



Rotenone Use in North America (1988–1997)

By William McClay

ABSTRACT

Rotenone has been used as a management tool by fisheries managers for more than 50 years. In recent years, a few projects have resulted in public controversy and in some states, rotenone use has been limited or temporarily prohibited. The American Fisheries Society's Task Force on Fishery Chemicals developed and implemented a Rotenone Stewardship Program for fisheries management using Federal Aid Administrative Funds. An initial survey of fish and wildlife agencies in North America was conducted to determine current trends, restrictions, and issues. The survey accounted for an estimated 87% of the rotenone used. The number of states and provinces using rotenone has changed little since 1949, but the quantity of rotenone used declined during the ten-year survey period of 1988–1997. Manipulation of fish communities to maintain sport fisheries and quantification of fish populations (sampling) were the most common uses of rotenone by North American fish and wildlife agencies. Other important uses included treatment of rearing facilities and eradication of exotic fish. The most important issues facing fish and wildlife agencies using rotenone were public acceptance and understanding of projects and environmental concerns. Responses from the survey were used to develop a manual of administrative and technical guidelines for the safe and effective use of rotenone.

Introduction

Fisheries managers rely on a wide variety of tools for the management and assessment of fish populations to maintain diverse and productive aquatic ecosystems and high quality recreational fisheries. One of the most valuable tools is the piscicide rotenone, which was first used in the United States in 1934 in Michigan (Ball 1948; Lennon et al. 1971; Cumming 1975) and in Canada in 1937 (M'Gonigle and Smith 1938). The use of rotenone as a fisheries management tool is taught in at least 38 of 75 North American colleges and universities that teach fisheries programs and related courses (G. Tichacek, retired, Illinois Department of Conservation, pers. comm.). Techniques for the use of rotenone to sample fish communities and for reclamation and fish control activities are covered extensively by Bettoli and Maceina (1996).

Important uses of rotenone in fisheries management include:

- control of undesirable fish;
- eradication of harmful exotic fish
- eradication of fish in rearing facilities and ponds to eliminate competing species;
- quantification of populations;
- treatment of drainages prior to impoundment;
- eradication of fish to control disease; and
- restoration of threatened or endangered species.

The application of a piscicide is the only method other than complete dewatering that will extirpate entire

populations of fishes. Complete elimination of fish is often needed to accomplish the critical fish management activities of removing predatory exotic species, restoring threatened and endangered species, and controlling fish diseases. Rotenone is the only sampling method that provides for an accurate estimation of standing crop of diverse fish communities.

Despite the importance of rotenone in fisheries management, its continued availability and use are uncertain. Most rotenone treatments have occurred without incident; however, putting any chemical into water, especially one that kills fish, can create controversy.

A small number of treatments have resulted in public controversy. Incidents in California, Colorado, Michigan, and Minnesota resulted in adverse public reaction and negative publicity in the news media. Some of these incidents could possibly have been avoided if the responsible agency had (a) garnered more public input and support prior to treatment and not been in an adversarial role with local communities, (b) done a better job of implementing the treatment with appropriate procedures and qualified personnel, or (c) provided better technical, administrative, legal, and political support. Public relations issues included fish mortalities downstream of the application site and persistence of treatment chemicals in water and air. As a result, the use of rotenone was temporarily prohibited in one state (Michigan) and has been limited in several others.

The use of rotenone is increasingly a concern to environmental and animal rights groups, and the future use of rotenone, even for small projects, has been threatened in several states, most notably New York and California. As more demands are placed on the continent's water

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bodies and the public becomes more environmentally aware, we must respond with guidelines to use rotenone prudently with minimal impacts and controversy.

In 1993, the American Fisheries Society (AFS) Task Force on Fishery Chemicals submitted a proposal to develop and implement a Rotenone Stewardship Program for fisheries management using U.S. Fish and Wildlife Service Federal Aid Administrative Funds. The proposal was accepted for funding in 1997. The first task was to conduct a survey of current uses, issues, and restrictions so the stewardship plan would reflect current knowledge and concerns.

Methods

A detailed questionnaire was sent to fisheries management agencies in all of the provinces of Canada, the states of the United States, the District of Columbia, and to regional U.S. Fish and Wildlife Service offices. The survey was not sent to other federal agencies, universities, private consultants, or private individuals that use approximately 10% of the total sales of raw material (R. Fisher, AgrEvo Environmental Health, Inc., pers. comm.).

Agencies were asked to report rotenone usage (liquid or powder formulation) for the 10-year period of 1988–1997 by type of water body (standing or flowing). They also were asked to identify issues experienced when using rotenone, and indicate what type of information and guidance they needed in a handbook of administrative and technical procedures.

The survey requested information on the weight of powder and volume of rotenone formulations used. It was difficult to compare use among the different formulations (5% powder, 5% liquid, and 2.5% synerized liquid) because of the different percentages of rotenone in each formulation. Therefore total quantities of rotenone in the various formulations were converted to kilograms of active rotenone used. Thus, in this paper, all references to kg of rotenone refer to kg of active ingredient. This allows comparisons of the quantities of rotenone used between the two 5-year periods of the survey (1988–1992 and 1993–1997), among purposes of treatment, and between water types (static and flowing waters), regardless of formulation. The conversion assumes rotenone is 5% by weight in all liquid and powder formulations. Liquid formulations contain either 5% rotenone by weight or 2.5% rotenone by weight with a 2.5% synergist by weight. Powder is generally sold on a 5% rotenone by weight basis. The synergized formulations are used as if they were 5% weight formulations (i.e., the treatment rate is not generally doubled because of the reduced rotenone content). Use data statistics were analyzed with and without the 1990 data for Strawberry Reservoir (Utah) because of the effect this treatment had in skewing the data. This one treatment required 20,000 kg of powdered rotenone, representing 43% of the powder used during the 10 years covered by the survey.

A summary of the results from the survey and their significance are discussed below.

Results

A total of 95 questionnaires were sent to 68 United States and 20 Canadian agencies, the District of Columbia, and 7 U.S. Fish and Wildlife Service offices. A total of 78 (82%) responses were received. Responses were received from 55 state agencies (80%) representing 48 of the 50 states and 15 Canadian agencies (75%) representing 11 of the 12 provinces and territories. Responses were also received from the District of Columbia and seven U.S. Fish and Wildlife Service offices. Several states and provinces had more than one agency respond because of divided management responsibilities. Responses were not received from Arizona, Colorado, or Saskatchewan. Information about the Northwest Territories was included in the response from Manitoba.

Most agencies indicated the data on the quantities of rotenone used for various purposes in standing and flowing waters were reliable and based on verifiable records. However, a few agencies indicated some of their historical records did not allow them to differentiate quantities used for various purposes. Therefore, some of the quantities reported for specific purposes were estimated by the agency.

Scope of use

Of the 78 responding agencies, 48 (62%) reported using rotenone in the last 10 years (1988–1997). Rotenone was used in 37 states (77%) and 5 provinces or territories (42%) during the survey period. Thirty-three of the states and 4 provinces used rotenone as recently as 1997.

Of the 29 responding agencies who did not use rotenone:

- eight were responsible for managing marine environments and indicated rotenone was not effective in systems with tidal and wave currents.
- five agencies indicated they used rotenone 15–20 years ago and had no need to do so now.
- nine agencies did not provide reasons for not using rotenone.
- seven agencies indicated they stopped using rotenone due to in-house policies, administrative requirements,

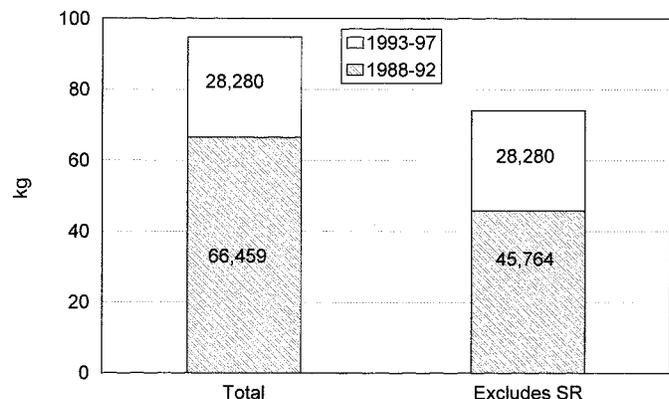


Figure 1 compares quantities of rotenone (kg active ingredient from all formulations) used in the United States and Canada during the two five-year periods of 1988–1992 and 1993–1997. Shown are quantities including and excluding rotenone used in the large 1990 Strawberry Reservoir, Utah (SR), treatment.

or regulations (five), expense (one), or because of environmental concern (one).

Quantities of rotenone used

During the 10-year period, a total of 94,739 kg of rotenone were used (Figure 1). However, 20,695 kg (22%) were used on one project (Strawberry Reservoir, Utah) in 1990 (Figure 1). The treatment of Strawberry Reservoir accounted for 1.4% of the liquid and 42.6% of the powder used during the survey period. Rotenone use declined 57% from the first (1988–1992) to the second (1993–1997) 5-year period of the survey when the amount used in Strawberry Reservoir is included and declined 38% when it is excluded (Figure 1).

The preferred formulation of rotenone used appears to have changed between the two 5-year periods of the survey (Figure 2). Agencies now appear to be placing greater emphasis on the use of powder where practical. The amount of liquid rotenone used declined 65% (35,406 kg to 12,405 kg) from the first to the second 5-year period. The influence of the Strawberry Reservoir treatment on liquid use was minimal.

The amount of powdered rotenone used declined 49% (31,053 kg to 15,875 kg) from the first to the second 5-year period (Figure 2). However this decline is not a true representation of use because the data is skewed by the Strawberry Reservoir treatment in 1990 (in the first 5-year period). This treatment required 20,000 kg of the 31,053 kg of powder used (64%) in the first 5-year period. When the Strawberry Reservoir data is excluded, powdered rotenone use actually increased 44% (11,053 kg to 15,875 kg) from the first to the second 5-year period (Figure 2).

Most of the rotenone (97.5%) used during the survey period was applied to standing water (Figure 3). Of the 92,382 kg of rotenone applied, nearly equal amounts came from liquid (45,644 kg) and powder (46,738 kg) formulations (Figure 3). In flowing waters, 92% (2,167 kg) of the rotenone came from liquid formulations. This difference reflects the inability to effectively use powdered rotenone in flowing waters.

Uses of rotenone

Manipulation of fish communities to maintain sport fisheries was the most common reason for using rotenone (Figure 4). This type of treatment accounted for 42% of the waters treated (2,050 treatments) using 72% (68,944 kg) of the rotenone. Of the 1,838 km of streams treated, 38% (697 km) were treated to maintain sport fisheries, and of the approximately 400 hm³ of standing water treated, 40% (160 hm³) were treated to maintain sport fisheries (Figure 5).

Quantification of fish populations (sampling) was the second most common purpose (Figure 4). This accounted for 31% (1,482 treatments) of waters treated, illustrating the importance many agencies place on this sampling technique. Fourteen of the 37 states (38%) indicated they used rotenone for this purpose. This accounted for 4% (84 km) of the flowing water treated and 6% (23 hm³) of the standing water treated (Figure 5). Although a significant use of

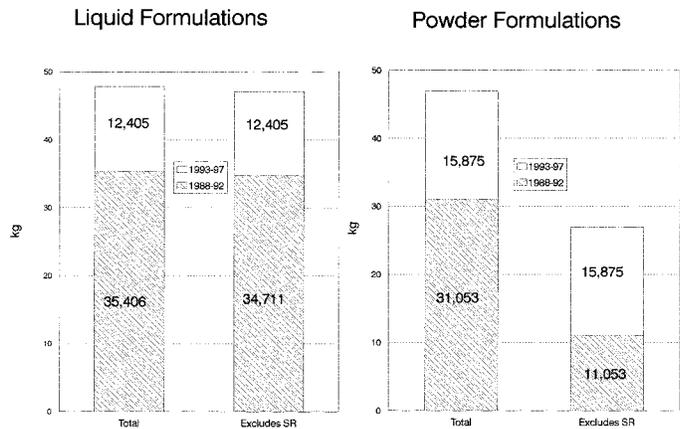


Figure 2 compares quantities of rotenone (kg active ingredient) used from liquid and powder formulations in the United States and Canada during the two five-year periods of 1988–1992 and 1993–1997. Shown are quantities including and excluding rotenone used in the large 1990 Strawberry Reservoir, Utah (SR), treatment.

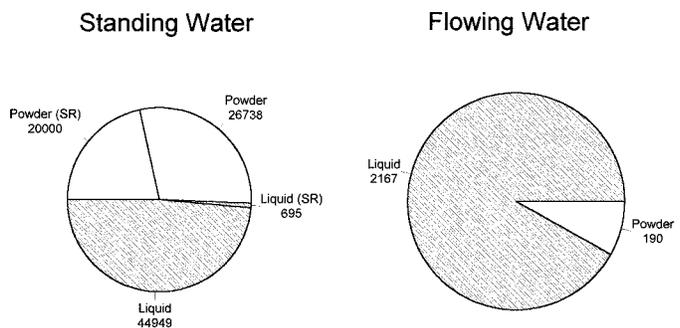


Figure 3 compares quantities of rotenone (kg active ingredient) used from liquid and powder formulations in standing and flowing waters of the United States and Canada during the period of 1988–1997. Shown are quantities including and excluding rotenone used in the 1990 Strawberry Reservoir, Utah (SR), treatment.

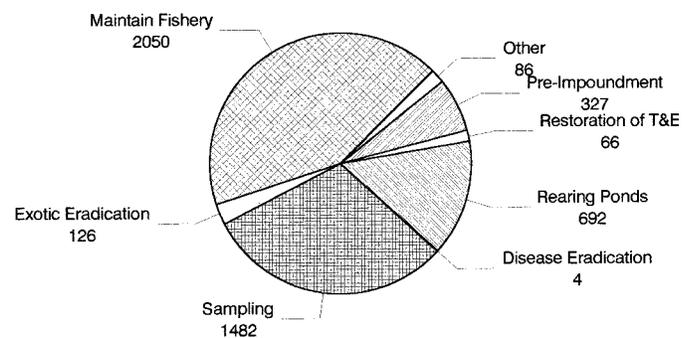


Figure 4 compares the number of rotenone treatments by objective conducted in the United States and Canada during the period of 1988–1997.

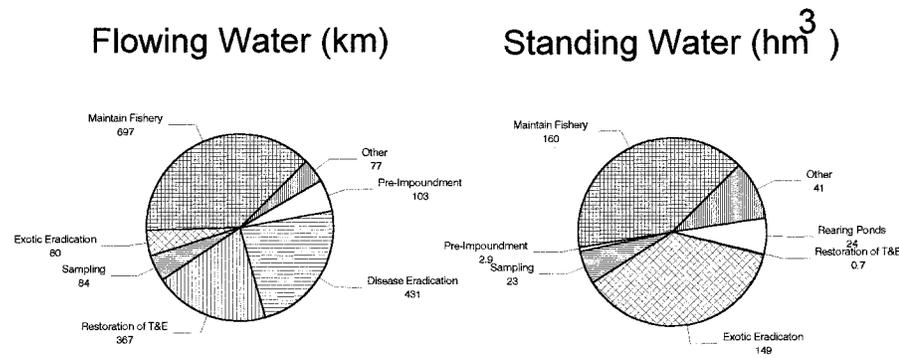


Figure 5 compares the length (km x 1,000) of flowing water and volume (hm³ x 1,000) of standing water treated with rotenone by objective in the United States and Canada during the period of 1988–1997.

rotenone in terms of the number of waters treated, the volume of water treated and quantity of rotenone used (2,114 kg) were minimal, indicating the treatments were small.

The treatment of rearing facilities or rearing ponds ranked third in terms of the number of waters treated (Figure 4). Rearing facilities and rearing ponds represented 14% (692 treatments) of the total number of waters. Many states did not provide actual numbers even though estimates of volume treated and gallons used were provided. Twelve of the 31 states (39%) indicated they used rotenone for this purpose. The volume of water treated was small (24 hm³) compared to other purposes for treating standing water (Figure 5).

Treatments aimed at the eradication of exotic fish ranked fifth (126 treatments) in terms of the number of waters treated (Figure 4), but ranked second (149 hm³) in terms of the total amount of standing water treated (Figure 5) and used 18% (17,219 kg) of the rotenone.

Rotenone treatment procedures

Agencies were asked to respond with a “yes” or a “no” to questions on whether they used specific treatment procedures (Table 1). The majority indicated that permission was required to use rotenone, that they detoxified with potassium permanganate, but that chemical monitoring was not performed.

Table 1 lists the treatment procedures that fish and wildlife agencies in the United States and Canada use for rotenone. Not all responses total 100% because not all agencies answered all questions.

Treatment procedure	# of agencies	Yes %	No %
Government permit/permission required	48	81	19
Detoxify with potassium permanganate	46	72	21
Environmental impact analyses/assessment	48	48	52
Effectiveness and impacts monitored:			
With bioassay	48	42	58
With water samples for chemical analysis	45	25	69

Regulation of rotenone

Rotenone is not regulated by the agencies that use it. Of the 37 states using piscicides, the majority are regulated by a state department of agriculture or by a state environmental agency. All five Canadian provinces or territories using rotenone are regulated by an environmental agency.

Issues related to rotenone

Agencies were asked to respond with a “yes” or a “no” to a series of questions relating to specific issues that have arisen in the past 10 years (Table 2). Collection and disposal of dead fish and impacts of rotenone on public health were the two most numerous issues mentioned.

Other less frequently listed issues included: (a) killing of game fish and public perception about piscicide use; (b) U.S. Forest Service ban on the use of piscicides; (c) cattle grazing near treated water; (d) registration; and (e) loss of use as a survey technique.

Most important issues facing users of rotenone

Agencies using rotenone were asked to provide their view of the two most important issues facing users of rotenone. Thirty-nine of the 49 agencies responded by citing 83 different issues. Many agencies cited the same or similar issues. These issues were grouped into eight categories based on their similarities (Table 3). Agencies overwhelmingly identified public acceptance and understanding, environmental concerns, and “usability” of the product as the most important category of issues confronting them.

Public acceptance and understanding of rotenone use was the most frequently mentioned issue category. Issues most often mentioned were a lack of public knowledge and understanding of the management decisions that led to rotenone treatments, the purpose of the project, and the beneficial uses of rotenone. Also mentioned frequently was a lack of public acceptance for using chemicals in the water and for killing fish. Agencies cited complications arising when opposition groups became organized, secured financing, and mounted legal challenges.

Environmental concerns were the second-largest issue category. These issues had their origins from both the public sector and from those governmental agencies with management responsibilities. One frequently mentioned environmental concern focused on biodiversity-related decisions that led to (a) single-species management (e.g., waters managed for trout only), (b) management directed toward quality sport fish populations (as opposed to “non-managed waters”), or (c) management directed toward threatened and endangered species. Other environmental concerns focused on the impacts (real or perceived) of rotenone treatments on nontarget species such as invertebrates, mussels, amphibians, and those wildlife and

domestic animals which may eat fish killed by rotenone. "Usability" of rotenone was the third-largest issue category. Issues included restrictions on use due to labeling, legislative mandates or policy, restrictions placed on use for sampling, registration costs, and economics (agency budgets and cost effectiveness).

The fourth issue category included issues related to general toxicology, general public health, carriers and inert ingredients, and drinking water safety.

The remaining four issue categories (and major issues) were (a) availability of the product (especially relicensing and reregistration of the liquid formulation), (b) animal rights, (c) methods (stream treatments, effective detoxification, and effective use in population management and assessment), and (d) miscellaneous issues such as public distrust of state and federal agencies, documentation and control of use, lack of specific, useful, and practical information on impacts of treatments, proper training for applicators, and project goals being met for extended periods of time.

Requested information and guidance

Twenty-six of the 49 agencies made suggestions for the type of information and guidance they desired in a handbook of administrative and technical procedures. The suggestions have been grouped into the following broad categories:

- Background information—(a) regulatory history; (b) national policy on the use of rotenone; (c) definitions of "restricted use chemical"; (d) literature sources; and (e) role of federal agencies in state projects.
- Environmental information—(a) short-term and long-term impacts; (b) minimizing impacts on nontarget species; (c) long-term effectiveness of rotenone treatments to assist in preparing environmental documents; (d) sensitivities of various species to rotenone; and (e) water quality, persistence, and degradation.
- Legal considerations—(a) who can legally purchase and use rotenone; and (b) legal considerations for fish disposal, use and disposal of rotenone and their containers, and public notification.

Table 2 lists the rotenone-related issues that fish and wildlife agencies in the United States and Canada have addressed during the ten-year period of 1988-1997. Not all responses total 100% because not all agencies answered all questions.

Issue	# of	Yes	No
Collection and disposal of dead fish	48	48%	52%
Impact of rotenone (or other ingredients) on public health	46	42%	54%
Impact of rotenone (or other ingredients) on surface or ground water quality	47	31%	67%
Adequate public notification and education	47	31%	67%
Animal welfare—fish	47	31%	67%
Animal welfare—wildlife	46	29%	67%
Impact on invertebrates	47	27%	71%
Piscicide residues in fish	46	21%	75%
Liability and property damage	46	15%	81%
Impact of rotenone (or other ingredients) on air quality	47	8%	90%
Other issues (see text)	44	13%	79%

Table 3 lists in order of frequency the rotenone related issue categories that fish and wildlife agencies in the United States and Canada considered important.

Issue category	Rank
Public acceptance/understanding	1
Environmental concerns	2
Usability of the product	3
Public health/toxicology concerns	4
Availability of the product	5
Animal rights/welfare concerns	6.5
Miscellaneous	6.5
Methods/techniques	7

- Management considerations—(a) when is rotenone the best management choice; (b) description of practical uses; (c) appropriate uses; and (d) alternative methods.
- Public health information—(a) impact to applicators and the general public; (b) assessment for human and animal exposure; (c) cancer risk; (d) fish consumption; and (e) contact with treated water.
- Public information—(a) dealing with anti-fish-treatment public; (b) public relations strategies that will garner support or minimize opposition; (c) public information on the use of rotenone as a management tool; and (d) dealing with animal rights activists.
- Technical information—(a) safe handling, storage, shelf life, and disposal; (b) effective concentrations; (c) application and detoxification procedures; (d) bioassay methods for determining toxicant level; (e) chemical analysis methods; (f) influence of environmental factors on application and detoxification effectiveness; (g) selectivity and application rates; (h) methods for reservoir fish population assessment; (i) new designs for applying powdered rotenone; (j) application rate table for specific concentrations and flows; and (k) procedures for fish disposal.

Discussion

The present survey primarily targeted state and provincial fisheries agencies. The survey was also directed to the regional offices of the U.S. Fish and Wildlife Service, but not all uses were reported (i.e., use on refuges and by Cooperative Fishery Units). Additionally, numerous states reported that other federal agencies used rotenone, including the Tennessee Valley Authority, U.S. National Park Service, and Bureau of Land Management. It was also learned that some Native American tribes use rotenone on reservation lands. However, rotenone use by these agencies, consultants, and other entities was assumed to be a minor component of

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Joel Trumbo



A California Department of Fish and Game fish biologist checks the delivery of rotenone into Silver King Creek, Carson-Iceberg Wilderness Area, Toiyabe National Forest, during a treatment for the restoration of Paiute cutthroat trout (*Oncorhynchus clarki seleniris*, federally listed threatened) in 1993.

overall use. Sales data showed that AgrEvo Environmental Health, Inc., which captures about 85% of the piscicide market (Fisher, pers. comm.), sold approximately 13% of their product to federal agencies, consultants, and other groups not included in the survey. Thus, the agencies surveyed accounted for about 87% of the total piscicide market for rotenone.

The use of rotenone as a piscicide in North America is as widespread today as ever even though the quantity used has declined. In the 10 years between its first use in 1934 (in Michigan) and 1949, 34 states reported using rotenone (Solman 1950). A United Nations-sponsored report on world use of rotenone revealed that by 1970, 39 states (and two provinces) had used rotenone to reclaim waters (Lennon et al. 1971). A later survey covering the period 1970–1974, targeted exclusively at the state and territorial fisheries agencies of the United States, determined

that 49 states used rotenone (S. B. Penick & Company, unpublished data, 1974).

In 1987 the rotenone supplier, AgrEvo Environmental Health, Inc., conducted a telephone survey of United States and Canadian fisheries agencies to estimate market size; however, no data on actual use were collected. A review of the data sheets from that survey revealed that 37 states and three provinces were current users of rotenone.

The present survey suggests that the quantity of rotenone used is continuing to decline, although the number of states using rotenone has changed little since 1949. Thirty-seven states (and five provinces or territories) used rotenone, which continues the 50-year trend where 35 states have historically utilized rotenone as a fisheries management tool. However, since 1974, major users of rotenone (> than 50 kg annually) have declined. Thirty-four states were major users in 1974 (S. B. Penick & Company, unpublished data, 1974), but this survey showed a decline to 25 states (and two provinces) in 1987 and a further decline to 14 states (and one province) in 1997. Quantities of rotenone used also declined during the survey period. Rotenone use declined 57% from 1988–1992 to 1993–1997. When the rotenone used in Strawberry Reservoir is excluded, use declined 38% between the two 5-year periods. Bettoli and Maceina (1996) also noted decreasing use of rotenone for sampling and reclamation of fish populations.

Despite this decline, rotenone continues to be an important management tool for most fisheries agencies in North America, and its use as a fisheries management tool continues to be taught in many colleges and universities. Nearly 95,000 kg of rotenone (liquid and powder formulations) were used during the 1988–1997 period. Managers appear to be placing greater emphasis on the use of the powder formulation, particularly for treating standing waters. This trend is probably due to the reduced cost and improved distribution techniques for the powder formulation, as well as increased environmental and public health concerns for

the inert ingredients contained in liquid formulations. Although liquid formulations have been proven safe for use, some agencies have found it more difficult to plan and execute treatments using these formulations because of demands for environmental monitoring studies not normally required for projects that utilize the powder formulation.

Agencies responding to the survey provided their perception of the major issues in using rotenone. They overwhelmingly identified public acceptance and understanding of rotenone use, environmental concerns, and continued usability of the product as major issues. A common theme to many of the issues cited was the lack of public knowledge and understanding of the management decisions which led up

Charlie Thompson



A Utah Division of Wildlife Resources biologist pumps a slurry of powder rotenone from a barge into Strawberry Reservoir during a treatment for control of Utah chub (*Gila atraria*) and Utah sucker (*Catostomus ardens*) in 1990.

to rotenone treatments, the purpose of the project, and the beneficial uses of rotenone. In spite of this recognition, only 48% indicated that they performed environmental impact analyses or assessments on proposed projects.

To overcome these issues, agencies must do a better job of communicating project objectives and environmental trade-offs to the public. For example, public support for renovating a fish community may be generated when managers can demonstrate that the current community is the result of human-induced perturbations and that the only alternative is complete renovation. Further, the public often does not understand that some short-term losses may be offset by long-term benefits including, but not limited to, many years of improved angling opportunity.

In response to the request by agencies for more information and guidance on the use of rotenone, a manual was developed (Finlayson et al. 2000) which will assist fisheries managers by providing administrative and technical guidelines for the safe and effective use of rotenone. Emphasis is placed on planning and public involvement commensurate with the scope of the project. There are also plans for a public information program to educate the public on the benefits and risks of rotenone use. An electronic information system for fisheries biologists that will provide up-to-date information on current use restrictions, experts in the use of rotenone, important issues and solutions, and the registration status of rotenone are also under development. 

Acknowledgments

Brian Finlayson, chair of the AFS Fish Management Chemicals Subcommittee, and Rosalie Schnick, chair of the AFS Task Force on Fishery Chemicals, organized the Rotenone Stewardship Program, secured funding, developed the initial draft of the survey, and reviewed the manuscript.

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