IMPACTS OF TWO-STROKE ENGINES ON AQUATIC RESOURCES

Human recreational activities impact aquatic resources directly and indirectly. Winter recreation affects aquatic organisms mainly by indirect impacts due to pollution. Two-stroke engines can deposit contaminants on snow, leading to ground and surface water quality degradation, which subsequently may impact aquatic life.

LIFE HISTORY AND STATUS

Fish are important components of aquatic ecosystems and are important links in the transfer of energy between aquatic and terrestrial environments. Native and non-native fish, aquatic microorganisms, insects, and crustaceans integrate into a complex aquatic community. In Yellowstone National Park there are 12 native and 6 introduced fish species (Varley and Schullery 1983). In the Yellowstone area and the Rocky Mountain region, trout and other salmonids (Family Salmonidae) are the major game species. Native fish include Yellowstone cutthroat trout (*Oncorynchus clarki bouvieri*), westslope cutthroat trout (*O. clarki lewisi*), Snake River cutthroat trout (*O. clarki*), arctic grayling (*Thymallus articusi*), mountain whitefish (*Prosopium williamsoni*), mountain sucker (*Catostomus platyrhnchus*), longnose sucker (*C. catostomus griseus*), Utah sucker (*C. ardens*), mottled sculpin (*Cottus bairdi*), redside shiner (*Richardsonius hydrophlox*), Utah chub (*Gila atraria*), longnose dace (*Rhinicthys cataractae*), and speckled dace (*R. osculus*). Non-native fish species include rainbow trout (*O. mykiss*), brown trout (*Salmo trutta*), eastern brook trout (*Salvelinus fontinalis*), lake trout (*S. namaycush*), and lake chub (*Couesius plumbeus*).

Some fish species are becoming endangered as populations decrease from human exploitation, environmental degradation, and competition and predation from exotic or introduced species. While no fish species in the Yellowstone area are listed under the Endangered Species Act, the fluvial Arctic grayling, westslope cutthroat trout, and Yellowstone cutthroat trout are considered species of concern in Wyoming, Montana, and Idaho. All three species have been petitioned for federal listing under the Endangered Species Act (50 CFR Part 17), and it has been determined that listing of the fluvial Arctic grayling as endangered is warranted but precluded at this time. Determinations for the other two species are pending.

HUMAN ACTIVITIES

Much of the existing literature relating to impacts on aquatic biota has been restricted to outboard engines on boats that discharge a variety of hydrocarbon compounds directly into the water column (Bannan 1997). However, the discharge of snow machine exhaust directly into accumulated snow may provide a corollary. For example, emissions from snowmobiles have been implicated in elevated lead contamination of snow along roadsides (Ferrin and Coltharp 1974). Although lead is no longer a concern, hydrocarbons are still deposited on the top layer of snow along snowmobile trails (Adams 1974).

Contaminants from two-cycle engine exhaust include carbon monoxide, hydrocarbons, Methyl-*tert*-butyl ether (MTBE), Nitrous oxides (NO_x), and particulate matter (White and Carrol 1998). Considerable variation exists among these compounds with respect to

toxicity and persistence in water or aquatic sediments. Temperature and dilution rate (*i.e.*, mixing by propellers) appear to affect volatility (*e.g.*, evaporation rate) and long-term distribution of specific compounds. Because two-cycle engine exhaust contains numerous types of hydrocarbons, analyses typically focus on effects of only the more persistent types, particularly polycyclic aromatic hydrocarbons (PAH).

Studies of Lake Tahoe suggest that localized reductions of zooplankton populations may occur in areas of high boat usage. Deleterious effects can occur both in terms of mortality and histopathological response (Tahoe Research Group 1997). Extensive laboratory tests in Sweden documented that rainbow trout exposed to typical levels of engine exhaust could be negatively affected in growth rates, enzyme function, and immune responses (Balk et al. 1994). Also, sex-specific differences were observed, which could lead to alteration of normal reproductive function. MTBE is an oxygenated additive emitted from engine exhaust that is soluble in water and does not break down readily. However, no formal Environmental Protection Agency (EPA) drinking water standards are set for this compound. Nitrous oxides contain nitrogen, which can be a limiting nutrient in aquatic systems. It is considered a small risk because of its small percentage to total atmospheric deposition rates. However, it can contribute to eutrophication. As a result, some concerned investigators have recommended restrictions on the number of two-cycle engines allowed in high usage areas of Lake Tahoe (Tahoe Research Group 1997). Similar concerns have been voiced for Lake Michigan, Isle Royale National Park, and San Francisco Bay.

Under certain environmental conditions, toxicity of some PAH compounds may increase substantially. The toxicity of PAH can be "photo enhanced" in the presence of ultraviolet light (UV) and become 50,000 times more toxic under field conditions in the presence of sunlight. When PAH are in the bodies of aquatic organisms and absorb UV light, the energized molecules or their reactive intermediates can react with biomolecules to cause toxicity that can lead to death of aquatic organisms (Allred and Giesy 1985, Holst and Giesy 1989).

Impacts to aquatic species that can be attributed to atmospheric deposition from snowmobiles have not been well studied. Field studies are extremely difficult to conduct because atmospheric deposition rates could be affected by numerous factors, including temperature, proximity to water, and combustion efficiency of individual snowmobiles. One of the more extensive studies used caged brook trout to determine effects of exhaust on fish. Exhaust components taken up by fish correlated with levels present in the environment as a result of snowmobile use (Adams 1974). Uptake of exhaust hydrocarbons and other compounds occur through the gills during respiration. It is thought that hydrocarbons are incorporated into fatty tissues, such as visceral fat and the lateral line, in a manner similar to chlorinated hydrocarbon pesticides.

Tremendous uncertainty accompanies discussion of this topic with reference to affects on aquatic resources of the GYA. The current lack of quantitative data reduces comparisons between outboard engines and anticipated effects from a specific level of snowmobile use. However, it appears reasonable that higher concentrations from emissions will likely accumulate as a result of grooming roads with the constant packing of exposed snow. These accumulated pollutants will enter adjacent watersheds during the spring melt, which generally occurs from April through June. Pollutants entering the watershed will be concentrated during this snowmelt, producing a strong "pulse" in the system. Similarly,

impacts from acid rain in the eastern United States are confounded by the accumulation of the acid in snow, with subsequent melting producing a pulse of acidity in a short time and causing very low pH in many streams (Carline et al. 1992, Haines 1981).

POTENTIAL EFFECTS

Protection of park aquatic resources and restoration of native species are primary management goals of the National Park Service. In Yellowstone National Park, groomed snowmobile roads are often adjacent to major aquatic systems (*e.g.*, Firehole River, Madison River, Gibbon River, Yellowstone River, Lewis River, and Yellowstone Lake). The Yellowstone River from the Yellowstone Lake outlet to the Upper Falls contains Yellowstone cutthroat trout. The Madison River is a potential reintroduction site for westslope cutthroat trout. The Gibbon and Madison rivers may contain fluvial Arctic grayling. Snowmobiling occurs on Hebgen, Jackson, and other small lakes located in the greater Yellowstone area. There are also areas where snowmobiles cross open water.

Hydrocarbon pollution in water may initially persist on the surface but will eventually settle into the water column, increasing exposure to fish and invertebrates. Investigations have shown dramatic increases in some contaminants in water exposed to snowmobile exhaust; some of these increases are on the order of 30 times (Adams 1974). Accumulation may also occur in sediments (Lazrus et al. 1970). Fish receive contamination from different trophic levels that are sustained in both open water and sediment environments. These pollutants accumulate in the food chain, and accumulations in fish would result in uptake by piscivorous predators including bald eagle, osprey, otter, pelican, and grizzly bear.

Physiological responses of fish to increased loads of hydrocarbons and other contaminants may increase direct and indirect mortality rates. Rainbow trout and cutthroat trout begin spawning in early spring (March through July), exposing developing embryos during this period. Research has shown that even at extremely low levels of hydrocarbon pollution, impacts may include chromosomal damage; retarded growth and development; disruption of normal biological functions, including reduced stamina for swimming and maintaining positions in streams (Adams 1974); and death.

Invertebrate vulnerability is not known; however, it is likely that early instar development may be impacted by hydrocarbon pollution entering the water. Many winter shredders (invertebrates that consume large organic debris) are emerging, mating, and laying eggs in early spring (*e.g.*, stoneflies). These developing embryos may, therefore, be more susceptible to pollutants during spring runoff periods.

Impacts of winter recreational activities on fish and other aquatic resources occur mostly where oversnow machines concentrate along groomed motorized routes and winter destination areas. In situations where snowmobiling occurs over open water (D. Trochta 1999), obvious impacts will include direct discharge into aquatic habitats. Appreciable contamination from emissions from backcountry snowmobiling probably occurs less frequently. However, dispersed snowmobile travel affects vegetation (J. T. Stangl 1999), causing erosion and damaging natural water courses and banks. Snowmobiles can cause degradation of stream and lake quality and affect aquatic species and their habitat.

Management of oversnow machine recreation should encourage the development of clean emission standards. Strict emission

requirements for two-stroke engines would mitigate impacts to water quality and, subsequently, aquatic environments. Restricting motorized winter recreation near streams, lakes, and wetland habitats would minimize direct impacts to aquatic resources.

LITERATURE CITED

Adams, S. E. 1974. Effects of lead and hydrocarbons from snowmobile exhaust on brook trout *Salvelinus fontinalis*. Transactions of the American Fisheries Society 104(2):363–373.

Allred, P. M., and J. P. Giesy. 1985. Solar radiation induced toxicity of anthracene to *Daphnia pulex*. Environmental Toxicology and Chemistry 4:219–226.

Balk, L., G. Ericson, E. Lindesjoo, I. Petterson, U. Tjarnlund, and G. Akerman. 1994. Effects of exhaust from two-stroke outboard engines on fish. Nordic Council of Ministers, Copenhagen, Denmark.

Bannan, M. 1997. The effects of powerboat emissions on the water quality of Loch Lomond. Post-graduate annual report. Glascow University and University Field Station, Great Britain.

Carline, R. F., W. E. Sharpe, and C. J. Gagen. 1992. Changes in fish communities and trout management in response to acidification of streams of Pennsylvania. Fisheries 17(1):33–38.

Ferrin, R. S., and G. P. Coltharp. 1974. Lead emissions from snowmobiles as a factor in contamination of snow. Proceeding of the Utah Academy of Science, Arts and Letters 51(1):116–118.

Haines, A. 1981. Acid precipitation and its consequences for aquatic ecosystems: a review. Transactions of the American Fisheries Society 110:669–707.

Holst, L. L., and J. P. Giesy. 1989. Chronic effects of the photo-enhanced toxicity of anthracene on *Daphnia magna* reproduction. Environmental Toxicology and Chemistry 8:933–942.

Lazrus, A. L., E. Lorange, and J. P. Lodge, Jr. 1970. Lead and other metal ions in United States precipitation. Environmental Science and Technology 4(1):55–58.

Tahoe Research Group. 1997. The use of two-cycle engine watercraft on Lake Tahoe: water quality and limnological considerations. Report to Tahoe Regional Planning Agency, Lake Tahoe, California, USA.

Stangl, J. T. 1999. Effects of recreation on vegetation. Pages 119–121 *in* T. Olliff, K. Legg, and B. Kaeding, editors. The effects of winter recreation on wildlife: a literature review and assessment. National Park Service, Yellowstone National Park, Wyoming, USA: In Press.

Trochta, D. 1999. The effects of snowmobiling across open water. Pages 161–162 *in* T. Olliff, K. Legg, and B. Kaeding, editors. The effects of winter recreation on wildlife: a literature review and assessment. National Park Service, Yellowstone National Park, Wyoming, USA: In Press.

Varley, J. D., and P. Schullery. 1983. Freshwater wilderness: Yellowstone fishes and their world. Yellowstone Library and Museum Association, Yellowstone National Park, Wyoming, USA.

White, J. W., and J. N. Carrol. 1998. Emissions from snowmobile engines using biobased fuels and lubricants. Report prepared for the state of Montana Department of Environmental Quality, Helena, Montana, USA.