AUTHORITY, BACKGROUND AND GUIDELINES FOR DEPARTMENT RECOMMENDATIONS ON WINTER FLOWS FOR SMALL HYDRO DEVELOPMENT

I. Authority

A. The department, as the agency responsible for the management of the state's fish and wildlife resources, participates in all federal and state permitting and licensing processes for small hydro development. The department conducts extensive review of small hydro projects, consults with other agencies and makes recommendations to the permitting and licensing agencies.

B. The Fish and Wildlife Coordination Act authorizes the U.S. Fish and Wildlife Service and state agencies responsible for fish and wildlife resources to investigate all proposed federal undertakings and non-federal actions needing a federal permit or license which would impound, divert, deepen, or otherwise control or modify a stream or other body of water and to make recommendations to the federal agency. In addition, the Act requires that wildlife conservation be coordinated with other features of water resource development programs. Since a federal licensing procedure is an integral part of small hydro development, FWP must be actively involved. Coordination with the U.S. Fish and Wildlife Service is maintained on all hydro applications.

C. The Federal Energy Regulatory Commission (FERC) is the primary licensing and regulatory agency for non-federal hydroelectric development. A small hydro developer must obtain a FERC license or exemption from licensing if the power is to be sold to a utility connected to an interstate grid system and/or on a navigable stream. The two FERC procedures of primary concern to this policy are minor license (short-form license) and case-by-case exemptions.

D. In 1980 FERC, responding to the Energy Security Act of 1980, issued Order 106 establishing regulations to exempt certain projects on a case specific basis from all of Part 1 of the Federal Power Act; including licensing. An applicant for exemption must consult with fish and game management agencies to solicit Terms and Conditions (T & C's) necessary to protect fish and wildlife resources. All prescribed T & C's are binding on the applicant if the exemption is granted by FERC.

E. The short-form license is available for projects less than 5 Mw and differs from the exemption in that the department's terms, conditions, and stipulations are not considered by FERC to be binding. Instead, they are considered by FERC along with the applicant's position. The decision is made by FERC on appropriate conditions, stipulations and mitigations for short-form license projects.

II. Background

A. Unlike regions of the United States having greater rainfall, monthly stream flows in the mountain streams of Montana are almost totally dependent on the annual snowpack. As a result, approximately 76 percent of the mean annual water yield is passed in Montana's streams during the snow runoff months (May-July), leaving only 24 percent for the remaining nine months. Flows are lowest during the months of November through March. During each of these five months from 1.4 to 2.1 percent of the mean annual water yield is passed, on the average.

B. An extensive literature review (attached) has shown that winter mortalities of trout in mountain streams are primarily the result of catastrophic events caused by the harsh climatic conditions. Anchor ice in particular is very harmful to trout and other aquatic life. Since the period of lowest flows in Montana coincides with the winter months, added stress to the fish population could occur if flows were further depleted. Winter flow depletions reduce the amount of available living space for trout and their food supply, and have the potential to increase the mortalities resulting from catastrophic weather events by reducing the escape cover.

C. Given the fact that trout and their food supply are already impacted, sometimes severely, by typical winter conditions, which include the naturally occurring low flows, it is a reasonable conclusion that winter water depletions will aggravate an already stressful situation. Potentially, winter flow depletions could lead to even greater winter losses and the possible devastation of the fish populations.

D. In response to small hydro applications for exemption or short-form license, the department's approach in the past has been to recommend a level of instream flow protection that severely restricted or eliminated winter withdrawals in most years.

III. Guidelines

A. Considering the severity of the winter environment and its impact on a stream's carrying capacity, the department's

INTRODUCTION

The literature contains little information concerning the instream flow methods that can be applied to mountain streams to determine the amount of flow that is needed during the winter months to sustain the existing wild trout populations. Due to the lack of published methods, the Montana Department of Fish, Wildlife and Parks (MDFWP) has developed its own policy regarding winter flow depletions. This policy is based on biological considerations reported in the literature and the physical characteristics of Montana's trout streams in winter.

The purpose of this paper is to briefly review the literature pertaining to trout streams in winter and present arguments in support of the present instream flow policy of the MDFWP.

LITERATURE REVIEW

Trout Mortalities in Winter

It is well accepted that substantial losses of wild trout can occur in winter, particularily in mountain streams that are subject to icing and other harsh weather conditions. Needham et al (1945) reported that the overwinter losses of all brown trout ranged from 26 to 85 percent and averaged

60 percent over four years in Convict Creek, a small stream in the Sierra Nevada Mountains of California. Winter losses of the larger trout (four inches and longer) were higher, ranging from 48 to 91 percent and averaging 80 percent over four years.

In Montana, there is little quantitative data documenting the winter trout mortality that occurs in mountain streams. Mortality data, however, are available for study sections of the upper Gallatin and upper Madison rivers (Table 1). The physical environment of these rivers, like mountain streams, is also affected by icing and other harsh winter conditions. Even though the trout in these rivers are subject to angler related mortalities in summer, the winter mortality rates usually exceed those during the warmer months, a fact attributable to the severity of the winter environment.

Evidence of elevated mortalities in winter indicates that the winter environment ultimately limits the numbers and pounds of trout that can be maintained indefinitely by the aquatic habitat of high elevation streams. Severe winter conditions appear to affect all age-groups of trout, although Stalnaker and Milhous (1983) consider the overwinter losses of young-of-the-year trout to be most limiting to the population.

Table 1. Summer (mid April - mid September) and winter (mid September - mid April) mortality rates (%) for age II and older trout in study sections of the Madison and Gallatin rivers (unpublished data from R. Vincent, Fisheries Biologist, MDFWP, Bozeman).

Rainbow Trout - Durnam Study Section - Gallatin River

	Mortality (%)		
Year	Summer	Winter	Annual
1980-81	17	53	61

Brown Trout - Varney Study Section - Madison River

	Mortality (%)		
Year	Summer	Winter	Annual
1977-78	-	47	-
1978-79	33	9	39
1979-80	24	50	62
1980-81	21	42	54
1981-82	9	-	-

Rainbow Trout - Snoball Study Section - Madison River

	Mortality (%)		
Year	Summer	Winter	Annual
1980-81	28	34	52

Causes of Winter Mortality

Various studies have addressed the causes of winter mortality in mountain streams. Maciolek and Needham (1952) observed that heavy subsurface ice created dams, which blocked the flow into side channels and caused a substantial mortality of trout in Convict Creek, California. Ice, slush, collapsing snow banks, and fluctuating flows resulting from the periodic breakup of ice dams were considered by Reimers (1957) to greatly influence winter trout losses. Needham and Jones (1959) concluded that the primary causes of winter mortality in higher elevation streams exposed to severe weather conditions were:

1. The sudden collapse of snow and ice into the water, causing death by either direct crushing or suffocation against the stream substrate, or both.

2. The dewatering of sections of streams through the creation of ice jams and snow and anchor ice dams, resulting in the suffocation of fish.

3. The sudden dewatering of flooded side channels or other areas by the breakup and dispersal of ice and snow dams, resulting in the suffocation of fish.

Anchor ice in particular can be very destructive to trout and other aquatic life (Butler, 1979). During nights when clear skies provide maximum radiant heat loss from the land and water and air temperatures are low enough to supercool the stream, small ice crystals, called frazil ice, form in the water. The frazil ice drifts downstream and attaches to the first object in its path, accumulates and forms a mat of anchor ice over the bottom. Frazil ice alone can be harmful to fish by plugging their mouths and gills, resulting in suffocation. Tack (1938) reported such a fish kill in trout ponds.

As the anchor ice accumulates, ice dams are built up in various sections of the stream. As the ice mass builds, the stream becomes elevated and is forced out of its bed, becoming impounded in areas frequently flooded in the spring. Areas habitually used by fish can be obliterated by the ice, causing fish to lose their orientation and swim aimlessly through the ice caverns. As heat from the sun is absorbed during the day, the anchor ice and ice dams melt and the stream quickly returns to its former bed, stranding fish and other aquatic organisms in the overflow areas. This sequence can be repeated night after night if conditions are right.

Heavy snow cover on the ground, streambanks and tops of instream boulders insulates against radiant heat loss and prevents the supercooling of the stream. Anchor ice is therefore more likely to form during periods of sparse snow cover, such as early winter and in drought years.

The work of the above authors indicates that sudden catastrophes such as suffocation under collapsed snowbanks or the dewatering of stream sections by ice dams are primarily responsible for the high mortalities of stream dwelling trout in winter.

<u>Trout Food Supply in Winter</u>

Winter is often thought of as a period when food is abundant in trout streams. This belief is based on the fact that most of the semi-aquatic insects that serve as the primary food of stream trout overwinter on the stream bottom in their immature stages before emerging as winged adults during the warmer months. Logan (1961) found the bottom food organisms to be abundant during the winter in Bridger Creek, a small stream arising in the Bridger Mountains of Montana. Convict Creek, California, supported higher standing crops of aquatic food organisms during the winter than in summer (Maciolek and Needham, 1952).

The winter food supply can be depleted by ice action. Reimers (1957) continued the bottom sampling program initiated by Maciolek and Needham for Convict Creek and observed that the highest standing crops of aquatic food organisms occurred in summer rather than in the winter. The conflicting results were attributed to the severity of the weather. Reimers' study was conducted during average and extremely severe winters while the results of Maciolek and Needham were obtained in a mild winter. During the average and severe winters, repeated anchor ice formation resulted in sudden releases of water which scoured the stream bottom and dislodged the bottom organisms. Ice and slush dams formed by the accumulation of released anchor ice further depleted the food organisms by exposing the bottom habitat to partial drying, freezing and rewatering. The end result was a gradual depletion of the food organisms through the winter.

These results indicate that the populations of semi-aquatic insects in high elevation streams can be reduced during a typical winter. Given the severity of most winters in the mountain regions of Montana, the depletion of food organisms in winter and early spring is likely a common event.

Feeding and Digestion in Winter

Trout in mountain streams are reported to feed regularly in winter whenever drifting food organisms are available. The daily breakup of anchor ice in Sagehen Creek, a small stream in the Sierra Nevada Mountains of California, dislodged bottom organisms which were readily consumed by trout, even when the water temperature was between 32 and 33 F (Needham and Jones, 1959). Maciolek and Needham (1952) made a similar observation, reporting that trout in Convict Creek, California, fed regularly in the freezing water throughout the winter. Reimers (1957) stated that reduced winter feeding among healthy stream dwelling trout should be attributed to the scarcity or unavailablity of food rather than a lack of interest in food. He also found that digestion proceeded slowly but steadily at temperatures closely approaching the freezing point.

Although trout will actively feed in winter and digest and utilize this food, feeding does not appear to be an absolute necessity for winter survival. Starvation experiments conducted by Reimers (1957) indicated that healthy trout are adapted to and are capable of surviving many months of fasting, especially in cold water. While an abundant winter food supply is obviously an asset to the well-being of stream trout, the ability of healthy trout to survive long periods of starvation relegates winter food conditions to a secondary role in determining winter survival. However, food scarcity can be a significant mortality factor in severe winters when the physical environment is barely tolerable to trout (Reimers, 1957).

Winter Trout Movements

The studies of Stefanich (1951), Logan (1961), Lewis (1967) and Leathe and McMullin (1984) support the conclusion that the vast majority of resident trout inhabiting Montana's mountain streams are found year-round within a relatively limited home territory. This applies to mountain streams in other areas of North America as well (Miller, 1957 and Rinne, 1982).

In contrast to these findings, Chapman and Bjornn (1968) reported that salmonids in some Idaho streams move downstream in the fall, a response attributed to declining water temperatures, with non-anadromous species often returning upstream in the spring. Mallett (1963) reported a downstream movement of westslope cutthroat trout in the fall and an upstream movement in the spring in the Middle Fork of the Salmon River. Similar movements of westslope cutthroat trout have not been observed in Montana (Montana Department of Fish and Game, 1979 and Graham et al, 1980).

Wickers et al (1982) used implanted transmitters to investigate the movements of brown trout under surface ice cover in the Laramie River, Wyoming. Near freezing water temperatures were found to significantly decrease movements. When ice cover and low water temperatures first occurred, brown trout showed an increase in movement, attributed to re-orientation, followed by a decrease in movement as the winter progressed. In contrast, Logan (1961) reported that the movements of rainbow trout in Bridger Creek, Montana, appeared to be slightly greater in December, January and February when the temperatures were low and surface ice was present. Much of the movement reported by Logan was highly localized as indicated by the fact that, during the 10-month study, over half of all tagged trout found in the 900 foot long study section were recovered within 150 feet of their initial place of capture.

Habitat Selection in Winter

Needham and Jones (1959) observed that rainbow and brook trout in Sagehen Creek, California, were in close proximity to shelter during winter daylight hours. Shelter consisted of overhanging bushes, projecting snow banks, and a deep sheltered pool protected by exposed roots. Trout were more numerous in shallow water during the night than during the day.

Cooper (1953), working on brook trout streams in Michigan, reported that in spring, summer and fall trout were found in pools, riffles or near cover within the main stream. These habitats were completely deserted during winter, when the trout were found only in low velocity areas under banks, in piles of stones and rocks or amid heavy accumulations of brush and debris.

Wickers et al (1982) tenatively defined the winter microhabitat preferences for adult brown trout in medium sized streams that were totally ice covered. Preferred resting microhabitats (assumed to be the most heavily used microhabitats by trout) were areas having a thick covering of sheet ice, water depths of 0.50 - 0.99 feet, mean velocities <0.50 fps, and a substrate consisting of rubble and gravel. Brown trout preferred shallower depths when total ice cover was present in contrast to the pre-ice resting preference for deep pools. This finding is in agreement with Logan (1961), who observed that rainbow trout in Bridger Creek, Montana, were mainly found in pools during spring, summer and fall, while in winter many trout moved into shallower water having surface ice cover.

Lewis (1967) reported that brown and rainbow trout in Little Prickly Pear Creek, Montana, tended to move into pools in winter while in summer trout inhabited pools and riffles about equally. Chapman and Bjornn (1968) concluded that there are advantages for stream dwelling salmonids to occupy deeper, quiet waters associated with cover in winter. The greater use of the deeper habitats in winter, as reported by these authors, is in contrast to the findings of Logan (1961) and Wickers et al (1982).

Hartman (1963) stated that juvenile rainbow trout, brown trout and coho salmon have seasonal behavioral similarities.

Juveniles of these species in winter show a stronger association with the bottom than in summer. It was postulated that such winter behavior affords protection against predation and displacement. Movement away from cover or the emergence from the bottom in summer allows the juveniles to effectively feed during the season when drifting food is more abundant and the higher metabolic rate allows more food to be used.

Some salmonids enter the substrate in winter. Chapman and Bjornn (1968) reported that young steelhead and chinook salmon, anadromous species not found in Montana, often overwinter in the stream substrate under large stones, rocks and debris. Hanson (1977) documented this behavior for resident cutthroat, which entered the substrate when winter water temperatures decreased to 4.4C or less. This behavior was considered an adaption to avoid predators, physical damage by ice and unnecessary energy expenditures (Chapman and Bjornn, 1968).

Habitat selection by salmonids can be different in winter than during warmer periods, a conclusion substantiated by the work of the above authors. There is, however, no general concensus concerning the makeup of the preferred winter habitats. Many factors, including the species and life stages of fish and the presence or absence of surface ice and other forms of cover, appear to influence winter habitat usage. Subsurface ice can also play an important role by obliterating typical fish habitats and flooding and dewatering others. This forces fish to utilize whatever habitat remains regardless of its suitability.

Winter Activity of Trout

Maciolek and Needham (1952) and Needham and Jones (1959) observed actively feeding trout in California mountain streams throughout the winter when water temperatures were at or near freezing. In the latter study, trout also defended territories during the winter.

These findings dispute the commonly held opinion that wintering trout in mountain streams are indifferent to food and exist in a torpid or inactive state. Other observations, such as young salmonids entering the substrate in winter and juveniles showing a stronger association with the bottom in winter than during warmer months, demonstrate that in some situations fish are less active in winter.

Winter Water Availability in Montana

Unlike regions of the U.S. having greater rainfall, monthly stream flows in the mountain streams of Montana are almost totally dependent on the annual snowpack. As a result, streams exhibit two distinct flow periods; a relatively

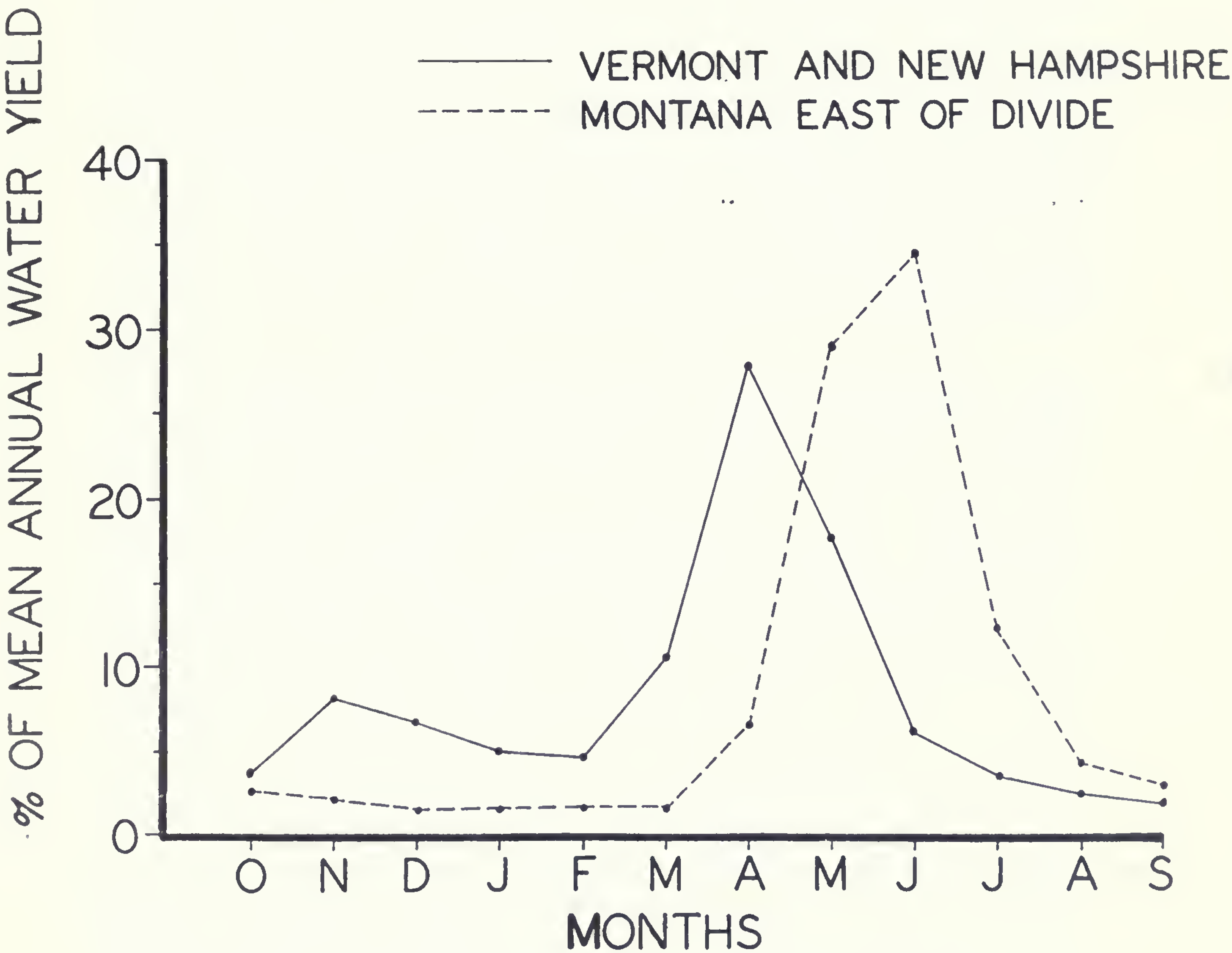

Figure 1. Comparison of monthly water availability for East coast streams (Vermont and New Hampshire) and mountain trout streams in Montana (east of Continental Divide).

brief snow runoff period when a large percentage of the annual water yield passes through the stream, and a lengthy nonrunoff or low flow period, characterized by relatively stable base flows maintained primarily by ground water outflow.

Regional differences are evident when the monthly water availability for Montana's mountain streams is compared to that for streams in other parts of the U.S., such as the East coast (Figure 1). The monthly values in this figure are an average for five unregulated streams in each of the two regions.

For Montana's streams, approximately 76 percent of the mean annual water yield is passed during the snow runoff months of May, June and July, leaving only 24 percent to be passed during the remaining nine months. In contrast, approximately 56 percent of the annual water yield for East coast streams passes during the three high flow months of March, April, and May, leaving 44 percent for the remaining nine months.

In Montana, the period of lowest flows occurs during the winter from November through March. During each of these five months, from 1.4 to 2.1 percent of the annual water yield is passed, on the average. In the East, the period of lowest flows occurs during summer and early fall from July

through October. During each of these four months, from 1.9 to 3.4 percent of the annual water yield is passed.

Three basic differences are evident;

1. Monthly water availability in Montana's streams is less evenly distributed than occurs in the East, a region where annual precipitation is greater and where rainfall contributes significantly to year-round flows.

2. The availability of water is greatest in Montana in May, June and July. In contrast, the high flow period in the East begins in late winter.

3. The period of lowest flows in Montana occurs in winter, while Eastern streams have their lowest flows in summer.

SUMMARY OF LITERATURE REVIEW

1. Trout mortality rates in high elevation streams that are subjected to harsh winter weather conditions are typically higher in winter than during the warmer months. This supports the well accepted view that the winter environment ultimately limits the trout carrying capacity of mountain streams.

2. Sudden catastrophes associated with the severity of winter weather such as suffocation under collapsed snowbanks or the alternate dewatering and flooding of stream sections by ice dams are primarily responsible for the elevated trout mortalities in winter.

3. Anchor ice can be very destructive to trout and other aquatic life.

4. Trout in mountain streams were observed to feed regularly in winter whenever drifting food organisms were available.

5. The semi-aquatic insects that provide food for trout can be depleted by ice action during a typical winter.

6. The ability of healthy trout to survive long periods of starvation, especially in cold water, relegates winter food conditions to a secondary role in determining winter survival.

7. The commonly held opinion that trout in mountain streams winter in a torpid or inactive state is disputed in the literature.

8. It is unlikely that the resident trout populations of the vast majority of mountain streams in Montana undergo significant movements or migrations in winter.

9. Habitat usage by trout in winter can be different from that in warmer periods. However, there is no general concensus concerning the makeup of the preferred winter habitats.

10. Subsurface ice plays an important role in determining winter habitat usage by periodically obliterating some local habitats and alternately flooding and dewatering others, forcing fish to utilize whatever habitat remains regardless of its suitability.

11. In Montana's mountain streams, the period of lowest flow occurs in winter from November through March. During each of these five months, from 1.4 to 2.1

percent of the mean annual water yield is passed, on the average.

WINTER INSTREAM FLOW POLICY AND RATIONALE

The winter instream flow approach of the MDFWP has been to recommend a level of instream flow protection that severely restricted or eliminated winter withdrawals in most years. This approach has been recently revised to prohibit winter water depletions altogether. The justification for protecting winter flows is primarily based on the fact that winter is the period most detrimental to trout survival in mountain streams that are subjected to icing and other severe weather conditions. For these streams, the harsh winter environment ultimately limits the numbers and pounds of trout that can be maintained indefinitely by the aquatic habitat. Winter flow depletions would only serve to aggravate an already stressful situation, leading to even greater winter losses and the possible devastation of the fish populations.

The fact that the flows in Montana's mountain streams are lowest in the winter further justifies the policy of prohibiting winter depletions. The assumption that more water provides space for more fish has let to the well accepted conclusion that the period of lowest stream flows is most limiting to fish. The coupling of the low flow period with harsh winter weather conditions, a situation occurring in Montana, increases the severity of the stream environment in winter.

Winter flow depletions will expose a greater area of the stream bed to radiant heat loss, thereby increasing the likelihood the stream will supercool and form anchor ice. Because flows are already at their lowest natural levels in winter, even small depletions can greatly increase the amount of exposed stream bed. The volume of water in a stream channel alone may provide some insulation against heat loss, slowing down the supercooling process and in turn the formation of anchor ice. When anchor ice does form, obliterating some stream habitats and alternately flooding and dewatering others, the maintenance of the normal stream flow likely benefits fish by providing greater survival space. Mortalities caused by catastropic weather events will be even greater if the escape space is reduced, an event likely to result when winter flows are depleted. Total stream freeze-up is also possible given sufficient winter depletions. Such an event occurred in Rattlesnake Creek, Montana, following winter flow reductions (D. Workman, per. comm.).

In winter the primary concern in regard to food production is to maintain enough wetted habitat to overwinter the immature stages of the semi-aquatic insects that serve as the primary food of stream trout. Sufficient food must be available to allow the trout to recover from the rigors of winter and begin to grow when the water warms and fish metabolism increases. Trout survival will be affected if the spring rise in water temperature is not accompanied by an increase in food.

A less important function of the food producing area in winter is to supply food for wintering trout. While the scarcity or unavailability of food is only considered a secondary cause of winter mortality, it can be important during those winters in which the physical condition of the environment is so degraded by ice as to be barely tolerable to trout.

The naturally occurring low flows of winter reduce the amount of riffle habitat (the food producing area of streams) to its lowest level of the year. Due to the wide, shallow configuration of riffles, flow reductions affect this habitat type much more severely than the deeper pools and runs. Winter flow levels alone, particularly during below normal water years, can affect the food supply through its influence on the amount of riffle habitat that is available to overwinter the bottom organisms. Ice action can further deplete the food organisms by subjecting riffle sections to sudden scouring and partial drying and freezing during the anchor ice cycles. The combination of harsh weather conditions and the naturally occurring low flows can severely reduce the food supply in some years, potentially affecting trout survival during the winter and in subsequent months as well. Winter flow depletions have the potential to reduce the food supply even further.

The eggs of several species of salmonids (brook trout, brown trout, bull trout, kokanee salmon and mountain whitefish) are deposited in the gravels of mountain streams during the fall. Incubation of these eggs proceeds slowly during the winter months due to low water temperatures, and the fry typically emerge from the gravels during early spring. During the winter incubation period these eggs are susceptible to mechanical destruction resulting from ice scour as well as mortality caused by freezing and dessication. Winter flow depletions have the potential to aggravate the above causes of egg mortality.

When considering the severity of the winter environment and its impact on trout and other aquatic life, a prudent approach for deriving instream flow recommendations for Montana'a unregulated mountain streams is to prohibit winter (approximately November through March) flow depletions altogether. Until studies of the winter flow needs of trout can prove otherwise, a policy of no winter depletions is advisable if the goal is to maintain the trout populations at their existing levels. Given this goal and the available biological information, no other approach can be justified at this time.

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