# ROTENONE REVIEW ADVISORY COMMITTEE FINAL REPORT AND RECOMMENDATIONS TO THE ARIZONA GAME AND FISH DEPARTMENT

December 31, 2011

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**In Memory of Hugh Holub**

Hugh Holub was an active member of the Rotenone Review Advisory Committee until his untimely death in September of 2011. He spent numerous hours reviewing studies on rotenone, communicating with experts, candidly clarifying the concerns of people in Southern Arizona and sharing that information with the Committee. Throughout his adult life he was the voice of reason for issues in “Baja Arizona”, using humor and satire to emphasize his position. He will be sorely missed.

## Executive Summary

The use of rotenone as a piscicide in Arizona prompted concerns over the potential human health and ecological impacts that may result from rotenone exposure, and resulted in proposed state legislation (50th Legislature, 1st regular session in 2010: 2010: S.B. 1294; H.B. 2114) that would have significantly limited the Arizona Game and Fish Department's (AGFD) ability to use rotenone in the future. In June 2011, the AGFD Director authorized the Rotenone Review Advisory Committee (Committee) to advise and make recommendations to the Director, and through him the Arizona Game and Fish Commission, with respect to matters within the areas of its members experience and expertise regarding the use of rotenone and other piscicides for Arizona fisheries and aquatic wildlife management. In that regard, the Committee's purpose was to review reports and research gathered by the Department and Rotenone Review Advisory Committee's - organized Subcommittees, to gather input from other experts contacted by the Committee and Subcommittees, and to provide technical expertise, opinion, and analysis regarding the use of rotenone and other piscicides in the following areas:

- Subcommittee 1: Current State and Federal Regulations, Internal Policy, Public Involvement, and Best Management Practices
- Subcommittee 2: Human Health and the Environment
- Subcommittee 3: Alternate Management Strategies
- Subcommittee 4: Recreation, Economic and Social Impacts

The Subcommittee's worked separately to provide technical expertise, opinion, and analysis in their subject areas, resulting in a final report and set of recommendations for the Committee's consideration. The Committee's product was to provide a final set of written recommendations to the Director. In making its recommendations to the Director, the Committee considered the best available science and expertise regarding the use of rotenone and other piscicides and the potential impacts due to changes in current practices, policies or regulations in the areas referenced above.

The Committee held meetings in Phoenix, Arizona on June 22, August 30, November 1, and November 21, 2011. The Subcommittees met numerous times during July, August, September, and October 2011. The Subcommittee's presented their final reports and recommendations to the Committee on November 1. On November 21, the Committee approved the final recommendations and presented them to the Director.

## Final Recommendations Approved by the Rotenone Review Advisory Committee

1. The Arizona Game and Fish Department (AGFD) Commission should formally adopt the Rotenone Standard Operating Procedures (SOP) Manual (Finlayson et al. 2010) as the minimum mandatory standard for the planning and implementation of rotenone piscicide projects in Arizona. All AGFD piscicide applications of rotenone in Arizona should be consistent with U.S. Environmental Protection Agency labeling requirements, appropriate state and federal laws and regulations, and the Rotenone SOP manual (Finlayson et al. 2010). **–ADOPTED, no dissent**

2. The AGFD should develop a public awareness or involvement plan during the development of each piscicide project with consideration of the following factors: stakeholder involvement, the potential for human, non-target species and ecological exposure, the sensitive nature of the project, and the concerns of the public expressed during the public outreach process. Elected and appointed officials that represent the public in the project area should be briefed and invited to participate in the public awareness process as appropriate. **– ADOPTED, no dissent**

3. The AGFD should develop a project specific operating protocol when there is a known or suspected direct hydrologic connection with groundwater wells and rotenone treated water within the project area as required in the Rotenone SOP Manual (Finlayson et al. 2010). This would include an appropriate monitoring plan and a mitigation plan to reduce rotenone levels to 40 ppb or lower or providing alternative water supply as appropriate. **–ADOPTED, no dissent**

4. The AGFD should make certain that the rotenone or other piscicide application project supervisors have received American Fisheries Society or National Conservation and Training Center Piscicide Training and all rotenone or other piscicide application project personnel have undergone appropriate training for their level of involvement on handling the chemical and minimizing the human and non-target species exposure. **–ADOPTED, no dissent**

5. The AGFD should make sure the public and elected or appointed officials in Arizona have ready access to the Final Rotenone Review Advisory Committee Report, Executive Summary, and updated Frequently Asked Questions developed as a result of the Committee's research. **–ADOPTED, no dissent**

6. The AGFD should use potassium permanganate (or other approved oxidizers) to neutralize rotenone or other piscicide treated water at the downstream end of the treatment area in all flowing water applications to maintain control of the treatment and minimize exposure outside of the treatment area. **–ADOPTED, no dissent**

7. The AGFD should monitor the scientific literature related to rotenone or other piscicides and their potential impacts on human health and the environment and periodically communicate with the U.S. Environmental Protection Agency to ensure that its policies and practices account for any advances in knowledge about the risks posed by piscicide use or ways to minimize exposure to humans and the environment. **–ADOPTED, no dissent**

8. The AGFD should recognize the recreation, economic, and social value of having rotenone as a tool to manage fish populations. The AGFD should also recognize the very limited number of alternatives available to accomplish fisheries management goals and objectives where full eradication of fish species from a water body is necessary. Considering these factors, the AGFD should have the ability to use rotenone in a manner consistent with the product label and Rotenone Standard Operating Procedures Manual (Finlayson et al. 2010), which will minimize impacts to the environment, and avoid impacts to human health and drinking water supplies. **–ADOPTED, no dissent**

9. The AGFD should have the ability to use other registered piscicides provided they can be applied in a safe manner that minimizes impacts to the environment, and avoids impacts to human health and drinking water supplies. Other registered piscicides should continue to be available for use as a fisheries management tool in Arizona considering the limited options available for full eradication and removal of fish species. **–ADOPTED, no dissent**

10. The AGFD should adopt the revised piscicide treatment process as developed by the Regulations Subcommittee to include the following key changes or additions to process steps:
    - Incorporate the Rotenone Standard Operating Procedures (SOP) Manual (Finlayson et al. 2010) as an absolute minimum procedure for all piscicide projects.
    - Initiate, maintain, and document public scoping (for both support and opposition), engagement, and coordination early in the project planning process and through project development and implementation (also per SOP).
    - Thoroughly evaluate other methods of fish removal prior to decisions on piscicide use.
    - Incorporate the legally-required Arizona Pollutants Discharge Elimination System permit process into the AGFD piscicide treatment process which requires a General Permit for treatments from the Arizona Department of Environmental Quality (ADEQ) (for applicable waters).
    - Incorporate the Arizona Game and Fish Commission public review and appeals process for proposed piscicide treatments. **–ADOPTED, no dissent**

11. The AGFD should establish firm criteria to define situations that justify piscicide treatments on an emergency rapid response basis and add this step to the revised process for AGFD piscicide treatments. **–ADOPTED, no dissent**

12. The AGFD should review and revise the piscicide treatment process as necessary to maintain safe, effective, and responsible application of piscicides. **–ADOPTED, no dissent**

13. The AGFD should implement a National Environmental Policy Act Environmental Impact Statement for all proposed piscicide treatments in Arizona. **–WITHDRAWN FROM CONSIDERATION AFTER DISCUSSION**

# CHAPTER 1. STATE AND FEDERAL REGULATIONS, INTERNAL POLICY, PUBLIC INVOLVEMENT, AND BEST MANAGEMENT PRACTICES SUBCOMMITTEE FINAL REPORT

**Prepared for the Rotenone Review Advisory Committee by:** Subcommittee Chair: Larry Riley, Arizona Game and Fish Department; and Subcommittee Members: Ben Alteneder, Arizona Wildlife Federation; Mike Fulton, Arizona Department of Environmental Quality; Chuck Graf, Arizona Department of Environmental Quality; Hugh Holub (Deceased), Patagonia; Jack Peterson, Arizona Department of Agriculture; Robert Shuler, Shuler Law Firm; Jeff Sorensen, Arizona Game and Fish Department; Steve Spangle, U.S. Fish and Wildlife Service

## Executive Summary

The State/Federal Regulations, Internal Policy, Public Involvement, and Best Management Practices (BMPs) Subcommittee was charged with reviewing and documenting the relevant regulations, policies, and best management practices that govern the application of piscicides (pesticides used for fish eradication) by the Arizona Game and Fish Department (AGFD). Other subcommittees focused on potential issues of concern associated with the use of these products, human and environmental health and safety implications, and alternative tools for the control or eradication of fishes. This subcommittee focused on the current and foreseeable regulations governing the use of piscicides, the current policies and processes used by the AGFD as it conducts piscicide projects, the conformance of those projects with regulations, and the identification of possible gaps and recommendations that could improve the AGFD's processes for implementing piscicide projects.

The subcommittee found that the AGFD's current process for planning and implementing piscicide projects was designed around the existing governing regulations, and conformed to those requirements. New regulatory processes for approving and reporting pesticide discharges through Arizona Department of Environmental Quality (ADEQ) and new rotenone labels expected in 2012 that will advise applicators to use the Rotenone Standard Operating Procedures (SOP) Manual (Finlayson et al. 2010) in order to conform to the labels require the AGFD to amend its current process. The subcommittee also identified opportunities for improvement to the current process to enhance public involvement and provide clear avenues for the public to express any concerns about proposed piscicide applications by AGFD and seek remedial action.

The subcommittee identified the relevant regulations and policies pursuant to the application of piscicide projects (Table 1). The subcommittee identified 11 gaps or opportunities for improvement in the AGFD's current process, and offered specific recommendations to improve each gap (Table 2). The AGFD's current process and the subcommittee's recommendations for a revised process are illustrated in Table 3.

## Subcommittee Charge

The subcommittee was charged with reviewing and documenting the relevant regulations, policies, and BMPs that govern the use of pesticides designed and used for the control or management of fishes (piscicides). The AGFD selectively utilizes piscicides (i.e., pesticides specifically labeled under the Federal Insecticide, Fungicide, and Rodenticide Act [FIFRA] for removal of fish) in fisheries management activities. These fisheries management activities may address:

- The removal of a fish assemblage that is not desired in a specific location for possible replacement to restore a native assemblage of aquatic wildlife.
- The removal of a target species of fish as a rapid response to an invasive species infestation that poses a risk to human health or safety, to Arizona's wildlife resources, or to Arizona's economic well-being.
- The removal of a fish assemblage that is not desired in a specific location for possible replacement to restore a valued sport fishing economic resource.

By far, the first of these management activities is the most common. These activities are usually restricted to headwater locations (small streams) or isolated bodies of water.

The subcommittee reviewed the regulatory setting for the use of these tools, including the current governing regulations and foreseeable new regulations. The subcommittee also reviewed the AGFD's guiding policies and process in light of the governing regulations and recommended process improvements in the form of a revised process.

The Regulatory Setting

Aquatic wildlife is identified by state statute as property of the state (A.R.S. 17-102). By law (A.R.S. 17-301.C; 17-301.D; and 17-301.D.4), the use of pesticides (or poisons) for taking aquatic wildlife on public lands is prohibited except by the AGFD under the guidance of the Arizona Game and Fish Commission. This restriction applies to all individuals, organizations, and agencies (federal, state, and local). The AGFD works with partner agencies and organizations that may have a fisheries management goal that involves removal and or replacement of an existing population of fish or fish assemblage; and insists on presence and leadership in any application of a pesticide to achieve a fisheries objective. There are possible exceptions: private, isolated ponds or tanks on private lands where the landowner may use piscicides to manage their non-federally listed fish, and on Native American Tribal lands which are sovereign and they have their own authorities to manage fish on Tribal lands. On joint projects, such as Apache trout recovery, the AGFD works closely with Tribal biologists and managers to conduct piscicide treatments in areas that share connected waters. We are unaware of any instances where piscicide treatments have occurred in the state without the direct involvement and guidance of the AGFD in recent years.

Pesticides are evaluated, registered, and labeled for use by the U.S. Environmental Protection Agency (EPA) under FIFRA. There are two pesticide formulations that are registered by the EPA for fish removal, rotenone and antimycin-A. Both products were recently exhaustively reviewed by EPA to determine their eligibility for reregistration, and both were reregistered as restricted-use pesticide for piscicide use in 2007. As restricted-use pesticides, each chemical can only be acquired and applied by (or under the supervision of) applicators certified by the State. The AGFD certifies its applicators through the Arizona Department of Agriculture, and supplements training for applicators though coursework provided through the National

Conservation Training Center operated by the U.S. Fish and Wildlife Service and/or through equivalent training by the American Fisheries Society.

While the two basic active ingredients – rotenone and antimycin-A – are labeled for use, antimycin-A is no longer commercially available. Thus, antimycin-A applications are limited at the current time and are based on small supplies currently held in inventory by some state and federal fish and wildlife service agencies. Only Rotenone formulations are currently available for purchase.

Much of the fisheries management work of the AGFD occurs on public lands with public funds. Actions on federal lands or using federal grant monies trigger decision making processes allied with those federal partners. As a result, the AGFD uses decision-making processes that are predicated on the National Environmental Policy Act (NEPA) which link in most instances with evaluations under the Endangered Species Act (ESA), the National Forest Management Act, and the Federal Lands Policy Management Act. A listing of the governing regulations, policies, and practices is presented in Table 1.

Table 1. Regulations and Policies identified by the State/Federal Regulations, Internal Policy, Public Involvement, Best Management Practices Subcommittee, October 2011.

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| **Policies and regulations relevant to piscicide applications in Arizona:**<br>National Environmental Policy Act (NEPA), 1969; CEQ Guidelines, 40 CFR (1502.16 part e);<br>Section 7, Endangered Species Act (ESA) of 1973, as amended;<br>Executive Order 11987, Exotic Organisms; Executive Order 13112, Invasive Species; and 50 CFR 92;<br>Federal Insecticide, Rodenticide, and Fungicide Act (FIFRA) of 1970 (CFR Title 40);<br>Clean Water Act (CWA) amendments of 1977, (P.L. 95-217);<br>ADEQ standards (Arizona Administrative Code Title 18, Ch 11(401));<br>Arizona Pesticide Contamination Prevention Program (ARS 49-301 through 310 and ACC R18-6-101 through 303);<br>Aquifer Protection Permit Program (ARS 49-241 through 252 and ACC R18-9-101 through 303);<br>Arizona Pollutants Discharge Elimination System (AZPDES) (ARS 49-255 through 265 and ACC R18-9-A901 through D905);<br>Title 17 Game and Fish, Chapter 3 Taking and Handling Wildlife (ARS 17-301);<br>Occupational Safety and Health Act (OSHA) (CFR 1155 Title 29) |
| **Additional policies relevant to piscicide applications on Forest Service or Bureau of Land Management lands:**<br>National Forest Management Act (16 USC §§ 1600-1614);<br>Wild and Scenic Rivers Act (P.L. 90-542)<br>Wilderness Act (P.L. 88-577)<br>National Trails Act (P.L. 90543);<br>Bureau of Land Management district specific Resource Management Plan (RMP) |

A thorough review of the AGFD's piscicide treatment processes and how the relevant current regulations and policies guides that process is provided in the document "Use of Piscicides in Arizona" in Appendix A. The subcommittee recognized that the AGFD's existing process for piscicide application treatments is formed around regulations, requirements, policies, and guidance available prior to November 1, 2011 and determined that it was adequate for that purpose.

Improving the Arizona Game and Fish Department's Current Process

The subcommittee focused its limited time and attention on steps that could be taken to improve the AGFD's current process. Identification of improvement opportunities was guided by reasonably foreseeable modifications to federal and state regulations and requirements, and by suggestions keyed to enhancing public involvement and engagement in the AGFD's process.

Two reasonably foreseeable modifications to state and federal regulations and requirements regarding the use of these pesticides are on the immediate horizon. The reregistration eligibility determinations (US EPA 2007a, b) will result in modifications to the labels for the products with the piscicidal active ingredients. Label directions for pesticide use must be followed by applicators, and failure to follow label directions on the part of an applicator is a violation of federal law. The labels for rotenone products, once finalized with EPA, will require that applicators follow the guidance within the Rotenone SOP Manual (Finlayson et al. 2010) that were developed in partnership among the American Fisheries Society, and the product registrants, in order to conform to the labels. The Rotenone SOP Manual (Finlayson et al. 2010) provides important guidance on the safe and effective use of rotenone and the subcommittee recommended its immediate adoption by the AGFD.

Further, as a result of a recent court order (U.S. Cotton Council v. EPA, 2009), the EPA and states with delegated authority under Section 402 of the Clean Water Act have developed General Permits for the discharge of Aquatic Pesticides. The Arizona Department of Environmental Quality (ADEQ) has developed an Arizona Pesticide General Permit that became effective on October 31, 2011. The Arizona General Permit is guided by the template developed by the EPA:

- Permit coverage is required for treatments on all "Waters of the United States".
- The permit does address the use of piscicides.
- The permit coverage is threshold driven, based upon surface area or linear measure of stream to be treated.
- Virtually all of the treatments conducted by the AGFD would require coverage under the General Permit.

Based upon this emerging requirement for coverage under the Arizona Pesticide General Permit for discharge of piscicides to Waters of the United States, the subcommittee recommended immediate adoption of the requirements and integration into the AGFD process.

The subcommittee analyzed the AGFD's current process for the application of piscicides looking for opportunities to increase public involvement and engagement. The intention was to identify opportunities early on in the planning process to engage the public and seek out their issues and concerns about any proposed treatments, opportunities to inform the public on impending decisions regarding piscicide treatments, and identify the opportunity for the public to appeal an AGFD decision to the Arizona Game and Fish Commission if they had persisting concerns.

To identify opportunities for improvement, the subcommittee evaluated the AGFD's current process and identified gaps or places where improvements could be inserted. The gaps were refined into findings of the subcommittee, and corresponding recommendations were formulated. The subcommittee's identified gaps, findings, and specific recommendations are summarized in Table 2. The recommendations were incorporated into the current process map, and a proposed revised process map was generated as a part of the subcommittee's recommendations to the Rotenone Review Advisory Committee.

Table 2. Gaps or opportunities for improvement identified by the State/Federal Regulations, Internal Policy, Public Involvement, Best Management Practices Subcommittee during their meetings in October 2011; and corresponding recommendations on a revised process to the Rotenone Review Advisory Committee (see Table 3; Revised Process for AGFD Piscicide Treatments).

| Gap or Opportunity | Finding | Recommendation |
|---|---|---|
| Emergency response: There is no process step in recognition of possible emergency conditions that may need rapid response. Rapid response (if sufficiently justified by circumstances that pose risks to human health or safety, risk of extirpation of a rare species, or significant damage to Arizona's Economy) may circumvent some public engagement. | Emergency Treatments as rapid responses to invasions by unwanted or invasive aquatic species are not incorporated into the current process. Criteria should include risks to human health or safety posed by invasions, environmental risks associated with extreme threat of extirpation of a rare species, or risks to Arizona's economic well-being. | Anticipate and incorporate process steps for piscicide treatments that are justifiable as emergency rapid responses. Establish firm criteria to define situations that justify an emergency rapid response. [Revised Process Step 3] |
| One-on-one engagement of the public: While one-on-one meetings to determine issues, concerns, and opportunities with landowners, permittees, and downstream users have been occurring in the current process, they have not been formally recognized as a public engagement process. | While the current process requires engagement with landowners, permittees, and downstream users in individual contacts, it fails to recognize and document this as a formal step in the public engagement process. | Document the existing process step as a component of the public engagement process in the Revised Process. Maintain records in piscicide treatment 'project' file documenting contacts and issues, concerns, and opportunities identified. [Revised Process Step 7][Per SOP] |

| Gap or Opportunity | Finding | Recommendation |
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| | | |
| Integration of ADEQ Pesticide General Permit (PGP) Process: Need to integrate notification process for PGP Notice of Intent (NOI). | ADEQ completed the PGP as required in the court order in the case of U.S. Cotton Growers v. EPA. The PGP went into effect on October 31, 2011. No process step currently documents the emerging need to file a NOI[1], when applicable, to conform to the PGP process. | Implement process steps in the Revised Process for conformance with PGP Requirements (NOI) for treatments in appropriate waters. Process steps should require submission of those PGP materials as required under the General Permit; and they should be retained in AGFD project files whether required for submission or not. [Revised process step 9] |
| | No process step currently recognizes the need to develop and maintain a Pesticide Discharge Management Plan (PDMP), when required, to conform to the PGP process. | Implement process steps for conformance with PGP Requirements (PDMP[2]). Process steps require submission of the PDMP as required under the Pesticide General Permit, and to be retained in the AGFD project files whether required for submission or not. [Revised process step 9] |
| | No process step currently recognizes the need to maintain application records to conform to the PGP process. | Implement process steps for conformance with PGP requirements (record keeping). [Revised process step 30] |

[1] The NOI is not deemed a public notification process per se. It notifies ADEQ of a proposed action and a request for coverage under the General Permit. General Permits are issued because these actions are deemed, as a class, to have limited impacts that do not justify an individual permit (Chris Henninger, ADEQ, personal communication, 2011). Note that, in its review of an NOI, ADEQ could deem an action to exceed the level of impact considered justifiable under a General Permit and require alternative permitting.

[2] NOIs and PDMPs are required for Treatments in "Waters of the U.S." as defined by the Water Pollution Control Act (Federal Clean Water Act), and based on thresholds defined in ADEQ's PGP. ADEQ may not accept such records where not indicated or required by the PGP. Recommendations of this subcommittee include development and retention of such materials in project files, even if not required for submission.

| Gap or Opportunity | Finding | Recommendation |
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| | No process step currently recognizes the need to provide annual reporting to ADEQ to conform to the PGP process. | Implement process steps for conformance with PGP requirements (annual reporting). [Revised process step 30] |
| Integration of Rotenone Standard Operation Procedures (SOP) Manual (Finlayson et al. 2010): the current process does not incorporate some process steps identified in the Rotenone SOP Manual. | The current process has not incorporated steps associated with the soon to be label-recommended Rotenone SOP Manual. | Immediately adopt and incorporate the Rotenone SOP Manual as an absolute minimum and mandatory procedure for all piscicide treatment projects. [Revised process steps 2, 4, 5, 6, 20, 22, 25 and 27] |
| Not ALL possible piscicide uses require public engagement: In this instance, we noted that a lack of a federal nexus could eliminate the need for any public engagement. | Instances exist in the current process where public engagement may not be required. | All piscicide treatment projects should include some level of public engagement. Engagement should include scoping (see item below) and opportunities for local involvement. IF projects elicit sufficient public controversy, OR expressed interest in a public hearing, OR information suggesting the need for public involvement, THEN engagement would include direct meetings with the public in the vicinity of the project location. [Revised process step 6][Per SOP] |
| Public scoping for identification of public issues, concerns, or opportunities is not a REQUIRED step in NEPA processes: Public scoping is an OPTION that may be employed in development of Environmental Assessments. | Instances exist in the current process where public scoping may not be required. | Public engagement processes for all piscicide treatment projects should include public scoping to identify issues, concerns, and opportunities for analysis. [Revised process step 6][Per SOP] |

| Gap or Opportunity | Finding | Recommendation |
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| Appeal process: While there may be formal appeal processes for some federal partner decisions on projects that use piscicide treatments, it is not clear if there are state (AGFD) appeals processes. | As decision maker, the AGFD should include a process for appeal of decisions to apply piscicides. | The Arizona Game and Fish Commission (AGFC) is the Policy Board governing the actions of the AGFD. All actions and transactions of the AGFC, with few exceptions, must take place in open public session. Utilize the existing petition process for requesting review of a proposed AGFD action by the AGFC for review in a public forum. [Revised process step 22] |
| Public notice of impending treatment: There is no process step requiring public notification of an impending treatment. | Consistent with the Rotenone SOP Manual, AGFD should implement required process steps notifying the public of an impending piscicide treatment. | Prior to implementation, the Revised Process should include notifications of the public, affected water well users, grazing permittees, and recreators of an impending treatment. [Revised process steps 25, 26, 27] [Per SOP] |

Table 3. Revised Process Map for AGFD Piscicide Treatments, as reviewed and modified by the State and Federal Regulations, Internal Policy, Public Involvement, Best Management Practices Subcommittee during their meetings in October 2011.

| **Process Step** | **Activity** | **Assess** | **If Yes** | **If No** |
|---|---|---|---|---|
| 1 | Project proposed by agency staff, landowner, or stakeholder | Use piscicide to remove undesirable fish from project site? | Proceed to next step | Try/evaluate other methods |
| 1 – as modified [a] | Project proposed by agency staff, landowner, or stakeholder | Have evaluated other methods as not feasible and propose to use piscicide to remove undesirable fish from project site? | Proceed to next step | Try/evaluate other methods |
| 2 – new [b, c] | Fishery management plan on the water to be treated | Is there a management plan for that water that identifies the option to use piscicide applications, and was that plan approved through a public input process? | Proceed to next step | Develop a management plan with public input incorporated |
| 3 – new [a] | Is this proposed project and emergency rapid response? (awaiting criteria development) | Risk to human health or safety, risk of extirpation of a rare species, or significant damage to Arizona’s economy? | Proceed to next step, but this action may expedite some public engagement | Proceed to next step |
| 4 | Describe project background and need | Current process to describe project background and need | If feasible, proceed to next step | If significant problems, try other method |
| 4 – as modified [b] | Describe project background, need, and treatment plan | Use the Checklist worksheet to be developed per project (see Appendix A) | If feasible, proceed to next step | If significant problems, try other method |
| 5 – new [b] | Involved parties meet to develop expectations on proposed project, including how much public scoping and outreach needed | | Proceed to next step | Don’t proceed until remedied |

| Process Step | Activity | Assess | If Yes | If No |
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| 6 – new [b, c] | Initial public scoping with local community and stakeholders on proposed project (before large investment in staff time and expense) | Is there support or significant opposition to proposed project? | If support, proceed to next step | If opposition, implement public engagement plan keyed to level of concern expressed |
| 7 | Document staff, landowner, permittee, and downstream user concerns | Is there support or significant opposition to proposed project? | If support, proceed to next step | If opposition, try another method or conduct further evaluation and outreach |
| 7 – as modified [a, c] | Document staff, landowner, permittee, and downstream user concerns | Is there support or significant opposition to proposed project? | If support, proceed to next step | If opposition, try another method, conduct further evaluation and outreach, or seek AGFD Director approval to continue. If AGFD Director approves, proceed to next step. If AGFD Director does not approve, try another method. |
| 8 | Develop project treatment plan and safety/contingency plan | AGFD internal "peer review" of treatment plan and project goal | If feasible, proceed to next step | If significant problems, back to start and reassess |
| 9 – new [a] | Notify Arizona Department of Environmental Quality (ADEQ) on project – if project is a Waters of the U.S. and send Notice of Intent (NOI) and Pesticide Discharge Management Plan (PDMP) | Is the project within the scope of the approved Pesticide General Permit (PGP)? | Proceed to next step | Prepare PDMP for AGFD records. If ADEQ approves, proceed to next step. If ADEQ does not approve, try another method |

| Process Step | Activity | Assess | If Yes | If No |
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| 10 | Complete AGFD environmental compliance documents for project | Will the project occur on federal land of have a federal nexus? | Proceed to next step | Skip to step 19 |
| 11[c] | Project scoping notice to public (e.g., Federal Register, water bills, press release, newspaper, agency website, public meeting) | Sufficient public notice on development of Draft Environmental Assessment (EA)? | Proceed to next step | Provide feedback |
| 12 | Federal action agency prepares a Biological Assessment (BA), Draft EA, and Pesticide Use Plan (PUP) | Do the BA, Draft EA, and PUP accurately reflect the project and possible impacts to habitat, species, human safety, etc.? | Proceed to next step | Provide feedback |
| 13 [c] | Draft EA completed and released for public comment period | Sufficient public outreach on the Draft EA? Was there a local informative meeting? | Proceed to next step | Provide feedback |
| 14 | EA finalized with public comments addressed in Appendix | Are public comments addressed? Final EA accurate? | Proceed to next step | Provide feedback |
| 15 | U.S. Fish and Wildlife Service (FWS) issues the Biological Opinion on Final EA | Does the Biological Opinion support the best EA alternative? | Proceed to next step | Back to step 11 and reassess |
| 16 | Federal action agency issues a Record of Decision (ROD) or Finding of No Significant Impact (FONSI) on project | Does the ROD/FONSI support the best EA alternative? | Proceed to next step | Back to step 11 and reassess |
| 17 [c] | Public notice on Final EA, Biological Opinion, and ROD/FONSI | Sufficient public notice on environmental documents finalized? | Proceed to next step | Don’t proceed until remedied |
| 18 [c] | Are the final environmental compliance documents contested or appealed? | Is there a formal request for an appeal? Filed on time? | Do appeal comment period | Proceed to next step |

| Process Step | Activity | Assess | If Yes | If No |
|---|---|---|---|---|
| | | | | |
| 19 | AGFD completes the internal Environmental Assessment Checklist (EAC) on proposed project, identifies funding sources, staff resources, links to planning documents | Sufficient coordination among staff and landowners? Best Management Practices (BMPs) for reducing incidental take of non-target species? State Historical Preservation Office (SHPO) review? | Proceed to next step | Don't proceed until remedied |
| 20 – new [b] | Informational memo sent to AGFD Director if there is significant conflict or concerns by stakeholders. Implement public engagement plan regarding proposed treatment plan. | If public concern, hold public meeting in area of proposed treatment. Are significant conflicts or concerns addressed in a public forum and project given approval to proceed? | Proceed to next step | Don't proceed until remedied |
| 21 – new [a, c] | AGFD produces media release and publishes planned action decision | | Proceed to next step | Don't proceed until remedied |
| 22 – new [b, c] | Public or private individual(s) may petition Arizona Game and Fish Commission (AGFC) Commission to hold action pending AGFC review/decision in a public meeting | Public appeal process | If appealed and AGFC endorses, proceed to next step | If appealed and AGFC holds, cease action |
| 23 | U.S. FWS Federal Aid office approves EAC if federal nexus | Eligible funding, approved methods, and Theatened and Endangered species take? | Proceed to next step | Don't proceed until remedied |
| 24 | Finalize project logistics, staff needs, treatment dates (and alternate dates) | Is the project ready to go (e.g., supplies, staff, weather, flows)? | Proceed to next step | Don't proceed until remedied |

| Process Step | Activity | Assess | If Yes | If No |
|---|---|---|---|---|
| 25 – new [b] | Notify users of domestic wells within the treatment area and/or neutralization zone of impending treatment (7-10 days pre-treatment per Rotenone SOP Manual) | | Proceed to next step | Don't proceed until remedied |
| 26 – new [a] | Notify permitees and landowners within treatment area and/or neutralization zone of impending treatment (7-10 days pre-treatment) | | Proceed to next step | Don't proceed until remedied |
| 27 – new [b] | Post signage in treatment area for public notification | | Proceed to next step | Don't proceed until remedied |
| 28 | Implement project per treatment plan | | | |
| 29 | Evaluate whether application was successful or not | Was there 100% removal of the target species as a result of the treatment? | Proceed to next step | Repeat step 28 or reevaluate |
| 30 | Report findings to involved parties | | | |
| 30 – modified [a] | Report findings to involved parties, including ADEQ PGP reporting, and maintain records in conformance with PGP requirements | | | |

[a] Added or modified per Subcommittee findings
[b] Additions to the process per the Rotenone SOP Manual (Finlayson et al. 2010)
[c] Steps that allow public and stakeholder involvement and comment

Table 3. Acronym Key

ADEQ = Arizona Department of Environmental Quality
AGFD = Arizona Game and Fish Department
BA = Biological Assessment
BMPs = Best Management Practices
EA = Environmental Assessment
EAC = Environmental Assessment Checklist (per AGFD)
FONSI = Finding of No Significant Impact
NOI = Notice of Intent
PDMP = Pesticide Discharge Management Plan
PGP = Pesticide General Permit
PUP = Pesticide Use Plan
ROD = Record of Decision
SHPO = State Historic Preservation Office
SOP = Rotenone Standard Operating Procedures (SOP) Manual (Finlayson et al. 2010)
U.S. FWS = U.S. Fish and Wildlife Service

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## Recommendations to the Rotenone Review Advisory Committee

1. Establish firm criteria to define situations that justify piscicide treatments on an emergency rapid response basis and add this step to the revised process for AGFD piscicide treatments.

2. Adopt the revised AGFD piscicide treatment process as developed by this Subcommittee to include the following key changes or additions to process steps:

a. Incorporate the Rotenone Standard Operating Procedures (SOP) Manual (Finlayson et al. 2010) as an absolute minimum procedure for all piscicide projects.

b. Initiate, maintain, and document public scoping (for both support and opposition), engagement, and coordination early in the project planning process and through project development and implementation (also per SOP).

c. Thoroughly evaluate other methods of fish removal prior to decisions on piscicide use (also per SOP).

d. Incorporate the legally-required Arizona Pollutants Discharge Elimination System permit process into the AGFD piscicide treatment process which requires a PGP for treatments from ADEQ (for applicable waters).

e. Incorporate the Arizona Game and Fish Commission public review and appeals process for proposed piscicide treatments.

# CHAPTER 2. HUMAN HEALTH AND THE ENVIRONMENT SUBCOMMITTEE FINAL REPORT

**Prepared for the Rotenone Review Advisory Committee by the Human Health and Environment Subcommittee:** Subcommittee Chair: Herb Guenther, Rotenone Review Advisory Committee Chair; Subcommittee Co-chair: Mike Fulton, Arizona Department of Environmental Quality; and Subcommittee Members: Philip Bashaw, Arizona Farm Bureau; Jennifer Botsford, Arizona Department of Health Services; Julie Meka Carter, Arizona Game and Fish Department; Brian Davidson, Environmental Protection Agency; Phil Fernandez, Glendale Community College and Zane Grey Chapter Trout Unlimited; Chuck Graf, Arizona Department of Environmental Quality; Jeff Gray, R and R Partners; Nicolas Hild, Arizona State University; Rodney Held, Arizona Department of Water Resources; Don Herrington, Arizona Department of Health Services; Doug Kupel, City of Phoenix; Hsin Lin Cox, Arizona Department of Health Services; Moira McKernan, U.S. Fish and Wildlife Service; Chuck Paradzick, Salt River Project; Jack Peterson, Arizona Department of Agriculture; Amanda Reeve, Arizona State Representative; Mark Schaefer, U.S. Institute for Environmental Conflict Resolution; Robert Shuler, Shuler Law Firm; Kirk Young, Arizona Game and Fish Department

## Part 1. Human Health Impacts from the Use of Rotenone as a Piscicide

### Executive Summary

The use of rotenone as a piscicide in Arizona prompted public concerns over the potential human health and ecological impacts that may result from rotenone exposure, and resulted in proposed state legislation (50$^{th}$ Legislature, 1$^{st}$ regular session in 2010: 2010: S.B. 1294; H.B. 2114) that would have significantly limited the Arizona Game and Fish Department's (AGFD) ability to use rotenone in the future. In August 2011, the Human Health and Environment Subcommittee (herein Subcommittee), part of the AGFD Director-initiated Rotenone Review Advisory Committee (a Blue Ribbon Evaluation Committee), was asked to evaluate the environmental persistence of rotenone when used in fisheries and aquatic invasive species management and the potential threats to human health and the environment. This task was accomplished by conducting a comprehensive scientific and technical literature review, summarizing pertinent studies and topics in report form, and making recommendations to the Rotenone Review Advisory Committee on existing or suggested methods to reduce negative impacts from rotenone use as a piscicide, if applicable. The issues addressed were the primary concerns introduced by S.B. 1294 and H.B. 2114 proponents, as well as issues deemed necessary by the Subcommittee to investigate during this process including the Environmental Protection Agency's (EPA) reregistration process and the relation of Parkinson's disease and rotenone exposure. The results are presented in this Executive Summary and Part 1 of the Subcommittee's report. The other piscicide registered by the EPA, antimycin-A, was not analyzed in this report because it is not currently commercially available.

*Environmental Protection Agency's Risk Assessment and Reregistration for Rotenone*

The EPA has regulatory responsibility for the registration and reregistration of pesticides. Every 15 years (or sooner if necessary) the reregistration process is initiated and involves a thorough review based on scientific data to evaluate the potential hazards based on the current registered use, determine the need for additional data to supplement the health and environmental risk assessments, and evaluate criteria to ensure a registered pesticide will have "no unreasonable adverse effects". Rotenone was reregistered by the EPA in 2007 for piscicide (a pesticide poisonous to fish) use only (EPA 2007). During the reregistration process, the EPA used risk assessments to evaluate the frequency and level of exposure that may occur in humans and ecological receptors upon exposure to rotenone. The EPA determined the Level of Concern (LOC) rotenone concentrations for each potential exposure scenario (e.g., dietary risk, residential and recreational risk, occupational risk), which are 1000 times less than the no observed adverse effect level (NOAEL) for specific exposure routes (EPA 2007). This reflects a 10x uncertainty factor for interspecies extrapolation, a 10x uncertainty factor for intraspecies variation, and a 10x database uncertainty factor because a potentially critical effect (neurotoxicity) cannot be assessed quantitatively with the existing database. When critical factors cannot be assessed quantitatively with the existing database, EPA applies a 10x uncertainty factor to establish exposure limits that ensure the protection of public health and ecological systems. As a result of the reregistration process, the EPA determined the maximum treatment concentration of rotenone for piscicide use at 200 parts per billion (ppb = µg/L).

The EPA considered the greatest potential for human exposure to rotenone to be inhalation, dietary, and dermal exposure routes that may occur from agricultural and residential uses, which are no longer registered uses (as of 2007), and these exposures by certified piscicide applicators would be negligible (EPA 2006). The EPA requires personal protective equipment (PPE) to minimize occupational exposure, including chemical resistant gloves, socks and chemical resistant shoes, double layer clothing protection (e.g., coveralls), a full-face respirator for mixers handling rotenone powder, and a dust/mist respirator for mixers and applicators of backpack sprayers and drip stations. The PPE's now required based on the 2007 reregistration process will be on the new product labels in 2012 to ensure handler safety, and they are also highlighted in the Rotenone Standard Operating Procedures (SOP) Manual (Finlayson et al. 2010).

Rotenone is unlikely to contaminate groundwater because of its rapid degradation, and although it will bind to soils and sediments, it is not anticipated to leach under most circumstances (EPA 2006). As a registered piscicide, rotenone is expected to kill fish and aquatic invertebrates within the treatment area, but exposure risk to terrestrial organisms is relatively low because it is applied directly to water. The EPA considered wildlife exposure to rotenone by way of consuming bank vegetation during or post piscicide application unlikely and did not analyze potential impacts. To reduce potential impacts of rotenone leaving the treatment area in flowing water, potassium permanganate ($KMnO_4$) is often applied, where appropriate, as an oxidizing agent to neutralize rotenone treated water at the downstream end of the treatment area (Finlayson et al. 2010). To date, there are no records of rotenone contamination of any groundwater wells without a direct hydrologic connection to the treated surface water (Ridley et al. 2007; McMillin and Finlayson 2008). If domestic wells with hydrologic connection to the treatment area exist, the public or private water users must be notified 7-14 days before the treatment (EPA 2007; Finlayson et al. 2010). The water users would be advised not to consume the water if active rotenone concentrations were greater than 40 ppb, which is the level determined safe for drinking water consumption.

*The Rotenone Model for Parkinson's Disease*

Rotenone is a selective inhibitor of mitochondrial complex 1 within the dopaminergic neurons and also produces brain lesions that have similar features to Lewy bodies, aggregates of proteins observed in the nerve cells within the brains of patients with Parkinson's disease (PD). Scientists developed the "rotenone model" or "rotenone rat model" to induce neurotoxicity with rotenone exposure and examine the pathogenesis of PD in vitro (e.g., in cellular culture) and in vivo (e.g., internally via intravenous injections) in rats and mice. The purpose of studies using the rotenone model was to examine the pathway of PD and not the toxicity of rotenone from its use as a pesticide (EPA 2005). Animal models using pesticides to investigate the etiology of PD are limited in scope because they do not produce the actual disease state and model only the motor features of PD (Cicchetti et al. 2009), using very high doses of rotenone administered to rodents using methods not relevant to realistic human exposure (Brown et al. 2006; Raffaele et al. 2011). The potential realistic exposure of humans to rotenone during piscicide treatments, as regulated by the EPA, is not comparable to the dose required to cause the development of PD symptoms in rodents by way of chronic intravenous injections of rotenone (Bové 2005; EPA 2006).

*Parkinson's Disease and Occupational Exposure*

To date, there are no published studies that conclusively link exposure to rotenone and the development of clinically diagnosed PD. Some correlation studies have found a higher incidence of PD with the occupational (e.g., agricultural use) exposure to pesticides among other factors (e.g., Tanner et al. 2009, 2011), and some have not (e.g., Hertzman 1994; Firestone et al. 2010). It is very important to note that in case-control correlation studies, causal relationships cannot be assumed and some associations identified in odds-ratio analyses may be chance associations. Only one study (Tanner et al. 2011) found an association between occupational rotenone and paraquat use and PD in agricultural workers, primarily farmers. However, there are substantial differences between the methods of application, formulation, and doses of rotenone used in agriculture and residential settings compared with aquatic use as a piscicide, and the agricultural workers interviewed were also exposed to many other pesticides during their careers. Recently, the results of epidemiological studies linking pesticide exposure to PD have been criticized due to high variation among study results, generic categorization of pesticide exposure scenarios, questionnaire subjectivity, and the difficulty in evaluating the causal factors of PD (Raffaele et al. 2011).

*Conclusions*

Rotenone is a naturally occurring substance derived from the roots of tropical plants in the bean and pea family that are found primarily in Malaysia, South America, and East Africa. People have utilized rotenone for centuries to capture fish for food in areas where these plants are naturally found, and it has been used in fisheries management as a piscicide (pesticide that kills fish) in North America since the 1930s. The EPA considers the chronic exposure to humans to piscicidal applications of rotenone to be low for the following reasons: the rapid degradation of rotenone; faster degradation and control of treatment end point by neutralization with $KMnO_4$, where appropriate; the cancellation of some application methods; new required engineering controls to protect applicators; applications follow piscicide label requirements; and there is adequate signing and public notice or area closures to minimize public exposure to treated waters (EPA 2007).

Relative scientific evidence suggests the potential realistic exposure of humans to rotenone during piscicide treatments, as regulated by the EPA, is not comparable to the dose (concentration and duration) required to cause the development of PD symptoms in rodents by way of chronic intravenous injections of rotenone into the sub-cutaneous, jugular vein, and substantia nigra (mid-brain), or by chronic oral administration of rotenone at high doses (Bové 2005; EPA 2006). Rotenone applied as a piscicide degrades quickly, is not expected to contaminate groundwater, and human exposure of the treatment area is restricted during treatment, all of which make an environmental exposure to rotenone highly unlikely to cause PD or PD-like symptoms (Bové 2005).

Studies that have found an association between PD and occupational exposure to rotenone focused on agricultural workers that had a history of occupational exposure to pesticides. There are substantial differences between the methods of application, formulation, and doses of rotenone used in agricultural and residential settings compared with piscicide use. Through the EPA reregistration process of rotenone, occupational exposure risk is minimized by: new requirements that product labels specify a revised maximum treatment concentration at 200 ppb beginning in 2012, the development of engineering controls for some of the rotenone dispensing equipment, and the requirement for applicators to wear specific PPE when using rotenone (EPA 2007). Overall, the occupational risk for the piscicide use of rotenone will be negligible if used at concentrations no higher than the maximum treatment concentration and when certified applicators use the rigorous Rotenone Standard Operating Procedures (SOP) Manual (Finlayson et al. 2010) developed.

## Environmental Protection Agency's Risk Assessments and Reregistration for Rotenone

### *What is rotenone?*

Rotenone is a naturally occurring substance derived from the roots of tropical plants in the bean and pea family that are found primarily in Malaysia, South America, and East Africa. It is derived from ground up plant roots to make a powder formulation or extracted from the roots to make a liquid or crystalline formulation. People have utilized rotenone for centuries to capture fish for food in areas where these plants are naturally found, and it has been used in fisheries management as a piscicide (pesticide that kills fish) in North America since the 1930s. Rotenone affects gill breathing organisms by inhibiting respiration by blocking biochemical pathways of cell metabolism, specifically the reduced nicotinamide adenine dinucleotide (NADH)-dehydrogenase segment of the respiratory chain and resulting in mortality with prolonged exposure. Rotenone has also been used as an insecticide in residential products for control of fleas, ticks, and mites on pets and livestock; and for control of aphids on garden plants. Rotenone was used widely in North America for agricultural use as a botanical insecticide for use in fruit and vegetable crops.

*Rotenone Reregistration*

The Environmental Protection Agency (EPA) has regulatory responsibility for the registration and reregistration of pesticides per the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). FIFRA requires that every pesticide be reregistered every 15 years. The EPA will determine if a pesticide reregistration must be reevaluated if there is new evidence of human and/or environmental risks that were unknown or unable to determine during the initial reregistration process. The reregistration process involves a thorough review based on published scientific data and the review of all data pertaining to the active ingredient. The process ensures the reevaluation of the potential hazards based on the current registered use of the pesticide, determines the need for additional data to supplement the health and environment risk assessments, and evaluates criteria as defined by FIFRA that a registered pesticide will have "no unreasonable adverse effects" (EPA 2006, 2007).

Rotenone was originally registered in the U.S. in 1947 for use in agriculture and as a piscicide. From 2004 to 2007, EPA conducted the reregistration process for rotenone and the final Reregistration Eligibility Decision (RED) for rotenone as a restricted use pesticide for piscicidal use only was published in 2007. Per the EPA and product labels, rotenone for piscicide use is for retail sale and use by Certified Applicators or persons under their direct supervision and only for the uses covered by the Certified Applicator's certification (see Appendix A). Rotenone was not reregistered for agricultural, livestock, and residential uses resulting from registrant requests to voluntarily cancel all uses except for piscicide use.

*Human Health Risk Assessment*

The EPA uses risk assessments to evaluate the frequency and level of exposure that may occur in humans and ecological receptors exposed to a specific chemical. It is a scientific process, and the risk depends on how much of a chemical is in the environment (e.g., soil, water, and air), the amount of exposure a person or ecological receptor may encounter, and the toxicity of the pesticide. The human health risk assessment evaluated rotenone toxicology, dietary risk, residential and recreational risk (post-application risk), occupational risk, and human incident data (EPA 2006, 2007). Under current labels, the maximum treatment concentration for rotenone (piscicide labels) is 250 parts per billion (ppb; µg/L). However, the EPA revised the maximum treatment concentration during the reregistration process to 200 ppb because it is the solubility limit of rotenone in water, and requires all rotenone product labels to adjust the maximum treatment concentration to 200 ppb, which will occur in 2012. The EPA determined the Level of Concern (LOC) rotenone concentrations for each potential exposure scenario (e.g., dietary risk, residential and recreational risk, occupational risk), which are 1000 times less than the no observed adverse effect level (NOAEL) for specific exposure routes (EPA 2007). For the reregistration of rotenone, the EPA developed exposure limits that were *1000 times less* than the NOAEL for rotenone exposure to account for uncertainty factors within the existing database for rotenone. This reflects a 10x uncertainty factor for interspecies extrapolation, a 10x uncertainty factor for intraspecies variation, and a 10x database uncertainty factor because a potentially critical effect (neurotoxicity) cannot be assessed quantitatively with the existing database. When critical factors cannot be assessed quantitatively with the existing database, EPA applies a 10x uncertainty factor to establish exposure limits that ensure the protection of public health and ecological systems.

Toxicity – Based on epidemiologic and animal studies, the EPA determined that rotenone is not carcinogenic to humans and therefore it was classified as a Group E carcinogen, which is defined by no evidence of carcinogenicity in humans.

The EPA conducted toxicity assessments to determine at what level or dose observable adverse effects in humans could occur (EPA 2006). Rotenone has high toxicity through oral ingestion and inhalation exposure routes, and low toxicity through dermal exposure routes. The $LD_{50}$ (median lethal dose) for acute oral ingestion exposure by a rat consuming rotenone ranges between 39.5 to 102 mg active ingredient rotenone/kg (females and males, respectively; equivalent dose = 0.00004 oz/2.2 lb and 0.0001 oz/2.2 lb), and the EPA classifies rotenone as highly toxic to mammals ingesting rotenone at these quantities. On a chronic exposure basis, rats lost between 10-50% body weight from chronic oral ingestion exposure. The $LD_{50}$ for acute inhalation of rotenone in rats was 0.0212 mg/L ($7.4780 \times e^{-10}$ oz/0.2642 gal) for males and females combined. The acute toxicity of rotenone administered dermally to rabbits was considered low, at a $LD_{50}$ greater than 5 g/kg (0.0050 oz/2.2 lb). For dermal exposure tests, rotenone was applied to rabbits in crystal form and with a rotenone brittle extract to encourage absorption.

Dietary Risk – For consumption in humans, rotenone exposure could occur as a result of consumption of treated water and eating fish with rotenone residues following treatment (EPA 2006). The EPA estimated the acute dietary exposure (drinking water only) at 200 ppb (maximum treatment concentration and maximum solubility of rotenone), and assumed water is consumed immediately after treatment without degradation to rotenone. The estimated exposure concentration was below the EPAs LOC. To estimate the uptake of rotenone via fish consumption, the EPA also conducted an additional acute dietary assessment including the drinking water contribution at 200 ppb and including fish treated with rotenone, and the resulting assessment was also below the LOC. For chronic drinking water exposure, data for the assessment was based on a chronic oncogenicity study where rotenone was orally administered to rats in concentrations of 0, 7.5, 37.5 and 75 parts per million (ppm) daily for two years. Doses for rats were given by mg/kg/day at 0.375 (7.5 ppm), 1.88 (37.5 ppm), and 3.75 (75 ppm) mg/kg/day based on the standard food factor for rats of 0.05. Although no mortality was observed in the control or treatment groups, male and female rats lost weight in the mid- and high-dose groups compared to the control group. During the experiment, the lowest observed adverse effect level was 37.5 ppm (1.88 mg/kg/day) based on decreased body weight. Thus, the toxicity end points and corresponding NOAEL was 7.5 ppm (0.375 mg/kg/day) for chronic oral exposure, which equates to 0.0004 mg/kg/day once EPA included the additional uncertainty factor which is 1000 times lower than the NOAEL. Based on the risk assessment, at a dose of 0.0004 mg/kg/day the LOC for chronic drinking water exposure for adult humans was estimated at 140 ppb and for infants and children the LOC was 40 ppb. To ensure treatments do not exceed the 40 ppb drinking water LOC, registrants are required to undergo mitigation measures such as label restrictions and water quality monitoring requirements.

For perspective, using estimates reported by Finlayson et al. (2000), the estimated single lethal dose to humans is 300-500 mg/kg body weight. During a rotenone treatment using a concentration of 250 ppb (previous maximum treatment concentration), a 160 lb person would have to drink more than 23,000 gallons of treated water to achieve a lethal dose.

Residential and recreational risk – As a restricted use pesticide, rotenone is for sale only to Certified Applicators and the public is prohibited from entering treated water bodies during treatment (EPA 2006). However, the public may be exposed to an area previously treated with a piscicide by performing recreational activities in post-treatment water such as swimming ("post-application risk"). The EPA determined that at the maximum treatment concentration of rotenone of 200 ppb, the risk to adult humans swimming in treated water on the day of application resulting in dermal and incidental oral ingestion exposure to rotenone was 1000 times less than the NOAEL. For toddlers, the short-term risks for swimming on the day of the application were *not* 1000 times less than the NOAEL, thus 90 ppb was determined to be the LOC for short-term dermal and incidental oral ingestion exposure from swimming in rotenone treated water.

Because rotenone degrades rapidly, the EPA minimizes the risk to swimmers during piscicide treatments with rotenone by requiring closures (or swimming prohibition) for 72 hours post treatment in flowing water applications or if analytical chemistry shows ≤ 0.09 ppm active rotenone. For standing water applications, the area is closed for 14 days post application or when analytical chemistry shows ≤ 0.09 ppm active rotenone (per the Rotenone SOP Manual [Finlayson et al. 2010]). Signage for area closures are placed near public access points and sometimes by public notification via press release.

Occupational risk – The occupational exposure to rotenone was considered for piscicide applications only, as the product registrants voluntarily cancelled all uses of rotenone except for piscicide use during the reregistration process (EPA 2006). The EPA considered the greatest potential for human inhalation, dietary, and dermal exposure to occur from agricultural and residential uses, and these exposures by certified piscicide applicators to be negligible.

Exposure scenarios were developed using the tasks of piscicide handlers in preparation for, and during applications, including mixers and/or loaders, applicators, mixer/loader/applicators, and loader/applicators. The frequency and duration of how rotenone exposures occur were estimated to determine which toxicological endpoints are appropriate in handler exposure scenarios. EPA used the maximum treatment concentration of 200 ppb as well as the current maximum labeled concentration of 250 ppb to determine handler risk and different levels of personal protection equipment (PPE) were used to determine handler exposure risk at those treatment concentrations.

The EPA used toxicity data from studies using rats to estimate occupational risk in humans, and they used exposure scenarios for workers wearing baseline work clothing (e.g., long pants and shirt, socks and shoes), no respirator, and no gloves during exposure to more protective measures that would lower exposure risk. The results of the occupational risk assessment indicated many of the handler exposure risks were higher than the LOC, and the EPA now requires future product labels to be reduced from 250 ppb to 200 ppb and for additional PPE to be incorporated into the label. For example, exposure scenarios at 200 ppb with PPE consisting of chemical resistant gloves, socks and chemical resistant shoes, double layer clothing protection (e.g., coveralls), a full-face respirator for mixers handling rotenone powder, a dust/mist respirator for mixers and applicators of backpack sprayers and drip stations reduced the risk of exposure, thus, additional PPE will be required on the new product labels to ensure handler safety. New product labels incorporating new standard operating procedures such as new PPEs will be finalized and become effective in 2012 (EPA, personal communication).

Human incident data – The EPA reviewed several incident data sources for reported incidents as a result of agricultural, residential, and piscicide applications (EPA 2006). No deaths or poisonings were reported, and eye irritation was the most common symptom. Other symptoms included skin irritation, throat irritation, nausea, and coughing, and to a lesser degree headaches, dizziness, peripheral neuropathy, numbness, and tremor.

Summary – During the reregistration process for rotenone, the EPA determined a LOC rotenone concentration for each potential pathways to exposure to rotenone, and developed rotenone concentration limits for piscicide use that were *1000 times less* than the NOAEL in toxicity and dietary studies (EPA 2006). Rotenone is a non-carcinogen in humans, but acute exposure to rotenone through oral ingestion and inhalation can be toxic during acute exposures. Oral ingestion in humans is unlikely, except as a result of consumption of treated water. However, a fatal dose of rotenone is ultimately impossible, because a man weighing 154 lb would have to consume 47,115 gallons of rotenone treated water to reach the $LD_{50}$ based on oral consumption of rotenone in rat experiments. To reduce the risk of human exposure to rotenone treated water, the EPA guidelines state treated waters must be closed to public access during and post-treatment from 3-14 days, or depending on rotenone concentrations ($\leq$ 0.09 ppm).

EPA considered the greatest potential for human inhalation, dietary, and dermal exposure to occur from agricultural and residential uses, and these exposures would be negligible for piscicide use. In summary, the EPA considers chronic risk to humans from rotenone exposure during piscicide applications to be low based on the following reasons: the rapid degradation of rotenone; faster degradation and control of treatment end point by neutralization with $KMnO_4$, where appropriate; the cancellation of some application methods; new required engineering controls to protect applicators; applications follow piscicide label requirements; and there is adequate signing and public notice or area closures to minimize public exposure to treated waters (EPA 2007). Overall, the occupational risk for the piscicide use rotenone will be negligible if used at concentrations no higher than the maximum treatment concentration and when certified applicators and professional fishery professionals use the rigorous standard operating procedures developed.

*Ecological Risk Assessment*

The ecological risk assessment evaluated the environmental fate and transport of rotenone, and ecological exposure and risk to aquatic and terrestrial organisms (EPA 2005, 2006, 2007). The risk assessment also determined the acute toxicity of potassium permanganate ($KMnO_4$) to aquatic vertebrates.

Environmental fate and transport – Rotenone degrades quickly when released into water, with half-lives of a few hours to several weeks depending on the environment (e.g., temperature, pH, turbidity)(EPA 2005). It can degrade rapidly from aqueous photolysis (sunlight), thus, degradation would be rapid on sunny days in clear water. Rotenone will also degrade more rapidly in warm water compared with cold water. Rotenone is not persistent in the environment because of its low vapor pressure ($6.9 \times 10^{-10}$ torr) and Henry's law constant (measure of solubility of gases in liquids; $1.1 \times 10^{-13}$ atm-m$^3$ mol$^{-1}$), and it is mobile to moderately mobile in soil and sediment (log $k_{ow} = 4.10$). For more information on rotenone degradation in water and soil, see Chapter 2: Environmental Fate and Ecological Impacts.

Rotenone is unlikely to contaminate groundwater because of its rapid degradation, and although it will bind to soils and sediments, it is not anticipated to leach in most circumstances. One of those circumstances may be in very sandy soil types with low carbon levels where leaching may occur, but groundwater is not likely to become contaminated because of rotenone's rapid degradation in water. Steps can be taken to accelerate the degradation of rotenone to reduce exposure risks outside of the treatment area, such as neutralization of rotenone by $KMnO_4$ at the downstream end of the treatment area. To date, there are no records of rotenone contamination of any groundwater wells that are isolated from surface water.

Ecological exposure and risk to aquatic organisms – Aquatic organisms at risk from rotenone treatments include fish, invertebrates, and amphibians in the aquatic phase. The EPA conducted a risk assessment to estimate rotenone toxicity, exposure scenarios, and risk to fish and invertebrates (EPA 2005). As a registered piscicide, rotenone is expected to kill fish and aquatic invertebrates within the treatment area. As a result, at maximum treatment concentrations of 200 ppb rotenone for lakes/ponds and 50 ppb for streams/rivers, a 96 hour exposure exceeded the acute risk quotient (point estimate of exposure/point estimate of effects) LOC for fish and invertebrates in the treatment area. Chronic risk quotients also exceeded the LOC at the same maximum treatment levels for fish exposed to rotenone for 32 days and invertebrates exposed to rotenone for 21 days. For more information on the impacts to aquatic organisms from rotenone exposure, see Chapter 2: Environmental Fate and Ecological Impacts.

Ecological exposure and risk to terrestrial organisms – The EPA conducted dietary risk assessments to determine the lethal dose of rotenone for birds and mammals (EPA 2005, 2006). The $LD_{50}$ (median lethal dose) for acute oral ingestion exposure by a rat consuming rotenone ranges between 39.5 to 102 mg active ingredient rotenone/kg (females and males, respectively; equivalent dose = 0.00004 oz/2.2 lb and 0.0001 oz/2.2 lb), and the EPA classifies rotenone as highly toxic to mammals ingesting rotenone at these quantities. On a chronic exposure basis, mammals lost between 10-50% in their body weight from chronic oral ingestion exposure. For birds, the $LD_{50}$ for acute oral ingestion exposure ranged between 1680-2200 mg/kg and the EPA classifies rotenone as only slightly toxic to birds, and chronic exposure tests were not conducted.

The exposure risk to terrestrial organisms is relatively low because rotenone for piscicide use is applied directly to water. The EPA's risk assessment for terrestrial organisms estimated toxicity (using dietary toxicity studies), exposure scenarios, and potential risk to birds and mammals. It is possible that piscivorous (fish eating) birds and mammals may feed on dead or dying fish within a treatment area, although piscicide treatment protocols often recommend collection and/or burial of dead fish where practicable. The EPA determined that based on rotenone residuals in yellow perch (*Perca flavescens*) and common carp (*Cyprinus carpio*) during a rotenone treatment, a 1 kg (2.2 lb) bird would have to consume thousands of fish to achieve a lethal dose (274,000 perch; 43,000 small carp). Thus, it is not possible that piscivorous birds would consume enough rotenone contaminated fish to result in a lethal dose. Similarly for mammals, if a 1 kg (2.2 lb) mammal fed exclusively on rotenone treated fish, the concentration of ingested rotenone would be below the estimated median lethal equivalent concentration.

It is possible that some birds and mammals may consume vegetation bordering stream or lake banks that was sprayed with rotenone during a piscicide treatment by an applicator operating a backpack sprayer unit. The EPA estimated exposure concentrations of rotenone in the form of foliar residues on vegetation (e.g., grass) that may be consumed by wildlife following non-piscicide applications of rotenone before the product registrants withdrew their requests for reregistration for those uses of rotenone; the EPA considered wildlife exposure by way of piscicide applications to rotenone residues on vegetation unlikely (EPA 2005). For agricultural applications (maximum application rate of 0.01 lb active ingredient rotenone per acre), no acute risk LOCs were exceeded based on the estimated exposure concentration of birds to rotenone by ingesting vegetation with rotenone residues. For residential applications with higher maximum treatment concentrations (0.00064 – 2.9 lb/acre), the dietary and dose-based acute oral ingestion exposure by birds were above the LOCs at concentrations greater than 0.22 lb/acre. For small mammals, the acute risk LOC was exceeded from the consumption of short grass with rotenone residues as a result of agricultural applications of rotenone. The acute risk LOC was exceeded from the consumption of multiple vegetation types as a result of residential applications of rotenone. For piscicide use, the equivalent concentrations used during applications are much lower than for agricultural and residential uses. For example, the equivalent application concentration for liquid rotenone is 0.0000040 lb/gallon in streams and 0.0000075 lb/gallon in lakes.

The possibility of plants absorbing rotenone after stream or lake treatments is highly unlikely, because rotenone adheres to soils and is nearly insoluble in water; it degrades quickly in surface water, sediments, and with warmer water temperatures; and is generally unlikely to leach substantially. When leaching does occur, rotenone travels vertically less than 1 inch in most soil types. However, EPA prohibits the diversion and use of water containing rotenone for irrigation due to risk concerns for terrestrial plants when rotenone is applied directly because rotenone tolerances with this exposure have not been established. For piscicide use, rotenone is not applied to terrestrial plants.

The EPA did not conduct a risk assessment to evaluate potential risk to birds and mammals from drinking rotenone treated water. However, using the $LD_{50}$ determined for rats at 39.5 mg/kg active rotenone, for a cow weighing 1,620 lb (735 kg) the adjusted $LD_{50}$ is 5.70 mg/kg. A cow at this weight would have to consume 4.19 g of rotenone, or would have to ingest 5,535 gallons of treated water (at 200 ppb rotenone concentration) to reach a median lethal dose. Rotenone is typically applied directly to water when used as a piscicide; thus, the likelihood that significant quantities of rotenone would be applied to grass where cattle are foraging is considered low. It is also improbable that cattle have the physical capacity to drink enough gallons of treated water to receive a lethal dose of rotenone.

Acute toxicity of $KMnO_4$ to aquatic vertebrates and invertebrates – $KMnO_4$ is a powerful oxidizing agent that is used to neutralize rotenone treated water to prevent rotenone from leaving the treatment area. The EPA did not conduct risk assessments for $KMnO_4$, but used data from summarized studies published in EPA's ECOTOX database, which provides information on the toxicity of chemicals to aquatic and terrestrial organisms (EPA 2005). $KMnO_4$ can be moderate to highly toxic to fish during acute exposure, and some species of fish are more sensitive to $KMnO_4$ than others. The data was limited on the acute toxicity of $KMnO_4$ to aquatic invertebrates, but appears to be highly toxic. For more information on $KMnO_4$, see Chapter 2: Environmental Fate and Ecological Impacts.

Summary – Rotenone is unlikely to contaminate groundwater because of its rapid degradation, and although it will bind to soils and sediments, it is not anticipated to leach under most circumstances (EPA 2005). As a registered piscicide, rotenone is expected to kill fish and aquatic invertebrates within the treatment area, but exposure risk to terrestrial organisms is relatively low because it is applied directly to water. The EPA considered wildlife exposure to rotenone by way of consuming bank vegetation during or post piscicide application unlikely and did not analyze the potential impacts. To reduce potential impacts of rotenone leaving the treatment area in flowing water, $KMnO_4$ is applied as an oxidizing agent to neutralize rotenone treated water at the downstream end of the treatment area. To date, there are no records of rotenone contamination of any groundwater wells that are isolated from surface water.

The EPA considers chronic risk to humans from rotenone exposure during piscicide applications to be low based on the following reasons: the rapid degradation of rotenone; faster degradation and control of treatment end point by neutralization with $KMnO_4$, where appropriate; the cancellation of some application methods; new required engineering controls to protect applicators; applications follow piscicide label requirements; and there is adequate signing and public notice or area closures to minimize public exposure to treated waters (EPA 2007).

The Rotenone Model for Parkinson's Disease and Web of Science Summary

Parkinson's disease (PD) is the one of the most common neurodegenerative diseases, but the pathogenesis is not fully understood. Most scientists acknowledge that both genetic and environmental factors may influence the development of PD; however, the roles as well as the degree of contribution of each factor are the subject matter of much debate. In 1982, four habitual heroin users purchased and injected a new or synthetic form of heroin and subsequently developed Parkinsonism (Langston et al. 1983). Upon investigation, the patients had injected a form of heroin that also contained MPTP (1-methyl-4-phenyl-1,2,3,6-tetrahydrophyridine), which is metabolized to the neurotoxin MPP+, a commonly used herbicide also called cyberquat (Ross and Smith 2007). Neurotoxins can create selective destruction of the dopamine neurons of the substantia nigra; clinical PD is diagnosed by cell loss in the substantia nigra (within the mid brain), severe dopamine depletion in the striatum (part of the forebrain) (Di Monte 2001), and one or more of the four most common motor symptoms of the disease (resting tremor, slow movement, rigidity, and postural instability). In subsequent years, research models were developed using herbicides or other toxins (e.g., epoxomicin, 6-hydroxydopamine, paraquat, and rotenone; Ross and Smith 2007) similar to MPTP to test the pathogenesis of sporadic PD by producing some of the symptoms of PD in vivo (within the living organism) using rodents and in vitro (within a medium) using cells from rodents or humans.

MPTP is considered the most established research model and is used to study the pathogenesis as well as neuroprotective strategies of PD. Once MPTP is metabolized to the neurotoxin MPP+, it becomes concentrated in dopamine neurons and inhibits complex 1 of the mitochondrial electron transport chain, ultimately resulting in cell death within the substantia nigra. Rotenone, which was used commonly as an insecticide and now is registered only as a piscicide, is considered a selective inhibitor of complex 1 and also produces cytoplasmic inclusions in nigral neurons (lesions) that have similar features to Lewy bodies, aggregates of protein observed in the nerve cells within the brains of PD patients (Di Monte 2001). Thus, scientists developed the "rotenone model" or "rotenone rat model" to induce neurotoxicity and examine the pathogenesis of PD in vitro and in vivo in rats. The purpose of studies using the rotenone model was to examine the pathway of PD and not the toxicity of rotenone (EPA 2005).

It is important to note that rats are most commonly used in the experiments and they do not demonstrate pathologic Parkinsonism, but they can reproduce some of the PD-like symptoms. In fact, the rotenone model used on intact mice produced behavioral symptoms of PD, but failed to produce the degeneration of dopaminergic neurons and lacked the formation of nigrostriatal lesions seen in most rat models with chronic IV administration, often mixed with solvents to increase absorption (Richter et al. 2007). Animal models using pesticides to investigate the etiology of PD are limited in scope because they do not produce the entire disease state and model only the motor features of PD (Cicchetti et al. 2009). One of the limitations with the rotenone model is the specificity with the formation of the Lewy body-like lesions, producing variability that raises doubts on the accuracy of the model.

While rotenone model studies may investigate the pathways of PD, they are not directly relevant to realistic exposures to rotenone in humans. For example, the rotenone model most successfully produces PD symptoms when administered via chronic intravenous infusion (often with solvents to enhance absorption). Sometimes the injections are into the jugular vein, but recent studies found better results with sub-cutaneous injections or directly into the part of the brain involved in PD, the substantia nigra. Chronic oral administration of rotenone has been conducted in a small number of studies (Cicchetti et al. 2009) and results have not been favorable to produce PD symptoms. Another common method of investigation is the use of a simple pesticide cellular model, which typically test the gene-environment interactions between toxins and neural cells in vitro and the results are not comparable to exposure to the registered use of rotenone. One of the largest shortcomings of PD animal models, including the rotenone model, is the inability to mimic the route and period of time over which human exposure to pesticides realistically occurs (Raffaele et al. 2011). For this reason, the results of rotenone model studies were not used by EPA during the human health risk assessment during the reregistration of rotenone (EPA 2007).

Formulations of rotenone used as a piscicide contain varying amounts of active rotenone, generally from 5-8% (e.g., Prentox rotenone fish toxicant powder, CFT Legumine, Prenfish toxicant). The EPA recommends rotenone be applied as a piscicide at less than the maximum treatment concentration of 200 ppb (µg/L) (i.e., 0.2 parts ppm [mg/L]) (EPA 2007). During chemical treatments to remove fish in streams or rivers, a liquid rotenone formula is used that typically contains 5% active rotenone, and per the label the recommended concentration of 0.5 to 1.0 ppm of the formula would contain 0.025 to 0.100 ppm active rotenone, which equates to 25 – 100 ppb active rotenone. The rotenone model studies typically use in vivo experiments with rats or mice with injections of 2-3mg/kg/day of rotenone for up to 6 weeks to observe Parkinson's disease-like symptoms (e.g., Betarbet et al. 2000; Sherer et al. 2003; Bové et al. 2005; Ramachandiran et al. 2007; Franco et al. 2010). Most studies using oral administration of rotenone have produced little neurotoxicity in animals, possibly because ingested rotenone would break down during digestion (Bové et al. 2005). However, Pan-Montojo et al. (2010) documented some PD-like symptoms in mice fed 5 mg/kg/day of rotenone (mixed with the solvent chloroform to aid in absorption) for 5 days per week for 3 months, and Inden et al. (2007) documented PD-like systems in mice fed high doses of rotenone on a chronic basis.

For perspective considering that the maximum treatment concentration of rotenone per the EPA is 200 ppb (and maximum solubility of rotenone in water), which equates to 200 µg/L (µg active rotenone per liter of water) active rotenone, a 1 kg (2.2 lb) rat would need to be injected with 4 gallons of the 200 µg/L rotenone solution daily for 6 weeks to achieve the 3 mg/kg/day concentration used in rotenone model studies. For a typical stream treatment using 50 ppb active rotenone (50 µg/L), a 70 kg (154 lb) human would have to be injected with 1,109 gallons of a 50 µg/L rotenone solution daily for 6 weeks to achieve the 3 mg/kg/day concentration.

The Web of Science database has been cited in correspondence to the EPA during the reregistration process and this citation has recently been used widely in reference to S.B. 1294 and H.B. 2114 (Arizona's 50th Legislature; 1st regular session in 2010): "The Web of Science presently lists 210 scientific papers connecting rotenone and Parkinson's disease". The Web of Science database is available for public access at Arizona State University; otherwise, it is available by subscription only. To evaluate the scientific papers cited above, several searches within the Web of Science database were conducted and are discussed below.

Within the Web of Science database, citations can be found using search terms within search categories including: topic, title, and author. The majority of studies listed for the search terms "rotenone model" and "Parkinson's" (n=214) within the *topic* category were for studies researching the rotenone model of induced PD using either injections of rotenone into rats and mice, or experiments with cellular cultures. The majority of studies used the rotenone cellular model (43%; n=64), and the next most common study was using the rotenone rat model using IV methods (21%; n=42). Smaller numbers of studies used the rotenone model using chronic oral administration (2%; n=4), used Drosophila or other invertebrates as test subjects (5%; n=10), or a combination of methods (4%; n=8). Similarly, 464 citations were listed for the search terms "rotenone" and "Parkinson's" within the *topic* category were also for studies researching the rotenone model of induced PD using the methods described above.

*Summary*

The purpose of studies using the rotenone model is to examine the pathway of PD and not the toxicity of rotenone from its use as a pesticide (EPA 2005). Animal models using pesticides to investigate the etiology of PD are limited in scope because they do not produce the actual disease state and model only the motor features of PD (Cicchetti et al. 2009), using very high doses of rotenone administered to rodents over long time periods using methods not relevant to realistic human exposure. The relevance of the results of these studies in relation to rotenone use in fisheries management and the potential effects from exposure during piscicide treatments is not addressed in rotenone model studies. The potential realistic exposure of humans to rotenone during piscicide treatments, as regulated by the EPA, is not comparable to the dose required to cause the development of PD symptoms in rodents by way of chronic intravenous injections of rotenone into the sub-cutaneous, jugular vein, and substantia nigra, or by chronic oral administration of rotenone at high doses. Piscicidal use of rotenone as a restricted use pesticide degrades quickly, is not expected to contaminate groundwater, and restricts human exposure of the treatment area during treatment, all of which make an environmental exposure to rotenone highly unlikely to cause PD or PD-like symptoms in humans (Bové et al. 2005).

Parkinson's Disease and Occupational Exposure

While pesticide induced animal models typically study the pathways of specific PD symptoms, other studies have focused on the risk of the development of PD from genetic, environmental, or occupational factors. Studies that look at associations (through retrospective interviews) between the risk of PD and occupation typically measure statistical significance by odds-ratio values, which are based on logistic regressions of population-based case-controlled models (see references to follow). Case-controlled study models consist of interviewing (in person or by questionnaire) a group of PD patients (typically diagnosed by a physician) and a control group; questions typically include general information on age, sex (M or F), ethnicity, education, smoking history, and occupation, and more specific information on occupational and chemical exposure information.

The results of epidemiological studies of pesticide exposure have been highly variable. Studies have found no correlations between pesticide exposure and PD (e.g., Jiménez-Jiménez 1992; Hertzman 1994; Engel et al. 2001; Firestone et al. 2010), some have found correlations between pesticide exposure and PD (e.g., Hubble et al. 1993; Lai et al. 2002; Tanner et al. 2011) and some have found it difficult determine which pesticide or pesticide class is implicated if associations with PD occur (e.g., Engel et al. 2001; Tanner et al. 2009). Case control studies may have several potential biases and limitations, including the incorrect diagnosis of PD, under- or overestimation of pesticide use by interviewed subjects, and volunteer bias when recruiting study subjects. It is important to note that in case-control correlation studies, causal relationships cannot be assumed and some associations identified in odds-ratio analyses may be chance associations. Recently, epidemiological studies linking pesticide exposure to PD have been criticized due to the high variation among study results, generic categorization of pesticide exposure scenarios, questionnaire subjectivity, and the difficulty in evaluating the causal factors in the complex disease of PD, which may have multiple causal factors (age, genetics, environment)(Raffaele et al. 2011). A specific concern is the inability to assess the degree of exposure to certain chemicals, including rotenone, particularly the concentration of the chemical, frequency of use, application (e.g., agricultural, insect removal from pets), and exposure routes (Raffaele et al. 2011).

Of the studies finding correlations between pesticide exposure and PD, many have found the risk of PD to be greater when correlated with multiple factors including occupational use of pesticides (Lai et al. 2002; Elbaz et al. 2009); occupations such as farming, legal, religious and construction (Priyadarshi et al. 2001; Tanner et al. 2009); rural living (Lai et al. 2002); and well water consumption (Lai et al. 2002; Gatto et al. 2009). The specific dose-response relationships among chemical types and usages, however, have not been evaluated in most studies. Rather, individuals taking the surveys may select "pesticide use" and possibly the duration of use such as "5, 10, or 20 years", but without specific information such as chemical type, form (i.e., liquid, powder), specified use, and safety precautions used when handling the chemicals.

Tanner et al. (2009) reported that the risk of PD was significantly higher in two major occupational code groups based on odds-ratios from logistic regression models: legal occupations and construction/extraction fields. An increased risk of Parkinsonism was associated with two of the minor occupational code groups: ever working as a lawyer or judge, or as a religious worker. Although four groups were a priori identified to be at risk for Parkinson's based on mechanistic theories or existing publications, they were not statistically significant. These groups included: education, training, and library; health care practitioner and technical; health care support; and farming, fishing, and forestry. The authors also reported that occupational pesticide use was associated with risk of PD, however, the use of rotenone was only reported by one individual with PD and one individual in the control group, and was not statistically significant. Interestingly, of the individuals that reported to use pesticides (n=71/1030; 7%), 72% were farmers and 25% worked in building or grounds maintenance, but the risks of PD for the occupational codes "farming, fishing, and forestry" and "building and grounds cleaning" were not significant. It is important to note that in the Tanner et al. (2009) publication, in addition to occupational code groups chosen for analysis, the authors chose putative materials that had some association to PD. These included pesticide use, welding, and cleaning with solvents. They considered only the occupational exposure to these materials. For example, pesticide exposure via gardening, residential use, and consumption were not included in the analysis.

A study examining the risk of PD from pesticide (oxidative stressors and mitochondrial complex I inhibitors) exposure was published by Tanner et al. (2011); the individuals surveyed were pesticide applicators (primarily farmers) and their spouses. Their results indicated that rotenone and paraquat were similarly associated with PD using the odds-ratio analysis approach. Specifically for rotenone, individuals that used rotenone were 2.5 times more likely to be associated with PD, regardless if individuals were exposed to the chemical 5, 10, or 15 years prior to the diagnosis of PD. However, the methods of exposure (i.e., inhalation, dermal, oral), type of rotenone formulation (i.e., wet powder, liquid), concentration of rotenone, and delivery mechanisms per rotenone use (i.e., agriculture – handgun, airblast, groundboom; aquatic – aerial, sprayer, drip stations) were not reported in the surveys. It is also impossible to separate any difference between the influence of rotenone or paraquat use, or other pesticides, on PD associations because the survey asked individuals if they were exposed to *any* of a list of 18 chemicals within their occupations.

Due to these limitations in the analysis techniques used in the Tanner et al. studies (2009, 2011), it is difficult to apply the results of these studies to the potential risk of PD involved with rotenone use in fisheries management. For example, most of the studies that identified a link between farming or the occupational use of pesticides and an increase risk of PD did not identify if piscicide exposure to rotenone was a factor included in the analysis. There are substantial differences between the methods of application, formulation, and doses of rotenone used in agriculture and residential settings compared with aquatic use as a piscicide.

Rotenone is currently registered by the EPA as a restricted use pesticide for piscicide use only. In 2006, the technical registrants voluntarily cancelled all livestock, residential and home owner uses, domestic pet uses, and all other non-piscicide uses. During the registration process, EPA conducted risk analyses for acute and chronic human health impacts including drinking water exposure risk, occupational exposure risks, environmental fate, and ecological impacts (EPA 2005, 2006). Turner et al. (2007) also published a risk assessment for the piscicidal formulations of rotenone, and other studies have investigated rotenone toxicity when used in fisheries management (Ling 2003). Mitigation measures within the EPA's RED for rotenone in 2007 included ways to minimize public exposure to treatment areas by restricting public access to water bodies during treatment, and these restrictions are included in the product labels (EPA 2007).

Other pesticides that have been associated with an increased risk of PD from prolonged or occupational exposure include insecticides permethrin and beta-hexachlorocyclohexane (beta-HCH; carcinogen, no longer registered by EPA), herbicides paraquat and 2,4-dichlorophenoxyacetic acid, and fungicide maneb (Parkinson's Disease Foundation; www.pdf.org; Jeng et al. 2007; Tanner et al. 2009).

*Summary*

To date, there are no published studies that conclusively link exposure to rotenone and the development of clinically diagnosed PD. Some correlation studies have found a higher incidence of PD with exposure to pesticides among other factors, and some have not. It is very important to note that in case-control correlation studies, causal relationships cannot be assumed and some associations identified in odds-ratio analyses may be chance associations. Only one study (Tanner et al. 2011) found an association between rotenone and paraquat use and PD in agricultural workers, primarily farmers. However, there are substantial differences between the methods of application, formulation, and doses of rotenone used in agriculture and residential settings compared with aquatic use as a piscicide, and the agricultural workers interviewed were also exposed to many other pesticides during their careers. Through the EPA reregistration process of rotenone, occupational exposure risk is minimized by: new requirements that state handlers may only apply rotenone at less than the maximum treatment concentrations (200 ppb), the development of engineering controls to some of the rotenone dispensing equipment, and requiring handlers to wear specific PPE.

To truly evaluate if the occupational use of rotenone as a piscicide or the risk of individuals residing close to a treatment stream or lake increases the risk of PD, carefully designed analytic studies utilizing appropriate control populations would be required to further test hypotheses regarding rotenone exposure from piscicide use and PD risk in relation to formulation, concentrations, methods of use, and PPE used.

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**Part 2. Environmental Fate of Rotenone, Impacts to Non-Target Organisms, and Use of Potassium Permanganate**

Executive Summary

The use of rotenone as a piscicide (pesticide to eradicate fish) in Arizona prompted concerns over the potential human health and ecological impacts that may result from rotenone exposure, and resulted in proposed state legislation (50$^{th}$ Legislature, 1$^{st}$ regular session in 2010: S.B. 1294; H.B. 2114) that would have significantly limited the Arizona Game and Fish Department's (AGFD) ability to use rotenone in the future. In August 2011, the Human Health and Environment Subcommittee, part of the AGFD Director-initiated Rotenone Review Advisory Committee (a Blue Ribbon Evaluation Committee), was asked to evaluate the environmental persistence of rotenone when used in fisheries and aquatic invasive species management and the potential threats to human health and the environment. This task was accomplished by conducting a comprehensive scientific and technical literature review, summarizing pertinent studies and topics in report form, and making recommendations to the Rotenone Review Advisory Committee on existing or suggested methods to reduce negative impacts from rotenone use as a piscicide, if applicable. The issues addressed were the primary concerns introduced by S.B. 1294 and H.B. 2114 proponents, as well as issues deemed necessary by the Subcommittee to investigate during this process including the environmental fate of rotenone, impacts to non-target organisms, and the use of potassium permanganate ($KMnO_4$) as a neutralizing agent. The results are presented in this Executive Summary and Part 2 of the Subcommittee's report. The other piscicide registered by the EPA, antimycin-A, was not analyzed in this report because it is not currently commercially available.

*Environmental Fate of Rotenone*

Rotenone degrades rapidly in water, and temperature and sunlight significantly increase the degradation process (e.g., Schnick 1974). Rotenone and rotenolone, a byproduct formed during the breakdown process, will persist longer in lake environments compared to stream environments, as well as in deep and cold waters (Finlayson et al. 2001). Typically these chemicals will dissipate to undetectable amounts within one to three weeks post-treatment in lake environments, and immediately (2 – 48 hours) in stream environments (EPA 2007; Brown 2010; CDFG 2010; MFWP 2011). During piscicide treatments, most commonly during stream treatments, the oxidizer $KMnO_4$ is used, where appropriate, to further accelerate the degradation process and prevent rotenone from moving past the downstream end of treatment areas.

Rotenone is highly insoluble in water and strongly absorbs to soil particles in bottom sediments and to suspended particles in the water column, limiting its mobility and availability to bioaccumulate in organisms (Turner et al. 2007). These factors also make rotenone unlikely to leach through soils and reach groundwater, and thorough long-term monitoring of groundwater wells in treatment areas in California (10 years), and short-term monitoring of wells in Montana never detected rotenone, rotenolone, or any formulation products (Skaar 2002; Ridley et al. 2007; McMillin and Finlayson 2008). If leaching does occur, rotenone will move vertically through soils typically less than one inch deep (Dawson 1986), making it unlikely to be absorbed by the roots of bank vegetation. The degradation rate of rotenone in soils will increase with high organic matter and clay content in soils, temperatures, and with time due to its unstable and volatile nature (Schnick 1974; Hinson 2000).

Rotenone products will typically use additives within formulations to increase rotenone's solubility in water, and although some of these compounds may be toxic at high concentrations, they are used in trace amounts, typically in the parts per billion or parts per trillion when applied to water (Finlayson et al. 2000). The insolubility of rotenone requires the use of additives in liquid formulations including volatile organic compounds (VOC), semi-VOCs (e.g., naphthalene, xylene), and other inert ingredients (e.g., piperonyl butoxide). None of these additive ingredients exceed drinking water quality criteria established by the EPA if the rotenone products are used according to the product labels. Thorough groundwater monitoring in California in rotenone treatment areas has never documented any of these chemicals in wells, and they degrade relatively quickly in surface water and soils (Finlayson et al. 2001; Ridley et al. 2007; McMillin and Finlayson 2008).

*Impacts to Non-Target Organisms*

The impacts of rotenone exposure to aquatic invertebrates are highly variable and most studies report temporary or minor effects (e.g., Melaas et al. 2001; Vinson et al. 2010). Short-term impacts on aquatic invertebrates are likely because they are capable of rapid recovery from disturbance, they have high reproductive capability, relatively short life cycles, and are dispersal by nature. Typically, invertebrate abundance will decrease immediately following a treatment, but increase substantially for most groups of organisms within a matter of months up to one year (Vinson et al. 2010). While invertebrate biomass will return to pre-treatment levels, the longer-term effects often produce changes to the invertebrate community composition by the underrepresentation of some species and the presence of previously undocumented species, perhaps filling vacated niches (CDFG 2010).

The exposure risk to terrestrial organisms is relatively low because rotenone for piscicide use is applied directly to water. Rotenone toxicity studies typically use concentrations much higher than those used in fishery management applications, and with different delivery methods that would occur from exposure to a piscicide treatment (e.g., Marking 1988). Oral ingestion of rotenone by terrestrial organisms is not a realistic exposure. However, consumption of treated water, vegetation with rotenone residues, or dead fish consumed within a treatment area may be more realistic routes of exposure (EPA 2007). Study results have determined that terrestrial organisms such as mammals and birds would need to consume pounds of treated fish (e.g., 1 kg [2.2 lb] bird = consumption of thousands of pounds of fish), pounds of vegetation with rotenone residues, and gallons of treated water (e.g., 735 kg cow [1,620 lb] = consumption of 4,615 gallons) at amounts that aren't physically possible or probable to reach a lethal dose.

The greatest impact to amphibians from rotenone treatments is at the tadpole stages, and rotenone exposure can result in mortality as well as reduced growth from chronic exposure (e.g., EPA 2008; Little and Calfee 2008). Reptiles are generally less susceptible to rotenone exposure, but certain species such as garter snakes may decrease in numbers because of impacts to their amphibian and fish forage base (Hayes and Price 2007).

*Potassium Permanganate($KMnO_4$)*

$KMnO_4$ is a powerful oxidizer that is often applied during flowing water treatments as a neutralizer to increase the degradation process of rotenone and reduce exposure risks outside of treatment areas, where appropriate. In addition to use as an oxidizer for piscicide treatments, $KMnO_4$ is also used in similar concentrations in municipal drinking water plants for disinfection purposes, to remove manganese and iron, for odor and taste control, and to control invasive species in drinking water reservoirs (EPA 1999).

*Conclusions*

During project development, fishery managers must evaluate the potential impacts closely, developing their treatment plan to minimize potential impacts to the public and all non-target species, especially those most sensitive to rotenone exposure. The Rotenone Standard Operating Procedures (SOP) Manual (Finlayson et al. 2010) serves as a critical guide for this process and per the new product labels expected for release in 2012, applicants can conform to the labels via guidance on the safe and effective use of rotenone described in the Rotenone SOP Manual. Scientific monitoring indicates treatments close to groundwater wells will not contaminate groundwater, thus, there is little to no risk of public exposure to drinking water containing rotenone, rotenolone, or any formulation products from wells without a direct connection to treated surface water. Terrestrial wildlife may be exposed to treatment areas, but are unable to consume enough treated water or vegetation with rotenone residues to reach toxic levels (EPA 2006). The most sensitive species to be impacted by rotenone exposure include fish, aquatic invertebrates, and amphibians. While the recovery of aquatic invertebrates is usually short-term, the long-term impacts to amphibian populations, especially rare species, are unknown and should be considered during the development of a proposed treatment project and the treatment implementation plan (EPA 2008).

## Environmental Fate of Rotenone

*Rotenone Fate in Surface Water*

Rotenone degrades rapidly in water, with the rate of degradation dependent upon factors including temperature, light, turbidity, depth, alkalinity, organic debris, and treatment concentration (Schnick 1974; Hinson 2000). Temperature has the greatest influence on the rate of degradation, with degradation rates increasing with water temperature (Schnick 1974; Finlayson et al.. 2000; Brown 2010). Rotenone degrades 10 times faster at $23^oC$ than at $1^oC$ (Gilderhus et al.. 1986). As such, several studies have shown that rotenone degrades slower during the winter than in the summer, and degrades slowly when applied under ice and snow cover because of low temperatures and low light intensity (Schnick 1974; EPA 2006).

Sunlight is the next major factor that increases the degradation of rotenone because of the chemical’s sensitivity to photolysis. Finlayson et al. (2001) documented longer rotenone degradation rates in deep lakes compared to shallow lakes, attributing this to greater light penetration in shallow waters. High alkalinity may increase the rate of degradation (Schnick

1974). Clemens and Martin (1953) reported that rotenone persisted for 3-6 days in clear ponds with low alkalinity but only 1-3 days in clear ponds with high alkalinity.

Turbidity can slow the degradation of rotenone. Dawson et al. (1991) reported that rotenone will adsorb to suspended particles and persist for longer periods of time. Turbidity also reduces light penetration into water, thus reducing photolysis of rotenone, resulting in a longer breakdown period (Hinson 2000). Thus, dissolved organic matter does not contribute to the degradation of rotenone (Brown 2010), and the absorption of rotenone to sediments limits its mobility and its availability for organisms to bioaccumulate the chemical from the water column (Turner et al. 2007).

Laboratory studies show that rotenone is unstable and degrades quickly, with half-lives in soft water ranging from 13 days at 17$^{o}$C (62$^{o}$F) to 22 days at 12$^{o}$C (54$^{o}$F). However, degradation of rotenone in natural conditions during a piscicide treatment is much quicker due to exposure to additional factors (e.g., temperature, light, turbidity) that speed the breakdown (CDFG 2007b). For rotenone treatments in two types of freshwater ponds – earthen bottom and concrete bottom – at a concentration of 250 ppb active rotenone, the half-lives of rotenone in the earthen pond dissipated two to three times faster than concentrations in the concrete pond (earthen pond 1.8 days [spring], 0.7 days [summer], 1.8 days [fall]; concrete pond 3.7 days [spring], 1.3 days [summer], 5.2 days [fall]). Finlayson et al. (2001) reported that rotenone treatments using concentrations of 2-4 ppm in lakes and reservoirs generally degraded to undetectable levels within one to three weeks, with longer degradation times corresponding to lower water temperatures. Following the two major rotenone treatments at Lake Davis in California, rotenone was detected in the surface water for 48 days after the 1997 treatment, and 36 days after the 2007 treatment, although at very low concentrations (CDFG 2007c). For example, rotenone concentrations following the 2007 treatment were below 20 ppb less than two weeks post-treatment.

The basic dilution by freshwater during stream treatments allows for accelerated degradation, typically degrading to undetectable levels quickly, from 2 – 48 hours (EPA 2007; Brown 2010; CDFG 2010; MFWP 2011). Volatilization is perhaps the most important factor promoting rotenone degradation during stream treatments (Brown 2010). Acetone or other solvents (volatile organic compounds [VOCs]) are used in rotenone formulations to aid in dilution into water, and the volatilization of these chemicals in turbulent environments likely contributes to the degradation of rotenone, particularly over rubble substrates in streams.

The degradation of rotenone can be accelerated by the application of an oxidizing agent such as potassium permanganate ($KMnO_4$). This dry crystalline substance is mixed with stream or lake water (most often streams) to produce a concentration of liquid sufficient to detoxify the rotenone. Neutralization is accomplished after about fifteen to thirty minutes of exposure time between $KMnO_4$ and rotenone treated water (Finlayson et al. 2010). When $KMnO_4$ is used during piscicide treatments in streams, sentinel fish are placed within and at the downstream end of the neutralization zone to monitor the efficacy of the rotenone neutralization process. Rotenone is determined to be effectively neutralized when sentinel fish at the downstream end of the neutralization zone are alive and do not exhibit any symptoms from exposure with rotenone, which typically occurs at 30 minutes travel-time downstream of the $KMnO_4$ application station.

Rotenone degrades into 20 separate compounds, primarily rotenoids, only one of which – rotenolone (6αβ, 12αβ-rotenelone) – is considered toxic (Cheng et al. 1972), but only 1/10$^{th}$ as toxic as rotenone (Finlayson et al. 2001; Pellerin 2008). Rotenolone presence generally parallels rotenone residues, and is rarely found in the absence of rotenone (Pellerin 2008). Rotenolone was found to persist for 6 weeks post treatment in cold (<10$^{o}$C, 50$^{o}$F) alpine lakes with low alkalinity, and will degrade faster in warmer water like rotenone. Finlayson et al. (2000) reported that rotenone may be more sensitive to photolysis than rotenolone, partially explaining the longer persistence of rotenolone, especially in the alpine lakes that may have very clear water and greater solar radiation properties.

*<u>Rotenone Fate in Sediment</u>*

Rotenone is very slightly soluble in water, thus emulsifying agents and solvents are added to formulations to help disperse the product in surface waters for piscicide treatments (CDFG 2007b). The octanol-water partition coefficient ($k_{ow}$) is a measure of the relative proportion of the chemical partitioning into an organic phase versus liquid water. It is a surrogate measure of a chemical's mobility in a saturated water-soil system, in which soil organic carbon serves as the organic phase into which the chemical sorbs. Log values of $k_{ow}$ < 5 mean that a greater proportion of the chemical partitions into the soil phase and thus is unavailable for transport through the soil in the water phase and there is a reduced likelihood of bioaccumulation. Soils with higher organic carbon content (as compared to clean sands, for example), can decrease the mobility of a chemical through the soil. Rotenone's octanol-water partition coefficient is log $k_{ow}$ = 4.10, and because of rotenone's insolubility in water, it strongly adsorbs to soil particles, both in bottom sediments and in suspended particles in the water column (Dawson et al. 1991). This adsorption to the sediments limits its mobility and its availability for organisms to bioaccumulate the chemical from the water column (Turner et al. 2007).

Because rotenone adheres to soils and is nearly insoluble in water, it is unlikely to leach from soils and reach groundwater (Finlayson et al. 2001; CDFG 2007b; Tuner et al. 2007). Dawson (1986) found that rotenone leaches vertically less than 2 cm (0.8 in) in most soil types and less than 8 cm (3.1 in) in sandy soil (also reported by Hisata 2002). To date, there are no records of rotenone contamination of any groundwater wells that are isolated from surface water (see section on *groundwater* below).

Rotenone has been shown to adsorb into bottom sediments from surface water of treated lakes, (Dawson et al. 1991; CDFG 2007a, b) and degradation rates increase as soil organic matter and clay content increase (Cavoski et al. 2007), as well as temperatures. Dawson et al. (1991) found that rotenone disappeared from earthen ponds 2-3 times quicker than from concrete lined ponds, by adsorption into sediments in addition to the degradation within the water column. They also determined that rotenone did not persist within the sediments, degrading to below limits of detection within 14 days following a treatment in spring (46$^{o}$F, 8$^{o}$C) and within 3 days following treatments in summer (72$^{o}$F, 22$^{o}$C) and fall (59$^{o}$F, 15$^{o}$C), indicating degradation was also related to water temperature. Rotenone and rotenolone persisted in the sediment of Lake Davis for 55 days following the 1997 fall treatment (56$^{o}$C, 13.5$^{o}$C), and for up to 6 months following the 2007 fall treatment (63$^{o}$C, 17.2$^{o}$C), and were never detected again after rigorous monitoring (CDFG 2007a). Although rotenone and rotenolone samples were detected for a longer period of time than the treatment in 1997, the concentrations were extremely low and continued to lower over time. For example, rotenone concentrations in most of the sediment samples taken following the 2007 treatment were less than 100 ppb less than one month post-treatment.

It is uncommon to find rotenone in sediments following a stream treatment (Finlayson et al. 2000). Finlayson et al. (2001) tested the sediments of a number of streams treated with rotenone, and most samples found no detectable residues of rotenone or rotenolone. One sample contained a barely detectable residue of rotenone, but it disappeared within 7 days.

*Rotenone Fate in Groundwater*

Because rotenone has a very low solubility in water, readily binds to sediment (Dawson et al. 1991; Turner 2007), is unlikely to leach from soils (Finlayson et al. 2000), and travels through soils at depths of 1-3 inches (Dawson et al. 1991; Hisata 2002), it is very unlikely to reach groundwater or wells. Thorough monitoring of wells in California post rotenone treatments confirms this to be an accurate assumption.

Twenty-six wells near nine rotenone treatments in California were monitored from 1987-1997; residues of rotenone, rotenolone, or other constituents of the formulations were never found in any of the wells monitored (Finlayson et al. 2001). The 26 wells ranged from 3’ to 220’ deep and were from 1’ to 2300’ away from rotenone treated water (mostly streams and rivers) and well samples were collected over multiple days (from 1-456 days after treatment). Eighty wells in the vicinity of Lake Davis, California were monitored for VOCs and piperonyl butoxide (PBO; a synergist) from the rotenone formulation following the rotenone treatment in 1997; no contamination of these wells with rotenone or its constituents was ever detected (Carlsen et al. 1999). PBO is relatively stable synergist with very low toxicity, and is used in pesticide products that contain other chemicals such as pyrethrins, pyrethroids, rotenone, and carbamates (NPIC 2000). Groundwater samples collected for 10-years following the 1997 Lake Davis rotenone treatment and after the 2007 treatment have not detected rotenone, rotenolone, or other ingredients in rotenone formulations in any of the wells monitored (CDFG 2007a, c; Ridley et al. 2007).

It is possible that wells with a direct hydrologic connection to treated surface water may detect rotenone, rotenolone or any formulation products during treatments. For example, pre-rotenone treatment investigation of 17 wells surrounding Lake Diamond, Oregon, found that the shallow aquifer surrounding the lakes was closely related to the lake levels, with most wells showing a strong response to fluctuating lake levels indicating a hydrologic connection to the lake (Eilers 2008). Post-treatment, small traces of rotenone, rotenolone, and VOCs were detected in two wells; however, no traces were detected in the duplicate test analyses. The EPA Reregistration decision for rotenone requires the rotenone concentration to be 40 ppb or below to be safe for drinking water consumption and the Rotenone SOP Manual (Finlayson et al. 2010) provides the associated EPA requirements and guidance (EPA 2007). If domestic wells with hydrologic connection to the treatment area exist, the public or private water users must be notified 7-14 days before the treatment. The water users would be advised not to consume the water if active rotenone concentrations were greater than 40 ppb, which is the level determined safe for drinking water consumption. Thus, monitoring requirements for wells with hydrologic connection to treated surface water may apply if rotenone concentrations are anticipated to be greater than 40 ppb.

*Rotenone Fate in Air*

Due to its low Henry's Law constant (1.1 x $10^{-13}$ atm-$m^3$/mol), rotenone is not expected to volatilize into the air appreciably from treated surface water. The small amount of rotenone that may volatilize into the air will be readily degraded. The half-life for the degradation reaction in air is estimated to be 1.2 hours (CDFG 2007b); the half-life represents the amount of time required for half of the chemical to break down. After one half-life, 50 percent of the original compound remains, after two half-lives 25 percent remains, and this process continues through the chemical's degradation. Odor from treatments or decaying fish may persist for a short period of time post treatment.

Because EPA toxicity assessments revealed high toxicity for the inhalation of rotenone, the EPA determined that rotenone applicators using backpack sprayers or mixing powdered rotenone would have the highest risk of exposure to airborne rotenone. They mitigated these concerns by supporting the Rotenone SOP Manual (Finlayson et al. 2010) as a guidance document for label conformance, and requiring product labels to incorporate safety precautions such as specific personal protective equipment (PPE) to prevent inhalation exposure.

*Fate of Other Organic Materials in Formulated Rotenone Products*

There are several formulations of rotenone used currently or formally used for piscicide treatments including: Nusyn-Noxfish (cancelled), Pro-Noxfish (cancelled), Prentox Fish Toxicant Powder (active), Prentox Prenfish Toxicant (active), CFT Legumine (active), and Chem Fish Regular and Synergized (active).

Studies in California since 1987 have documented the four rotenone formulation constituents commonly detected in waters treated with certain rotenone products that act as synergists or emulsifiers (e.g., Nusyn-Noxfish, Pro-Noxfish): naphthalene, 2-methylnaphthalene, xylene, and trichloroethylene (TCE), which are highly volatile and water soluble (Finlayson et al. 2001; Skaar 2002). These constituents are also referred to as VOCs or semi-VOCs, and tended to dissipate to non-detectable levels in 2-3 weeks in lake systems and were not detected in flowing waters. The fate of TCE is particularly important, since it is a carcinogen. However, the concentrations of TCE and xylene found never exceeded the EPA drinking water standards; drinking water standards for naphthalene and 2-methylnaphthalene have not been developed. Naphthalene, 2-methylnaphthalene, xylene, and TCE were never found in the groundwater within 26 wells or in soil at five sediment sites monitored since 1987 following rotenone treatments in California (Finlayson et al. 2001).

The CFT Legumine formulation contains two main inert carrier components that make up approximately 93% of the formulation by weight, including N-methyl-pyrrolidone (NMP) and diethylene glycol monoethyl ether (DEGEE). These two solvents are infinitely soluble in water, do not tend to bind to sediment particles, and are used in a variety of pesticide products (CDFG 2007a). They do not readily volatilize from surface waters, but the small amounts that do volatize will be readily degraded with an atmospheric half-life of up to 12 hours. Neither component will undergo hydrolysis or direct photolysis. Aerobic biodegradation is main mechanism for removal of these components from aquatic systems (CDFG 2007a).

CFT Legumine contains trace amounts of inert naphthalenes, methylnaphthalenes, and alkylated benzenes. These components are more volatile than NMP and DEGEE, but make up less than 1% of the formulation and are not expected to significantly contribute to the fate or transport of CFT Legumine (CDFG 2007a). The CFT Legumine formulation also contains polyethylene glycol (PEG) that is part of the inert ingredient Fennodefo 99™. This is a highly soluble chemical, with low volatility, and rapidly degrades in a matter of days by biodegradation, hydrolization, and photolytic oxidation. PEG's could feasibly travel to groundwater because they are highly soluble, but they occur at very low concentrations in the formulation and rapid biodegradation makes this unlikely. Hexanol is also present as a solvent, has limited volatility, and degrades rapidly through photolytic and biological degradation mechanisms. Trace benzenes are minor components of CFT Legumine, which have limited volatility, and rapidly degrade through photolytic and biological mechanisms (Fisher 2007). CFT Legumine formation lacks the synergist PBO, which allows it to achieve toxicity in fish at twice a faster rate.

Water quality testing conducted on Comanche Creek and Costilla Creek in New Mexico post-rotenone treatments with CFT Legumine found no residues of rotenone, rotenolone, NMP, DEGEE, benzenes, toluenes, or naphthalenes in 2007 and 2008 within the treatment areas and downstream of treatments (New Mexico Department of Game and Fish, personal communication).

The EPA recognizes the need for certain formulations to use synergists or emulsifiers, and registrants are required to submit an updated confidential statement of formula for each product within rotenone formulations that are greater than 0.1% active ingredient. If there are concerns about risks of specific inert ingredients, the EPA may take steps to address such risks.

*Case Study: Rotenone Treatments in Lake Davis, California*

California Department of Fish and Game (CDFG) conducted a rotenone treatment on Lake Davis, California in the fall of 1997 to eradicate invasive northern pike (*Esox lucius*) populations (Ridley et al. 2007). Surface water monitoring by CDFG and California Department of Health Services (CDHS) after the treatment detected rotenone and rotenolone within the reservoir for the first 48 days following treatment, and they were not detected again. The half-life of rotenone during the 1997 treatment was 7.7 days. VOCs and semi-VOCs were detected in the water for up to two weeks post-treatment, and concentrations of the synergist PBO was found to persist in deep and cool waters for 9 months post-treatment (Finlayson et al. 2001; CDFG 2007a). PBO is relatively stable and photolysis does not contribute significantly to its degradation, so its levels are thought to be reduced primarily through dilution. Cold water temperatures during the 1997 Lake Davis treatment are assumed to explain the slow degradation of rotenone, rotenolone, and PBO. Sediment samples taken by CDFG and CDHS after the 1997 treatment detected rotenone, rotenolone, and semi-VOCs for 55 days post-treatment; no VOCs were ever detected in sediment samples.

The persistence of PBO was the source of much of the controversy in the Lake Davis treatment because it was detectable in the surface water much longer than was originally anticipated by CDFG. To address concerns by City of Portola residents over groundwater contamination as a result of the treatment, the Plumas County Environmental Health Department (PCEH) set up a 10-year groundwater monitoring program post-treatment to monitor groundwater adjacent to Lake Davis and in Big Grizzly Creek downstream of the dam. The program monitored 80 wells near Lake Davis from 1998-2008 for PBO and VOCs. Out of 1400 samples, there were four verified detections of VOCs in five wells, all of which were below the maximum contaminant levels for drinking water, were commonly used in household products, and were detected 3 – 8 years post-treatment. Thus, it was determined that no contamination related to rotenone treatments at Lake Davis occurred, and there was no impact on groundwater quality (http://www.dfg.ca.gov/lakedavis/welltesting.html). Separately from PCEH, CDFG sampled groundwater from five wells within the Lake Davis treatment area at 5, 14, 90, 194, and 324 days post-treatment and never detected rotenone, rotenolone, VOCs, semi-VOCs, or PBO at any well.

Another result of persisting PBO, rotenone, and rotenolone from the 1997 treatment was the closure of the lake for public use for an unanticipated amount of time. At the time of the rotenone treatment, the city of Portola drew a portion of its water from Lake Davis, and had to rely on other sources of water until the chemicals dissipated. Following the treatment, the municipal water supply in the City of Portola began using water from a geochemically separate aquifer, which continues today (CDFG 2007c). Another factor that made the 1997 treatment even more controversial was the neutralization zone in Big Grizzly Creek, which was not sufficient to fully neutralize rotenone and resulted in an unintended fish kill in the creek. These factors ultimately impacted the popular tourist town of the city of Portola, which relies on public lake use as a major source of tourism-generated revenue and prompted a $9.1 million dollar lawsuit against the state of California and criminal charges against CDFG. The criminal charges were dropped when the settlement was reached, and the settlement compensated the city of Portola for economic and infrastructure assistance, Plumas County for economic and infrastructure assistance, Plumas County for improvements to the Lake Davis Water Treatment Plan, and for individual claims for personal injury, property damage, or business loss as a result of the rotenone treatment.

A second treatment was conducted in September of 2007, either because some northern pike survived the first treatment in 1997 or they were again illegally stocked back into the reservoir. CFT Legumine, which lacks the synergist PBO, was used to treat Lake Davis in 2007 (McMillin and Finlayson 2008). Water was held within the Lake Davis reservoir for four months post-treatment before any water was allowed to discharge downstream into Big Grizzly Creek. Rotenone persisted in Lake Davis for approximately 32 days with a half-life of 5.6 days, and rotenolone persisted for 54 days. NMP persisted in the lake for 39 days, DEGEE persisted for 68 days, and Fennedofo 99™ persisted for 90 days in the lake. In the lake sediments, rotenone persisted for up to 6 months, NMP persisted for 2 months, Fennedofo 99™ persisted for 4 months, and DEGEE was only detected one month post treatment (McMillin and Finlayson 2008). No constituents of CFT Legumine were found in groundwater wells near Lake Davis following the 2007 treatment, but monitoring will continue in 80 wells for up to 10 years by PCEH (PCEH 2007; McMillan and Finlayson 2008).

*Bioconcentration and Bioaccumulation of Rotenone*

Bioconcentration is the accumulation of chemicals into biological tissues at concentrations greater than those it was exposed to in the water or air (CDFG 2010). Bioaccumulation in the food chain results in higher chemical concentrations in predators. Bioconcentration and bioaccumulation can measure the persistence of chemicals in the tissues of living organisms.

Rach and Gingerlich (1986, cited in CDFG 2007) examined concentrations of rotenone and the rate of breakdown in tissues of several species of warmwater fish. They found rotenone concentrations and the rate of breakdown within tissues to vary by fish species, and considered the bioconcentration factors to be moderate to low compared to other organic compounds. At sublethal concentrations of rotenone, which would not result in mortality, exposure to the chemical does not appear to bioconcentrate in biological tissues because of the rapid detoxification of rotenone by liver enzymes.

A study on the bioconcentration of rotenone in brown bullheads (*Ameiurus nebulosus*) that survived the 2007 Lake Davis rotenone treatment sampled fish tissues at 3, 10, 30, and 212 days post-treatment. The average rotenone concentrations in tissue samples were <10 ppb (<10 mg/kg) at 30 days post-treatment and undetectable at 212 days post-treatment. Other constituents in rotenone formulations (e.g., rotenolone, NMP, and Fennedefo99 ™) were not detected at 30 days post-treatment. Rainbow trout stocked 2 months after the treatment were also tested at 212 days post-treatment and no compounds were detected (Carlsen et al. 1999; http://www.dfg.ca.gov/lakedavis/tissuestudy/). Early bioconcentration in fish tissues was found to be highest in the head and viscera (inedible parts for humans) and lowest in the flesh (edible parts for humans) (Carlsen et al. 1999).

Bioaccumulation occurs when a substance accumulates in higher concentrations in predators high in the food chain than prey items lower on the food chain. Rotenone does not bioaccumulate in the food chain (CDFG 2007; 2010). Adsorption of rotenone in the stomach and intestines of birds and mammals that eat live or dead fish is slow and incomplete, and what little is adsorbed is metabolized effectively by the liver into less toxic excretable metabolites. Ling (2003) reported that rotenone is not easily absorbed in higher mammals and is effectively broken down by the liver and oxidation in the gut.

Effects to Non-Target Organisms from Rotenone Exposure

*Aquatic invertebrates*

Natural variation in macroinvertebrate communities is a function of natural fluctuations in aquatic ecosystems, spatially (e.g., between and within streams) and temporally (e.g., seasonal)(Leunda et al. 2009). Macroinvertebrates are sensitive to changes in food availability (Brokaw 1981), sediment, dissolved organic matter, substrate, temperature, and light (Gravelle et al. 2009), which are some of the controlling factors that explain for variations in macroinvertebrate biomass, species composition, and species diversity. It is common for the density and composition of aquatic insects to be greatly impacted by stochastic events such as floods and drought, but they generally recover quickly (within one year)(Hickey and Salas 1995;

Minshall 2003). While macroinvertebrate abundance may return to pre-event levels, the species composition and diversity may be altered, and wide variations may continue for 5-10 years (Minshall 2003). Human activities may also induce variation in macroinvertebrate community structure by practices such as logging (Gravelle et al. 2009) and grazing (Rinne 1988; McIver and McInnis 2007).

Rotenone affects aquatic invertebrates the same way as fish, by inhibiting respiration by blocking biochemical pathways of cell metabolism, specifically the reduced nicotinamide adenine dinucleotide (NADH)-dehydrogenase segment of the respiratory chain (Mangum and Madrigal 1999). The sensitivity of aquatic invertebrates to rotenone varies, with the most tolerant species consisting of decapod crustaceans (order Decapoda), followed by caddis fly larvae (order Trichoptera), snails (order Basommatophora), clams (order Unionoida), larval dragonflies/damselflies (order Odonata), midges (order Diptera), and mayflies (order Ephemeroptera)(Pellerin 2008).

Numerous studies have examined the impacts of rotenone on aquatic invertebrates. Most report temporary or minor effects, but some have reported long-term effects. For example, Mangum and Madrigal (1999) treated the Strawberry River in Utah with rotenone in 1990 and found invertebrate abundance to decrease immediately following treatment, but increased substantially (above pre-treatment levels) for some groups of organisms within 1-2 months (midges and black flies). The most sensitive species were in the Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (also called EPT) orders, which had a very high mortality rate post treatment and began recovering within one year. EPT species are generally the most sensitive to stochastic events and human disturbances (Gravelle et al. 2009). Of the sensitive taxa, 7-14% of the species were still unaccounted for in the project area five years post-treatment. While aquatic invertebrate biomass in general was not impacted, the macroinvertebrate community composition and stability was impacted by the underrepresentation of some sensitive species post treatment, and the presence of previously undocumented species, perhaps filling vacated niches (CDFG 2010).

Other studies have documented mostly negligible effects from rotenone treatments on aquatic invertebrate populations. For example, four wetland ponds were treated with rotenone in west-central Minnesota at a 3 ppm (300 ppb) concentration to assess short- (1-3 weeks) and long-term (1 year) impacts on invertebrates and zooplankton (Melaas et al. 2001). The results revealed a significant short-term decrease in zooplankton abundance in the water column, with the majority of species recovered seven months post treatment; reductions in benthic aquatic invertebrate abundances were observed in only two taxa.

Vinson et al. (2010) conducted a literature review of studies that assessed the impacts of piscicides on invertebrates in lentic (lake) and lotic (stream) systems. Study results on the impacts to invertebrates from rotenone treatments in lentic systems have been highly variable, and treatment concentration and duration are influential. Similar to the results documented by Melaas et al. (2001), zooplankton were more sensitive to rotenone than benthic organisms and populations recovered within one month to three years. Most studies of treatments in lotic systems documented immediate and short-term declines in invertebrate abundance and species diversity, and EPT species were most sensitive. Most invertebrate assemblage abundances returned to pre-treatment levels in less than one year, but recovery of taxonomic diversity and community structure ranged from two to five years. In general, Vinson et al. (2010) summarized that short-term impacts on aquatic invertebrates are possible because they are capable of rapid recovery from disturbance, they have high reproductive capability, relatively short life cycles, and are dispersal by nature (MFWP 2011). However, they also reported variation among study results due to several factors including treatment concentration and duration, study design and sampling frequency, and the natural variation in toxicity of rotenone among invertebrate species. The reduced abundance of aquatic invertebrates may temporally impact organisms that prey on these species such as birds and newly stocked fish. Most research has found that the aquatic invertebrate community would recover rapidly from a piscicide treatment, and often the timing of restocking fish into treated waters allows sufficient time for the insect base to recover. For birds, they would likely emigrate to nearby habitats until full recovery of the aquatic community (MFWP 2011).

*Terrestrial birds and mammals*

The exposure risk to terrestrial organisms is relatively low because rotenone for piscicide use is applied directly to water. Studies examining the toxicity of rotenone typically use rotenone concentrations much higher than those used in fishery management applications, with different delivery methods. For example, Marking (1988) conducted studies with rats and dogs fed high concentrations of rotenone (7.5 – 75 mg/kg/day) for six months to two years, and the observable effects included weight loss, diarrhea, and decreased food consumption, but documented a lack of tumors and reproductive problems. Other studies have documented that rotenone does not cause birth defects, gene mutations, or cancer (cited in MFWP 2011). It is possible that birds and mammals are tolerant of oral doses of rotenone because natural enzymes in their digestive tracts neutralize rotenone, compared with the rotenone uptake mechanisms in fish and aquatic invertebrates.

The EPA conducted dietary risk assessments to determine the lethal dose of rotenone for birds and mammals. The $LD_{50}$ for acute oral ingestion exposure by a rat consuming rotenone ranges between 39.5 to 102 mg active ingredient rotenone/kg (females and males, respectively; equivalent dose = 0.00004 oz/2.2 lb and 0.0001 oz/2.2 lb), and the EPA classifies rotenone as highly toxic to mammals ingesting rotenone at these quantities. On a chronic exposure basis, mammals lost between 10-50% of their body weight from chronic oral ingestion exposure. For birds, the $LD_{50}$ for acute oral ingestion exposure ranged between 1680-2200 mg/kg and the EPA classifies rotenone as only slightly toxic to birds, and chronic exposure tests were not conducted.

The EPA's risk assessment for terrestrial organisms estimated toxicity (using dietary toxicity studies), exposure scenarios, and potential risk to birds and mammals. It is possible that piscivorous (fish eating) birds and mammals may feed on dead or dying fish within a treatment area, although rotenone labels and the Rotenone SOP Manual (Finlayson et al. 2010) recommend collection and/or burial of dead fish where practicable. The EPA determined that based on rotenone residuals in yellow perch (*Perca flavescens*) and common carp (*Cyprinus carpio*) during a rotenone treatment, a 1 kg (2.2 lb) bird would have to consume thousands of fish to achieve a lethal dose (274,000 perch; 43,000 small carp). Thus, it is not possible that piscivorous birds would consume enough rotenone contaminated fish to result in a lethal dose. Similarly for mammals, if a 1 kg (2.2 lb) mammal fed exclusively on rotenone treated fish, the concentration of ingested rotenone would be below the estimated median lethal equivalent concentration.

It is possible that some birds and mammals may consume vegetation bordering stream or lake banks that was sprayed with rotenone during a piscicide treatment by an applicator operating a backpack sprayer unit. A human health and ecological risk assessment for rotenone completed for the U.S. Department of Agriculture, Forest Service, did not analyze this exposure scenario because they determined it irrelevant to aquatic applications (Durkin 2008). The EPA estimated exposure concentrations of rotenone in the form of foliar residues on vegetation (e.g., grass) that may be consumed by wildlife following non-piscicide applications of rotenone before the product registrants withdrew their requests for reregistration for those uses of rotenone; the EPA considered wildlife exposure by way of piscicide applications to rotenone residues on vegetation unlikely. For agricultural applications (maximum application rate of 0.01 lb active ingredient rotenone per acre), no acute risk LOCs were exceeded based on the estimated exposure concentration of birds to rotenone by ingesting vegetation with rotenone residues. For residential applications with higher maximum treatment concentrations (0.00064 – 2.9 lb/acre), the dietary and dose-based acute oral ingestion exposure by birds were above the LOCs at concentrations greater than 0.22 lb/acre. For small mammals, the acute risk LOC was exceeded from the consumption of short grass with rotenone residues as a result of agricultural applications of rotenone. The acute risk LOC was exceeded from the consumption of multiple vegetation types as a result of residential applications of rotenone. For piscicide use, the equivalent concentrations used during applications are much lower than for agricultural and residential uses. For example, the equivalent application concentration for liquid rotenone is 0.0000040 lb/gallon in streams and 0.0000075 lb/gallon in lakes.

The EPA did not conduct a risk assessment to evaluate potential risk to birds and mammals from drinking rotenone treated water. However, the EPA studies for the human health risk assessments used rats to determine that the acute dietary exposure (drinking water only) of 200 ppb (maximum application concentration) is below the LOC. Finlayson et al. (2000) estimated that a 0.25 lb (0.113 kg) bird would need to consume 25 gallons of treated water in 24 hours to receive a lethal dose. Similarly for a large mammal, a cow weighing 1,620 lb (735 kg) would have to ingest 4,615 gallons of treated water to reach a median lethal dose (EPA, personal communication).

*Amphibians and Reptiles*

The greatest impact to amphibians from rotenone treatments would be at the tadpole stages because adults have been found to have low sensitivity to rotenone (MFWP 2011). A study on the impacts to federally threatened Chiricahua leopard frog (*Rana chiricahuensis*) tadpoles exposed to rotenone treated water determined the $LC_{50}$ to be 1.1 mg/L (1.1 ppm), which is within the treatment range as a piscicide (Little and Calfee 2008). Other studies have found similar results for tadpoles, with $LC_{50}$s of 0.005 and 0.30 mg/L for the northern leopard frog (*R. pipiens*) and southern leopard frog (*R. sphenocephala*) frogs, respectively.

The EPA conducted a recent risk assessment to evaluate the potential direct and indirect effects on the aquatic-phase (eggs, larvae, tadpoles, juveniles, and adults) of the federally threatened

California red-legged frog (CRLF)(*R. aurora draytonii*) and its critical habitat from piscicide applications of rotenone (EPA 2008). They used freshwater fish data to determine the acute and chronic risks to CRLF because no acceptable rotenone toxicity data was available for larval amphibians. EPA estimated the acute toxicity for the aquatic-phase CRLF at the 96-hour $LC_{50}$ to be 1.94 µg/L (1.94 ppb) active rotenone concentration. The chronic toxicity study produced a 32-day no observed adverse effect concentration (NOAEC) at 1.01 µg/L (1.01 ppb) active rotenone concentration, which resulted in reduced growth. The risk quotients (estimate of high-end risk) for direct effects to larval CRLF substantially exceeded the acute and chronic LOCs and the likelihood of direct individual mortality was 100%, so the EPA determined a May Affect and Likely to Adversely Affect to CRLF from exposure to piscicide applications of rotenone and the potential for modification of CRLF critical habitat a possibility. The EPA also determined that indirect effects to aquatic-phase and terrestrial-phase CRLF may occur from reductions in aquatic invertebrate forage items.

Reptiles (air breathing) are not expected to be directly impacted by piscicide rotenone treatments, although garter snakes (*Thamnophis* spp.) are known to feed on trout and may be impacted by reductions in trout post treatment. Post-rotenone treatment monitoring of amphibian and reptile populations at Diamond Lake, Oregon, documented most species in the same areas as pre-treatment, with the following exceptions: 1) lack of neotenic (aquatic-phase) salamanders in specific areas in the lake accessible to fish [reduction presumably from rotenone treatment], 2) reduced numbers of garter snakes [presumably from lack of amphibians for forage base post-treatment], and 3) poor Cascade frog (*R. cascadae*) recruitment [presumably regionally based declines or an effect of treatment](Hayes and Price 2007).

<u>Use of Potassium Permanganate to Neutralize Rotenone</u>

The oxidizer $KMnO_4$ can be applied to treated waters as a neutralizer to accelerate the degradation of rotenone and reduce exposure risks outside of the treatment area. Currently, the powder form of $KMnO_4$ is the only chemical allowed on rotenone labels for rotenone neutralization. In this role, $KMnO_4$ is used to oxidize and break down rotenone into naturally occurring non-toxic compounds of potassium, manganese, and water. The neutralization period by $KMnO_4$ takes between 15-30 minutes contact time (travel time) within rotenone-treated water, and the rotenone product labels recommend using live fish in cages at downstream intervals to monitor the effectiveness of neutralization.

For piscicide neutralization treatments, rotenone labels (e.g., CFT Legumine) specify that $KMnO_4$ can be applied to result in a stream concentration of 2-4 ppm $KMnO_4$, depending on the rotenone concentration used during the treatment and the oxygen background demand of the water. The Rotenone SOP Manual (Finlayson et al. 2010) recommends a residual level of 1 ppm $KMnO_4$ be maintained at the end of the contact zone and recommends the ratio for rotenone neutralization by $KMnO_4$ to be 1.5-2.0:1.0. For example, if the rotenone treatment rate was at a concentration of 1 ppm CFT Legumine, the application rate of $KMnO_4$ would be 4 ppm to account for 2 ppm $KMnO_4$ to neutralize 1 ppm CFT Legumine + 1 ppm $KMnO_4$ for background oxygen demand in water + 1 ppm $KMnO_4$ residual at the 30-minute travel time mark. The residual amount of $KMnO_4$ gives water a pink or purple color.

A variety of oxidizing chemicals are used in the treatment of drinking water depending on factors such as the source of the water supply (groundwater or surface water), amount of organic matter dissolved or suspended in the water, other constituents in the water (e.g., iron, manganese, nitrogenous compounds), potential of the oxidant to form toxic byproducts, ease/safety of handling and use, and cost. Most small public water systems that rely on groundwater disinfect with sodium or calcium hypochlorite because of relative ease and safety of use. These chemicals are used to disinfect water in storage tanks and to maintain a free chlorine residual in the distribution system. $KMnO_4$ is used as an oxidizer mainly in larger community drinking water plants supplied with surface water or a mix of groundwater and surface water. It is generally used in the first stage of water treatment to oxidize organic matter so that chlorination chemicals applied later do not create excessive levels of disinfection byproducts. $KMnO_4$ may also be used to remove iron and manganese from drinking water supplies (0.94-1.92 ppm), for odor and taste control (0.25 – 20 ppm), and to control invasive species in drinking water reservoirs such as zebra mussels (*Dreissena polymorpha*) and Asiatic clams (*Corbicula fluminea*)(0.5 – 4.8 ppm)(EPA 1999; Arizona Department of Environmental Quality, personal communication).

$KMnO_4$ is a strong oxidizer and should be handled carefully when in powder form and when mixing with water. Personal protective equipment is recommended in the Material Safety Data Sheet (MSDS) for $KMnO_4$ and includes: gloves, apron, vapor/dust respirator when mixing, and splash goggles. Concentrations of $KMnO_4$ used to neutralize rotenone can be toxic to fish, varying by fish species. For example, Kori-Siakpere (2008) found the lethal concentration of $KMnO_4$ treatment on fingerling African catfish (*Clarias gariepinus*) to be 6 ppm (based on 3.2 ppm $LC_{50}$). Marking and Bills (1975) found 2 ppm $KMnO_4$ to be a lethal dose to rainbow trout (*Oncorhynchus mykiss*). Because concentrations of $KMnO_4$ > 2 ppm may occur within the 30-minute travel-time neutralization zone, fish mortality is likely to occur.

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## Recommendations to the Rotenone Review Advisory Committee

The Human Health and Environment Subcommittee considers rotenone piscicide treatments, when applied by appropriately trained fishery professionals in a manner consistent with the Environmental Protection Agency's labeling requirements, state and federal laws and regulations, and using the Rotenone Standard Operating Procedures Manual (2010), minimizes potential risk to a level that is 1000x below any observable adverse effect on humans and non-target species, based on a review of the available scientific literature. The Subcommittee proposes the following recommendations to the Arizona Game and Fish Department (AGFD):

1. The AGFD Commission should formally adopt the Rotenone Standard Operating Procedures (SOP) Manual (Finlayson et al. 2010) as the minimum and mandatory standard for the planning and implementation of rotenone piscicide projects in Arizona.

2. All AGFD piscicide applications of rotenone in Arizona should be consistent with U.S. Environmental Protection Agency labeling requirements, appropriate state and federal laws and regulations, and the Rotenone SOP Manual (Finlayson et al. 2010).

3. The AGFD should develop a public awareness or involvement plan during the development of each rotenone or other piscicide project with consideration of the following factors: stakeholder involvement, the potential for human, non-target species and ecological exposure, the sensitive nature of the project, and the concerns of the public

expressed during the public outreach process. Elected and appointed officials that represent the public in the project area should be briefed and invited to participate in the public awareness process as appropriate.

4. The AGFD should develop a project specific operating protocol when there is a known or suspected direct hydrologic connection with groundwater wells and rotenone treated water within the project area (as required in the Rotenone SOP Manual [Finlayson et al. 2010]). This would include an appropriate monitoring plan and a mitigation plan to reduce rotenone levels to 40 ppb or lower or providing alternative water access or supplies as appropriate.

5. The AGFD should make certain that the rotenone or other piscicide application project supervisors have received American Fisheries Society or National Conservation Training Center Piscicide Training and all piscicide application project personnel have undergone appropriate training for their level of involvement in handling the chemical and minimizing the human and non-target species exposure.

6. The AGFD should make sure the public and elected or appointed officials in Arizona have ready access to the Final Rotenone Review Advisory Committee Report, Executive Summary, and updated Frequently Asked Questions developed as a result of the Committee's research.

7. The AGFD should use potassium permanganate (or other approved neutralizers) to neutralize rotenone or other piscicide treated water at the downstream end of the treatment area in all flowing water applications to maintain control of the treatment and minimize exposure outside of the treatment area.

8. The AGFD should monitor the scientific literature related to rotenone or other registered piscicides and their potential impacts on human health and the environment and periodically communicate with the U.S. Environmental Protection Agency to ensure that its policies and practices account for any advances in knowledge about the risks posed by piscicide use or ways to minimize exposure to humans and the environment.

# CHAPTER 3. ALTERNATIVE MANAGEMENT STRATEGIES SUBCOMMITTEE FINAL REPORT

**Prepared for the Rotenone Review Advisory Committee by:** Subcommittee Chair: Charles Paradzick, Salt River Project; and Subcommittee Members: Scott Rogers, Arizona Game and Fish Department; Robert Shuler, Shuler Law Firm; Philip Bashaw, Arizona Farm Bureau

Executive Summary

In response to proposed legislation in 2011 limiting the use of rotenone in Arizona, the Arizona Game and Fish Department (AGFD) convened a committee (Rotenone Review Advisory Committee) of interested stakeholders to advise and make recommendations to the AGFD Director and, through him the Arizona Game and Fish Commission (AGFC), regarding the use of rotenone and other piscicides for Arizona fisheries and aquatic wildlife management. As part of that evaluation, the Alternative Management Strategies Subcommittee reviewed alternative methodologies for eradicating and/or suppressing individual fish species or entire fish community populations. The subcommittee reviewed published literature and conferred with fisheries managers to identify current and potential alternative techniques and options. We summarized the fisheries management objectives that could be accomplished using each technique, and reviewed the environmental and human health concerns that may arise or need to be factored into project implementation.

Based on the review, there are few alternatives to rotenone that have the potential to fully eradicate fishes from Arizona water bodies; these included chemical treatments using antimycin-A, mechanical removal, and dewatering. Although there is one product containing antimycin-A (Fintrol®) that is currently registered as a piscicide by the Environmental Protection Agency (EPA), it is currently commercially unavailable for treatments. The use and effectiveness of mechanical and dewatering techniques are constrained by environmental and logistic factors, such as the volume of water to be treated by mechanical removal, and the legal and physical limitations to dewatering a system. There is some promise of novel chemicals, genetic techniques, and biocontrol but these would require extensive and costly research, development, impact assessments and their approval, labeling (where appropriate), and permitting prior to deployment in the field. Based on this review, and given the findings of the other subcommittees, the recommendation to the Rotenone Review Advisory Committee, and the AGFD Director, is to continue to allow the use of registered piscicides where safe, effective, and where no other viable alternatives exist. The subcommittee also recommends that AGFD continue to work and partner with other resource agencies and interested stakeholders to pursue the development of novel techniques as future alternatives or complementary approaches to rotenone.

Introduction

Over the past two centuries, the overall goal of fisheries management has been to produce sustainable biological, social, and economic benefits from renewable aquatic resources (Lackey 2005). Fisheries provide direct economic, cultural, and recreational benefits to the public. Fisheries also provide indirect benefits to the public through the public's awareness that a particular natural resource exists. Society and individuals receive intangible benefits from preserving species and habitats, especially those in danger of extinction (Lackey 2005).

Fisheries management in the 1800s and early 1900s were centered on optimization of direct benefits to the public by maximizing economic and recreational opportunities. By the 1990s, management objectives for many freshwater fisheries in North America had shifted from optimizing commodity output to protecting habitat or preserving imperiled species. Fisheries managers in the state of Arizona strive to strike a balance between providing sport fishing opportunities and native fish conservation.

Threatened and endangered fish are currently managed for both direct and indirect benefits to the state. They are also protected by the Endangered Species Act (ESA) and their conservation is mandated by law. Internationally, the Convention on Biological Diversity (http://www.cbd.int/) imposes legal obligations on all signatory countries to conserve their biodiversity, manage their fisheries resources in a sustainable manner, and promote fair and equitable distribution of the benefits of each nation's genetic and biological resources.

Fish removal has remained a necessary tool in fisheries management throughout history. Non-native fish species (invasive species, those not native to the area, or those that have expanded beyond their native range with the aid of humans or due to anthropogenic change to the environment), including exotic species (those from a foreign land) can adversely affect native fish populations. Non-native species have contributed to the decline of approximately two-thirds of the threatened or endangered fishes in the U.S. through competition for resources, predation, and hybridization with non-native fish (Lackey 2005). Conservation of native fish species in the state of Arizona often requires the removal of non-native fish species.

Not all non-native fish species are perceived to be management problems in the state of Arizona. Many highly valued fish species were intentionally introduced by fisheries managers and continue to enjoy widespread public support. Rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), largemouth bass (*Micropterus salmoides*), and bluegill (*Lepomis macrohirus*) are among the species of fish introduced to Arizona. These species provide important sport fishing opportunities for the public and revenue to the state in specific areas and waterbodies. Occasional illegal introductions of unwanted fish species threaten important sport fisheries within the state. Northern pike (*Esox lucius*) removal in Ashurst Lake as well as pike and bullhead catfish (*Ameiurus* spp.) removal in Rainbow Lake are examples of fish removals to protect important rainbow trout sport fisheries in the state of Arizona.

<u>Purpose and Need</u>

In response to proposed legislation in 2011 limiting the use of rotenone in the state, AGFD convened a blue ribbon evaluation committee (Rotenone Review Advisory Committee) of interested stakeholders to advise and make recommendations to the AGFD Director and, through him the AGFC, regarding the use of rotenone and other piscicides for Arizona fisheries and aquatic wildlife management. Among the factors to be considered in determining the future use of rotenone and piscicides was the evaluation and efficacy of alternative methods of eradicating and/or suppressing fish populations.

The goal of the Alternative Management Strategies subcommittee was to identify currently available fish eradication techniques and tools, and evaluate those alternatives, with an eye towards comparing and contrasting the alternatives with chemical piscicides. A secondary goal was to identify future alternative tools and techniques that may hold promise in eradicating and/or suppressing fish populations. To accomplish these objectives, an overview is provided of the management goals associated with fisheries projects because those goals ultimately drive the selection of the appropriate removal methodology. The tools and techniques that are currently available to resource agencies as alternatives to piscicides are summarized, and these techniques must be both biologically effective in removing and/or suppressing fish species, and legal under current laws and regulations. For each alternative method, the key environmental, human health, and regulatory factors of concern when implementing such projects were summarized. The potential future alternatives and the factors limiting their implementation were reviewed. Alternatives addressed were compared and contrasted with piscicide use using the data and results from the Human Health and the Environment Subcommittee report. In conclusion, recommendations were developed for consideration by the AGFD as it moves forward in determining the efficacy and use of rotenone in Arizona.

<u>Fisheries Management Objectives</u>

Important factors in selecting a tool or technique to control fish species and populations are the management purposes of the intended action and the known effectiveness of the tool to accomplish the objectives. Generally, fishery management objectives include: 1) altering sport fish populations to improve angler opportunities; 2) conservation of native aquatic species (fish, amphibians, and aquatic reptiles) including those that are listed as threatened or endangered under the ESA; and 3) controlling and mitigating the threat of invasive or pest species that may harm sport or native fish populations.

In Arizona, where the amount of perennial water is limited, these management objectives are often not mutually exclusive– fisheries managers must balance the sport fish opportunities with native fish conservation (see Subcommittee Report on Recreation, Economic, and Social Impacts of Rotenone), while also mitigating unwanted introduced non-native fish species that can impact the ecology of aquatic systems and disrupt management plans. A good example of how these goals are integrated at a watershed scale is the Little Colorado River Management Plan (Young et al. 2001). As fisheries managers implement resource plans, fish removal projects often become necessary to: 1) <u>reduce</u> competition and/or predation among or between species; 2) <u>eliminate</u> competition and/or predation among or between species; 3) <u>eliminate</u> genetic swamping from interbreeding with similar species (e.g., removal of introduced rainbow trout from native Apache [*O. apache*] or Gila trout [*O. gilae*] streams); and/or 4) <u>reduce</u> or <u>eliminate</u> invasive species. The difference between reduction and full elimination in management objectives is a key factor in the selection and evaluation of particular tools or techniques prior to project implementation.

Currently, fisheries managers have three primary tools or strategies to control fish populations: 1) registered and commercially available piscicides (e.g., rotenone); 2) mechanical removal (e.g., deploying netting or other trap devices, or electrofishing equipment); and 3) habitat or environmental manipulation (e.g., altering water levels and dewatering habitats). Each technique has benefits and limitations dependent upon the target fish species, location and size/volume/depth of the water body being treated, human and environmental concerns, and regulatory considerations. These factors and considerations are summarized below for each technique. This synthesis was largely based on the results and conclusions of a recent U.S. Geological Survey report (Dawson and Kolar 2003): "Integrated management of techniques to control nonnative fish". This comprehensive report, funded by the U.S. Bureau of Reclamation, Phoenix Area Office, was specifically targeted at fisheries management and projects in Arizona and New Mexico.

Fish Removal Tools and Techniques

*Chemical – Piscicides*

Since 1990, AGFD has used either rotenone or antimycin-A to remove nonnative fish in 37 waters. Of these treatments 22 (59%) utilized rotenone, whereas 15 (41%) utilized antimycin-A. Of the rotenone treatments, about 68% (n = 15) treated golf course ponds or stock tanks, 18% were stream treatments (n = 4), and 14% were lake treatments (n = 3). In comparison, all projects using antimycin-A were in stream environments. At present, rotenone is the only chemical (piscicide) available to managers for fish removal projects in Arizona. One product containing antimycin-A (Fintrol® Concentrate) is currently registered by the Environmental Protection Agency (EPA) for use as a piscicide, but the product is not commercially available at present from the sole manufacturer (Aquabiotics Corporation). Selective registered piscicides, such as 3-trifluoromethyl-4- nitrophenol (TFM) and Bayluscide®, were specifically developed for sea lamprey control in the Great Lakes region and are not used in the state of Arizona. Below we reviewed the key factors related to rotenone, as well those related to antimycin-A should it become available for use in the future.

Management purpose and effectiveness – Rotenone and antimycin-A are generally considered non-selective fish toxicants (Dawson and Kolar 2003; AFS 2009), causing mortality of all gill-breathing organisms within a treated area. While in some instances due to varying levels of species-specific sensitivity, both products can be used to target a particular fish species or used to treat only portions of a large water body (such as a cove within a lake), their use over the last 25 years in Arizona has primarily been for the purpose of eliminating all fish from the receiving water. Often the treatment coincides with other management measures, such as the construction of fish passage barriers to preclude reinvasion of unwanted fish into the treated area, followed by the restocking of selected species.

There are a number of environmental and logistical considerations that may limit the treatment effectiveness. The factors that managers often consider during the planning phase of projects include, but are not limited to, water quantity (e.g., stream flow rates and lake volumes), water quality (e.g., pH, turbidity, and temperature), habitat complexity that may preclude sufficient mixing and diffusion of chemical (e.g., emergent vegetation or freshwater spring seeps), and connectivity of the treated area to other water bodies (e.g., remote stock ponds or impoundments) that may harbor and allow immigration of unwanted fish species (AFS 2009).

Both rotenone and antimycin-A can provide complete eradication of fish populations or in some instances can be formulated to target specific species, and both rapidly degrade and are not persistent in the environment. The primary advantages of antimycin-A compared to rotenone are that fish cannot sense the chemical and once fish are exposed, the effect is irreversible and mortality is certain. The disadvantages of antimycin-A compared to rotenone are the higher costs of the product and treatment, the product is currently not available commercially, and antimycin-A is not effective at high pH levels (>8.5). Both chemicals have impacts to non-target aquatic organisms, no impacts to terrestrial organisms, and require measures to avoid human exposure that are factored into the EPA's reregistration decisions for each chemical (i.e., drinking water supplies and recreation) (EPA 2007a,b; AFS 2009).

Overall, rotenone and antimycin-A piscicide treatments are highly successful. A survey was conducted among western state fish and wildlife agencies on the success of rotenone and antimycin-A treatments from 1938 – 2011, with input from Arizona, California, Colorado, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. Out of a total among all states of 305 treatments (rotenone and antimycin-A combined), 85% (n=258) were considered successful based on chemical effectiveness at fish eradication only. When other factors were included such as artificial fish barrier failure, illegal stocking, and human error that compromised treatments after their initial success, the success rate was reduced to 75% (n=228/305) (AGFD, personal communication). In Arizona, rotenone and antimycin-A treatments since 1990 have had a 95% (n = 35/37) success rate based on chemical effectiveness, with the success rate reduced to 70% (n = 26/37) because of barrier failure or illegal stocking following the initial treatments which resulted in nonnative fish returning to the treatment areas.

Environmental and Human Health Impacts – The Human Health and the Environment Subcommittee report on environmental and human health effects fully describes the environmental (e.g., water quality, environmental persistence, impacts to non-target aquatic and terrestrial organisms), and potential human health effects from rotenone exposure; thus, that information was not presented here and is incorporated by reference.

Antimycin-A was first registered by the EPA as a piscicide in 1960; it is classified as a Restricted Use Pesticide due to aquatic toxicity and the need for highly specialized applicator training. Based on the reregistration process in 2007 (that assures the product will not have "unreasonable adverse effects"), the EPA determined that application of antimycin-A per the label was safe and would not cause adverse affects to humans (EPA 2007a; AFS 2009). For example, based on the allowable treatment concentrations, an average adult (154 lbs) could drink ½ gallon of treated stream water per day for an entire lifetime with no adverse affects anticipated (Ott 2006).

Antimycin-A is known to cause short-term adverse impacts to invertebrates (reductions in abundance and diversity). Studies suggest that impacts are less severe for species that burrow, use interstitial spaces, or have protective cases. Over longer time periods, few months to years following treatments, the impacts were found to be minimal to the abundance, biomass, and diversity of invertebrates (EPA 2007a; AFS 2009).

Regulatory, Permitting, and Public Review of Projects – The State and Federal Regulations, Internal Policy, Public Involvement and Best Management Practices Subcommittee report describes the public review and permitting necessary to implement rotenone treatments in Arizona. The report also provides an overview of the best management practices followed during piscicide projects to minimize exposure to the environment, public, and the applicators; that report is also incorporated by reference within this report. The regulatory requirements, permitting, and public review for antimycin-A projects are the same for rotenone projects.

*Mechanical and Physical Removal*

Mechanical fish capture and removal includes a suite of techniques that consist of a variety of gear types: traditional hook and line, nets, seines, traps, and electrofishing (applying electricity to a water body from the shore, boat, or backpack unit to stun, immobilize, and allow capture of fish). All gear types are selective to some extent and often will target specific species, size classes, or areas within the water body (Nielsen and Johnson 1983). Mechanical means of catching fish are frequently utilized to capture and remove unwanted fish species.
Evidence of successful mechanical removal was first observed in commercial fisheries when fish stocks were overexploited. However many of these fisheries have recovered with sound quotas set by fisheries managers.

Almost all fish species are highly fecund and produce numerous offspring. As fish are removed from a system, compensatory survival of young and juvenile fish increases. Most fish populations are driven by compensatory mechanisms. While projects involving mechanical removal are frequently successful at removing a large portion of a fish population, this success is generally short lived as the new recruits rapidly replace those removed (Kulp 2000; California Department of Fish and Game 2003; Meyer et al. 2006; Weidel et al. 2007; Peterson et al. 2008; Carmona-Catot et al. 2010; Coggins et al. 2011). Most populations of fish recover to pre-treatment levels soon after the mechanical removal is concluded.

Mechanical removal of fish is labor intensive and expensive, and to date only chemical treatments using piscicides and complete dewatering of a system have been shown to remove all unwanted fish in large or complex systems (Finlayson 2010). However, mechanical removal continues to be utilized in Arizona and has been successful in meeting several management objectives to suppress populations of particular species where complete dewatering or chemical renovation is not currently feasible (see examples below). Based on discussions with AGFD fisheries managers and review of the literature, there were no known instances of projects that successfully removed all fish from a water body using mechanical techniques.

Management purpose and effectiveness – As noted above, fisheries managers utilize mechanical removal in selective locations where the intent is to reduce the abundance of a particular species (or multiple species) or alter the size class and structure of fish populations. The advantages of mechanical removal techniques include the relative ease with which gear can be deployed, and for some gear types such as seines and nets, use does not require extensive training. However, use of electrofishing equipment requires extensive safety training and experience to reduce risk to the personnel conducting the work, as well as to minimize impacts to non-target organisms. Overall, mechanical removal, except for possibly very small isolated systems with low habitat complexity, does not allow for full removal or elimination of fish species. The effectiveness of both passive gear types (e.g., hoop nets or traps) and active techniques (e.g., seining or electrofishing of portions of a water body) is limited by habitat complexity, water quantity (e.g., flow rates, depth, and treatment area), water quality (e.g., water clarity can effect fish capture rates, and salinity influences electrofishing effectiveness), and fish species (e.g., size classes and species-specific capture rates).

Environmental and Human Health Impacts: There are little to no empirical data on the impact of mechanical removal projects on the environment or human health, except for investigations of the impact of electrofishing on non-target species (Snyder 2003). However, based on experience with past projects, for most gear types the impact of projects on water quality would be minor and temporary (e.g., increase of turbidity while workers are wading in a stream or setting nets). There would be no impact on water quantity during projects unless successful use of a technique was coupled with the reduction of flow rates and/or water volumes.

Depending on the gear type used, there may be short-term and temporary impacts to non-target organisms including fish, amphibians, reptiles, and/or aquatic invertebrates inadvertently captured in nets or stunned by electrofishing. In some cases, capture and the stress caused by handling may cause mortality. Within a project area, no impacts to terrestrial organisms (including wildlife, domestic animals, or livestock) would be anticipated from mechanical removal efforts.

For projects that involve mechanical removal using traps, nets, or seines, there would be no public health concerns. Electrofishing devices can cause injury and death to equipment operators or assistants if not used properly and with precautions. The electrical field generated by the equipment is small and localized (e.g., 0 – 20 feet) and is controlled by the system operator; thus, the risk to the public during operations is essentially nonexistent. Operators and the field assistants are extensively trained prior to field use and must wear protective clothing to prevent shock and injury.

Regulatory, Permitting, and Public Review of Projects – In Arizona, the AGFD regulates the capture of fish and permits individuals and agencies seeking to utilize mechanical removal. Approval by the AGFD (e.g., via Scientific Collecting Permit program) for these actions does not require public notification or review. The AGFD coordinates fisheries projects that occur on federal lands or water bodies; however, fish projects that do not involve chemicals, land disturbance, or other actions by the federal agencies would not require public review [e.g., National Environmental Policy Act (NEPA) compliance]. The AGFD does review each fish removal project using their internal Environmental Assessment Checklist (EAC) process, which allows staff and managers to identify and address any potential environmental as well as socio/political concerns prior to project implementation.

For federal agencies carrying out, authorizing, or funding a fish removal project, the action, depending on its level of significance and effect on the environment, may be subject to public review through the NEPA process. For federal projects that occur in locations where a project overlaps the distribution of federally listed threatened or endangered species, and if a listed species, or its designated critical habitat could be adversely affected, the individual or agencies must obtain a permit under the Section 7 of the ESA. The ESA permits issued by the U.S. Fish and Wildlife Service (FWS) in those instances do not have a public review comment period, but they are posted on the FWS website and subject to judicial review. When a federal project could impact a federal listed species, there is often a concurrent NEPA process allowing public input and review. For state wildlife agency actions that overlap a listed species, environmental compliance is through section 6 of the ESA, and does not involve a public review. Fish removal projects by all other non-federal parties that may impact a listed species are addressed under Section 10 of the ESA (Habitat Conservation Plans (HCP) and Research and Recovery Permits) and often include a NEPA process and public review for the issuance of a take permit.

Mechanical Removal Projects in Practice – The following summaries of recent projects are provided to assist in understanding the use and challenges of mechanical removal projects:

> ***Ashurst Lake*** - Ashurst Lake is an important rainbow trout sport fishery in northern Arizona. In the late 1990s, northern pike were illegally introduced into the lake. In 2009, a creel survey revealed that fewer than 10% of the 40,000 trout stocked in this lake had been captured by anglers. A fisheries survey in that same year showed that the lake was populated almost exclusively by large pike, and that few if any rainbow trout had survived predation by pike. In the spring of 2011, the AGFD deployed 30 gill nets over eight days to remove pike from Ashurst. Creel surveys from the summer of 2011 suggest that this effort was successful in removing numbers of pike sufficient to increase the trout angling catch rates over those observed in 2009 to a rate of near 0.5 trout/hour (AGFD, personal communication). It is likely that these removal efforts will continue annually or biennially until chemical renovation or complete dewatering of Ashurst Lake can be carried out.
>
> ***Fossil Creek*** - Fossil Creek is home to a variety of native fish species including roundtail chub (*Gila robusta*), headwater chub (*G. nigra*), speckled dace (*Rhinichthys osculus*), longfin dace (*Agosia chryogaster*), desert sucker (*Catostomus clarki*), and Sonora sucker (*C. insignis*). Non-native fish species including the piscivorous smallmouth bass (*M. dolomieu*) began to inhabit Fossil Creek in the mid 1990s and native fish species in Fossil Creek were rare by 2000. A fish barrier was constructed and a chemical treatment with a piscicide to remove non-native fish took place in 2004. Native fish quickly recovered and are currently quite numerous in the renovated reach of Fossil Creek. In August 2011, smallmouth bass were discovered in the previously treated section of Fossil Creek just upstream of the fish barrier. These bass were mechanically removed to reduce the likelihood of movement of this species upstream of a proposed temporary barrier. A crew of five AGFD employees and 4 FWS employees removed 53 bass over three weeks utilizing gill nets, hoop nets, spears, and angling. A temporary barrier was constructed in September of 2011. No bass have been observed upstream of the newly constructed barrier. Bass remain above the original barrier in spite of the intense mechanical removal efforts and will likely need to be removed through piscicide treatment.
>
> ***Grand Canyon*** - Predation by rainbow trout may be partially responsible for the reduced population of the endangered humpback chub (*G. cypha*) in the Grand Canyon (Yard et al. 2011). Dewatering and piscicide treatments are not currently feasible in a system as large as the Colorado River. Intensive and expensive mechanical removal in 2004 - 2007 successfully reduced the abundance of rainbow trout by over 90% in a 10-mile reach of

the Colorado River near its confluence with the Little Colorado River (Coggins et al 2010). Rainbow trout abundance recovered by 2010 and further mechanical removal is being considered (AGFD, personal communication)

*Removal by Water Level Manipulation or Dewatering*

In very rare instances, fisheries managers may be able to reduce or eliminate fish from a water body through water level manipulation or complete dewatering. Water level manipulation, where feasible, may also be used to increase the effectiveness of a chemical treatment or mechanical removal project. If timed appropriately, changes to water levels can be used to disrupt the life cycle of particular fish species, allowing the manager to favor or limit the successful breeding or survivorship of a species (see Horseshoe-Bartlett HCP below).

In Arizona, however, where water is in such limited supply and highly managed under a complex set of laws and water rights, the ability to alter reservoir management and/or stream flow is very limited. Additionally, as with mechanical removal, the impact of an action that results in suppression, but not full elimination, of a target species, is often temporary and may not yield long-term results. For small, managed water bodies (e.g., stock tanks or refuge ponds) where the inflow can be controlled (e.g., turning off groundwater wells) and/or pumping or releases can be used to empty a reservoir, dewatering may be possible, which would allow full elimination of all fish species. While the exact number of Arizona projects that have used dewatering to eliminate fish is not known, because of the unique circumstances required to carry out the treatment, it is estimated that its use relative to chemical treatments is small (AGFD, personal communication).

Management purpose and effectiveness – As noted above, managers may manipulate water levels to favor one species or a suite of species over others, but the effect generally does not result in full elimination of species and is temporary. In those locations where full dewatering is possible, fish can be eliminated from an isolated or closed water body.

Environmental and Human Health Impacts – Altering water levels and/or dewatering obviously would have significant effects on water quantity; however, impacts to water quality would be site specific, depending upon initial characteristics, the length of time the levels are drawn down, and the subsequent rate and quality of water use to refill the reservoir.

The effects of water level manipulation on non-target aquatic organisms (e.g., amphibians, reptiles, and invertebrates) would be dependent upon the magnitude, timing, and duration of the action and could cause reductions in the available habitat area and may disrupt or impede critical life cycle needs and functions. Impacts to non-target aquatic organisms may be either short or long-term, and in some cases the action may cause a permanent loss of specific species. Dewatering of certain water bodies, such as stock ponds, could also reduce the availability of water for terrestrial species including livestock.

Unless the water body is used as a public water supply, there would be no effects on human health anticipated from the implementation of a fish removal project that utilizes water level manipulation.

Regulatory, Permitting, and Public Review of Projects – Managers seeking to implement a project that alters water levels would coordinate the work with the appropriate person or agency that holds the water rights (issued by the Arizona Department of Water Resources). As with mechanical removal, it is likely that the AGFD would coordinate projects that involve water manipulation for the intended purpose of altering a fishery. For those projects where a federal agency does not have an action or discretion over the water management, and when those projects do not involve chemicals, land disturbance, or other action by the federal agencies, the fish removal project would not require public review [e.g., NEPA compliance]. The AGFD does review each project using their internal EAC process, which allows for staff and managers to identify and address any potential environmental as well as socio/political concerns (e.g., livestock water impacts) prior to implementation.

For federal agencies carrying out, authorizing, or funding a fish removal project, the action, depending on its level of significance and effect on the environment, may be subject to public review through the NEPA process. For federal projects that occur in locations where a project overlaps the distribution of federally listed threatened or endangered species, and if a listed species, or its designated critical habitat could be adversely affected, the individual or agencies must obtain a permit under Section 7 of the ESA. The ESA permits issued by the FWS in those instances do not have a public review comment period, but they are posted on the FWS website and subject to judicial review. When a federal project could impact a federally listed species there is often a concurrent NEPA process allowing public input and review. For state wildlife agency actions that overlap a listed species, compliance is typically through section 6 of the ESA and does not involve a public review. Fish removal projects by all other non-federal parties that may impact a listed species are addressed under Section 10 of the ESA (HCP and Research and Recovery Permits) and often include a NEPA process and public review for the issuance of a take permit.

Water Level Manipulation Projects in Practice: The following summaries of recent projects are provided to assist in understanding the use and challenges of water level manipulation projects:

***Horseshoe-Bartlett Reservoirs Habitat Conservation Plan-*** In June of 2008, Salt River Project received an incidental take permit under Section 10 of the ESA for the operation of Horseshoe and Bartlett Reservoirs on the Verde River. The permit included take for 16 aquatic and riparian dependent species, of which 13 were native fish, amphibians, and reptiles (SRP 2008). For the aquatic species, FWS was concerned with 1) stranding in the reservoir during drawdown and injury to fish that passed through the outlet works; and 2) the increased competition and predation on native aquatic species caused by non-native fish that breed in the reservoirs and migrate out of the reservoirs to up or downstream waters.

To minimize the effects of non-native fish production, SRP agreed to modify the operation of Horseshoe Reservoir to, as feasible, draw the reservoir down as early and as rapidly as possible in the spring and to minimize carry over storage (Paradzick et al. 2006). The results of this operation, as anticipated and captured in post-permit monitoring, disrupted the spawning and survivorship of non-native bass and sunfish species (*Lepomis* spp.), and shifted the fish population to carp (*Cyprinus* spp.) and goldfish (*Carassius* spp). While the water level manipulation is working as intended, the action does not fully eliminate bass or sunfish (or other non-native fish that occur in the Verde River) from utilizing the reservoir.

***Perkins Tank*** - Perkins Tank is a small reservoir (<4 surface acres) located about 20 miles south of Williams. It is one of several in the Williams area that is managed with the help of the Northern Arizona Flycasters (NAF) as a unique catch-and-release trout fishery. In the spring of 2001, NAF club members reported green sunfish in Perkins reservoir. In November 2001 the pond was drained using pumps, with the help of NAF, to remove the illegally stocked green sunfish. Pumping occurred over a period of a week using six pumps (24 hours/day). Complete dewatering was successful in removing green sunfish from the pond and the pond was restocked with trout when it refilled. To date, green sunfish have not been observed in the lake.

Potential (Future) Alternatives

As noted above, the currently available options for fully controlling or eliminating unwanted fish species in Arizona water bodies are limited to rotenone, and dewatering and/or mechanical removal. Fisheries and conservation managers are continuously looking for additional options and novel concepts to control and manage aquatic species, which include other chemicals and piscicides, genetic manipulation, and biocontrol. In general, for these techniques to be available for use, extensive and time consuming research and field testing, as well as human health and ecological impact assessments, leading to review and permitting by the EPA, would be required. The following section provides an overview of some of the techniques that resource managers have or are considering investigating to control fish species.

*Chemicals – Non-Specific*

Dawson and Kolar (2003) reviewed research and published reports and found over 35 chemical compounds that are known to control fish, could function as a general (non-selective ) piscicide, but are currently unregistered and not permitted for use (e.g., ammonia, copper sulfate, lime). The application of these chemicals in the environment is strictly regulated by the EPA. For most of the potential candidate general and selective piscicides, the data required to satisfy the safety and efficacy requirements of the EPA are not available, and the cost of producing the data would be high (Dawson and Kolar 2003; Clarkson and Hedwall 2007). Additionally, many of the chemicals are highly toxic, cause high impacts to non-target organisms, and/or may persist in the environment for long periods of time, which would likely preclude their registration as piscicides by the EPA (Dawson and Kolar 2003).

*Chemicals – Taxon-Specific*

Clarkson and Hedwall (2007) conducted a review of available fish control technologies specifically for the Colorado River and Gila River basins and recommended a suite of technologies to investigate. Included in their recommendation was the research, development, and permitting of taxon-specific piscicides to target problematic non-native fish that have been introduced into arid streams. As noted above, selective piscicides have been successfully developed for sea lamprey (*Petromyzon marinus*) as well as goldfish and the northern pikeminnow (*Ptychocheilus oregonensis*), to protect salmon (*O.* spp) in the Pacific Northwest. Their proposal estimated that the cost to test and expand the use of (re-label) an existing piscicide may require 5 years and $5 million; while the time and cost to develop and register a new product may take 8 – 10 years and between $35 - 50 million.

*Genetic Bio-Control*

Kapuscinski and Patronski (2005) reviewed the potential for the development of bio-control technologies. The following sections, excerpted from Clarkson and Hedwall (2007) and revised based on input from AGFD (AGFD, personal communication), provide an overview of the conclusions of the Kapuscinski and Patronski (2005) report.

Although still in relative infancy, research into genetic methods for bio-control holds strong potential as another technology against non-native aquatic species that can avoid non-target species impacts. The field can be broadly divided into techniques to achieve population control using recombinant DNA (transgenic), gene manipulation (Genetically Manipulated Organisms [GMOs]), or chromosome set (ploidy; triploid sterilization) manipulation methods. The appeal of transgenic or GMO methods for bio-control lies with their seeming lack of effects to non-target organisms and their potential to achieve complete bio-control (i.e., total extinction of a targeted population). Controversies with the methods include untested social and ecological considerations, including unknown public reaction to release of a transgenic organism into the wild and a largely uncharted risk assessment of this new technology.

Ploidy manipulations enable production of organisms whose chromosomes are derived entirely from the male or female parent, or where the number of chromosome sets of the organism is changed. The result of either technique is sterility or near-sterility, and therefore some degree of population control can be achieved by introducing large numbers of sterile organisms into the population. This technique has been widely practiced with certain insect pests and with sea lamprey control in the Great Lakes, and has been variously successful. The limitation of the method for non-native species control within watersheds that hold threatened and endangered species is that non-native species populations must first be increased significantly through release of sterile individuals, thereby adding additional impacts to native species populations without certainty of subsequent non-native species population reduction. However, in certain circumstances the technique holds promise toward the general goal of controlling non-native species populations.

As indicated above, chemicals or bio-controls would likely require labeling by EPA under Federal Insecticide Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), a time intensive and expensive process. Genetic bio-control tools would also require Federal Drug Administration (FDA) approval. Certainly all of this is expensive. Clarkson and Hedwall (2007) estimated that the time and total cost to develop and deploy a transgenic approach could be 20 years and $15 - 20 million, and the research and development of a ploidy manipulation bio-control program could take five years and $3 - 5 million.

Conclusions

The tools currently available for fisheries managers to fully eradicate a target fish species are limited. Chemical piscicides can be effective in a variety of water bodies, but treatments can have impacts to the environment and non-target organisms, and care must be taken during implementation to avoid impacts to humans and drinking water supplies. Alternatives to chemical treatments include mechanical removal and dewatering of impoundments. These techniques can be effective but have limited application in the field, being generally restricted to very small impoundments where water levels can be controlled and managed. Fisheries managers and natural resource agencies continue to look at potential new techniques, but the development and deployment of those are constrained by the cost and time needed to conduct research, human health and environment studies, and the registration process to allow their safe use in the field. The Alternative Management Strategies Subcommittee recommends the AGFD continue to work and partner with other resource agencies and interested stakeholders to pursue the development of novel techniques as future alternatives or complementary approaches to rotenone applications.

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Recommendations to the Rotenone Review Advisory Committee

Provided that rotenone and other registered piscicide can be applied in a safe manner that minimizes impacts to the environment, avoids impacts to human health and drinking water supplies, and considers the concerns of local citizens and communities in the project area, the Alternative Management Strategies Subcommittee recommends, that due to the limited options available for full eradication and removal of fish species, rotenone, and other register piscicides, should continue to be available for use as a fisheries management tool in Arizona when no other viable alternatives exist.

# CHAPTER 4. RECREATION, ECONOMIC, AND SOCIAL IMPACTS FINAL REPORT

**Prepared for the Rotenone Review Advisory Committee by:** Subcommittee Chair: Elroy Masters, Bureau of Land Management; and Subcommittee Members: Ben Alteneder, Arizona Wildlife Federation; Doug Kupel, City of Phoenix; Don Mitchell, Arizona Game and Fish Department; Chuck Paradzick, Salt River Project; Robert Shuler, Shuler Law Firm; Earl Stewart, USDA Forest Service

## Executive Summary

The Recreation, Economic, and Social Impacts Subcommittee is one of four subcommittees within the Rotenone Review Advisory Committee, and was composed of various individuals from federal, state, and city governments and the public sector that had varying degrees of experience with the use of piscicides. The objective of the subcommittee was to evaluate the potential recreational, economic, and social impacts associated with the use of, or loss of piscicides as a tool for aquatic species management in Arizona. The subcommittee held one meeting to organize and set direction for the final report, and formed subgroups comprised of federal government, state government, city and county government, and public interest. Each subgroup completed an analysis of the potential recreational, economic, and social impacts that may result from the use of, or loss of, piscicides as it relates to their particular subgroup, which are included in the final report. The report also details the economic importance of managing Arizona's diverse aquatic resources to protect recreational opportunities and the quality of life of the general public in Arizona.

Fishing in Arizona is good for the state's economy, and the Arizona Game and Fish Department's (AGFD) ability to effectively manage its recreational fishing opportunities is vital to the continued existence of this economically important resource. In 2006, over 400,000 anglers in Arizona and the accompanying industry provided over 14,000 jobs, $174.9 million in tax revenues (federal, state, and local), $849 million in retail sales, and $1.3 billion overall that contributed to the state's economy (Southwick Associates 2007). Arizona's anglers are investing in sport fishing opportunities, and the ability for the AGFD to continue providing sport fishing opportunities is closely tied to the continued conservation of native aquatic species. The AGFD fisheries program depends on recreational stocking to meet the public's demand for angling opportunities, and simultaneously implements wildlife conservation actions for species listed as endangered or threatened under the Endangered Species Act (ESA) and other sensitive species. These two actions are linked partly through mitigation activities to off-set impacts from the sport fishing program on native aquatic species. One conservation action is to restore native aquatic species to their historical ranges, which often requires the use of piscicides to remove nonnative fish occupying those habitats before restoration actions can be implemented. If AGFD is unable to implement fish removal projects using piscicides, the result may be a significant increase in resources, cost, and time to implement fish removal projects, potentially resulting in a decision to not stock certain waters and a consequential decline in fishing-related expenditures that benefit local economies, particularly rural communities.

Federal agencies, particularly land management agencies including the U.S. Department of Agriculture Forest Service (USFS) and the Bureau of Land Management (BLM), allow multiple-use activities associated with recreational and economic pursuits, and operate under laws and policies that mandate the conservation of wildlife (AISAC 2008). In addition, both agencies have obligations under 7 (a)(1) of the Endangered Species Act (ESA) to conserve threatened and endangered species. Specifically, individual National Forests or Monuments contain objectives in their management plans that are based on maintaining desired native and nonnative species assemblages within the lands they manage, as well as objectives to minimize the impacts of invasive species on native ecosystems. Without the ability to use piscicides, land management objectives for recreational, native aquatic species, and invasive species management may not be met, and could have negative impacts on many land uses occurring on public lands. When populations of threatened or endangered species are at risk of uplisting or extinction, and sensitive species are vulnerable to becoming federally listed, agencies lose land management flexibility which could have negative impacts on the public and land management uses such as livestock grazing, vegetation management, fuels management, and special use permits for a wide variety of actions.

Effective implementation of conservation and mitigation actions for sensitive aquatic species is essential in meeting regulatory compliance for many of Arizona's water supplies. Water management agencies, such as municipal water utilities that treat and deliver surface water flows to end users, work in partnership with water providers such as Salt River Project (SRP), U.S. Bureau of Reclamation (USBR), and the Central Arizona Water Conservation District to make sure the environment is protected while allowing water to be stored, managed, and delivered to the citizens of Arizona, as well to generate clean and renewable hydro-electric power through dam operations. One of law that has had significant impact on water management in the western United States is the ESA. Water managers in Arizona work with government agencies and nongovernmental organizations to conserve and protect native fish species in an effort to keep them from being listed and potentially requiring expensive environmental compliance and mitigation. Thus, a number of private, municipal, city, and federal water management programs directly or indirectly rely on the use of piscicides as a tool for fisheries management to conserve sensitive aquatic species while maximizing the long-term certainty of water supplies. The inability to use piscicides as a tool for fisheries management could ultimately place a greater burden on water mangers as project implementation becomes more difficult or impossible, species become more imperiled, and regulatory pressure increases to find alternatives to conserve native species. If additional aquatic species are listed in the future that occur near or in the operational area of water supplies, the regulatory burden of finding and implementing alternative mitigation actions to maintain management flexibility will likely fall on the water managers, which would increase costs and could jeopardize future water supplies.

Introduction

The Recreation, Economic, and Social Impacts Subcommittee is one of four subcommittees within the Rotenone Review Advisory Committee, and was composed of various individuals from federal, state, and city governments and the public sector that had varying degrees of experience with the use of piscicides. The objective of the subcommittee was to evaluate the recreational, economic, and social impacts associated with the use of, or loss of piscicides as a tool for aquatic species management in Arizona. The subcommittee held one meeting to organize and set direction for the final report, and formed subgroups comprised of federal government, state government, city and county government, and public interest. Each subgroup completed an analysis of the potential recreational, economic, and social impacts that may result from the use of or loss of piscicides as it relates to their particular subgroup, which are included in this final report. It is difficult to assess what the loss of piscicide use may be in terms of recreation, economic, and social impacts separately; therefore, they is significant overlap within this report.

Recreation and Economic Impacts

There are nearly 40 million anglers in the United States, which collectively generate over $45 billion in retail sales, $125 billion in overall economic output, $16.4 billion in state and federal taxes, and over one million jobs in a given year (Southwick Associates 2007). America's anglers are not only investing in sport fishing opportunities, they are investing in fisheries conservation and management since license sales are one of the primary funding sources for most state wildlife agencies, which manage both recreational and native aquatic species. In 2006, over 400,000 anglers in Arizona and the accompanying industry provided 14,483 jobs, $174.9 million in federal, state, and local taxes, $849 million in retail sales, and $1.3 billion in total that contributes to the state's economy (Southwick and Associates 2007). Thus, fishing in Arizona is good for the economy, and the state's ability to effectively manage its recreational fishing opportunities is vital to the continued existence of this economically important resource.

The ability for the Arizona Game and Fish Department (AGFD) to continue to provide sport fishing opportunities is closely tied to the continued conservation of native aquatic species. The AGFD fisheries program depends on recreational stocking to meet the public's demand for angling opportunities. Simultaneously, the AGFD implements wildlife conservation actions for species listed as endangered or threatened under the Endangered Species Act (ESA) and other sensitive species. These two actions are partially linked through mitigation activities to off-set impacts from the sport fishing program on native aquatic species. One conservation action is to restore native aquatic species to their historical ranges, which often requires the use of piscicides to remove nonnative fish occupying those habitats before restoration actions can be implemented. Although it is difficult to quantify, the loss of the state's ability to use management tools such as piscicides could result in an inability to stock sport fish in some areas, potentially resulting in a decline in demand for fishing equipment and licenses, and a decline in fishing-related expenditures to businesses, including restaurants, hotels, boat rentals, fuel stations, and bait and tackle shops. With less fishing-related expenditures, job opportunities in the associated service industries may also decrease. For many small, rural communities, fishing is a primary attraction, and local businesses depend on the income generated from anglers. For these communities, the elimination of stocking in some areas could result in a substantial loss to the local economy because anglers may provide a substantial percentage of the income to local businesses. State tax revenue and licensing fees could also decline with the loss of sport fish stocking locations.

An example of the positive impacts of piscicide use for fish removal, recreationally and economically, was the Lake Havasu Fishery Improvement Program that was implemented in the 1990s. A piscicide was applied to backwater habitat in Lake Havasu to remove nonnative fish and use the backwater habitat as grow out facilities for endangered native fish. The native fish portion of the program mitigated the impacts of the sport fish stocking program and recreational improvements to the lake. An economic report found the improvements to the sport fishery and recreational areas to benefit the Lake Havasu regional communities by a conservative $30 million a year (Anderson 2001), also while improving backwater habitat for native fish. In this case, the use of a piscicide was the most effective method of fish removal and resulted in a substantial economic boost to the local economies.

Beyond AGFD's ability to manage recreational angling opportunities and native aquatic species is the ability to manage invasive aquatic species, which is vital to the environmental health of the state's aquatic resources. Invasive aquatic species in Arizona include bullfrogs, crayfish, mussels, and nonnative fishes (AISAC 2008). Once established, invasive species have the ability to displace native plant and animal species (including threatened and endangered species) and alter a community's character by enhancing even more invasions. Over 40% of the threatened and endangered species in the U.S. and 24% of species at risk in Canada are threatened with extinction because of predation, parasitism, and competition from invasive aquatic species. Over 50,000 non-native species have invaded the U.S. and Canada. In the U.S. alone, 536 nonnative fish have been identified. Based on damages and control in terms of dollars per year, fish are the most serious aquatic invasive species in the U.S. costing $5.4 billion annually (Pimentel 2004). Piscicides are a critical tool to manage invasive fishes because they are the most effective fish removal technique compared to other methods (see Alternative Management Strategies for a detailed analysis). While each invasive species may require specific strategies for management, the ability of the AGFD to use piscicides to manage an aquatic invasive species can be a critical tool for invasive species control in Arizona.

*Land Management Agencies.*— Federal agencies, primarily the U.S. Department of Agriculture Forest Service (USFS) and the Bureau of Land Management (BLM), manage the largest portion of lands in Arizona (42%). Both the USFS and BLM lands allow multiple-use activities associated with recreational and economic pursuits, and operate under laws and policies that mandate the conservation of wildlife (AISAC 2008). In addition, both agencies have obligations under 7(a)(1) of the ESA to conserve threatened and endangered species. Specifically, individual National Forests or Monuments contain objectives in their management plans that are based on maintaining desired native and non-native species assemblages within the lands they manage. For example, the BLM's Bradshaw-Harquahala Record of Decision and Approved Resource Management Plan states the BLM will work in cooperation with AGFD and the U.S. Fish and Wildlife Service (FWS) to re-establish Gila topminnow (*Poeciliopsis occidentalis*), Gila chub (*Gila intermedia*), and desert pupfish (*Cyprinodon macularius*) into suitable habitat sites throughout the planning area (BLM 2010). Land management activities, including recreation, livestock grazing, and fuel management, are limited to minimize impacts on lands occupied by these species. In addition, the desired future condition for wildlife and fisheries states the distribution and abundance of invasive animals will be contained, and through active management, the impact of invasive species on native ecosystems will be reduced from current levels.

Management plans for National Forest's in Arizona similarly reference the ability to maintain, restore, or enhance the diversity, distribution, and viability of populations of native wildlife. For example, the Coconino National Forest Land Management Plan state's one of the Forest's objectives to manage habitat to maintain viable populations of wildlife and fish species and improve habitat for selected species. Additionally, they work with the AGFD to achieve management goals and objectives on proposals for the reintroduction of extirpated species into suitable habitat, and indentify and protect areas containing threatened, endangered, and sensitive species (USFS 1987). Specifically, the Coconino National Forest Land Management Plan specifies that at least 70 miles of perennial stream be restored during the life of the plan and since nearly every stream on the Coconino National Forest contains non-native aquatic species, this will not be possible without the use of piscicides as the most effective fish removal method. When populations of threatened, endangered, or sensitive species are at higher risk of extinction or may become protected under ESA, there may be an accompanying loss of flexibility for federal agencies due to an inability to use piscicides for fish removal projects. The loss of land management flexibility could have negative impacts on the public and land management uses such as livestock grazing, recreation, vegetation management, fuels management, and special use permits for a wide variety of actions such as big game guiding, hunting, and forest product removal.

As discussed previously, piscicides are an important component to implementing recovery projects for native aquatic species and without the tool, the USFS specifically could lose potential matching dollars for recovery projects with many partnerships, including Trout Unlimited; USBR Central Arizona Project (CAP) mitigation funds for Gila Basin native fish conservation projects; National Fish and Wildlife Foundation (NFWF) grants; National Fish Habitat Action Plan funding; Federation of Fly Fishers; Northern Arizona University; Arizona State University; University of Arizona; and many in-kind contributions from every type of stakeholder that may be involved in piscicide projects, including ranchers that support removal of illegal baitfish stocking within allotments on USFS lands. Lost partnerships would also jeopardize cooperative work with the AGFD. Examples include the Fossil Creek project to remove smallmouth bass, Gila trout recovery in West Fork Oak Creek and the Pinaleño Mountains, topminnow reintroduction projects, stock tank renovations, and many other native fish stream or lake recovery projects where removal of all nonnative fish is necessary and where partnerships drive project momentum and funding. For every USFS dollar invested in partnerships, the USFS often sees a 3-fold investment from non-federal contributions. It can be expected that similar impacts would also apply to other land management agencies including the BLM.

*Water Management.*—Effective implementation of conservation and mitigation actions for sensitive aquatic species is essential in meeting regulatory compliance for many of Arizona's water supplies. Piscicide use for fish removal projects can be used in a targeted basis to accomplish regulatory obligations in a biological and cost-effective manner. The loss of the ability to implement piscicide projects could ultimately place a greater burden on water mangers as project implementation becomes more difficult or impossible, species become more imperiled, and regulatory pressure increases to find alternatives to conserve native aquatic species as well as manage invasive species.

Local water agencies, such as municipal water utilities that treat and deliver surface water flows to end users, work in partnership with water providers such as Salt River Project (SRP), USBR, and the Central Arizona Water Conservation District, the entity that manages the Central Arizona Project (CAP) canal, to make sure the environment is protected while allowing water to be stored, managed, and delivered to the citizens of Arizona. For water managers serving central Arizona, the primary management goals are to maximize certainty of the water supply from both a hydrologic and regulatory perspective. Effective management of this essential resource requires high levels of flexibility in accessing and providing varying water supplies (i.e., surface supplies from storage reservoirs on the Colorado, Salt, and Verde rivers, and groundwater) to meet municipal, industrial, commercial, and Tribal needs. For reservoir operators, such as the SRP, maximizing reservoir storage capacity and flexibility in system operations is vital to maintaining and managing current and future supplies. A key component to meet this goal is working with local, state, and federal agencies to assure compliance with laws and regulations that could affect a provider's ability to manage the resource (i.e., regulatory certainty).

In some cases, water managers have worked with agencies and non-governmental organizations to conserve native fish species in an effort to keep them from being listed and potentially requiring expensive compliance and mitigation (e.g., Stillman Lake Renovation project, Verde River, for roundtail chub restoration). When projects are considered federal actions, some of which include water management and deliveries that may affect listed species, the federal agencies are required to consult with the FWS under Section 7 of the ESA[3]. One of the more significant recent consultations addressed USBR actions for the CAP canal that transports water from the Colorado River to metropolitan Phoenix and Tucson. The CAP consultation resulted in extensive native fish conservation actions throughout the Gila River Basin to mitigate impacts from the CAP canal operation, many of which include successful fish removal projects using piscicides that are part of required recovery actions as a result of the consultation.

The Gila River Basin Native Fish Conservation Program (Program; also known as the CAP Fund Transfer Program) was developed to partially mitigate impacts of the CAP canal on threatened and endangered native fish of the Gila River Basin. The FWS concluded in a 1994 Biological Opinion (BO) that the CAP is a conduit for transfers of non-indigenous fish and other aquatic organisms from the Lower Colorado River (where the CAP originates) to waters of the Gila River Basin. The BO identified the spread and establishment of non-native aquatic organisms as a serious long-term threat to the status and recovery of native aquatic species, following a long history of habitat loss and degradation. The Program is funded by the USBR, and is directed by the FWS and USBR, in cooperation with the New Mexico Game and Fish Department (NMGFD) and AGFD. Highest priority projects for the program are those that are necessary to: 1) prevent extinction and stabilize populations in the wild; and 2) replicate rare populations in the wild. To accomplish those priorities they identified a set of actions, which include, among many other tasks, constructing fish passage barriers to protect existing populations and control non-native aquatic species above barriers; and where necessary, non-native fish removal projects using piscicides or other effective methods. One of the keystone projects funded by the program was the construction of the Fossil Creek fish barrier, chemical treatment of the creek using a piscicide, followed by restocking of the creek with native fish species.

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[3] Section of the ESA requiring federal agencies to evaluate impacts to listed species and their habitats.
[2]Section of the ESA requires non-federal entities to receive an incidental take permit after preparation of a Conservation Plan (CP) if activity may incidentally "take" a listed species.

The USBR is also the federal water management agency that controls and operates the dams and reservoirs of the Colorado River system. The USBR requires substantial operating flexibility so that it can maximize water deliveries to contractors in Arizona, California, and Nevada as well as to generate and deliver clean and renewable electricity from dams along the Colorado River. The Colorado River provides water to over 30 million people in Arizona, California, and Nevada, serves over one million acres of agriculture, and generates more than 8.7 billion kilowatt per hour per year. Due to the need to comply with the ESA for threatened and endangered species native to the Colorado River, USBR in cooperation with AGFD uses piscicides as a means to protect native threatened and endangered species in the lower Colorado River system consistent with species management needs and requirements. The USBR relies on operational flexibility to balance water, power, environment, and recreational needs of Colorado River system users as it operates Glen Canyon, Hoover, Davis, and Parker Dam. The use of piscicides is one of the management tools that provide the necessary operational flexibility and social benefits for recreational users.

For non-federal water managers, when operations may harm a listed species, regulatory compliance is provided under Section 10 of the ESA[2]. A key component of compliance under Section 10 is the development and implementation of a Habitat Conservation Plan (HCP) that identifies a set of mitigation obligations to offset impacts to listed species, while allowing for the otherwise lawful activity. In Arizona, there are a number of HCPs, but the two that primarily address water management and impacts to aquatic species include SRP's Horseshoe-Bartlett HCP on the Verde River, and the Lower Colorado River Multi-Species Conservation Plan (MSCP) which is a partnership among Arizona, California, and Nevada federal and non-federal water managers and state and federal wildlife agencies.

Although piscicides such as rotenone are not used in conjunction with all HCPs in Arizona, they are an important tool for some areas. It is important that this tool be available on those occasions when it is needed, as there are few effective alternatives. HCPs provide for non-federal parties to comply with the ESA when otherwise lawful activities may harm a species or their habitats. HCPs can apply to both listed and non-listed species, including those that are candidates or have been proposed for listing. HCPs are planning documents that are required as part of an application for an incidental take permit. The permit allows the permit-holder to legally proceed with an activity that would otherwise result in the unlawful take of a listed species. In the rare event that jeopardy to the species cannot be avoided, the FWS may be required to revoke the permit. In extreme cases, revocation of permits could result in a loss of access or limitations on the management of surface water supplies.

Proactive conservation of sensitive aquatic species is an important first step in maximizing long-term certainty of water supplies. Actions taken to prevent listing of species preclude the possibility of the need to conduct expensive analyses, ESA consultation with the FWS, and potential operational constraints and/or expensive mitigation. In an effort to head off species declines, SRP has participated in the Native Fish Conservation Team lead by AGFD, and is a signatory to the 6 Native Fish Species State Conservation Agreement. Under this Team and Agreement, the participating agencies and organizations work toward identifying key projects and coordinated implementation to benefit native fish. A number of high priority projects identified include fish removal projects using piscicides. Loss of rotenone and other piscicides would hamper those proactive conservation efforts, likely reducing their effectiveness in many areas, and potentially leading to additional species listings. If additional aquatic species are listed in the future that occur near or in the operational area of water supplies, the regulatory burden of finding and implementing alternate mitigation actions to maintain management flexibility likely will fall on the water managers, which would increase costs and could jeopardize future water supplies.

For SRP and the many municipalities that depend on SRP for water, the Roosevelt HCP (covers 4 bird species) and the Horseshoe and Bartlett HCP provide important protection to native species while allowing water management and use to continue. In June of 2008, the FWS approved the Horseshoe and Bartlett reservoirs HCP. The plan minimizes and offsets harm that the operation of the two Verde River reservoirs may pose to federally threatened and endangered wildlife, fish, and other sensitive species. The HCP covered 16 species: 10 native fish, two garter snakes, one leopard frog, and three birds. As a result of SRP's commitment, to minimize and mitigate the impact to the covered species and their habitat and in partnership with the City of Phoenix, the FWS is permitting the loss of some individual animals (take) that may result from dam operations over the next 50 years. Included among the mitigation obligations SRP is required to implement for the 13 aquatic fish, reptile, and amphibian species is funding for the AGFD to raise native fish at their Bubbling Ponds Hatchery (BPH) on Oak Creek and stock those fish in the Verde River watershed. The mitigation action supports AGFD's ongoing efforts with federal, state, and private landowners to implement conservation projects, which may include piscicide treatments in preparation to receive fish raised at BPH. While the Horseshoe-Bartlett HCP does not have a direct obligation to fund fish removal projects using piscicides or other methods, often those projects are necessary prior to stocking. The inability to use piscicides as a tool in fisheries management would make it more difficult and likely more expensive to implement conservation projects in the Verde watershed. The inability to use piscicides could reduce the effectiveness of conservation projects, negatively impact listed and sensitive species populations, and ultimately place increased pressure on wildlife, land, and water managers to identify and fund alternate conservation projects.

The Lower Colorado River Multi-Species Conservation Program (MSCP) is a partnership of federal and non-federal stakeholders, created to respond to the need to balance the use of Lower Colorado River water resources with the conservation of native species and their habitats in compliance with the ESA. There are 57 member agencies participating in the MSCP, including 29 Arizona water and power users. The program provides ESA compliance for continued operation of Colorado River dams and reservoirs, and water distribution systems for hydro-electric generation from the lower Colorado River system dams. The MSCP is a long-term (50-year) plan to conserve at least 26 species of fish and wildlife species along the lower Colorado River from Lake Mead to the Southerly International Boundary through the implementation of an HCP. Implementing the MSCP will create over 8,000 acres of new habitat including nearly 6,000 acres of cottonwood-willow, over 1,300 acres of honey mesquite, close to 500 acres of marsh, and 360 acres of backwater habitat.

The backwater habitat is crucial to the successful implementation of the MSCP. It normally consists of two types, connected to the river or disconnected from the river. Disconnected backwaters are the preferred type of backwater for achieving HCP goals for razorback sucker and bonytail chub. All non-native fish must be removed from backwater habitats (whether created or pre-existing) in order for native fish to be stocked and raised successfully. Native fish are removed before a piscicide treatment and are placed in alternative holding facilities during the treatment; they are returned to backwater habitats post-treatment. The challenges associated with fish removal projects using piscicides in backwaters is an ongoing issue as non-native predatory fish can be introduced by several ways including barrier/isolation failure, illegal stocking, and potentially by birds. The program has specifically used rotenone to chemically treat two MSCP disconnected backwaters: Imperial Ponds and Beale Lake.

The only possible way to guarantee total removal of all fish from a backwater is to completely drain the pond and allow the soil to become desiccated to a depth of several inches, which is not possible unless the backwater is perched well above the elevation of the river. In the lower Colorado River system, there are very few if any existing backwater locations perched sufficiently high above the Colorado River elevation to allow complete drainage and desiccation. Thus, rotenone has been used successfully as a piscicide in combination with the drainage of ponds to a practical level. Without the ability to use piscicides, fish removal in backwaters will have to be conducted very differently and in some cases may be virtually impossible, further limiting the selection of sites as potential backwater habitats. Alternatives to piscicides include electro-fishing, gill-netting, drainage, and in cases where these techniques do not work, abandoning the site and developing a new one (for a detailed analysis see Alternative Management Strategies Report). These alternatives vary in effectiveness and cost, but other than complete desiccation, none are as effective as rotenone in removing fish from disconnected backwaters and other methods can be less effective, more costly, and labor intensive. If the use of rotenone or other piscicides is restricted, the cost of maintaining existing backwater habitat and developing new backwater habitat will increase significantly.

For municipal water utilities that work in conjunction with large water providers to meet the daily water needs of Arizona's citizens, aquatic chemicals, including rotenone formulations, have been used in partnership to allow the HCPs to continue to meet their stated goals. Many of these water utilities are very large. For example, the City of Phoenix has a water service area containing an estimated 1.455 million persons based on the 2010 U.S. Census. The Phoenix service area represents about 39 percent of Maricopa County's population and 23 percent of the total population of Arizona. The incorporated area of Phoenix covers 546 square miles. In addition to the Phoenix service area, the City of Phoenix also serves portions of the Town of Paradise Valley and provides treatment services to adjacent providers on a limited basis.

In a normal supply year, the City of Phoenix meets more than 90 percent of its water demands from surface water sources. These include water from the Salt and Verde Rivers delivered through the SRP and water from the Colorado River delivered by the CAP. The City of Phoenix has worked diligently with its partners to protect threatened and endangered species in these watersheds under the ESA by the creation of HCPs on both the Salt and Verde Rivers and through the MSCP on the Lower Colorado River. These allow the City of Phoenix to support threatened and endangered species and their habitats while allowing water development and delivery to continue for the many residents and neighbors that depend on the City of Phoenix for their water supply. The City of Phoenix and its partners have also voluntarily created hundreds of acres of habitat for fish and wildlife species, which may also be enjoyed by the public. For example, the Tres Rios Ecosystem Restoration Project, located on the Salt and Gila Rivers, is currently in construction and will provide over 900 acres of riparian and wetland environments. The Rio Salado Habitat Restoration Area has restored approximately 600 acres of the Salt River near downtown Phoenix. The Rio Salado Oeste Environmental Restoration Project in Phoenix is currently in the design stage and will provide over one thousand acres of riparian habitat in the Salt River from 19$^{th}$ Avenue to 83$^{rd}$ Avenue.

While it is difficult to determine the financial impact on water managers that would result with the state's inability to use of piscicides, there has been some estimate of the financial impact from losing the protection HCPs provide. During a detailed analysis of the economic impact of designating Horseshoe Reservoir as critical habitat, it was determined that if alterations to reservoir operations were necessary to protect threatened and endangered species, the result could cause the loss of approximately five percent of the Phoenix water supply in a normal year. This impact was estimated to be between $147 and $162 million over a 50-year period. The economic impact of losing the protections provided by the Roosevelt HCP, the Horseshoe and Bartlett Reservoirs HCP, and the MSCP could affect up to ninety percent of the City's supply in a normal year and would be far reaching. The economic impacts identified to the City of Phoenix could be a representative example for the more than 50 CAP water contractors and other Arizona Colorado River users.

Because the ability to use piscicides play a vital role in AGFD's ability to manage its aquatic resources, the loss of this tool is likely to result in significant additional barriers to native species restoration, invasive species management, the sport fish stocking program, water delivery infrastructure, and public land use, all of which could have a negative impact on Arizona's economy, recreational angling opportunities, and employment.

Social Impacts

The use of piscicides as a management tool provides extensive public benefit. The economic benefit provided by AGFD's sport fishing program is vital to the economic health of Arizona, especially its rural communities. It is apparent that the successful management of Arizona's native aquatic resources is heavily tied to the economic success of Arizona and the quality of life currently experienced by the public. The inability to use piscicides could impact quality of life attributes in which nonnative fish or invasive species can play a prominent negative role. For example, fishing in Arizona is good for the economy, and the state's ability to effectively manage its recreational fishing opportunities is vital to the continued existence of this economically important resource. As discussed previously in this report, the ability to stock sport fish in Arizona is heavily tied to mitigation actions to conserve native aquatic species impacted by stocking. Some mitigation actions may be limited by the inability to use piscicides, which may jeopardize stocking activity, and thus limit recreational angling opportunities in some areas. Because much of Arizona's recreational fishing waters are located in rural areas, Arizona's rural communities would likely suffer the most proportionally and such a loss could be devastating to the rural communities that rely on revenues from recreational angling.

The recovery of many native aquatic species in Arizona depends on the availability of piscicide use, particularly where hybridization or predation by nonnative fish on native species are the primary threats. The inability to use piscicides to recover native fish, for example, may lead to increased land management restrictions and requirements necessary to meet the intent of the ESA (e.g., increased requirements to minimize impacts from land uses such as grazing, mining, and forest harvest practices; restrictions on special use permits such as outfitter guides, municipal water users, recreation, and irrigation diversions). Not only would increased regulations put burdens on the land management agencies, they could also result in significant losses of revenue and traditional uses of public lands for people whose livelihood depends in part on use of federal lands. Additionally, the importance of recovering endangered species, and preventing future listings, is an inherent value important to many people and organizations formed specifically to protect and restore biological diversity and ecosystem health. When species go extinct, the scientific, genetic, medical, cultural, and educational values of those species can be permanently lost.

Conclusions

The loss of piscicides as a management tool has apparent, sweeping impacts on the public as a whole, as management agencies lose their flexibility to use appropriate tools to the manage water resource systems, including dams and reservoirs, as well as to generate renewable hydro-electricity. The use of piscicides, when other tools will not get the job done, allows AGFD to manage its aquatic resources with the least amount of impact, helping Arizona to maintain its swimmable, drinkable, and fishable waters free from invasive species where desired. The federal government as well has relied upon this tool to improve recreational opportunities and multiple land uses on public lands throughout the state, which also impacts the quality of life in Arizona. For water management, the importance of mitigating impacts to aquatic species is equally important to city and county government agencies because the use of these tools allows water management entities to provide for and continue to develop consistent water delivery to the citizens of the state and improve riparian habitat in locations where it greatly improves the quality of life for the public.

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Recommendations to the Rotenone Review Advisory Committee

The Recreation, Economic, and Social Impacts Subcommittee recognizes the importance of piscicides as a key and irreplaceable tool for managing aquatic resources in Arizona, and recommends that piscicides continue to be available for use by the AGFD.

# APPENDIX A. PISCICIDE USE IN ARIZONA

## Introduction

The Arizona Game and Fish Department (AGFD) uses rotenone and antimycin-A for piscicide (pesticide for fish eradication) applications as a tool for fisheries management in Arizona with careful planning for when, where, and how it is used. Since 1990, AGFD has applied rotenone to 22 waters (e.g., lake, stream, stock tank) to remove non-native fish. Rotenone has primarily been applied to ponds or stock tanks (68%; n = 15/22), and to a lesser amount and streams (18%; n = 4/22) and lakes (14%; n = 3/22). In comparison, since 1990 AGFD has applied antimycin-A to 15 waters, all of which were in stream environments. Antimycin-A was reregistered by the Environmental Protection Agency (EPA) as a piscicide in 2007, however, there is only one company that manufactures the chemical (Aquabiotics®) and they have halted production. Thus, AGFD currently uses primarily rotenone for piscicide treatments. Per the EPA, any piscicidal users must consult their local Fish and Game Agency before applying rotenone or other registered piscicides.

## Fisheries Management Plan

Fisheries in Arizona may be managed by water body, recreational fish species, native fish species, or a combination of each. In Arizona, rotenone treatments are typically applied for species specific fisheries management, for the protection and/or restoration of native fish, or to remove invasive species. Often fisheries management plans are influenced by species specific Recovery Plans, which typically identify goals and objectives for specific waters within historical range of the particular threatened or endangered species to be restored and remain occupied. Rotenone projects are proposed based on the future desired condition of particular water bodies or for specific species that are supported by the fisheries management plans, Recovery Plans, or equivalent.

## Applicable Laws and Regulations

All applications of rotenone on public land are overseen by a certified pesticide applicator (required by the Federal Insecticide, Fungicide, and Rodenticide Act [FIFRA] law and Arizona Revised Statutes Title 3). The primary applicators and treatment project leaders that are employed by AGFD must be certified pesticide applicators by the Arizona Department of Agriculture and 1) follow the product label as regulated by the EPA; 2) follow extensive American Fisheries Society standard operating procedure requirements as guided by the EPA; 3) follow manufactures Material and Safety Data Sheet (MSDS) information; 4) follow required National Environmental Policy Act (NEPA) and Endangered Species Act (ESA) requirements; 5) follow AGFD internal review and approval for every proposed rotenone treatment; and 6) obtain a Pesticide General Permit from the Arizona Department of Environmental Quality (ADEQ) for each piscicide treatment. More detail for each of these guidelines and/or requirements is discussed below.

*EPA Registration and Product Label*.— All pesticides must be registered by the EPA; rotenone went through the reregistration process that was completed in 2007. Rotenone is a "restricted use" pesticide, which means it may only be applied by certified applicators (or under the direct supervision of) using recommended concentrations as directed by product manufacturers on the product label. The chemicals are registered by the EPA and manufacturer labels are reviewed and approved by the EPA. The language for pesticide labels must be approved by the EPA before it can be sold or distributed in the United States. The rotenone label includes pertinent information critical to the application of the chemical, including.

- Pesticide hazard class and first aid instructions
- Instructions for storage and disposal
- Instructions for use
    - Treatment site, concentration, method
    - Dilution instructions
    - Treatment timing and frequency
    - Detoxification methods
    - Re-entry interval

*American Fisheries Society: Rotenone Standard Operating Procedures (SOP) Manual (Finlayson et al. 2010).*—Rotenone application, including timing, frequency, concentration, and neutralization are implemented by AGFD according to product label directions, the Rotenone SOP Manual, and specifications as established in a Pesticide Use Proposal (PUP). Prior to the Rotenone SOP Manual, AGFD used the 2000 version: Rotenone Use in Fisheries Management; Administrative and Technical Guidelines Manual (Finlayson et al. 2000). The 2010 rotenone SOP manual was developed to include changes made to the use of rotenone by the EPA during the reregistration process in 2007. The 2010 rotenone SOP manual thus provides current guidance on rotenone applications with detailed information on the following:

- Formulations, public health, environmental fate
- Preliminary planning: public involvement, laws and regulations, internal review and approval
- Preliminary treatment plan: rotenone and detox chemical, logistics, fish rescue, restocking, equipment needs
- Intermediate planning: environmental laws and analysis, waste discharge requirements, endangered species, public and agency involvement
- Treatment: treatment rates and strategies, treatment areas, detox methods (if necessary), use of liquid and/or powder formulations, use of bioassays to monitor efficacy, monitoring requirements for aquaculture and drinking water

*Material and Safety Data Sheet (MSDS).*—To maintain Office of Safety and Health Act (OSHA) compliance, AGFD provides applicators and any personnel working on a rotenone treatment the MSDS for the chemical. The MSDS for a rotenone product includes important information including chemical identification, hazardous components, fire and explosion hazard data, reactivity data, health hazard data, precautions for safe handling and use, and control measures (e.g., personal protective equipment [PPE]).

*NEPA and ESA Compliance.*—Proposed rotenone and antimycin treatments on public lands in Arizona go through the NEPA process typically because a federal nexus typically exists. When a federal nexus exists, the land management agency such as the U.S. Department of Agriculture Forest Service (USFS) conducts an environmental analysis (e.g., Categorical Exclusion, Environmental Assessment [EA], or Environmental Impact Statement [EIS]) to describe the proposed action, evaluate alternatives, and evaluate the potential impacts on the environment that may result from the proposed action. The NEPA evaluation investigates potential impacts of the proposed action to water resources, vegetation, wildlife, special-status species, soils, heritage resources, recreation, wilderness (if applicable), and addresses cumulate impacts. Public involvement during the NEPA process is initiated during the scoping period to review the proposed action during the beginning of the project, and comments are addressed by the federal agency. The public is also given the opportunity to review the pre-decisional environmental analysis for at least a 30-day period.

If during the environmental analysis of the proposed action it is determined the proposed action will not significantly affect the environment, the agency will issue a finding of no significant impact (FONSI). The FONSI may also address measures which an agency will take to mitigate potentially significant impacts. An EIS is prepared if the EA determines the environmental consequences of a proposed federal action may be significant. To date, proposed rotenone and antimycin treatments in Arizona have been evaluated through EAs only. The NEPA process can be the longest part of project development, often requiring 2-3 years until completion.

When any Threatened or Endangered species are within a proposed piscicide treatment area, through Section 7 of the Endangered Species Act, the federal agency (e.g., USFS) conducts a biological assessment to determine if the project will "likely affect" the species in question. The federal agency must initiate formal consultation with the U.S. Fish and Wildlife Service if the species is likely to be adversely affected by the proposed piscicide project.

*Internal Review and Approval*.—Proposed piscicide treatments by AGFD require an internal NEPA process called the Environmental Assessment Checklist (EAC). This internal EAC process must be completed, reviewed, and approved before a piscicide treatment is conducted, regardless if there is a federal environmental analysis. The EAC must include background of the project, purpose and need, detailed project description (treatment plan), and documented coordination with other agencies and landowners (if applicable). The EAC is reviewed at multiple levels prior to approval, including Nongame and Habitat branches, Regional Supervisor level, and Assistant Director level.

*Arizona Pollutant Discharge Elimination System (AZPDES) Permits*.—Beginning October 31, 2011, rotenone treatments require a Pesticide General Permit under the AZPDES permit issued by the Arizona Department of Environmental Quality (ADEQ) for the regulation of surface water pollutants and to be in compliance with the Clean Water Act and EPA. The permit application will contain information currently included in project planning documents such as the project specific NEPA and EAC, and individual preliminary treatment plans.

*Certified Pesticide Applicator*.—At least one certified pesticide applicator is required to review the proposed rotenone treatment plan, recommend the Pesticide Use Proposal (PUP) required for treatments on National Forest and Bureau of Land Management Land, and oversee the chemical treatment. Most biologists at AGFD that participate on chemical treatments are certified pesticide applicators. Applicators may certified by the state or a program endorsed by the EPA. Most AGFD biologists working on piscicide treatments have also received additional training and certification by taking the American Fisheries Society course: Planning & Executing Successful Rotenone & Antimycin Projects or the National Conservation and Training Center course: Rotenone and Antimycin Use in Fish Management. Both courses are 4 ½ day training classes that provide a foundation for the planning and execution of fish sampling/control/eradication projects using the fish management chemicals rotenone and antimycin. Both training courses are recommended by the EPA.

Preliminary Treatment Plan and Implementation

The preliminary treatment plan is developed during the project planning process and it is completed, reviewed, and tentatively approved internally prior to project implementation. The preliminary plan is developed following the product label and with guidance from the rotenone SOP manual, and includes assessments of the physical and chemical characteristics of the water body; barriers, ownership, and obstructions; rotenone and the neutralization chemical (if applicable); public interest; interagency responsibilities; logistics and preliminary schedule; fish salvage; restocking; personnel and equipment needs; and budget.

*Public Notification*.—Depending on the treatment location, there are public notification and treatment area restrictions based on the water body and proximity to downstream users (including livestock permittees) and homeowners prior to the treatment. The land management agency typically issues a temporary closure order to restrict public access to treatment and stocking areas.

*Project Personnel*.—Project leaders working on the treatment are required to be certified pesticide applicators and/or AFS or NCTC course certified. Other personnel working on the project that are not certified applicators are given training to include safety procedures including personal protective equipment, pesticide handling procedures, first aid, emergency procedures, exposure hazards, MSDS, and given the location of documents pertinent to the safety of the treatment. Personal protective equipment including goggles, chemically resistant gloves and shoes, and long-sleeved shirt/pants or Tyvek suits is required when working on rotenone treatments. Per the new product labels, full-face respirators will be required when handling undiluted product.

*Treatment Concentration*.—Determining treatment concentrations and strategies depends on many factors including the type of water, environmental factors such as pH, temperature, depth, turbidity, flow rate, percentage of active ingredient in the product, and the sensitivity of the target species. Prior to a rotenone treatment, a bioassay is conducted with the target species in the site water to identify the minimum concentration within label guidance that is effective. For standing and flowing waters, the recommended rotenone treatment concentrations for species in Arizona ranges between 0.5 – 2.0 parts per million (ppm) of 5% active ingredient rotenone, which is equivalent to 0.025 – 0.10 ppm active rotenone. For reference, the EPA requires rotenone concentrations to be below 200 ppb active rotenone; rotenone treatments in Arizona in ppb equate to 25 – 100 ppb active rotenone. The EPA requirement of a maximum of 200 ppb active rotenone for treatments is 1000 times below the dose known to have no effects in humans (No Observable Effects Level – NOEL). Applications >40 ppb active rotenone in waters with drinking water intakes or hydrologic connections to wells require certain notification processes, monitoring, or neutralization of the chemical.

*Treatment Application and Duration*.—Stream treatments deliver liquid rotenone in the desired concentration using drip buckets and backpack sprayers. Streams are typically treated when stream flow is at a minimum. Drip buckets consist of a reservoir and a delivery apparatus; the reservoirs in Arizona are typically 5-gallon buckets. The delivery system provides regulated flow of rotenone (diluted into water) to the stream to maintain a constant concentration of rotenone. Drip buckets are monitored by individuals for the duration of the treatment to ensure consistent feed rates. Rotenone is applied to flowing water via drip buckets for 4 to 8 hours and buckets are spaced at 1 – 2 hour travel time intervals or based on bioassay results. Typically this results in drip buckets spaced ½ to 2 miles apart depending on water flow travel-time and stream gradient. A non-toxic dye such as Rhodamine WT or Fluorescein is used to determine travel time prior to the rotenone treatment. Sprayers apply diluted liquid rotenone using backpack spray units to backwater areas of streams and rivers, seeps, springs, and hard to reach areas.

Lake treatments deliver liquid rotenone in the desired concentration using a combination of buckets placed in boats with a peristaltic pump to dispense liquid into the water, and sprayers using backpack spray units or spray units directly from the boat. A rotenone powder/gelatin/sand mixture is sometimes used in both stream and standing water treatments to treat upwelling groundwater in springs, streams, and lakes and other areas with limited water circulation. Treatment concentration and duration depends on the surface area and volume of water of a particular water body, calculated in acre-feet. For standing water, treatments are recommended in the rotenone SOP manuals (both 2000 and 2010) to be completed within 48 hours so the entire water body is at the desired concentration before rotenone begins to degrade.

In both stream and standing water applications of rotenone, caged live fish ("sentinel" fish) are placed strategically within the treatment area to monitor efficacy of the treatment. Two rotenone treatments are typically completed back-to-back to ensure effective fish eradication. A third treatment is conducted if post-treatment surveys at least 48 hours post-treatment have found live fish within the treatment area.

*Neutralization.*—Rotenone treated water is neutralized to minimize exposure to non-target organisms downstream of the treatment area with the following exceptions (per Rotenone SOP Manual): 1) there is no discharge from the treatment area or the water goes dry no more than 2 miles or 2 hours travel-time from the lowest drip station; or 2) there is dilution (< 2 ppb active rotenone) when treated waters flow into an untreated tributary. Most stream treatments of rotenone in Arizona have operated a neutralization station at the downstream-most end of the treatment reach. Sentinel fish are placed above the neutralization station and at the ½ hour and 1 hour flow locations downstream of the neutralization stations to monitor the effectiveness of rotenone and the neutralization treatment. The neutralization station delivers a concentration of $KMNO_4$ (potassium permanganate; as recommended on product label and in rotenone SOP manual) until sentinel fish directly above the neutralization station survive for at least 4 hours.

*Post-treatment monitoring/critique*.—The AGFD monitors the efficacy of the treatment by conducting a short-term assessment to: 1) determine effectiveness of treatment by doing visual or electrofishing surveys to document any potential fish survival; 2) determine when the public can reenter the area and/or when water is safe for consumption; 3) monitor recovery of baseline environmental conditions (if pre-treatment levels were measured); and 4) develop a written report of all aspects of the treatment.

*Restocking*.—Restocking plans are developed during the preliminary planning stages and incorporated into the NEPA analysis, ESA evaluation, and internal EAC processes. The restocking plan will vary on many factors. For example, rotenone will take longer to degrade in standing water treatments, thus delaying the time post-treatment for restocking. For some streams treated to restore native trout, the streams may be left fishless for several months post-treatment to allow the invertebrates to recover because they are the primary food source for trout.

*Project background, need, and treatment plan.*—During the initial phases of project development, project managers answer a number of questions to determine the management need for fish eradication, the most appropriate methods of fish removal to use, and the background needed to develop and implement the project. This information can be used to draft the project's statement of need, Pesticide Use Plan (PUP), Notice of Intent (NOI), Pesticide Discharge Management Plan (PDMP), project treatment plan, safety and spill contingency plan, and environmental compliance documentation. Note: this is a sample list of questions that project managers may use and it will vary project by project. This exercise is part of the process during the planning to implementation of piscicide projects (see Figure 1: planning to implementation of rotenone/antimycin projects).

- Identify target pest and other species present.
- Management goals for the site and watershed.
- Management goals for the aquatic species at the site.
- Is this treatment a priority in statewide fisheries management context.
- Identify ESA listed, candidate or special status species present in area or to be reintroduced.
- Review of fish removal methods appropriate for management goals of the site, and review previous methods used.
- Develop public involvement plan, project scoping, and public meeting plan. Determine if media notices are necessary prior to treatment. Develop signage plan prior to treatment.
- Identify project partners, planning group, advocates, and define how project coordination will be conducted.
- Identify local community concerns and recreational use of the area.
- Identify timelines for planning to implementation, including environmental compliance, permits, etc.
- Identify need for NOI for Pesticide General Permit from ADEQ.
- Define site location – land ownership and access.
- Develop spill contingency plan for application. Ensure MSDS and safety info available to applicants and others working on chemical application.

- Salvage plan for fish, wildlife, or macroinvertebrates if necessary and logistics for holding facilities.
- Identify risks to downstream species in case of an uncontrolled treatment.
- Identify if there are domestic water wells or livestock drinkers with hydrologic connection to treatment and neutralization area. If treatment will be above 40 ppb (if rotenone), identify if well testing or alternative water must be supplied.
- Identify sources of reinvasion of target species into treated water.
- Neutralization plan for stream applications and identify need for standing water neutralization.
- Identify if dead fish removal and disposal is needed.
- Pre-treatment sampling effort and site visits by project staff to collect data needed for implementation.
- Identify current grazing leases in treatment/neutralization reach and downstream water users.
- Identify water quality, substrate type, organic load, and spring or wetland presence.
- Identify if certified applicators are available and if they have AFS or NCTC piscicide training.
- Identify equipment needs and logistical considerations for the application.
- Identify what kind of piscicide will be used, concentration, duration of treatment, number of treatments, application methods, and timing (season) of treatment.
- Determine level of post-treatment monitoring.
- Determine restocking plan.

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## APPENDIX B. FREQUENTLY ASKED QUESTIONS

**What is rotenone?**[1]

Rotenone is a naturally occurring substance derived from the roots of tropical plants in the bean and pea family that are found primarily in Malaysia, South America, and East Africa. It is derived from ground up plant roots to make a powder formulation or extracted from the roots to make a liquid or crystalline formulation. People have utilized rotenone for centuries to capture fish for food in areas where these plants are naturally found, and it has been used in fisheries management as a piscicide (pesticide that kills fish) in North America since the 1930s. Rotenone affects gill breathing organisms by inhibiting respiration by blocking biochemical pathways of cell metabolism, specifically the reduced nicotinamide adenine dinucleotide (NADH)-dehydrogenase segment of the respiratory chain and resulting in mortality with prolonged exposure. Rotenone has also been used as an insecticide in residential products for control of fleas, ticks, and mites on pets and livestock; and for control of aphids on garden plants. Rotenone was used widely in North America for agricultural use as a botanical insecticide for use in fruit and vegetable crops.

**When is it appropriate to use rotenone as a fish removal tool?**[1]

Fish removal has remained a necessary tool in fisheries management throughout history. Harmful fish species (invasive species, those not native to the area, or those that have expanded beyond their native range with the aid of humans or due to anthropogenic change to the environment), including exotic species (those from a foreign land) can adversely affect wildlife. Harmful aquatic species have contributed to the decline of approximately two-thirds of the threatened or endangered fishes in the U.S. through competition for resources, predation, and hybridization.

In general, rotenone is used as a fish removal tool to meet the following objectives when mechanical removal or habitat or environmental manipulation (e.g., dewatering) is not feasible or effective: 1) altering sport fish populations to improve angler opportunities; 2) conservation of native aquatic species (fish, amphibians, and aquatic reptiles) including those that are listed as threatened or endangered under the Endangered Species Act (ESA); and 3) controlling and mitigating the threat of invasive or pest species that may negatively impact wildlife human health, or cause economic harm.

**How and when is rotenone applied?**[2]

Rotenone liquid is typically packaged in 1-, 5-, 30- and 50-gallon containers and powder is typically in 50- and 200-pound containers. Applications are generally made with boats in lakes, reservoirs and ponds, with direct metering into moving water such as streams, and with hand-held equipment such as backpack sprayers in difficult to reach areas. Rotenone may be applied at any time of year, but most applications typically occur during warm months when the compound is more effective and degrades more rapidly. Rotenone is usually applied during low water conditions to limit amount of area treated and piscicide needed. On-site bioassays are performed to identify the lowest effective concentrations for use during the treatment.

**What is the reregistration process of rotenone by the Environmental Protection Agency (EPA)?[1]**

The EPA has regulatory responsibility for the registration and reregistration of pesticides. Every 15 years (or sooner if necessary) the reregistration process is initiated and involves a thorough review based on scientific data to evaluate the potential hazards based on the current registered use, determine the need for additional data to supplement the health and environmental risk assessments, and evaluate criteria to ensure a registered pesticide will have "no unreasonable adverse effects". The EPA will determine if a pesticide reregistration must be reevaluated if there is new evidence of human and/or environmental risks that were unknown or unable to determine during the initial reregistration process. Rotenone was reregistered by the EPA in 2007 for piscicide use only (EPA 2007). During the reregistration process, the EPA used risk assessments to evaluate the frequency and level of exposure that may occur in humans and ecological receptors upon exposure to rotenone.

**How did the EPA determine safe levels of rotenone to be applied?[1]**

The EPA determined the Level of Concern (LOC) for rotenone concentrations for each potential exposure scenario (e.g., dietary risk, residential and recreational risk, occupational risk), which is 1000 times less than the no observed adverse effect level (NOAEL) for specific exposure routes (EPA 2007). This reflects a 10x uncertainty factor for interspecies extrapolation, a 10x uncertainty factor for intraspecies variation, and a 10x database uncertainty factor because a potentially critical effect (neurotoxicity) cannot be assessed quantitatively with the existing database. When critical factors cannot be assessed quantitatively with the existing database, EPA applies a 10x uncertainty factor to establish exposure limits that ensure the protection of public health and ecological systems. As a result of the reregistration process, the EPA determined the maximum treatment concentration of rotenone for piscicide use to be 200 parts per billion (ppb = µg/L).

**How much rotenone is used?[2]**

The concentration of active rotenone used to eradicate fish varies with the target species and environmental conditions from 12.5 to 200 ppb; which is 12.5 to 200 parts of rotenone in 1,000,000,000 parts of water (equivalent to 0.07 – 1.1 lb [1.1 – 18 oz] of rotenone in an Olympic-size swimming pool of 666,430 gallons).

**How safe is rotenone to the public and applicators?[2]**

Millions of dollars have been spent on research in testing laboratories and environmental monitoring studies to determine the safety of rotenone prior to registration in the U.S. by the EPA and in Canada by the Pest Management Regulatory Agency. Extensive acute (short-term) and chronic (long-term) tests on rotenone have been conducted. Rotenone is not considered a carcinogen (capable of causing cancer), mutagen (capable of causing genetic mutation), teratogen (interferes with normal embryonic development), or reproductive toxin (affects reproductive capabilities). The public will be excluded from treatment areas until rotenone residues have dissipated to safe levels, and applicators are required to wear additional safety gear to minimize rotenone exposure.

**What is a safe level of rotenone exposure?[3]**

The EPA has suggested a safe level for rotenone in drinking water of 40 ppb and a safe level for water contact (e.g. swimming) of 90 ppb. These safe levels assume a conservative worst-case lifetime exposure to rotenone. These are conservative levels since most treatments result in rotenone residues persisting for no longer than a few days to a few months.

**How were safe levels of rotenone determined?[1]**

To determine safe chronic drinking water exposure concentrations for rotenone, the EPA used data from a study where rotenone was administered to rats in concentrations of 0, 7.5, 37.5 and 75 parts per million (ppm or mg/L) daily for two years (equating to 0, 0.375, 1.88, and 3.75 mg/kg/day, respectively)(EPA 2006). Although no mortality or serious abnormalities were observed in any of the treatment groups, male and female rats lost weight in the mid- and high-dose groups. Thus, the lowest observed adverse effect level was 37.5 ppm, so the EPA used the 7.5 ppm as a toxicity end point for chronic oral consumption by humans and applied an additional uncertainty factor which is 1000 times lower than the lowest observed adverse effect level (equating to 0.0004 mg/kg/day or 40 ppb).

For perspective, using estimates reported by Finlayson et al. (2000), the estimated single lethal dose to humans is 300-500 mg/kg body weight. During a rotenone treatment using a concentration of 250 ppb (previous maximum treatment concentration), a 160 lb person would have to drink more than 23,000 gallons of treated water at one sitting to achieve a lethal dose.

The EPA considers chronic risk to humans from rotenone exposure during piscicide applications to be low based on the following reasons: the rapid degradation of rotenone; faster degradation and control of treatment end point by neutralization with potassium permanganate, where appropriate; the cancellation of some application methods (agriculture and residential); new required engineering controls to protect applicators; applications follow piscicide label requirements; and there is adequate signing and public notice or area closures to minimize public exposure to treated waters (EPA 2007).

**When can the public access the water after treatment?[3]**

The public will not be allowed in contact with the treated water until rotenone residues have dissipated below 90 ppb. Although the maximum treatment concentration for rotenone is 200 ppb, many treatments will occur at rotenone levels less than 90 ppb and in these cases contact can commence immediately after the treatment process has been completed. The EPA minimizes risks of exposure for swimmers during rotenone treatments by requiring closures (or swimming prohibition) post-treatment until levels are safe for swimming and/or consumption per EPA guidelines.

**What is Parkinson's disease (PD) and its relationship to rotenone?[2]**

People with PD have less dopamine producing cells in the brain which typically results in tremors and rigidity. It is a complicated disease likely affected by both genetics and the environment. Published literature over the past ten years indicated that rotenone exposure under certain laboratory conditions could reproduce several symptoms of PD in rodents. Although rotenone is toxic to the nervous system of insects and fish, commercial rotenone products have presented little hazard to humans over many decades of use and are not considered a cause of PD.

**Does rotenone use in fisheries management cause PD?[3]**

There is little doubt that rotenone and other chemicals that directly inhibit the mitochondrial energy chain can under certain laboratory exposure conditions reproduce symptoms of PD in animal models. These studies use intravenous (directly into the vein) injections, subcutaneous (below the skin) injections, or intragastric (stomach tube) routes of exposure with the rotenone dissolved in solvents and stabilizers to enhance tissue penetration. The purpose of the animal model studies is often to document possible PD models, not in finding the cause(s) of PD. The laboratory exposures used limit their applicability to humans because they avoid the normal protective measures of the human body through dermal and oral exposure. For example, a two-year long study where rotenone was mixed in the food of rats, using much higher dosages of rotenone, did not produce PD symptoms.

For perspective considering that the maximum treatment concentration of rotenone per the EPA is 200 ppb active rotenone, a 1 kg (2.2 lb) rat would need to be injected with 4 gallons of the 200 ppb rotenone solution daily for 6 weeks to achieve the 3 mg/kg/day concentration used in rotenone model studies. For a typical stream treatment using 50 parts ppb active rotenone, a 70 kg (154 lb) human would have to be injected with 1,109 gallons of 50 ppm rotenone solution daily for 6 weeks to achieve the 3 mg/kg/day concentration as used in the studies.

**How are the epidemiological studies of rotenone exposure and PD related to exposure to rotenone used in fisheries management?[1]**

To date, there are no published studies that conclusively link exposure to rotenone and the development of clinically diagnosed PD. Some correlation studies have found a higher incidence of PD with the occupational (e.g., agricultural use) exposure to pesticides among other factors (e.g., Tanner et al. 2009, 2011), and some have not (e.g., Hertzman 1994; Firestone et al. 2010). It is very important to note that in case-control correlation studies, causal relationships cannot be assumed and some associations identified in odds-ratio analyses may be chance associations. Only one study (Tanner et al. 2011) found an association between occupational rotenone and paraquat use and PD in agricultural workers, primarily farmers. However, there are substantial differences between the methods of application, formulation, and doses of rotenone used in agriculture and residential settings compared with aquatic use as a piscicide, and the agricultural workers interviewed were also exposed to many other pesticides during their careers. Recently, the results of epidemiological studies linking pesticide exposure to PD have been criticized due to high variation among study results, generic categorization of pesticide exposure scenarios, questionnaire subjectivity, and the difficulty in evaluating the causal factors of PD (Raffaele et al. 2011).

The potential realistic exposure of humans to rotenone during piscicide treatments, as regulated by the EPA (application rate of rotenone used as a piscicide shall not exceed 200 ppb), is not comparable to the dose required to cause the development of PD symptoms in rodents by way of chronic intravenous injections of rotenone into the sub-cutaneous, jugular vein, and substantia nigra. Piscicidal use of rotenone as a restricted use pesticide degrades quickly, is not expected to contaminate groundwater, and restricts human exposure of the treatment area during treatment, all of which make an environmental exposure to rotenone highly unlikely to cause PD or PD-like symptoms (Bové 2005). Overall, the occupational risk for the piscicide use rotenone will be negligible if used at concentrations no higher than the maximum treatment concentration and when certified applicators and professional fishery professionals use the rigorous standard operating procedures developed.

**What are the dangers from consuming fish from rotenone treated water?[3]**

Fish killed by rotenone should not be consumed by humans because of concern for salmonella and other bacteriological poisoning that may occur from consuming fish that have been dead for a period of time. The rotenone residues in dead fish carcasses are quickly broken down by physical and biological reactions.

It is possible that piscivorous (fish eating) birds and mammals may feed on dead or dying fish within a treatment area, although piscicide (fish killing) treatment protocols often recommend collection and/or burial of dead or dying fish within a treatment area where practicable. During the EPA's risk assessment process for terrestrial organisms, it was determined that based on rotenone residuals in yellow perch and common carp, a bird or mammal would have to consume thousands of pounds of contaminated fish in one sitting to result in a lethal dose.

**How are the effects of rotenone restricted to the treatment site?[3]**

Potassium permanganate, through a chemical reaction called oxidation, deactivates rotenone. Potassium permanganate can be added into the flowing water stream at the point where the effects of rotenone are no longer desired. Potassium permanganate is used worldwide in treatment plants to purify drinking water.

**What happens to rotenone after it is applied to the water?[2]**

Rotenone is a compound that breaks down very rapidly in the environment. Rotenone degrades quickly through physical (hydrolysis and photolysis) processes and biological mechanisms. An increase in temperature or sunlight increases the breakdown rate of rotenone.

**How long does rotenone persist in water and sediment?[2]**

Numerous monitoring studies have shown that rotenone residues typically disappear within about one week to one month, depending on environmental conditions. The half-life (time required for ½ of material to breakdown) for rotenone varies from about 12 hours to 7.5 days, and is inversely related to temperature. Rotenone is typically applied when water temperatures are warm to optimize effect on the fish and the breakdown rate in the environment. If necessary, potassium permanganate can be used to speed-up (within 30 minutes) the breakdown of rotenone.

**What are the risks of contaminating groundwater?[1]**

Rotenone is highly insoluble in water and strongly absorbs to soil particles in bottom sediments and to suspended particles in the water column, limiting its mobility and availability to bioaccumulate in organisms. These factors also make rotenone unlikely to leach through soils and reach groundwater, and thorough long-term (10 years post-treatment) monitoring of 80 groundwater wells in treatment areas in California, and short-term monitoring of over 26 wells in California and Montana never detected rotenone, rotenolone, or any formulation products following rotenone treatments (Skaar 2002; Ridley et al. 2007; McMillin and Finlayson 2008). If leaching does occur, rotenone will move vertically through soils typically less than one inch deep (Dawson 1986), making it unlikely to be absorbed by the roots of bank vegetation.

**How does rotenone affect aquatic animals?[2]**

Because rotenone is selectively toxic to gill breathing animals, fish are the most sensitive, followed by aquatic invertebrates and gill breathing forms of amphibians. Benthic invertebrates appear less sensitive than planktonic invertebrates, smaller invertebrates typically appear more sensitive than their larger counterparts, and aquatic invertebrates that use gills appear more sensitive than those that acquire oxygen through the skin, or that use respiratory pigments or breathe atmospheric oxygen. Studies have shown that amphibians and invertebrates will repopulate an area after rotenone breaks down.

**Will wildlife be affected from consuming water or food containing rotenone?[2]**

Birds and mammals are tolerant of rotenone having natural enzymes in the digestive tract that neutralize rotenone. Birds and mammals that eat dead fish and drink treated water will not be affected. Rotenone does not concentrate in fish tissue, rotenone residues are broken down quickly in the environment, and rotenone is not readily absorbed through the gut of an animal eating the fish or drinking the water. Most fish quickly sink to the bottom of treated water and rapidly decompose making the likelihood of extended exposure through the diet of terrestrial animals very low. This difference in toxicity between fish and birds and mammals coupled with its lack of environmental persistence makes the use of rotenone a good fish management tool.

**Will wildlife be affected by the loss of their food supply following a rotenone treatment?[2]**

During rotenone treatments, fish-eating birds and mammals can be found foraging on dying and recently dead fish for up to several days after treatment. Following this abundance of dead fish, a temporary reduction in food supplies may result until fish and invertebrates have been restored. However, most of the affected species are mobile and will seek alternate food sources or forage in other areas. In unique situations like the fledging of young raptors, dead fish may be brought into the treated water body for extended periods of time to provide for an uninterrupted food supply or the timing of the treatments can avoid periods of time when raptors are raising their young.

**Will wildlife or livestock be affected by grazing on vegetation along the perimeter of treated waters?**

Terrestrial wildlife may be exposed to treatment areas, but are unable to consume enough treated water or vegetation with rotenone residues to reach toxic levels. The EPA did not conduct a risk assessment to evaluate potential risk to birds and mammals from drinking rotenone treated water. However, the EPA studies for the human health risk assessments used rats to determine that the acute dietary exposure (drinking water only) of 200 ppb (maximum application concentration) is below the LOC. Finlayson et al. (2000) estimated that a 0.25 lb (0.113 kg) bird would need to consume 25 gallons of treated water in 24 hours to receive a lethal dose. Similarly for a large mammal, a cow weighing 1,620 lb (735 kg) would have to ingest 4,615 gallons of treated water (at 200 ppb treatment concentration) to reach a median lethal dose (EPA, personal communication).

It is possible that some birds and mammals may consume vegetation bordering stream or lake banks that was sprayed with rotenone during a piscicide treatment by an applicator operating a backpack sprayer unit. A human health and ecological risk assessment for rotenone completed for the U.S. Department of Agriculture, Forest Service, did not analyze this exposure scenario because they determined it irrelevant to aquatic applications (Durkin 2008). The EPA estimated exposure concentrations of rotenone in the form of foliar residues on vegetation (e.g., grass) that may be consumed by wildlife following non-piscicide applications of rotenone before the product registrants withdrew their requests for reregistration for those uses of rotenone; the EPA considered wildlife exposure by way of piscicide applications to rotenone residues on vegetation unlikely.

**Does rotenone affect all animals the same?[4]**

No. Fish are most susceptible, with rotenone inhibiting a biochemical process at the cellular level making it impossible for fish to use the oxygen absorbed in the blood and needed in the release of energy during respiration. All animals including fish, insects, birds, and mammals have natural enzymes in the digestive tract that neutralize rotenone, and the gastrointestinal absorption of rotenone is inefficient. However, fish (and some forms of amphibians and aquatic invertebrates) are more susceptible because rotenone is readily absorbed directly into their blood through their gills (non-oral route) and thus, digestive enzymes cannot neutralize it.

**How many rotenone treatments have been conducted by the Arizona Game and Fish Department (AGFD)?**

Since 1990, AGFD has used rotenone as a fish removal tool in 22 waters. Of the rotenone treatments, about 68% (n = 15) treated golf course ponds or stock tanks, 18% were stream treatments (n = 4), and 14% were lake treatments (n = 3).

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[1]Source: Rotenone Review Advisory Committee Final Report

[2]Source: American Fisheries Society. 2010. Maintaining North America's healthy native aquatic ecosystems: rotenone's role in eradicating invasive fishes, parasites and diseases. Fish Management Chemicals Subcommittee. http://www.fisheriessociety.org/rotenone/

[3]Source: Original source – American Fisheries Society. 2010. Maintaining North America's healthy native aquatic ecosystems: rotenone's role in eradicating invasive fishes, parasites and diseases. Fish Management Chemicals Subcommittee. http://www.fisheriessociety.org/rotenone/ and modified with information from the Rotenone Review Advisory Committee Final Report.

[4]Source: Modified from Finlayson, B.J., R. Schnick, R. Cailteux, L. DeMong, W. Horton, W. McClay, C. Thompson, and G. Tichacekl. 2000. Rotenone use in fisheries management: administrative and technical guidelines. American Fisheries Society. Bethesda, Maryland.

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## <u>APPENDIX C. ROTENONE REVIEW ADVISORY COMMITTEE DRAFT AND FINAL CHARTER</u>

# Rotenone Review Advisory Committee Charter
# Draft Final - May 9, 2011

### I. Authority

The Committee will be called the Rotenone Review Advisory Committee (Committee). It is authorized by the Director of the Arizona Game and Fish Department (Department) and will serve at the pleasure of the Director.

### II. Purpose & General Function

**<u>Purpose</u>**: The purpose of the Committee shall be to advise and make recommendations to the Department Director and, through him the Commission with respect to matters within the areas of its members experience and expertise regarding the use of rotenone and other piscicides for Arizona fisheries and aquatic wildlife management. In that regard, the Committee will:

- Review reports and research organized and coordinated by the Department for presentation to the Committee.
- Provide a final set of written recommendations to the Director.
- Establish subcommittees as necessary in furtherance of the Committee's purpose.

**<u>Committee Recommendations</u>**: The Committee shall consider the best available science regarding rotenone/piscicides and consider recommendations and potential impacts due to changes in current practices, policies or regulations in the following areas:

- Potential risks to human health
- Public benefits, including recreational opportunity, and economic and social impacts regarding:
    - The management of Arizona's sport fishing resources
    - The management of threatened and endangered species
    - The management of invasive species
- Rules, Statutes and policies/procedures for use, to include process for review, approval and implementation of projects.

**<u>Subcommittees</u>**

The Committee shall consider forming subcommittees to provide technical expertise, opinion and analysis in the following areas.

- Public Health
- Alternate Management Strategies
- Recreation, Economic and Social Impacts
- Internal Policy, Public Involvement and Best Management Practices

The subcommittees will each have a chair and vice chair that are members of the Committee, but may contain outside experts who are not members of the Committee.

**Meetings**: The Committee will meet at least 4 times per year. Written and telephonic notices of upcoming meetings will be made to members at least ten (10) days before a meeting.

**Recommendations Report**: The Committee shall provide the Director a final draft of recommendations developed by Committee not later than 31 December 2011.

**Minutes**: Minutes of the meeting will be the responsibility of the Department. Copies will be mailed to the Committee within 30 days of the meeting and will be posted on the Department web site.

**Attendance**: Members are strongly encouraged to attend each meeting. Those members that cannot attend a meeting(s), the Director may approve a proxy or their official designee to fill the position.

**Public Announcements**: The Department will make public announcements through its existing information program. Media queries will be handled by the Department's Information Branch.

## III. Organization and Membership

**Organization**: The Committee will have a Chair appointed by the Director and membership as reflected in this paragraph. A member of Department staff shall be designated to act as secretary to the Committee. The members shall be appointed by the Director. The term of service for members will be not more than one year from the date of appointment, subject to earlier resignation or departure from the Committee.

**Membership**: Membership will include a member or representatives from:

Chair: Herb Guenther
Arizona House of Representatives:
Arizona Senate:
Arizona Game and Fish Department:
Arizona Department of Environmental Quality:
Arizona Department of Water Resources:
Arizona Department of Agriculture:
Arizona Department of Health Services:
Salt River Project:
City of Phoenix:
Environmental Community:
Angler Community:
Medical Community:
Ranching Community:
Farming Community:
Agricultural Interests:
USFWS:

USBLM:
USFS:
CAWCD:
and others, at the discretion of the Director.

## IV. Compensation & Expense Requirements

The Department is not authorized to compensate or reimburse expenses associated with Committee member participation.

# Rotenone Review Advisory Committee Charter
# Final - June 24, 2011

## I. Authority

The Committee will be called the Rotenone Review Advisory Committee (Committee). It is authorized by the Director of the Arizona Game and Fish Department (Department) and will serve at the pleasure of the Director.

## II. Purpose & General Function

**Purpose**: The purpose of the Committee shall be to advise and make recommendations to the Director and, through him the Commission with respect to matters within the areas of its members experience and expertise regarding the use of rotenone and other piscicides for Arizona fisheries and aquatic wildlife management.

In that regard, the Committee shall review reports and research organized and coordinated by the Department and Subcommittees, and provide technical expertise, opinion, and analysis regarding the use of rotenone and other piscicides in the following areas:

- Public Health and Environment
- Alternate Management Strategies
- Recreation, Economic and Social Impacts
- Current State and Federal Regulations, Internal Policy, Public Involvement, and Best Management Practices

The Committee will provide a final set of written recommendations to the Director.

**Committee Recommendations**: In making its recommendations to the Director, the Committee shall consider the best available science regarding the use of rotenone and other piscicides and the potential impacts due to changes in current practices, policies or regulations in the following areas:

- Potential risks to human health and the environment
- Public benefits, including recreational opportunity, and economic and social impacts regarding:
  - The management of Arizona's sport fishing resources
  - The management of threatened and endangered species
  - The management of invasive species
- Rules, Statutes and policies/procedures for use, to include process for review, approval and implementation of projects.

**Subcommittees**
The Committee shall consider forming subcommittees to provide technical expertise, opinion and analysis in the following areas:

- Public Health and the Environment
- Alternate Management Strategies
- Recreation, Economic and Social Impacts
- Current State and Federal Regulations, Internal Policy, Public Involvement, and Best Management Practices

The subcommittees will each have a chair and vice chair that are members of the Committee, but may contain outside experts who are not members of the Committee.

**Meetings**: The Committee will meet at the call of the Director. Written and telephonic notices of upcoming meetings will be made to members at least ten (10) days before a meeting.

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Chair: Herb Guenther
Arizona House of Representatives:
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Arizona Game and Fish Department:
Arizona Department of Environmental Quality:

Arizona Department of Water Resources:
Arizona Department of Agriculture:
Arizona Department of Health Services:
Salt River Project:
City of Phoenix:
Environmental Community:
Angler Community:
Medical Community:
Ranching Community:
Farming Community:
Agricultural Interests:
USFWS:
USBLM:
USFS:
and others, at the discretion of the Director.

## IV. Compensation & Expense Requirements

The Department is not authorized to compensate or reimburse expenses associated with Committee member participation.

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