

Cackling goose	<i>Branta canadensis minima</i>
California gull.....	<i>Larus californicus</i>
Canada goose	<i>Branta canadensis</i>
Canvasback.....	<i>Aythya valisineria</i>
Caspian tern.....	<i>Sterna caspia</i>
Cassin's finch	<i>Carpodacus cassinii</i>
Chipping sparrow	<i>Spizella passerina</i>
Chimney swift	<i>Chaetura pelagica</i>
Coal tit	<i>Parus ater</i>
Common goldeneye.....	<i>Bucephala clangula</i>
Common loon.....	<i>Gavia immer</i>
Common yellowthroat	<i>Geothlypis trichas</i>
Cooper's hawk.....	<i>Accipiter cooperi</i>
Dark-eyed juncos	<i>Junco hyemalis</i>
Dickcissel.....	<i>Spiza americana</i>
Domestic chicken	<i>Gallus gallus</i>
Double-crested cormorant	<i>Phalacrocorax auritus</i>
Elegant tern	<i>Sterna elegans</i>
European starling.....	<i>Sturnus vulgaris</i>
Evening grosbeak	<i>Coccothraustes vespertinus</i>
Ferruginous hawk.....	<i>Buteo regalis</i>
Franklin's Gull.....	<i>Larus pipixcan</i>
Fulvous whistling-duck.....	<i>Dendrocygna bicolor</i>
Gadwall.....	<i>Anas strepera</i>
Golden-crowned kinglet.....	<i>Regulus satrapa</i>
Great blue heron	<i>Ardea herodias</i>
Great horned owl	<i>Bubo virginianus</i>
Great-tailed grackle.....	<i>Quiscalus mexicanus</i>
Green-backed heron	<i>Butorides striatus</i>
Green-winged teal	<i>Anas crecca</i>
Guanay.....	<i>Phalacrocorax bougainvillii</i>
Herring gull	<i>Larus argentatus</i>
Horned lark	<i>Eremophila alpestris</i>
House sparrow	<i>Passer domesticus</i>
Japanese quail	<i>Coturnix japonica</i>
Kestrel.....	<i>Falco tinnunculus</i>
Killdeer	<i>Charadrius vociferus</i>
Lapland longspur.....	<i>Calcarius lapponicus</i>
Laughing gull	<i>Larus atricilla</i>
Least tern.....	<i>Sterna antillarum</i>
Lesser scaup	<i>Aythya affinis</i>
Lincoln's sparrow	<i>Melospiza lincolni</i>
Loggerhead shrike	<i>Lanius ludovicianus</i>
MacGillivray's warbler	<i>Oporornis tolmiei</i>
Magnolia warbler.....	<i>Dendroica magnolia</i>
Mallard	<i>Anas platyrhynchos</i>
Merlin	<i>Falco columbarius</i>
Mountain chickadee	<i>Parus gambeli</i>
Northern bobwhite.....	<i>Colinus virginianus</i>
Northern cardinal.....	<i>Cardinalis cardinalis</i>
Northern goshawk.....	<i>Accipiter gentilis</i>
Northern pintail.....	<i>Anas acuta</i>
Northern shoveler.....	<i>Anas clypeata</i>
Osprey	<i>Pandion haliaetus</i>
Peregrine falcon.....	<i>Falco peregrinus</i>
Pigeon.....	<i>Columba livia</i>

Pine siskin *Carduelis pinus*
 Red kite *Milvus milvus*
 Red-eyed vireo *Vireo olivaceus*
 Red-necked grebe..... *Podiceps grisegena*
 Red-shouldered hawk *Buteo lineatus*
 Red-tailed hawk *Buteo jamaicensis*
 Red-winged blackbird..... *Agelaius phoeniceus*
 Ringed turtle-dove..... *Streptopelia risoria*
 Ring-necked pheasant *Phasianus colchicus*
 Rose-breasted grosbeak *Pheucticus ludovicianus*
 Royal eagle..... *Aquila chrysaetos*
 Rufous-sided towhee *Pipilo erythrophthalmus*
 Savannah sparrow *Passerculus sandwichensis*
 Scarlet tanager *Piranga olivacea*
 Sharp-shinned hawk *Accipiter striatus*
 Snow goose *Chen caerulescens*
 Sparrow hawk *Accipiter nisus*
 Swainson's hawk..... *Buteo swainsoni*
 Tennessee warbler *Vermivora peregrina*
 Tree swallow *Tachycineta bicolor*
 Turkey..... *Meleagris gallopavo*
 Violet-green swallow *Tachycineta thalassina*
 Western Canada goose... *Branta canadensis moffitti*
 Western grebe..... *Aechmophorus occidentalis*
 Western tanager *Piranga ludoviciana*
 White-faced ibis *Plegadis chihi*
 White-throated sparrow *Zonotrichia albicollis*
 White-throated swift..... *Aeronautes saxatalis*
 White-winged scoter *Melanitta fusca*
 Wilson's phalarope..... *Phalaropus tricolor*
 Wood duck *Aix sponsa*
 Yellow-rumped warbler *Dendroica coronata*
 Zebra finch *Poephila guttata*

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