

**ASSESSMENT OF INVERTEBRATE RESEARCH
IN YELLOWSTONE NATIONAL PARK.**

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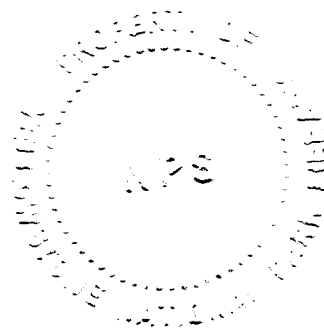
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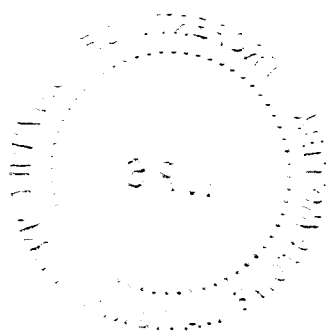


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PREFACE

Invertebrate Research and Management
in Yellowstone National Park, Wyoming.

Mission Statement

Yellowstone National Park staff are in the process of identifying park invertebrate research, inventory and monitoring needs. The goal of this process is to summarize past and present invertebrate research and to identify directions for future research and monitoring. The questions addressed in this document are: ^{1.)} what does the park know about the invertebrate fauna (Chapter one), ^{2.)} what does the park need to know (Chapter two), ^{3.)} recommendations for classifying studies and identifying needs (Chapter three), ^{4.)} and how should future management address invertebrate inventory and monitoring (Chapter four).

The role of invertebrates within an ecosystem ^{is usually} under-
^{or overlooked} emphasized ^{by} management unless the insect is an economic pest such as the bark beetle. Public perception of the invertebrate as a lower life-form and so-called 'vertebrate chauvinism' leads to an ^{underestimation of} ~~reduces~~ the importance of the spineless kingdom within an ecosystem (Norton, 1986). Furthermore terrestrial arthropods are often overlooked when assessing possible impacts on a managed ^{by arthropods or fire or floods?}

area, despite the important roles arthropods play in ecosystem recovery (Kemp, 1989; Norton, 1986).

Invertebrates also play an important role by affecting vertebrates important to management. For example, grasshopper biomass can surpass ungulate biomass on a given range, and potentially account for an equal ^{amount of} ~~impact on the~~ ^{use} vegetation (Kemp, 1989; Frank, pers. commun.). Leaf mining insects can have a significant impact of foliage and tree growth for deciduous trees, such as aspen, which confounds the assessment of the grazing impact by ungulates. For Yellowstone Park to accurately assess the apparent influence of ungulates on the northern range or the fragile nature of thermal hot springs, the role of the arthropod grazers and primary producers must not be forgotten (Ibid).

In this document, invertebrate research ^{in YELL} is summarized with an emphasis on terrestrial arthropods, with theoretical and practical applications for future research and monitoring programs ^{are also presented.} Potential monitoring ^{of key or indicator} species will be discussed along with recommendations for future research and inventory goals.

CHAPTER ONE

Summary of Invertebrate Research

Overview

Invertebrate research, inventory, and monitoring goals for Yellowstone National Park should be systematically identified. Past studies on invertebrates have addressed pest management concerns or were unsolicited projects submitted by independent university researchers, ^{who were usually not oriented to addressing} ~~with little coordination or~~ ~~identification of management objectives.~~ ^{concerns.} Since Management does not currently recognize any invertebrates as species of special concern, nor are there any standards for non-pest invertebrate research.

Invertebrate data could be used as a management tool if an interactive approach--examining inter- and intraspecific interactions--is adopted. An interactive approach would be the examination of predator/prey dynamics, niche relationships, and competition--the three main indices of invertebrate community health, stability and diversity (Pianka, 1983; Norton, 1986). Postfire recovery, successional stages, and ecosystem integration are measured by species diversity and community stability as important indices of ecosystem resilience.

While the interactive approach may be the most useful for large-scale projects, the analysis of an individual species provides important information on a particular habitat type. For example, the role and distribution of the leafhopper in its preferred habitat may affect the distributions of large herbivores, while the role of the honeybees, solitary bees, and butterflies in a pollination complex may not. However, to understand the ^{complexities and key factors} ~~inner workings and controls~~ leading to a certain distribution of leafhoppers, or the outbreak of pine bark beetle, the community level approach--interactions included--is critical.

Invertebrate research and management goals for Yellowstone Park should be outlined as part of the park's resource management objectives. ^{An index of program needs} ~~A format~~ should be developed to integrate current research and monitoring along with future proposals. Unsolicited proposals should be guided towards matching ~~defined~~ research and management needs as defined in the Resource Management plan. This format should indicate habitat or community types and interactive elements to be inventoried or researched.

Research Permit Summary

Invertebrate research projects were summarized by compiling ^{data} ~~records~~ from ^{YELL} collection permits and the ^{records of the} University of Wyoming National Park Service Research Center at Grand Teton National Park, Wyoming. ^{This} ~~These~~ ^y ~~summaries~~ ^{Covers} ~~indicate~~ the number of projects initiated in the park or through the Research Center, but by no

means represent a comprehensive view of all invertebrate research done in the park.

Types of Invertebrate research can be described using five broad categories: single species/genus, multiple species/order, community level, aquatics, and pests. In this report each category will be discussed with a project overview. A cross-reference list of species and current common names are included in Appendix I. Species identified in the park from either the Annual Investigators Reports or from research summaries are listed in Appendix II. A list of the principal investigators and their primary study organism is included in Appendix III.

Single Species/Genus Studies

Single species/genus research involves studies of habitat preferences, distribution ranges, and population levels without an examination of the interactive ^{ions} effects between species or genera (Table 1). Fourteen studies concentrated on single species/genus systems including parasitic pest species such as the mosquito Aedes evoles (Nielsen, 1982), the moose biting fly Haematobosae alcis (Anderson, 1974), the face biting fly Musia autumanalis (Burger, 1970), black and deer flies of the families Chrysops and Hybomitra (French, 1986), and non-pests such as the crane flies of the family Simuliidae (Alexander, 1943) and gastropods (Creel, 1977).

Single species studies also concentrated on the interactions with host species (large ungulates in H. alcis and M. autumnalis), possible controls (Aedes evoles by Nematode mermithid worms) and population densities (Tipulidae, sp.; Tabanidae: Chrysops and Hymomitra; Simulidae, sp.). The remainder of the studies concentrate on single species systems (Dewey, 1969; Buschinger, 1974; Ybarrondo, 1989), their distribution in the park (Rees, 1948; Nielson, 1983; O'Neill, 1986; Sun, 1988), or single genus systems (Mills et al, 1943; Evans, 1961; Wiegert, 1979; Table 1). One study dealt with the interaction of two species within an ecosystem (Kuenzel, 1977), and another examined behavioral differences between species within the same habitat (O'Neill, 1986). Overall, the single species/genus studies have generally concentrated on ~~the~~ distribution ~~of a species~~ or the effects and control of non-economic pests within the park.

Multiple Species/order Studies

Multiple species studies concentrate on the interactions of selected members of a community and are the closest approach to community system studies without the inherent complexity (Table 2). Interactions include predator/prey dynamics and interspecific competition or mutualistic relationships. Studies of the interrelationships between species of an order or suborder of invertebrates are the most common type of multiple species

study (Armitage, 1953; Collins, 1975; Burger, 1977; Wheeler, 1980; Bowser, 1986; French, 1986). These relationships between orders include distributions with host plants, timing of species emergence and species flight patterns as related to habitat parameters. Other studies examined the interaction between several orders or species as isolated segments within a defined community (Bartow, 1970; Wiegert, 1979; Mitchell and Wiegert, 1971; Resh and Barnby, 1984). Two other multiple order studies attempted to deal with preliminary community-level processes within specific community types--stream and thermal (Armitage, 1953; Collins, 1975; Mansbach, 1986).

Handwritten notes: A circle around the word "between" with an arrow pointing to it and the word "within" written next to it. Another arrow points from the underlined phrase "interaction between" to the word "within".

The multiple species studies help bridge the gap between single species studies and community level studies by providing information on some of the interactions between chosen segments of the community. By narrowing the scope of the community approach, several studies have successfully described interspecific interactions and niche breadths for isolated communities (Collins, 1975).

Community Level and Baseline Studies

Community ecology is an important concept in ecosystem management. Invertebrates and their interactions with vertebrate populations are a critical element within any ecosystem (Norton, 1986). Apparent key relationships such as the dynamics between a vertebrate grazer and forage plant species, may be compromised

when invertebrate herbivores are examined. For example, the grazing pressure by grasshoppers on the available forage on the Northern Range may surpass that of the ungulates (Kemp, 1989). If managers are interested in the control of the grasshopper population, the interactions between several orders of invertebrates becomes important. An apparent outbreak of grasshopper populations may be caused by an increase in the numbers of the grasshopper itself, or by a change in the numbers of parasitic wasps that attack the immatures, the beetles that eat the adults, and the ants that carry off the eggs. The scenario continues with the interactions of ^{mammalian} vertebrate and avian predators as the next step in complexity. For the park to benefit from community level research, researchers need to sort through and identify each level of community structure and component communities within a greater community unit. ↓ these are vertebrates

Community stability and resilience to perturbations are critical when examining the ecosystem as a whole. Ecology texts define community structure as the pattern of resource allocation among species and the "patterns of their temporal and spacial abundances" (Cody and Diamond, 1975). A community is formed by parameters like competition such that "...component species are selected and co-adjusted in their niches and abundances to fit with each other and resist invaders..." (Diamond, 1975). The two driving forces creating a community, instead of an assemblage of individuals, are competition and predation (Connell, 1975). To predict the vitality of a given community type, the underlying

structure--as formed by competition and predation--is an essential key to ecosystem management (Mattson, 1976; Norton, 1986). That structure may be simple in the case of some desert ecosystems, or complex with several hierarchical levels of component communities integrating to form the greater compound community (Price, 1983).

The first step for a community level approach to invertebrate research or monitoring is gathering baseline information on the families and orders of species present (Forman and Godron, 1986). However, baseline data on species composition is conspicuously absent from current invertebrate research projects in Yellowstone (Christianson, pers. commun.). Postfire research has been initiated to gather baseline data on invertebrate composition within different burn treatments (Lavigne, 1989; Lowrie, 1989). However, without the prefire database on invertebrate populations, post-fire research cannot make accurate predictions on recovery rates, interactions between species, or recolonization events (Christianson, pers. commun.).

Community studies has been a minor part of past invertebrate research projects. Of approximately 67 principal invertebrate research studies, only 11 ~~projects~~ involve^d multiple species interactions and 10 ~~others conducted~~ preliminary community level research (Table 3). Of the ten studies related to community processes, three were related to pest management and control (Johnson, 1952; Myers, 1960; Despain, 1983), and three ~~others~~ ^{to} ~~concentrated on~~ specialized communities such as thermal

environments (Dewey, 1969; Fischer and McClelland, 1983; Collins, 1975; Mansbach, 1986). The remaining studies gathered baseline order/family data (Lowrie, 1989), multiple order/species data including two postfire recovery efforts (Lavigne, 1989; Lowrie, 1989), one inventory study (Baggley, 1934) and one incomplete effort still in progress (Perkes, 1987). These studies examine the distributions and population sizes of various insect groups in different burn treatments.

In sum, the baseline invertebrate research performed to date in the park provide information for future community level integration. The baseline studies and the preliminary research on distinct habitat units such as the thermal areas, provide an important base upon which an understanding of community structure can be built. Once the basis for community structure has been determined, researchers can make recommendations for inventory or monitoring species as indicators of community stability. A leaf borer may be an important indicator of the health of an aspen community, while the presence of mound building ants in sagebrush may indicate a healthy seedbank and a strong community resilience to perturbations. Without the ^{Knowledge of} ~~the~~ ^{inherent} interactive components controlling population numbers and density ~~inherent to~~ ⁱⁿ a community system, the important keystone species controlling populations could be overlooked.

Aquatic studies

Aquatic studies have focussed primarily on the immature invertebrates since they are an important prey base for Yellowstone's fisheries. Since the fishery resources are heavily ^{Public-?} used and have active political support groups, a large number of studies on the aquatic invertebrates have been completed (Table 4). These studies detail the different aquatic communities and the impacts of different fishery resources on the invertebrates. However, the interactions between the different types of immature invertebrates, and the effects of fish predation on the mature insect population should be studied. The interface between the aquatic and terrestrial habitats--for the different lifestages of insects--along with riparian zones is a potential area of research and monitoring for indicator species (Mahoney, pers. commun.).

Pest Studies

Pest systems have been studied primarily by the Forest Service and the state agencies of Montana and Wyoming. Gypsy moth studies have been on-going for several years co-sponsored by several agencies (Tunnock, 1975; Forest Service, 1977-present; Sweaney, pers. commun.). Mountain pine bark beetle systems have ^{? what does this refer to?} been well documented along with the effects of spraying, the impact of pesticides, and the use of biological controls (Table 5). The Forest Service (1977-present) has been the principal investigator on many of the beetle control studies; however, Weigert (1975-78) and Romme (1977) did some preliminary work on

the response of trees to beetle attack, and the historical perspectives on beetle infestations. Since beetle outbreaks are still monitored in the park, the use of biological controls such as predators, competitors, or parasites is an important consideration for future research, inventory and monitoring.

Synopsis of Invertebrate Records

Park Invertebrate Collections

The park's terrestrial invertebrate collection dates to the 1930's and is presently in need of revamping and updating. Most of the collection has not been inventoried, nor are the specimen names ^{in accord with taxonomic nomenclature.} ~~up to~~ current ~~scientific standards~~. The lepidopteran collection, for example, dates from the early 1930's and many of the specimens are in poor shape, ^{and} ~~are~~ missing tags, and information on the specimen's field location (Lutz, pers. commun.). ^{In order} For the invertebrate collection to be ^{fully utilized} ~~used~~ as a scientific tool, the collection needs to be updated, re-housed in an accessible location, and properly stored in marked boxes in storage cabinets.

Park Permit System

The process of extracting information on invertebrate research completed or initiated in the park can be difficult with the current format of Annual Investigator's Reports and the University of Wyoming Summary Bulletin (1988 edition). An

improved tracking system could greatly enhance the informational content of the permits, and allow park researchers and managers to make better use of research results to formulate decisions. When new studies are initiated, the tracking system could provide investigators with an important information base, and would allow them to address collection needs. Such a system would also help insure that information and specimens are returned to the park or otherwise properly repositied.

Published Results

There are a limited number of published results from studies within Yellowstone. Many studies were initiated as part of a graduate program (Bowser, 1986), or for personal interest of the principal investigator (Sun, 1988). The studies represented in the scientific literature include taxonomic references (Alexander, 1943; Burger, 1974; Buschinger, 1974), life history and distributions (Kuenzel and Wiegert, 1977), and multiple species evaluations (Collins, 1975; Collins, 1977; Collins, Mitchell and Wiegert, 1976).

The published results show that within Yellowstone National Park, studies tend to focus on single species systems with information on taxonomy, life histories, and distributions of the selected species. There tends to be limited information on communities of insects found in a particular habitat type with the exception of thermal and aquatic systems (Collins, 1975). For example, there is ample information on the mosquitoes of wet

meadows (Nielsen, 1982), but none on other insects co-existing with the mosquitoes or even act as predators or prey for different phases of the life cycle of the mosquito (Nielsen, 1982; Wiegert, 1974).

There is good information on the thermophilic invertebrate communities including details on the predator-prey interactions, inter- and intra-specific competition, limitations in habitat use, and niche sizes and breadths of the component species (Collins, 1975). The information obtained from the thermophilic communities required several cases of manipulation (the removal of all individuals on a particular algal mat--Wiegert, 1975), and long-term studies with several key investigators spanning a ten year period (Wiegert, 1970-80). The complete study results include detailed descriptions of the habitat niches of each species within the thermal system, along with predation and competition effects on the habitat and on the principal species (Collins, 1975-77).

Baseline data collections along with preliminary community research have started recently with the present emphasis on postfire habitat recovery. The role of the invertebrate is critical to how fast and well an ecosystem responds to a perturbation such as fire. The postfire research efforts on the invertebrate fauna concentrate on gathering data on individual numbers, group representation (Lavigne, 1989; Lowrie, 1989), species and generic diversity (Lavigne, 1989). Since prefire invertebrate data was limited, these studies concentrate on the

distributions and population sizes of various invertebrate groups in different burn treatments (Christianson, pers. commun.).

Conclusions

The current practice of listing invertebrate species names, taxonomic distinctions, population numbers, and locations in the Annual Investigator's Report should not be the extent of the records of invertebrate research within Yellowstone. For management to use invertebrate data, there should be additional information applicable to particular habitat types found within the park. For instance, understanding the interactions of arthropod predators and prey within mature lodgepole pine habitat. These interactions provide important clues on the control of the bark beetle, or other economic insect pests.

Studies defining an invertebrate community within a particular habitat type or examining the controls of population densities and species diversity are the most useful for long range inventory, monitoring, and resource planning. The stability and resilience of these communities to large scale perturbations is a crucial part of understanding the Yellowstone ecosystem.



Table 1. Single Species/genus Research Projects listed in chronological order.

<u>Author</u>	<u>Species/genus or family</u>	<u>Year</u>
Alexander, C. P.	Tipulidae: sp	1943
Rees, D. M., F. C. Harmston	Culicidae: sp	1948
Anderson, J. R.	<u>Haematobosae alcis</u>	1974
Burger, J. F.	<u>Musia autumanalis</u>	1970
Buschinger, A.	<u>Formicoxenus hirticornis</u>	1974
Collins, R.C.	Simulidae: sp	1989
Dewey, J. E.	<u>Ephydra thermophila</u>	1969
Evans, H. E.	Scoliidae: sp	1961
Kuenzel, N. J.	<u>Tachytrechus angustipeanis</u>	
	Polichopodidae: sp	1977
Mills, H. B., W. L. Jellisons, G. M. Kohls	Siphonaptera: sp	1943
Nielson, L. T.	<u>Aedes evoles</u>	
	Culicidae: sp	1982
O'Neill, K. M.	Hymenoptera: Sphecidae	1986
Sun, S.	<u>Dananus plexippus</u>	1988
Wiegert, R.	Odonata: sp	1979
Ybarrondo, B.	Tropisternus sp	1989

Invertebrate index list from Yellowstone Park collection permits (through June 30, 1989) and the University of Wyoming National Park Service Research Center summary (1988).



Table 2. Multiple Species/order Research Projects listed in chrononlogical order.

<u>Author</u>	<u>Species/order</u>	<u>Year</u>
Armitage, K. B.	Riffle insects	1953
Burger, S. F.	Diptera: Rhagionidae	1966-77
Bartow, D. H.	Coleoptera, Diptera	1970
Mitchell, R., R. G. Wiegert	Paracoenia: Ephydridae	
	Partnuniella: Hyarachnellae	1971
Wiegert, R. G.	Acranids, Ephydridae, parasitic flies	1979
Collins, N. C.	Diptera: Ephydridae	1975
Wheeler, G. C.	Formicidae	?1980
Resh, V. H. and Barnby	Hemiptera: Saldidae, Diptera: Ephydridae	1984
Bowser, G.	Lepidoptera	1986
French, F. E.	Chrysops, Hybomitra	1986
Mansbach, A. C.	Lepidoptera, invertebrates	1986
Whitcomb, R. F.	Flexamia, Laevicephalus	1986
	Homoptera: Cicadellidae	

Invertebrate index list from Yellowstone Park collection permits (through June 30, 1989) and the University of Wyoming National Park Service Research Center summary (1988).

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Table 3. Baseline and Community Level Research Projects listed in chronological order.

<u>Author</u>	<u>General Topic</u>	<u>Year</u>
Baggley, G. F.		
M. Barrows	Forest insects	1934
Johnson, P. C.	Forest insects	1952
Myers, M. W.	Forest insects	1960
Dewey, J. E.	Seed and Cone insects	1969
Despain, D.	Forest insects	1982
Fischer, W. C., and		
R. B. McClelland	Cavity nesting birds	
	and associated insects	1983
Mansbach, A. C.	Invertebrates	1986
Lavigne, R. J. and		
J. Lockwood	Invertebrate postfire	
	response	1989
Lowrie, D.	Invertebrate postfire	
	communities	1989

Invertebrate index list from Yellowstone Park collection permits (through June 30, 1989) and the University of Wyoming National Park Service Research Center summary (1988).



Table 4. Aquatic Research Projects listed in chronological order.

AQUATIC STUDIES

<u>Author</u>	<u>Species/genus</u>	<u>Year</u>
Forbes, S.A.	Aquatic insects	1893
Muhkowski, R.A.	Ecology	1929
Hazzard, A.S.	Aquatic insects	1937
Berry, S.S.	Mollusks	1952
Stillman, B.S.	Mollusks	1952
Armitage, K.B.	Riffle insects	1953
Coleman, R.W.	Dipetera	1953
Kenk, R.	Planarians	1963
Davenport	Aquatic insects	1972
Bergerson, E.P., W.J. McConnell	Aquatic insects	1973
Hjortsberg	Sport fishing	1974
Creel, G.C.	Gastropods	1978
Newell, R.L.	Aquatic insects	1977
Roemhild, G.	Trichoptera	1982

Invertebrate index list from Yellowstone Park collection permits and the University of Wyoming National Park Service Research Center summary (1988).



Table 5. Pest Research Projects List in Chronological Order.

<u>Author</u>	<u>Species/genus</u>	<u>Year</u>
Evenden, J.C.	Defoliation	1923
Eaton, C.B., H.A.		
Jaynes, J.M. Muiry		
	Spruce budworm	1948
Terrell. T.T.	Spruce budworm	1951-61
Davis, J.M., D.A.		
Isler, B. Maksymiuk,		
T.T. Terrill	Spruce budworm	1957
Isler, D.A., B.		
Maksymiuk	Spruce budworm	1958
Denton, R.E.	Spruce budworm	1960
Billings Gazette	Bark Beetles	1972
Livingston Enterprise		
	Bark Beetle	1972
Fleming, M.D.,		
R.M. Hoffer	Southern pine beetle	1974
Hamel, D.R., M.D.		
McGregor, M.J. Berg		
	Mountain Pine Beetle	1975
Johnson, P.C.	Spruce budworm	1975
Forest service	Mountain Pine beetle	1976
Romme, W.	<u>Dentroctonus ponderosae</u>	1980?
Sweaney, J.	Gypsy moth	1980-
Despain, D.G.	Insects/diseases	1983
Tunnock, S.	Gypsy moth	?
YNP	Silver fish	?

Invertebrate index list from Yellowstone Park collection permits and the University of Wyoming National Park Service Research Center summary (1988).



CHAPTER TWO

Theoretical Approaches for Invertebrate
Research and Monitoring.

Overview

Invertebrate research in the park has concentrated on single species systems with taxonomic definitions, population sizes, and general distributions. For park managers and staff to use the invertebrate information in designing management objectives, invertebrate research should concentrate on systems that integrate with other park resources. Community level studies examining the interrelationships between invertebrates, plants, and animals would be useful to understand and interpret the stability of an ecosystem, or the ability of the system to recover from a perturbation (resilience). In this chapter, theoretical definitions for communities, community structure and component communities will be discussed emphasizing the invertebrate's role within an ecosystem. In the following definitions of communities, remember that the unit of study is the invertebrate--a small organism with a large number of generations per year. These organisms are easily manipulated, and complex community relationships can be determined over a relatively short period of time. In contrast, vertebrate community systems have fewer generations, and are subject to stronger political influences than spineless ones (Norton, 1986).

Finally, the higher the number of trophic levels, the more

complex the system (Price, 1983; Norton, 1986). By examining the role of the invertebrate community by each trophic level, simple relationships can be charted. Therefore, managers should have a strong understanding of ecological and community structure theory to identify indicator species, and direct future research objectives.

Ecological Community Theory

Ecological community structure is an important element in any ecosystem. Yellowstone can be regarded as consisting of a series of communities defined by habitat, physical parameters, or timing. How each particular community responds to a perturbation helps managers understand the stability and resilience of the ecosystem as a whole.

Ecological communities can be defined several different ways. A community can be described as a group of populations of plants and animals in a given location, or as an assemblage of species populations which occur together in space and time (Magurran, 1988; Bagdonas, pers. commun.). A community can also be viewed as a series of relationships between the component species (Price, 1983). For example, a community can consist of an array of guild relationships (animals utilizing similar resources) or as a series of predator/prey relationships (food webs or trophic level analysis; Pianka, 1983). A community can also be defined by the interactions among species forming these distinctive guild clusters. The interactions regulate species diversity through

the processes of competition and predation (Forman and Godron, 1980). This view of ecological communities gives communities a structure beyond a simple assemblage of species occurring in the same location, and that structure should be understood before the whole community is examined (Pianka, 1983).

Community structure

Community structure is responsible for the numbers and kinds of species within the community (Denno, 1983). The structure of the community is defined by the complex interactions between members and the community properties emerging from these interactions (Pianka, 1983). With the interactions defining the associations within the community, any given community can be broken into a series of component communities (Price, 1983). A component community is a subunit of a community--defined as an assemblage of species associated with some micro-environment or resource (Price, 1983). A tree hole or a rotting log within a subalpine fir community could be considered as a component community within the subalpine fir habitat type of a given age. Community structure can then be described as a complex mix of component communities interacting to varying degrees (Price, 1983).

Component communities are an important concept to stress to resource managers as an identifiable smaller segment of a compound community (Price, 1983). For example, a study on the invertebrate community within mature lodge pole pine stands (LP3)

is easier to identify and study than a study of the invertebrates within lodge pole pine stands of any age. A component community is simpler than a compound community, and thus can be isolated and thoroughly studied within a reasonable time frame. A rotten log as a component community has fewer environmental variables, and more specialized species than the larger subalpine fir community type. This simplification allows researchers to focus on specific interactions within a selected community by reducing environmental heterogeneity (as the environment becomes more complex, more species are likely to co-exist because there will be more available ecological niches--Price, 1983). Within a component community such as the rotten log the number of ecological niches are limited and the complexity of interactions is limited. With the rotten log example, the relationships between different bark boring beetles, parasitic wasps, and ants can be isolated, as compared to the possible number of invertebrate interactions within subalpine fir habitat. Relationships discovered by isolating component communities can be expanded upon to examine the interactions within the greater habitat type. These component systems can be integrated at a later date once the analysis of organizational processes such as predation, competition, and specialization, is completed (Price, 1983).

The analysis of component communities within greater compound communities provides the park with an important missing link. The existing single species studies and multiple species

studies can be used to define some potential component communities for future examination. The incorporation of pieces of the puzzle for each habitat type on a step by step basis can be handled as research dollars and priorities fluctuate.

Indicator species

Species of special concern are those species identified in the park resource management plan, or through the federal List of Endangered and Threatened Species (although there is no currently agreed definition of special concern). For the invertebrates, a species of special concern could be also be regarded as a indicator species within as community. An indicator is a species, or guild of species controlling species diversity within a community (Pianka, 1983; Forman and Godson, 1986). These indicators species can be predators such as a parasitic wasp, or the Tachyoneus flies in thermal systems, that control the population densities of selected prey species through predation (Kuenzel, 1977). In communities with limiting resources, such as thermal algal mats of a specific temperature range, a predator can control a prey species population density and distribution (Collins, 1975).

Yellowstone managers can expand this definition of indicator species to identify species for monitoring purposes. For example, an indicator of the health of selected aspen groves may be the density of leaf borers. The condition of the northern range may be contingent on the grasshopper biomass density

(Frank, pers. commun.) or the levels of pine bark beetle outbreaks may be assessed through examining predators such as parasitic wasps.

The identification of indicator species is contingent upon understanding their role within the component community. Researchers should identify the role of selected indicators and their expected density based on interactions within the community. For example, the Pardosa spiders may be important predators of the wolf spider group (Lycosidae), but they may be rare or highly dispersed within any given community. Other potential indicator species may only be present on alternate years, with population numbers that fluctuate wildly. A vertebrate example would be the rare sightings of wolverines or bobcats within the park. As top order predators, these species may have a low expected density--population numbers may be less than ten for the ecosystem. However, these species, like the sphinx moths of mature fir habitats, are indicators of habitat types or prey population densities (rodents in some cases).

Invertebrate indicator species should be easily identified by field personnel, and common enough for population and monitoring estimates. The identification of indicators should be based on their ability to control species diversity or density within a given community or habitat type (Norton, 1986).

Conclusions

A basic understanding of community ecology and theory is important for all park managers. The invertebrate world operates on a scale much smaller than the vertebrates, and to understand the controlling forces on invertebrate populations, the scale must be adjusted to look at communities. In the past, the park has been able to focus on a particular species and use that species as a pivotal point for a series of studies. However, for the invertebrates, a single species is generally not of interest, yet the role of a species within a greater community is.

The park should acknowledge the important role of invertebrates within an ecosystem through improving the current management objectives. Community ecology is one important way to integrate the invertebrate role into management objectives. Each study type represents a piece of a jigsaw puzzle, and the key to understanding invertebrates is putting those pieces together. The whole represents the roles of each species, and component communities within a greater habitat or community. An understanding of the Yellowstone ecosystem hinges on an understanding of the role of invertebrate communities on the environment.

CHAPTER THREE

Future Program ObjectivesHierarchical Key**Overview**

Invertebrate work in the past has concentrated on a wide variety of predominately single species studies. Future work in the field should shift from the single species emphasis to cover a broad array of interactions. To help the park direct future invertebrate research efforts, a committee was formed consisting of park personnel and university professors. The committee met on September 20, 1989. Participants included Tim Christiansen (~~University of Wyoming~~)^{and}, Karolis Bagdonas ^{of the} (~~University of Wyoming~~)^{and}, Tom Olliff ~~(NPS-Yellowstone)~~, Rich Klukas ~~(NPS-Yellowstone)~~, Marilyn Lutz ~~(NPS-Yellowstone)~~, Jim Sweaney ~~(NPS-Yellowstone)~~, Stu Coleman ~~(NPS-Yellowstone)~~, and Gillian Bowser ^{of} ~~(NPS-Yellowstone)~~. The committee defined park invertebrate needs and examined the present state of invertebrate research and collections.

Several conclusions regarding permit systems, and future invertebrate research were reached. To improve data retrieval from the current permit system published data should be kept in research files, along with species lists and specimen locations. Researchers removing specimens from the park should notify park personnel of the repository location and a tracking system

installed to insure the safe return of all specimens to the park archives.

Future invertebrate research should be directed towards fulfilling needs ^{of} in the park's database. ^{In order to systematically} ~~To identify these holes in~~ ^{research needs} ~~a systematic manner~~, the committee proposed using a hierarchical dichotomous key design. The proposed key could be used to sort ^{analyze all} ~~through~~ research proposals and identify where a particular study falls in relation to past work. In this section, the hierarchical key will be discussed in detail, with relevant management examples.

Hierarchical Key

Invertebrate research could be organized into a framework identifying priorities and current needs. The hierarchy is based on levels of complexity ranging from the simplest type of study, like the examination of a taxonomic order, to the more complex species interactions and multiple order studies. The proposed hierarchy has six major levels, each with a series of subdivisions and branches similar to a dichotomous key. Each level represents a part of a potential study plan, where the first level decides what order or species of insects to look at; the second level, where in the park to do the study; and the third, what types of interactions--or level of intricacy to examine.

Levels within the hierarchical key consist of a series of subdivisions, which allows studies to be listed along several branches within a variety of subdivisions. A subdivision consists of types or variations within the greater level. Each branch within the subdivision represents the particular niche within the given type. For example, the environmental level consists of subdivisions representative of the major recognized habitat types with branches for different age classes. The branch for pine bark beetle would be environment (level), Mature Lodgepole pine (subdivision), and LP2 or LP3 for the stand age (branch).

The hierarchical key would allow each research project to be traced to a particular branch identifying the type of study, the theoretical base, and other studies on the same organism. The key would also identify the parks invertebrate records deficiencies, and potential areas for future research and monitoring. The key would organize park invertebrate research by arranging studies along the branches in the order of complexity. More complex studies such as those dealing with interactions between several orders of invertebrates would appear in several places while descending through the hierarchical key. Conversely simple studies would fall out at the earlier branches or levels within the key since their applicability to a wider theoretical base would be more limited. A study detailing the species of crane flies within Yellowstone would fall on the branch genus within the level order and subdivision taxonomy, for example, but

would not appear in the environment level at all. A study of the interactions between ephydrid flies and their predators would appear on the appropriate branches under order, within the sublevel thermal under the environmental level, and within the interaction level on the branch of predator/prey interactions. In this manner, all studies could be weighed and areas for future concentration on invertebrates identified.

The six major levels--order (I), collections (II), special emphasis (III), environment (IV), baseline (V), and interactions (VI)--identify different management and research needs. Each level will be discussed under the following sub-sections along with the decision making processes inherent to the proposed hierarchical key design. Revellent examples of past studies and proposed studies are demonstrated throughout. Recommendations for specific studies will be given in the conclusions.

Order (I)

The first level within the hierarchical key is the taxonomic order of the organism. This level assumes that most of the unsolicited research is submitted for a particular organism. By using order as the first level on the hierarchical key, the researcher can easily ascertain the extent of previously performed research on that particular taxonomic order.

Within the order level, there are three subdivisions: suborder (Ia)--including family and genus, distribution (Ib), and

taxonomy (Ic). Each subdivision indicates which orders have been studied in the past, to what extent specimens were examined, and where distribution data were included (Bowser, 1986; Nielsen, 1982). The order level attempts to separate studies examining large numbers of individuals (Lowrie, 1989; Lavigne and Lockwood, 1989) from other studies concentrating on a particular order, describing the taxonomic or morphological details (Alexander, 1943; Buschinger, 1974).

Suborder (Ia). Studies providing species lists to the park without information on collection sites or taxonomic details would fall within the suborder subdivision. Studies with missing location records, or incomplete data without accompanying habitat, distribution, or taxonomic information (French, 1986; Whitcomb, 1986), along with ongoing studies where data have not been analyzed, or incomplete annual investigators reports were filed, would all fall within the suborder subdivision (Mansbach, 1986; Bartow, 1970).

The suborder division would be an important indicator of the current status of the park's invertebrate knowledge. The listing of studies within the suborder division would help identify potential areas of research. For example, coleoptera (beetles) is the largest suborder of insects, yet only one genus within the order (Dendroctonus-pine bark beetles) has been studied in any detail (Romme, 1977; USFS, 1970-80). Since there are several different varieties of bark beetles (round headed and flat

headed), along with a host of predaceous beetles (long-legged, and scarab), the coleoptera are severely under-represented in study proposals.

Distribution (Ib). Studies addressing park-wide population sizes and locations, including long term monitoring, would fall into the distribution category. Population sizes, or species lists should be included within this category if the study includes location data. A study of gastropods of Yellowstone where only the species names were listed (Creel, 1977) would fall within the suborder (Ia) level. Conversely a study of lepidoptera with locations listed for the specimens collected or observed, would be a distribution (Ib) level study (Bowser, 1986).

Distribution studies can also include studies detailing a particular habitat distribution. Collins (1975) and Resh and Barnby (1988) examined the distributions of selected members of ephydriidae (Diptera) on the algal mats of thermal areas (these studies could also appear further down the key on the environmental level).

Taxonomy (Ic). Studies describing the life history or physical characteristics of a species without addressing the locations within the park would fall into the taxonomy (Ic) subdivision. Studies on the details of anatomy or morphological

comparisons between two sympatric species would be listed under taxonomy (Alexander, 1943; Buschinger, 1974; Anderson, 1974).

Collections (II)

The collections level provides a tracking device on the status of the park invertebrate collections. The present permit system requires researchers to return any specimens to the park for archive purposes. The present permit system stipulates that specimens can be retained by institutions, but must be recorded in a permanent file and be made available to the public (Blacker, pers. commun.). Park Service guidelines (36 CFR2.5g) requires that all researchers provide the park service with cataloging data for specimens collected in the park and retained--whether for Park Service storage or in approved repositories (Blacker, pers. commun.). However, there is no current method of enforcing that stipulation, and the invertebrate collections have suffered accordingly. The park archives should have at least the collection records, species lists, or the specimens themselves as mandated by law (36CFR2.5g). This information should be logged in the archive system for the Automated National Catalog System (ANCS) and verified for specimens to be of any value to incoming researchers. Specimens without the accompanying collection records or species lists are of limited use to the park staff or independent researchers.

The collections level would help reaffirm the permit requirement that all specimens be returned to the park, and

identify archive needs and current invertebrate collection status. Currently, the invertebrate collection should be verified by specialists, and collection records updated. Species appearing in the collection not currently listed in state records are valuable and should be cataloged. These specimens should be verified, and accurate records of collection location and dates are critical.

The collection level has three subdivisions: collection needs (IIa), collection accession (IIb), and specimen tracking (IIc). Each subdivision attempts to systematically address the invertebrate collection's problems as identified by the invertebrate committee.

Collection Needs (IIa). Collection needs provides the park and incoming researchers with a list of the current specimens within the park collection. Each order could be identified with a code indicating the status of specimens within the collection. For example a possible code could be:

1= Collection complete. New species and state records require a specimen, voucher lists for common species.

2= Collection incomplete. List indicates the specimens in good condition, all other specimens must be verified and cataloged through the park archives.

3= No current collections. All specimens collected must be housed in park archives.

The coding system would help each researcher know the status of their chosen invertebrate within the park's archive system. However, even if the park has a representative specimen, the researcher must supply cataloging data for all specimens retained in repositories other than the park's. By identifying the park's collections needs to incoming researchers, the park could take advantage of the researcher's expertise to gain valuable archive specimens.

Collection Accession (IIb). As the park's current invertebrate collection is accessioned into ANCS, each specimen must be verified and checked. Invertebrate specimens should not be accessioned until verified by an expert on that taxonomic group. Specimens requiring verification should be sent out to the proper institutions in a timely manner with documentation tracing where and when the specimens were sent. Incoming researchers could then assess the validity of the collection based on the accession code, and verification records. Verified specimens are an important research tool, however unverified specimens accessioned into the archive system can lead to grave errors on species lists, and state records.

The above recommendations would require documentation tracing the verification process, along with outdated names as

annotations to older specimens. Accession records should be generated as each study is initiated through the proposed key.

Specimen Tracking (IIc). A system for tracking invertebrate specimens housed outside of the park archive system is critical, and could be accomplished with improvements to the present permit system. Specimens leaving the park should be tracked with documents indicating the permanent housing location, the field locations of the specimens, and species lists for the park records. Valuable specimens such as state records or endemic species should be housed in the park. However, when exceptions are made, detailed field notes should be left with the park records along with the permanent housing location. All field notes collected in association with specimens gathered in the park is considered NPS property and should be included with the completed catalog cards.

Each study should document where specimens are sent and when they are expected to return. Reasonable time limited should be set on all specimens leaving the park, and follow-up procedures initiated if the time frame is exceeded.

Special Emphasis (III)

The special emphasis level covers all endangered, threatened and currently listed species of special concern. Within the special emphasis level, there are four subdivisions: species of special concern (IIIa); indicator species (IIIb); species

important to other vertebrate species (IIIc); and biological controls (IIId).

Species of Special Concern (IIIa). These species would be identified on federal or state threatened and endangered lists, including pests and species identified as special concern in the resource management plan (note that there is no agreed definition for special concern). However, invertebrates suffer from a poor public image, and a good deal of vertebrate chauvinism (Norton, 1986). Public perception of invertebrates as lower life forms and unable to suffer, leaves the invertebrate below possible consideration (Norton, 1986). The only insects to rise to the public's eye are the pests that cause the aesthetic degradation of forests, or the harassment of backcountry visitors.

Unfortunately, the federal registers are equally at fault as public perception with very few insects from the temperate zone appearing on the federal endangered species list--despite the recent extinction of the Xerces blue butterfly in the west (1960's). Without a change in public perception towards the invertebrate, federal and state registers will continue to under-represent endangered invertebrates. The presence of this level (IIIa) in the proposed hierarchical key is to emphasize the importance of identifying rare and endemic species potentially belonging on the federal endangered list.

Indicator Species (IIIb). Species identifying particular habitat types or conditions could be used as indicator species. For example, certain species of sphinx moths (Lepidoptera: Sphingidae) only occur in healthy mature lodgepole pine forests. The relative abundance of such a moth may be used as a relative measure of the health of various mature lodge pole pine stands within the park.

Indicators could also be species that survived major habitat changes. Pleistocene relics are species left over from the glaciation of Pleistocene times in high mountain areas, or from the various ice ages (Mani, 1968). These species tend to have profoundly discontinuous distributions usually occurring in small isolated population pockets (Mani, 1968). Pleistocene relics help describe prehistoric distributions of organisms with limited representation in the fossil records. Such relics found within Yellowstone could be important clues to past habitat and ecosystem types. For example, small isolated pockets of the Gillette's Checkerspot (Hypodryas gilletti)--a butterfly endemic to the Yellowstone region--occur throughout the Rocky Mountain region (Bagdonas, per. com.; Williams, per. com.). The distribution of these pockets suggests a previous distribution of the butterfly's preferred wet meadow habitats along the rocky mountain chain. With the incoming ice age, small pockets of these wet habitat types survived in the higher altitude, and the butterfly presently survives in these pockets.

Species Important to Vertebrates (IIIc). Invertebrate species affecting the distribution or population of vertebrates important to Yellowstone Park management should be separated from other invertebrates studies. The effect of an invertebrate on a vertebrate population could have broad reaching conclusions. The grasshopper (Orthoptera) could be a significant grazer on the northern range, for example, and directly compete with the elk populations for forage. Conversely, miller moths (Lepidoptera: Noctuidae) are an important prey item for grizzly bears, which are federally endangered species, and thus could significantly effect summer bear distributions. Recent work on the miller moths has shown that the distribution of bears--both black and grizzly--was influenced by the distributions of the moths on the high elevation plateaus, as the bears congregated to feed on the high protein moth aggregates (Bagdonas, pers. commun.). A study examining the distribution of miller moths in high density aggregates could have far reaching conclusions on grizzly bear distributions (Bagdonas, pers. commun.).

Biological Control (IIId). A biological control species is a predator or competing species of a target pest species affecting the target's distribution and population levels. Species that could be used for biological controls of recognized pests within Yellowstone include mermithid worms for mosquito control (Nielson, 1982), parasitic wasps and spiders for beetle control, and ladybugs for mite and aphid control.

Environment (IV)

The environment level refers to biophysical components such as plant community types (recognized by vegetation mapping techniques or GIS systems), geological features (slope, aspect), and environmental features (xeric, mesic, etc.). Within the environmental level there are three major turns or sublevels: thermal areas (IVA), alpine areas (IVB), and perturbations (IVC); and a series of subdivisions for each major habitat type within the park (IVa-h).

Thermal Areas (IVA).

Thermal systems have been studied extensively in Yellowstone since those habitats are a unique part of the Yellowstone ecosystem. Thermal studies include hot pools, thermal runoff channels, and geyser basin areas (Collins, 1974; Wiegert, 1970-79). Since the thermal nature of the areas alters the growing season, as well as the physiological adaptations to the temperature and acidity, these studies must be separated from other invertebrate research (Wiegert, 1970). Furthermore, the presence of endemic thermophilic organisms within the fragile thermal basins, may lead to collection restrictions.

Thermal area research is an important area of emphasis in Yellowstone. The beautiful colors associated with the algal mats of the thermal basin have a complex ecosystem consisting of

several orders of bacteria, algae and invertebrates (Collins, 1974). Understanding the ecology and interdependence of these organisms is important for the preservation of the thermal systems within the park. The fragility of the algal mats, and the birth and decay of thermal pools is all intertwined with the invertebrate community that grazes the algal mats, and all the associated invertebrate predators (Collins, 1974).

Alpine Ecology (IVB)

The alpine ecology sublevel allows work concentrating on the alpine systems to be divided from work on other habitats without the environmental stress of the high altitude. Since alpine ecosystems tend to contain more relic populations and species than low elevation areas (Mani, 1968), this sublevel could help identify potential areas of research that could uncover relict populations or other rare species.

Perturbations (IVC)

The perturbation sublevel divides studies concentrating on disturbances to the environment from other types of studies. Perturbations are defined as changes within an ecosystem altering the environmental regime. Large scale events such as the 1988 fires could be the focus of studies addressing the effects of habitat change on invertebrate populations. For example the postfire invertebrate research examined burned and unburned plots in sagebrush and lodgepole pine habitat (Lavigne, 1989; Lowrie,

1989). The focus of this research design was the effects of fire on invertebrate populations through the change within a habitat type--not between sagebrush and lodgepole pine habitat differences--although the question could be addressed. Since the premise of perturbation research differs from other types of research--the effect of the perturbation being paramount in the study design--the perturbation parameter should be considered before the environmental sorting.

Habitat Types (IVD). The environmental level is further divided into the major habitat groups such as lodgepole pine (IVDa)--with a branch for each age class (LP1=IVDa1, LP2=IVDa2, etc.), subalpine fir (IVDb), sagebrush (IVDc), etc.. Each habitat branch has further divisions for slope, aspect, moisture and age of stand. Studies describing habitat details would appear further out on a habitat branch than one with just the cover type.

Baseline (V)

Species diversity and relative population abundance within a defined habitat type represent baseline data for the invertebrate populations. Studies examining baseline data on the relationships between several orders of insects are critical to understanding community concepts. Within the level of baseline

data there are a series of sub-levels: relative population abundance (Va), species diversity (Vb), and niche relationships (Vc).

Relative Population Abundance (Va). Populations can be compared according to the relative importance within a given habitat type (Norton, 1986). The relative abundance of different populations allows a measure of the representation of common versus rare species based on numbers of individuals. Relative abundance is a common way of studying diversity when species identification is uncertain. However, relative abundance does not adequately represent rare or highly dispersed species such as top level predators (Norton, 1986).

Species Diversity (Vb). Species diversity is a mathematical measure used to describe the relative presence of different species within a community (Pianka, 1983; Pielou, 1977). A community can be described as simple or complex--implying numerous interactions of various kinds (Norton, 1986) depending on the level of species diversity. By using a measure of community complexity, such as species diversity, managers can compare communities between different habitats and over a period of time. Thus changes in communities can be charted through changes in species diversity.

Diversity can be described by either the Shannon Weaver Index or other similar mathematical functions as a logarithmic

relationships between the number of individuals of a given species and the total number of individuals in the population (Pianka, 1983: Pielou, 1977). There are three basic kinds of diversity: Within habitat diversity, between habitat diversity and total diversity (Norton, 1986). The three different types of diversity can be distinguished based on the use of ecologically distinct boundaries. For example, within habitat diversity would require the ability to distinguish between energy flows into and out of the particular habitat (Norton, 1986). However, in some instances, such as thermal ecosystems, the system may be isolated enough that an assessment of the flows across habitat boundaries can be made. Therefore the more practical measure for resource managers is the total diversity concept, which is a function of within habitat and between habitat diversity, and does not require sharp ecological boundaries (Norton, 1986).

Diversity allows population comparisons to be made by using an index that weighs control populations to treatments or compares between habitat types. By using a mathematical expression for species diversity, the over-representation of a locally abundant species (such as ants from a colony) can be corrected. For example, species counts based on the presence of identifiable species (an important qualifier for invertebrate research) do not reflect the complexity inherent in ecosystems (Norton, 1986). To measure the dependency and complex relationships between abundance of different species, diversity indices are used.

Niche Relationships (Vc). Species diversity, relative abundance and niche relationships allow one to measure the strength of a community through its ability to withstand perturbation, or to maintain species diversity (Norton, 1986; Price, 1983). Niche relationships are the physical parameters used by a species within a community. For example Pardosa spiders occupy the niche of ambush predators within mature forested habitats. The spider's niche is described by its prey, the preferred habitat, and the constraints placed on the spider by competitors. Niche relationships are an important measure of ecosystem function and response. Community indices such as stability, the maintenance of species diversity (but not necessarily species composition), and niche relationships are important when measuring ecosystem function. For example, the stability of a community can be characterized by the complexity of the foodwebs, and the species interactions (Pianka, 1983). Managers could use the niche relationships to assess the ability of the system to withstand stress. A community with low species diversity, and simple interactions between the species such as the thermal algal mats, may be more susceptible to a perturbation since each species occupies a restricted niche (based on temperature, acidity and light (Collins, 1975). By using the combination of species diversity, niche relationships, and foodweb complexity, each community can be characterized along a scale useable for management decisions.

Interactions (VI)

Interactions are critical to measure when one species effects the niche relationships, distribution, or population size of another species. This effect could be precipitated through predator/prey relationships, competition, or species displacement. The common theme throughout the interaction sublevels are cause and effect relationships. Cause and effect relationships include all interactions where the presence of one species reduces or increases the population size or distribution of another species through competition, niche reduction or predation (Price, 1983).

Studies at the interaction level would be the most complex studies within Yellowstone, and represent a pivotal point in ecosystem and community analysis. Studies examining species interactions can in turn determine the role of selected keystone species--species that significantly control a system's character and functioning without necessarily being dominant in abundance, or in biomass (Norton, 1986). Since these keystone species provide information on the dependency relationships within a community, they could be important monitoring tools for managers to determine community health within a given habitat type.

Summary

Invertebrate research can be prioritized by the use of the proposed hierarchical key. The key helps identify which

areas of research are over-emphasized, and which are lacking. Figure one demonstrates the use of the key with the published research from previous studies within Yellowstone. For example, there is a preponderance of studies examining a sub-order or order of invertebrates with no further information gained (Morris, 1981; Creel, 1977; Whitcomb, 1986; French, 1986). Conversely, there are six studies concentrating on thermal ecosystems (Bartow, 1970; Collins, 1975; Kuenzeland Wiegert, 1977; Mansbach, 1986; Resh and Barnby, 1984; Wiegert, 1970-77) and none on alpine ecology. Two studies looked at species occurring in particular habitat types (Lodgepole Pine--Romme, 1977; O'Neill, 1986), and two studies examined the effects of perturbations (Lavigne, 1989; Lowrie, 1989).

Areas of particular interest to managers such as endangered species, or monitoring species were under-represented according to the hierarchy. One study examined the use of possible biological controls (Nielsen, 1982), and one proposed study would like to assess the effects of an invertebrate of a vertebrate predators distribution (Bagdonas, pers. commun.; Christiansen, pers. commun.).

Studies of higher complexity such as the interdependent species relationships important to community function are poorly represented in the existing invertebrate work. The hierarchical key shows that one study examined the aspect of predator/prey relationships within a non-thermal environment (Nielsen, 1982),

and two studies did so within a thermal system (Collins, 1975; Kuenzel and Wiegert, 1977).

In conclusion the proposed hierarchical key allows the easy identification of potential areas for future attention. The systemic sorting of studies onto particular branches allows incoming researchers and park managers to identify the current needs for invertebrate research. By developing such a tool, future research and monitoring plans can be tracked on the same chart and funding can be guided into targeted areas.

Hierarchical Key: summary outline

Order (I)

- Suborder (Ia)
- Distribution (Ib)
- Taxonomy (Ic)

Collections (II)

- Collection needs (IIa)
- Collection accession (IIb)
- Specimen tracking (IIc)

Special Emphasis (III)

- Species of Special concern (IIIa)
- Indicator species (IIIb)
- Species important to vertebrates (IIIc)
- Biological controls (IIId)

Environment (IV)

- Thermal Areas (IVA)
- Alpine Ecology (IVB)
- Perturbations (IVC)
 - Lodgepole pine (IVDa)
 - Subapline Fir (IVDb)
 - Spruce/fir (IVDc)
 - Sagebrush (IVDd)
 - Wet meadow (IVDe)
 - Dry meadow (IVDf)

Baseline (V)

- Relative abundance
- abundance (Va)
- Species Diversity (Vb)
- Indices of community
- function (Vc)

Interactions (VI)

- Predator/prey relations (VIa)
- Niche relationships (VIb)
- Keystone species (VIc)

CHAPTER FOUR

Recommendations for Future Research and Monitoring.

Overview

The following list of topics for future research was developed through the literature review on invertebrate research performed in the park, and using the recommendations of the invertebrate committee members. This list is not meant to be all inclusive, and other avenues and directions of research may be guided by future managers. However, I feel that based on the preceding discussions, several specific topics can be suggested that fit under the hierarchical concept developed in the previous chapter.

Selected Orders for Future Study

There are several orders of invertebrates that have not been studied in detail within Yellowstone. Since some of those orders are important elements of the decay processes (beetles--Coleoptera), nutrient cycling (earthworms--Annelida, millipedes--Diplopoda, centipedes--Chilopoda), or pollination and seed dispersal (ants--Hymenoptera: formicidae; butterflies and moths--Lepidoptera), the park needs to have at least some basic data on species occurrence and distribution. For example, the

scarabaeidae family of beetles are important detritivores as well as predators to some important economic pests such as the pine bark beetles. However, Yellowstone has not had a single study on the scarabaeidae. Furthermore, the Hymenopterans are important pollinators and seed dispersers and therefore critical to postfire recovery. Again, Yellowstone does not have a species list for either of these families.

Order studies are the simplest studies for the park to complete. The academic community especially in the fields of zoology and entomology is full of professors willing to work summers in Yellowstone. The park should identify the above mentioned orders as areas of interest to the park for ecosystem recovery, and basic inventory and research.

Baseline Data Collection

Baseline invertebrate research is critical to any further examination of the effects of the 1988 fires on the Yellowstone ecosystem. Two studies have begun baseline postfire research (Lavigne--University of Wyoming, Lowrie--University of New Mexico) which should be extended to cover at least two seasons. A single year of data on invertebrates is almost meaningless, and to abandon the postfire invertebrate projects after a year would mean the loss of valuable information.

Baseline research should also be extended to cover several other habitat types such as alpine, wet meadows, spruce and fir habitats. These studies should be ongoing and could be covered

with a minimum expense of personnel and time. The park should set a goal to complete an invertebrate inventory by the early 1990's. The number of environmental questions within the Yellowstone ecosystem related to alleged over-grazing, human development and fire effects are all tied to the invertebrate response as one of the primary drivers of ecosystem recovery (Norton, 1986).

Invertebrate Collections

The invertebrate collection needs to be updated and verified. The present permit system could be used as a vehicle to update the collection with the addition of a tracking system for the return of specimens to the park and the verification of specimens by experts. Priority should be placed on gaining a scientifically valid invertebrate collection accessioned into ANCS. Specimens should also be properly mounted, tagged, and fumigated by the researcher before being placed into the archives.

Endangered Species, Species of Special Concern

The park's resource management plan should be updated to include identified endangered and threatened invertebrates. The park should be surveyed for possible locations of suitable habitats for those endangered species. Close records should be kept of all specimens, especially those representing state records. For example, one visit by an expert to the lepidopteran

collection revealed five state records for Wyoming and Montana (Bagdonas, pers. commun.). Future visits to the invertebrate collection could yield more state records for other orders of invertebrates. Species representing state records, or those on federal lists should have a monitoring and identification program such as a simple sighting form for field personnel. These forms could track possible populations of rare, endangered and endemic species.

Environment Types

The park has limited information on the role of invertebrates within a particular habitat type. This information could fall under the auspices of baseline data collection, as long as the study design distinguishes between identifiable habitat types. For example, Nielsen (1973) began preliminary research on the distributions of culicidae within different habitat types. However, there have not been any further attempts along those lines.

The park could target certain environmental types as suggested areas of research for incoming researchers. For example, the high alpine tundra, or plateaus are presently suggested areas for work on the miller moths (Lepidoptera: Noctuidae) aggregations and their affect on grizzly bear distributions (Bagdonas, pers. commun.). Further work may reveal other previously undiscovered invertebrate distributions

affecting grizzly bear movements such as ants and other seed hording insects.

Alpine Ecology

The alpine ecosystem, although a minor component (<10%) within Yellowstone, is fragile and impacted by human use and nearby industrial pollutants (acid precipitation). Other changes in the environment affecting the alpine community include shifts in the timberline level, and global warming. Each of these factors could be charted through changes in the highly specialized alpine insect communities. As industrialization moves closer to the park's boundaries, a monitoring scheme for alpine invertebrates should be in place to chart the effect of the increased pollutants in the area.

Species Interactions and Community Complexity

Interactions represent the inherent complexity to ecosystem research (Norton, 1986; Christiansen, 1989). The park currently does not have studies examining the role of invertebrates interactions within the greater ecosystem, or community type. Data of this type are critical to understanding managed ecosystems and their ability to withstand human use and other perturbations (Norton, 1986).

Species diversity is also used as an index of the stability of the community (through the buffering against environmental change by increased complexity within the food chains--Price,

1975) and the relative success of management programs. For example, species diversity is often used as an index of change within a park, with the idea that the decline in species diversity is indicative of a decline in ecosystem stability (Norton, 1986; Pianka, 1983; Price, 1975). Species diversity is actually made up of an index weighing species abundance and total community size. In this context of diversity, species composition is not a factor used in the calculations and the actual species composition is not important in maintaining species diversity. For example, as the community matures over time--or approaches a climax condition, many studies show a stable state diversity, a period of time when the diversity index no longer fluctuates (Pielou, 1977; Pianka, 1983; Price, 1975). However, the composition within that community can still be in a state of flux, where for each species going extinct, a new colonizer moves in--leaving the total diversity constant.

Park managers tend to use the term species diversity to mean species composition (Norton, 1986). In this sense of the term, diversity per se is actually a representation of community evenness and not truly diversity (Norton, 1986). However, for inventory and monitoring purposes the species composition is important, although for the park to monitor invertebrate species composition, time and monies not currently available would be required. However, if the park were to use the keystone species theory, where single species could be monitored that played an important role in maintaining the community's complexity and

stability, then such a monitoring program could be cost effective.

Keystone species are not necessarily the most abundant, nor the top order predators. They are, however, a driving force behind community change or stability when the system is impacted by a large scale perturbation (Norton, 1986). For the park to choose a series of keystone species for monitoring particular habitat types, baseline data must be collected. Therefore, the implementation of an effective monitoring program for invertebrates or community change, information on the baseline invertebrate fauna is the next important step for management (Christiansen, pers. commun.).

A program on community recovery and stability should include monitoring a series of traps or collection sites, and a chart of species diversity throughout the growing season. This data would serve towards the identification of keystone species, the generation of species lists for each habitat type, and important information on ecosystem recovery. A simple study design should be formulated in such a way that field personnel could collect the data with a minimum input of time and training.

Conclusions

The recommendations discussed above are summarized in table 8. These recommendations should guide future research projects, but are no mean a comprehensive list of all of the needed invertebrate research and monitoring. The general

consensus of the invertebrate committee was that there were extensive areas of invertebrate research needed in the park. However, since invertebrate ecology is a much more extensive field than mammalian ecology with a larger array of organisms to cover, the committee feels that for park management to gain useful information on the invertebrate fauna, a comprehensive management and research plan should be addressed. Table 8 is a start towards developing a management plan and direction, along with the proposed hierarchical key.

Conclusion of Report

This document should serve towards directing statements in the resource management plan for Yellowstone National Park on invertebrates. The recommendations in this document are meant to guide resource managers in structuring a program to increase the value of invertebrate work. Invertebrates, as an overlooked component of the system may be critical to the recovery of the northern range, pivotal in the over-grazing issue, and control the life and death of the thermal systems that made Yellowstone into a national treasure. It cannot be said too many times, that the role invertebrates play in ecosystem function, and the formation of landscape ecology is one of far reaching importance.

Table 6. List of Proposed Topics for Invertebrate Research in Yellowstone Park.

<u>Level</u>	<u>Organism</u>	<u>Area</u>
Order	Coleoptera scarabidae	parkwide
	Annelida	parkwide
	Diplopoda	parkwide
	Chilopoda	parkwide
	Lepidoptera: Noctuidae Noctuniae Notodontidae Sphingidae	parkwide
	Hymenoptera	parkwide
Baseline	community (soil and surface)	wet meadows different canopy classes alpine
Perturbations	postfire samples	sagebrush lodge pole pine
Collections	Specimen updating	parkwide
Endangered, species of special concern	not yet identified	parkwide
Interactions	species diversity species composition	selected habitat types selected habitat types

Projects listed are selections from a wide array of needed research. This table is a guide for potential areas of research and is not meant to be all inclusive.



APPENDIX I

Common and Scientific Names for Invertebrate Species and Families
Studied in Yellowstone National Park

<u>Scientific Name</u>	<u>Common Name</u>
Araneida	spiders
<u>Aedes evoles</u>	mosquito
Anopheles	mosquito
	(genus)
Chrysops	biting flies
Cicadellids: Flexamia, Laevicephalus	leafhopper
Coleoptera	beetles
Culex	mosquito
	(genus)
Culiseta	mosquito
	(genus)
Diptera: Rhagionidae	flies (order)
Paracoenia: Ephydriidae	brine flies
<u>Ephydra thermophila</u>	thermal fly
Forminicipidae:	
<u>Formicoxenus hiticornis</u>	Guest ant
Gastropods	snails
<u>Haematobosae alcis</u>	Moose fly
Hemiptera: Saldidae	Shore bugs
Hybomitra	biting flies
Hymenoptera: Sphecidae	

<u>Philanthus zebratus</u>	Beewolves
Lepidoptera	Butterflies and moths (order)
Mollusks	shelled invertebrates
<u>Musia autumanalis</u>	Face fly
(bison)	
Partnuniella: Hyarachnellae	water mite
Planarians	aquatic invertebrate
Polichopodidae	
Odonata	Dragonflies
Scoliidae	digger wasps
Simuliidae	Black flies
Siphonaptera	fleas
<u>Tachytrechus angustipeanis</u>	predaceous flies
Tipulidae	Crane flies
Trichoptera	aquatic beetle
Tropisternus	aquatic beetle

APPENDIX II

Species List From Research Permits Completed In YellowstoneThermal Communities

EPHYDRIDAE (Brine flies)

Ephyrdra bruesi CressonParacoenia turbida CuranP. bisetosaLamproscatella dictaeta LoewAtissa litoralis CoreScatella stagnalis Fallen

SALIDIDAE (shore bugs)

Micracanthia quadrimarculata ChampionSaldula sp.S. comatula ParshleyS. nr. arenicola

PARSITENGONA (water mites)

Hygrobates sp.Partnuniella thermalisSperchon sp.Thermacarus nevandiensis Marshall

DOLICHOPODIDAE (long-legged flies)

Chrysotus arcuatusTachytrechus angustipennis LoewT. grandetarus Green

CHIRONOMIDAE (flies)

Paratendipes thermophilus Townes

PTEROMALIDAE (parasitic wasps)

Urolepis rufides Ashmead

Eurolepis sp.

CICINDELLIDAE (tiger beetles)

Cicindella sp.

LYCOSIDAE (wolf spiders)

Geolycosa sp.

Lycosa sp.

Pardosa altamontis

Pirata cf. maculatus

P. insularis

Schizorosa sp.

Tarentula aculeata

ORTHOCLADIUS (midge)

Bizzia setulosa

CARABIDAE (beetles)

Nebria sp.

HYDROPHILIDAE (beetles)

Hydrophilid species not identified

ELMIDAE (beetles)

Microcylloepus sp.

Non-Thermal Communities

CHILOPODA (centipedes)

various species not yet identified*

CLUBIONIDAE (spiders)

various species not yet identified

COLEOPTERA (beetles)

Dentroctonus ponderosae

D. monticula

Monochamus scutellatus Say

Pachyta lamed L.

COLLEMBOLA (springtails)

various species not yet identified

DICTYNIDAE (spiders)

various species not yet identified

DIPLOPODA (millipedes)

various species not yet identified

DIPTERA (flies)

Haematobosca alcis Snow

H. irritanus

Hybomitra sp.

Musca autumnalis

CULICIDAE (mosquitoes)

Aedes campestris Dyar and Knab

A. canadensis Theobald

A. cataphylla Meigen

A. communis DeGeer

A. dianteaus Howard

A. dorsalis Meigen

A. excrucians Walker

A. fitchii Felt and Young

A. hexodontus Dyar

A. impiger Walker
A. implicatus Vockeroth
A. increpitus Dyar
A. intrudens Dyar
A. inornata Williston
A. pioips Dyar
A. pullatus Coquillett
A. punctor Kirby
A. schizopinax Dyar
A. spencerii Theobald
A. ventrovittis Dyar
Anopheles earlei Vargas
A. punctipennis Say
Culex tarsalis Coquillett
C. territans Walker
Culiseta alaskaensis Ludlow
C. impatiens Walker
C. incidens Thomson

ERIGONINAE (spiders)

various species not yet identified

FORMICIDAE (ants)

Formicoxenus hirticornis Emery
Formica obscuripes

GNAPHOSIDAE (spiders)

various species not yet identified

HEMIPTERA (true bugs)

various species not yet identified

HESPERIDAE (skipper butterflies)

Amblyscirtes vialis (Edwards)*

Carterocephalus palaemon (Pallas)

Epargyreus clarus

Erynnis icelus

E. persius

E. afranius

E. juvenalis

E. pacuvius

Hesperia uncas (Edwards)

H. comma (Scudder)

H. nevada (Scudder)

H. pahaska (Leussler)

H. juba (Scudder)

H. leonardus

Hesperopsis libya

Oarisma garita (Reakirt)

Ochlodes logan

O. sylanoides (Boisduval)*

Pholisora catullus

Polites peckius

P. draco (Edwards)

P. themistocles (Latreille)

P. mystic (Edwards)

P. origenes (Fabricius)

P. origenes rhena (Edwards)

P. sonora (Skinner)

P. sabuleti (Boisduval)

Pyrqus ruralis

P. centaureae

P. communis

Thorybes pylades

HOMIPTERA (true bugs)

various species not yet identified

HYMENOPTERA (social insects)

Philanthus crabroniformisP. pulcherP. PsycheP. zebratus

LINYPHIINAE (spiders)

various species not yet identified

LYCAENIDAE (blue butterflies)

Agriades rusticaIncisalia (Callophyrs) augustus (Boisduval)I. eryphon (Boisduval)I. mitouraMitoura. spinetorum (Hewitson)M. siva (W.H. Edwards)*Callophyrs affinis (Edwards)C. sheridanni (Barnes and Benjamin)Celestrina argiolusChalceria rubidusC. heteroneaEpidemia nivalisE. helloidesE. dorcusE. mariposaEveres amyntulaEuphilotes enoptesGaeides edithaG. xanthoidesGlaucopsyche lygdamusG. piasusLycaena cupreus (Edwards)

L. melissa

L. argyrogonomun

L. phlaeas

L. philoeas

Harkenclenus titus (Fabricius)*

Plebju saepiolas (Grinnell and Grinnell)*

P. saepiolas (Boisduval)

P. icariodes (Blackmore)

P. icariodes (Edwards)

P. glandon

P. acmon (dos Passos)

P. shasta (Scudder)

Satyrium fuliginosum (Klots)

S. saepium (McDunnough)*

S. sylvinus (Boisduval)*

S. acadica (Watson and Comstock)

Strymon melinus (McDunnough)

LYCOSIDAE (wolf spider)

various species not yet identified

NEMATODA (flatworms)

Romanomermis sp.

NYMPHALIDAE (brushfooted butterflies)

Clossiana (Boloria) selene atrocostalis

C. freiija browni

C. kriemhild

Proclossiana eunomia

Charidryas gorgone

C. acastus

C. nycteis

C. palla

Danaus plexippus

Euptoieta claudia

Hypodryas (=Clossiana) gillettii

Limenitus archippus

L. weidmeyerii

Nymphalis vau-album

N. californica

N. milberti

N. antipoa

Occidryas (=Euphydryas) anicia

O. edithia

O. chalcedona

Phyciodes campestris

P. palliada

Polygonia satyrus

P. oreas

P. faunus

P. progre*

P. zephyrus

Speyeria aphrodite

S. coronis

S. zerene

S. callippe

S. callippe

S. atlantis

S. atlantis

S. hydasphe

S. mormonia

Vanessa atalanta

V. cardui

V. virgininensis

V. annabella

ORTHOPTERA (grasshoppers and crickets)

Anabrus cerciata

A. longipes

A. simplex

Arphia pseudonietana Thomas

Camnula pellucida Scudder

Cratypedes neglectus Thomas

Cyphoderris strepitans

Eritettix simplex Scudder

Melanoplus bivittatus Say

Trimerotropis latifasciata Scudder

various species not yet identified

PAPILIONIDAE (swallowtail butterflies)

Euphœades rutulus rutulus (Lucas)

E. nitra (Edwards)

E. multicaudatus

E. eurymedon*

Papilio polyxenes

E. oregonius

Parnassius clodius (Dyar)*

P. clodius (Stichel)*

P. phœbus (Edwards)

P. hermadur (Hy. Edwards)

P. olympius (Burdick)

Papilio bairdi (Edwards)

P. zelicaon (Lucas)

P. indra (Reakirt)*

Euphœades glaucus (Rothschild and Jordan)

PHILODROMIDAE (spiders)

various species not yet identified

PHOLOIDAE (spiders)

various species not yet identified

PIERIDAE (white and cabbage butterflies)

Anthocharis sara (Lucas)

Colias meadii

C. eurytheme (Boisduval)

C. philodice (Godart)

C. occidentalis (Scudder)

C. interior

C. gigantea (Klots)

C. alexandra (Edwards)

C. pelidne

Euchloe ausonides (Hy. Edwards)

E. olympia (Edwards)

E. hyantis (Edwards)*

Neophasia menapia

Pontia (Pieris) beckerii (Edwards)

P. sisymbrii

P. protodice (Boisduval and Le Conte)

P. occidentalis (Reakirt)

P. napi (Harris)*

Artogeia rapae (Linnaeus)

PLECOPTERA (stoneflies)

various species not yet identified

PSOCOPTERA (barklice)

various species not yet identified

PTCHOPTERIDAE (crane flies)

Ptychoptera pendula

P. lenis

SALTICIDAE (spiders)

various species not yet identified

SATYRIDAE (butterflies)

Cercyonis pegalaC. oetusC. stheneleCoenonympha hadyeniiC. tulliaErebia calliasE. episodeaE. magdalenaE. theanoOeneis chryxusO. juttaO. uhleri

THERIDIIDAE (spiders)

various species not yet identified

THOMISIDAE (spiders)

various species not yet identified

THYSANOPTERA (thrips)

various species not yet identified

TIPULIDAE (craneflies)

Tipulinae

Prionocera primoverisTipula lunatipulaT. oreomyzaT. yamatotipula

Cylindrotominae

Cylindrotoma pallescens

Limoniinae

Eriopteriini

Cryptolabis molophiloidesC. pachyphallus

Erioptera gonempeda yellowstonesis

E. empeda tristimonia

Gonomyia idiocera

G. gonomyia

Molophilus molophilus

Ormosia ormosia (several subspecies)

Limoniini

Limonia alexandriaria phalangioides

L. dicronomyra

Pediciini

Dicranota raphidolabis cayuga

Ornithodes harrimani

Pedicia triyphona

Polyangaeus subapterogyne

Ula paupera

Hexatomini

Archilimnophila subunica

Hexatoma eriocera eriophora

Limnophila phylidorea

L. elaephila

L. galactopoda

Pilaria phaeonota

Pseudolimnophila vidua

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