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A CREEL CENSUS OF THE SALMONID FISHERY IN SOUTH SANDY CREEK, NEW YORK

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ABSTRACT

A creel census of the salmonid fishery (primarily for chinook salmon) in South Sandy Creek (N.Y.) was conducted in the fall of 1976 to determine fishing pressure, number of fish taken and catch rate. A total of 3,266 anglers spent 9,066 hours fishing the 6.75-mile study section during the 44-day census period. Fishing pressure on weekends and holidays differed significantly from that on weekdays. Fish caught totalled 5,469 for a catch rate of 0.6 per hour for all anglers and 1.06 per hour for successful anglers. Chinook salmon constituted 96 per cent of the catch. Just prior to the start of the census, possession of any salmon was prohibited due to Mirex contamination. Nevertheless, substantial fishing pressure was observed indicating the importance of the fishery for sport fishing alone, although a dramatic increase did follow the later relaxation of the ban. It is pointed out that the data reflect a fishery under unique controls and do not represent typical conditions.

South Sandy Creek rises in western Lewis County (N.Y.) and flows westward to Lake Ontario. The foundation of an old dam at Monitor Mills, nearly 7 miles above its mouth, is a barrier to the upstream migration of salmon. It has been stocked with chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) since 1974 and has increased in popularity with fishermen due to its proximity to the Salmon River, the major fishing stream for salmon in eastern Lake Ontario. Each day, when the water level in the Salmon River rises due to operation of a hydroelectric plant, there has been an influx of anglers to the smaller stream. Salmon have generally moved into South Sandy Creek from mid-September through early November, and a creel census to estimate fishing pressure and catch rates was carried on from September 18 to October 31 in 1976 when the first run of mature salmon (chinook, 3+; coho 2+) from fish stocked in this stream returned to spawn.

During the preceding summer, laboratory analyses were made of fish from Lake Ontario, and six species, including chinook salmon and coho salmon, were found to contain Mirex, a polychlorinated hydrocarbon known to be harmful to humans, in concentrations exceeding health standards for consumption. On September 14, 1976, just prior to the start of the census, the State Department of Environmental Conservation, on recommendation from the State Health Department, banned possession of all salmon from these waters. It did not prohibit fishing, but required that any salmon taken be immediately returned to the water. Then, on October 2, 1976, this restriction was eased to permit each angler to possess three trophy fish, i.e., chinook salmon 35 inches or more in length and coho salmon 32 inches or more in length.

METHODS

The 6.75-mile portion of South Sandy Creek below Monitor Mills was selected for study (Figure 1). This section was divided into two parts: (1) from the mouth to Route 3 (1.85 miles) where only angling was permitted; (2) from Route 3 to Monitor Mills (4.90 miles) where both angling and snatching[1] were allowed. For the part above Route 3, the stream is roughly paralleled on each side by a road, and along these roads access points where anglers were accustomed to park their vehicles were identified as shown in Figure 1. The parking areas at the bridge on Route 3 served the part of the stream below that point.

The survey was made on 27 days between September 18 and October 31 and included all weekend days and holidays (15) plus 12 randomly selected weekdays. The census consisted of two main parts: estimates of fishing pressure and catch statistics. Since fishermen were to a large extent restricted to the known access points for parking their cars, estimates of fishing pressure were made by tallying all cars at these points at prescribed intervals. On each survey day, a census agent drove around the road circuit connecting the access points at 3-hour intervals from 7:00 a.m. to 7:00 p.m. and counted the number of angler vehicles. A circuit usually took 20 minutes. Between such circuits, anglers who had finished fishing were interviewed for information concerning the number in their party, their county of residence, the number of hours fished, their fishing methods and the nature of their catch. This method of survey was biased in that it did not provide data for fishermen who walked to the stream or reached it by boat.

To determine whether data for the ratio of anglers per car and for the length of angler trips on weekends and holidays could be combined with those for weekdays, the average values recorded were compared by the Z-test which tests for the difference in means. The results indicated that the data for the two periods were significantly different and could not be combined (Table 1).

[1] The Fish and Wildlife Law defines snatching as "taking fish not attracted by bait or artificial lure, by snatching with hooks, gangs or similar devices, whether or not baited."

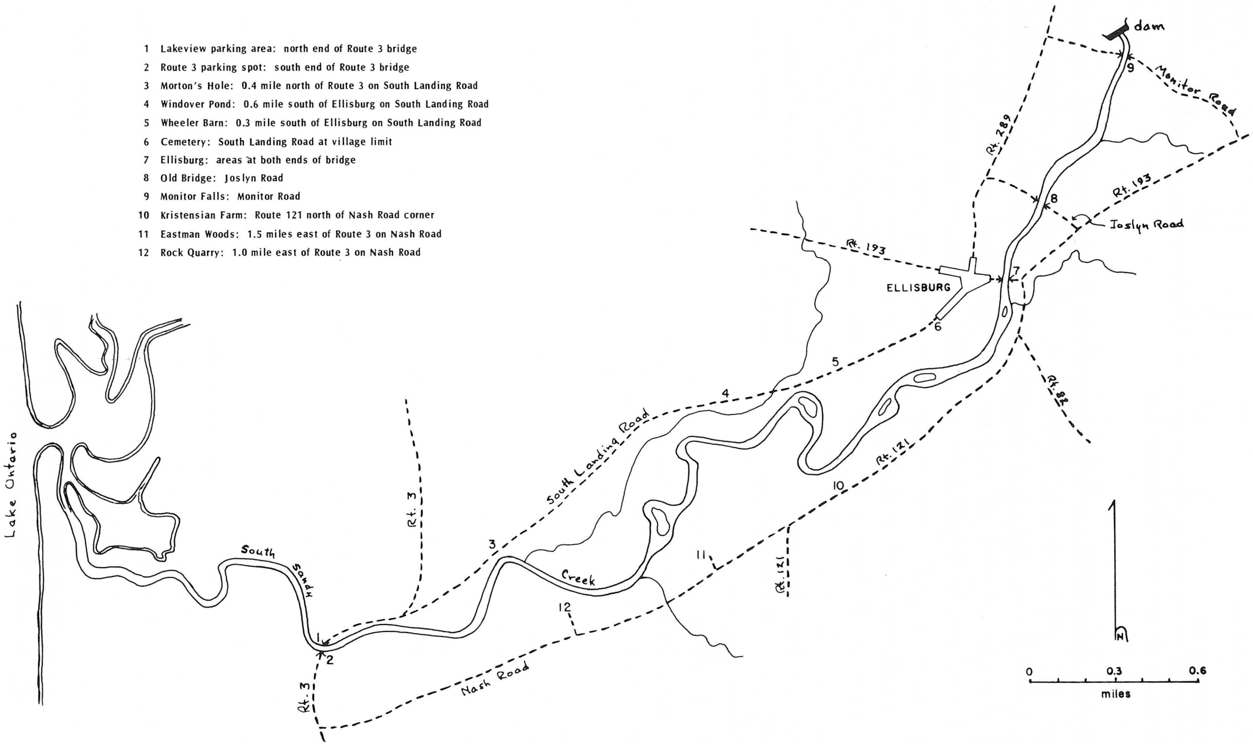

Figure 1. Map of study section of South Sandy Creek from Lake Ontario to dam at Monitor Mills. Numbers along roads paralleling stream indicate parking areas where census data were obtained.

TABLE 1. STATISTICAL COMPARISON OF DATA FOR CREEL CENSUS IN SOUTH SANDY CREEK WITH RESPECT TO WEEKENDS AND HOLIDAYS VS. WEEKDAYS

Item	Weekends and holidays	Weekdays	Z-test
Average anglers per car	2.2	1.8	3.93*
Average hours fished	3.2	2.4	3.78*

* Significant at 95 per cent confidence level.

Therefore, in estimating fishing pressure, the data collected for each day-type, i.e., weekend and holiday vs. weekday, were treated separately. In each case, the total number of cars recorded was multiplied by the average number of anglers per car based on the interviews made. To minimize duplication of anglers, because the length of the average angler trip did not always correspond to the car count interval, the result was then multiplied by a factor derived by dividing the count interval (3 hours) by the average trip length recorded. For weekends and holidays, the data covered the entire period. For weekdays, the average per census day was calculated and extrapolated to cover all the weekdays in the period. The sum of the two represented total fishing pressure.

To make these estimates more precise, aerial counts of anglers were made from a Department helicopter on five occasions at the same time ground counts of cars were being made on the road circuit. The aerial counts averaged 1.2 times those based on simultaneous ground counts of cars.

Thus, fishing pressure (as total number of anglers) was estimated by the formulas

$$P = WEP + WDP$$
$$WEP = (CC \times C_e \times I/A_e) \times E$$
$$WDP = (CC \times C_d \times I/A_d) \times E \times T_p/T_w$$

where

WEP = weekend and holiday pressure
WDP = weekday pressure
CC = total number of cars counted
C_e and C_d = average number of anglers per car on weekends and holidays and on weekdays, respectively
I = count interval = 3 hours
A_e and A_d = average length of angler trip on weekends and holidays and on weekdays, respectively
E = correction factor (1.2) derived from helicopter counts
T_p = total days in survey period
T_w = number of weekdays censused

The number of hours fished was calculated by multipling the fishing pressure for each day-type by the corresponding average length of angler trip.

During interviews with anglers, the number of fish they caught (salmon, rainbow trout, brown trout and lake trout) was recorded together with the number of hours they had fished. The number caught per hour was computed on a daily basis and then averaged for each day-type. These values, multiplied by the respective total numbers of hours fished, gave the total catch in each case.

RESULTS

A total of 3,266 anglers spent 9,066 hours fishing the 6.75-mile study section of South Sandy Creek during the 44-day census period. As the study progressed, the census agent became somewhat of a fishing guide. Knowing generally where the "hot spots" were on a given day proved to be a valuable asset in developing a personal rapport with the salmon fishermen. It was found much easier to collect desired information from satisfied anglers.

FISHING PRESSURE

Fishing pressure—a result of angling regulations, ease of access to the stream and fishing success—was spread unevenly over the study section. The part where snatching was not permitted (1.85 miles from the mouth of the stream to Route 3) received 4.3 per cent of the total pressure or 77 angler trips per mile for the study period. The 4.9 miles from Route 3 to Monitor Mills, where snatching was permitted, received 95.7 per cent of the pressure or 638 angler trips per mile. Access as well as angling restrictions may have been a deterrent to fishing in the part where snatching was banned because a boat was necessary to reach pools near the mouth. Throughout the study period, average fishing pressure on weekends and holidays was twice that on weekdays, reflecting the fact that more anglers have an opportunity to fish on weekends.

Although the entire upstream section of the creek was used, fishing pressure was heaviest in areas close to easy access sites. Locations where a road crossed or came close to the stream were of particular importance. The bridge in the village of Ellisburg, for example, became a meeting place of sorts where anglers exchanged stories and discussed the finer points of salmon fishing. From this vantage point, movement of salmon and successful angling could be followed.

By far the most significant factor in determining the distribution of fishing pressure, however, was the upstream migration of salmon. Movement of fish into the study section coincided with a rise in the

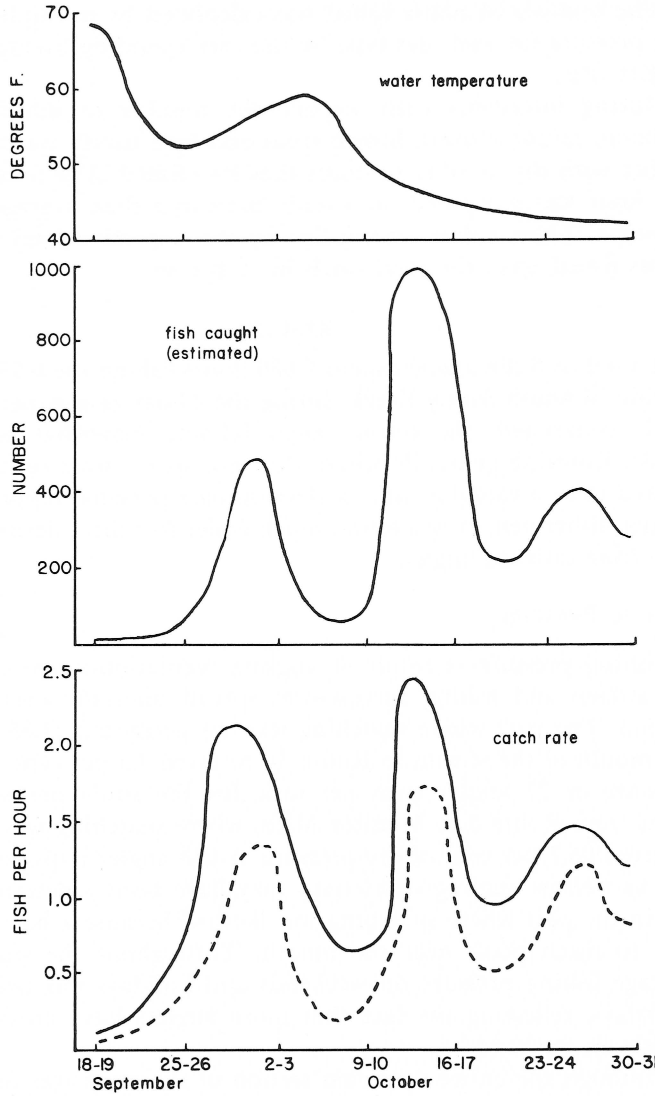

Figure 2. Fluctuations in water temperature, fish caught and catch rate during census of salmonid fishery in South Sandy Creek in 1976. Dates noted represent weekends. For the catch rate, solid line represents successful anglers and dash line represents all anglers.

water level and lowering of water temperature (Figure 2). An influx of fish and a corresponding increase in the catch rate were observed during periods of high water. In general, once salmon entered the stream, they continually moved upstream. As the season progressed, fishing pressure shifted from the lower sections of the stream to upper areas where fishermen had more opportunity to catch fish.

During the period when all fish had to be returned to the water because of the special health hazard regulation, an average of 42 anglers spent 114 hours per day fishing South Sandy Creek. This evidenced the importance of the fishery and indicates that a substantial amount of pressure will be exerted (for sport fishing alone) as long as salmon fishing is available. After the possession of trophy fish was allowed, fishing pressure doubled. Being allowed to keep a trophy catch gave many anglers the incentive to get out and fish.

LENGTH OF ANGLER TRIP AND CATCH RATE

The average length of fishing trips was 3.2 hours on weekends and holidays compared with 2.4 hours on weekdays (Table 1). Fish caught totalled 5,469 for a catch rate of 0.6 per hour or 1.7 per trip for all anglers, or 1.06 per hour for successful anglers (Table 2). Chinook salmon constituted 96 per cent of the catch. Comparison with data for the Salmon River from 1973 to 1975 (Table 3) shows that fishermen in South Sandy Creek spent less time and caught more fish.

As the season continued and more salmon entered the stream, the catch rate increased. The trends in catch rate over the study period for all anglers and for successful anglers are illustrated in Figure 2, together with the concurrent variations in the number of fish caught and in water level and temperature. Comparison of these data shows that both the catch rate and the number of fish taken increased during

TABLE 2. SUMMARY OF FISH CAUGHT AND CATCH RATE IN SOUTH SANDY CREEK

Item	Value	
Total number of anglers	3,266	
Successful anglers (per cent of total)	42.6	
Total number of hours fished	9,066	
Total number of fish caught	5,469	
Fish caught per hour (all anglers)	0.6	
Fish caught per hour (successful anglers)	1.06	
Composition of catch	**Number**	**Per cent**
Chinook salmon	5,257	96.13
Coho salmon	167	3.05
Rainbow trout	38	0.69
Lake trout	4	0.07
Brown trout	2	0.04
Cohook (coho × chinook hybrid)	1	0.02
Total	5,469	100.00

TABLE 3. AVERAGE LENGTH OF FISHING TRIPS AND SALMONID CATCH RATES IN SALMON RIVER COMPARED WITH THOSE IN SOUTH SANDY CREEK

Stream and year	Average fishing trip (hours)	Catch rate (fish per hour)
Salmon River*		
1973	4.5	0.03
1974	4.5	0.11
1975	5.3	0.06
South Sandy Creek		
1976	2.8	0.60

* Unpublished data furnished by Tommy Brown, Dept. Nat. Res., Cornell Univ., Ithaca, N.Y.

periods of rising water. Increased flow and high water triggered an influx of salmon and resulted in more successful fishing.

It is not known how many fish were caught more than once, but it is likely that many were, especially while the complete ban on possession was in effect. This would increase the catch rate recorded compared with what it would have been if all the fish taken had been kept. Another factor contributing to a high catch rate is the fact that during the later stages of spawning activity salmon were easier to land.

ANGLING METHODS

Anglers reported that early in the season salmon hit lures near the mouth of the stream. Limited attempts were made by some anglers upstream to take salmon by using conventional gear, i.e., lures and flies. However, 95 per cent of all the fish taken were caught by snatching, although this was permitted in slightly less than three-quarters of the study section.

EFFECT OF RESTRICTING POSSESSION OF FISH

The restrictive regulations resulted in fewer anglers fishing for a greater number of salmon. Coupled with this was the maintenance of a high baselevel population of catchable fish caused by the returning of landed fish to the stream. Both of these consequences enhanced catch rates and total catch. When possession of trophy fish was permitted, all anglers became more selective, fished longer and took more fish (Table 4).

The large number of fish in the stream associated with the ban on possession caused an overflow of individuals into feeder streams. Little Deer Lick Creek and Bear Creek, in particular, contained many salmon in the late spawning stage.

TABLE 4. COMPARATIVE FISHING PRESSURE AND CATCH RATES IN SOUTH SANDY CREEK BEFORE AND AFTER BAN ON POSSESSION OF FISH WAS EASED TO PERMIT KEEPING TROPHY FISH

Item	Weekends and holidays		Weekdays	
	Before	After	Before	After
Number of anglers per days	63	117	33	74
Successful anglers (per cent of total)	20.83	47.24	27.93	50.78
Hours fished per day	202	373	79	177
Average length of fishing trip (hours)	3.1	3.3	2.4	2.4
Total number of fish caught per day	40	243	40	138
Fish caught per hour (all anglers)	0.2	0.65	0.5	0.78
Fish caught per hour (successful anglers)	1.2	1.01	0.81	1.19
Social factor (per cent)*	22.6	41.7	21.1	29.3

* Proportion of anglers whose residence was 100 miles or more from South Sandy Creek.

TABLE 5. DATA CONCERNING 105 CHINOOK SALMON TAKEN FROM SOUTH SANDY CREEK

Item	Value
Sex ratio (females per male)	2.4
Length (millimeters)	
Average	888
Range	750-1,005
Weight (grams)	
Average	8,195
Range	4,750-11,500
Lamprey marks (per fish)	
Average number	0.8
Frequency (per cent)	
0	52.4
1	26.7
2	11.4
3	6.7
4	2.8

OTHER DATA

A sample of 105 chinook salmon averaged 888 millimeters (35 inches) in length and 8,195 grams (18 pounds) in weight (Table 5). Lamprey marks averaged 0.8 per fish for this group, but 52.4 per cent had none and 26.7 per cent had only one.

For the entire study period, more than a third of all the anglers interviewed resided 100 miles or more from South Sandy Creek. On weekends and holidays, use by non-local fishermen doubled when possession of trophy fish was permitted (Table 4).

DISCUSSION

Plans for this study had been made long before the ban on possession of fish taken in South Sandy Creek was instituted. Therefore, it was decided to go ahead with the study as planned, despite the fact that a marked effect on fishing pressure could be expected. That fishing pressure was still substantial indicates the importance of the fishery for sport fishing alone, although a dramatic increase did follow the later relaxation of the ban.

Prohibition of snatching in the part of the stream below Route 3 reserved a section for those who wished to use other methods of angling on fish not subjected to snatching. Since this regulation was being instituted for the first time on this stream, it is difficult to assess its success. However, interviews indicated a general satisfaction with separating the stream in this manner.

The results of this study have a number of implications regarding the management of South Sandy Creek. However, in considering the data, one must be aware that regulations affecting the salmon fishery not only were unusual but changed during the study period, greatly influencing the findings. It must be recognized that conclusions reflect a fishery under unique controls and, therefore, do not represent typical conditions.

A RATING SYSTEM FOR THREATENED AND ENDANGERED SPECIES OF WILDLIFE[1]

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ABSTRACT

A rating system for systematically determining the relative status of native wildlife species and for assessing the likelihood that the potential for survival of a threatened or endangered species can be enhanced by the efforts of a wildlife agency is described. The status index is derived from graded evaluations under a degree of threat factor, a regional uniqueness factor and a social-ecological-economic factor. The program success index is derived from the status index and a recovery potential factor. The evaluations to be applied under each factor are defined and given numerical values that can then be used in equations to yield comparable ratings. The status and program indices, considered in conjunction with the required actions and estimated costs of an effective management effort, provide the basis for developing a comprehensive, justifiable and effective endangered species program.

The Federal Endangered Species Act of 1973 provides the legal mandate for the U. S. Departments of Interior and Commerce to have joint jurisdiction over threatened and endangered species of wildlife and to conduct research and develop recovery and management plans for these species. Section 6c of the Act allows the states to enter into cooperative agreements with the U.S. Fish and Wildlife Service for aid and funding, provided the state agency has authority over resident threatened and endangered species and has established acceptable conservation programs for them. When the present paper was written (1978), 21 states had entered into such an agreement.

New York State enacted an endangered species law in 1970 and adopted a list of such species in the same year, but a major program effort was not undertaken until after Federal matching funds became available in October 1976. It soon became apparent that there was need for a review of this list as well as for development of a list of threatened species. It was also recognized that development of a comprehensive program would require the determination of priorities for the allocation of available funds and that for this purpose there was

[1] The authors wish to thank Dr. Edgar Reilly of the New York State Museum and Science Service for making his files available and others who provided data on particular species. Thanks are also extended to the many employees and consultants of the State Department of Environmental Conservation, especially Eric Fried and Dr. James Powers, for help and suggestions during the development of the system and preparation of the manuscript.

need for a method of ranking the species according to their relative status.

Two rating systems that had been proposed[2] for determining funding priorities in the Federal program were reviewed for applicability at the state level. Sparrowe and Wright (1975) had devised a complex system requiring large quantities of biological data that were often unavailable or non-existent, but it offered little perspective on program direction or funding priorities. A rating system drafted by the Federal Office of Endangered Species[3] presented a much simpler method that took into account both the biological aspects of wildlife and related human values but required more subjective judgement in its application. The latter was chosen as a model on which to base a rating system for evaluating the status of threatened and endangered species in New York. There were three major reasons for the choice: (1) it used information that was to some extent available for all species in the State; (2) it was simple, yet it encompassed both the biological needs of wildlife and their ecological, economic and human relationships, considerations that are especially important in a public-supported program; and (3) it could be easily modified to apply to any species of wildlife, regardless of status, and to the more localized situations encountered at the state level.

METHODS

The Federal rating system used three categories of evaluation to develop numerical rankings of the species considered. Each category represented the assessment of one or more factors according to defined components assigned numerical values. The three categories, the factors considered under each and the manner in which they were used to develop the ranking for a given species may be summarizd as follows:

priority index = degree of threat factor × (taxonomic factor + ecological-socioeconomic factor)
score = priority index × recovery potential factor
optional score = score × action factor

The purpose of this system was to develop funding priorities for the threatened and endangered species on the Federal list, but the methods of evaluating the factors recognized were neither apparent nor discussed in the paper describing it.

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[2] So far as the authors have been able to learn, neither had actually been put into practice.

[3] Titled "Endangered Species Priority System" and designated FWS/OES No. 301.3, this was apparently prepared in 1976 and was seen only in draft form.

This Federal system was used as the basis for a rating system in New York. The portions adopted were the format of three major categories of factors with defined components, the basic concepts behind several of the factors and the recovery potential factor almost as written. The rating for a given species is based on a status index and a program success index.

The status index is derived from three factors each of which is assessed according to five graded valuations (numbered 1 to 5). These factors are: (1) a degree of threat factor the components of which are designed to cover the possible range of status and the extent of threat to the population being considered; (2) a regional uniqueness factor the components of which are designed to evaluate the degree of localization and imminence of threat to a population as well as to compare the status of the species within the state to that throughout its range; and (3) a social-ecological-economic factor to take into account public attitudes toward a particular species and the ecological and economic significance of the species. Due to the paucity of data concerning such values, the latter factor is necessarily the most subjective of the three. Following are definitions of the values under each factor. These are framed in terms of conditions in New York and apply to species and subspecies.

Degree of threat

1. Status undetermined Species possibly subject to some degree of threat in New York but about which available information on its relative abundance and/or habitat conditions or requirements is insufficient for judgement.
2. Peripheral, unique or localized Species for which New York is on the fringe of its natural range and/or which has unique or specialized habitat requirements. Threat is mainly due to either marginal habitat conditions or limited habitat tolerance.
3. Extirpated Species historically found in New York, but which no longer occur there as breeding populations due to either natural or man-induced causes.
4. Theatened Species whose populations in New York are subject to a significant threat from known or unknown causes, but which face little danger of extirpation within the foreseeable future if certain actions are taken and maintained.
5. Endangered Species in danger of extirpation in New York due to either natural or man-induced causes and whose survival requires special actions or assistance.

Regional uniqueness

1. Species currently subject to some degree of threat locally in New York, but apparently healthy and stable throughout the major part of its range.
2. Species possibly subject to some degree of threat generally in New York, but whose habitat or population is not subject to immediate hazard from natural or man-induced causes in the foreseeable future, and apparently healthy and stable throughout the remainder of its range.
3. Same as 2, but threat in New York likely to materialize within the foreseeable future.

4. Species currently subject to some degree of threat throughout a major part of its entire range.
5. Species subject to some degree of threat whose entire range is within New York State.

Social-ecological-economic

1. Species having few supporters outside the scientific community and an unknown or apparently insignificant economic value or role in the ecosystem.
2. Species for which there is some public awareness, mainly restricted to special interest factions, but whose economic value or role in the ecosystem is unknown or apparently insignificant.
3. Species for which there is widespread public awareness but limited public support, and whose economic value or ecological role is apparently significant.
4. Species for which there is strong public awareness and opinion, and whose economic value or ecological role is apparently significant.
5. Species for which there is the highest degree of public awareness and support or that is of significant economic or ecological value.

The status index was found to be most representative when the factors were weighted as follows:

status index = 3 (degree of threat factor + 2 (regional uniqueness factor) + social-ecological-economic factor

Thus, the resultant values for the index could range from 6 to 30 and would represent an increase in the endangerment of a species as they became greater.

Significantly threatened or endangered species may be considered to be those that are rated 4 or 5 under the degree of threat factor. These may then be arrayed according to their ranking in the status index. Since such a list is based only on the rating for the degree of threat factor, the status index value could rank a threatened species higher than an endangered species because of the variability introduced by the other two factors. Therefore, no predetermined cut-off point for "threatened" or "endangered" can be expected.

For the species so selected, a program success index is obtained by applying the recovery potential factor:

program success index = status index × recovery potential factor

The recovery potential factor covers the range of possibilities for improving the status of a species and takes into consideration the species' biological characteristics and habitat requirements as well as the responsible agency's ability to undertake and maintain certain necessary actions. Assessments under this factor are graded according to the following definitions which apply only to the selected significantly threatened or endangered species.

Recovery potential

0.2 This applies to species that may be extinct, that cannot be located in New York or that have been extirpated in the State and for which favorable habitat there no longer exists. Because the changes in their former habitat are so great or, if migratory, because a critical part of their life cycle is spent outside New York, work on them, even if funded, would probably fail to reestablish them.

0.5 This applies to species that, regardless of all-out recovery or reestablishment effort, are likely to become extirpated in the wild in New York or would be unable to produce viable populations. Their distribution, status and potential range are generally known. Although habitat conditions may still be favorable, other factors such as low reproductive potential, lack of support by the public, etc. may currently prevent their recovery or reestablishment.

1.0 This applies to species that have a fair chance if action is taken and continued. However, their future cannot be assured because of susceptibility to fire, vandalism, hurricanes, competition with exotic species, oil and chemical spills, etc.

2.0 This applies to species whose future can virtually be assured through identifiable recovery actions. Many species qualify here because their being listed as threatened or endangered has resulted from threatened or actual loss of habitat that need not be permanent. If removal of the threat or restoration of destroyed habitat is feasible, their future may be considered promising.

The resulting numerical values for the program success index indicate the relative likelihood that a species' potential for survival can be enhanced by the efforts of a wildlife agency. Species with little potential for improvement tend to be poor funding risks in a comprehensive, public-supported endangered species program. Once the species under consideration have been rated in this way, the actions necessary for improving the status of each may be outlined and costs estimated. This information in conjunction with the program success index serves as a basis for decisions concerning the direction, priorities and extent of an endangered species program.

RESULTS

Before this priority rating system was applied to the species native to New York State, several preliminary steps were taken. It was not applied to fish, marine mammals or invertebrates due to limitations on information, time and personnel. Excluding these groups, New York has 596 species of wildlife, and all those with no known threat to their populations or habitats within the State were omitted from consideration. Also omitted were migratory species a critical part of whose life cycle is spent outside New York. This left 209 species that merited rating. For these, the kinds of information needed were determined, and forms were prepared to assure that data were collected consistently. Published and unpublished literature sources, authorities and naturalists were consulted. Information on the distribution of all species of vertebrate wildlife in the State was donated by the New York Sate Museum and Science Service.

Assessment with respect to the components of the factors recognized was done independently by several people, and a rating was agreed upon for each species. If ratings for a species differed, additional in-

TABLE 1. MANNER OF CALCULATING STATUS INDEX VALUES AS USED FOR WILDLIFE SPECIES IN NEW YORK

Species	Factor*			Status index value
	Degree of threat	Regional uniqueness	Social-ecological-economic	
Indiana bat (*Myotis sodalis*)	3 x 5	2 x 4	1 x 3	26
Timber wolf (*Canis lupus*)	3 x 3	2 x 4	1 x 4	21
Eastern woodrat (*Neotoma floridana*)	3 x 4	2 x 3	1 x 2	20
New England cottontail (*Sylvilagus transitionalis*)	3 x 2	2 x 4	1 x 3	17
Black bear (*Ursus americanus*)	3 x 2	2 x 2	1 x 4	14
Fox squirrel (*Sciurus niger*)	3 x 2	2 x 1	1 x 3	11

* Figures in each case represent weighted assessment (see text); sum equals index value.

formation was collected until a concensus could be reached. Status values were then calculated as illustrated in Table 1, and the species that had been rated 4 or 5 under the degree of threat factor were listed according to these values (Table 2). Low values of 24 for endangered species and 18 for threatened species resulted. In addition, there were three species, considered extirpated in New York (rated 3 under the degree of threat factor) but for which suitable habitat may still exist there, that might warrant efforts to reestablish them. For this reason, they were also rated and, because of their high evaluation under other factors, their status indices were above those for many of the threatened species: timber wolf (*Canis lupus*)–21; puma (*Felix concolor*)–21; lynx (*Lynx canadensis*) –21.

The species listed in Table 2 were rated according to the recovery potential factor, and the program success index for each was determined as illustrated in Table 3 in which they are listed according to these values which reflect the probability of success for a program to improve their status. Not surprisingly, the endangered species were grouped in the middle and at the lower end of the program success index, indicating their status to be more precarious than that of the threatened species. This also applied to the extirpated species.

For species deemed to merit special effort to improve their status, the actions required may be determined and costs estimated. Two examples of how this might apply are shown in Table 4. The actions

TABLE 2. WILDLIFE SPECIES IN NEW YORK CONSIDERED THREATENED OR ENDANGERED, ACCORDING TO STATUS INDEX VALUE

Species	Status index
Endangered*	
Peregrine falcon (*Falco peregrinus*)	28
Bald eagle (*Haliaeetus leucocephalus*)	28
Indiana bat (*Myotis sodalis*)	26
Atlantic ridley turtle (*Lepidochelys kempi*)	26
Atlantic leatherback turtle (*Dermochelys coriacea*)	26
Atlantic hawksbill turtle (*Eretmochelys imbricata*)	26
Atlantic green sea turtle (*Chelonia mydas*)	26
Atlantic loggerhead turtle (*Caretta caretta*)	26
Golden eagle (*Aquila chrysaetos*)	24
Roseate tern (*Sterna dougallii*)	24
Threatened§	
Eastern bluebird (*Sialia sialis*)	23
Osprey (*Pandion haliaetus*)	22
Cooper's hawk (*Accipiter cooperii*)	22
Massasauga rattlesnake (*Sistrurus catenatus*)	22
Bog turtle (*Clemmys muhlenbergii*)	22
Timber rattlesnake (*Crotalus horridus*)	21
Least tern (*Sterna albifrons*)	21
Ipswich sparrow (*Ammodramus sandwichensis princeps*)	21
Loon (*Gavia immer*)	21
Marsh hawk (*Circus cyaneus*)	20
Raven (*Corvus corax*)	20
Yellownose vole (*Microtus chrotorrhinus*)	20
Long-tailed shrew (*Sorex dispar*)	20
Spotted salamander (*Ambystoma maculatum*)	20
Cricket frog (*Acris crepitans*)	20
Eastern woodrat (*Neotoma floridana*)	20
Eastern tiger salamander (*Ambystoma tigrinum*)	19
Spruce grouse (*Dendragapus canadensis*)	18
Northern bog lemming (*Synaptomys borealis*)	18
Blanding's turtle (*Emydoidea blandingi*)	18

* Rated 5 under degree of threat factor.
§ Rated 4 under degree of threat factor.

noted in each case are essentially what would be needed for such a program. However, the figures for the time necessary to do the various jobs are wholly hypothetical. Nevertheless, they have been chosen to illustrate the fact that for some species (e.g., the bald eagle) the total amount of time needed annually would be high and would remain high, while for others (e.g., marine turtles) it would be low to begin with and rapidly diminish. Cost would vary according to prevailing rates.

TABLE 3. PROGRAM SUCCESS INDEX FOR THREATENED AND ENDANGERED SPECIES IN NEW YORK AS DERIVED FROM STATUS INDEX VALUE AND RECOVERY POTENTIAL FACTOR IN EACH CASE

Species	Status index value	Recovery potential factor	Program success index
Eastern bluebird	23	2	46
Massasauga rattlesnake	22	2	44
Bog turtle	22	2	44
Osprey	22	2	44
Ipswich sparrow	21	2	42
Timber rattlesnake	21	2	42
Raven	20	2	40
Cricket frog	20	2	40
Eastern tiger salamander	19	2	38
Blanding's turtle	18	2	36
Spruce grouse	18	2	36
Peregrine falcon*	28	1	28
Bald eagle*	28	1	28
Indiana bat*	26	1	26
Golden eagle*	24	1	24
Roseate tern*	24	1	24
Cooper's hawk	22	1	22
Least tern	21	1	21
Loon	21	1	21
Marsh hawk	20	1	20
Yellownose vole	20	1	20
Long-tailed shrew	20	1	20
Spotted salamander	20	1	20
Eastern woodrat	20	1	20
Northern bog lemming	18	1	18
Atlantic ridley turtle*	26	0.2	5.2
Atlantic leatherback turtle*	26	0.2	5.2
Atlantic hawskbill turtle*	26	0.2	5.2
Atlantic green sea turtle*	26	0.2	5.2
Atlantic loggerhead turtle*	26	0.2	5.2

* Endangered species (see Table 2).

DISCUSSION

A major prerequisite for development of an endangered species program by a state wildlife agency is a systematic method of determining native species that are endangered or threatened and their relative status, as well as the feasibility and probable cost of restoration efforts. Given such information, the agency can then develop a comprehensive program based on the needs of the species, the desires of the public and the available funding. The rating system described here can be an effective means of identifying and comparing the species to be considered.

TABLE 4. EXAMPLES OF THE ACTIONS REQUIRED AND TIME NECESSARY FOR PROGRAMS TO IMPROVE THE STATUS OF ENDANGERED SPECIES*

Action	Time§		
	Year 1	Year 2	Year 3
Bald eagle			
Survey of historical nesting, migration and wintering areas	8	3	1
Survey of current wintering areas	40	46	49
Determination of toxicant levels in food supplies	6	6	6
Assessment of causes of mortality	7	7	7
Development and coordination of restoration program	15	13	11
Assessment of localities and habitat suitable for releasing bald eagles	6	3	1
Total	82	78	75
Marine turtles			
Search of literature	3	. .	. .
Collection of information on historical beachings and sightings in New York	5	1	. .
Collection of data from beached individuals and disposal of remains	2	2	2
Development of system for collecting beached individuals, notifying proper authorities and disposing of remains	3	. .	. .
Cooperation with Federal and State law enforcement agencies	1	1	1
Total	14	4	3

* Actions are essentially those required; time is hypothetical.
§ Person-weeks.

The component definitions under the several factors used are sufficiently comprehensive to be applicable to all native species in New York with a minimum of subjectivity. The system is also dynamic, as the rating of individual species can be easily updated and quickly compared, and it provides a basis for systematic review and analysis. However, the value of the system ultimately depends on the quality and consistency of subsequent administrative decisions with regard to program and fiscal commitments, and it can be used to explain program actions when the agency is questioned by interested parties.

The indices derived in applying the system facilitate direct comparison of one species with another. For the indices to be meaningful and reliable, the definition selected under each factor must be that which best fits the available information for the species involved, and all decisions must be as objective and consistent as possible. The collaboration of two or more people in rating a species will aid in eliminating personal bias, especially if the rating is done independently and the results compared later. Disagreements in ratings should be resolved through the collection of additional information if necessary.

Certain assumptions must be made in applying this system: (1) all ratings are based on available information that is subject to continual updating; (2) if more than one component of a factor applies to a species, the one having the highest value must be consistently chosen; (3) if insufficient information is available, decisions must be made in favor of the species; (4) to be considered extirpated, a species must have disappeared since the European settlement of North America; (5) if a species is considered extirpated, it must be rated as such in order for the degree of threat factor to retain reliability; (6) the meaning of "local" or "localized" must be considered relative and dependent on the requirements of the species and the characteristics of the habitat; (7) the meaning of "within the foreseeable future" must be dependent on the particular habitat characteristics involved and the imminence of threatened development or natural change, but it must denote a period within which future events can be predicted with a fair degree of accuracy; (8) care should be taken in rating peripheral species so as to avoid giving a high rating to a species at the edge of its natural range unless some other threat can be documented.

The status index appears to be a valid representation of the relative status of the wildlife species in the State. However, since the information used is generally broad and not very detailed, the list of threatened and endangered species derived from it should be considered provisional, pending more definitive data. A rating system requiring more detailed biological information might be developed that would modify this list to yield a more accurate appraisal of threatened or endangered status. Perhaps a system modeled on the concepts and methods proposed by Sparrowe and Wright (1975) would be appropriate.

The program success index appears to be a meaningful indication of the potential for a state agency to bring an endangered or threatened species to the point of "delisting." The numerical values for the species considered reorder them according to the probable effectiveness of management action. A public-supported program cannot afford to place high priorities on species for which little or no benefit can be expected for funds and effort expended.

The status and program success indices, considered in conjunction with the required actions and estimated costs of an effective management effort, provide the basis for developing a comprehensive, justifiable and effective endangered species program. This system is presently being used by the Endangered Species Unit of the New York State Department of Environmental Conservation. If it should become administratively desirable, such indices could be derived in essentially the same manner for any of the species not included in the analyses so far.

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PREDICTING ROTENONE DEGRADATION IN LAKES AND PONDS[1]

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ABSTRACT

The rate of natural degradation of rotenone in a lake was estimated by suspending rotenone solutions at a series of depths in clear and opaque plastic bags. Logarithms of rate constants for all deep samples and for surface and epilimnetic samples in opaque bags were proportional to temperature, with degradation occurring more slowly than was estimated by Post (1958). Detoxification of surface samples in clear bags was in good agreement with Post's findings, indicating that light plays an important role in detoxification of surface waters. Equations were developed for estimating detoxification times and appropriate treatment dates in relation to the fall overturn for lakes and ponds under a variety of conditions.

The usefulness of rotenone as a fish-management tool depends on the fact that it degrades fairly rapidly in natural waters. Its use would be enhanced if the rate at which this degradation occurs could be predicted. Post (1958) made a serious attempt to do this, using laboratory preparations of rotenone at a series of temperatures and pH values. The preparations were held under constant indoor illumination, and residual rotenone concentrations were determined by a colorimetric procedure (Post, 1955) sensitive to 0.05 ppm of rotenone (0.2 ppm of 5 per cent commercial formulation). He found that the rate of degradation varied systematically with temperature. His data also indicated a possible slight increase in the detoxification rate with increasing pH values between 7.0 and 8.5. Evidence for this latter variation was not conclusive. It is clear, however, that the stability of rotenone does not depend on pH to anything like the extent observed for antimycin by Marking and Dawson (1972). In general, the observed detoxification times were quite variable, but it was possible to derive two empirical equations for determining time to detoxification.

More recent field and laboratory observations have shown deviations in both directions from Post's results. It is a common observation of fisheries managers that hypolimnetic water in deep lakes often remains toxic to fish longer than the approximately 30 to 40 days after treatment predicted by Post's equations. There have also been observations

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-9-R. The authors wish to thank the members of the Hunter Lake Association for their cooperation in permitting the lake to be used as an experimental site, and for protecting the buoy and suspended samples from possible accidental damage or vandalism.

of shallow, warm lakes becoming non-toxic, often quite suddenly, within a shorter period than predicted. Marking and Bills (1976), under unspecified lighting conditions, determined de-activation indices and half-lives for rotenone solutions at 12° and 17° C. Loeb and Engstrom-Heg (1970) found that rotenone dispersions held under normal indoor lighting at 65° F. would detoxify quite rapidly after a variable latent period of 2 to 7 days. When rotenone was re-introduced into detoxified jars, detoxification recurred after a shorter latent period. This phenomenon was not observed in jars held at 47° F. These appeared to detoxify gradually and at a slow rate.

It is well known that rotenone is photochemically unstable, undergoing oxidative decomposition in the presence of strong light. The reaction is more rapid at higher temperatures and light intensities (Subba-Rao and Pollard, 1951; Cohn et al., 1945). The decomposition products were originally identified as dehydrorotenone, which is non-toxic to fish, and water. Cheng et al. (1972), using more modern techniques, were able to identify 20 degradation products, mainly rotenoids, from photodecomposition of rotenone dissolved in acetone.

Rotenone degradation in the well-lighted surface waters of a warm pond is probably a rather complex process, involving light penetration and intensity as well as probably other and unknown variables. In any case, it is quite rapid and is not likely to pose serious fishery management problems, except perhaps with respect to maintaining a toxic concentration for a long enough period to get a complete kill on resistant fish.

Prediction of rotenone degradation in cold, poorly-lighted hypolimnetic waters was seen as both a more important problem and an easier one to solve, because of the fewer variables involved. It is obvious that ability to predict hypolimnetic detoxification rates would help a fisheries manager in scheduling the restocking of a treated pond. It is perhaps less obvious that this ability is of the utmost importance in scheduling treatments of lakes and ponds with year-around outlets, particularly where a lengthy drawdown period is not possible. In such a situation, it would be quite possible to treat a lake and safeguard downstream fish populations, either by a drawdown or by potassium permanganate treatment of the outlet until the surface water detoxified, only to have a recurrence of toxic hypolimnetic water in the outlet at the fall overturn. This series of events could be avoided by a sufficiently early treatment or dealt with by a second detoxification effort. In some instances an analysis of thermal and morphometric data might indicate that it could not occur, and thus free the biologist in charge to concentrate on some other aspect of his job.

During the summer of 1973, project personnel studied the problem experimentally at the DeBruce Laboratory and at Hunter Lake, a

TABLE 1. LIMNOLOGICAL DATA FOR HUNTER LAKE ON AUGUST 7, 1972

Depth (meters)	Temperature (degrees C.)	Dissolved oxygen (ppm)	Dissolved carbon dioxide (ppm)	Alkalinity (ppm)	TDS*	pH
0	20	9	tr	14	36	7.5
3.04	19	. .	. .	. .	. .	. .
4.57	18	. .	. .	. .	. .	. .
6.09	14	9	5	14	37	7.0
7.92	10	. .	. .	. .	. .	. .
9.14	8	. .	. .	. .	. .	. .
12.19	6.5	7	15	21	49	6.6
13.72	6.5	. .	. .	. .	. .	. .

* From conductivity.

small (33 hectares) oligotrophic lake situated on a hilltop between DeBruce and Liberty in Sullivan County (N.Y.). Hunter Lake is underlain by shales and sandstones of the Honesdale formation, has a maximum depth of about 15 meters and has a distinct summer thermal stratification with a well-oxygenated hypolimnion. Limnological data for late-summer conditions are given in Table 1.

METHODS

Pairs of 10-liter water samples were obtained from the surface of Hunter Lake, and at depths of 3, 6 and 11.3 meters (10, 20 and 37 feet), and placed in clear and opaque plastic bags. All except the surface samples were taken with a Kemmerer water sampler. Each sample was treated with commercial 5 per cent rotenone formulation (Noxfish) to give an initial concentration of 0.75 ppm of formulation. The sample bags were then attached to an anchored line and lowered to the depth from which they were taken. A maximum-minimum thermometer was attached to the line along with each pair of bags. The assembly was marked with a brightly colored buoy at the surface. At approximately weekly intervals, the bags were brought to the surface, and a 2-liter sample was removed from each. The samples were returned to the laboratory, diluted to 8 liters and bioassayed with trout at 18.3° C. (65° F.) using the method of Loeb and Engstrom-Heg (1971). Since yearling brown trout were not available, concentration-response curves were determined for fingerling brown trout and rainbow trout in 8 liters of rotenone dispersion at 18.3° C. The curves had the following formulas:

$$\text{brown trout:} \quad \log 100C = \frac{10.29}{T} + 0.7404$$

$$\text{rainbow trout: } \log 100C = \frac{10.40}{T} + 0.6021$$

where:

C = Noxfish concentration in ppm

T = response time in minutes to loss of equilibrium

If the toxicity of the diluted sample was below the threshold for trout, the remainder of the bag contents was brought back to the laboratory and bioassayed without dilution. Residual rotenone activities were estimated from the bioassay data. When the mixture in a bag had detoxified, it was replaced with a new and identical mixture. After the first bioassays, frequency of sample retrieval from the various depths was adjusted to match the apparent rate of detoxification. Surface and shallow samples were bioassayed more frequently than the deep samples.

Estimated rotenone activities for clear and opaque bags from each depth were plotted against time on semilogarithmic paper, and half-lives were estimated by inspection on the assumption that detoxification occurred at a constant negative exponential rate. The corresponding rate constants, $k = 0.693$/half-life, were plotted against the mean temperature at each depth for each test.

RESULTS

The rotenone dispersions in clear bags held at the surface detoxified much more rapidly than samples receiving any other treatment (Figure 1). Retrieval was not frequent enough to yield exact data on the detoxification rate for these samples, but in general they detoxified within 8 days, which is in keeping with the findings of Post (1958) and Loeb and Engstrom-Heg (1970). All other samples detoxified more slowly than would be predicted by Post's equations. At 3 meters, samples held in clear bags detoxified more rapidly than those in opaque bags, though the results from the clear bags were somewhat variable, perhaps reflecting changes in light penetration (Figure 2). At 6 meters and at 11.3 meters, samples in clear and opaque bags appeared to detoxify at essentially the same rates (Figures 3 and 4).

Detoxification rates for surface and 3-meter opaque bags and for all bags held at 6 and 11.3 meters fitted into a consistent pattern and showed a clear-cut dependence on temperature. When the estimated rate constants for each depth were plotted on a logarithmic scale against the corresponding mean temperatures, the points were approximately linear (Figure 5). A regression line was fitted, yielding the equation

$$(1)\ \log_e k = 0.1298t - 5.270$$

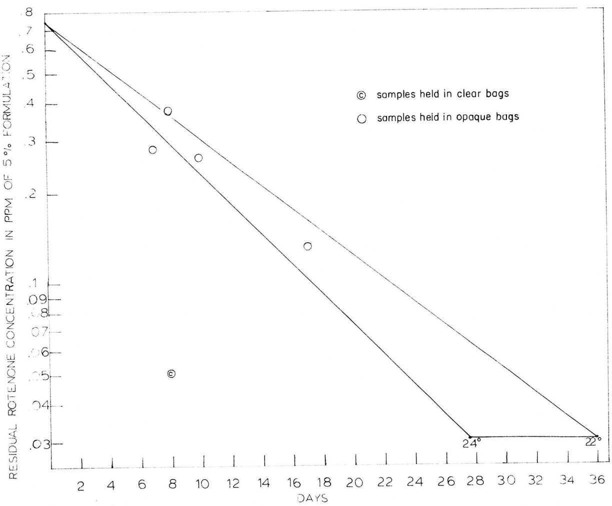

Figure 1. Detoxification of 0.75 ppm of rotenone formulation at the surface of Hunter Lake. Lines indicate detoxification rates obtained from equation (4) using maximum and minimum surface temperatures of 24° C. and 22° C., respectively. Detoxification time shown for clear bags is maximal for this treatment.

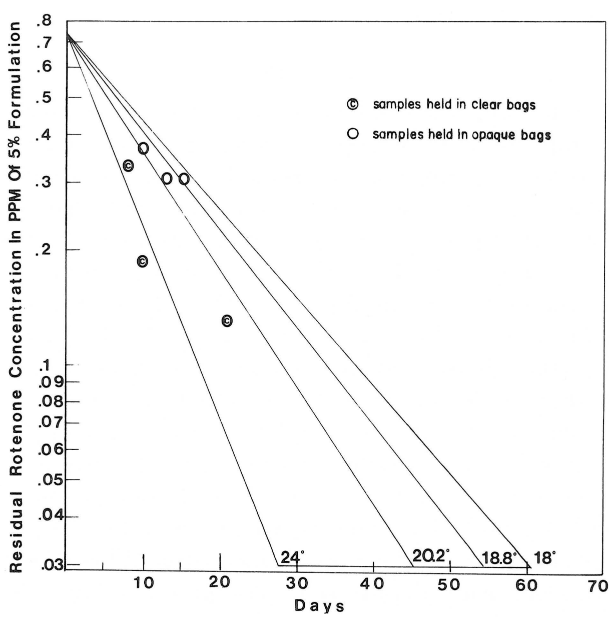

Figure 2. Detoxification of 0.75 ppm of rotenone formulation at 3 meters (10 feet). Lines indicate detoxification rates obtained from equation (4) using temperatures of 18° C., 18.8° C., 20.2° C. and 24° C. The range of temperatures observed was 18° C. to 24° C., and the range of mean temperatures for individual tests was 18.8° C. to 20.2° C.

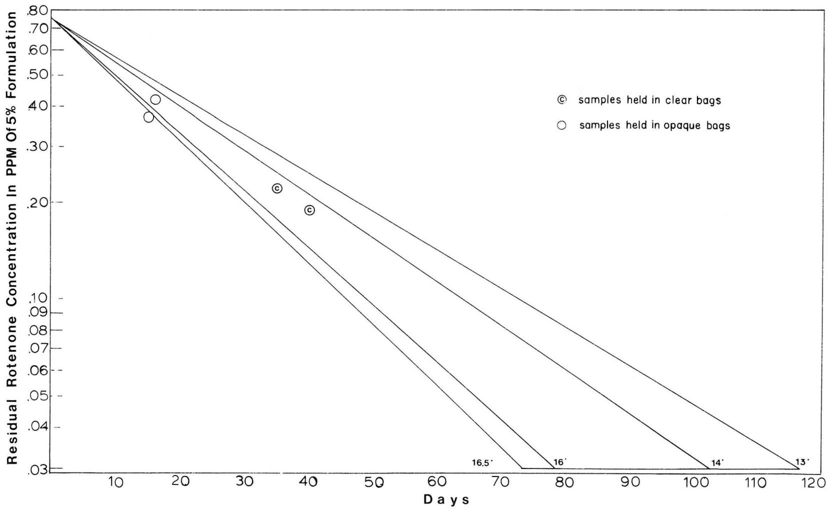

Figure 3. Detoxification of 0.75 ppm of rotenone formulation at 6 meters (20 feet). Lines indicate detoxification rates obtained from equation (4) using temperatures of 13° C., 14° C., 16° C. and 16.5° C. The range of temperatures observed was 13° C. to 16.5° C, and the range of mean temperatures for individual tests was 14° C. to 16° C.

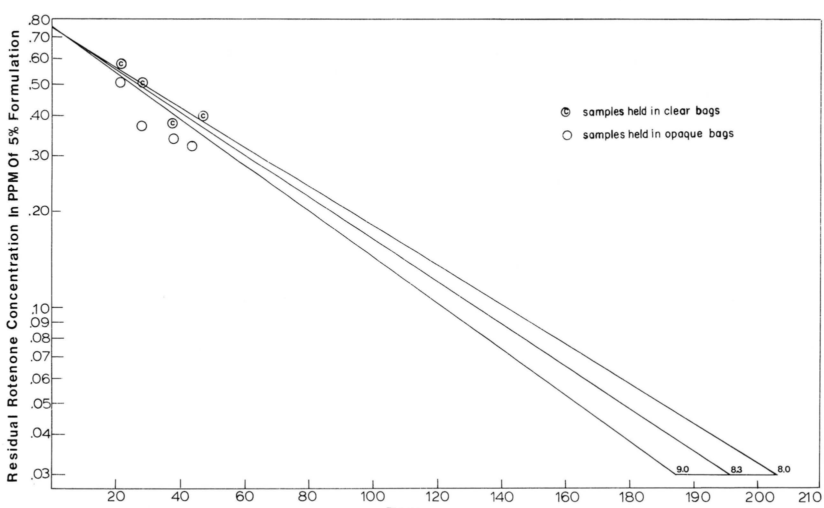

Figure 4. Detoxification of 0.75 ppm of rotenone formulation at 11.3 meters (37 feet). Lines indicate detoxification rates obtained from equation (4) using temperatures of 8° C., 8.3° C. and 9° C. The range of temperatures observed was 8° C. to 9° C., and the mean temperature for the test period was 8.3° C.

where:

k = a rate constant
t = Celsius temperature

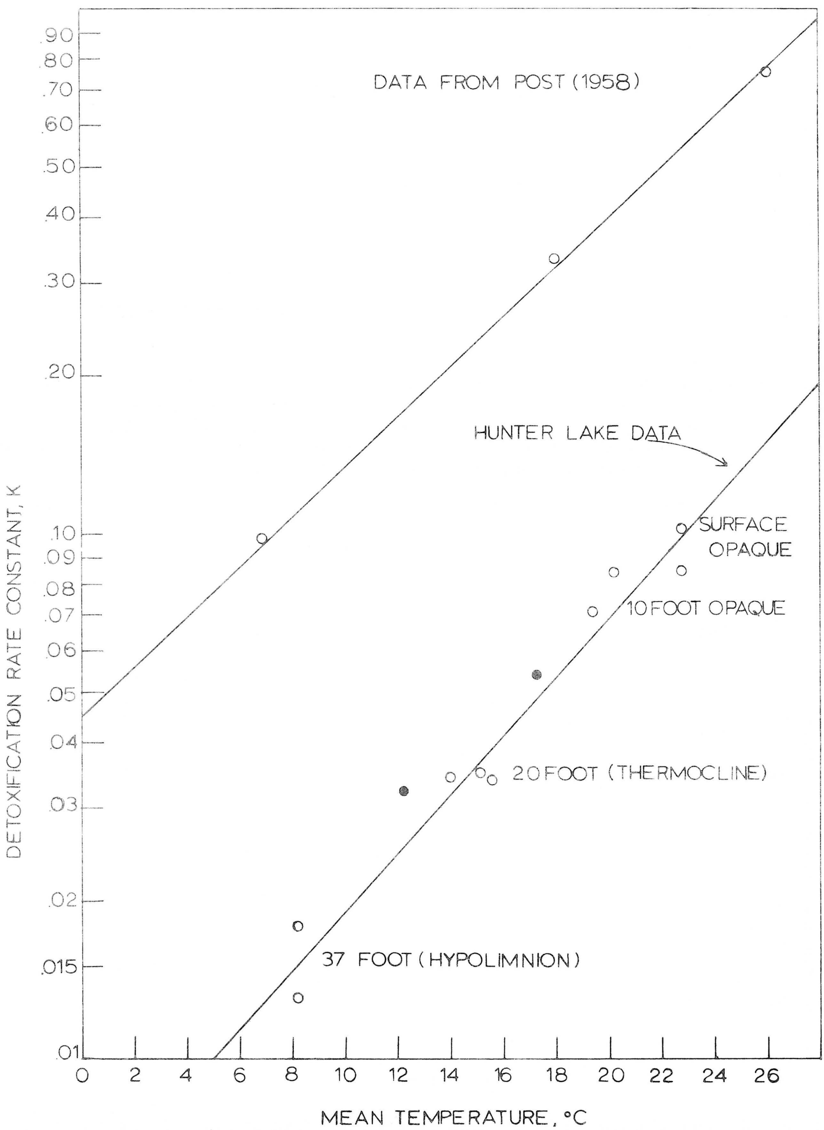

Figure 5. Rotenone detoxification rate and temperature. Upper line (from equation 11) is typical of lighted surface conditions as studied by Post (1958). Lower line (from equation 1) represents deep and opaque samples from Hunter Lake. Dark circles represent data from Marking and Bills (1976).

It is noteworthy that the results obtained by Marking and Bills (1976), using a totally different approach, coincide very closely with these findings.

If detoxification occurs at a constant negative exponential rate for a given temperature, the time to detoxification can be computed as

$$(2)\quad T = \frac{\log_e R_1/R_2}{k}$$

where:

T = time in days
R_1 = initial rotenone concentration
R_2 = threshold rotenone concentration
k = the rate constant

Equations (1) and (2) can be combined to yield

$$(3)\quad \log_e T = \log_e (e^{5.270} \times \log_e R_1/R_2) - 0.1298t$$

which can be simplified to

$$(4)\quad \log_e T = \log_e (194.4 \times \log_e R_1/R_2) - 0.1298t$$

For example, for 10° C. water treated with 0.5 ppm rotenone formulation and an assumed threshold concentration of 0.03 ppm of formulation,

$$\begin{aligned}
R_1 &= 0.5 \\
R_2 &= 0.03 \\
R_1/R_2 &= 16.67 \\
\log_e R_1/R_2 &= 2.813 \\
\log_e T &= \log_e (194.4 \times 2.813) - 0.1298\,(10) \\
&= \log_e 547 - 1.298 \\
&= 6.304 - 1.298 \\
&= 5.006 \\
T &= 149 \text{ days}
\end{aligned}$$

DISCUSSION AND APPLICATION

Equation (4) has some fascinating implications. For instance, at the bottom of a deep lake at 4° C., the predicted detoxification time for 0.5 ppm of 5 per cent rotenone formulation would be 325 days. A 1 ppm dispersion would persist for 405 days. However, only an elementary knowledge of limnology is needed to realize that toxic conditions would not persist that long in nature. In the normal course of events, the epilimnion would detoxify much more rapidly and, at the fall overturn, the toxic water would be greatly diluted. During late fall, early winter and the spring warmup period, there would be additional surface detoxification, followed by further dilution of the bottom water at the spring overturn. In addition, there would probably be further dilution from tributary streams and springs. To deal with rotenone detoxification as it occurs in the real world, it is useful to modify equation (4) to

$$(5)\ \log_e T = \log_e (194.4 \times \log_e R_1/DR_2) - 0.1298t$$

where:

D = a dilution factor

There are two types of questions that fisheries management biologists are likely to ask about rotenone degradation, namely:

1. When should "pond X" be treated in order to have non-toxic conditions by late fall, so that the pond can be restocked and so that there will be no toxicity problem in the outlet?
2. When will "pond Y", which has been treated on September 11, become sufficiently non-toxic for restocking and/or re-opening the outlet?

The first question can usually be answered with greater ease and precision than the second. In most instances, answering it should be part of the reclamation planning process.

Let us consider some examples involving an 8-hectare (20-acre) pond that is scheduled for rotenone treatment at 0.75 ppm formulation because of an excessive population of stunted yellow perch. The volume is 490,000 cubic meters (roughly 400 acre-feet), the maximum depth is 20 meters, and there is a well marked thermocline at 7-8 meters. The hypolimnion has a volume of 122,500 cubic meters (100 acre-feet) and a temperature of 10° C. (50° F.). All tributary streams are warm and there are no significant deep springs. Fall overturn normally begins about November 15. It can be assumed that the epilimnion and the small mesolimnion will detoxify fairly rapidly, and that the hypolimnion will detoxify according to equation (4) with t = 10° C.

The dilution factor can be computed as

$$(6)\ D = Vt/Vh$$

where:

Vt = total volume
Vh = hypolimnetic volume

In this case, volumes will be measured in acre-feet, and stream discharges in cubic feet per second because 1 cubic foot per second is approximately equal to 2 acre-feet per day.

Vt = 400
Vh = 100
D = 4
R_1 = 0.75
R_2 = 0.03 (threshold concentration for stocking trout)

$R_1/DR_2 = 0.75/0.12 = 6.25$
$\log_e R_1/DR_2 = 1.833$
$\log_e T = \log_e (194.4 \times 1.833) - 0.1298\,(10)$
$= 5.876 - 1.298$
$= 4.578$
$T = 97$ days

The pond should be treated at least 97 days before November 15, or no later than August 10, if fall stocking is anticipated. There is a built-in safety factor in this calculation, since it is almost certain that there would be additional dilution from cold runoff and precipitation during late October and November.

Suppose that fall stocking is not planned, and that the pond has a surface outlet stream with an average discharge of 2 cubic feet per second that empties half a mile downstream from the pond into a trout stream with a flow of 3 cubic feet per second. The problem is whether the trout stream will need protection during the fall overturn. In this case

$$(7)\quad D = Vt/Vh \times Q_2/Q_1$$

where:

Q_1 = discharge of the outlet stream
Q_2 = discharge of the trout stream below the confluence

Here

Vt = 400 acre-feet
Vh = 100 acre-feet
Q_1 = 2 cubic feet per second
Q_2 = 5 cubic feet per second
$D = 400\,(5)/100\,(2) = 10$
$R_1/DR_2 = 0.75/0.03\,(10) = 2.50$
$\log_e R_1/DR_2 = 0.916$
$\log_e T = \log_e (194.4 \times 0.916) - 0.1298\,(10)$
$= 5.182 - 1.298$
$= 3.884$
$T = 49$ days

No protection will be needed at the fall overturn if the pond is treated before September 26.

Suppose that the same pond has cold inlet streams with a discharge of 1 cubic foot per second. It can be assumed that this water will descend and mix with the hypolimnion and that the outflow will consist of displaced surface water. As has been noted, 1 cubic foot per second is approximately equal to 2 acre-feet per day. In this case, dilution would not be sudden, but would resemble another detoxification process, occurring simultaneously with rotenone degradation. This can be handled in much the same way as a biologist would handle two simultaneous sources of mortality in a fish population. Dilution at 2 per cent per day can be converted to a rate constant, k_2, equal to

$-\log_e (1 - Q/Vh)$ where Q is the daily tributary discharge and Vh is the hypolimnetic volume, both measured in the same terms. Unless Q is quite large, k_2 will be approximately equal to the daily dilution rate. In this case it is 0.0202. It is now advisable to go back to equations (1) and (2). Equation (2) can be rewritten as

$$(8)\quad T = \frac{\log_e R_1/DR_2}{k_1 + k_2}$$

For the hypothetical pond

$$\begin{aligned}
\log_e k_1 &= 0.1298\,(10) - 5.270 \\
k_1 &= 0.0188 \\
k_2 &= 0.0202 \\
k_1 + k_2 &= 0.0390 \\
\log_e R_1/DR_2 &= 1.833 \\
T &= 1.833/0.0390 \\
&= 47 \text{ days}
\end{aligned}$$

In this case, the pond should be treated before September 28 if fall stocking is contemplated. If protection of the trout stream is the only concern

$$\begin{aligned}
R_1/DR_2 &= 2.50 \\
\log_e R_1/DR_2 &= 0.916 \\
T &= 0.916/0.0390 \\
&= 23 \text{ days}
\end{aligned}$$

and treatment could occur as late as October 23.

A related problem is presented by the situation in which a pond is drawn down before treatment and it is possible to estimate the time required for it to fill back up to the outlet level. Suppose it is a pond of 400 acre-feet that is drawn down to 250 acre-feet before treatment. It is estimated that it will fill at 5 acre-feet per day and require 30 days (400-250/5) to refill. Assuming that the surface water will detoxify within 30 days, the primary concern again is what might happen at the fall overturn. All that is necessary here is to base R_1 on the normal volume of the pond and use equations (1) and (8) or equation (4). If part of the inflow is cold, a value for k_2 could be included. If the pond were to be treated with 1 ppm of rotenone formulation at drawdown, R_1 would equal $1 \times 250/400 = 0.625$ ppm. A surface drawdown essentially skims off the epilimnion, so that the value of D would be unchanged. In the case of a drawdown from a deep outlet, the volume of the hypolimnion would become less and the ratio $D = Vt/Vh$ would obviously change.

Predicting the duration of rotenone toxicity in a treated pond, particularly when toxicity persists beyond the fall overturn, is a more difficult and less certain process, since temperatures and dilution rates will vary through the fall and winter. Nevertheless, considering the same pond, an attempt to predict how long it would remain toxic if it were treated on October 25 may be made by assuming the following conditions:

Period	Bottom temperature	Tributary discharge (cubic feet per second)
October 25 - November 15	10° C.	1
November 15 - December 15	6° C.	3
December 15 - end of winter	4° C.	1

For the first period, equation (8) must be solved for R_2, the rotenone concentration at the end of the period. Since the time interval (October 25-November 15) would be 21 days, this equation would become

$$\frac{\log_e 0.75/4R_2}{0.0188 + 0.0202} = 21$$

This yields a solution of 0.083 ppm of rotenone formulation on November 15. This is about the toxicity threshold for contrarchids, but would still be toxic to trout. Perhaps detoxification would be complete within the November 15-December 15 period. However, things have changed. It is now the whole pond rather than the hypolimnion that is being diluted by the stream, and dilution from epilimnetic water has already occurred, so $D = 1$, and

$$\begin{aligned}
k_2 &= -\log_e (1 - 3/400) = 0.0075 \\
\log_e k_1 &= 0.1298\,(6) - 5.270 \\
&= -4.491 \\
k_1 &= 0.0112 \\
k_1 + k_2 &= 0.0187 \\
T &= \frac{\log_e (0.083/0.03)}{0.0390} \\
&= \log_e 2.767/0.0390 = 1.0176/0.0390 \\
&= 26 \text{ days}
\end{aligned}$$

Detoxification could be expected by December 11, but not with any great certainty. If T had been greater than 30 days, it would have been necessary to solve for R_2 again and repeat the process for the next period. It should be obvious that the preferred procedure is to plan for detoxification at the fall overturn and to set the treatment date accordingly.

It should be noted that all of these calculations tend to be conservative in the sense of allowing a good safety factor. The choice of Hunter Lake for a data base was deliberate. It is likely that degradation would occur somewhat more rapidly in a richer lake with a higher pH and more biological activity.

Detoxification rates in surface waters are sometimes of interest, particularly where an outlet stream must be blocked or chemically detoxified, or where the whole body of water is shallow and unstratified. For such waters, the findings of Post (1958) appear to be a good rough guide (again on the conservative side) to detoxification rates. His equations were originally published in the form:

$$(9)\ T = 93 - 4t/3 \text{ (for temperatures under } 60^\circ \text{ F.)}$$

and

$$(10)\ T = 38 - 3t/7 \text{ (for higher temperatures)}$$

where:

T = detoxification time in days
t = Fahrenheit temperature

In this form, they apply only to the special case where R_1 equals 1 ppm of 5 per cent formulation, R_2 corresponds with the threshold of colorimetric detection at about 0.1 ppm, and there is no dilution. These equations were plotted, and a series of rate constants were obtained for different temperatures. The logarithms of these constants again fell in a straight line when plotted against temperature (Figure 5). The slope is quite similar to that obtained for the Hunter Lake data, but the rates are obviously higher. The regression equation is

$$(11)\ \log_e k = 0.1088t - 3.0908$$

where:

t = Celsius temperature

Using the format of equation (4), this yields

$$(12)\ \log_e T = \log_e (22.0 \times R_1/R_2) - 0.1088t$$

For $R_1 = 1.0$ and $R_2 = 0.1$, this equation yields a curve that corresponds very closely with the two straight lines of equations (9) and (10). Where gradual dilution is a factor, equation (11) can be used to obtain k_1 in equation (8). For instance, in the real case of Marl Bed Pond near Wayland (N.Y.), the pond volume is approximately 120 acre-feet, and the outlet flow (which should balance inlet flow) was measured in September 1975 as 4.6 cubic feet per second or 9.2 acre-feet per day. If the pond were treated with 1 ppm rotenone formulation at a homogeneous temperature of 20° C.

$$\begin{aligned}
\log_e k_1 &= 0.1088\,(20) - 3.0908 \\
\log_e k_1 &= 0.922 \\
k_1 &= 0.398 \\
k_2 &= -\log_e (1 - 9.2/120) \\
&= -\log_e 0.923 \\
&= 0.080 \\
k_1 + k_2 &= 0.478 \\
R_1 &= 1.0 \\
R_e &= 0.03
\end{aligned}$$

and, using equation (8)

$$T = \frac{\log_e (1.0/0.03)}{0.478} = \frac{3.50}{0.478}$$
$$= 7.3 \text{ days}$$

Detoxification would probably be complete within 8 days. Marl Bed Pond outlet empties into Mill Creek, which has a discharge of about 10 cubic feet per second below the confluence. To protect trout in Mill Creek, it would probably be necessary to treat the outlet for

$$T = \frac{\log_e 1.0/(10/4.6) \times 0.03}{0.478} = \frac{2.73}{0.478}$$
$$= 5.7 \text{ days}$$

This pond is often quite turbid, probably as a result of carp activity. If the pond did not clear up after treatment, equation (1) might be a better estimation of k_1 than equation (11). Then

$$\begin{aligned} \log_e k_1 &= 0.1298\,(20) - 5.270 \\ &= -2.674 \\ k_1 &= 0.069 \\ k_2 &= 0.080 \\ k_1 + k_2 &= 0.149 \\ T &= 2.73/0.149 \\ &= 18 \text{ days} \end{aligned}$$

If the pond were to be treated, there should be a contingency plan for detoxifying the outlet for up to 18 days.

CONCLUSIONS

The data obtained at Hunter Lake provide a good basis for estimating rotenone detoxification times in a wide variety of lake and pond situations. It would usually be a matter of personal preference whether this were done by using equations (1) and (8), the most general case, or by using equation (5), which is a combined version with rather wide application. For surface waters and for clear, shallow unstratified ponds, equations (11) and (12), derived from the work of Post (1958), are probably more appropriate. It is usually easier to establish a target date for detoxification and schedule the pond treatment accordingly than to predict a detoxification date for a pond whose treatment date has been chosen as a result of other considerations.

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POISONING OF WILD BIRDS BY ORGANOPHOSPHATE AND CARBAMATE PESTICIDES

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ABSTRACT

Eight instances are reported in which organophosphate or carbamate (cholinesterase inhibitor) pesticides applied for various purposes killed wild birds. It is believed that thousands of birds are being killed in this way, and more such cases are anticipated because of the widespread use, and often misuse, of these pesticides. Methods are suggested for investigating wildlife poisonings of this sort.

In recent years, considerable attention has been given to chlorinated hydrocarbons and heavy metals as toxicants in birds. However, thousands of birds and other wildlife have been killed by organophosphate and carbamate pesticides, but little research has been done on the impostance of these compounds as wildlife mortality factors. Both of these pesticides are readily available and widely used by the public, governmental agencies and licensed pesticide applicators to kill society's real or imagined invertebrate pests.

The organophosphate and carbamate pesticides are, in general, not very persistent, but they are usually far more acutely toxic than chlorinated hydrocarbons. Organophosphate and carbamate pesticides inhibit the neural enzyme cholinesterase. This allows acetylcholine to accumulate at the nerve junctions causing alteration of the transmission of nerve impulses across synapses. The parasympathetic nervous system and the neuromyal junctions, as well as the central nervous system, are severely affected in acute poisoning. Signs of such poisoning include pupil constriction, muscle fasciculation, decreased heart rate, respiratory difficulties leading to respiratory arrest, paralysis and convulsions (Davis et al., 1971; Dreisbach, 1974).

Eight cases investigated by the Department's Wildlife Pathology Unit at Delmar have been selected to illlustrate instances in which cholinesterase inhibitor pesticides have killed wild birds in New York, frequently in large numbers.

Case 1. Waterfowl Killed on an Estate Lawn

On October 7 and 8 in 1970, approximately 200 ducks, mainly mallards (*Anas platyrhynchos*), but including some black ducks (*Anas rubripes*), were reported dead and dying on an estate lawn and adjacent stream near Rochester. Upon field investigation, over 100 dead ducks were found, and about an equal number were in distress. The distressed ducks exhibited goose-stepping ataxia, wing and tail spasms, dyspnea and prostration. Many of the debilitated birds recovered in a few hours, without treatment, to what appeared, in the field, to be a normal status. Organophosphate and carbamate pesticides are rapidly metabolized, and the rapid recovery of some of the debilitated ducks was a good, but not positive, indication of poisoning by a cholinesterase inhibitor pesticide.

The waterfowl had been fed cracked corn on the estate lawn for some time, and the trouble arose when an organophosphate pesticide was applied on the same area where the ducks fed. Diazinon 14 G (14.3 per cent active ingredient) was applied at the rate of 1 pound per 1,000 square feet for chinch bug control, and the granules were not thoroughly washed into the soil. The label directions on the pesticide stated "... this product is toxic to fish and wildlife. Keep out of lakes, streams, or ponds. Birds feeding on treated areas may be killed". Diazinon (0, 0-diethyl 0-(2-isopropyl-4-methyl-6-pyrimidinyl) phosphorothioate) is very toxic to waterfowl, the LD_{50} for mallards 3-4 months old being 3.54 (2.37-5.27) milligrams per kilogram (Tucker and Crabtree, 1970). According to Biester and Schwarte (1965) Diazinon used for insect control proved highly toxic to white pekin ducks. Ducklings, 8 and 15 days old, all died 1 hour after spraying. Older birds, 22 to 36 days of age, had a 75 per cent loss in a 24-hour period after being exposed to Diazinon.

Ten mallards were submitted to the Wildlife Pathology Unit for necropsy. All were in good flesh, and their crops and gizzards were filled with cracked corn (Figure 1). The lungs, kidneys and livers were congested. Cultures for bacterial pathogens were negative as were

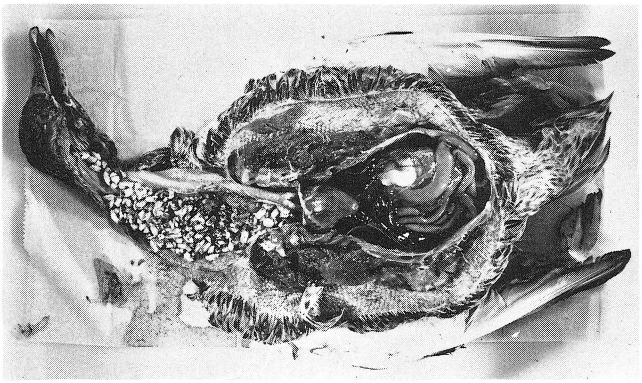

Figure 1. A mallard believed to have been killed by Diazinon poisoning. Birds poisoned by organophosphate or carbamate pesticides frequently die with large quantities of the contaminated food (in this case corn) in the upper alimentary canal.

tests for botulism. Trace levels (0.003-0.020 ppm) of Diazinon were found by gas chromatograph analyses done at the Agricultural Experiment Station at Geneva (N.Y.) There was an approximately 24-hour lapse between death and necropsy, and a 21-day delay before the pesticide analyses could be run. This is believed to have resulted in a breakdown of the Diazinon, causing much lower tissue levels than would have been found if it had been possible to do the analyses more promptly. However, after the data had been reviewed, the cause of the deaths and sickness in the ducks was attributed to Diazinon.

CASE 2. CANADA GEESE KILLED AT A GOLF COURSE

On April 29 and May 29 in 1974, the organophosphate pesticide Dursban (0, 0-diethyl 0-3, 5, 6-trichloro-2-pyridyl phosphorothioate) was applied to some of the greens on a golf course at Northport in Suffolk County, reportedly to control sod webworm. In addition, Diazinon was applied to part of the greens on May 29. On May 5, eight Canada geese (*Branta canadensis*) were found dead, and on June 3, following a severe rainstorm on June 1, approximately 35 geese were found dead or dying on the golf course property. The dying geese displayed dyspnea, convulsion, phonation and prostration. Dursban has an LD_{50} of ≥ 80 milligrams per kilogram for Canada geese (Tucker and Crabtree, 1970), but the LD_{50} of Diazinon for this species is unknown. However, waterfowl were reportedly killed at Busch Gardens in Florida when they ingested grass contaminated with 0.06 ppm of Diazinon (Schobert, 1974).

On necropsy of eight geese, all were found to be in good flesh, but the lungs were congested, and in several that died in ponds on the golf course water containing algae was present in the tracheae. Cultures from the liver and material from the large intestine were negative for pathogenic bacteria, and tests for botulism were negative. The crops and gizzards were largely empty, except for a few pieces of grass. Pooled livers and gizzard contents from four birds were submitted to the Department's Pollution Laboratory at Rome for gas chromatography. The tests showed that there were 0.99 ppm of Diazinon and 0.38 ppm of Dursban in the gizzard contents, and 0.05 ppm and 0.09 ppm, respectively, in the liver samples. Based on the history of pesticide application on the golf course, symptoms in the moribund geese, gross pathology and the results of the chemical analyses, the cause of death was attributed to organophosphate pesticide poisoning, although some of the geese that were badly debilitated by the poisoning had entered ponds on the golf course and apparently drowned when they couldn't control their heads to keep them out of the water.

CASE 3. CANADA GEESE KILLED ON A GOLF COURSE

On October 7, 1976, 12 dead Canada geese were found on a State golf course in the Town of Smithtown in Suffolk County, and in a short time about an equal number died, the latter showing the usual signs (tremors, dyspnea, ataxia) of poisoning by a cholinesterase inhibitor pesticide. Diazinon had been applied to the greens on October 6 to control insect pests. Two geese were submitted to the Wildlife Pathology Unit for examination.

The geese were in excellent flesh and showed no signs of trauma or of parasitic or contagious infectious disease. The lungs and kidneys were congested. The alimentary canals were empty, but tissue samples were submitted to WARF Institute, Inc. for analyses of organophosphate pesticides. The livers contained 0.018 ppm and 0.014 ppm, and the gizzards 0.34 ppm and 5.3 ppm, of Diazinon. From the history of pesticide application on the golf course, symptoms exhibited by the birds, gross pathology and chemical analyses, it was concluded that the geese had died from Diazinon poisoning.

CASE 4. CANADA GEESE KILLED ON A GOLF COURSE

On June 7, 1977, Canada geese were reported to be sick and dying on a golf course in the Town of Orangetown in Rockland County. A field investigation was made, and 25 geese were picked up. It was reported that parts of the golf course had been recently treated with the organophosphate pesticide Dasanit (0, 0-diethyl 0-p- (methylsulfinyl) phenyl phosphorothioate) to control insect pests. Samples of sod from the sprayed areas were also taken. Dasanit is highly toxic to mallards, the LD_{50} being 0.749 (0.595-0.944) milligrams per kilogram. Dasanit was reported to have killed wild turkeys (*Meleagris gallopavo*) on a golf course on Jekyll Island in Georgia (Nettles, 1976).

Postmortem examination revealed grass and grass roots in the birds' esophagi and proventriculi. The lungs were congested, but the birds were in good flesh, and no trauma, parasitic disease or contagious infectious disease was discovered. Two pooled samples of crop and gizzard contents, and two sod samples, were submitted to WARF Institute, Inc. for analyses of organophosphate pesticides. Gas chromatograph analyses showed 4.0 ppm and 25.0 ppm of Dasanit for the two food samples, while both sod samples yielded 13 ppm.

The Dasanit package label has the standard warning that the product is toxic to fish and wildlife and that birds feeding on treated areas may be killed. The user of the product assumes the risks, and each application is indeed a risk because all golf courses and lawns are also wildlife habitat.

CASE 5. BIRDS KILLED AT AN INDUSTRIAL LAGOON

On April 25, 1975, three birds, a hooded merganser (*Lophodytes cucullatus*), lesser yellowlegs (*Totanus flavipes*) and horned lark (*Eremophila alpestris*), were submitted anonymously from Middleport to the Wildlife Pathology Unit for diagnosis of the cause of death. The birds had undergone considerable postmortem tissue deterioration, but necropsies showed them to be in good flesh and free of trauma, but to have congested lungs. There was no suggestion of parasitic or infectious disease, and a toxic substance was thought to have been the probable cause of death of these dissimilar birds. More particularly, a cholinesterase inhibitor pesticide was suspected, and an investigation was begun. It was found that a pesticide manufacturer (F.M.C. Corporation) had a plant in Middleport together with an approximately 10-acre industrial lagoon. A review of pesticides manufactured at the plant suggested that carbofuran, a carbamate pesticide, might be the cause of the mortality. Carbofuran (2, 3-dihydro-2, 2-dimethyl-7-benzofuranyl methylcarbamate), also known as Furadan, was a strong suspect because of its great toxicity for birds. The LD_{50} is 0.397 (0.500-0.315) milligrams per kilogram for mallards and 4.15 (2.38-7.22) milligrams per kilogram for pheasants (*Phasianus colchicus*) according to Tucker and Crabtree (1970).

The alimentary canals of the birds were devoid of food, but the gizzard of the merganser and the intestines of the yellowlegs and horned lark were submitted to the Department's Pollution Laboratory at Rome for analysis of the suspected pesticide. Results showed 9.57 μg. of carbofuran from the merganser's gizzard, and 11.68 μg. and 472.4 μg. of carbofuran from the intestines of the yellowlegs and horned lark, respectively. Two water samples from the lagoon were submitted to the State Department of Health and found to contain 59 ppm and 65 ppm of carbofuran and 33 ppm and 25 ppm of hydrolyzed carbofuran. Five milliliters of this lagoon water would contain from 0.295 to 0.325 milligrams of carbofuran (not counting hydrolyzed carbofuran) which is close to the mean LD_{50} for mallard ducks. A few sips of this water would be sufficient to cause severe intoxication with carbofuran in mallards and other birds. Samples of lagoon water, taken at the same time, caused death within 30 minutes in two experimental Canada geese after drinking the water *ad libitum,* and leopard frogs (*Rana pipiens*) suffered the same fate when placed in shallow pans of it. The frogs were apparently killed by absorbing the carbofuran through their moist, vascular skin. Microscopic examination of this water was negative for live protozoans.

Carbofuran was confirmed by another laboratory when tissues from a piedbilled grebe (*Podilymbus podiceps*) and two spotted sandpipers

(*Actitus macularis*) that had died at the same lagoon were submitted for analysis to the State Food Laboratory of the State Department of Agriculture and Markets. The laboratory reported 4.16 ppm of carbofuran and a trace of 3 hydroxy-carbofuran from the grebe's intestine, and 94.4 ppm and 10.50 ppm of carbofuran from the livers of the sandpipers.

On May 29, the author visited the F.M.C. Corporation's lagoon. It was bordered with grasses and weeds, but much of the water's edge consisted of sand-like beaches that would be attractive to shorebirds. Goldfish placed in samples of the lagoon water showed immediate distress and died within 1½ minutes. When the bottom was examined it was found to be strewn with bird feathers, bird bones and decaying bird carcasses. Numerous leopard frogs and American toads (*Bufo americanus*) were found dead in the water, and meadow voles (*Microtus pennsylvanicus*) were found dead along the shore. The surface of the pond was littered with dead insects. Damselflies and dragonflies (Odonata) were seen flying about the lagoon area. A damselfly landed in the water nearby and in a short time exhibited tremors. It was picked from the water and in about a minute appeared dead. A robin (*Turdus migratorius*) observed drinking lagoon water exhibited tremors within several minutes and when reached a few minutes later was dead. Also picked up dead, but suitable for necropsy, were a gadwall duck (*Anas strepera*), pintail duck (*Anas acuta*), three spotted sandpipers and two semipalmated plovers (*Charadrius semipalmatus*). In addition, in the area surrounding the lagoon were found the skeletons of Canada geese, great blue herons (*Ardea herodias*) and ducks. Decaying carcasses of woodchucks (*Marmota monax*), raccoons (*Procyon lotor*) and skunks (*Mephitis mephitis*) littered the ground. It is possible that carbofuran was responsible for the mammal mortalities, but necropsies were not carried out on the carcasses.

It was estimated that this carbofuran-contaminated lagoon was responsible for killing thousands of migratory birds. Tissues from eight birds taken for necropsy on May 29 were submitted to the Department's Pollution Laboratory at Rome, and analyses showed similar levels of carbofuran as had been found in the earlier samples. The information gained in this investigation was turned over to authorities in the U.S. Fish and Wildlife Service. Legal action was taken, and the lagoon was done away with, being replaced by a waste system that does not create a hazard for wildlife.

CASE 6. PURPOSEFUL POISONING OF BIRDS BY A FARMER

On August 6, 1975, it was reported to the Department that birds were dying on, and in the vicinity of, 30 acres of farmland at Watermill in Suffolk County. In the immediate field investigation, over 100 dead birds were found, all of which were seed eaters or omnivores, primarily starlings (*Sturnus vulgaris*), purple grackles (*Quiscalus quiscula*), mourning doves (*Zenaidura macroura*), red-winged blackbirds (*Agelaius phoeniceus*) and herring gulls (*Larus argentatus*). The farmland had been planted the day before to winter wheat. However, piles of wheat seeds with a purplish crystaline material mixed in were also found about the field, and it appeared that pesticide-contaminated wheat had been placed to purposely kill birds. The dead birds and samples of the wheat mixture were submitted to the Wildlife Pathology Unit for examination.

On necropsy the birds were found to have crops full of wheat, and in some cases the purplish crystaline material could be seen in the crop contents. Other than postmortem autolysis and congested lungs, no remarkable gross pathology was noted. It appeared that the toxic substance was rapidly fatal as the wheat seeds had generally not gone further than the birds' crops.

A sample of the suspect wheat seeds and tissues from the gizzard and liver of a herring gull and mourning dove were submitted to the State Food Laboratory of the State Department of Agriculture and Markets for analysis for organophosphate and carbamate pesticides. Their report showed 2,000 ppm of carbofuran in the wheat seed sample and 1.71 ppm of carbofuran in the gull's gizzard (which contained several wheat seeds), but carbofuran was not detectable in the liver. The findings for the mourning dove were similar (4.6 ppm in the gizzard, not detectable in the liver). The liver findings were not surprising because the birds had undergone considerable decay while lying dead in the hot August weather, and carbamate pesticides are, generally, rapidly broken down in carcasses under these conditions. The chemical analyses were reported on August 26.

On August 27, it was reported that birds were dying on farmland at Bridgehampton, also in Suffolk County, and Harold W. Knoch, senior wildlife biologist of the Department, who visited the site on the same day found that the land was owned by the same farmer who owned that at Watermill. He reported that a harvested potato field had been ". . . planted in a winter cover crop which was 2-3″ tall. Throughout the field there were numerous small piles of grain mixed with purplish crystals. These piles were connected by a single set of footprints. The field was littered with many dead mourning doves, some of which were within 2-3 feet of grain piles." Knoch submitted 75 mourning doves, a purple grackle, a pigeon (*Columba livia*), wheat samples and samples of mixtures of field soil and grain to the Wildlife Pathology Unit. The piles of poisoned grain were picked up, and the contaminated ground was plowed in an attempt to prevent further poisoning.

Postmortem findings were similar to those for specimens from the Watermill site. Tissue samples from three mourning doves showing the least decay (hence most likely to evidence the pesticide), two samples of wheat and two samples of the wheat and soil mixture were submitted to the State Department of Health for analyses for carbamate pesticides. Chromatographic analyses showed 1,700 and 1,800 ppm of carbofuran in the wheat samples and 5,400 and 6,700 ppm in the mixtures of wheat and soil. The latter were heavily contaminated with purplish crystals, and concentrations of them were apparent to the naked eye. Gizzard tissue from the doves contained 7.8-17.0 ppm, and liver tissue 1.7-21.0 ppm, of carbofuran.

Legal action was taken against the farmer, and he paid $1,502.50 in a civil compromise. This case illustrates that there are individuals who recognize the extreme toxicity of pesticides like carbofuran and are willing to chance illegal applications in order to kill birds, and probably other animals. It also shows the degree of conflict between birds and some farmers, as well as the extent to which one person went to protect winter cover crops.

CASE 7. PROBABLY PURPOSEFUL POISONING OF BIRDS BY A FARMER

During early January 1977, numerous birds, mostly mourning doves, pigeons and starlings, were reported dying in Lower Township in Cape May County, New Jersey. Hundreds of birds were dead or moribund, and a Federal agent submitted seven mourning doves to the Wildlife Pathology Unit to determine the cause of death. The gross pathology was suggestive of poisoning by a cholinesterase inhibitor pesticide. The doves were in excellent flesh, but their lungs were congested with blood. Their crops were filled with kernels of field corn, and a few kernels were present in the gizzards.

A pooled sample of corn from the doves' crops was submitted to WARF Institute, Inc. for analysis of organophosphate pesticides. Analyses showed 142 ppm of parathion and 0.5 ppm of methylparathion in the crop contents. Parathion (0, 0-diethyl 0-p-nitrophenyl phosphorothioate) is known to be highly toxic to birds. The LD_{50} for 3- to 4-month-old mallards is 2.13 (1.54-2.96) milligrams per kilogram, and for house sparrows it is 3.36 (2.43-4.66) milligrams per kilogram, according to Tucker and Crabtree (1970).

It was suspected that a local farmer, with cribs containing exposed corn, had attempted to control depredating birds by poisoning. However, the evidence obtained was not sufficient to warrant legal action.

CASE 8. PURPOSEFUL POISONING OF BIRDS BY A BIRD HATER

On July 6, 1977, at least 42 birds were reported to have plunged from the sky and fallen from trees into yards in New Milford, New Jersey. Dead birds included bluejays (*Cyanocitta cristata*), purple grackles and house sparrows. Investigation by a special agent of the U.S. Fish and Wildlife Service led to a woman who had recently entered a neighbor's yard with a garden hose and had then proceeded to shoot water into birdhouse entrances in order to kill nestlings. The woman reportedly disliked birds and their songs. Bread, having a strong chemical odor, was found on the woman's garage roof, and most of the dead birds were found on properties adjacent to her home.

A bread sample, eight purple grackles and four bluejays were submitted to the Wildlife Pathology Unit for examination. Postmortem examination revealed congested lungs and kidneys and occasional small hematomas in the sternal area. No visible bread was present in the esophagi or gizzards. However, microscopically, starch granules were found in the gizzard contents of several birds, and the moist, pasty gizzard contents gave a positive starch reaction to iodine. Pooled samples of the livers, and of the small intestines, of the grackles, and similar samples for the bluejays, together with the bread sample, were sent to WARF Institute, Inc. to be analysed for organophosphate pesticides. The grackle livers contained 0.83 ppm and the small intestines 12.5 ppm of Diazinon, and the corresponding values for the bluejay specimens were 4.1 ppm and 33.8 ppm, respectively. The bread sample contained 14,300 ppm of Diazinon. It was concluded that Diazinon was the cause of death of the birds.

This case illustrates that there are people in our society who hate birds and who will use pesticides and other means, illegally, to kill birds that their neighbors cherish. Despite warnings that pesticides should be applied only as directed, it is clear that some individuals will use dangerous pesticides for whatever purpose they desire.

DISCUSSION

The cases described illustrate the potential hazard that the use, and especially the misuse, of organophosphate and carbamate pesticides have for wild birds. Although less subject to becoming poisoned by these substances, other wildlife can be affected as well. It is clear that misuse is often purposeful.

Wildlife poisonings with these pesticides can be expected to continue. Over 100 kinds have been produced, and over 200 million pounds are manufactured annually in the United States (Anonymous, 1972). They are widely applied by private interests on forests, farms, lawns, gardens and golf courses, and by governmental agencies for a variety of pest problems. Golf courses seem to have particular problems because of heavy applications of pesticides to control turf insects while at the same time being attractive feeding sites for grazing geese and other birds. It is important that the public be aware of the wildlife mortality that may result from using cholinesterase inhibitor pesticides, and unnecessary use should be avoided. Flagrant misuse should be considered grounds for prosecution. Accordingly, some guidelines may be suggested for obtaining information in cases where poisoning with organophosphate and/or carbamate pesticides is suspected.

Investigation should be as prompt and thorough as possible. Delaying field examination because of a weekend or holiday may result in the disappearance of many or all of the wildlife carcasses. In addition, if the carcasses undergo extensive decay, postmortem examination will be difficult and it may be impossible to find the suspect pesticide by chemical analysis. Notes should be made as to who applied the pesticide, where and when it was applied, what compounds and quantities were used, and what the purpose was. The names of witnesses and any statements by them about the application and subsequent wildlife mortality should be taken. Clinical signs shown by the wildlife should be recorded.

At the site of a suspected poisoning with pesticides of this sort, the field investigator should make sure it is safe to enter sprayed areas and take appropriate precautions when necessary (e.g., wearing protective clothing, respirator). All dead wildlife should be picked up, placed in plastic bags and labelled as to species, sex, age, date and location. A representative sample of specimens should be immediately placed on ice (for standard postmortem examination) and, if possible, another group should be frozen (to preserve chemical poisons). Both samples should be submitted to a wildlife pathologist or other specialist, together with a letter giving the history of the specimens and any pertinent related circumstances including information (receipts from carriers, etc.) to document continuity of evidence in case legal action is undertaken. When possible, samples of soil, grass, grain or other material believed contaminated with the toxicant should be submitted in labelled, chemically clean, glass containers.

Sometimes pesticide-contaminated material can be picked up, harrowed, plowed under or washed into the soil to prevent further wildlife poisonings. It may also be possible to station people and/or zon guns at the site to scare wildlife temporarily from the contaminated area.

If distressed birds or other wildlife are present, they may require assistance in recovery to avoid their injuring themselves or being killed by predators while debilitated. Ducks and other birds can often be held in cages or well ventilated boxes, out of the hot sun, for from a few minutes to, generally, a few hours, until they have recovered sufficiently to care for themselves. Otherwise, in the case of waterfowl, they may enter the water and drown in their uncoordinated condition. For prompt attention, a local veterinarian may be called to treat birds believed intoxicated by organophosphate or carbamate pesticides. He should be given a complete history of the case to aid in the choice of treatment. Organophosphate poisoning may be treated with intramuscular injections of atropine sulfate and intravenous administration of Protopam (pyridine-2-aldoxime methochloride), but according to Dreisbach (1974) the latter may be harmful in cases of carbamate poisoning.

This paper has dealt primarily with acute poisoning. Further research is needed concerning the effects on wildlife of sublethal poisoning and chronic exposure to these pesticides.

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HOMING MECHANISM OF SPAWNING WHITE SUCKERS IN WOLF LAKE, NEW YORK[1]

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ABSTRACT

The sensory basis for homing in white suckers was examined by conducting displacement experiments in Wolf Lake (N.Y.) during the 1975 spawning run. Fish were blinded, olfactorily occluded, or released in presumably unfamiliar parts of the lake with the result that only the olfactorily occluded fish had their homing ability impaired. Analysis of the locations where test fish were recaptured suggests that olfaction may play an important role in the entry of white suckers into the spawning stream.

The white sucker (*Catostomus commersoni*) has demonstrated the capacity to home to a restricted spawning area (Dence, 1940, 1948; Olson and Scidmore, 1963). Dence first noted this while working with a population in Wolf Lake, near Newcomb, New York.[2] He marked over 12,000 fish collected in the two spawning streams and recaptured 6,000 of them in subsequent years during their spawning runs. More than 95 per cent of the fish recaptured had returned to the stream where they were originally marked, exemplifying the widely used definition of homing, i.e., "the return to a place formerly occupied instead of going to other equally probable places" (Gerking, 1959). Thus, Dence demonstrated the ability of suckers in Wolf Lake to home to spawning streams, but he did not determine the sensory mechanism by which they are able to recognize their home streams.

Several sensory mechanisms have been postulated to explain how migrating fish recognize home areas and/or orient themselves over long distances. Among these are visual or tactile recognition of local landmarks (Hasler, 1956; Williams, 1957), sun compass orientation (Hasler et al., 1958) and olfactory recognition of the home stream (Gunning, 1959; Hasler, 1966; Scholz et al., 1976). This paper de-

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[1] The author wishes to thank the staff, particularly Donald Behrend and William Tierson, of the Adirondack Ecological Center of the State University of New York College of Environmental Science and Forestry for providing lodging and access to Wolf Lake during this study, as well as R. Beamish for demonstrating the use of his trap net. Field assistance was provided by Ken Huntington, Alan Stehl and Kurt Werner, and Shelby Gerking critically reviewed the manuscript.

[2] At the time of Dence's work the Wolf Lake population was considered a dwarf subspecies, *Catostomus commersoni utawana*. Subsequent work by Beamish and Crossman (1977) in Wolf Lake questioned the validity of the subspecific designation. Consequently, white sucker (*Catostomus commersoni*) is used in this paper, but it should be recognized that it is the same population referred to by Dence as dwarf suckers.

scribes the results of field experiments which suggest that olfaction is the sensory system used in homing by white suckers in Wolf Lake.

MATERIALS AND METHODS

Wolf Lake is located in the Adirondack region on the Huntington Wildlife Forest near Newcomb in Essex County (N. Y.) and has an area of 58.2 hectares, a maximum depth of 14 meters and a length of 1.6 kilometers. It is a soft-water lake stained with humic compounds, a situation characteristic of many Adirondack lakes. The lake occupies two basins (north and south) that are partially divided by a mound that rises to within 4 meters of the surface (Figure 1).

A small stream, the North Inlet, enters the lake at its northern end. It drains a watershed of approximately 1.7 square kilometers, descending 360 meters from its headwaters to its mouth over a distance of 2.1 kilometers. Soils in the upper watershed are of the Becket bouldery, fine sandy loam type with significant amounts of rock outcrop and Canaan association types in the headwaters.[3] Near the mouth of the stream and completely encompassing the spawning grounds of the white sucker are poorly drained mineral and organic soils of the Aquepts-sapriests complex.

In the headwater and mid-sections of the North Inlet, the principal tree species were yellow birch (*Betula lutea*), sugar maple (*Acer saccharum*), hemlock (*Tsuga canadensis*), beech (*Fagus grandifolia*), red spruce (*Picea rubens*), balsam fir (*Abies balsamea*), white ash (*Fraxinus americana*) and red maple (*Acer rubrum*). Understory plants included witchhobble (*Viburnum alnifolium*), striped maple (*Acer pennsylvanicum*), basswood (*Tilia americana*) and numerous herbs and ferns. Around the spawning grounds, grasses and sedges dominated with some alder and spruce present also.

The South Inlet flows some 870 meters from its headwaters in a bog to its mouth at the southern end of the lake and drains a watershed of approximately 1.5 square kilometers of almost level terrain. In its headwaters, soils consist of rock outcrop and Canaan association types with some Becket bouldery sandy loam. In its mid-section, Becket bouldery sandy loam predominates with some Peru bouldery sandy loam interspersed. Near its mouth, including all of the spawning grounds of the white sucker, the stream passes through poorly drained mineral and organic soils of the Aquepts-sapriests complex.

In the headwaters and mid-section of the South Inlet, the principal tree species were yellow birch, sugar maple, beech, red spruce, hemlock and red maple. The understory consisted chiefly of mountain maple

[3] Soil designations derived from soils map of the Huntington Wildlife Forest prepared by the U.S. Soil Conservation Service (1973).

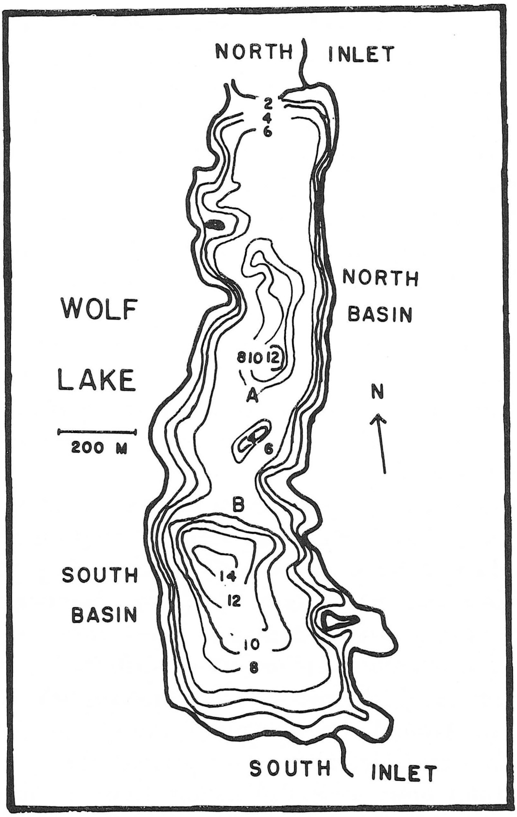

Figure 1. Map of Wolf Lake on the Huntington Wildlife Forest near Newcomb, New York. Redrawn from Heady (1942); depth interval in meters.

(*Acer spicatum*), witchhobble, alder (*Alnus incana*), raspberry (*Rubus* sp.), hawthorn (*Crataegus* sp.), white cedar (*Thuja occidentalis*), ferns, herbs and grasses. At the mouth and in the vicinity of the sucker spawning grounds, yellow birch, white cedar, red spruce, alder, witchhobble, ferns and herbs were common.

In both inlets, the spawning grounds of the white suckers were shallow, sandy-bottom reaches that extended from just above the mouth upstream for approximately 200 meters.

Three field experiments were conducted to determine the role of local landmarks, sun compass orientation and olfaction in the successful homing of white suckers to their spawning streams. The study took place during the spring of 1975 using fish from the spawning runs that began on May 21. In the next three days, 500 suckers were collected by seining from each inlet, fin clipped and allotted to the different tests as shown in Table 1. The experiments were run concurrently due to the brief duration of the spawning run, which had the advantage of providing essentially identical conditions for all.

Fish examined for recaptured individuals were collected in two ways. A trap net (Beamish, 1973) was set in the lake at the mouth of each inlet and run daily for the duration of the 9-day spawning period. In addition, the spawning reaches of the inlets were seined daily with a 2-meter minnow seine and a 9-meter bag seine. All catches

TABLE 1. NUMBER OF WHITE SUCKERS SEINED FROM SPAWNING STREAMS AT THE BEGINNING OF THE SPAWNING RUNS IN THE SOUTH INLET AND NORTH INLET OF WOLF LAKE IN 1975 ACCORDING TO THE MANNER OF MARKING AND THEIR ALLOCATION IN THE HOMING EXPERIMENTS

	Local landmark experiment		Sun compass orientation and olfaction experiments		
Item	Control	Displaced	Control	Blinded	Olfactorily occluded
South Inlet					
Date					
May 21	. .	. .	100	100	73
22	100	100	. .	. .	27
23	. .	. .	. .	. .	. .
Total	100	100	100	100	100
Marking*	RV and LP	RV and RP	RV and dorsal	RV	RV and anal
Release point§	B	A	A	A	A
North Inlet					
Date					
May 21	. .	. .	6	10	6
22	. .	. .	80	80	81
23	100	100	14	10	13
Total	100	100	100	100	100
Marking*	LV and RP	LV and LP	LV and dorsal	LV	LV and anal
Release point§	A	B	A	A	A

* Designations represent clipped fins as follows: RV—right pelvic; LV—left pelvic; RP—right pectoral; LP—left pectoral. "Dorsal" and "anal" indicate that these fins were notched.

§ See Figure 1.

were examined for fin-clipped fish. Recaptures were transferred to a live box, held for the duration of the run and released. By recapturing fish in the lake off the mouths of the streams as well as in the streams on the spawning grounds, one could differentiate between individuals that had responded positively to the stream and those that had not.

LOCAL LANDMARK

To determine whether suckers were relying on local landmarks or were capable of long-distance orientation, 100 fish from the South Inlet were released at point A (Figure 1) in the North Basin (test group), and 100 others were released at point B in the South Basin (control group). Similarly, 100 fish from the North Inlet were released at each point. If fish from the South Inlet, for example, were more familiar with the landmarks in the South Basin than they were with the ones in the North Basin and were using those landmarks to return to their home spawning stream, the proportion of the experimental fish from that inlet that returned to it should be greater for the control group than for the test group.

SUN COMPASS ORIENTATION

To determine whether the fish were able to maintain a compass direction relative to the sun, 100 blinded fish and 100 control fish from each inlet were released at point A. Blinding was accomplished by removing the eye lens as described by Gunning (1959). Ten additional individuals were blinded and held for the duration of the experiment (9 days) in a live box to determine the degree of mortality from this procedure. All survived in excellent condition, but they became darker in coloration than the untreated fish.

OLFACTION

The reliance on olfactory clues for homing by suckers was tested by plugging the olfactory sacs of 100 specimens from each inlet and releasing the fish at point A. A small piece of cotton was inserted into the posterior nares and worked into the olfactory sac with a blunt probe until it filled the sac and blocked the anterior incurrent nares. The behavior of these fish was compared with that of the same control group that was used for the sun compass orientation experiment.

RESULTS

The results are summarized in Table 2. Each fish recaptured was recorded as to whether it had homed successfully or had strayed, i.e.,

TABLE 2. DISTRIBUTION OF WHITE SUCKERS RECAPTURED DURING THE SPAWNING RUN IN WOLF LAKE IN 1975

Item	Local landmark experiment		Sun compass orientation and olfaction experiments		
	Control	Displaced	Control	Blnded	Olfactorily occluded*
Fish from South Inlet					
Number recaptured	52	32	66	17	19 (11)
Homed successfully					
Number	49	26	61	15	11 (7)
Per cent	94	81	92	88	58
Recaptured fish that entered stream					
Number	19	15	38	3	0 (1)
Per cent	37	47	58	18	0
Recaptured fish that remained in lake					
Number	33	17	28	14	19 (10)
Per cent	63	53	42	82	100
Fish from North Inlet					
Number recaptured	36	48	39	14	21 (9)
Homed successfully					
Number	15	33	18	9	11 (3)
Per cent	42	69	46	64	52
Recaptured fish that entered stream					
Number	20	34	29	8	3 (0)
Per cent	56	71	74	57	14
Recaptured fish that remained in lake					
Number	16	14	10	6	18 (9)
Per cent	44	29	26	43	86

* Figures in parentheses represent fish that had lost one or both nasal plugs.

was taken at the other inlet from the one where it was originally seined. It was also recorded as to whether it was retaken in the lake at the mouth of the stream or in the stream proper. Comparisons between experimental groups and controls were made by using fourfold tables and Fisher's exact test or, when the numbers were large, the chi-square test. The data are presented according to the three experiments carried on.

LOCAL LANDMARK

Of the 200 white suckers from the South Inlet that were marked and released, 84 were recaptured. The degree of homing for those released in their home basin (94 per cent) was somewhat greater than that (81 per cent) for those displaced to the North Basin, possibly because the latter had to travel somewhat farther. The difference, however, was not significant ($P = 0.07$), suggesting that the fish were not simply recognizing the home stream from close range with the aid of local landmarks, but were able to orient themselves and migrate over distances of up to 1 kilometer. Dence (1948) concluded that, after spawning, suckers in Wolf Lake redistributed themselves throughout the lake, since he recaptured marked fish from the North Inlet in all parts of the lake in trammel net sampling during the summer. Both of these pieces of evidence cast doubt on the hypothesis that white suckers remain near their spawning stream throughout the year and depend on local landmarks for homing during the spawning run.

Of the 200 suckers from the North Inlet that were marked and released, the number recaptured was also 84, but only 42 per cent of those released in their home basin had homed successfully compared with 69 per cent for those that had been displaced to the South Basin. It is not clear why the degree of homing, especially for the control group, was so low for the fish from the North Inlet.

SUN COMPASS ORIENTATION

Of the 100 blinded suckers and the 100 control fish from the South Inlet that were released in the center of the lake (point A), 17 and 66, respectively, were recaptured (Table 2), and of these 88 and 92 per cent, respectively, had homed successfully. Thus, the blinded fish homed as well as the controls ($P = 0.44$), indicating that their lack of vision did not impair either their orientation or recognition of home.

Of the suckers from the North Inlet, 14 of the blinded fish and 39 of the controls were recaptured. However, while 64 per cent of the test fish had homed, only 46 per cent of the controls did so. Again, it is not clear why the degree of homing among the controls was so low.

OLFACTION

Of the 100 suckers from the South Inlet that had their olfactory sacs plugged and were released in the center of the lake (point A), 30 were recaptured (Table 2), of which 19 still had both cotton plugs in place at the time. Only the latter were used for statistical comparison, and of these 58 per cent had homed. However, this was a considerably lower proportion than the 92 per cent for the control group. That the controls homed more accurately than the olfactorily occluded fish ($P = 0.001$) suggests that olfaction is an essential sensory system enabling white suckers to home to their spawning grounds. It may be noted that of the 11 test fish that had lost one or more cotton plugs at the time of recapture, seven had homed successfully.

Of the olfactorily occluded suckers from the North Inlet, there were 30 recoveries, of which 21 had both cotton plugs in place. For the latter, 52 per cent had homed, but meaningful comparison cannot be made because of the failure of the controls to return. Nevertheless, the general conclusion that olfaction is needed for successful homing is not rejected since only 11 olfactorily occluded fish homed and 10 strayed.

BEHAVIOR OF CONTROL FISH FROM THE NORTH INLET

The low degree of homing among both control groups from the North Inlet is difficult to explain. Perhaps there was a tendency for these fish to follow individuals involved in the larger South Inlet run which, based on total numbers of suckers trapped and seined, was judged to be some five times larger than the run in the North Inlet.

There is some evidence to support this explanation. In the study reported by Dence (1940, 1948) members of the larger run always homed with greater accuracy than those of the smaller run (99.1 vs. 85.3 per cent, respectively). In addition, the present author marked fish from the North Inlet in 1973 before the spawning run as part of a different experiment and recaptured some of them in 1973 and 1975. Since the North Inlet run was much larger than the South Inlet run in 1973 and the reverse was true in 1975, recovery data (Table 3) are of interest. The proportion that successfully homed in 1973 was significantly greater than that in 1975, which suggests a direct relationship between the size of the run and the accuracy of homing. Since the elapsed time from the beginning of marking to the termination of recapture was only 9 days, it may be seen how North Inlet fish could become disoriented. The South Inlet results, however, clearly demonstrate the importance of oldfaction.

TABLE 3. RELATIVE DEGREE OF HOMING EXHIBITED BY UNIMPAIRED WHITE SUCKERS FROM THE NORTH INLET OF WOLF LAKE MARKED BEFORE THE SPAWNING RUN IN 1973 AND RECAPTURED BY SEINING DURING THE SPAWNING RUNS IN 1973 AND 1975.

Year	Number recaptured	Homed*		Number strayed	Relative size of run in North Inlet§
		Number	Per cent		
1973	158	142	90	16	larger
1975	85	65	76	20	smaller

* $\chi^2 = 6.84$, $0.01 > P > 0.005$. with 1 degree of freedom.

§ Compared with the run in the South Inlet in the same year.

Recapture Locations

Several interesting relationships appear when the recapture locations for the control fish from the South Inlet are compared with those for the test groups (Table 2). The displaced fish in the local landmark experiment were caught in the stream in about the same proportion as the local landmark controls ($\chi^2 = 0.052$, $0.50 > P > 0.25$, with 1 degree of freedom). In contrast, both the blinded and the olfactorily occluded fish were taken significantly less frequently in the stream than the corresponding control fish ($P = 0.0032$ and < 0.0001, respectively, for the two test groups). It is not surprising that the blinded fish entered running water less frequently than the control fish since it is well known that the ability to see the stream bottom is an important aspect of orientation to current (Jones, 1968). Fish unable to see the bottom would be less likely to sense displacement arising from the current. Tactile contact with the bottom would, however, enable the fish to sense the current and may account for the few blinded fish that did enter the stream. But the most interesting result is the fact that no olfactorily occluded fish were taken in the stream. Apparently, these fish continued to search in the vicinity of the stream as evidenced by the catch in the trap net just off its mouth.

The corresponding relationships for the fish from the North Inlet were generally similar, although three (14 per cent) of the olfactorily occluded fish that were recaptured had entered the stream.

DISCUSSION

From the results of this study, neither a system similar to the sun-compass mechanism to orient over distances nor visual recognition of local landmarks appears to be a necessary condition for successful homing by white suckers in Wolf Lake. Rarely, however, do they enter their spawning stream when they are olfactorily impaired. The fact that olfaction seems essential for home-stream recognition and possibly for distance orientation by suckers in Wolf Lake raises the question of how they become initially imprinted to their home stream. Jensen and Duncan (1971) demonstrated that coho salmon (*Oncorhynchus kisutch*) can be imprinted in a relatively short time (36-70 hours). Since white sucker fry are rarely found in the spawning streams after absorbing the yolk sac (R. G. Werner, unpublished data), they would have to become imprinted in a very short period. However, it is not known whether the capacity of their olfactory apparatus at that young age would enable them to discriminate sufficiently for accurate homing. An alternative hypothesis would be that suckers in Wolf Lake are simply imprinted during their first spawning run and then return in subsequent years to the stream of first spawning.

Kleerekoper (1967) presented experimental evidence suggesting that olfactory cues may release a positive rheotactic response in fish. He also proposed that this response would serve quite well for fish that were migrating upstream, since whenever they took a "wrong" turn they would lose the home odor and with it the positive rheotactic behavior. Consequently, they would then drift downstream until they reencountered the odor. The failure of most of the olfactorily occluded fish to enter the spawning stream suggests that this mechanism may be at work in homing white suckers. The scarcity of olfactorily impaired suckers in the spawning streams, in contrast to the control fish, indicates that they seldom enter running water until they have received the proper olfactory cue. They may simply search the shoreline until they encounter the odor from the home stream, whereupon a positive rheotactic response is released and the fish swims up the spawning stream.

The work of several investigators demonstrates the precision with which fish can discriminate between odors (Hasler and Wisby, 1951; Gunning, 1959). The suckers in Wolf Lake are apparently capable of distinguishing between the odors of two streams whose mouths are only 1.6 kilometers apart and whose drainage basins are composed of similar bedrock, soil and vegetation.

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THE AMERICAN LOBSTER IN WESTERN LONG ISLAND SOUND[1]

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ABSTRACT

During 1974, 1975 and 1976 the catch of American lobsters (*Homarus americanus*) by cooperating fishermen in western Long Island Sound was examined. Females first reached maturity at about 60 millimeters in carapace length, and most were mature at about 80 millimeters. Males reached maturity at a smaller size, essentially all of those larger than 56 millimeters being mature. Most of the catch was comprised of lobsters between 71 and 80 millimeters, whereas the landings consisted chiefly of lobsters between 81 and 90 millimeters. While females dominated both the catch and the landings, most of the large lobsters (over 100 millimeters) were males. There was an indication that females preferred deeper water than males. The frequency of culls among the lobsters caught was variable and tended to increase as the season progressed. While summer and winter molt periods were observed, the known fall molt was not seen because it occurs at a time when the commercial fishery was inactive. Molt increments averaged about 10 per cent of the pre-molt carapace length. There was no evidence that the present minimum legal size limit for lobsters in these waters does not allow for adequate reproduction.

Recent studies of the American lobster (*Homarus americanus*) in Long Island Sound have dealt primarily with larval distribution (Lund and Stewart, 1970), movement and habitat (Lund et al., 1973) and food habits (Weiss, 1975). Only Lund et al. (1973) touched upon size in relation to maturity and molting.

Primarily based on the work of Lund and his co-workers, the State-Federal Lobster Scientific Committee decided that Long Island Sound, particularly its western half, should be treated as a separate management area (Lobster Scientific Committee, 1974). This group gave high priority to determining the size at maturity and the size composition of lobsters in western Long Island Sound. As a result, the New York State Department of Environmental Conservation undertook a study to obtain this information for lobsters in these waters and the size composition and sex ratio of lobsters available to (caught by) and landed by the commercial fishery. This paper incorporates the results of that study with additional data on the proportion of

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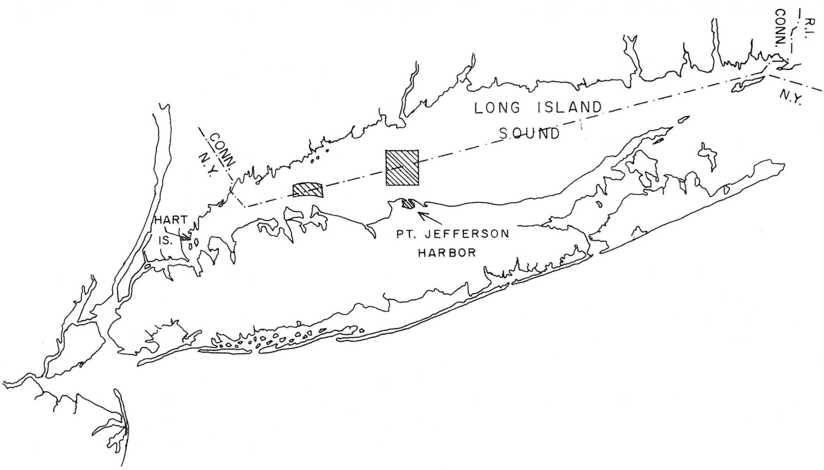

Figure 1. Map of Long Island Sound showing areas (cross-hatched) fished by co operating lobster fishermen.

cull lobsters in the catch and landings, time of molting, molt increments, length-weight relationship and incidence of certain parasites.

This work was made possible only with the cooperation of commercial fishermen, and the areas fished by those who participated are shown in Figure 1. Water depths at these sites were generally greater than 25 meters, except for a limited area in Port Jefferson Harbor that ranged between 4 and 10 meters in depth.

METHODS

The authors accompanied the cooperating commercial fishermen on 56 trips on western Long Island Sound during the periods of May

TABLE 1. TRIPS MADE WITH COOPERATING COMMERCIAL LOBSTER FISHERMEN IN WESTERN LONG ISLAND SOUND, NUMBER OF TRAPS HAULED AND NUMBER OF LOBSTERS CAUGHT

	1974			1975			1976		
Month	Trips	Traps hauled	Catch	Trips	Traps hauled	Catch	Trips	Traps hauled	Catch
January	.	. .	. .	. .	. .	. .	1	168	403
February	. .	. .	. .	. .	. .	. .	1	114	46
March	. .	. .	. .	. .	. .	. .	2	297	394
April	. .	. .	. .	. .	. .	. .	2	318	1,040
May	2	637	933	4	960	2,653	. .	. .	. .
June	4	1,135	1,831	3	748	1,175	. .	. .	. .
July	5	459	2,357	7	1,645	5,086	. .	. .	. .
August	6	906	3,631	6	1,257	3,937	. .	. .	. .
September	5	499	1,725	6	880	2,940	. .	. .	. .
October	1	130	268	1	47	249	. .	. .	. .

to October in 1974 and 1975 and January to April in 1976 (Table 1). On these trips, 11,228 trap hauls were made and 28,609 lobsters were caught. Only one trip was made in October, in 1974 and 1975, because the fishermen were in the process of removing their gear for the season. Only one trip in January and one in February were made in 1976 because of adverse weather conditions.

Project personnel measured (to the nearest millimeter) the carapace length of all lobsters caught and recorded the sex, shell condition (hard, soft or "paper shell"), culls (those lobsters missing one or both chelae or having one or both chelae small and regenerating) and the presence or absence of extruded ova on females. The catch was all lobsters in the traps of the fishemen, whereas landings were those kept for sale. The latter consisted of the catch less all ovigerous females, less all sub-legal lobsters (under 81 millimeters in carapace length), less those legal-sized lobsters the fishermen considered too soft or papery to keep, less those barely legal lobsters that "did not gauge". The cooperating fishermen measured lobsters with gauges that spanned a gap about 0.4 millimeter wider than the 3 3/16-inch (81-millimeter) minimum legal size limit in effect in New York and Connecticut, in whose waters they fished.

A sample of 956 lobsters of all sizes was bought from the fishermen and taken to the Department's marine laboratory at Flax Pond where they were again measured to the nearest millimeter in carapace length and weighed to the nearest 2 grams. A random sample of these was used to determine length-weight relationships. Unless pleura were damaged, the outside width of the second abdominal segment of the females was measured to the nearest millimeter, and the ratio of that width to the length of the carapace, compared with the carapace length, was used as an indicator of maturity as described by Krouse (1973), Skud and Perkins (1969) and Squires (1970). A total of 561 females were so measured.

Most (939) of the lobsters were dissected, and the gonads, digestive tracts and rectal tissues were preserved in 65 per cent isopropyl alcohol and 35 per cent glycerol for later examination. During dissection, prior to preservation, the color of the ovaries was noted. Krouse (1973) stated that a dark green ovary was indicative of maturity. Skud and Perkins (1969) stated that a green ovary indicated maturity. At a workshop of the State-Federal Lobster Scientific Committee in November 1975, those present (including the senior author) concluded that a dark green ovary, or any ovary of non-uniform color showing dark green tissue, was a valid indicator of maturity in female lobsters. However, the authors felt that there was some question as to when "light green" becomes "green", and when "green" becomes "dark green". Therefore, while respecting ovarian color as a valid indicator

TABLE 2. CRITERIA GIVEN BY DIFFERENT AUTHORS FOR USING OVA DIAMETER AS AN INDICATOR OF MATURITY IN FEMALE LOBSTERS

Degree of maturity	Mean diameter (millimeters)		
	Krouse (1973)	Skud and Perkins (1969)	Squires (1970)*
Immature	≤ 0.4	< 0.4	0.5 - 1.2
Developing	0.5 - 0.7	0.4 - 0.8	. .
Mature	≥ 0.8	> 0.8	1.3 - 1.5

* Used terms "small ova" for those 0.5-1.2 millimeters in diameter and "potentially mature" for those measuring 1.3-1.5 millimeters.

of maturity, they chose not to rely on this indicator alone in the present study.

Krouse (1973), Skud and Perkins (1969) and Squires (1970) all gave criteria for ova diameter as an indicator of maturity (Table 2), and those at the workshop concluded that the mean ova diameter should be determined for each area of the lobster's range. Mean ova diameters were determined, using the method described by Krouse (1973) and Skud and Perkins (1969), by measuring ova removed from the ovaries and magnified at 90X under a dissecting microscope with a micrometer eyepiece. Mean diameters of the ova from 249 dark green ovaries ranged from 0.68 to 2.03 millimeters, with an overall mean of 1.32 ± 0.36. Based on two standard deviations from the mean, the possible range in mean diameter for ova from mature ovaries was 0.60 to 2.04 millimeters. Since only six of the 249 dark green ovaries examined had ova with a mean diameter of 0.80 millimeter or less, the authors chose to be conservative and apply the criterion of Skud and Perkins (1969), i.e., a mean diameter of greater than 0.80 millimeter, as an indicator of maturity in female lobsters.

The other indicator of maturity in female lobsters was the size of ovigerous females measured in the field. Since female lobsters extrude their eggs in late summer or fall, and since the eggs begin to hatch in early summer, the proportion of ovigerous females among all females of similar size should be highest in late fall or spring. For each size group of females, the proportion that was ovigerous in May (the most feasible time in the project's field schedule) was calculated and used as an indicator of size at maturity.

As an indicator of maturity for male lobsters, the presence of sperm in the testes and/or vas deferens, as described by Krouse (1973), was used. The preserved gonads of 381 males were softened by boiling for 15 or 20 seconds in tap water. A smear of the contents was then made on a glass slide and examined for the presence or absence of sperm at a magnification of 450X under a compound microscope.

Digestive tracts and rectal tissues were examined, both with the naked eye and at a magnification of 90X under a dissectiong microscope, for the presence or absence of parasites that according to Uzmann (1970) would indicate whether lobsters had spent time in coastal or offshore waters.

Molt increments were recorded for lobsters that shed either while being held for dissection or while in the live wells and traps of the cooperating fishermen. Measurements of carapace length were made of the cast shell and on the lobster itself after it had hardened sufficiently to yield a valid reading.

FINDINGS

The data recorded are presented according to the major topics considered.

SIZE AT MATURITY

Size at maturity was of interest because of the relationship of minimum legal size limits for the commercial fishery to the maintenance of adequate reproduction.

FEMALE The proportion of the female lobsters in each 5-millimeter size group for those examined in 1974 and 1975 that had mature ova (mean diameter greater than 0.8 millimeter) in their ovaries is shown in Table 3 and Figure 2. These data indicate that some females matured when as small as 55 to 59 millimeters in carapace length. Almost half were mature at 70 to 74 millimeters, and over 80 per cent at 75 to 79 millimeters. All the females examined that had a carapace length of 86 millimeters or more had mean ova diameters indicative of maturity.

TABLE 3. PROPORTION, ACCORDING TO 5-MILLIMETER SIZE GROUPS, OF FEMALE LOBSTERS EXAMINED THAT HAD OVA WITH A MEAN DIAMETER GREATER THAN 0.8 MILLIMETER

Size group* (millimeters)	Number examined	Mean ova diameter greater than 0.8 millimeter	
		Number	Per cent
Less than 55	46	0	0.0
55-59	27	1	3.7
60-64	52	3	5.8
65-69	67	26	38.8
70-74	96	47	49.0
75-79	113	91	82.3
80-84	79	74	93.7
85-89	31	30	96.8
90-94	10	10	100.0
95-99	3	3	100.0

* Carapace length.

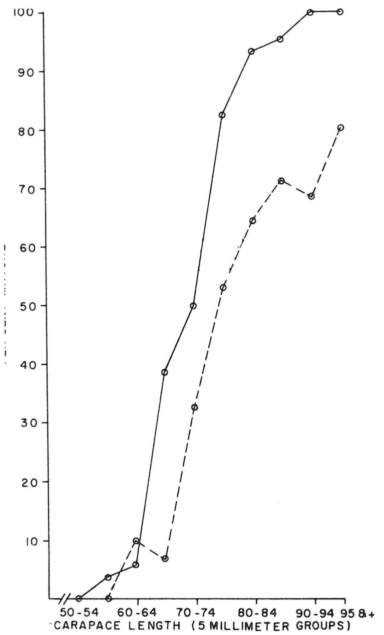

Figure 2. Proportion of female lobsters taken in 1974 and 1975 that had mature ova in their ovaries (solid line) and proportion of ovigerous females among all females caught during May in 1974 and 1975 (dash line).

TABLE 4. PROPORTION, ACCORDING TO 5-MILLIMETER SIZE GROUPS, OF FEMALE LOBSTERS EXAMINED DURING MAY THAT WERE OVIGEROUS

Size group* (millimeters)	Ovigerous (per cent)		
	1974	1975	Total
60-64	0.0	12.5	10.0
65-69	33.3	3.8	6.9
70-74	57.5	29.2	32.4
75-79	76.1	46.7	51.9
80-84	79.6	53.5	64.1
85-89	85.3	55.0	72.1
90-94	78.5	47.8	68.3
95 and over	88.9	66.7	80.0

* Carapace length

The proportion of the female lobsters that were ovigerous in each 5-millimeter size group for those examined during May in 1974 and 1975 is shown in Table 4 and Figure 2. These data indicate that females first became mature when 60 to 64 millimeters in carapace length and that about half were mature at 75 to 79 millimeters. The smallest ovigerous female recorded had a length of 64 millimeters.

The curve derived from plotting the ratio of the width of the second abdominal segment to carapace length against the carapace length should show a relatively level line where all females are immature, an inflection or upward curve at the onset of maturity and an asymptote where all, or nearly all, are mature. Figure 3 shows that

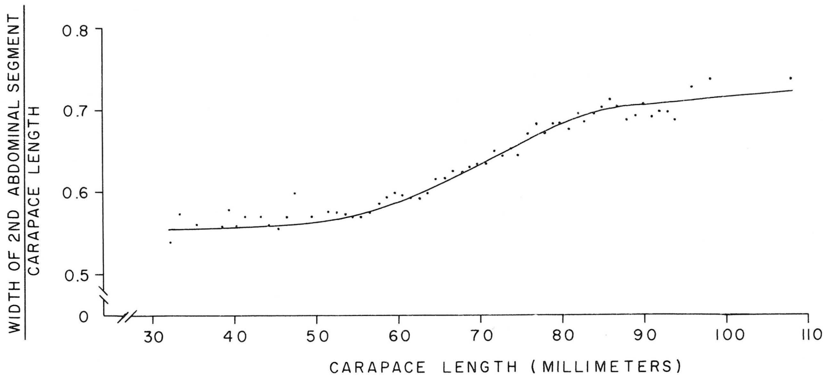

Figure 3. Ratio of the width of the second abdominal segment to the carapace length compared with the carapace length for female lobsters caught in 1974 and 1975.

the onset of maturity appeared at about 60 millimeters and that essentially all the females were mature at about 85 millimeters. The high points at 96, 98 and 108 millimeters were from single animals, and the latter two represented the same individual at different intermolt periods.

A variety of criteria thus gave similar results. Female lobsters in western Long Island Sound first reached maturity at about 60 millimeters in carapace length, and most were mature at about 80 millimeters. These data confirm the findings of Lund et al. (1973) who used yet another indicator of maturity, the presence of sperm in the seminal receptacle. Project findings, however, differ from those of Krouse (1973) for Maine and Skud and Perkins (1969) for the canyons of the continental shelf off southern New England and New York. Those studies indicated that only a small fraction of female lobsters reached maturity at sizes below 90 millimeters.

MALE Based on the presence of sperm in the testes and/or vas deferens (Table 5 and Figure 4), male lobsters in western Long Island Sound first reached maturity at 40 to 44 millimeters in carapace length, and over half were mature at 50 to 54 millimeters. Except for one 73-millimeter individual, all males larger than 56 millimeters were mature. The smallest male that had sperm in the testes and/or

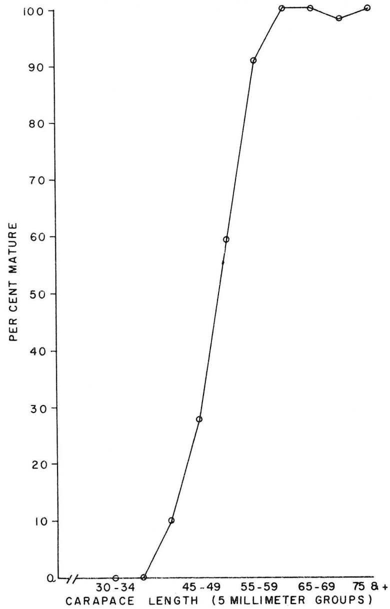

Figure 4. Proportion of male lobsters taken in 1974 and 1975 that had sperm in the testes and/or vas deferens.

TABLE 5. PROPORTION, ACCORDING TO 5-MILLIMETER SIZE GROUPS, OF MALE LOBSTERS EXAMINED THAT WERE MATURE BASED ON THE PRESENCE OF SPERM

Size group* (millimeters)	Number examined	Sperm in testes and/or vas deferens		
			Present	
		Absent	Number	Per cent
30-34	5	5	0	0.0
35-39	10	10	0	0.0
40-44	10	9	1	10.0
45-49	18	13	5	27.8
50-54	27	11	16	59.3
55-59	33	3	30	90.0
60-64	28	0	28	100.0
65-69	39	0	39	100.0
70-74	49	1	48	98.0
75 and over	162	0	162	100.0

* Carapace length

vas deferens had a length of 44 millimeters. These results are similar to the findings of Krouse (1973) in Maine.

SIZE COMPOSITION

Because of the wide range in the size of lobsters caught by the commercial fishery, length-frequency tables at 1-millimeter intervals would be too bulky for inclusion in this paper. These data are available in Briggs (1976). Also, because of the large number of lobsters in certain size groups, length-frequency histograms (even using 5-millimeter intervals) when reduced to a size suitable for publication would not be clear for groups in which few lobsters were caught.

CATCH Of the lobsters caught during the study: 6,096 males ranged from 17 to 126 millimeters in carapace length and averaged 76.4 millimeters; 16,264 non-ovigerous females ranged from 21 to 118 millimeters and averaged 78.1 millimeters; and 6,249 ovigerous females ranged from 64 to 120 millimeters and averaged 80.0 millimeters. The size distribution among the ovigerous females differed markedly from that reported for other areas. Both Krouse (1973) in Maine and Skud and Perkins (1969) in the offshore waters of southern New England and New York found few ovigerous females under 90 millimeters.

Data, compiled in 5-millimeter size groups but lumping the smaller and larger groups, show the general size composition of the catch according to sex and reproductive status (Tables 6, 7 and 8). For the catch as a whole, most of the lobsters were in just two size groups, 71-75 and 76-80 millimeters. Most of the largest individuals (over 100 millimeters) were males. Similarly, Skud and Perkins (1969) and Zawacki (undated) found that most of the largest lobsters they caught were males.

Interestingly, the data from the relatively shallow waters of Port Jefferson Harbor, considered separately, showed a different size composition (Table 9). No lobsters smaller than 66 millimeters were caught, while most exceeded 80 millimeters. The principal size groups were 76-80 and 81-85 millimeters. In similar shallow-water stations (5-12.5 meters) near Hart Island, Environmental Analysts (1975) found greater average lengths for lobsters than those recorded by the present project in the deeper waters (over 25 meters) of western Long Island Sound where most of its sampling was done.

LANDINGS As noted under methods, landings were less than the total catch because only marketable lobsters were kept. As a result, the size composition of the landings differed slightly, most of the lobsters ranging between 81 and 90 millimeters (Tables 10 and 11). Landings constituted a higher proportion of the total catch during the winter and early spring of 1976 than they did during the late spring through early fall in 1974 and 1975. However, the actual number of lobsters, in both the catch and landings, was higher in the late spring and summer. As in the catch, most of the largest lobsters (over 100 millimeters) landed were males. Skud and Perkins (1969) found similar results in the commercial catches (landings) they examined from the canyons off the continental shelf.

Table 6. Size Composition of Catch of Male Lobsters By Commercial Fishery in Western Long Island Sound

Size group* (millimeters)	May	June	July	August	September	October	Total
1974							
65 and less	8	61	42	52	44	3	210
66- 70	0	21	38	100	46	4	209
71- 75	8	47	86	282	145	23	591
76- 80	17	80	169	334	224	37	861
81- 85	13	48	62	66	13	4	206
86- 90	9	36	37	29	11	2	124
91- 95	5	11	17	19	6	1	59
96-100	7	3	3	9	6	0	28
101 and over	1	0	7	15	2	2	27
Total	68	307	461	906	497	76	2,315
Range	40-124	30- 99	30-126	29-122	26-103	49-114	29-126
Mean	80.3	74.0	76.6	75.9	74.7	76.8	75.7
1975							
65 and less	5	16	56	66	43	1	187
66- 70	23	20	42	60	41	1	187
71- 75	106	70	190	220	158	7	751
76- 80	265	135	348	520	496	44	1,808
81- 85	47	47	110	92	33	3	332
86- 90	27	18	71	36	7	2	161
91- 95	14	10	18	16	3	0	61
96-100	2	2	10	2	0	0	16
101 and over	0	1	10	6	2	0	19
Total	489	319	855	1,018	783	58	3,522
Range	45-100	41-105	27-114	17-122	19-124	45- 87	17-124
Mean	77.8	77.4	77.2	75.9	75.7	77.3	76.6

TABLE 6. (*continued*)

Size group* (millimeters)	January	February	March	April	Total
			1976		
65 and less	1	0	0	1	2
66- 70	3	2	1	1	7
71- 75	8	0	3	30	41
76- 80	25	5	22	67	119
81- 85	10	0	19	25	54
86- 90	7	1	10	7	25
91- 95	1	0	1	7	9
96-100	0	0	0	1	1
101 and over	0	0	1	0	1
Total	55	8	57	139	259
Mean	79.2	76.5	67-114	61- 98	60-114
Range	60- 94	67- 86	81.6	79.1	79.6

* Carapace length

Table 7. Size Composition of Catch of Non-ovigerous Female Lobsters By Commercial Fishery in Western Long Island Sound

Size group* (millimeters)	May	June	July	August	September	October	Total
			1974				
65 and less	8	69	67	79	63	4	290
66- 70	6	40	67	107	54	7	281
71- 75	24	98	221	448	142	21	954
76- 80	59	257	796	1,092	252	56	2,512
81- 85	48	110	323	372	94	6	953
86- 90	33	89	185	226	35	3	571
91- 95	12	29	56	39	8	0	144
96-100	1	8	14	10	8	0	41
101 and over	1	5	3	7	2	0	18
Total	192	705	1,732	2,380	658	97	5,764
Range	50-102	29-110	30-110	30-118	25-112	42- 90	25-118
Mean	79.2	77.4	78.8	78.1	75.8	76.0	78.0
			1975				
65 and less	14	22	74	90	52	7	259
66- 70	47	18	86	56	56	2	265
71- 75	295	88	702	443	315	16	1,859
76- 80	681	246	2,154	1,230	819	68	5,198
81- 85	110	39	342	514	217	9	1,231
86- 90	58	24	1 59	232	48	2	523
91- 95	15	5	42	41	11	0	114
96-100	1	1	16	12	6	0	36
101 anc er	2	0	0	3	0	1	6
Total	1,223	443	3,575	2,621	1,524	105	9,491
Range	45-105	45- 96	31-100	22-104	30-100	21-101	21-105
Mean	77.5	76.9	77.7	79.1	77.1	75.8	77.9

Table 7. *(continued)*

Size group* (millimeters)	January	February	March	April	Total
			1976		
65 and less	1	0	2	4	7
66- 70	4	0	25	10	39
71- 75	37	8	42	105	192
76- 80	91	9	57	191	348
81- 85	63	6	30	139	238
86- 90	33	7	8	105	153
91- 95	11	0	0	18	29
96-100	0	0	0	3	3
101 and over	0	0	0	0	0
Total	240	30	164	575	1,009
Range	65- 94	71- 89	69- 95	31- 98	31- 98
Mean	80.3	79.9	81.4	80.4	80.5

* Carapace length

TABLE 8. SIZE COMPOSITION OF CATCH OF OVIGEROUS FEMALE LOBSTERS BY COMMERCIAL FISHERY IN WESTERN LONG ISLAND SOUND

Size group* (millimeters)	May	June	July	August	September	October	Total
1974							
65 and less	0	0	0	0	0	0	0
66- 70	1	5	1	8	4	1	20
71- 75	32	51	14	38	77	17	229
76- 80	240	326	63	180	314	51	1,174
81- 85	194	221	49	57	78	14	613
86- 90	142	156	28	45	61	9	441
91- 95	53	50	8	12	29	2	154
96-100	7	8	1	4	4	0	24
101 and over	4	2	0	1	3	1	11
Total	673	819	164	345	570	95	2,666
Range	67-116	66-120	69- 97	68-103	67-104	69-111	66-120
Mean	82.8	82.3	81.8	80.3	80.2	79.3	81.4
1975							
65 and less	1	0	0	0	0	0	1
66- 70	8	2	6	1	6	0	23
71- 75	129	62	84	38	88	13	414
76- 80	574	220	353	205	416	61	1,829
81- 85	139	64	130	41	76	9	459
86- 90	68	49	63	39	37	2	258
91- 95	14	12	11	9	7	0	53
96-100	6	3	6	4	1	1	21
101 and over	1	1	3	3	2	0	10
Total	940	413	656	340	633	86	3,068
Range	64-103	68-103	70-105	70-111	67-110	71- 97	64-111
Mean	79.1	78.4	78.8	80.1	78.7	78.3	78.9

TABLE 8. *(continued)*

Size group* (millimeters)	January	February	March	April	Total
			1976		
65 and less	0	0	0	0	0
66- 70	1	0	1	4	6
71- 75	15	1	14	54	84
76- 80	67	6	46	207	326
81- 85	21	1	6	44	72
86- 90	3	0	3	14	20
91- 95	0	0	3	3	6
96-100	1	0	0	0	1
101 and over	0	0	0	0	0
Total	108	8	73	326	515
Range	70- 96	75- 82	70- 95	68- 92	68- 96
Mean	78.7	78.6	78.6	78.4	78.5

* Carapace length

TABLE 9. SIZE COMPOSITION OF CATCH OF LOBSTERS BY COMMERCIAL FISHERY IN PORT JEFFERSON HARBOR, ACCORDING TO SEX AND REPRODUCTIVE STATUS OF FEMALES

Size group* (millimeters)	Sex and reproductive status		
	Male	Female	
		Non-ovigerous	Ovigerous
65 and less	0	0	0
66- 70	2	2	0
71- 75	5	3	1
76- 80	10	17	3
81- 85	16	3	2
86- 90	7	12	3
91- 95	5	6	0
96-100	16	6	1
101 and over	18	1	0
Total	79	50	20
Range	67-126	66-101	75- 97
Mean	91.1	84.8	83.4

* Carapace length

CULLS

Cull lobsters (those with missing or damaged claws) are of concern because they are of lower market value than undamaged lobsters of the same size. The proportion of cull lobsters in the catch is shown in Table 12. Usually between 12 and 15 per cent of all males were culls, the proportion varying from 5.9 to 22.8 per cent, with the lowest figures in May. Among ovigerous females, culls varied between 4.6 and 21.2 per cent, usually being less than 10 per cent in the summer and between 12 and 15 per cent in the winter. Among non-ovigerous females, culls varied between 8.2 and 27.6 per cent, usually being between 8 and 12 per cent. For all groups, cull rates were usually highest from August through October.

Table 12 also shows the proportion of cull lobsters in the landings. The variations were greater than in the catch. Culls varied from zero to 20.0 per cent among males and from 1.5 to 45.5 per cent among females. The lowest proportions in the landings of both sexes (usually less than 10 per cent) were in May and June, while the highest were in October and February when relatively few lobsters were landed.

Thomas (1973) in Maine generally found less than 10 per cent culls among his cluster samples of legal (81 millimeters and larger) lobsters from pounds. Morrissey (1975) reported (for wooden traps such as those used in western Long Island Sound) cull rates of from 16.4 to 24.2 per cent for all sizes of lobsters from various areas in Maine. Morrissey also reported only 2.8 per cent culls among legal

Table 10. Size Composition of Landings of Male Lobsters By Commercial Fishery in Western Long Island Sound and Proportion of Catch Represented

Size group* (millimeters)	May	June	July	August	September	October	Total
1974							
81- 85	16	18	59	64	13	4	174
86- 90	9	13	35	29	13	2	101
91- 95	5	4	17	19	6	1	52
96-100	4	2	3	9	6	0	24
101 and over	1	0	7	15	2	2	27
Total	35	37	121	136	40	9	378
Percentage of catch§	51.5	12.1	26.2	15.0	8.0	11.8	16.3
1975							
81- 85	34	40	94	85	30	3	286
86- 90	26	17	63	36	7	2	151
91- 95	14	10	18	16	3	0	61
96-100	2	1	10	2	0	0	15
101 and over	0	1	10	6	2	0	19
Total	76	69	195	145	42	5	532
Percentage of catch§	15.5	21.6	22.8	14.2	5.4	8.6	15.1

Table 10. *(continued)*

Size group* (millimeters)	January	February	March	April	Total
		1976			
81- 85	10	0	19	23	52
86- 90	7	1	9	7	24
91- 95	1	0	1	7	9
96-100	0	0	0	1	1
101 and over	0	0	1	0	1
Total	18	1	30	38	87
Percentage of catch§	32.7	12.5	52.6	27.3	33.6

* Carapace length

§ Compared with corresponding totals in Table 6.

Table 11. Size Composition of Landings of Female Lobsters By Commercial Fishery in Western Long Island Sound and Proportion of Catch Represented

Size group* (millimeters)	May	June	July	August	September	October	Total
			1974				
81- 85	48	95	285	323	85	6	842
86- 90	32	88	167	217	35	3	542
91- 95	8	29	53	39	8	0	137
96-100	1	8	13	8	8	0	38
101 and over	1	5	4	7	2	0	19
Total	90	225	522	594	138	9	1,578
Percentage of catch§	10.4	14.8	27.5	21.8	11.2	4.7	18.7
			1975				
81- 85	88	27	308	446	205	8	1,082
86- 90	57	23	154	220	47	2	503
91- 95	15	5	41	39	11	0	111
96-100	1	1	16	11	6	0	35
101 and over	2	0	0	3	0	1	6
Total	163	56	519	719	269	11	1,737
Percentage of catch§	7.5	6.5	12.3	24.3	12.5	5.8	13.8

Table 11. *(continued)*

Size group* (millimeters)	January	February	March	April	Total
			1976		
81- 85	59	7	55	133	254
86- 90	33	5	28	104	170
91- 95	11	0	8	18	37
96-100	0	0	0	3	3
101 and over	0	0	0	0	0
Total	103	12	91	258	464
Percentage of catch§	29.6	31.6	38.4	28.6	30.4

* Carapace length

§ Compared with corresponding totals in Tables 7 and 8 combined.

TABLE 12. PROPORTION (IN PER CENT) OF CULL LOBSTERS IN THE CATCH AND LANDINGS BY COMMERCIAL FISHERY IN WESTERN LONG ISLAND SOUND

	Catch			Landings	
		Female			
Month	Male	Non-ovigerous	Ovigerous	Male	Female
1974					
May	7.4	10.4	7.7	6.3	4.3
June	22.8	8.5	8.4	14.3	5.8
July	13.1	8.2	7.3	13.2	5.2
August	13.8	14.3	4.6	14.0	12.8
September	8.4	14.0	11.9	15.0	15.2
October	11.8	8.3	11.8	11.1	22.2
1975					
May	5.9	9.7	5.6	7.9	16.0
June	8.8	10.4	7.0	13.0	1.5
July	13.0	9.1	10.2	14.9	7.9
August	14.9	16.2	7.9	13.1	14.3
September	14.8	17.9	8.7	11.9	21.2
October	19.0	27.6	21.2	20.0	45.5
1976					
January	9.1	12.5	14.8	5.6	14.6
February	12.5	10.0	12.5	0.0	25.0
March	12.3	14.0	12.3	13.3	15.4
April	12.9	11.5	13.5	15.8	10.9

lobsters from off Virginia. Scarratt (1973) found cull rates of from 4 to 19 per cent among lobsters from Prince Edward Island and from 4.7 to 12.0 per cent for several areas off Nova Scotia. He gave possible causes for claw loss as: handling by fishermen, aggressive interaction among lobsters in a dense population and, particularly for Prince Edward Island, shifting winter ice.

SEX RATIO

Females always greatly exceeded males in the catch (Table 13), and they usually exceeded males in the landings except in October 1974 and June 1975 when the ratio was even. However, the reverse was true for the data from the shoal waters of Port Jefferson Harbor. There, males exceeded females 19 to 60 (0.8 female per male). Also, Environmental Analysts (1975) found a similar dominance of males (0.4 female per male) in shoal waters near Hart Island.

In other areas, Zawacki (undated) found more males than females at an artificial reef in 3 meters of water in Shinnecock Bay, as did Briggs and Zawacki (1974) at an artificial reef in about 6 meters of water in Great South Bay, both on the south shore of Long Island (N.Y.). In deeper water, and in Maine, sex ratios tended to approach

TABLE 13. SEX RATIOS* FOR LOBSTERS IN CATCH AND LANDINGS BY COMMERCIAL FISHERY IN WESTERN LONG ISLAND SOUND

	1974		1975		1976	
Month	Catch	Landings	Catch	Landings	Catch	Landings
January	. .	. .	. .	. .	6.3	5.7
February	. .	. .	. .	. .	4.8	12.0
March	. .	. .	. .	. .	4.2	3.0
April	. .	. .	. .	. .	5.8	6.9
May	12.7	3.0	4.4	2.1	. .	. .
June	5.0	7.0	2.7	1.0	. .	. .
July	4.1	4.3	4.9	2.7	. .	. .
August	3.0	4.4	2.9	5.0	. .	. .
September	2.5	3.5	2.8	6.4	. .	. .
October	2.5	1.0	3.3	2.2	. .	. .

* Females per male.

1:1 (at least for lobsters of sizes below 80 millimeters) or to show a dominance of females (Briggs and Zawacki, 1974; Krouse, 1973; Skud and Perkins, 1969).

MOLTING

A recent molt may be discerned from the proportion of soft and "paper shell" lobsters in the catch. Among the lobsters examined during this study, the proportion was usually low (Table 14). In June 1974, however, 39.1 per cent of all the males caught were either soft or "paper shell". This strongly suggests a mass molt of males about that time. In 1975 a peak in the proportion of soft males occurred in July, and another was seen in January 1976. While there was no well-defined peak in the proportion of soft females in 1974, there did appear to be peaks in August 1975 and February 1976. Apparently, the peak of molting among females is generally a month or so after that among males. Lund et al. (1973) indicated that mass molts of

TABLE 14. PROPORTION (IN PER CENT) OF SOFT AND "PAPER SHELL" LOBSTERS IN CATCH BY COMMERCIAL FISHERY IN WESTERN LONG ISLAND SOUND

	1974		1975		1976	
Month	Male	Female	Male	Female	Male	Female
January	. .	. .	. .	. .	7.3	2.1
February	. .	. .	. .	. .	0.0	13.2
March	. .	. .	. .	. .	3.5	2.5
April	. .	. .	. .	. .	0.1	0.1
May	1.5	0.3	2.0	0.6	. .	. .
June	39.1	2.9	3.1	0.8	. .	. .
July	2.4	2.7	6.3	0.8	. .	. .
August	0.2	2.2	1.6	4.7	. .	. .
September	0.0	0.5	0.1	1.6	. .	. .
October	0.0	0.0	0.0	0.5	. .	. .

lobsters in Long Island Sound occurred in June and November in 1967 and 1968. The present data suggest the possibility of a third, winter, molt having occurred in early 1976.

Based on limited data, the growth increment (in carapace length) averaged 10.37 per cent (Table 15). However, the sample was small (only 32 individuals) and the standard deviation was relatively large (± 3.23). In other areas, molt increments were: 9-16.5 per cent for males and 10-11.5 per cent for females in areas off Newfoundland (Squires, 1970; Squires et al., 1974); 18.7 per cent for males and 16.7 per cent for females in offshore waters of southern New England (Cooper and Uzmann, 1971); and about 14 per cent in Maine (Dow, 1964) and Canada (Wilder, 1953). Unpublished data from Massachusetts (James Fair, personal communication) and Rhode Island (How-

TABLE 15. GROWTH INCREMENT FOR 32 LOBSTERS EXAMINED

Sex	Carapace length (millimeters)		Increase (per cent)
	Pre-molt	Post-molt	
Female	26	31	19.2
Female	33	37	12.1
Female	59	69	16.9
Male	61	69	13.1
Female	66	73	10.6
Female	66	74	12.1
Female	67	73	9.0
Female	67	76	13.4
Female	68	75	10.3
Female	68	78	14.7
Male	68	77	13.2
Female	70	76	8.6
Female	71	76	7.0
Female	71	78	9.9
Female	71	81	14.1
Female	72	79	9.7
Female	73	77	5.2
Male	73	81	11.0
Female	74	79	6.8
Female	75	79	5.3
Female	75	83	10.7
Female	76	82	7.9
Female	76	86	11.6
Female	77	83	7.8
Female	77	85	10.4
Female	77	85	10.4
Female	79	85	7.6
Female	79	85	7.6
Female	80	86	7.5
Male	80	85	6.3
Female	86	96	11.6
Female	98	108	10.2
Mean			10.37
Standard deviation			± 3.23

ard Russell, personal communication) show growth increments in carapace length of about 14 per cent.

LENGTH-WEIGHT RELATIONSHIP

Length-weight relationships were calculated for each sex from the standard equation: $W = cL^n$. This equation was solved by the method of GM regression, as described by Ricker (1973), for a random sample of 50 lobsters of each sex plus the largest and smallest (in carapace length) individuals of each sex that were weighed and measured (i.e., 52 paired observations for each sex). No culls or ovigerous females were used in these samples. The resultant equations were:

$$\text{Male:} \quad \log Y = -3.5993 + 3.2646 \log X$$

$$\text{Female:} \quad \log Y = -3.5697 + 3.2548 \log X$$

where:

Y = weight in grams

X = carapace length in millimeters

The calculated and observed weights showed close agreement (Table 16). There appeared to be little difference between males and females

TABLE 16. CALCULATED AND OBSERVED MEAN WEIGHTS FOR 52 MALE AND 52 FEMALE LOBSTERS

Carapace length (millimeters)	Male		Female	
	Calculated weight (grams)	Observed weight (grams)	Calculated weight (grams)	Observed weight (grams)
17	3	2	. .	. .
20	4	. .	. .	. .
30	17	. .	. .	. .
33	. .	. .	24	21
40	39	50	41	50
50	89	87	91	94
60	161	160	165	169
70	266	263	273	279
80	411	409	421	426
90	595	632	610	599
100	851	. .	871	. .
108	. .	. .	1,118	966
110	1,197	. .	. .	. .
118	1,461	1,344	. .	. .

in the range of sizes sampled, so an equation for the sexes combined, i.e.,

$$\log Y = -3.5947 + 3.2670\ X$$

was calculated and is shown graphically in Figure 5.

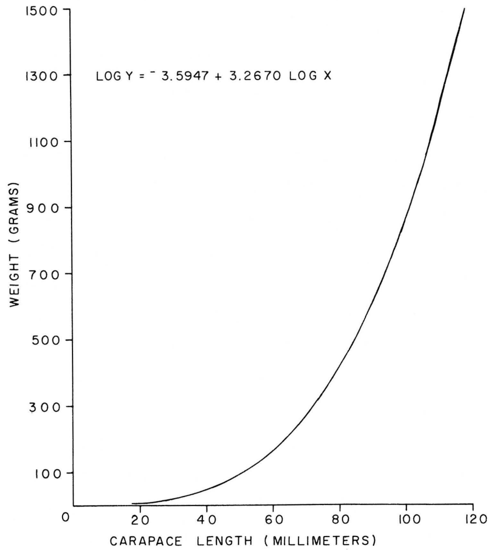

Figure 5. Length-weight relationship for sample comprising 52 lobsters of each sex.

PARASITES

Uzmann (1970) indicated that juveniles of an acanthocephalan (*Corynosoma* sp.) were almost exclusively restricted to lobsters from coastal waters, while larvae of a nematode (*Ascarophis* sp.) were almost exclusively restricted to lobsters from offshore waters. The acanthocephalan is found encysted on the digestive tract. The nematode is found in the rectal tissues. Only 11 (1.2 per cent) of 939 lobsters examined during the present project were found to be parasitised by the acanthocephalan and none by the nematode.

DISCUSSION

Female lobsters in western Long Island Sound mature at a smaller size than has been recorded elsewhere in the animal's range within the United States. The majority appear to be mature at a carapace length of 81 millimeters which is the present minimum legal limit in New York. Males mature at a smaller size than females, essentially all over 56 millimeters being mature. This is similar to findings elsewhere. The disparity in size between the sexes at maturity appears to offer no problem with mating, since small males can mate with much larger females (Hughes and Mattheissen, 1962). Females also molt about a month later than males, which may be an assist to mating since copulation can be achieved only when the female is soft shelled and the male hard shelled.

There are at least two molting periods among lobsters in western Long Island Sound, one in the late spring or early summer and another in the fall (November), although the data did not show the fall molt since the cooperating fishermen did not fish then. There was, however, indication of a possible third, winter, molt. Whether this winter molt was real, or whether hardening from the fall molt was delayed by low water temperatures during the winter, is speculative. Nonetheless, soft lobsters were found in January (males) and February (females). Conversation with lobstermen and with biologists from Connecticut tend to strengthen the authors' opinion that, in some years at least, there is a winter molt among lobsters in western Long Island Sound.

Since data on growth were derived from a relatively few individuals, the 10.37 per cent increase in carapace length, with a large standard deviation, may approximate the 14 per cent average molt increment generally accepted by biologists working with lobsters in the Northeast.

There may be a wide range (17-126 millimeters) in the size of lobsters caught in traps in western Long Island Sound. However, the bulk of the catch is in the pre-recruit 70-80 millimeter size. This is probably indicative of both heavy fishing pressure and gear selectivity. Most of the lobsters landed are less than 90 millimeters in carapace length. Few over 100 millimeters are caught. Most of these large lobsters are males, as is the case in other areas (although the actual sizes may be larger than found here). This is not unexpected since females, once mature, are thought to molt less frequently than males (much of their energy presumably being diverted from growth to the production of ova).

The sex ratios recorded, strongly biased toward females, indicate that relatively few males are found in the deeper (over 25 meters) waters of western Long Island Sound. There is also an indication from this and other studies that, for areas around Long Island, more males than females are found in shoal waters. Conversations with lobstermen who fish Long Island Sound, and with biologists from Connecticut, tend to support this.

The low incidence and type of parasitism tend to support other studies that indicate that lobsters in western Long Island Sound are non-migratory and constitute a unique population. The small size of the ovigerous females also tends to support the uniqueness of the lobster population in the area. However, there still remains the possibility that fishing pressure is so great that the lobsters do not reach a size or age great enough to become migratory. Cooper and Uzmann (1971) did get one return from Port Jefferson Harbor for a lobster that had been tagged offshore.

The proportion of culls among the lobsters caught increases as the season progresses. This could be either a result of heavy fishing pressure (handling of sub-legal and soft lobsters) or an indication of a dense population (aggressive interaction among lobsters, particularly when caught in traps). The authors tend to suspect both, and have commonly seen five and six trap trawls lifted containing 70 or more lobsters, as well as single traps with over 30 lobsters.

The findings of this study indicate no need for changing the 3 3/16-inch (81-millimeter) minimum size limit presently in effect in western Long Island Sound on the basis of protecting lobsters until they reach maturity. However, the results of ongoing studies (when analyzed) should provide additional information that is needed for determining proper size limits for the area.

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GENERAL NOTES

FOOD HABITS OF THE FISHER IN NORTHERN NEW YORK[1]

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As part of an investigation of the distribution and population dynamics of the fisher (*Martes pennanti*) in northern New York, information on food habits was obtained from carcasses supplied by cooperating trappers representing an area of some 18,000 square miles in the Adirondack region. During the trapping season of 1975 (October 25 to December 31) 114 trappers furnished 336 carcasses, and in 1976-77 (October 16 to January 2) 91 trappers furnished 192 specimens. Each carcasses was labelled as to the date and locality where taken and brought to one of the three regional offices of the Department in northern New York where it was frozen and stored for later necropsy. Upon necropsy, 405 digestive tracts were found suitable for analysis.

During the initial necropsy, 71 tracts were examined, while 291 were refrozen for later analysis and 43 were preserved in 10 per cent formalin. For examination, stomachs and intestines were placed in a food strainer or on screens of various-sized mesh (15 to 40 per inch) and washed under warm water to remove the small debris and dirt. The contents were then emptied into a white porcelain tray where the food items and other material were separated and identified.

Mammal identification was made mainly by hair characteristics using the keys of Mathiak (1938), Stains (1958) and Moore et al. (1974). Slides were prepared and hairs were identified under a dissecting microscope as described by Moore et al. (1974). Dorsal guard hairs were considered the most reliable for identification. Claws and teeth were also helpful when compared with known examples.

Birds were identified with the aid of the work of Pettingill (1970), while the following were helpful in identifying other fauna: reptiles and amphibians—Cognant (1958); fish—Eddy (1957); insects—Borror and White (1970) and Jacques (1947); spiders—Katson (1952); parasites—Chandier and Read (1964). The wildlife management technique manual (Giles, 1971) was used as an additional reference.

Vegetable materials were identified through the keys in Harlow (1946), Harlow and Harrar (1958), Foster (1962), Fernald (1950) and the handbook of the U.S. Forest Service (1974).

Insofar as possible, food items were identified to species. The data were recorded in terms of frequency of occurrence in the fisher specimens examined, and no distinction was made between material found in the intestine and that in the stomach or between the sexes.

FINDINGS

Of the 405 digestive tracts that were suitable for analysis, 83 (20.5 per cent) were empty. Of the 322 that contained food, 29 (9.0 per cent) were taken during late October, 154 (47.8 per cent) in November and 139 (43.2 per cent) in December and early January.

A total of 961 ingested items were identified representing the following groups: mammals (47.7 per cent), vegetation (43.9 per cent), birds (3.9 per cent), fish (0.8 per cent), insects (0.8 per cent), reptiles (0.2 per cent), arachnids (0.1 per cent) and miscellaneous (1.1 per cent). Also, parasites were found in 1.7 per cent. The fre-

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Projects W-135-D and W-136-D. The authors wish to thank the wildlife staffs of Regions 5 and 6 for help in collecting the fisher carcasses. Also, special thanks are extended to the many trappers who cooperated in the study.

TABLE 1. CONTENTS OF DIGESTIVE TRACTS OF 322 FISHER TRAPPED IN NORTHERN NEW YORK DURING THE LATE FALL AND EARLY WINTER

Item	Frequency	
	Number*	Per cent
Mammals		
Fisher (*Martes pennanti*)	129	40.1
Red squirrel (*Tamiasciurus hudsonicus*)	63	19.6
White-tailed deer (*Odocoileus virginianus*)	61	18.9
Snowshoe hair (*Lepus americanus*)	40	12.4
Meadow vole (*Microtus pennsylvanicus*)	30	9.3
Porcupine (*Erethizon dorsatum*)	21	6.5
Muskrat (*Ondatra zibethicus*)	17	5.3
White-footed mouse (*Peromyscus leucopus*)	17	5.3
Red-backed vole (*Clethrionomys gapperi*)	11	3.4
Short-tailed shrew (*Blarina brevicauda*)	8	2.5
Beaver (*Castor canadensis*)	6	1.9
Star-nosed mole (*Condylura cristata*)	6	1.9
Cottontail rabbit (*Sylvilagus floridanus*)	5	1.6
Gray squirrel (*Sciurus carolinensis*)	5	1.6
House mouse (*Mus musculus*)	4	1.2
Water shrew (*Sorex palustris*)	4	1.2
Common shrew (*Sorex cinereus*)	4	1.2
Chipmunk (*Tamias striatus*)	4	1.2
Raccoon (*Procyon lotor*)	3	1.0
Mouse (unidentified)	3	1.0
Skunk (*Mephitis mephitis*)	2	0.6
Pine marten (*Martes americana*)	1	0.3
Flying squirrel (*Glaucomys volans*)	1	0.3
Woodchuck (*Marmota monax*)	1	0.3
Hairy-tailed mole (*Parascalops breweri*)	1	0.3
Jumping mouse (*Zapus hudsonicus*)	1	0.3
Unidentified bones and claws	10	3.1
Total	299	92.8
Birds		
Ruffed grouse (*Bonasa umbellus*)	11	3.4
Red-winged blackbird (*Agelaius phoeniceus*)	4	1.2
Black-capped chickadee (*Parus atricapillus*)	3	1.0
Starling (*Sturnus vulgaris*)	2	0.6
Crow (*Corvus brachyrhynchos*)	1	0.3
Bluejay (*Cyanocitta cristata*)	1	0.3
Wood thrush (*Hylocichla mustelina*)	1	0.3
Thrush (*Hylocichla* sp.)	1	0.3
Duck (unidentified)	1	0.3
Unidentified birds	12	3.7
Total	27	8.4
Reptiles		
Garter snake (*Thamnophis sirtalis*)	1	0.3
Unidentified snake	1	0.3
Total	2	0.6
Fish		
Unidentified fish (Cyprinidae)	8	2.5

TABLE 1. (*continued*)

Item	Frequency	
	Number*	Per cent
Insects		
Lady beetle (*Hippodamia convergens*)	2	0.6
Whirlygig beetle (*Dineutes americanus*)	1	0.3
Honey bee (*Apis mellifera*)	1	0.3
Unidentified insects	4	1.2
Total	8	2.5
Arachnids		
Daddy longlegs (*Leiobunum vittatum*)	1	0.3
Vegetation		
Balsam fir (*Abies balsamea*)	65	20.2
Spruce (*Picea* sp.)	61	18.9
White pine (*Pinus strobus*)	54	16.8
Beechnuts (*Fagus grandifolia*)	50	15.5
Hemlock (*Tsuga canadensis*)	46	14.3
Grass (*Gramineae*)	30	9.3
Beech (*Fagus grandifolia*)	20	6.2
Apple (*Pyrus* sp.)	19	5.9
Red pine (*Pinus resinosa*)	9	2.8
White cedar (*Thuja occidentalis*)	7	2.2
Maple (*Acer* sp.)	7	2.2
Black cherry (*Prunus serotina*)	6	1.9
Ferns (*Dryopteris* sp.)	6	1.9
Pin cherry (*Prunus pennsylvanica*)	4	1.2
Birch (*Betula* sp.)	4	1.2
Club moss (*Lycopodium clavatum*)	4	1.2
Raspberry (*Rubus* sp.)	3	1.0
Hawthorn (*Crataegus* sp.)	3	1.0
Gray birch (*Betula populifolia*)	2	0.6
High bush cranberry (*Virburnum americanum*)	2	0.6
Plantain (*Plantago* sp.)	2	0.6
Choke cherry (*Prunus virginiana*)	2	0.6
Mountain ash (*Pyrus americana*)	2	0.6
Prince's pine (*Chimaphila* sp.)	1	0.3
Goldenrod (*Solidago* sp.)	1	0.3
Leatherleaf (*Chamaedaphne calycalata*)	1	0.3
American larch (*Larix laricina*)	1	0.3
Ground pine (*Lycopodium complanatum*)	1	0.3
Pondweed (*Potamogeton* sp.)	1	0.3
Strawberry (*Rosaceae*)	1	0.3
Pitcher plant (*Sarracenia purpurea*)	1	0.3
Basswood (*Tilia americana*)	1	0.3
Unidentified seeds	6	1.9
Total	204	63.5
Miscellaneous		
Stones	5	1.6
Trash (cellophane, string, small plastic bag)	5	1.6
Corn kernel	1	0.3
Total	11	3.4

TABLE 1. (*continued*)

Item	Frequency	
	Number*	Per cent
Parasites		
Roundworm (*Dracunculus* sp.)	7	2.2
Roundworm (*Ascaris* sp.)	3	1.0
Tapeworm (*Mesocestoides variabillis*)	3	1.0
Roundworm (*Capillaria* sp.)	1	0.3
Total	14	4.3

* For mammals, birds and vegetation, the totals are less than the sums of the figures for the food items listed because many tracts contained more than one item.

quency of occurrence of these items in the 322 tracts that contained food is shown in Table 1. A number of tracts also contained debris such as stones, wood, bark and trash that was probably taken incidentally to feeding or while in the trap. Following are brief comments on the foods eaten by these fisher.

MAMMALS

In 92.8 per cent of the digestive tracts that contained ingested items, at least one species was represented. A total of 25 species were identified.

It is believed that the high incidence of fisher remains (chiefly hair and claws) resulted mainly from the cleaning and grooming behavior of the animals or from efforts to free themselves from the trap, or possibly in some instances from another fisher carcass used as trap bait. Fisher have been observed by the senior author to prey on a trapped fisher.

Similarily, it is felt that the incidence of deer to a large degree represented feeding on trap bait or carrion. Approximately 73 per cent of the fisher examined had been trapped during the deer hunting season (October 23 to December 5). Trappers often use parts of deer for bait. Also, the entrails of field-dressed deer left in the woods by hunters would have been available. Several fisher were observed by the senior author feeding on deer carcasses in Hamilton County during the winter of 1977.

The principal species actually preyed upon by these fisher were the red squirrel, snowshoe hare and meadow vole. However, mice and shrews as a group were found in 23 per cent of the digestive tracts examined. Of interest are the 21 records of porcupine, one specimen from Clinton County containing 12-15 quills. It has long been recognized that the fisher seems able to prey on the porcupine with relative impunity. Of interest also is the specimen from Franklin County that contained claws and hair of a pine marten. With respect to the five stomachs cointaining beaver, it may be noted that beaver are often used as trap bait.

BIRDS

Birds were represented in 8.4 per cent of the tracts examined and included 37 individuals of eight species. That ruffed grouse occurred most frequently is of interest since the fisher has not been recognized as an important predator of grouse.

REPTILES, FISH, INSECTS AND ARACHNIDS

Two snakes constituted the reptile remains found in 0.6 per cent of the digestive tracts examined. Fish remains, believed to be of the minnow family (Cyprinidae), occurred in 2.5 per cent of the sample. Insects occurred in 2.5 per cent, and arachnids in 0.3 per cent.

VEGETATION

Vegetation occurred in 63.5 per cent of the tracts examined, the most frequently encountered species being balsam fir, spruce, white pine and hemlock. It is believed that most of this material, especially the twigs and leaves of trees and shrubs, was taken inadvertently when prey items were eaten or while the animal was in the trap. However, fruits and seeds, including apple, black cherry, pin cherry, choke cherry, hawthorn, high bush cranberry and mountain ash, were found in 10.1 per cent of the sample and probably were taken as food in most cases. Also, beechnuts were present in 15.5 per cent of the tracts, many stomachs and intestines being completely filled with the husks and meats. In many areas of northern New York the mast crop in the fall of 1976 was considered to have been exceptionally good. That beechnuts may be an important seasonal food of fisher when available is evidenced by the fact that they were present in 41.1 per cent of the sample for 1976-77 compared with only 8.0 per cent in 1975.

DISCUSSION

Many of the digestive tracts examined contained parts of mammals that it is believed had been used as bait by the trappers. In using specimens from sources of this sort for food habits studies, it would be helpful to have the type of bait used in each case recorded. Another problem encountered in this study was the amount of vegetative material that had been ingested inadvertently when prey items were eaten or while the animal was in the trap. Although this material was tabulated as stomach contents, a sound method of separating such extraneous items before tabulation would be desirable.

The data from this sample indictate that during the late fall and early winter in northern New York fisher eat a wide variety of foods, but that rodents, moles and shrews are the staples. They also show that, when available, beechnuts may be eaten in substantial quantities. The findings support the results of studies by Grinnell et al. (1937), De vos (1952) and Hamilton and Cook (1952), all indiacting that the fisher is a true opportunist feeding on mammals, birds, carrion, fruit and succulent vegetation, preference often being determined by availability.

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TWO OLD BEAVERS FROM THE ADIRONDACKS[1]

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On a study area in central Hamilton County (N.Y.) in the vicinity of the South Branch of the Moose River, beaver trapping was permitted in the spring of 1974 after having been prohibited for five years. Department personnel examined the 233 beavers taken and found two that were over 15 years old. One was a 52-pound (whole weight) female trapped February 24 on Indian Lake, and the other was a 36-pound male taken March 4 on Otter Brook, both in the Town of Morehouse. The skulls of both were saved for laboratory examination.

The first and second molars of the lower jaw of each specimen were ground longitudinally, and the ages of the animals were judged according to the cementum-layer technique of Van Nostrand and Stephenson (1964). Based on the independent determinations of six observers, the female was found to be 18½-19 years old and the male at least 19 years old. For the male, 17 annual cementum layers were clearly distinguishable together with two or three questionable layers. Additional molars were sectioned and examined according to the techniques of Stone et al. (1975) and Monson et al. (1973), and this approach gave the same age for the female but indicated the male to have been 23½-24 years old.

Since 1973, more than 2,400 beaver carcasses have been collected from cooperating trappers in Region 5[2] and examined by Department personnel. Only eight beavers over 12½-13 years old have been recorded, the present two specimens being the oldest. However, a 20-year-old beaver trapped in the Kapuskasing district of Ontario was reported by Novak (1972).

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project W-135-D.

[2] An administrative region of the Department comprising the counties of Clinton, Essex, Franklin, Fulton, Hamilton, Saratoga, Warren and Washington and constituting nearly 9,700 square miles.

OCCURRENCE OF THE SILVER LAMPREY IN THE HUDSON RIVER

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During ecological studies on the Hudson River in 1974, two silver lampreys (*Ichthyomzon unicuspis*)[2] were collected from traveling screens at the steam station of the Niagara Mohawk Power Corporation at mile 142 near Albany, N.Y., one on June 10 and the other on December 13. Water temperatures on these dates were 23° C. and 3° C., respectively. Lengths of the specimens were 260 and 270 millimeters, and weights were 33.5 and 47.8 grams, respectively. Hubbs and Trautman (1973) reported a mean length of 224 millimeters (range: 103-328 millimeters) for adults of this species.

The silver lamprey has been recorded in the Ohio River and Mississippi River drainages, the western tributaries of Hudson Bay and the Great Lakes, and the St. Lawrence River drainage including Lake Champlain (Hubbs and Lagler, 1964). But the species was not collected during surveys by the State Department of Conservation in the watersheds of the Upper Hudson system (Greeley and Bishop, 1933), the Mohawk-Hudson system (Greeley, 1935), the Delaware and Susquehanna Rivers (Greeley, 1936) or the Lower Hudson River (Greeley, 1937). Silver lampreys were considered rare in the Lake Ontario watershed (Greeley, 1940) and the St. Lawrence River watershed (Greeley and Greene, 1931), but moderately common in Lake Champlain (Greeley, 1930). The lack of records in the Hudson, Mohawk, Delaware and Susquehanna watersheds has continued to the present (R. Fieldhouse, N.Y.S. Dept. Environ. Cons., personal communication). There has also been no record of this fish in western Massachusetts (P. Oatis, Mass. Div. Fish. and Game, personal communication). Therefore, the probable origin of the specimens reported here was Lake Champlain which is connected with the Hudson River through the Champlain Canal.

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[1] Present affiliation: Detroit Edison Co., 2000 Second Ave., Detroit, Mich. 48226.

[2] Identifications were confirmed by C. Lavett Smith of the American Museum of Natural History, New York, N.Y., and the specimens have been deposited in this museum.

OCCURRENCE OF A KOKANEE IN THE HUDSON RIVER

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On December 17, 1974 a kokanee (*Oncorhynchus nerka*)[2], the lacustrine form of the sockeye salmon, was recorded from the Hudson River at mile 66 near Roseton, N.Y. The fish was collected off the traveling screens at the Danskammer Point Generating Station of the Central Hudson Gas & Electric Corporation. The water temperature was 3.0° C. and dissolved oxygen was 14.0 ppm. The specimen was a male measuring 261 millimeters in total length and weighing 161.5 grams. Extensive deterioration of the margins of the scales prevented accurate age determination by the scale method (only one annulus was discernable). It is possible that the scales had been partially resorbed as generally occurs in mature individuals (Vernon, 1975). However, since kokanee stocked in Connecticut lakes attained a total length of 258 millimeters at age II and 309 millimeters at age III (Whitworth and Sauter, 1972), it is probable that the present specimen was a 2 year old.

The kokanee is indigenous to Japan, the USSR and western North America from Oregon to Alaska (Nelson, 1968), and it has been introduced in the Great Lakes, the Rocky Mountain region and a number of localities in the eastern United States (Buss, 1975; Scott and Crossman, 1973). Possible sources of the present specimen are few. The only lake in the Hudson River watershed that is currently being stocked is Glass Lake near Averill Park in Rensselaer County (N.Y.) where fingerlings have been stocked for several years by the State Department of Environmental Conservation although to date there has been no record of successful spawning (R. Fieldhouse, N.Y.S. Dept. Environ. Cons., personal communication). Fingerlings were also stocked by the Department prior to 1971 in Lake Luzerne in Warren County which is in the Hudson River watershed, but there have been no reports of adults being caught there since that time (G. Lane, N.Y.S. Dept. Environ. Cons., personal communication). From 1964 to 1972 the Ontario Department of Lands and Forests stocked eyed eggs, fry and fingerlings in Lake Ontario, and in the fall of 1974 some 1,500 to 2,000 adults were reported to have been caught by gill net fishermen along the northern shore of the lake (W. J. Christie, Ont. Dept. Nat. Res., personal communication). It is possible that the present specimen could have moved from Lake Ontario into the Erie Canal or the Oswego Canal and thence through the Mohawk River to the Hudson River. Another possible source is the State fish hatchery at Warrensburg (N.Y.) where kokanee eggs are routinely incubated and hatched for stocking as fry and where the hatchery waters drain directly into the Hudson River.

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[2] Identification was confirmed by C. Lavett Smith of the American Museum of Natural History, New York, N.Y., and the specimen has been deposited in this museum.

TEMPERATURE TOLERANCE OF JUVENILE MUSKELLUNGE REARED UNDER HATCHERY CONDITIONS[1]

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Early developmental stages of organisms are often the most sensitive to changes in temperature. Over the entire life history of a fish, the response to temperature varies as the fish develops from egg to adult. No one temperature can be termed "good" or "bad" in itself, but must be considered in light of its effect on the various life stages and physiological activities of the fish.

Little is known about the role of temperature in the ecology of muskellunge (*Esox masquinongy*). Galat and Eipper (1969) found that 13° C. was an optimum for the incubation of muskellunge eggs. Hassan and Spotila (1976) reported that nearly hatched muskellunge fry reared at 25° C., had a critical thermal maximum[3] of 33.2°-36.1° C., while for those reared at 15° C. the critical thermal maximum was 29.8°-34.4° C. and for those reared at 7° C. it was initially 34° C. but dropped to 27.2° C after 29 days. Bonin and Spotila (1978) showed that both age and prior thermal history had important effects on the temperature tolerance of larval muskellunge. Scott (1964) reported that the lethal temperature of juvenile muskellunge acclimated to 25° C. was 32.5° C (with a resistance time of 400 minutes).

The present note concerns the temperature tolerance of juvenile muskellunge reared under hatchery conditions. The study was conducted at the State muskellunge hatchery on Chautauqua Lake in Chautauqua County (N.Y.). Muskellunge were maintained in outside troughs with ambient water temperatures and subject to the natural photoperiod, as described by Bonin and Spotila (1978). The ambient water temperature was recorded each test day at 0900.

The temperature tolerances of juvenile muskellunge were determined during a 53-day period between days 43 and 100 after hatching. On each test day, the critical thermal maxima were determined for 10 specimens between the hours of 0930 and 1400 EDT according to the method described by Hutchison (1961) and Bonin (1976). Results were analyzed graphically by the method of Hutchison (1961). The endpoint used in this study was the onset of spasms, which was followed immediately by the fish's complete loss of equilibrium and the cessation of its opercular movement.

The average critical thermal maximum for the juvenile muskellunge did not vary significantly through time (Figure 1) and ranged from 34.2° C. on day 80 to 34.9° C. on day 49. Initially 34.6° C on day 43, the average critical thermal maximum remained within ± 0.5° C. of this temperature for the remainder of the experiment. Ambient water temperatures ranged from 18.2° C. on day 53 to 20.2° C. on day 87.

Bonin and Spotila (1978) and Hassan and Spotila (1976) reported that larval muskellunge exhibited a marked decrease in the critical thermal maximum during swim-up, indicating that this period was critical in the development of these fish. Bonin and Spotila (1978) showed that, after swim-up, temperature tolerance increased regardless of environmental conditions for the first 25 days following hatching, after which it became dependent upon environmental conditions. The results of this study demonstrate that once the initial process of development is complete

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[1] This study was supported by the U.S. Energy Research and Development Administration (Contract No. E(11-1)-2502). The author wishes to thank Dr. James R. Spotila of the State University College at Buffalo for guidance and assistance during the investigation and for helpful criticism in the preparation of the manuscript. He also wishes to thank Norman Youmans and the personnel at the Chautauqua Lake muskellunge hatchery for their cooperation.

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[3] The critical thermal maximum represents the thermal point at which locomotor activity becomes disorganized and the organism loses its ability to escape from conditions which will lead to its death. It is an indicator of the temperature tolerance of a fish and a measure of its ability to acclimate to changes in temperature.

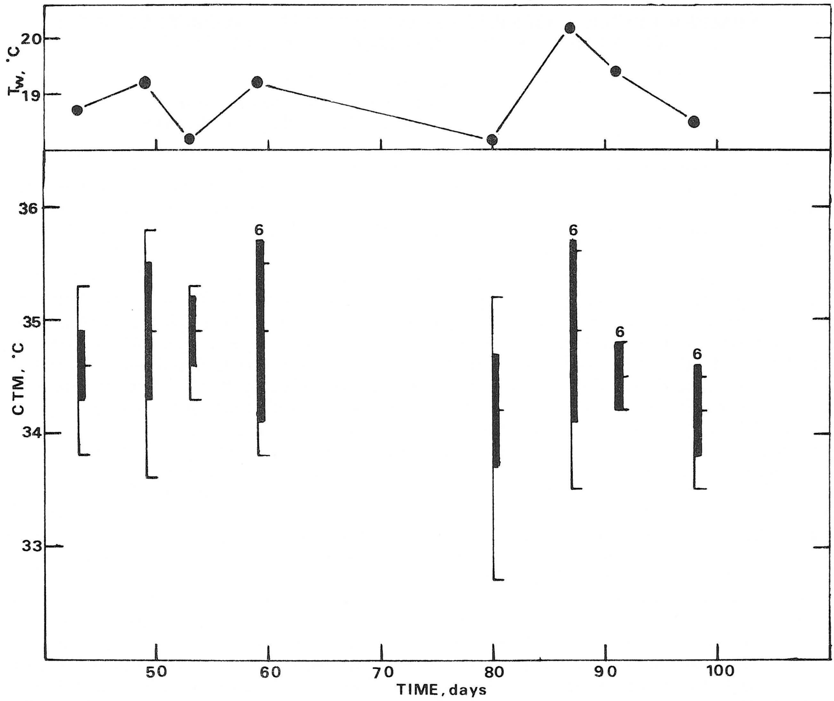

Figure 1. Water temperatures in the rearing troughs (upper) and critical thermal maxima for juvenile muskellunge studied for 53 days after hatching (lower) at the Chautauqua Lake hatchery. Vertical lines bounded by horizontal lines represent ranges, and center horizontal lines are means. Heavy vertical bars for days 43, 49, 53 and 80 represent $x \pm 2.262$ SE (sample size 10); those for days 59, 87, 91 and 98 represent $x \pm 2.571$ SE (sample size 6). That all of the bars overlap to some degree indicates the values are not significantly different ($P = 0.05$). Method based on Hutchison (1961).

(approximately 43 days after hatching) the critical thermal maximum for juvenile muskellunge remains relatively stable, at least until the fish are 100 days old. This suggests that juvenile muskellunge are able physiologically to adapt with little stress to the changing environmental conditions usually found in Chautauqua Lake. Their temperature tolerance appears to be similar to that of older individuals.

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EVIDENCE OF SUCCESSFUL REPRODUCTION OF COHO SALMON IN A NEW YORK TRIBUTARY OF LAKE ERIE[1]

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An excellent sport fishery has been developed in the Great Lakes with the introduction of coho salmon (*Oncorhynchus kisutch*) and chinook salmon (*O. tshawytscha*) starting in 1966 (Parsons, 1973). Significant numbers of these species were first stocked in the New York waters of Lake Erie in 1968 by the State Conservation Department with stock from Oregon and Michigan sources. Cattaraugus Creek has received the majority of the stocked salmon each year since the stocking program was begun. Natural reproductiion has apparently never made a significant contribution to the Great Lakes fishery for the introduced Pacific salmon, but it has been documented for these species in tributaries of Lake Superior and Lake Michigan (Peck, 1970; Parsons, 1973; Avery, 1974). In an unpublished report in 1972 to the Lake Erie Committee of the International Joint Commission, the Ontario Department of Lands and Forests noted successful reproduction of coho salmon in Young's, Fisher's and Normandale Creeks, all tributaries of Lake Erie.

On September 30, 1976 seven young coho salmon were collected by electrofishing in an approximately 0.4-kilometer section of Derby Brook, a tributary of Cattaraugus Creek in Erie County (N.Y.). Identification was verified by Dr. Douglas P. Dodge of the Sport Fisheries Branch of the Ontario Ministry of Natural Resources. Subsequent collections at this locality on October 20 and November 16 in 1976 yielded five additional specimens.

Derby Brook is a small stream, 3 to 4 meters wide and about 0.5 meter deep, that flows into Cattaraugus Creek 55 kilometers above its mouth. About 5 kilometers seem suitable for salmonid reproduction, although flow is probably marginal in the summer. Turbidity and siltation may be adverse factors at other seasons.

Total lengths of the specimens collected ranged from 8.9 to 11.6 centimeters, with an average of 10.7 centimeters. Scales from these fish had uneven spacing between the circuli, indicating stream life, rather than the even spacing usually found in hatchery-reared fish. It was inferred that they were spawned in the stream in the

[1] These observations were made during surveys of Lake Erie tributaries in Erie Countv (N.Y.) to assess natural reproduction of lake-run rainbow trout. The project was funded in part by the New York State Sea Grant, the National Trout and Salmon Foundation, and the New York State Council and Western New York Chapter of Trout Unlimited. The authors wish to thank Sallie P. Sheldon for field assistance, Dr. Douglas P. Dodge for verifying identification of the specimens and Dr. E. J. Crossman for reviewing the manuscript.

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fall of 1975 and thus represented natural reproduction. This conclusion is supported by the fact that the most recent prior stocking of coho salmon in Cattaraugus Creek had occurred nine months earlier (in January 1976) some 40 kilometers downstream from Derby Brook and had consisted of fish 15.0 to 17.0 centimeters in total length (William Shepherd, N.Y.S. Dept. Environ. Cons., personal communication). Also, five adult coho salmon had been observed in Derby Brook during electrofishing operations between mid-October and mid-November in 1975.

The authors believe that this is the first published record of successful reproduction, in terms of hatching, survival and growth, for coho salmon in the Lake Erie drainage of New York. However, in 1969 and again in 1971, personnel of the State Department of Environmental Conservation (unpublished data) found redds and dug up eggs of coho salmon in Clear Creek, another tributary of Cattaraugus Creek in Erie County.

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PUGHEADEDNESS IN A LARGEMOUTH BASS

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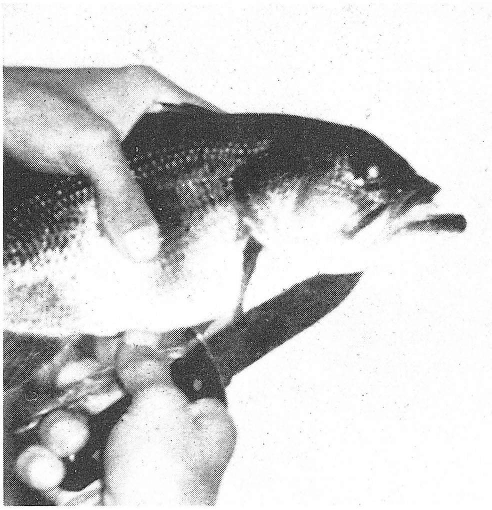
In July 1974, a pugheaded northern largemouth bass (*Micropterus salmoides salmoides*) was taken by angling in Brant Lake in Warren County (N.Y.). Because of its odd appearance, the angler, Mrs. Edward G. Frezon, sent a photograph to the State Department of Environmental Conservation where the abnormality was identified (Kelsey, 1974). Since then the present author, both from the photograph and from interviews with Mrs. Frezon, has compiled additional information concerning this specimen.

The bass measured 13.5 inches in total length and weighed approximately 1.75 pounds. It exhibited a condition index of 7.11 according to the formula of Thompson and Bennett (Bennett, 1962). The pugheadedness apparently did not hinder feeding, since the bass had eaten a golden shiner (*Notemigonus cryoleucas*) about 4.5 inches long and was caught on a shiner fished as live bait.

The bass exhibited the typical pugheaded features of a steep forehead, pushed-in snout and shortened maxilla. But examination of the photograph, as well as conversations with teh angler, did not indicate the condition of exopthalmic eyes usually associated with pugheadedness. However, the angler did note that the tongue was pinkish and seemed thicker than normal, both of which conditions could be observed in the photograph by using a magnifying lens. Herrick (1885) and Mansueti (1960) reported that a pigmented tongue sometimes accompanies pugheadedness. There was no evidence of mechanical injury.

Chew (1973) examined two pugheaded specimens of the Florida subspecies (*M. s. floridanus*), a male and a female, neither of which showed evidence of mechanical injury. Radiographs of both indicated modifications of the frontals, parasphenoid, nasal and vomer. The skull of the female and that of a typical bass of similar size were cleaned and compared, and nearly all the bones of the pugheaded fish were found to be modified to some degree. Unfortunately, the bass from Brant Lake was not available for skeletal examination.



Pugheaded largemouth bass taken in Brant Lake (N.Y.).

However, the author has examined several pubheaded bass taken from other lakes in New York State: one from Glass Lake in Rensselaer County; three from Kinderhook Lake in Columbia County; and three from North Long Pond in Rensselaer County. Pugheadedness was associated with the condition of semi-cross-bite, as reported in striped bass (*Morone saxatilis*) by Hickey et al. (1977), in the bass from Glass Lake and Kinderhook Lake. All these specimens were grouped according to degrees of pugheadedness as described by Hickey et al. (1977). The fish from North Long Pond exhibited primary pugheadedness, while those from the other two lakes exhibited secondary pugheadedness. The photograph of the bass from Brant Lake shows secondary pugheadedness. Hickey et al. (1977) defined primary pugheadedness as a mildly steep forehead only and secondary pugheadedness as:

(1) moderately steep forehead
(2) slight reduction in size of upper jaw, so that lower jaw protrudes beyond upper slightly more than normal
(3) possible malformation of maxilla and premaxilla bones
(4) with or without exopthalmia (bulging eyeballs)

Exopthalmia was not observed in any of the bass examined, and only one exhibited malformation of the premaxilla bones. In none of the fish personally examined by the author was the tongue abnormally thickened or pigmented.

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The *New York Fish and Game Journal* is devoted to presenting the results of research and management studies in New York, and other technical papers on related subjects, that pertain to fish and wildlife problems of concern to the Department of Environmental Conservation. It is published semi-annually and is distributed free to official conservation agencies and scientific institutions. It is also furnished free to selected libraries and conservation organizations in New York State. Others may subscribe at a rate of $1.50 per year or obtain individual issues for 75¢ per copy. Correspondence should be addressed to the Editor Robert W. Darrow, New York State Department of Environmental Conservation Wildlife Resources Center, Delmar, N. Y. 12054.

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