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An Investigation into the Impact of Outdoor Recreation on Water Quality

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AN INVESTIGATION INTO THE IMPACT OF OUTDOOR RECREATION ON WATER QUALITY

by

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Michael L. Young

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ABSTRACT

An Investigation into the Impact of Outdoor Recreation

on Water Quality

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This thesis was undertaken in order to explore aspects of the impact of outdoor recreation on water quality. It begins with a discussion of the rationale for monitoring and controlling such environmental degradation. Following sections include an investigation of water quality characteristics particularly indicative of recreational impact, a discussion of the potential contributions of various recreation activities to water pollution, a literature survey, a guideline for planning and implementing a water quality surveillance program, and recommendations for further research. Material for the thesis came from library research and was augmented by the author's personal experience as a water quality research technician.

(76 pages)

CHAPTER I

INTRODUCTION

Current knowledge of the impact of outdoor recreation on water resources is rather limited (Lime and Stankey, 1971). Most of the research of this subject has come about because of concerns of municipal water supply managers in safeguarding this resource from human contamination before distribution to their patrons. It is the intent of this thesis, however, to explore this question of recreational impact on water quality from a different viewpoint. It will be proposed that such knowledge can be a valuable tool to recreation planners and managers.

Many writers have emphasized the importance of the role of water resources in present and future recreation. Kittrell (1969) writes, "It may be said unequivocally that where there are people and where there is access to water, general recreational and scenic enjoyment of water will occur." The significance of the water orientation of recreation was also stressed by the Outdoor Recreation Resources Review Commission (1962). They have asserted the following:

> Water is a prime factor in most outdoor recreation activities. The commission's National Recreation Survey reports that 44 percent of the population prefers water based recreation over any others. Water also enhances recreation on land. Choice camping sites and picnic areas are usually those adjacent to or within sight of a lake or stream, and the touch of variety added by a pond or marsh enriches the pleasures of hiking or nature study. (p. 173)

The report later goes on to indicate that demand for water oriented recreation for the years 1962-2000 will far outstrip population growth. Similarly, Mueller, Gurin, and Wood (1962) predict that the future will see a greater increase in water oriented recreation activities than in other outdoor recreation endeavors.

Thus, the climbing intensity of human use of outdoor recreation resources suggests the possibility of an ensuing degradation of the quality of naturally occurring waters. This thesis begins an investigation of such impact by explaining various reasons for which research in this area is conducted. Following sections will discuss the major components of a water quality monitoring scheme, the pollutional effects of different leisure pursuits, and the findings of previous studies of this topic. Finally, a guideline for establishing a program to measure recreation impacts on water quality will be presented. In this manner, it is hoped that new light will be shed on a rather esoteric subject.

CHAPTER II

THE RATIONALE FOR MONITORING AND CONTROLLING RECREATIONAL IMPACT

This chapter deals with the first questions that anyone interested in researching recreational impacts on water quality must consider. That is, why should such study be undertaken? And, what are its goals?

This thesis will discuss three major topics used as rationale for research in this area. These include: 1. Ascertaining hazards to public water supplies; 2. Determining a recreational carrying capacity; and 3. Complying with the legal stipulations of the Federal Water Pollution Control Act. In a sense, all three of these reasons are closely related: each has the ultimate purpose of discerning at what level of human use contamination to nearby waters becomes unacceptable. However, distinctions between the three are embodied in their different goals for study. This point becomes evident in the discussions which follow.

Hazards to municipal water supplies

Over the last several decades there has been controversy as to whether recreation does indeed degrade water quality. Such discussions usually concern recreational privileges on and around municipal water supplies. In most cases, water works personnel oppose this usage because they feel water quality

deterioration will result. On the other hand, recreational interests, such as sporting clubs, generally are of the opinion that their impacts are negligible. Therefore, they favor opening watersheds to their benefit.

Those watershed personnel who oppose recreational privileges can cite studies to back up their opinions. For instance, Faneuf and Healy (1952), in an early treatise on this subject, noted that "serious" reservoir contamination on the Concord, New Hampshire, water supply had resulted from unauthorized use of the water and adjacent land areas. Other such studies will be discussed in Chapter IV.

Dangers stemming from recreational use of watersheds range from direct discharge of human waste (Peloquin, 1965) to turbidity caused by destruction of the watershed's vegetative cover (McKewen, 1966). Taylor (1964) has listed the following seven health hazards that result from recreational use of watersheds:

> 1. Promiscuous defecation by hikers or skiers along a stream or lake.
>
> 2. Discharge of toilet wastes from summer or winter resorts or camps upon the ground surface or into improper subsurface disposal systems with subsequent drainage into a source of water supply.
>
> 3. Bathing in water supply source.
>
> 4. Overboard discharge of toilet wastes from pleasure craft.
>
> 5. Accumulations of unburned hydrocarbons and combustion products from inboard and outboard motors.
>
> 6. Garbage and toilet discharges from marinas.
>
> 7. Body discharges of fishermen using a lake or stream. (p. 8)

Many water supply managers therefore feel that they cannot compromise losing high quality water to recreation. Bringham (1966) stated their position succinctly when he wrote "... recreation must run second when the prime function of the impoundment and its shoreline perimeter is provision of public water supply."

Two government councils, the Pollution Control Council, Pacific Northwest Area and the National Industrial Pollution Control Council have published articles that recognize hazards of recreation on water supplies. According to Bowering et al. (1961), the Pollution Control Council has determined that improperly planned sewage, garbage, and refuse disposal facilities in forest areas pose pollution problems. Further, the National Industrial Pollution Control Council (1971) states without qualification that "human activities in drainage areas of lakes, rivers, and seacoasts has a profound impact on water quality." The Council goes on to suggest that problems due to recreation stem from inadequate funding and planning, resulting in substandard campgrounds, overuse of areas, and inadequate water, sewer, and waste disposal systems.

Some writers, however, believe that recreation is not detrimental to water quality. Dodson (1963) noted that San Diego, California, has for many years allowed much recreation on its water supply reservoirs. Dodson asserts that no contamination due to recreation has ever been found. In writing of the Pacific Northwest, Benedetti (1964) maintains that good water supply and recreation are compatible. He claims that with proper control and public awareness and understanding neither water quality nor recreation need be sacrificed for the other. Studies supportive of this position are also discussed in Chapter IV.

A word of caution in interpreting the conflicting views of watershed managers is given by Reigner (1965). He points out that in considering the opposing sides of this controversy, one must be aware of the geographic concerns of those expressing opinions. It seems that water purveyors of the Northeast consider light pollution to be "serious" because many municipalities of that area use little or no treatment. On the other hand, West Coast water is generally given more thorough treatment, including filtration. Those watershed managers, therefore, are not greatly concerned with low-level or nonpoint pollution. Empirical data itself, then, and not its interpretation, perhaps should be given prime consideration in any discussion of recreational impacts on water quality.

The carrying capacity concept

Water quality studies may be undertaken in order to help define the recreational carrying capacity of an area. Stated simply, in the above context carrying capacity refers to the human use level that an area can sustain without unacceptable damage to either the physical resource (water, in this case) or to the recreational experience. Thus, carrying capacity, by definition, is a multidimensional, dynamic, and above all, subjective management strategy.

Lime and Stankey (1971) list three basic components of carrying capacity. These are: 1. Management objectives; 2. Visitor attitudes; and 3. Impacts on physical resources. The concern of water quality surveillance, of course, is with the third component. However, as Lime and Stankey point out, these three considerations are closely interwoven. Therefore, each will be briefly considered.

Management objectives refer to the goals for which the administrators of a recreation area strive. These objectives must describe what type or types of recreational experience is to be provided. Such experiences may fall anywhere along a continuum of environmental modification. Considerations of desires and needs of the public, therefore, are necessary to establish realistic management objectives.

The visitor attitude component concerns the quality of the recreational experience. That is to say, the relation of management objectives to visitor objectives are to be discerned. What the manager deems acceptable or satisfying may not be the same as what the recreationist has perceived (Hendee and Harris, 1970). Of course, management cannot rely solely on visitor opinion to formulate policy. This information, though, can be of great aid in defining what opportunities the public desires. Likewise, it can offer help in predicting how the patronage will respond to future decisions.

Finally, human impact on physical resources is monitored in order to help determine the carrying capacity of a recreational area. Any use of an ecosystem necessarily results in some change in its character. Examples include root exposure, loss of ground cover, destruction of wildlife habitat, and, of concern to this thesis, degradation of water quality. The amount of change that is acceptable is a subjective judgment that comes about through consideration of the other two components of carrying capacity, management objectives and visitor attitudes.

Most studies of recreational impacts on water quality have been concerned with how change affects a utilitarian purpose of the resource. Specifically, the majority of research in this area has been accomplished in order to discover possible hazards to public water supplies. Indeed, Kittrell (1969) states that uses of water constitute the prime reasons for water quality studies. This attitude is rather typical of water supply managers and engineers.

However, the question of how degradation of water quality affects the recreational experience is also valid rationale for study. Unfortunately, there has been little published research in this area. Certainly, standards, beyond which the quality of a recreational experience is degraded, exist. For instance, most states have established coliform standards for body contact activities, such as swimming. Although these standards are usually determined somewhat arbitrarily, health and aesthetics are considered in formulation. Perhaps future research in carrying capacity will define such limits for other types of recreation.

The Federal Water Pollution Control Act

A legal basis for monitoring and controlling recreational impacts on water quality was established when the Federal Water Pollution Control Act (FWPCA) became law (U.S. Congress, 1972). The objective of this legislation, as stated in the Act "... is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The Act further stipulates that by 1983 all waters will support propogation of fish and will be safe for recreational use wherever such goals are attainable.

The FWPCA is seen by Grefarth (1974) as one of the most complicated measures ever passed by Congress. Control of water pollution is delegated not only to the federal government, but to state, local, and private concerns as well. The states are given primary responsibility for control and enforcement of the Act. However, the Environmental Protection Agency (EPA) is the actual administrating agent and the states are required to function within the framework of a national program.

The Act emphasizes control of water pollution at its source. The requirements are rather clearly defined for point sources of contamination (e.g. industrial and sewage treatment plants), but not so for non-point sources (e.g. forestry, recreation). Section (304) of the Act requires that its administrator shall issue to appropriate federal agencies, the states, water pollution control agencies, and other concerned parties information that includes:

1. Guidelines for identifying and evaluating the nature and extent of non-point sources of pollution; and 2. Processes, procedures, and methods to control pollution resulting from such non-point sources as agriculture, silviculture, mining, and construction. (Recreation, however, is not specified in the legislation.) It appears, therefore, that requirements for control of non-point source pollution are left to administrative interpretation. Grefarth (1974) suggests that litigation or additional Congressional action is necessary to clarify the Act in this area.

Nevertheless, if water pollution is to be eliminated at its source, as the Act specifies, then control can only be through modification or elimination of such practices that have resulted in the contamination. For example, states may require stricter specifications for the location and design of outdoor toilet facilities. Similarly, implementation of a recreational rationing system, such as proposed by the Public Land Law Review Commission (1970), may become necessary to ensure that visitor pressure in parks and wilderness areas does not result in degradation of the quality of water resources. Although FWPCA emphasizes control of point source pollution, the Act clearly has implications for recreation planning and management.

CHAPTER III

COMPONENTS OF A WATER QUALITY SURVEILLANCE PROGRAM

In this section some of the characteristics of parameters commonly investigated in a program for analyzing the recreational impacts on water quality are described. Also, the rationale for their inclusion in such a program is given. The particulars of analytical technique, however, are not related. Such information can be found in the American Public Health Association's manual Standard Methods for the Examination of Water and Wastewater (1971).

The listing of parameters that follows is not intended to be complete. Kittrell (1969), for example, would include additional tests for biochemical oxygen demand, alkalinity, hardness, total dissolved solids, conductivity, pH, and temperature. Barton (1969) further suggests sampling for chlorides in a recreational impact survey. The point is, each monitoring scheme will be tailored to the specific location or watershed. Site characteristics, along with details of the types and extent of recreational use, are important factors which will influence the selection of parameters to be investigated.

Bacteriology

Sampling for the presence of bacteria of fecal origin is one of the most important tests in any study of human impacts on water quality (Meiman and

Kunkle, 1967). This analysis (usually of indicators of a pathogen rather than the organism itself) is of special significance to a study of the effects of recreation. The California Department of Public Health (1961) has written "... fecal matter may be deposited or washed into the reservoir wherever recreational activities are permitted." Similarly, Taylor (1964) reports that health hazards to water supplies can result from fecal contamination of recreationists. (See page 4.) Certain bacteria types always accompany such pollution. Glantz and Jacks (1968) have shown that this contamination can be traced to its source using microbial technique.

It is axiomatically assumed nowadays that pathogens of fecal origin can transmit disease. Indeed, Diesch (1970) has found that pathogens from wastes of domestic animals can cause disease in man via a water transmission medium. Such illnesses typically include dysentery, typhoid fever, cholera, gastroenteritis, and, less frequently, tuberculosis, brucellosis, tularemia, and leptospirosis (McKee and Wolf, 1971).

A usual sampling program includes tests for the detection of coliforms and fecal streptocci bacteria.

Coliforms. McKee and Wolf (1971) claim that coliform tests are the most practical analysis for indicating the presence of pathogenic bacteria. Unfortunately, coliform occurrence may not always indicate fecal pollution because the sources of this bacteria are diverse. For instance, the *Escherichia coli* strains are considered to be generally of fecal origin, while

Aerobacter aerogenes strains are usually thought to arise from a soil or plant source. Specific tests to identify the strains present are sometimes performed. The complexity involved, however, may prohibit such analysis from being undertaken routinely.

As a group, coliforms are harmless. Their presence in water, though, is an indication that pathogenic bacteria may also be found. For example, research by Kittrell and Furfari (1963) has shown that bacteria of the genus Salmonella, organisms responsible for causing typhoid and paratyphoid fever, occur along with coliforms. Unfortunately, the correlation between coliform levels and Salmonella may be rather small (Gallager and Spino, 1968). It is generally assumed, however, that any coliform presence signifies unsafe water.

The distance that coliforms can travel underground, as from a pit toilet, is highly site dependent. The magnitude of variation has been reported by Subrahmanyan and Bhaskaran (1950) to range from 1-232 feet. Factors that influence this subterranean movement are velocity of ground water flow, soil structure, and water table gradient (McKee and Wolf, 1971). These elements should be, but sometimes are not, considered in location of a recreational area's sanitary facilities.

Four factors which influence the survival of coliforms in water have been listed by Kittrell and Furfari (1963). They are as follows:

1. Stream size. The coliform die-off rate is higher in small streams.

2. pH. A value of 7.0 has been found to be optimal.

3. Sediment. Coliforms tend to be absorbed on suspended particles thereby increasing the die-off rate as the sediment settles.

4. Nutrient content. This influence is unclear. It seems to be a general rule, however, that waters of high nutrient content harbor large coliform populations.

Knowledge of these factors is essential in predicting how water quality is affected by a recreational activity or development.

A coliform sampling program is typically subdivided into two aspects. Specifically, these are total coliform (TC) tests in which all coliform organisms are measured and fecal coliform (FC) tests in which only those bacteria originating in animal wastes are counted. Because FC's come only from fecal matter of warm blooded animals, Geldrich (1970) and Kunkle (1970) have both claimed that they are better indicators of pollution than TC's. In fact, in the Kunkle (1970) study, an analysis of bacteria in agriculture runoff, it was found that TC's were abundant in roughly equal numbers below grazed and ungrazed areas. Fecal coliforms, on the other hand, were present in numbers significantly different between the two sites. Other studies (e.g. Johnson, 1975) have determined that TC's are better reflectors of land use impacts than FC's. It therefore seems reasonable that in order to obtain a valid indication of the effect of some activity on water quality both TC and FC tests should be included in the sampling program.

Fecal streptocci. This group of bacteria is native to the gut of warm blooded animals. Geldrich (1970) has pointed out that one advantage of using this group to test for fecal contamination is that they have a high tolerance to unfavorable stream conditions. Bartley and Slanetz (1960) even go so far as to state "... tests for fecal streptocci are more practical, efficient, and accurate than the coliform tests for evaluating almost all types of water."

The source of this organism, whether animal or human, can be fairly readily discerned, further increasing the value of using it as an analytical tool. Cooper and Ramadan (1955) suggest that this can be done through techniques that differentiate between the s. faecalis strain which comes from man and the s. bovis that originates in animals. Unfortunately, the method involved is probably too complex to be employed on a routine basis.

However, a much simpler technique to detect the origin of fecal contamination has been proposed by Geldrich and Kenner (1969). The method involves computing a ratio of numbers of fecal coliforms to numbers of fecal streptocci (FS). Their rationale is based on the fact that FC's come mainly from humans while FS's are contributed mostly by animals. Therefore, they suggest that if the FC/FS ratio is greater than 4.0 the pollution is likely to have resulted from human fecal contamination. A ratio of less than 0.7, however, is indicative of animal contamination. And finally, if the ratio value falls between the two figures the source is said to be indeterminate. For this scheme to be valid, Geldrich and Kenner state that the water must be obtained within 24 hours of fecal input because of the rapid FS die-off rate. This is the only restriction of a technique that can be of invaluable aid to the land manager in ferreting out the source of water pollution in a rural or wildland situation.

Nutrients

Mackenthum, Ingram and Parges (1964) report that nitrogen and phosphorus are the nutrients chiefly responsible for the fertilization of surface waters. In many cases, natural sources, such as through sedimentation, contribute the largest source of nutrients (Barton, 1969). However, prolific algal growths resulting from man-associated nitrogen and phosphorus have been documented by Hall and Sproul (1971).

Nitrogen and phosphorus occur naturally in water due to leaching of minerals in the process of degradation. However, they are seldom abundant because of rapid plant uptake and conversion into cell structures through photosynthetic action. On the other hand, animal wastes, according to McCarty (1967), likewise can be a nutrient source.

Laboratory analysis of the presence of nutrients normally consists of tests for orthophosphate, total phosphorus, nitrate (NO_3-N), and nitrite (NO_2-N). Ammonia (NH_3-N), too, has been shown to be characteristic of fecal pollution (Miner et al., 1966) and should also be examined.

A special hazard of excess nitrate concentration in drinking water is its effect in causing infant methemoglobenemia. This serious and sometimes fatal disease results in specific blood changes and cyanosis in very young children. As a preventative measure, the United States Public Health Association (U. S. Department of Health, Education, and Welfare, 1962) recommends that not more than 45mg/1 be allowed in drinking water.

Excessive nutrient content in water results in other problems as well. If the enrichment is such that algal growth imparts a "pea soup" appearance to the water degradation of aesthetics obviously results. Further, as this plant material dies and begins decomposition foul odors are exuded. In an extreme case reported by Borchardt (1969) enough of the odiferous hydrogen sulfide was produced to discolor the paint on lakeside dwellings. Still another complication of this plant decomposition stems from an increased demand on the water's dissolved oxygen (DO) content. A lowered DO then can have an insidious effect on the balance of the indigenous fish population. Since game fish (e.g. trout, bass) generally require more dissolved oxygen than do "rough" fish (e.g. carp, suckers) Hall and Sproul (1971) suggest that plant decomposition can cause the fishery to shift toward favoring the production of the undesirable species.

Barton (1969) states that as related to recreation, "... greater emphasis must be accorded to nutrients, the aquatic growths they produce, and the consequent impacts on aesthetic qualities." He further suggests that special standards should be developed and enforced in wilderness areas if man is to keep his impact in those places minimal.

Turbidity

Turbidity refers to the clarity or light penetration properties of water. Characteristically, it is the result of the presence of microorganisms, organic detritus, silica and other minerals, sewage or industrial wastes, and silt or clay from erosion (McKee and Wolf, 1971). According to Brown (1974), the mechanical compaction of the soil surface by animals (presumably to include man) can result in extreme erosion rates which, of course, are instrumental in reducing the clarity of naturally occurring water. Such may very well be the consequence of intense recreational use.

McKee and Wolf (1971) state that effects of turbidity include aesthetic deterioration, taste problems, a decrease in primary photosynthetic production because of shallower light penetration, and possible toxic effects at high concentrations. It is therefore of prime importance to the recreational manager to see that turbidity levels are kept minimal.

Proper land treatment and shoreline stabilization are seen by Barton (1969) as necessary steps to keep down sediment input in recreational waters. Such preventative measures can impede the deterioration of shorelines in areas that receive heavy human use. An extreme example of the expansion of a lake's perimeter because of recreational impact is related by Barton (1969). He reports that the shoreline of Minnesota's Lake Winnibigoshish is receding some 40 feet per year in places. Fortunately, he notes, the soils in that location are rather infertile. If the opposite were the case nutrient enrichment problems might occur concomitantly with sediment complications. When this takes place only the most drastic measures can restore a lake's recreational attraction.

Oil

Oil contamination, as related to recreation, results from the exhaust discharges of outboard motors. The obvious environmental consequences of such pollution is the degradation of the visual properties of a lake or stream. Other problems, however, may be consequent. These include increases in oxygen demand, production of noxious odors, and harmful effects on fish and other aquatic life.

Increased oxygen demand is an outcome of the natural purification process of oil oxidation. Approximately 3.3 grams of oxygen are required to completely oxidize 1 gram of oil (Barton, 1969). Such a high demand can affect aquatic life in the same manner as that resulting from excess nutrient enrichment (see page 17).

Oil can also have a direct effect on fish life. Shelford (1917) showed that fish growth and reproduction are decreased in the presence of oil. Similarly, English, McDermott, and Henderson (1963) report that when the usage of motor fuel on a body of water reaches the level of 8 gallons per million gallons of lake water a tainting of fish flesh occurs.

Oil pollution degrades aesthetics not only through its effect on visual qualities, but by production of foul odors as well. English, McDermott, and

Henderson (1963) have proposed that the threshold of odor creation is reached when the usage level of 1 gallon of fuel per million gallons of water is attained. However, he asserts that the smell is not "objectionable" until the usage level of 3 gallons per million is achieved. These conditions have already been met in some places and are described in Chapter IV.

Lead

Lead contamination of waterways is possible through its deposition in the exhaust of gasoline powered recreational vehicles such as motorboats and snowmobiles. The effects of lead are well known. Kidney, liver, and brain damage, plus central nervous and reproductive system deterioration are possible consequences of man's ingestion of large quantities of this substance. Similar effects have been noted in other animals as well (Ferrin, 1974).

Jones (1938) has demonstrated that lead salts are quite toxic to fish in soft water with lead concentrations of 100-400 parts per billion (ppb). In harder water no visible effects on fish were noted. This finding he attributes to the precipitation of lead in highly mineralized water.

Lead poisoning has also taken its toll of waterfowl. Kortwright (1942) writes that because of the bird's uptake of lead shot from pond bottoms "... lead poisoning ... is proving to be a factor of considerable importance in the decline of our waterfowl." Presumably, lead deposition from gasoline powered vehicles can produce similar consequences.

Lead, of course, is taken up by organisms other than fish and waterfowl. Gale et al. (1973) surveyed stream organisms (e.g. algae, snails, crayfish) below areas of lead mining activity in Missouri for contents of this and other heavy metals. They found that the stream's plants and animals near the mine tailings contained high lead contents. This amount decreased directly as distance from the source of contamination increased. Lead pollution, therefore, was shown to pervade all aspects of the biota of the aquatic ecosystem.

Biological sampling

For the detection of non-point sources of pollution this technique is employed probably much less frequently than analysis of the preceding parameters. Barton (1969), however, recommends that biological sampling should be a part of a system for monitoring recreational impacts on water quality. The ultimate purpose of biological sampling is to predict the response of native populations of aquatic organisms to specific changes within the natural environment (Weber, 1973).

The rationale behind sampling for biological activity is that unpolluted streams normally support a large variety of aquatic organisms with relatively few of any one kind. Therefore, a change in this balance may be a good indication that toxic contamination has occurred. For purposes of analysis any biological group may be used--fish, algae, plankton, bottom dwellers, etc. However, the latter group, the bottom dwellers (benthos), is the biological component normally analyzed (Kittrell, 1969). Both qualitative and quantitative measurements are made to investigate the state of the ecological balance.

Attempts to judge effects on a single or a few species have not been successful. Rather, many species should be given consideration. According to Kittrell (1969), the best indicators are larval stages of stoneflies, mayflies, caddis flies, and riffle beetles. Less sensitive are scuds, sowbugs, certain snails, and larvae of blackflies, horseflies, and certain midges. Most pollution tolerant are sludgeworms and bloodworms.

Reaction to moderate organic pollution may create some reduction in the numbers of organisms most sensitive to this effect. A corresponding increase in populations of more tolerant ones will follow. In an extreme case of organic pollution, all the sensitive organisms can be obliterated. The result is that large numbers of one or two kinds of very tolerant life forms remain.

Biological sampling may also reveal silt pollution. When this has occurred the settled sediment has covered the bottom and smothered life there. Reductions in numbers of sensitive organisms follows along with build-ups of the tolerant ones.

Kittrell (1969) cautions that the type of stream bottom must be considered in interpretation of biological data. He notes that a scarcity of benthos may not be indicative of pollution in the stream if the bottom consists of shifting sands. This is because instability and scouring action leave little area for attachment of these animals. Conversely, deposited silt provides a suitable habitat for burrowing insect larvae. Kittrell maintains that hard clay bottoms are most unsuitable for animal life while rubble bottoms appear to be the best.

CHAPTER IV

CONTRIBUTIONS OF VARIOUS RECREATIONAL ACTIVITIES TO WATER POLLUTION

Information concerning effects of different types of recreation in causing water pollution is somewhat limited. Nonetheless, several researchers have discussed this topic, although in many cases their conclusions are based on subjective judgments and not on quantifiable data. This chapter reviews the findings of such research with respect to seven recreational activities.

As stated previously, it is both the type and the extent of recreation that determine its impact. Clearly, after a certain level of use the most innocuous activities can threaten the integrity of an ecosystem. By the same token, though, harmful activities can inflict negligible impact if lightly practiced. Therefore, caution should be employed in interpreting conclusions reached without considerations of intensity or amount of use.

Camping, picnicking, and hiking

The pollution hazards of camping and the related activities picnicking and hiking have been discussed probably more than those of any other type of recreation. (For example, see Reil, 1956; Taylor, 1964; Reigner, 1965; Barton, 1969; Hall and Sproul, 1971; and Johnson, 1975.) Concerning the effects of these activities, Hall and Sproul have written:

> Picnicking and camping and the use of the water tends to contribute organic and inorganic wastes, pathogenic organisms, toxic and odor producing substances, and just plain trash to the environment of recreational areas.

Certainly many variables are involved in determing the seriousness of pollution due to camping. Factors to consider, therefore, obviously include intensity of use, method of sanitary disposal, proximity to water bodies, and terrain (especially soil type).

Barton (1969) has recounted the special problems of wilderness camping. Disposal of sanitary wastes in these areas pose unusual problems due to the lack of roads and energy sources. Consequently, servicing of disposal systems is a difficult task. Pit toilets, installed in such a manner as to prevent contamination of nearby waters, seem to be the logical method of sanitation in remote areas. However, when the physiography of an area renders the pit toilet inadequate, Barton proposes using a non-effluent system, such as the combustion toilet, or exporting waste materials to a proper treatment facility. Some locales, in fact, are said by Barton to be evaluating the use of helicopters or airplanes as "flying honeywagons."

Solid wastes, too, pose special disposal problems in wilderness areas. The decomposition of these materials, Barton claims, may contribute an abundance of trace elements and major ions to the water. Landfills, if available, are not an answer to this problem. They merely delay the entrance of the articles into the water. Here again, exportation of the material seems to be the only solution to a potentially serious problem.

Hunting

Hunting per se probably has no more effect on water quality than hiking or even bird watching. Karalekas and Lynch (1965) have reported that hunting allowed on the watershed of the Springfield, Massachusetts, water supply does not appear to be a source of trouble. However, other writers have referred to special problems that hunting can impose on water resources. Reigner (1965), for example, is concerned that hunters can greatly add to erosion and sediment problems through their use of off-road vehicles. And another writer, Peloquin (1965), proposes that health hazards can result from the hunter leaving offal and dead game near water bodies. Peloquin writes that he actually observed such a situation on the banks of the Merrimack River close to the intake of the water supply of Lowell, Massachusetts. Generally, however, the problems associated with hunting are subsumed under those described in the preceding section on camping and related activities.

Fishing

As a leisure pursuit, fishing is one of the most popular. Indeed, the report of the National Industrial Pollution Control Council (1971) states that there are 50.6 million fishermen in the United States--a figure representing just under 25 percent of the population. Stroud (1963) reports that at least 93 percent of the nation's water supply reservoirs are open to public fishing. It is a fallacy, however, to interpret this fact to be an indication that this activity is not a potential contributor to water pollution. The evidence is conflicting.

Graham (1957) is of the opinion that fishing on public water supplies poses no hazards. To support his position he states that engineers in charge of the Catskill Mountain watersheds have found no correlation between numbers of fishermen and levels of coliform bacteria. Indeed, John Aalto, a Catskill engineer, is reported by Graham to have stated: "Fishing on our reservoirs causes no sanitary or water contamination problems." Similarly, Toole (1965) writes that fishing on Massachusetts' Quabbin Reservour has not polluted the water.

Evidence to the contrary, however, is provided by Karalekas and Lynch (1965) and by Minkus (1965). Karalekas and Lynch report that the coliform counts of the Springfield, Massachusetts, reservoir (see page 37) increased following allowance of fishing and boating. Later, when fishing privileges were rescinded, the water quality did in fact show a marked improvement. The Minkus study similarly revealed rising coliform counts after the permission was given for fishing on the Hartford water supply reservoir (see page 38).

It therefore appears that no general conclusions as to the effects of fishing can be made. The high percentage of water supply reservoirs that allow this activity probably reflects more of the power of individuals and special interest groups in influencing public policy than it does an endorsement by water managers of the harmlessness of this recreational pursuit.

Boating

The hazards of man-powered or electric propelled boating are most likely the same as those mentioned previously for fishing. However, gasoline powered craft, through their discharge of lead and other heavy metals and oils from the engine's exhaust, pose much greater pollution problems.

Such contamination, unfortunately, is a natural consequence of the use of 2-cycle outboard engines. These motors are usually employed for boat propulsion because of their lighter weight per horsepower output than the more conventional, and less polluting, 4-cycle models. Such gains, nevertheless, are offset by the 2-cycle's much higher rate of fuel consumption and its production of copious amounts of noxious fumes. Indeed, Schuster (1971) found that anywhere from less than 10 percent to greater than 50 percent of the fuel of a 2-cycle engine is directly wasted through exhaust discharge.

According to Muratori (1968), in 1966 there were approximately 6.7 million 2-cycle outboard engines in use in the United States. Further, the Federal Water Pollution Control Administration (1968) reports that in 1967 some 40 million persons went out in boats at least two times. Such heavy usage undoubtedly has had untold impact on water and shoreline environments. Stewart and Howard (1968), in fact, make the point that while catastrophic oil tanker disasters make newspaper headlines, everyday pollution from outboard motor use does not. Such seeming lack of concern of the environmental consequences of motor boating is given an explanation by Muratori (1968).

He proposes that because the churning action of the propeller homogenizes the exhaust fumes into the water and delays their arisal for a distance 50 feet or more astern, the boat operators themselves are unaware of any problem.

As mentioned before, the discharges of a 2-cycle engine are laden with unburned fuels. English, McDermott, and Henderson (1963) report that 105 grams of oil and 57 grams of gasoline are expelled for every gallon of fuel that an outboard motor consumes. Also, he finds that 80 percent of the non-volatile substances (lubricating oils) are removed by coagulation, filtration, and sedimentation while none of the volatile ones are cleansed from the water through natural processes.

The amount of petroleum products thus expulsed into the nation's lakes and streams is indeed high. Muratori (1968) calculates that if each 2-cycle outboard engine wastes only 10 percent of its fuel, then more than 100 million gallons per year end up as scum on the United States waters. Such a quantity of fuel represents an amount many times greater than that discharged in the infamous Torry Canyon tanker disaster of 1968.

Oil pollution from outboard motors may work indirectly to decrease the clarity of a lake's waters. Stewart and Howard (1968) propose that the turbidity increases of lower Lake George, New York, observed in the last several years may be due to oxygen deficiencies that stem from oil discharges. It seems that contaminants are not being naturally degraded because of a deficit of available oxygen. As much as three-quarters of the dissolved oxygen, in fact, is said by Stewart and Howard to be required to oxidize the oil. In this manner, problems due to the presence of suspended matter (see page 18) may very soon become evident in parts of that lake.

Odor production from oil discharges is yet another complication resulting from heavy outboard motor use in Lake George. Threshold odor levels are reported by Stewart and Howard to already have been reached in some areas. The authors further predict that if present trends continue the "objectionable" stage will be reached by 1976 thereby imparting a semi-permanent foul odor to the water. Such a fate, presumably, may be in store for other intensely used recreational lakes as well.

An obvious practical solution to the biological and aesthetic problems posed by outboard motor use is installation of pollution control devices similar to those required on automobiles. Certain manufacturers, most of which have resisted such proposals in the past, have indeed begun to incorporate new designs that eliminate these problems. Thus, new motors use a much reduced oil/gas ratio, they have greatly improved gas mileage, and these engines no longer discharge fuel through their exhausts. The lead expulsion problem, too, is eliminated by use of lead free gasoline. Of course, it will be many years before these new motors are present in numbers sufficient to reduce pollution impacts. In the meantime, Muratori (1968) proposes that small and average size lakes must be closed to outboard use wherever problems are eminent. Regardless of the distaste that many boat owners undoubtedly will feel toward this suggestion, it appears to be a necessary step to save much of the nation's dwindling water resources from the fate of Lake George.

Snowmobiles

This activity is included because of its phenomenal growth and popularity in the face of a dearth of knowledge of its environmental impact. Indeed, a literature search revealed a total lack of information regarding the consequences of snowmobiling on water quality. Nevertheless, general conclusions based on related research will be suggested.

It is estimated that today there are 2 million registered over-snow vehicles in the United States and Canada and that there are many more that are not registered (Doherty, 1974). Ferrin (1974) states that snowmobiling is only one facet of the "amazing growth" of winter sports in the United States. Further, he hypothesizes that the mechanized orientation of society in the U. S. is the primary factor responsible for its notable expansion as a recreational endeavor.

Ferrin (1974) measured lead deposited by these vehicles in the snowpack and has alluded to the possibility of this toxic metal finding its way into nearby streams during runoff periods. In his study, he simulated light, medium, and heavy snowmobile use by making a predetermined number of passes per week over marked trails. Specific sampling sites were established both beside and below the path to detect lateral and vertical movement, respectively, of the contaminant. There was also a control area (no snowmobile passes) which was sampled regularly to obtain baseline data.

His results showed conclusively that snowmobiling does result in lead accumulation both beside and below the machine's path. In fact, the amount of the metal detected increased logarithmically as intensity of use went up. Ferrin also points out that on all treated areas the quantity of lead detected exceeds the United States Public Health Association 50ppb drinking water standard. Control areas, meantime, averaged a safe 29ppb lead content.

To predict that this metal definitely will enter local waterways perhaps is nothing more than speculation. Nevertheless, studies by Krueger (1972) and by La Barre, Milne, and Oliver (1973) lend credence to such conjecture. Krueger measured runoff from snowbanks alongside a street in Cambridge, Massachusetts, and recorded an average lead concentration in the water of 3.9 parts per million (ppm). The similar study by La Barre et al. found that there was an average of .11 ppm lead content in the melt water of Ottawa, Canada's, snowdumps.

Further supportive of the possibility of lead passing from the snow into runoff are the findings of Gerdel (1954). He has demonstrated that when snow-pack contains horizontal ice bands (layers) contaminated melt water can be directly funneled into a receiving body of water. Here, again, the potential for snowmobile impact on water quality is evident. Obviously, there is a need for more research in this area.

Swimming

Evidence concerning the effect of swimming on water quality is inconclusive. Certainly there is a surfeit of factors to consider before submitting generalizations of its contributions to water pollution.

Minkus (1965) reports that the amount of contamination is much greater in Hartford, Connecticut's, Compensating reservoir, which is used for swimming, boating, and fishing, than in the city's water supply reservoir that is closed to recreation. However, he does not differentiate between these activities as to source of contamination. Rosebery (1964), in his study of recreational impacts on Forrest Lake, Missouri, (see page 45) took samples at a depth of 20 feet just off the public swimming beach. He found the pollution to be consistently low, although it was variable by depth and time. Finally, the California Department of Public Health (1961) found that for the high use area of Folsom Reservoir the median most probable numbers of total coliforms, fecal coliforms, and fecal streptocci for uncontrolled swimming were equal to or higher than those for picnicking, shore fishing, boat launching, or supervised swimming. These studies seem to indicate, therefore, that only the most intensive swimming activity poses a real threat to water quality. Even so, the contributions are highly site dependent.

Summer homes

The National Industrial Pollution Control Council (1971) states that waterways are the location of a majority of the more than 1.5 million vacation homes currently in existence. Riehl (1956) writes that the allowance of recreational privileges on municipal water supply reservoirs might bring a demand for cottage sites. This, he contends, should not be tolerated because of the "greater pollutional load" concomitant with such development. This contamination seems to arise from two sources--the use of the home as a base for water oriented activities and through potential inadequacies of sanitary disposal systems.

Hall and Sproul (1971) have discussed the hazards of the latter problem. Specifically, they are concerned that the improper location of septic tank drainfields with respect to water bodies can lead to viral and nutrient contamination. It seems that this facility is normally installed with specifications that are based on the prevention of bacterial leakage into proximal waters. However, they have found that viruses and plant nutrients can move farther through the soil than bacteria. Hence, present standards for the location of septic tank drainfields may actually offer only token protection to water quality.

Hasler and Ingersoll (1968) are concerned with the nutrient input consequent to summer home development. They have reported that Cochran Lake of northern Wisconsin has deteriorated so badly since the first cottages were built on its shores that the lake now resembles a "300 acre caldron of pea soup." This may be an extreme example, but it nonetheless vividly portrays the hazards of uncontrolled shoreline development.

CHAPTER V

REVIEW OF PREVIOUS RECREATIONAL IMPACT STUDIES

Several full scale studies have been undertaken in the past to detect effects of recreation on water quality. Although most research has indeed found that recreation alters the state of naturally occurring water, the conclusions reached as to the seriousness of such impact are highly diverse. Of the summaries of eight studies that follow, four have found impacts to be significant and four have determined that the consequences are negligible or nonexistent.

Boundary Waters Canoe Area study

Arnett Mace, an hydrologist, and two assistants in the summer of 1970 conducted a water quality survey of nine campsites and control areas within the Boundary Water Canoe Area (BWCA) of northern Minnesota. At sample points (canoe landings) and controls (usually similar water edge areas about 200 feet from campsites) water samples were taken for measurement of temperature, specific conductivity, turbidity, hydrogen ion concentration, dissolved oxygen, nitrites, nitrates, total Kjeldahl nitrogen, total phosphate, and coliform bacteria. The data were then related to use levels.

Their findings, as reported by King (1971), revealed that coliform populations in the water near campsites were significantly higher than they were at the control points. This discovery was particularly pronounced at the medium to high use sites in the Moose Lake chain as shown below.

Table 1. Coliform populations for the various use classes of campsites.

Location	Use Categories		
	High[a]	Medium	Low
Campsite	4.61[b]	6.63	5.83
Control	0.28	1.95	4.68
Difference	4.33	4.68	1.15

[a]High use sites, located on the Moose Lake chain, received over 1100 visitor days total use. Medium use sites were on the Moose Lake chain and Lake Isabella and had over 500 visitor days total use. Low use sites were on Lake Isabella and Isabella River with under 300 days total use.

[b]Figures represent numbers of coliform/100 milliliter water.

Source: Merriam et al., 1973, p. 24.

A statistical analysis of variance of this data showed that the differences in bacteria populations between campsites and controls were highly significant.

As shown in Table 1, the different coliform populations of campsites and controls is much greater for high and medium use areas than for low use areas. This leads to the hypothesis that recreational camping in the BWCA affects the population of fecal bacteria near the areas of use. Further, the degree of influence seems to depend on the number of people who stay at the location.

This research also found that recreation resulted in higher phosphate concentration and increased turbidity levels in the vicinity of the campsites. However, other parameters (listed on page 35) were not found to be affected by human use.

Merriam and Smith (1974) in writing of this study have concluded that the findings indicate that the total effect on the lakes is generally small. Nevertheless, they point out that oligotrophic lakes such as those of the BWCA may require control of site usage in order to maintain overall water quality. Inadequate sanitary facilities, they suggest, is the root cause of the problems in this popular recreational area.

Springfield, Massachusetts, study

In 1965 two water supply reservoirs near Springfield, Massachusetts, were surveyed in order to determine what changes, if any, in water quality could be attributed to a previous rescension of fishing privileges on these lakes.

The first reservoir, Ludlow, had been opened to fishing in 1948. Approximately 15,000 persons per year had used the impoundment for such purpose. However, problems such as littering, illegal fire building, swimming, vandalism, and even personal abuse of supervisory employees had forced the Springfield Board of Water Commissioners to close the reservoir to further fishing activity. The results of the study seem to justify the action of the board. Karalekas and Lynch (1965) report that a very definite drop in coliform populations followed almost immediately after the rescension went into effect. This data is summarized in Figure 1, page 39.

The other reservoir studied, Cobble Mountain, corroborated the findings at Ludlow. Opened to fishing in 1950, the privilege was banned due to problems stemming from recreational use. As shown by Figure 2, page 40, it was revealed that the lake harbored higher densities of coliform bacteria during the years that it was opened to fishing than the time either preceding or following the ban. Again, the evidence lent justification to rescension of recreational privileges on the grounds of harm to a public water supply.

Hartford, Connecticut, study

The Water Bureau of the Hartford, Connecticut, Metropolitan District conducted a water quality study to compare bacteria populations between two reservoirs, one closed to recreation and one open to such use. According to Minkus (1965), the purpose in performing this research was to test the contention that recreational use of public water supply leads to serious water quality degradation.

The closed reservoir, Barkhamstead, had absolutely no recreation allowed on its waters or surrounding lands. In fact, the area was completely fenced to prohibit human entry. The other reservoir, Compensating, had extensive boating, fishing, and swimming use.

Results of the study indicated that Barkhamstead Reservoir had uniformly low most probable numbers (MPN) of coliform bacteria throughout the year.

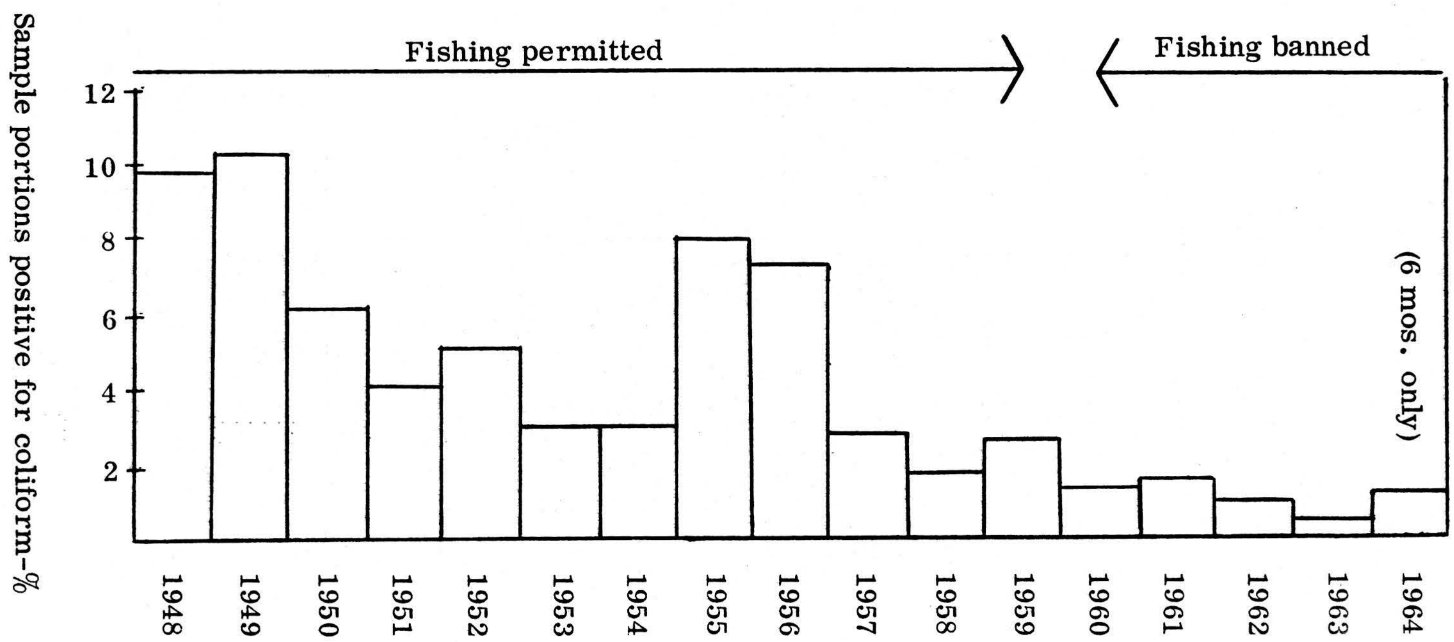

Figure 1. Results of coliform sampling, Ludlow Reservoir, Springfield, Massachusetts.

Source: Carswell, Symons, and Robeck, 1969, p. 300.

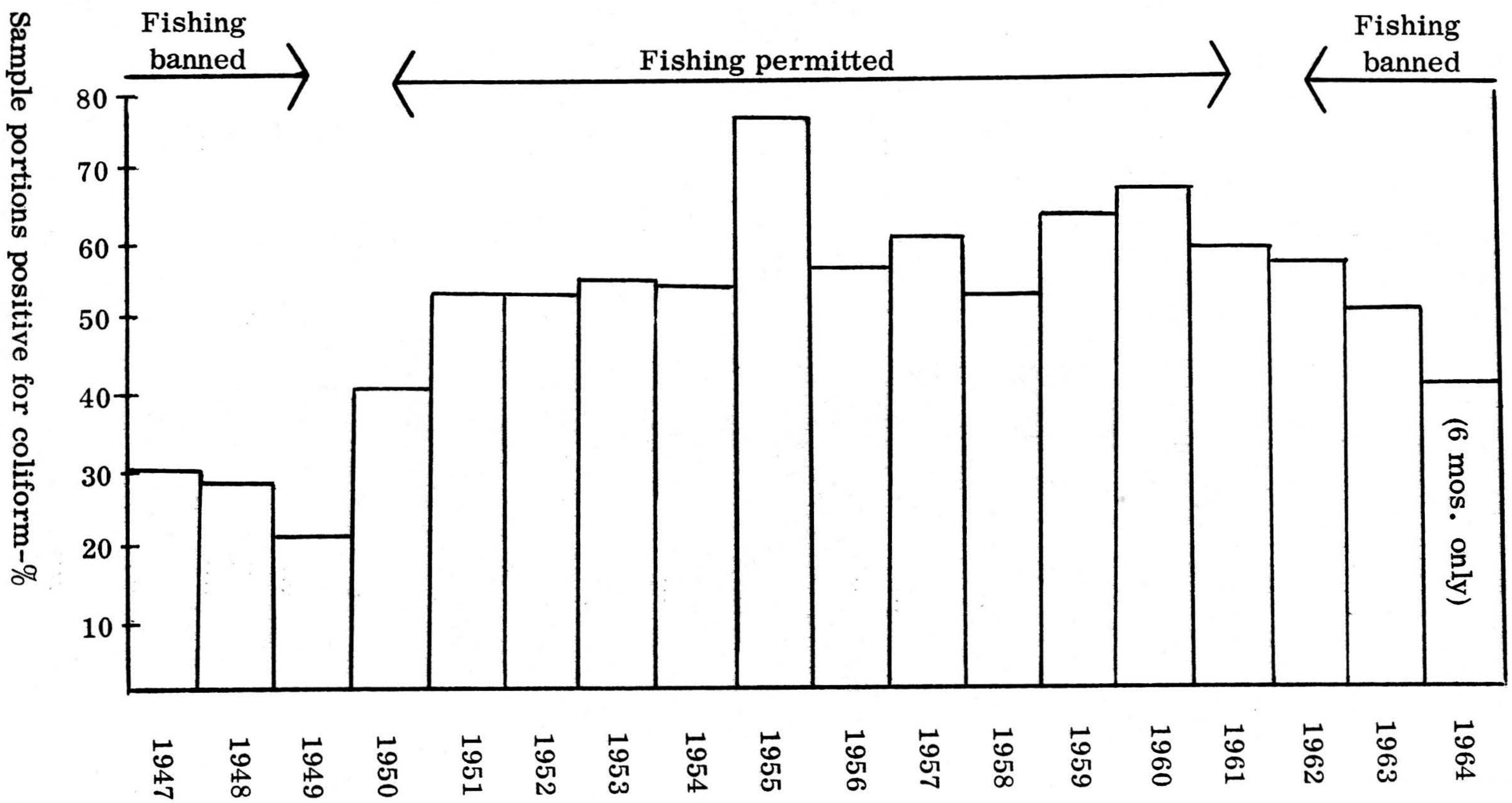

Figure 2. Results of coliform sampling, Cobble Mountain Reservoir, Springfield, Massachusetts.

Source: Carswell, Symons, and Robeck, 1969, p. 301.

Conversely, Compensating Reservoir showed much higher counts during the summer with the initial increase coinciding with the start of the April fishing season. Once more, a public water supply agency has shown that recreation degrades the nature of its product.

South Fork of the Ogden River,
Utah, study

A recent study was conducted on the South Fork of the Ogden River (Johnson, 1975). This stream, located in the mountains just east of Ogden, Utah, was chosen for research because of its heavy recreational use orientation and because of the little amount of water quality data available for the river. The purposes for undertaking this study were fourfold. Johnson wanted to: 1. Investigate recreational impacts on the watershed; 2. Determine sources of possible pollution; 3. Postulate a correlation between recreational use and changes in water quality; and 4. Collect data that could be useful to planners and administrators for managing present and future recreational use and development.

Thirteen sampling stations were established along the river and its principal tributary, Beaver Creek. These sites were chosen with respect to land use activities so that water quality data would indicate pollutional impact. The stations, therefore, were located proximate to campgrounds, picnic areas, public parks, summer homes, private camps, and, for purposes of comparison, agriculture and grazing activities. Actual sampling took place between February and November, 1974, with water taken weekly before and after the summer recreation season (mid-May through Labor Day) and twice a week during that time. Laboratory analysis included extensive tests for bacteriological, chemical, and physical parameters.

Johnson also conducted several automobile surveys during the summer season to detect recreation use patterns. These inquiries revealed that fully 93 percent of weekend users participated in some form of water based activity. During weekdays this figure dropped to 84.5 percent. The most popular weekend pursuit was found to be picnicking (47 percent), while during the week camping (36 percent) was determined to be the most sought activity. Also, Johnson found from the survey that short term weekend use contributed much more to overall intensity of use than did long term weekday use.

Data analysis indicated that bacteriological parameters proved to be the best reflectors of land use patterns along the river. In fact, the bacteriological examinations revealed that recreational use was the prime contributor to water pollution during the heavy use summer months. The other parameters were determined to be of little utility as indicators of land use impact.

Total coliform counts were found to be good reflectors of the intensity of the use of a recreational site. Specifically, Johnson calculated that during the heavy use period 71 percent of the samples that were to reflect recreation activity had higher TC counts on Monday than on Thursday of the same week. Similar comparisons from stations representing agriculture and grazing activity showed only 44 percent with higher counts. Analysis of fecal coliform and fecal streptoccus did not reveal this pattern. However, FC's were determined to be the best bacteriological indicator of seasonal recreation impact.

Interestingly, Johnson ascertained that the correlation between bacterial contamination and visitor use was much stronger for the total number of visits rather than for the length of visitation. That is, he found that high intensity, short duration weekend use had greater impact on water quality than did fewer, long term weekday visits. A possible explanation offered by Johnson is that the short term visitors use toilet facilities more frequently and/or that they concern themselves less with taking care of recreation facilities than long term visitors. This finding, apparently, has never been corroborated in any other research of this nature.

It was concluded by this study that recreation definitely can contribute to water quality degradation. On the Ogden River's South Fork, however, Johnson sees no immediate health hazard. He suggests a management goal should be to use water quality data, along with other information, to determine a recreation carrying capacity for this area. Currently, the carrying capacity is seen as being limited by the facilities available and not by impacts on the quality of the water. Nonetheless, Johnson cautions that if more visitations occur without updating and modernizing the facilities, the carrying capacity could be surpassed in the not too distant future. Johnson states that managers and planners must be aware of water quality problems and strive to keep such impact minimal.

Washington State Department of Health study

The Washington State Department of Health in 1965 asked the United States Public Health Service to undertake a study to determine what effect recreation activities have on watersheds of protected areas. The rationale for the study was to obtain data that would help the department respond to public pressure to open these places to recreational use.

Three watersheds, all similar in terrain, elevation, climate, and animal populations, but differing in human use, were chosen for analysis. The three were: Cedar River, Washington, a closed watershed; Green River, Washington, open to limited recreation; and Clackamas River, Oregon, a watershed with unrestricted human use. Objectives of the study included the demonstration of the influence of increasing human use on the three watersheds and the determination of the quality of water flowing from a protected area.

Samples from stations set up along each river were taken either once or twice weekly during the study period, 1965-1967. Laboratory analysis encompassed tests for enteric human bacteria and viruses as well as extensive examinations of physical and chemical parameters. A computer program designed by the United States Forest Service (James and Ripley, 1963) used in conjunction with traffic counter data estimated the human use of each area. Also, animal populations were considered in the study. This information was provided by the respective state wildlife agencies.

The results, as summarized by Lee, Symons, and Robeck (1970), revealed that increases in the human populations on the Cedar (0.7 man-days/square mile maximum), Green (1.4 man-days/square mile maximum), and Clackamas (5.7 man-days/square mile maximum) were insufficient to produce an influence on water quality that was measureable. Because of high animal populations on all three watersheds the authors concluded that the low bacteria counts could be attributed to that influence. Enteric pathogens were found at the most downstream stations on all three rivers. Curiously, the number of samples determined to have positive pathogenic enterobacteriacae was nearly three times greater on the closed watershed than on the open one. This finding seemingly gives credulence to the authors' contention that the pollution is not of human origin. No viruses were detected in any sample.

Lee, Symons, and Robeck conclude by implying that this data does not necessarily indicate that human use has no effect on bacterial populations. Rather, they assert that by present technique no influence on indicator densities could be determined. They suggest that more sensitive detection methods be developed in order to better show changes in water quality due to human use.

Forrest Lake, Missouri, study

Forrest Lake, a 702 acre impoundment near Kirksville, Missouri, was surveyed from June, 1958, through May, 1960, in order to determine what effect recreational use has on water quality. This lake, surrounded by Thousand Hills State Park, receives heavy recreational use--over 300,000 people visited the park during the study period. Recreational activities in order of importance were found to be sightseeing, picnicking, swimming, fishing, motorboating, camping, and water skiing. Water samples, taken weekly at a depth of 10 feet, were reflective of high and low intensity use areas.

Rosebery (1964) reports that both total coliform and fecal streptoccus densities increased with depth. Further, he found that the area of highest recreation activity showed in the summer highest TC and FS densities (although such a trend was not evident in the other seasons). His conclusion drawn from this study was that at present coliform and streptoccus levels water quality degradation is negligible.

Bozeman, Montana, study

Walter and Bottman (1967) have reported the findings of a three year study which compared bacterial and chemical differences between a closed and an open watershed near Bozeman, Montana. Hyalite Reservoir, a catchment for a 30,080 acre watershed, and its drainage stream are extensively used for recreation. Activities include camping, fishing, boating, and swimming. The closed reservoir, Mystic, receives the drainage of 28,160 acres. This watershed had been closed to recreation since 1920. Its fenced perimeter was regularly patrolled by United States Forest Service personnel and city officials.

Representative samples were collected weekly during the summer months. Bacterial analysis included tests for coliforms, enterococci, and standard plate counts. Chemical examination was performed in the field through the use of a portable kit.

Results of the bacteriological analysis displayed exactly the opposite of what might have been expected. The researchers found that there were consistently higher standard plate counts, coliform counts, and enterococcus counts from the Mystic area (closed) than from the Hyalite area (open). Specifically, counts were greater in Mystic than Hyalite for 74 percent of the coliform analyses, 59 percent of the enterococcus analyses, and 56 percent of the standard plate analyses.

Although Walter and Bottman submit no certain explanation for these surprising results, they do propose a possibility. They suggest that fecal contamination by animals, which are likely to be closer to water in the area closed to human entry, accounts for the higher bacteria populations. However, since no actual enumeration of wildlife in the area was made, this proposal is only speculation.

In order to substantiate the findings of Walter and Bottman, further research was undertaken. Stuart et al. (1971) did, in fact, find in this study that for the years 1968 and 1969 the closed watershed yielded coliform counts from four to six times greater than did the open watershed. Similarly, chemical analysis revealed normally higher ion concentrations in the closed watershed.

A new administrative policy, initiated in the spring of 1970, allowed the opening of the Mystic watershed to limited recreation. Significant changes in water quality, again the opposite of what one might expect, occurred that year. Decreases in coliform populations were observed at all sample stations of the closed watershed. In fact, an approximate 20 percent decline in coliforms was noted for both the South Fork and Bozeman Creeks, the two major drainages of that watershed.

Stuart et al. conclude that there is only one possible explanation for these results. They suggest that large animal populations (including 300-500 elk and other indigenous big game) had been forced out due to the increased human activity. Therefore, less fecal contamination naturally followed.

This study is unique in that it showed a case wherein increased human activity actually decreases pollutional impact. Stuart and collaborators suggest that in the future careful consideration should be given to the advisability of closing mountain watersheds to protect them. What may be intuitively construed as a safeguard can, at least in this case, actually serve to produce the opposite effect.

California Department of Public Health study

The California State legislature in 1959 appropriated funds to the Department of Public Health in order to research the effects of recreation on water quality. Ongerth (1964) claims that the study was undertaken as a direct result of a campaign by fishermen's organizations, aware of a previous successful program on San Diego's water supply (see Dodson, 1963) to open more reservoirs to their use.

Twelve lakes were selected for this research. Among the twelve were reservoirs closed to recreation, some with limited use, and others around which intense recreation was oriented. It was the objective of this study to compare the water quality of open and closed watersheds and to compare differences within single reservoirs of unrestricted, light, and heavy use areas.

It was found by this study, and reported by the California Department of Public Health (1961), that under light usage some water quality degradation did occur. However, the contamination was practically negligible. Also, a bacterial increase correlating with rising recreational use was discovered. The report concluded, nonetheless, that no serious water quality deterioration could be attributed to recreation. Indeed, Ongerth (1964) found that the concentration of bacteriological indicators was generally at levels characteristic of clean surface waters.

CHAPTER VI

A GUIDE FOR PLANNING AND IMPLEMENTING A SCHEME TO MONITOR RECREATIONAL IMPACTS ON WATER QUALITY

It seems reasonable at this point to accept the hypothesis that water quality is an excellent indicator of the influence of land management policy above a point of a stream or in the proximity of a lake shore. In order to clarify the process of establishing a water quality surveillance program, a stepwise guideline, modified after Boynton (1972), will be submitted in this section. While the details, of course, are specific to the individual site, the proposed process will be general enough to apply in almost every situation. The steps will normally be followed in the sequential order as outlined below.

1. Establish management objectives

First of all, a determination of what the management needs of an area are must be made. Then, specific surveillance objectives or goals which will satisfy these requirements are established jointly by the land manager and a water quality specialist. The objectives should be carefully and concisely written out at this time. In this manner, Kittrell (1969) states that careful consideration of what the objectives actually represent is facilitated. Also, writing them down serves at least four other purposes to include: 1. decreasing the chances of misunderstanding of the program by those who actually operate it;

2. helping to eliminate the collection of nonessential data; 3. fixing the responsibility of those who supervise the study; and 4. providing a basis for the final evaluation of the program.

This first step is probably the most important one. It is here that the success or failure of a monitoring plan is many times determined. This may also be the most difficult stage because of the subjectivity necessarily involved. Personality clashes between planners, administrators, technicians, and other interested people may very well ensue. Caution, therefore, must necessarily be employed to assure that the objectives speak to the actual management needs of the area.

2. Review existing data

Existing data, including information of both water quality and quantity for the drainage, should be perused after establishment of objectives. Agencies, such as the United States Geological Survey, the Corps of Engineers, the Bureau of Reclamation, Environmental Sciences Services Administration (Weather Bureau), and state and local concerns, are likely sources to contact. The data found should be reviewed to help determine the frequency of sampling, station location, and the characteristics to monitor. This step is of great aid in reducing time and project cost.

3. Consider data interpretation

At this stage in planning a review of statistical utilization and interpretation needed to meet objectives is made. The statistical parameters prescribed will allow the data to be used to its fullest value: a reliance on visual comparisons and graphical representations is normally insufficient to completely evaluate a surveillance program.

Previously established monitoring objectives are used as a basis to describe the statistical needs and design of a plan. The hypotheses to be tested, therefore, will be incorporated into the objectives. Station location, frequency of sampling, and number of samples to be taken are at least partly established by the statistical design. Finally, and perhaps most importantly, the proper statistical scheme is influential in differentiation of natural and man induced changes in water quality.

4. Selection of parameters to monitor

Water quality characteristics that are indicative of water uses and responsive to the objectives of the surveillance program are now chosen for analysis. This is the most technical stage in the development of the monitoring plan. A thorough understanding of each parameter and their interrelationships is imperative before making the actual choices. Sometimes a comprehensive initial characterization of the water, including analysis of chemical, physical, biological, and bacteriological factors may be necessary before the final decision is made. In this manner, those characteristics that are irrelevant to the research, even though their study may prove to be of interest, are eliminated, thereby saving time and money.

5. Establish frequency of sampling

Several factors are necessarily considered in selecting the frequency of sampling. One of these, mentioned previously, is the dictates specified by the statistical design. Also important, however, are influences of specific use periods and normal daily and seasonal stream variation.

Specific use period is of particular relevance in sampling for recreational impact because of the seasonal nature of many leisure pursuits. Once the period for which the water quality impacts are to be measured is defined sampling should be designed to characterize the water only during that time. However, baseline data to be used for comparison may be obtained by starting the program just prior to the onset of the recreational activity.

Advantages of sampling only during the specific use period include: 1. Elimination of data not influenced by the activity for which the impact is to be assessed; 2. Reduction of the possibility of comparing data representative of differing flow periods; and 3. saving cost by concentrating the research effort only on the period of interest.

Some water quality characteristics merit special consideration because of annual or diurnal changes in the nature of a stream's or lake's water. Suspended sediment, for example, is a parameter that is highly flow dependent, especially in streams of mountain areas. Hence, caution should be used in the interpretation of data, in this case, that has resulted from analysis of samples obtained during periods of spring runoff.

Temperature, dissolved oxygen, and bacterial content, however, show marked diurnal fluctuations due to solar influences. Sampling every 2-4 hours for a 24 hour period may be necessary to describe the magnitude of fluctuation. Thereafter sampling each station at approximately the same time of day will yield results most representative of unnatural changes in water quality.

Surveillance of lakes requires still different considerations. Besides annual and diurnal variations, seasonal changes (turnovers) must also be taken into account. Here, again, the influence of a natural process on water quality can be extensive. Researchers must make every effort to separate those changes from ones induced by man.

6. Locate sample stations

After a careful consideration of objectives, the location of individual stations is made. The sites must be selected with respect to the activity for which the impact is to be monitored. Ideally, sample stations are representative of the water body in general so that analysis yields results that are indicative of actual changes that have taken place.

Traditionally, sample stations are located above and below a streamside activity or near and away from a lake shore use area. Water quality changes between the two sites, therefore, can be safely attributed to the influence of the activity in question.

7. Determine program cost

A full scale sampling program can be quite expensive. Kimball (1975), currently conducting research into the impact of ski area development on water quality, states that the cost of his project equals nearly 200 dollars per sampling day. Expenses typically include laboratory costs, wages to field workers, equipment purchases, and man hours necessary for program evaluation.

Economic considerations are included at this late stage in planning in order that the best program can be developed. If the budget does not allow total implementation the designers are now in a good position to request additional funds. However, in the case that the needed appropriations are not available certain aspects of the project perhaps can be reduced or eliminated while still allowing the objectives to be met. If the objectives cannot be attained, though, the program should be dropped or else postponed until such time that adequate funding is made available.

8. Evaluate the program

The design of a monitoring program should not be considered complete once implementation begins. An ongoing evaluative process is necessary to assure that the objectives are being met. A review of the data initially obtained may well suggest that changes in any aspect of the program are warranted. Likewise, the arisal of problems not foreseen in planning plus possible changes in budget, manpower, facility usage, etc. may dictate alterations in the layout of the monitoring scheme. In any case, it is absolutely necessary to see that any variations will still allow the original objectives to be reached.

Producing the final report

This topic is not embodied as a sequential step because at all aspects of planning and implementation it is wise to be aware of the final writeup and interpretation of the study. Every effort must be made to assure that the findings will be both informative and readily understandable by interested parties.

It is best to write or present the report as soon as possible after the research is completed and the data has been interpreted. This final phase of the program is properly accomplished by one who is familiar with all aspects of the project. Summaries of basic data and results of calculations are normally presented in graphic form. This way trends can be followed more easily than when they are in tabular form. Of course, the tabulated data should be available for the use of checking calculations and for future reference.

A basic map of sampling points along the river or lake can be included. Special note should be made of areas of human use, suspected pollution sources, intakes for municipal water works, etc.

Photographs, too, are good interpretive aids. These can be employed to depict either affects of pollution (dead fish, for example) or likely sources of contamination. Alternatively, the objectives of controlling pollution are well illustrated through the use of photos of people swimming in the water, drinking it, or otherwise enjoying this resource.

Kittrell (1969) states that the report should contain the basic where, whens, whys, and hows of the study. A full discussion of the findings and recommendations of actions necessary to correct any adverse situation will be embraced in a complete program writeup.

CHAPTER VII

SUMMARY AND CONCLUSIONS

In the last several decades the demand for recreational activities and opportunities has spiraled. One result of this phenomenon is physical impact on water resources. This thesis has endeavored to explain how such consequences occur and why they should be monitored and controlled. Also, summaries of previous and current research in this area have been included along with a general stepwise plan for constructing and implementing a recreational water quality monitoring scheme.

As pointed out by the National Industrial Pollution Control Council (1971), the role of government as a source of land use and management in outdoor recreation areas is of far greater importance than that of private or industrial concerns. Government at all levels has established parks and recreation areas, although many times this has been accomplished with inadequate funding and planning. The outcome, in some cases, has been water pollution problems stemming from construction of substandard campgrounds and other facilities, overuse of areas, and inadequate water, sewage, and waste disposal systems.

Preventative measures are much more likely to succeed in alleviating impacts on water resources than are corrective measures. Barton (1969) claims that corrective action only eliminates the grosser aspects of the complication and will never restore the water to its original character.

Care should always be employed in monitoring water quality so that the actual source of change may be discerned. This point has special implication to managers of lands administered under a multiple use mandate. During initial data interpretation it may well appear that the contamination has originated at the site of a recreation activity when, in reality, that may not represent the true source. Wildlife, agriculture, other types of land use, or even municipal waste discharges may represent the actual agent of water quality deterioration.

There appears to be several courses of action that can be taken in order to alleviate some of the harmful effects of recreation on water quality. Listed below are recommendations which will serve that end.

1. Technology can work to produce improved waste disposal systems for wildland and rural areas.

2. Behavioral research may help better define how human activity can be controlled.

3. Design and layout of recreation facilities can be improved so that the infliction of environmental damage is minimal.

4. Research into soil and vegetation types may reveal those kinds that are most resistant to human impact.

5. Greater efforts in defining recreation carrying capacity will serve to reduce visitor pressure in those areas suffering from environmental deterioration.

6. Studies into the recreational needs and desires of people will help in location of areas in which greatest emphasis should be placed on preventing water quality degradation.

It was hoped that this thesis would provide information that is of benefit to recreation managers, planners, and others not schooled in the intricacies of water science. Admittedly, it is normally the engineer or hydrologist, not the recreation specialist, who designs, implements, and evaluates water quality studies. Nevertheless, an awareness of the basic properties of water and how recreational activity can degrade its excellence are invaluable aids to the uninitiated in interpreting the implications of water quality data. In fact, there is no reason to suggest that only physical scientists can conduct water quality programs. It is likely that a scheme designed by one who has a knowledge of recreation behavior combined with an awareness of the science of water quality surveillance may produce results that will best relate to management goals and objectives.

Finally, it seems appropriate at this time to lend a note of caution to those interested in restoring and maintaining the integrity of water resources. Goodrich et al. (1970), after finding that elk were the source of the contamination of a mountain stream, concluded that sometimes by trying to meet water quality standards one may be attempting to keep water cleaner than that which naturally occurs. After all, there probably does not exist in nature anything resembling perfectly pure water.

LITERATURE CITED

American Public Health Association. 1971. Standard methods for the examination of water and wastewater. 13th ed. American Public Health Association, Washington, D.C. 874 p.

Bartley, C. H., and L. W. Slaneta. 1960. Types and sanitary significance of fecal streptocci isolated from feces, sewage, and water. American Journal of Public Health 50(10):1545-1552.

Barton, M. A. 1969. Water pollution in remote recreational areas. Journal of Soil and Water Conservation 24(4):132-134.

Benedetti, A. J. 1964. Watersheds and the recreational land use in the Pacific Northwest. Journal of the American Water Works Association 56(11): 1467-1473.

Borchardt, J. A. 1969. Eutrophocation-causes and effects. Journal of the American Water Works Association 61(6):272-275.

Bowering, R., K. H. Spies, A. T. Neale, and W. Bullard. 1961. Watershed control for water quality management, Pollution Control Council, Pacific Northwest Area, Portland, Oregon. 42 p.

Boynton, J. L. 1972. Managing for quality--a plan for developing water quality surveillance programs on National Forests in California. Proceedings of the Watersheds in Transition National Symposium, June 19-21, Ft. Collins, Colorado. pp. 84-90.

Bringham, A. P. 1966. Operators view. Joint discussion--Recreational use of watersheds. Journal of the American Water Works Association 58(10):1260-1263.

Brown, G. W. 1974. Forestry and water quality. Oregon State University Book Stores, Inc., Corvallis, Oregon. 74 p.

California Department of Public Health. 1961. Recreation on domestic water supply reservoirs. Bureau of Sanitary Engineering, Berkeley, California. (Original not seen; abstracted in Carswell, Symons, and Robeck, 1969.)

Carswell, J. K., J. M. Symons, and G. Robeck. 1969. Research on recreational use of watersheds and reservoirs. Journal of the American Water Works Association 61(6):297-304.

Cooper, K. E., and F. M. Ramadan. 1955. Studies in the differentiation between human and animal pollution by means of fecal streptocci. Journal of General Microbiology 12(2):180-190.

Diesch, S. L. 1970. Disease transmission of waterborne organisms of animal origins, pp. 265-285. In T. L. Willrich and G. E. Smith (eds.). Agriculture practices and water quality. Iowa State University Press, Ames, Iowa.

Dodson, R. E. 1963. Recreational use of reservoirs in San Diego. Journal of the American Water Works Association 55(9):1115-1119.

Doherty, J. E. 1974. Shame on the snow. National Wildlife 12(2):28-29.

English, J. N., G. N. McDermott, and C. Henderson. 1963. Pollutional effects of outboard motor exhaust--laboratory studies. Journal of the Water Pollution Control Federation 35(7):923-931.

Faneuf, A. G., and W. A. Healy. 1952. Misuse of water caused pollution at Concord, New Hampshire. Waterworks Engineering 105(2):131, 153-156.

Federal Water Pollution Control Administration. 1968. About boats and water pollution. U. S. Department of the Interior, Washington, D. C. 6 p.

Ferrin, R. S. 1974. Lead contamination of snow resulting from snowmobile exhaust emissions. Unpublished MS thesis. Utah State University, Logan, Utah. 104 p.

Gale, N. L., G. B. Wixon, M. G. Hardie, and J. C. Jennett. 1973. Aquatic organisms and heavy metals in Missouri's new lead belt. Water Resource Bulletin 9(4):673-688.

Gallager, T. P., and D. E. Spino. 1968. The significance of numbers of coliform bacteria as an indicator of enteric pathogens. Water Research 2(2):169-175.

Geldrich, E. E. 1970. Applying bacteriological parameters to recreational water quality. Journal of the American Water Works Association 62(2): 173-210.

Geldrich, E. E., and B. A. Kenner. 1969. Concepts of fecal streptocci in stream pollution. Journal of the Water Pollution Control Federation 41(8/2):R336-352.

Gerdel, R. W. 1954. The transmission of water through snow. American Geophysical Union Transactions 35(3):475-485.

Glantz, P. J., and T. M. Jacks. 1968. An evaluation of the use of Escherichia coli serogroups as a means of tracing microbial pollution in water. Water Resources Research 4(3):625-638.

Goodrich, T. D., D. G. Stuart, G. K. Bissonette, and W. G. Walker. 1970. A bacteriological study of the waters of Bozeman Creek's South Fork drainage. Proceedings of the Montana Academy of Sciences 30:59-65.

Graham, A. 1957. Wasted water. Outdoor Life 119(6):26.

Grefarth, B. G. 1974. The Federal Water Pollution Control Act and forestry. Journal of Forestry 72(12):757-759.

Hall, M. W., and O. J. Sproul. 1971. Water quality and recreational land use. Public Works 102(3):52-56.

Hasler, A. D., and B. Ingersoll. 1968. Dwindling lakes. Natural History 77(9):8-19.

Hendee, J. C., and R. W. Harris. 1970. Forester's perception of wilderness-user attitudes and preferences. Journal of Forestry 68(12):759-762.

James, G. A., and T. H. Riply. 1963. Instructions for using traffic counters to estimate recreation visits and use. United States Forest Service Research Paper SE-3, Washington, D. C. 12 p. (Original not seen; cited in Lee, Symons, and Robeck, 1970.)

Johnson, B. A. 1975. Water quality as an approach to managing recreational use and development on a mountain watershed. Unpublished MS thesis. Utah State University, Logan, Utah. 106 p.

Jones, J. R. E. 1938. The relative toxicity of salts of lead, zinc, and copper to the stickleback (Gasterosteus aculeatus L.) and the effect of calcium on the toxicity of lead and zinc salts. The Journal of Experimental Biology 15(3):394-407.

Karalekas, P. C., and J. P. Lynch. 1965. Recreational activities of Springfield, Massachusetts, water reservoirs past and present. Journal of the New England Water Works Association 79(1):18-31.

Kimball, K. R. 1975. Research project supervisor, Utah Water Research Laboratory, Logan. Personal interview, March 14.

King, J. 1971. The effects of recreational use on water quality in the vicinity of campsites in the Boundary Waters Canoe Area. Unpublished MS paper. University of Minnesota College of Forestry, St. Paul, Minnesota. 107 p. (Original not seen; abstracted in Merriam and Smith, 1974, and in Merriam et al., 1973.)

Kittrell, F. W. 1969. A practical guide to water quality studies in streams. U. S. Department of the Interior, Federal Water Pollution Control Administration. Cincinnati, Ohio. 135 p.

Kittrell, F. W., and S. A. Furfari. 1963. Observations of coliform bacteria in streams. Journal of the Water Pollution Control Federation 35(11): 1361-1384.

Kortwright, F. H. 1942. Ducks, geese and swans of North America. The Stackpole Company, Harrisburg, Pennsylvania. 476 p.

Krueger, H. W. 1972. Danger in the streets: a preliminary report on the distribution of lead from automobile exhausts in urban streets. Krueger Enterprises, Inc., Cambridge, Massachusetts. Project 22-2. (Original not seen; abstracted in Ferrin, 1974.)

Kunkle, S. H. 1970. Concentrations of bacterial indicators in farm surface runoff. Proceedings of the Cornell University Conference on Agriculture Waste Management, January 19-21. Ithaca, New York. 414 p.

LaBarre, N., J. B. Milne, and B. G. Oliver. 1973. Lead contamination of snow. Water Research 7(8):1215-1218.

Lee, R. D., J. M. Symons, and G. G. Robeck. 1970. Watershed human use level and water quality. Journal of the American Water Works Association 62(7):412-422.

Lime, D. W., and G. H. Stankey. 1971. Carrying capacity: maintaining outdoor recreation quality, p. 174-184. In E. vH. Larson (ed.). Recreation Symposium Proceedings. U. S. Government Printing Office, Washington, D. C.

Mackenthum, K. M., W. M. Ingram, and R. Parges. 1964. Limnological aspects of recreational lakes. United States Public Health Service Publication #1167, Washington, D. C. 176 p.

McCarty, P. L. 1967. Sources of nitrogen and phosphorus in water supplies. Journal of the American Water Works Association 59(3):344-366.

McKee, J. E., and H. W. Wolf. 1971. Water quality criteria. Publication 3-A. California State Water Resources Control Board, Sacramento, California. 548 p.

McKewen, T. D. 1966. State view. Joint discussion--Recreational use of watersheds. Journal of the American Water Works Association 58(10): 1270-1272.

Meiman, J. R., and S. H. Kunkle. 1967. Land treatment and water quality control. Journal of Soil and Water Conservation 22(2):67-70.

Merriam, L. C., and C. K. Smith. 1974. Visitor impact on newly developed campsites in the Boundary Waters Canoe Area. Journal of Forestry 72(10):627-630.

Merriam, L. C., C. K. Smith, D. E. Miller, C. T. Huang, J. C. Tappeiner II, K. Goeckerman, J. A. Blocmendal, and T. M. Costello. 1973. Newly developed campsites in the Boundary Waters Canoe Area--a study of five years of use. University of Minnesota Agriculture Experiment Station Bulletin 511. 27 p.

Miner, J. R., R. I. Lipper, L. R. Fina, and J. W. Funk. 1966. Cattle feedlot runoff--its nature and variation. Journal of the Water Pollution Control Federation 38(10):1582-1591.

Minkus, A. J. 1965. Recreational use of reservoirs. Journal of the New England Water Works Association 79(1):32-40.

Mueller, E., G. Gurin, and M. Wood. 1962. Participation in outdoor recreation: factors affecting demand among American adults. Outdoor Recreation Resources Review Commission, Study Report 20. Bureau of Outdoor Recreation, Washington, D. C. 94 p.

Muratori, A. 1968. How outboard motors contribute to water pollution. The Conservationist 22(6):6-8, 34.

National Industrial Pollution Control Council. 1971. Land and water pollution from recreational use. Sub-council Report. U. S. Government Printing Office, Washington, D. C. 24 p.

Ongerth, H. J. 1964. Watershed management and reservoir use--public viewpoint. Journal of the American Water Works Association 56(2): 149-158.

Outdoor Recreation Resources Review Commission. 1962. Outdoor recreation for America. Bureau of Outdoor Recreation, Washington, D. C. 246 p.

Peloquin, A. E. 1965. Basic health aspects of water quality. Proceedings of the Municipal Watershed Management Symposium, November 9-10. Amherst, Massachusetts. 35 p.

Public Land Law Review Commission. 1970. One-third of the nation's land. U. S. Government Printing Office, Washington, D. C. 342 p.

Reigner, I. C. 1965. Effect of recreation on water quality. Proceedings of the Municipal Watershed Management Symposium, November 9-10. Amherst, Massachusetts. 49 p.

Riehl, M. L. 1956. Discussion--recreational use of impounding reservoirs. Journal of the American Water Works Association 48(5):521-524.

Rosebery, D. A. 1964. Relationships of recreational use to bacterial densities of Forrest Lake. Journal of the American Water Works Association 56(1):43-59.

Schuster, W. W. 1971. Control of pollution from outboard engine exhaust: a reconnaissance study. Environmental Protection Agency, Water Pollution Control Research Series Project 15020, Cincinnati, Ohio.

Shelford, V. E. 1917. An experimental study of the effects of gas waste upon fishes, with special references to stream pollution. Bulletin III. State Laboratory. Natural History 38:381-412. (Original not seen; abstracted in Stewart and Howard, 1968.)

Stewart, R., and H. H. Howard. 1968. Water pollution by outboard motors. The Conservationist 22(6):6-8, 31.

Stroud, R. H. 1963. Fish conservation, p. 230-416. In I. N. Gabrielson (ed.). The Fisherman's Encyclopedia (rev. ed.). The Stackpole Company, Harrisburg, Pennsylvania.

Stuart, D. G., G. K. Bissonnette, T. D. Goodrich, and W. G. Walker. 1971. Effects of multiple use on water quality of high mountain watersheds: bacteriological investigations of mountain streams. Applied Microbiology 22(6):1048-1054.

Subrahmayan, K., and T. R. Bhaskaran. 1950. The risk of pollution of groundwater from borehold latrines. Indian Medical Gazette 85(9): 1327-1328. (Original not seen; abstracted in Biological Abstracts 25(5):1327-1328.)

Taylor, F. 1964. Watershed sanitation. Journal of the New England Water Works Association 78(1):1-15.

Toole, H. J. 1965. Recreational use of the Boston metropolitan water supply reservoirs and watersheds. Journal of the New England Water Works Association 79(1):1-14.

United States Congress. 1972. Public Law 92-500. 92nd Congress, Second Session, Washington, D. C. 87 p.

United States Department of Health, Education, and Welfare. 1962. Public Health Service Drinking Water Standards. Public Health Service Publication 956, Washington, D. C. 61 p.

Walter, W. G., and R. P. Bottman. 1967. Microbial and chemical studies of an open and closed watershed. Journal of Environmental Health 30(2):157-163.

Weber, C. I. (Ed.). 1973. Biological field and laboratory methods for measuring the quality of surface waters and effluents. U. S. Environmental Protection Agency, Cincinnati, Ohio. 199 p.

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