

*Exxon Valdez* Oil Spill  
Restoration Project Final Report

Spruce Bark Beetle Infestation Impacts on Injured Fish and Wildlife Species

Restoration Project 95060  
Final Report

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**Study History:** During the last eight years, an infestation of spruce bark beetles has been spreading through sections of southcentral Alaska, including portions of the *Exxon Valdez* oil spill area. This infestation became a concern to the *Exxon Valdez* Trustee Council because the damage done by the spruce beetle might impact the recovery of injured resources and/or might also alter the habitat quality of lands proposed for purchase with restoration funds.

**Abstract:** Literature reviews evaluating potential spruce bark beetle (SBB) impacts on the habitats of eight species injured by the *Exxon Valdez* oil spill yielded little of direct relevance. A brief summary of the injured species' geographic distribution, habitat usage and habitat requirements was used to determine the probable impacts of a large spruce die-off on habitat requirements. The effect of SBB infestations would vary directly with the percentage of spruce forming the mature forest canopy in a given area. In a mixed forest, remaining live spruce, conifers, and hardwoods would continue to provide many essential functions such as cover for wildlife species. For fish species, the residual trees would be capable of maintaining streambank stability while short-term large woody debris inputs would be enhanced but long-term recruitment rates and functions would be impacted. Harlequin ducks and river otters might experience positive short-term benefits from the increase in potential nesting/denning sites afforded by downed wood and dense undergrowth. Bald eagle and marbled murrelets would experience a decrease in the number of suitable nesting sites in areas where spruce is the dominant nesting tree. Silvicultural management options involving extensive timber harvest for control of SBB would likely prove detrimental to all injured species.

**Key Words:** Bald eagle, *Brachyramphus marmoratus*, cutthroat trout, *Dendroctonus rufipennis*, Dolly Varden, forest health, *Haliaeetus leucocephalus*, harlequin duck, *Histrionicus histrionicus*, *Lutra canadensis*, marbled murrelet, *Oncorhynchus clarki*, *Oncorhynchus gorbuscha*, *Oncorhynchus nerka*, pink salmon, river otter, salvage logging, *Salvelinus malma*, sockeye salmon, southcentral Alaska, spruce bark beetle.

**Project Data:** *Description of data* – a database consisting of 5,000+ literature citations regarding the biology of the spruce bark beetle. *Format* – Papyrus, a bibliographic file management system. *Custodian* – Steve Albert, Alaska Department of Fish and Game, Habitat and Restoration Division, Anchorage, Alaska. *Availability* – The bibliography is available in a read-only format on the CD-ROM attached to this report.

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## EXECUTIVE SUMMARY

Spruce bark beetles (SBB) are infesting white, Lutz and Sitka spruce trees within the range of the fish and wildlife species injured by the *Exxon Valdez* oil spill. In this project, we examined the possible impacts of spruce bark beetle outbreaks on eight species identified as injured by the *Exxon Valdez* spill, namely: the marbled murrelet (*Brachyramphus marmoratus*), harlequin duck (*Histrionicus histrionicus*), bald eagle (*Haliaeetus leucocephalus*), river otter (*Lutra canadensis*), pink salmon (*Oncorhynchus gorbuscha*), sockeye salmon (*Oncorhynchus nerka*), anadromous Dolly Varden (*Salvelinus malma*), and sea-run cutthroat trout (*Oncorhynchus clarki*), as well as the forest ecosystem upon which they depend. Within the defined *Exxon Valdez* oil spill area, the current spruce bark beetle infestation has been documented primarily on the Kenai Peninsula, with some activity on the west side of Cook Inlet.

The primary project objective was to learn more about the impacts of spruce bark beetle infestations on injured fish and wildlife species through intensive literature searches of automated databases and contacts with governmental agencies at the state, provincial, and federal levels in Canada and the U.S. Potentially relevant references were compiled in a bibliographic database management system. Library search results and literature collections of contributing forest researchers yielded over 5,000 citations in the database. Unfortunately, most of the references were related to various aspects of the biology of the bark beetle itself. Only a small number of references addressed the effects of beetle-killed forests on fish and wildlife, and none of these specifically addressed the eight species of concern. Our overall finding was that research geared to these questions—i.e., the overall effects of large stands of dead trees on the fish and wildlife communities—has not been made a high priority probably because of minimal impacts on these resources, logistical limitations, or a less important value associated with fish and wildlife resources in the past. The few studies that have addressed ecosystem impacts of infestations in other states may have limited applicability in southcentral Alaska due to different climatic factors (rainfall and decay rates) and natural forest cycles. For instance, the pattern and period of tree fall may be more accelerated on the wet Kenai Peninsula than in a study of the much dryer lodgepole pine forest in Utah (Stone 1995). Alaskan studies are needed to document the secondary impacts of an infestation in this climatic zone.

Since there was very little published literature addressing this topic directly, the best professional judgement of scientific researchers in Alaska was consulted along with the most applicable literature to determine the probable impacts of a large spruce die-off on the habitat requirements of the eight injured species.

In general, the effect of spruce bark beetle infestations on the eight injured species varied directly with the approximate percentage spruce composition in the mature forest canopy in a given area. Although not known to nest in dead trees, marbled murrelets would continue using other mature conifers such as hemlock, if available. Where the forest is almost exclusively spruce (such as along Kachemak Bay, parts of Kalgin Island, the lower Kenai Peninsula, and on Afognak Island), murrelets would most likely vacate the area with the nearly total loss of trees, reducing annual productivity. As long as some mature canopy trees remained to provide snow protection (either unaffected spruce trees or hemlock), harlequin ducks might possibly benefit from a spruce beetle

infestation, since it would increase the number of nest sites available on the ground by promoting rotting stumps, coarse woody debris, and low dense vegetation. In high snowfall and spruce-dominated areas, this potential benefit might be offset by the lack of snow-free sites available for nesting during late spring. Bald eagles seek the largest trees adjacent to their foraging areas for nesting. Within the current beetle-affected area, these trees are often cottonwood, and eagles therefore would not likely be affected by beetle damage. They would continue to use any remaining snags for hunting perches and/or nesting trees. River otters have continued to use mixed forests with SBB-killed trees. The increased amount of coarse wood on the ground from fallen trees might provide more denning opportunities, but this benefit might be offset for a period of time prior to reestablishment of the original forest canopy if the shelter/cover function provided by the overstory tree canopy diminished as dead trees fall over time. The effect of the spruce bark beetle infestation on fisheries resources is expected to be minimal, especially in riparian areas consisting of mixed stands where other tree species can perform some of the riparian functions normally attributable to spruce trees.

Resource managers have three primary means available for reducing SBB populations to improve forest health: silvicultural, physical, and chemical. Within the defined *Exxon Valdez* oil spill area, the last two alternatives have not been regarded economically or logistically feasible as reflected by the level of their usage. Landscape-level salvage operations or any program resembling large-scale salvage logging would likely be detrimental in varying degrees to all of the injured species mentioned above. These damaging effects could be reduced if only dead spruce trees were selectively harvested in a mixed forest with a minimum of heavy ground-based equipment, and an ample riparian buffer was retained. Retention of some dead trees as snags and the formation of long-term downed wood would benefit several of the injured species.

Despite the scarcity of citations addressing the effects of bark beetle infestations on specific fish and wildlife species, the related literature collected during this project will prove useful. The most relevant citations discuss the ramifications of SBB-killed trees on some parameter of the forest ecosystem, such as increased water runoff or density of snags for cavity-nesting birds. Several researchers have expressed interest in obtaining the resulting literature collection. Diskettes containing the database citations organized in Papyrus will be made available upon request from the junior author at Habitat & Restoration Division, Alaska Department of Fish and Game, Anchorage.

## INTRODUCTION

Spruce bark beetles (*Dendroctonus rufipennis*) are infesting white, Lutz and Sitka spruce trees within the range of the fish and wildlife species injured by the *Exxon Valdez* oil spill. There is only minimal knowledge of the geographic extent, role, or importance of mature spruce trees as habitat for injured species. Decreases in essential habitats resulting from bark beetle infestations could further stress these populations and prevent population recovery or lead to further population declines.

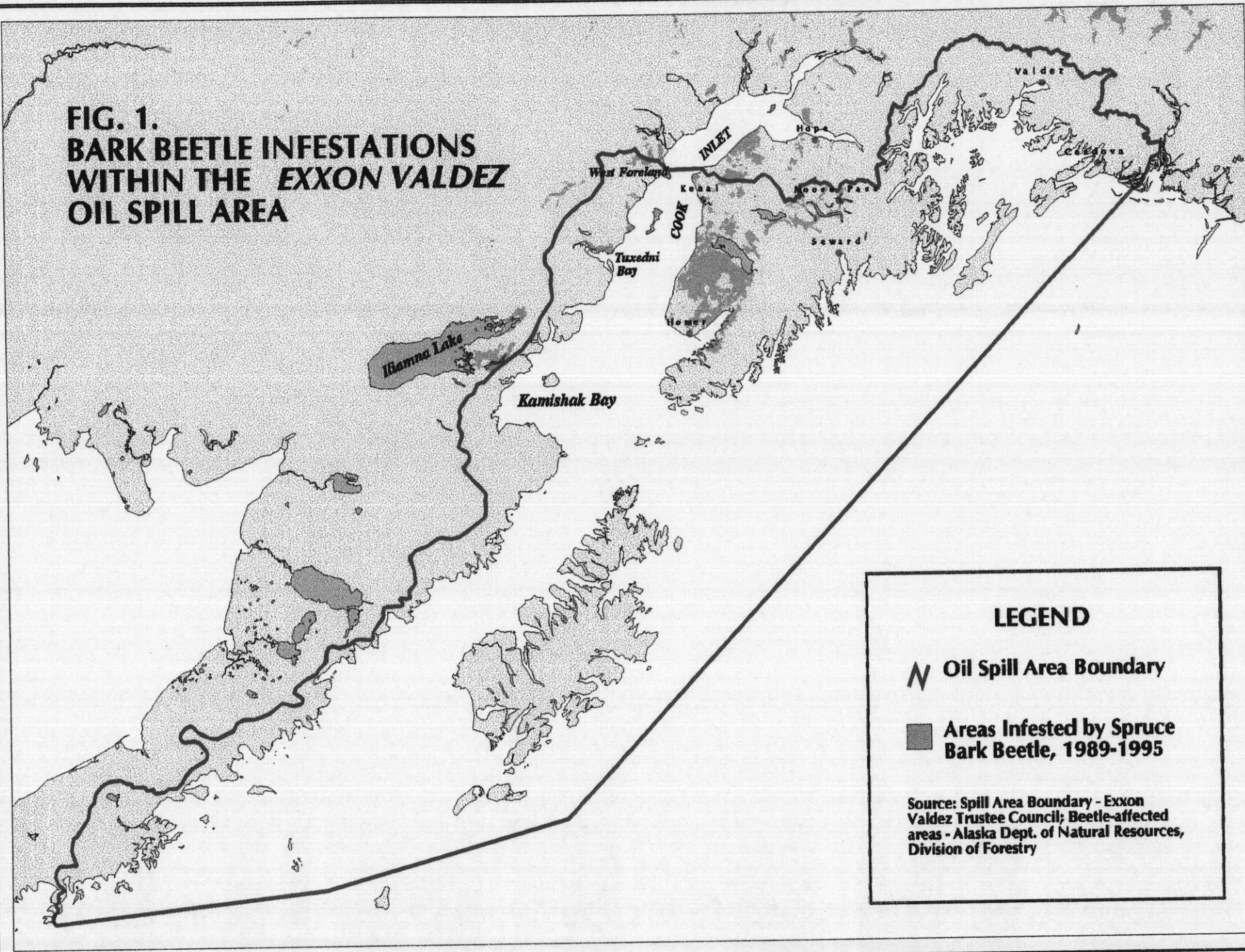
As previously stated in the Restoration Plan adopted by the Trustee Council on November 2, 1994, habitat protection and acquisition is one of the principal tools of restoration and is important to ensure the continued recovery of the spill area. Habitat protection may minimize further injury to resources and services already impacted and facilitate natural recovery. In many cases, the overall habitat value of public and private lands used by injured resources depends on the availability and condition of forest lands. The spruce bark beetle (SBB) infestation has significantly affected the current condition of forest lands within the spill area (Figures 1 and 2). This report was developed to synthesize the information available on SBB infestations, impacts on specific fish and wildlife resources, and methods of control. This information should guide the Trustee Council and land managers as they determine which habitat management actions would retain the essential habitat values, thereby aiding the recovery of injured resources dependent upon healthy forests. This project proposal has been reviewed by the Interagency Forest Ecology Study Team (INFEST).

The injured resources that will be addressed in this project include: marbled murrelets (*Brachyramphus marmoratus*), harlequin ducks (*Histrionicus histrionicus*), bald eagles (*Haliaeetus leucocephalus*), river otters (*Lutra canadensis*), pink salmon (*Oncorhynchus gorbusha*), sockeye salmon (*Oncorhynchus nerka*), Dolly Varden (*Salvelinus malma*), cutthroat trout (*Oncorhynchus clarki*), and the forest ecosystem upon which they depend and with which they interact.



## OBJECTIVES

This project was intended to compile information from the available literature regarding impacts from SBB infestation on injured fish and wildlife species and their habitats within the spill area (see Figs. 1 and 2). The primary project objective was to increase existing knowledge levels through intensive literature searches of automated databases and through contacts with governmental agencies at the state, provincial, and federal levels in Canada and the U.S. On a species-by-species basis, this report summarizes the information available on: 1) the direct and indirect impacts of SBB infestations on injured species and their habitats; 2) the importance of SBB-affected areas as habitat for injured resources; and 3) the consequences of SBB management alternatives (intended to curb existing infestations or to prevent future SBB outbreaks) *vis-à-vis* the habitat needs of injured resources.

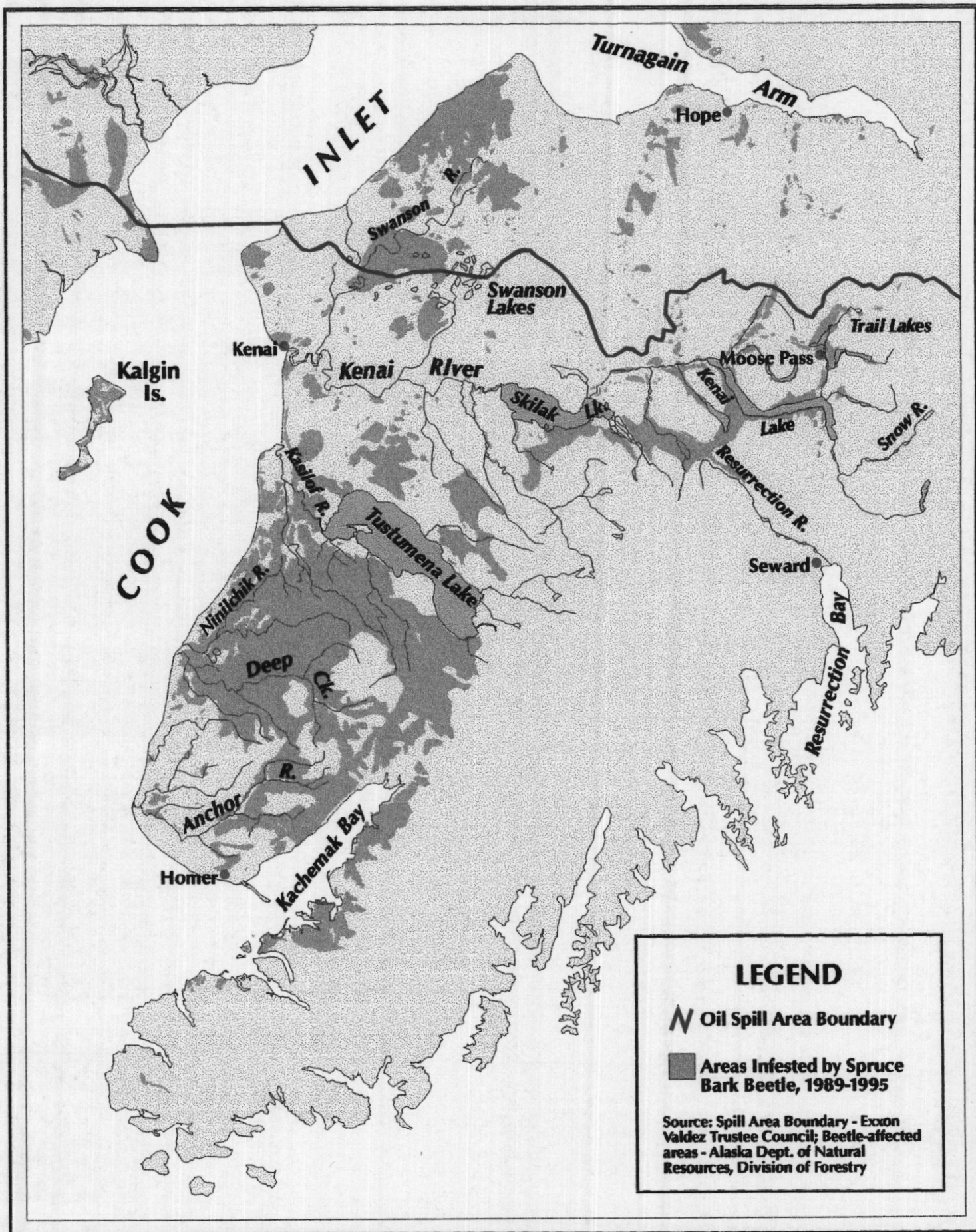
**FIG. 1.  
BARK BEETLE INFESTATIONS  
WITHIN THE EXXON VALDEZ  
OIL SPILL AREA**



**LEGEND**

-  Oil Spill Area Boundary
-  Areas Infested by Spruce Bark Beetle, 1989-1995

Source: Spill Area Boundary - Exxon Valdez Trustee Council; Beetle-affected areas - Alaska Dept. of Natural Resources, Division of Forestry



**Fig. 2. Primary Area of Bark Beetle Infestation Within the Oil Spill Zone**



## GEOGRAPHIC SETTING

In general, the spruce bark beetle's impact on habitat values for the injured species increases directly with the proportion of spruce in the forest composition within the individual species ranges. Moving from southeastern Alaska up the coast to the Kodiak Archipelago, the makeup of tree species changes. In southeast Alaska, coastal forests are dominated by western hemlock (*Tsuga heterophylla*) and Sitka spruce (*Picea sitchensis*), with a scattering of mountain hemlock (*Tsuga mertensiana*), western red cedar (*Thuja plicata*) and Alaska cedar (*Chamaecyparis nootkatensis*). Further north and west, western red cedar (to Frederic Sound) and Alaska cedar (to Prince William Sound) drop out of the mix. Cottonwood (*Populus trichocarpus*) is extensive along some of the glacial outwash rivers. Western hemlock becomes less important further west but is found as far as Cook Inlet. Sitka spruce remains as the most important tree in the coastal forests west of Cook Inlet and is the only conifer on Afognak and Kodiak Islands (Vioreck and Little 1972).

Within the oil spill affected area, the composition of forest canopy species forms a continuum. In coastal Prince William Sound, Sitka spruce and hemlock predominate. Along the outer coast of lower Kenai and on Afognak and Kodiak Islands, hemlock disappears and Sitka spruce becomes the sole conifer. Sitka spruce and white spruce (*Picea glauca*) hybridize readily in the Kenai Peninsula region (the hybrid is known as Lutz spruce), and this too forms a continuum. Rounding the Kenai Peninsula, the spruce trees become more dominated by white spruce genes, and are genetically less and less similar to Sitka spruce. In the central portion of and western side of Cook Inlet, the coastal canopy trees are mostly Lutz or white spruce. There are corresponding differences in annual precipitation and snowfall along these distributional boundaries as well.

The lowlands of the western Kenai Peninsula support a forest species composition typical of boreal forests: some black spruce (*Picea mariana*), white spruce, and paper birch (*Betula papyrifera*). Drier upland sites in the northern half of the peninsula feature combinations of white spruce, paper birch, poplar (*Populus balsamifera*), aspen (*Populus tremuloides*), and cottonwood along the floodplains (Jacobs 1989). Black spruce dominate poorly drained sites. Spruce tree mortality rates have been highest in the western and interior forests of the Kenai Peninsula during the current SBB infestation.

In general, outbreaks of the spruce bark beetle have been more frequent and severe in stands of Lutz spruce than in white or Sitka spruce (Holsten and Werner 1990). Black spruce are rarely affected. Along with host susceptibility, weather conditions play a role in the development of beetle outbreaks in southcentral Alaska. In the maritime Sitka spruce stands of southeast Alaska and Prince William Sound, cool summer temperatures and high precipitation limit the rate of beetle development. In the white spruce stands of interior Alaska, cold winter temperatures may help to contain beetle levels. The western lowlands and northern valleys of the Kenai Peninsula, however, can present more favorable conditions. Drier summers, milder winters, and the presence of susceptible species of spruce may allow beetle populations to rise to epidemic levels in these areas (Holsten and Werner 1990).

The best available information on the possible impacts of the current spruce bark beetle infestation to the eight injured species in the oil spill area is presented below. The discussion addresses each species' distribution relative to the current infestation, basic habitat requirements, and probable impacts. Although focusing primarily on the Kenai Peninsula where the SBB-infested portion of the spill area is concentrated, the conclusions apply to other affected parts of the spill area.

## HISTORICAL PERSPECTIVE OF CURRENT SPRUCE BARK BEETLE INFESTATION

Spruce bark beetle infestations in southcentral Alaska spruce forests occur commonly and, most of which, have been documented since 1920 (Holsten 1990). However, prior to 1920, very few people occupied the Kenai Peninsula. The historical record is limited to a small number of mapping, mining and forestry reconnaissance reports, and personal diaries. The current SBB outbreak has been characterized to be more intensive and widespread than all previously recorded infestations. For example, in the five-year period 1966-1970, the SBB infestation area was estimated at 300,000 acres and was considered the largest recorded period of SBB activity. The current infestation during the 1989-1994 period included more than 600,000 acres of new and ongoing SBB activity (Burnside 1994).

Veblen et al (1991) developed a methodology to detect past SBB outbreaks based on dendrochronological techniques, frequencies of release, and stand age structure analyses in the Rocky Mountains of Colorado. They observed that the mortality of dominant spruce during an outbreak resulted in increased growth rates of survivors and hypothesized that past SBB outbreaks would be reflected in coincident releases of trees over extensive areas. Fastie, Swetnam, and Berg (1995) compared tree ring data from sample sites in the northern and southern portions of the western Kenai Peninsula. They concluded that a substantial climatic event in the late 1870s led to a lethal SBB infestation that killed many mature spruce trees during the 1880s. This infestation (loss of overstory spruce) resulted in a dramatic increase in tree ring width growth rates from 1880 to 1930. Because most of the overstory was killed, more light, water, and soil nutrient resources were available to the young spruce survivors. The Fastie et al. study is significant because it suggests that such SBB outbreaks occur naturally when local conditions are optimal.

## METHODS

Knowing that the literature discussing both spruce bark beetles and any one of the eight species of concern would be extremely limited, we sought literature that might address the direct and indirect effects of SBB infestations on resident fish and wildlife in general. We began by contacting key bark beetle researchers and learned that some bibliographies already existed pertaining to spruce bark beetles and other forest health issues. Two such collections were compiled by an Alaskan researcher; the remainder came from sources out of state. We felt that

our time would be most productive if we used these existing collections of potentially relevant citations to build a literature database that could be searched, sorted, and expanded as the project evolved.

Over time, several such citation lists were located. The lists varied from bibliographies in word processor format to lengthy and formal electronic lists of citations downloaded from the Internet. All of these citations needed to be appropriately formatted and loaded into a database management system to allow us to examine, sort, and search them by topic.

The Papyrus Bibliography System was selected to serve this purpose. Papyrus (by Research Software Design, Portland, OR) was selected for the following reasons:

- ◆ The primary local forest management agencies, namely the U.S. Forest Service and the State's Division of Forestry, have or will be adopting this system.
- ◆ Papyrus offered certain beneficial features not available in the primary software alternative (ProCite). For instance, because the project involved consolidating lists of references from numerous sources, the Papyrus feature that identifies duplicate references was quite useful. ProCite did not have this feature.
- ◆ The manufacturers of Papyrus offer good customer support, which proved pivotal in efforts to load disparate data types onto the system.

A significant amount of time was required to load the source lists onto the Papyrus system. This involved manipulating the data in the source files, re-programming the import format codes within Papyrus, and much trial and error even with the assistance of support staff at Papyrus. However, given the number of citations on these lists (some over 1,000), and the fact that many contained abstracts and keywords, it was a far more attractive alternative than re-typing the entries.

University contacts also informed us of a specialized database in CD-ROM format that focused on forestry issues and would be a particularly good source of literature for our topic. This database (of mostly periodical literature) did not exist in Alaska, but the search was performed through a university library out of state. We devised a search strategy to identify literature that mentioned both a lethal forest insect (e.g., various bark beetles, budworms, etc.) and fish, wildlife, or one of the ecological functions that provide a component of their habitat (e.g. water runoff, fire hazard, or changes in the vegetational structure of the forest such as the dominance of canopy versus understory). The spruce bark beetle was not the only insect species included in the search terms because we recognized that impacts on fish and wildlife would be very similar for a number of different lethal forest insects. The citations resulting from these searches were loaded into the Papyrus database.

We also located references on the habitat needs of the eight injured species in this study. Researchers working on these species in Alaska (e.g., marbled murrelets or harlequin ducks)

directed us to appropriate literature sources. These individuals also offered their professional opinions on the effects of a SBB infestation on their subject species. Many of these researchers have also received funding from the Trustee Council.

### **Silvicultural Management Alternatives**

We evaluated several possible alternative strategies for managing spruce bark beetle infestations in Alaska to determine how widespread they had been implemented and whether they were environmentally acceptable and economically feasible. These silvicultural management alternatives are summarized below.

1. **No Treatment.** This alternative would allow the SBB infestation to run its course and to subside naturally.
2. **Sanitation Overstory Removal.** This treatment removes all infested and susceptible spruce and uses harvesting and site preparation techniques to regenerate a vigorous forest stand. The goal is to recover the economic value of the timber resource, remove dead trees and other trees at risk, and to suppress the SBB population. This is the most common management alternative utilized within the EVOS project area and is regarded as the most economically feasible.
3. **Sanitation Partial Cut.** This method removes infested and susceptible (low vigor) spruce trees to improve residual stand growth. Most of the larger trees are harvested leaving the residual stand below the recommended level of basal area.
4. **Pruning.** This technique involves the removal of the lower one-third of the live green crown. Generally, trees that have been pruned are less susceptible to successful attack by the SBB (Hard 1992).
5. **Thinning.** In most areas, the viability of this alternative is limited by the relatively high levels of SBB activity, the poor health and vigor of trees, and the amount of incipient rot. Thinning is normally only feasible in uninfested or lightly infested forest stands (Hard and Holsten 1985).
6. **Insecticides/Pheromones.** Insecticides such as carbaryl or lindane are applied to the lower portion of uninfested tree trunks to kill attacking adult beetles up to 2 years. Pheromones are chemical substances that influence insect behavior. Synthetically-produced aggregating pheromone can be used to attract SBBs to a trap tree. Anti-aggregating pheromone discourage SBBs from attacking trees. These methods are usually applicable in campgrounds, around private homes, or administrative sites. Insecticide application is not effective for trees that have already been attacked and can also be expensive.
7. **Trap Trees.** Large diameter uninfested spruce are felled in a shady area prior to beetle flight. Because beetles prefer to attack downed trees over standing trees, designated trap

trees can attract and absorb beetles to a much greater degree than adjacent standing trees. After trap trees have been infested they must then be removed, chemically treated, burned, or debarked. In areas where trap trees cannot be removed, green trees can be injected with a silvicide and then felled prior to beetle flight. These techniques have been utilized successfully but may be limited to accessible areas by high costs of access.

8. Prescribed Burning. This technique involves the piling and burning of infested trees that have been blown down to the ground or have been left after a logging operation

## RESULTS AND DISCUSSION

### **Bibliography Development**

To date, 5,371 references pertaining to spruce beetles, related forest health issues, and the eight injured species have been loaded into the Papyrus database. Almost all of these citations contain keywords to enable literature searches, and a large percentage contain abstracts. The bulk of these were obtained by loading large lists of potentially relevant references from various sources. Other pertinent references, including unpublished studies, were added individually to the database. Sources of the references include:

- ◆ A forest health bibliography (400+ citations, source: Ed Holsten, USFS, Anchorage)
- ◆ The literature used in creating SBexpert, a decision-support system model for spruce beetle management (approx. 500 citations, also from Ed Holsten, USFS, Anchorage)
- ◆ A collection of bark beetle literature compiled over the lifetime of a University of California, Berkeley forestry researcher, downloaded from the Internet (approx. 3600 citations)
- ◆ The responses to a mass-mailed inquiry previously sent out by the Alaska Department of Fish and Game (ADF&G) to resource managers across the U.S. and Canada. This inquiry specifically requested information on the fish and wildlife impacts of beetle-killed trees (approximately 75 citations)
- ◆ Search results from the CD-ROM database for forestry literature (approximately 1,700 citations)
- ◆ Extremely recent literature on bark beetles and the eight species was found using Current Contents (yielding less than 100 citations)

And, as mentioned above, other pertinent references on both spruce beetles and the eight injured species that were discovered through the course of the project.

Although the process of evaluating the relative worth of these references is ongoing, only a small fraction (<1%) of these discuss the effects of beetle-killed forests on anadromous and resident

fish and wildlife, and none of these specifically address the eight injured species of concern. Nevertheless, the literature in the database does broaden our understanding of the ecological relationships of beetle-killed trees in a dynamic forest ecosystem. Contacts at several research centers in the country have been very supportive in our efforts to investigate these questions, and have expressed interest in obtaining the resulting literature collection.

### **Injured Species Habitat Requirements and Potential Impacts Related to Spruce Bark Beetle Infestation**

Of the set of SBB management alternatives described in the Methods section, only the first two alternatives have been implemented to any measurable degree. The remaining alternatives were either limited by road accessibility, too expensive to apply over large areas, or limited by insufficient timber values to justify implementation in the field. Because these were the most common silvicultural alternatives, they were evaluated in Table 1 in terms of their potential impacts on the eight injured species.

**Table 1: Summary of Species Habitat Requirements and Spruce Bark Beetle Impacts**

INJURED	Known Habitat Usage/Requirements		Possible Spruce Beetle Impacts--	
SPECIES/ DISTR.	Breeding	Feeding	If Trees Retained	If Trees Removed
<p><b>MARbled MURRELET</b></p> <p><i>BRACHYRAMPHUS MARMORATUS</i></p> <p>WIDELY DISPersed ALONG COAST IN SOUTHCENTRAL AK. USUALLY WITHIN 12 MILES OF SHORE; FURTHER INLAND IN RIVER VALLEYS AND PASSES.</p>	<p>Widely dispersed &amp; secretive, 95% of entire population nests in AK. Fly inland to nest on moss-covered branches of large conifers (approx. 3% nest directly on ground in tundra areas, e.g. Aleutians).</p> <p>Most nesting occurs on densely forested slopes of large, old-growth hemlock or spruce trees. Larger timber stands are most attractive. Also, murrelets are more likely to use <b>inland</b> areas at the heads of bays and up river valleys.</p> <p>Best nesting conditions: low elevations near heads of bays, with extensive stands of large, old-growth trees with moss-covered branches.</p>	<p>Migrate offshore for winter. In summer, feed mostly on small fish in the water column, and invertebrates in shallow nearshore waters. Murrelets are documented as they fly inland from coastal foraging areas to their nests at dawn (from June-early August).</p>	<p>Murrelets are not known to nest in dead trees; their nest sites are highly susceptible to avian predation. It takes 150-200 years for new forest trees to develop the moss platforms used as nest sites by marbled murrelets. Some losses of spruce nesting trees can be made up by hemlock.</p>	<p>Loss of nesting habitat from logging is primary impact and cause of their decline elsewhere. A young forest (&lt;150 yrs old) does not have the moss pads and lateral branch size needed for nest sites. They prefer contiguous stands of mature coastal forest. Road-building and patchy logging would lead to increased nest predation.</p>
<p><b>HARLEQUIN DUCK</b></p> <p><i>HISTRIONICUS HISTRIONICUS</i></p> <p>NEST NEAR FAST-FLOWING STREAMS THROUGHOUT THE KENAI PENINSULA AND PWS.</p>	<p>Nest along shallow (0.5-1m deep), fast mountain streams, often near timberline. Nests concealed <b>under dense vegetation</b> within 5 m of streams with abundant macroinvertebrates. Return to same area every year to nest.</p> <p>Adults migrate daily between inland nests and coastal marine foraging habitats, only a few km apart. Congregate near the mouths of suitable breeding streams in late April &amp; early May. Young preyed on by ravens, mink, &amp; fox. 30-40% duckling mortality within first 2 weeks.</p> <p>Can be cavity nesters but 80-90% observed under a dead-fall or other woody debris. Goldeneye, buffleheads, and red-breasted mergansers also nest in cavities.</p>	<p>Carnivorous. Young feed on abundant macroinvertebrates along freshwater breeding streams (e.g., insects on surface &amp; on overhanging vegetation). Broods use stream bends where the current slows for feeding &amp; resting. Feed on salmon roe as it becomes available (e.g., July); can also move into lower portions of streams/intertidal areas to forage on roe &amp; small mollusks at that time. Adults forage in marine coastal waters nearby.</p> <p>In winter, all populations flock along exposed, rocky coasts &amp; nearshore area.</p>	<p>Dead beetle-killed trees would not offer the same snow protection for early nest occupancy in spring. However, the net increase in rotting stumps, woody debris and dense undergrowth would likely increase nesting potential of the area.</p>	<p>Harlequin ducks favor old-growth or mature forest with no logging history. They may use residual stream buffer areas. Harvesting of beetle-killed spruce could adversely affect food sources (stream invertebrates) through sedimentation and other channel impacts. To achieve adequate forest regeneration, harvesting could result in loss of undergrowth, deadfalls needed for nesting.</p>

INJURED	Known Habitat Usage/Requirements		Possible Spruce Beetle Impacts--	
SPECIES/ DISTR.	Breeding	Feeding	If Trees Retained	If Trees Removed
<p><b>BALD EAGLE</b></p> <p><i>HALIAEETUS LEUCOCEPHALUS</i></p> <p>HIGHEST CONCENTRATION IN MARITIME AREAS; ALSO ALONG MAJOR RIVER DRAINAGES, THOUGH DENSITIES DECLINE MARKEDLY IN THE MORE INTERIOR PARTS OF THE REGION.</p>	<p>Eagles need a land/water interface (shoreline or river), and prominences that are used for perches and nesting. Typically, these are the largest trees near the water. The vast majority nest along the coast in mature coniferous forests. Nest trees in southeast Alaska (Sitka spruce or hemlock) averaged 97 ft tall (probably 400-500 yrs old). Old-growth is the most important successional stage for both feeding and reproductive success. Along river systems, eagles nest in mature cottonwood trees. Eagles show strong preference for nest sites with overhead &amp; surrounding foliage which provides shelter from wind and rain. Nesting begins in early April; hatching (usually 2 eggs) in May.</p>	<p>Eagles eat primarily fish (herring, smelt, salmon), waterfowl, and seabirds. Seasonal concentration areas (e.g., Kachemak Bay in winter), exhibit: an abundant food source, day perches, suitable roosting habitat (conifers are more protective in winter).</p>	<p>Eagles often use cottonwoods for nesting in much of the beetle-killed zone, so only minimal impact to eagles in these areas. They would continue to use dead trees for hunting perches. Eagles prefer to nest in live trees due to shelter of overhanging foliage. Could be a loss of nesting potential in spruce-dominated areas such as Kachemak Bay.</p>	<p>In disturbed areas, the presence of remnant old-growth trees is important for recolonization. They avoid second growth forests lacking old-growth trees for nesting. Even when a 330 ft buffer zone was left, the high incidence of windthrow adjacent to cutover areas (17% of trees in 5 yrs) threatens bald eagle productivity by reducing perching opportunities.</p>
<p><b>RIVER OTTER</b></p> <p><i>LUTRA CANADENSIS</i></p> <p>ON KENAI, FAIRLY COMMON IN DRAINAGES SUPPORTING ANADROMOUS FISH, STREAMS CONNECTED TO LAKES, AND IN SHELTERED COASTAL WATERS SUCH AS THE SOUTH SHORE OF KACHEMAK BAY.</p>	<p>Breed in late winter through spring with a peak in May. Pupping the following April; usually 2-4 young. Need beach fringe timber, prefer spruce/hemlock. Exhibit strong selection for old-growth forest; avoidance of clear-cut areas. Old-growth is a critical component of otter habitat for successful reproduction. The mature forest canopy offers: protection during storms; the older trees' roots support the roof area of natal dens and tunnels in the shallow, water-saturated soils in coastal areas; decaying root masses seed development of new dens as older ones collapse. Otters heavily use a narrow strip of shoreline (from sea level to 30m elevation).</p>	<p>Coastal populations forage on intertidal slopes. Feed on many species, primarily fish (sculpins &amp; rockfish), gastropods, &amp; bivalves. River- and lake-dwelling otters eat entirely different species; these populations mostly live in anadromous waters to benefit from that food availability.</p>	<p>Canopy cover is important to coastal otters, as escape from storms and predation. Loss of tree needles in beetle-killed timber could result in reduced otter survival because of increased vulnerability to predation while on land. However, downed trees could also increase the number of denning sites. In interior Kenai Peninsula, otters still actively use areas of dead spruce.</p>	<p>Otters DO NOT use open logged areas, even 20 yrs after harvest, but may use adjacent areas &amp; tree buffer zones left along streams. Logging disturbances could cause abandonment of latrine sites ("protected areas" that mark territory). Although otters do feed on subtidal fish, perhaps the biggest threat is potential logging-related impacts to upland fish resources upon which otters depend.</p>



INJURED	Known Habitat Usage/Requirements		Possible Spruce Beetle Impacts--	
	SPECIES/ DISTR.	Breeding	Feeding	If Trees Retained
<p><b>PINK SALMON</b></p> <p><i>ONCORHYNCHUS GORBUSCHA</i></p> <p>IN MANY DRAINAGES IN COOK INLET AND PWS, WHERE MUCH OF THE SPAWNING IS INTERTIDAL.</p>	<p>Spawn intertidally or in streams within several miles of the sea from mid-July to October. Fry emerge in April &amp; early May; migrate quickly to sea. Preferred spawning depth in streams-- 0.2-0.5m; spawning temp: 7.2-13°C; incubation temp 4.4-13.3°C; adults are a cold water fish (5.6-14.6°C).</p> <p>Rate of return as adults depends on quality of rearing conditions during fry stage, lower food supply, water temp, and growth of fry mean fewer adults return the following year.</p>	<p>Fry eat eggs, amphipods &amp; copepods. Juveniles eat larger invertebrates &amp; small fishes. Young are preyed upon by other fish, invertebrates, marine mammals, and birds.</p>	<p>Increased streamflows associated with beetle-killed trees could have an adverse effect on pink salmon, considered a weak-swimming species. Higher water velocity could block returning adults.</p>	<p>Increased sedimentation could negatively affect spawning conditions and early fry stage. If so, fewer adults would return, resulting in reduced run size. Removal of live trees would exacerbate impacts from increased runoff patterns.</p>
<p><b>SOCKEYE SALMON</b></p> <p><i>ONCORYHNCHUS NERKA</i></p> <p>IN SEVERAL DRAINAGES IN COOK INLET &amp; PWS. THE VAST MAJORITY SPAWN IN LAKE SYSTEMS.</p>	<p>Between July &amp; October, redds are dug in gravel substrate with sufficient water flow &amp; dissolved oxygen for the eggs/alevins. Typically spawn in streams associated with a lake system. Fry emerge April to June, and use the lake as rearing habitat for 1-3 yrs before smolting. Optimal spawning depth: 0.3-0.5m; spawning temperature: 10.6-12°C; incubation temperature: 4.4-13.3°C; 9-12°C preferred for fingerlings &amp; young.</p>	<p>Adults feed on euphausiids, amphipods, copepods &amp; young fishes. Adults preyed on by marine mammals &amp; predatory fish. Young eat zooplankton from the nursery lakes. If overescapement, too many fry will deplete food supply; fewer smolts result.</p>	<p>Tree kill may increase runoff and in spruce-dominated areas the watershed could experience more extremes - higher peaks, etc. This affects all life stages (eggs, alevins, etc.). If dead trees left standing, rot will contribute more large woody debris to stream; effect on bank integrity depends on amount of spruce in the area.</p>	<p>Logging/road construction-related activities could increase sediment in streams. Fine sediments in salmonid rearing areas can clog fish gills, reduce feeding, lower survival of eggs or alevins &amp; destroy food sources. Also, removing the wood recruitment source will destabilize the creek channel over time.</p>

INJURED	Known Habitat Usage/Requirements		Possible Spruce Beetle Impacts--	
SPECIES/ DISTR.	Breeding	Feeding	If Trees Retained	If Trees Removed
<p><b>DOLLY VARDEN</b> (ANADROMOUS)</p> <p><i>SALVELINUS MALMA</i></p> <p>FOUND IN MOST RIVER DRAINAGES IN THE KENAI PENINSULA AREA</p>	<p>Adults spend summer in nearshore marine waters near natal streams; migrate to freshwater lakes to overwinter. Spawn in Sept-Oct. Live to be 12 or more years old.</p> <p>Young remain in freshwater for 3-4 yrs before moving seaward. They are found near logs and undercut banks, where they seek protection from predation.</p>	<p>Feed extensively in the nearshore marine habitat, therefore hard hit by the oil spill. In freshwater, invertebrates and small fishes are the main diet of adults.</p>	<p>Same general effects as on sockeye salmon, listed above.</p>	<p>Same as above.</p>
<p><b>SEA-RUN CUTTHROAT TROUT</b></p> <p><i>ONCORHYNCHUS CLARKI</i> (FORMERLY <i>SALMO CLARKI</i>)</p> <p>NO DIRECT POPULATION OVERLAP WITH BEETLE INFESTATION AREAS; THE NEAREST SMALL, SCATTERED RUNS ARE WITHIN PWS.</p>	<p>"Repeat spawners" but there can be 90% post-spawn mortality. Spawn in headwater tributaries of larger streams, between February &amp; May. They favor pools &amp; riffles. After spawning, adults and current year's smolt migrate to ocean between March &amp; July. Optimal temperature for incubation: 10-11°C; duration shortened by increased temperature. Young fish may take 1-4 yrs to move from natal stream to larger river, lake, or saltwater. Or, they may remain as resident fish (not all forms anadromous).</p>	<p>Remain in nearshore waters near natal streams to feed, return to freshwater lakes to overwinter.</p> <p>Fry &amp; juveniles feed on insects and crustaceans; as they grow they begin to eat smaller fish. In marine environment, they eat amphipods &amp; isopods, shrimp, small crabs, and other fish. In freshwater, fry preyed upon by many species of fish &amp; birds (herons &amp; kingfishers). Cover is very important for cutthroat (overhanging vegetation, undercut banks, logs &amp; rocks in stream).</p>	<p>Same general effects as above. More large woody debris in streams could increase survivorship. Their biomass in a stream has been shown to increase with the amount of cover present. Increased water velocity could block upsteam migration.</p>	<p>Same effects as above. Cutthroat are especially vulnerable to the adverse effects of logging and increased sediments because they inhabit headwater streams. However, they do not co-occur within the current areas of spruce infestation.</p>

## **Marbled Murrelets**

### **Distribution**

Survey data suggests that about 280,000 marbled murrelets (*Brachyramphus marmoratus*) reside in Alaska during the summer (Piatt and Naslund 1995). They are widely distributed along the coastline from southeastern Alaska to the western Aleutians. Most marbled murrelets in the breeding season are concentrated along of large tracts of coastal coniferous forests in southeast Alaska, Prince William Sound, and the Kodiak Archipelago. About 1-3% of murrelets breed wholly outside of forested lands in Alaska (largely along the Alaska Peninsula and the Aleutians), and these presumably all nest on the ground.

In the vicinity of the current spruce bark beetle infestation, areas of concentration include the following : southern Kenai Peninsula coast, lower Cook Inlet, Kachemak Bay, and Kamishak Bay. SBB infestation surveys completed during summer 1995 and 1996 indicated significant increases in tree mortality in Kachemak Bay, Kamishak Bay, and lower Cook Inlet (Alaska Department of Natural Resources 1996). Murrelets are most abundant in sheltered inside waters including bays, fjords, and island passes. Their summer distribution appears to be largely determined by the geographic co-occurrence of terrestrial breeding habitat (coastal old-growth coniferous forests, especially Sitka spruce and hemlock) and suitable marine foraging areas. Stratified coastal waters provide much better foraging than waters subject to strong tidal mixing (Piatt and Naslund 1995).

Small-boat surveys in 1993 suggest that about 60,000 use lower Cook Inlet in summer (Agler et al. 1994), as compared to adjusted population estimates of 89,000 marbled murrelets in Prince William Sound (Piatt and Naslund 1995). Within lower Cook Inlet, higher concentrations were detected in upper Kachemak Bay, Tutka Bay, and English Bay, in the Anchor Point area, Kalgin Island, Chitina Bay, and Kamishak Bay (Agler et al. 1994). In a summer 1993 survey in Kachemak Bay, where the SBB infestation has become extensive, the murrelet population was estimated at 11,000 birds (+/- 10,000 at 95% Confidence Interval) of which approximately 97% were marbled murrelets (Kendall pers. comm). Additional distribution information for marbled murrelets in Kachemak Bay can be found in Agler (1997).

### **Habitat Requirements**

Ninety-seven percent of marbled murrelets in Alaska nest in large, old-growth trees within large tracts of coastal coniferous forest (DeGange 1995). Because of high rainfall, mosses grow in great profusion in these areas—on the ground, on fallen logs, and on tree branches. Moss often covers the lateral branches of mature trees; murrelets use these moss pads as their nests. Eggs are laid (one per clutch) directly on the moss pads (Nelson and Hamer 1995). Kuletz et al. (1994) found that the best predictors of murrelets nesting in an area were the presence of large diameter trees and the number of potential nesting platforms containing moss or lichens. Murrelets prefer trees with high and broad platforms for nesting and takeoff, in stands with sufficient canopy openings to permit access—in other words, structural heterogeneity. They also tend to prefer dense cover over nesting platforms, probably as a means of avoiding avian

predation and for protection from severe weather. Sitka spruce and western and mountain hemlock are the most common nesting trees in Alaska (DeGange 1995). Overall, studies have determined that features conducive to marbled murrelet nesting habitat include low elevation locations near heads of bays, with extensive forest cover of large old-growth trees (Kuletz et al. 1994).

Locating marbled murrelet nests in a mature forest canopy is very difficult, and most studies have deduced nesting areas by observing nesting behaviors such as the adults' daily flights from marine foraging areas to the nest site in the early morning hours. The nests that have been located reveal several important attributes. The four nest sites located in southeastern Alaska were all at a relatively low elevation, within a few miles of salt water, in an uneven-aged stand of conifers, and used moss as a nesting substrate. Nests were located in trees that were substantially larger in diameter than most of the surrounding trees (DeGange 1995). Between 1991 and 1992, the most intensive searching effort for nests in Alaska yielded 14 tree nests on Naked, Afognak and Kodiak Islands (Naslund et al. in press). At Naked Island, 9 of 10 nests were in hemlock trees—either western or mountain; one was in Sitka spruce. All four nests on Kodiak and Afognak were in Sitka spruce, which generally reflects tree species availability in these areas. Nest tree diameters averaged 63 cm, and were larger than surrounding trees. The nest trees were greater than 200 years old; one on Naked Island was 495 years old. Nest trees had significantly more nest platforms and more epiphyte cover (moss and lichens) than surrounding trees. Another important feature was the amount of overhead cover. Canopy cover above nests ranged from 81-95%. Interestingly, many of the ground nests discovered in Alaska have also featured some form of cover directly overhead, usually overhanging rock or vegetation. The 14 tree nests were located in forests of high-volume, uneven-aged old growth trees forming contiguous stands of several hectares (Naslund et al. in press).

Most investigators believe that because most marbled murrelet nests have been located relatively close to the coast (usually within 35 km) there are energetic constraints on the distance adults can routinely travel and provision chicks that limit how far they will nest from the coast (DeGange 1995). Most Alaskan surveys of dawn murrelet activity have been conducted in the immediate coastal area, making it difficult to estimate how many may travel further inland to nest. However, the Seward Ranger District of the U.S. Forest Service has run several surveys and recorded the presence of murrelets as they fly inland to their nests at dawn. Birds have been heard near the mouth of the Snow River and on Kenai Lake near the mouth of Trail River (Figure 2), suggesting they nest as far inland as the Moose Pass area. As the surveyors moved progressively inland from the head of Resurrection Bay along the Seward Highway, fewer detections were noted—for example, while 50+ detections were recorded in one morning only eight miles out of Seward, only two birds were detected at Trail Lakes at the town of Moose Pass (26 miles from shore) in 1994 (Susan Howell, unpubl. data). The highest number of detections were concentrated in an area up to eight miles inland from the head of Resurrection Bay.

## **Impacts from Beetle-Killed Forest**

### **A. Standing dead trees**

Even though the moss nesting pads would persist as long as the affected spruce tree continues to stand, murrelets are not known to nest in dead trees. Cover above the nest can protect the eggs and chicks from avian predators (e.g., raptors, ravens, crows, jays). Predation is the major cause of nest failure in marbled murrelets, shown to account for 56% of the known nest failures (Nelson and Hamer 1995). Those nests that are better concealed and away from the forest edge tend to be more successful. Suitable moss platforms do not develop quickly; a forest stand must be approximately 150-200 years old before the moss platforms and limbs have grown sufficiently large for murrelet nests (K. Kuletz, pers. commun.)

Moose Pass is one inland forest area affected by spruce bark beetles where the presence of a few murrelets has been recorded. In this area, the primary conifer species are white spruce (*Picea glauca*) and mountain hemlock (*Tsuga mertensiana*) with the majority of the latter growing on the slopes just above the spruce. Based on the small size of the lateral limbs of the white spruce in this area, it is probable that any nesting marbled murrelets are using the larger hemlocks (greater than 50 cm (20 in) DBH, spaced 4.5-6.0 m (15-20 ft) apart which would provide a better nesting platform (S. Howell, pers. commun.). If this is the case, a die off of white spruce in this area might not hamper nesting murrelets a great deal—they would continue to nest on the moss pads of the large mountain hemlocks. On the other hand, if they are utilizing spruce for nesting trees, the beetle infestation could reduce the number of nesting murrelets in this area for a long time. Beetles tend to kill the oldest and largest trees that are most likely to be used for nesting. However, very few birds currently use this area for nesting (20+ miles from the coast) compared to those in the immediate coastal vicinity (S. Howell, unpubl. data).

Of course, a much more drastic impact to marbled murrelets would be expected in areas where spruce is the dominant nesting tree. In certain parts of Prince William Sound, spruce trees are the biggest trees, and the most likely to have flat limb surfaces covered with moss (K. Kuletz, pers. commun.). In other parts of southcentral Alaska, the forest is almost exclusively spruce, such as Kachemak Bay, Kalgin Island, the lower Kenai Peninsula, and Afognak Island. If beetles killed all potential nest trees, murrelets would most likely be displaced from such areas. Reduced nesting habitat would affect their annual productivity rate. At the present time, the spreading beetle infestation certainly threatens known murrelet nesting areas along the south side of Kachemak Bay (Figure 2).

## B. Salvage logging

The spruce bark beetle infestation will primarily affect old-growth spruce trees; salvage logging would affect spruce and hemlock and could result in the loss of even more nest trees depending upon the type of silvicultural treatment employed. We believe that nesting marbled murrelets in the Moose Pass area would be more adversely affected by salvage logging operations than from the dead spruce.

Salvage logging operations could impact marbled murrelets in numerous ways. The removal of most trees of a size suitable for nesting, live or dead, spruce or hemlock, would likely result in an immediate reduction in murrelet productivity. Leaving behind the live spruce (either younger or unaffected mature spruce) and hemlock would enable a more rapid reestablishment of nesting murrelets in a spruce-dominated forest, since it takes 150-200 years to develop the moss

accumulations and branches large enough for nesting (K. Kuletz, pers. commun.). If conducted during the nesting period, the disturbance (i.e., noise, road construction, equipment traffic) associated with nearby salvage operations could also affect nesting success rates.

Decreasing the area of contiguous coniferous forest (landscape fragmentation) would also limit their nesting potential, since large stand size was shown to be a factor in nest site selection (Kuletz 1991, Naslund et al. in press). Road construction in forested areas and fragmentation of mature forest habitat may increase predation by allowing avian predators increased access to murrelet nests. Because murrelets have low reproductive rates, small increases in predation could have damaging effects on population viability. Only 28% of all nesting attempts with known reproductive outcomes have been successful, and loss of eggs and chicks to avian predators was shown to be the most important cause of nest failure for those studied (DeGange 1995, Nelson and Hamer 1995).

Various logging methods would have varying effects on nesting marbled murrelets. Harvesting in small patches (10-20 acres) would fragment old-growth stands and most likely result in increased predation of murrelet nests, chicks and adults. Light, single tree selection would be expected to maintain high value nesting habitat so long as an adequate number of large, old growth trees are retained. Partial cuts involve the harvest of most of the large-sized trees and would likely result in a significant impact on nesting habitat availability. Salvage logging would eliminate nesting murrelets and they would not be expected to re-occupy a logged area for 125-150 years or until a suitable moss layer develops on branches (DeGange 1995).

Removal of old-growth habitat, predation from avian predators associated with forest edges and fragmented landscapes are the primary threats to marbled murrelet reproduction. Other important factors causing mortality in Alaska are commercial gill net fisheries and oil pollution (Piatt and Naslund 1995, U.S.D.A. Forest Service and Foster Wheeler Environmental Corporation 1995).

## **Harlequin Ducks**

### **Distribution**

Harlequin ducks (*Histrionicus histrionicus*) nest near fast-flowing streams throughout the Kenai Peninsula and Prince William Sound. Although no nesting surveys have been conducted on the western side of Cook Inlet, individual nests have been reported along Crescent River (M. Wiedmer pers. comm.) and within Lake Clark National Park (A. Bennett pers. comm.). Harlequin ducks are common throughout the year along the margins of Resurrection Bay, the Chiswell Islands, Kachemak Bay, the Barren Islands, and lower Cook Inlet (West 1994).

### **Habitat Requirements**

There are both coastal and inland-breeding populations of harlequin ducks in the study area, of which the coastal populations have been more intensely studied. In winter, all populations flock

along exposed, rocky coasts and nearshore areas, hence the oil spill in March 1989 affected both types of breeding populations.

Coastal nesting birds choose the largest salmon streams available and nest in their small, first order tributaries within a short distance from the shore (Crowley 1993). The adults travel to the estuaries and intertidal areas daily for foraging and loafing. They consume macroinvertebrates, clams, and mollusks. In a study of coastal-breeding harlequin ducks in eastern Prince William Sound, all nest sites were located within three kilometers of the ocean on southwest facing banks of small tributaries near timberline elevation. Nests were associated with large woody debris and shrubs, in shallow depressions or cavities, and beneath the canopy of old growth forest (Crowley 1993). Nests were found up to 25 m from the stream. The mature canopy cover in this area was most often provided by western hemlock (87%) and Sitka spruce (11%). Woody debris concealed 80% of the nests, either beneath deadfalls or in shallow cavities in rotting stumps or tree bases. Nest substrate was either conifer needles, moss, or both.

Less is known about the inland-nesting birds in southcentral Alaska. These sub-populations remain away from the coast during the breeding season and are sensitive to human disturbance. Since abundant coastal forage is not available, they seek streams with sufficient invertebrate populations to meet nutritional needs for survival and reproduction. For this reason, they tend to nest along bigger rivers and their tributaries. In Idaho, Montana, and British Columbia they appear to favor streams running out of lakes, which may provide a more abundant food source (Crowley 1993). Inland-breeding populations subsist on macroinvertebrates, aquatic insects, and fish roe although adults may also eat some small fish. In Idaho, they were most frequently observed in reaches of swiftly flowing water away from roads and trails (Cassirer and Groves 1992).

Harlequin ducks return to the same nesting region from year to year. Nest sites are generally concealed under woody debris, dead branches, and dense vegetation, although tree cavities and rock cliff cavities have also been used (Cassirer et al. 1993). Duckling mortality can be high: it was estimated at 59% in the Prince William Sound studies, occurring mostly between 15 - 35 days of age (Crowley and Patten 1995). Young are preyed on by ravens, mink, fox, etc.

### **Impacts from Beetle-Killed Forest**

Harlequin duck nests are generally positioned under the canopy of old-growth forest that intercepts snowfall and provides cover for earlier spring nest site availability. In the Prince William Sound studies, the canopy was provided by western hemlock or Sitka spruce. Other sections of coastal fringe forest within the oil spill area do not contain hemlock and are predominantly spruce, such as Kachemak Bay, the outer coast of the Kenai Peninsula, Afognak Island, and the western shoreline of Cook Inlet. In the current infestation, beetles have made measurable inroads into the coastal forest only in Kachemak Bay, although Afognak Island was the site of a large outbreak earlier in this century.

The current area of spruce bark beetle impact is more likely to overlap the nesting habitat of the inland-breeding populations of harlequin ducks (Figure 2). Once the needles have dropped from

standing spruce trees, they would not afford the same amount of snow protection to potential nest sites, perhaps delaying nest site occupancy in spring. In 1995 one nest site was discovered at the base of a live spruce tree in an area containing several trees killed by the spruce bark beetle (west side of Cook Inlet, M. Wiedmer, pers. comm.). If some mature canopy trees remained to provide snow protection (either unaffected spruce trees or hemlocks), dead trees from a SBB infestation would likely increase the number of nest sites available on the ground by promoting rotting stumps, woody debris, and a dense understory or shrub vegetation. Little information is available to determine the net impact of a bark beetle infestation on nesting habitat in a predominantly spruce area at this time. The relative importance of live canopy trees to provide snow protection would probably vary with the average snowfall in each region.

Logging may result in adverse effects on harlequin ducks. The Idaho study reported that 85% of all observations of adults and broods were in old-growth or mature forest with no logging history (Cassirer and Groves 1992). During nesting season (June), harlequins are subject to disturbances in their waterways and in adjacent forest areas, which could cause displacement of broods from foraging areas (Clarkson 1992). Pre-nesting hens may avoid areas with logging operations underway in their early exploration for nest sites (Cassirer and Groves 1992). After logging has ceased, harlequin ducks might nest in timbered areas adjacent to logged zones or in riparian buffer areas. Several researchers have made recommendations to minimize impacts of timber harvest. These include: leaving a 50 m undisturbed riparian corridor; and visual isolation and limited human activity during the nesting season (Cassirer and Groves 1991, Crowley and Patten 1995). However, the greatest risk to local harlequin duck populations is the potential threat to their food source (stream invertebrates) resulting from sedimentation and other channel structure impacts oftentimes associated with large-scale timber harvesting operations (Clarkson 1994). Therefore, the inland-breeding populations may be more vulnerable since they cannot exploit coastal forage food sources.

## **Bald Eagles**

### **Distribution**

Bald eagles (*Haliaeetus leucocephalus*) nest near coastlines, rivers, large lakes or streams that can provide adequate food supplies. Alaskan bald eagles nest in greatest numbers along the coastal areas of southeast Alaska, the Gulf of Alaska, Prince William Sound, the Kenai and Alaska Peninsulas, and the Aleutian Islands. Lesser numbers occur along Alaska's major river systems in the interior of the state and along the Bering Sea coast (U.S. Fish and Wildlife Service 1993).

Within the documented area of the current spruce beetle infestation (Figures 1 and 2), bald eagles commonly occur on the southern Kenai Peninsula coast and Prince William Sound. Population densities appear to be somewhat lower on the remainder of the Kenai Peninsula despite large potential food resources. A 1982 aerial survey of the Kenai National Wildlife Refuge found 32 nests, with the largest concentration in the Moose River drainage system (Alaska Department of Fish and Game 1985a). Eagle nests are also fairly common in the coastal areas of western Cook



Inlet and often occur several miles inland. Most water bodies in the Cook Inlet area freeze over, forcing eagles to move south and/or east for the winter.

### **Habitat Requirements**

Most bald eagles in Alaska nest in mature or old-growth timber, or on cliffs, sea stacks, and rock promontories if there are no suitable trees. Nests are generally built in locations where food is available in early nesting season. In forested areas, bald eagles typically select the tallest trees with limbs strong enough to support a nest that may weigh more than 1000 pounds.

Additionally, nest sites usually include at least one perch with a clear view of the water. Eagles hunt from a perch, and shoreline trees provide the visibility and accessibility needed to locate prey effectively. Nearly all nest trees are located within 180 m (600 ft) of water at a site that provides security and isolation (U.S. Fish and Wildlife Service 1993). Eagles eat primarily fish (herring, smelt, salmon), waterfowl, seabirds, small mammals and carrion (Sidle and Suring 1986); (U.S. Fish and Wildlife Service 1993).

In the more interior portions of Alaska, eagles typically nest in cottonwoods and white spruce that grow adjacent to rivers and lakes. But by far the majority nest along the coast in coniferous forests. In southeast Alaska nest trees tend to be Sitka spruce (78% in one study), although western hemlock, yellow cedar, and red cedar are also used. The nest trees studied averaged 97 ft tall and were probably between 400 and 500 years old. Few dead trees were used for nesting (6%), although many trees had a bushy or deformed top, providing a more suitable platform for the nest (Sidle et al. 1986). Eagles also prefer nest sites with overhead and surrounding foliage which provides shelter from wind and rain (Alaska Department of Fish and Game 1986a).

Bald eagle nests are constructed of large sticks and lined with moss, grass, plant stalks, lichens, seaweed, and/or sod, and range from 1.2-1.8 m (4-6 ft) in diameter. Nesting begins in early April; hatching (usually two eggs) occurs in May (Sidle and Suring 1986). A mated pair generally uses the same nest from year to year, sometimes for many decades. However, they may use alternative nest sites, and may also reoccupy nest sites after years of disuse (U.S. Fish and Wildlife Service 1993).

On the Kenai National Wildlife Refuge, the majority of bald eagle nests are found in cottonwood trees although aspen is also commonly used. In Kachemak Bay and Prince William Sound, eagles are found nesting in large cottonwood trees adjacent to a river or tidal slough and in large Sitka spruce trees along the coast (Alaska Department of Fish and Game 1986a).

Eagles congregate in winter in areas possessing an abundant food source, day perches, and suitable roosting habitat (Sidle et al. 1986). Kachemak Bay and the upper Kenai River (from lower Skilak Lake outlet to Sterling) are two such seasonal concentration areas within the beetle-affected region (T. Bailey, pers. commun.). Conifers provide winter shelter from storms in these areas.

## **Impacts from Beetle-Killed Forest**

Numerous eagle nests are located in areas known to be affected by spruce bark beetles. In the Kachemak Bay area, nest trees are often white spruce. In much of the rest of the current beetle infestation zone (i.e., western Kenai Peninsula and Cook Inlet), cottonwoods are often the most attractive trees for nesting because they are the largest trees near water that have a suitable branching structure to support a nest platform (T. Jennings, pers. commun.). Fewer white spruce trees in these areas display branching features suitable for nest building; as in southeast Alaska, spruce nesting trees may be limited to those with a broken top or some kind of deformity which better supports a nest platform. Staff at the Kenai National Wildlife Refuge (KNWR) estimated that of the 80 nest sites recently surveyed, less than 5 were in spruce trees; cottonwoods appear to be the preferred nest tree species in the KNWR and vicinity (T. Bailey, pers. comm.).

For those eagles nesting in cottonwoods, the spruce bark beetles would not appear to have much impact. Little information is available to determine the impact of dead versus live spruce trees on eagle behavior. Although overhead shelter in the form of foliage is preferred by nesting eagles, it is not essential and mated pairs might continue to use a nest site in a spruce tree after the tree was killed by beetles. Along the upper Kenai River, it is common to see eagles hunting from spruce tree perches in winter, though cottonwoods also serve this purpose (T. Bailey, pers. commun.). Eagles would be expected to continue using dead spruce trees as hunting perches along a watercourse; they often use snags for that purpose (P. Schempf, T. Jennings, pers. commun.). In time, however, these dead spruce trees would fall and perhaps reduce the number of nest and perching sites available in the given area. If spruce do not comprise the majority of the forest trees in a given area, this effect would not be significant.

Silvicultural treatments to control the bark beetle infestation or for salvaging dead timber could impact bald eagles. In the boreal forest portion of the project area (including the area west and north of a line drawn between Portage, through Moose Pass, across the north end of the Harding Icefield to the mouth of the Fox River in Kachemak Bay and then southwesterly out of Kachemak Bay to Mt. Douglas), there are no mandated riparian buffer requirements on private land. Unless riparian or shoreline fringes are left, logging activities could impact suitable nesting and perching habitat and force eagles out of the area (Corr 1974). Furthermore, nest trees in remaining timber fringes are extremely vulnerable to windthrow or damage. In one study of 100 m (330 ft) buffer zones around nest sites in southeast Alaska, bald eagle productivity was threatened by the high incidence of windthrow (i.e., uprooting and overthrow of trees by strong winds) adjacent to cutover areas, which reduced perching opportunities (Hodges 1982). The number of trees in the nest buffer zone was reduced by 17%, on average, within five years after the harvest (Sidle et al. 1986).

Second growth forests lacking old-growth trees are avoided for nesting; no bald eagle nests have been found in such areas in southeast Alaska. In contrast, adults and active nests were present in greater than expected numbers in one study where a formerly logged area contained remnant old-growth trees (Hodges et al. 1984).

Salvage harvesting operations, especially road construction, can also increase the risk of siltation (Furniss et al. 1991), surface erosion, and accumulation of aquatic debris, all of which could impact aquatic habitats which support potential prey species such as fish and waterbirds, upon which bald eagles are dependent for food (Hansen et al. 1984). Lowering the prey base can cause eagles not to breed (U.S. Army Corps of Engineers 1979). Even if a given nest tree is cottonwood, logging of adjacent dead spruce could result in disturbance and reduce nesting success. Existing bald eagle habitat management guidelines (USFWS 1993) provide a positive framework through which suitable habitat can be protected.

As part of a study on bald eagle nest site characteristics in western Oregon, Anthony and Isaacs (1989) studied the effects of human disturbance (timber harvesting, road construction, and the construction of private homes and recreational facilities) on bald eagle productivity. Results of this study indicate that productivity was lower at sites altered by logging or other human disturbance versus unaltered sites, productivity was negatively correlated to proximity to clearcuts and main logging roads. They also recommended that clearcut logging, road construction, hiking trails, and boat launch facilities should not be allowed within 400 m of nests.

### **Impacts from Salvage Harvest**

Forest management activities are a major disturbance affecting suitable bald eagle nesting habitat (Braun et al. 1975). Lowered nesting success rates and reduced productivity from nest sites adjacent to major roads or recently logged areas, compared to nest sites in undisturbed areas were documented in western Oregon (Anthony and Isaacs 1989). Reproductive failure may result from human activity near the nest sites, especially during the egg-laying and incubation stages of nesting. Nest abandonment can occur at any time as the result of frequent and persistent disturbance (Fyfe and Olendorff 1976). Disturbed eagles that leave their nest may inadvertently break eggs or injure young (Stalmaster et al. 1985). Timber harvesting in riparian areas can eliminate perching and roosting trees.

### **River Otters**

#### **Distribution**

On the Kenai Peninsula, river otters (*Lutra canadensis*) are fairly common in drainages supporting anadromous fish, streams connected to lakes, and in sheltered coastal waters such as the south shore of Kachemak Bay (Alaska Department of Fish and Game 1990, G. del Frate, ADF&G, pers. commun.). In the SBB infestation area, they inhabit anadromous water bodies such as Ninilchik River, Deep Creek, Stariski Creek, the Anchor, Kasilof, and Kenai rivers and Tustumena Lake (Figure 2). They also inhabit the vast network of lakes on the northern Kenai Peninsula (such as the Swanson River and lakes system). A dense population of river otters lives on the south side of Kachemak Bay, which is currently under study (Golden 1996).

## **Habitat Requirements**

Marine river otters are dependent on beach fringe timber, preferring spruce/hemlock forest; freshwater otters depend on naturally vegetated riparian areas with large trees for travel corridors (Sidle and Suring 1986). River otters exhibit strong selection for old-growth forest; they repeatedly have been observed to avoid clearcut areas, even 20 years after logging has ceased (Faro et al. 1994). Old-growth forest is a critical component for successful otter reproduction. The mature forest canopy offers: protection during frequent storms; the older tree's roots support the roof area of natal dens and tunnels in the shallow, water-saturated soils; these depressions also often contain freshwater from summer rains; and decaying root masses seed development of new dens as older ones collapse (Faro et al. 1994, Bowyer et al. 1995). Documentation of latrine sites, telemetry, and other observations have confirmed that otters heavily use a narrow band of old-growth forest within 30 m (100 ft) of the shoreline (Larsen 1983, Woolington 1984) and avoid commercially logged habitats (Bowyer 1995). Based on our review of river otter food habits data collected throughout Alaska, it appears that otters tend to prefer fish but ingested food species change by geographic location depending upon local prey availability and abundance. In a study of coastal otters in Kachemak Bay, Golden (1996) found that river otters primarily ate a wide variety of bony fishes. As Faro et al. (1994) concluded, preventing habitat alteration in this shoreline zone would be the best option towards restoring and maintaining pre-spill densities of river otters.

## **Impacts from Beetle-Killed Forest**

Mature canopy cover is critical to coastal otters, as escape from storms and predators. Loss of tree needles could result in reduced otter survival because of their increased susceptibility to predation while on land. Where spruce comprises a large majority of the forest cover adjacent to waterways (such as in Kachemak Bay), these effects would be most pronounced. Loss of needles from the canopy will stimulate growth of the understory and shrub layer, perhaps replacing the cover element for protection from predators within a few years. A longer-term impact in this area may arise from the toppling of the dead trees over time. River otters show strong selection for old-growth forest, both for the shelter provided by the overstory tree canopy and for the holes and crevices created by the root structure of large conifers (Bowyer et al. 1995). It is difficult to determine how much the natural windthrow of trees will alter or eliminate structural elements favored by otters in old-growth root structures, and/or whether the increased amount of bulk wood at the ground's surface and uplifted root structures from fallen trees could serve the same purpose.

In areas of the interior Kenai Peninsula currently affected by beetles, martens and other small mammals have been observed to use the beetle-killed and fallen spruce logs as cover elements (T. Bailey, pers. commun.). In the Cooper Landing area, the forest canopy is composed of a mixture of spruce, birch, cottonwood, and aspen. Although spruce trees there have been heavily impacted by bark beetles, river otter activity along this stretch of the Kenai River remains high (R. McAvinchey, pers. commun.).

Salvage logging would greatly impact the amount of habitat available to otters since they avoid logged-over sites, although they will use adjacent areas and tree buffer zones along streams. According to Mason and Macdonald (1986), otters are extremely sensitive to water quality and the level of human disturbance, especially overexploitation. Therefore, reductions in otter populations will occur if there is a deterioration of either of these factors through logging or from increased access resulting in human use of lakes and rivers supporting otter populations. Other disturbances associated with logging could cause abandonment of latrine sites used for marking territory or cause emigration of otters in the area. Perhaps the greatest impact related to large-scale salvage logging on river otters would be damage to the local fish resources upon which otters depend (G. del Frate, pers. comm.). Although relatively little information is available on freshwater river otters or more inland otter populations, the risks of adverse effects on fish resources are equally important for both coastal and inland river otter populations.

### **Fish Species**

The four injured fish species in this study will be grouped for discussion because of the similarity of habitats and potential impacts.

### **Distribution**

Pink salmon (*Oncorhynchus gorbuscha*) are located in many drainages of Cook Inlet and Prince William Sound, where much of the spawning is in the lower, intertidal areas. Within the area of concern for spruce bark beetles (Figures 1 and 2), pink salmon are produced in the Kenai and Kasilof river drainages and several small southern peninsula creeks such as Humpy Creek, Tutka Lagoon, Seldovia Creek, and Port Graham River (Alaska Department of Fish and Game 1985b).

Sockeye salmon (*Oncorhynchus nerka*) inhabit several drainages in Cook Inlet and Prince William Sound. Excluding the Copper River populations east of the target area, the vast majority of sockeye in this region spawn in streams and rivers associated with lakes. Sockeye salmon runs are strong in the Kasilof, Kenai, and Crescent river systems. In lower Cook Inlet, systems producing smaller runs of sockeye salmon are the English Bay lakes, Leisure Lake, Amakdedori and Mikfik creeks, and Aialik, Delight and Desire lakes (Alaska Department of Fish and Game 1985b).

Dolly Varden (*Salvelinus malma*, anadromous) are one of the most widespread fish species in this region and inhabit most river drainages on the Kenai Peninsula. Especially abundant in the upper main stem of the Kenai River, Dolly Varden are also found in the Kasilof River, Deep Creek, Ninilchik River, Stariski Creek and Anchor River (Alaska Department of Fish and Game 1985a).

Sea-run cutthroat trout (*Oncorhynchus clarki*) have never been documented in any of the beetle-infested areas shown in Figures 1 and 2. The closest would be small, scattered populations in various locations in Prince William Sound (e.g., Eshamy Bay, Knight Island, Esther Island, Billy's Hole, Green Island). The run size of cutthroats in most of these locations is less than 300 fish (McCarron and Hoffman 1993).

## **Habitat Requirements**

The spawning and rearing habitat requirements for these species are summarized in Table 1. In general, salmonids need: a variety of stream depth and flow features (e.g. pools and riffles); suitable streamflows, temperature conditions and water quality; instream cover elements (woody debris, undercut banks); stable streambanks and channel morphology; food supply; and sufficient amounts of clean spawning gravels to accomplish the freshwater portion of their life cycle.

## **Forest Resources and Practices Act Riparian Buffer Requirements**

The Forest Resources and Practices Act (FRPA) requires that buffer strips be retained along many streams to protect fish habitat from potential impacts from timber harvesting activities. Riparian buffers provide shade for favorable stream temperatures, nutrient inputs in the form of leaves and twigs, sources of large woody debris, and habitat for terrestrial macroinvertebrates that are used as food sources for juvenile anadromous and resident fish species. In addition, buffer strips act as a vegetative filter for stream water quality, and provide cover and movement corridors for big game, furbearers, birds, and small mammals.

In the coastal spruce-hemlock forest (Forest Region I) portion of the EVOS study area, Alaska Statutes 41.17 requires that 66-foot no-harvest riparian buffers be retained on both sides of anadromous fish streams on private land, a 100-foot buffer on federal lands, and a 300-foot buffer on state lands with logging permitted in the area from 100-300 feet from the stream. On state and federal lands high value resident fish also receive the same amount of riparian habitat protection. In the mixed white spruce forest of the boreal forest (Forest Region 2), the FRPA does not require retention of no-harvest riparian buffers on anadromous fish streams on private land and allows timber harvesting in the riparian zone if it can be done in a manner that protects fish habitat and maintains water quality. State and federal lands in the boreal forest region have identical riparian buffer requirements as described for the coastal forest.

## **Impacts from Beetle-Killed Forest**

### **A. Dead spruce trees**

The effects of standing or fallen dead spruce trees as a result of the bark beetle infestation would vary directly with the contribution that spruce makes to the riparian forest canopy. These potential effects are addressed in the following:

**Increased water runoff:** Many studies have demonstrated that tree mortality from an insect epidemic will increase the amount of runoff in the watershed because the dead trees no longer transpire or intercept precipitation. The degree and length of this effect is contradicted in the literature. In southwestern Montana a post-epidemic drainage manifested a 15% increase in annual water yield, a two- to three-week advance in the annual hydrograph, a 10% increase in low flows and little increase in peak runoff (Potts 1984). These effects were measured in the first five years after the epidemic which killed an estimated 35% of the total timber in the watershed. Bethlahmy (1974, 1975) records significant increases in streamflow in Colorado watersheds

which suffered heavy mortality from spruce beetle. His data suggests that flow may remain higher than normal for up to 25 years after the forests are killed. In contrast, a study on the effects of the southern pine beetle in Virginia found that the changes in water yield were insignificant forest-wide, and suggested that the effect was reduced and offset as new vegetation occupied the growing space (Leuschner et al. 1979). No adverse impacts in water quality resulted from this outbreak, because the soil disturbance was insignificant and the infestation spots were small and scattered. The different natural characteristics of the areas studied (e.g., arid versus moist climate; low versus high-gradient watersheds) and the percentage of canopy trees killed may account for the high variation in observed water yield changes.

In general, however, an increase in water flow may result from the SBB infestation in southcentral Alaska. In the worst-case scenario, where a majority of the watershed canopy is composed of dead spruce, the stream hydrograph would show more extremes--higher peaks, an earlier rise, etc., which could effect all life stages of salmonids (eggs, alevins, etc.). However, the changes in water flow noted above appear to be most acute in naturally arid regions, and may be less conspicuous in the moister hydrologic regime and denser vegetation of much of southcentral Alaska.

The effect of increased runoff would not be uniform for all injured fish species. Higher water velocity would likely trouble sockeye and Dolly Varden less than pink salmon that are not considered strong swimmers. Returning pink salmon spawners could be hindered by increased water velocity, although much of their population in this region spawns intertidally (Alaska Department of Fish and Game 1986b). Increased velocity could also block upstream migration of cutthroat trout (Pauley et al. 1989a), if beetle infestations were to spread to their regions.

As is the case for all habitat parameters considered, the degree of impact would vary significantly with the forest composition of the specified area; the higher the percentage of spruce in the forest canopy, the greater the observed impact.

Large woody debris: Wenger (1994a) analyzed several possible impacts of beetle infestation on fisheries resources for the Moose Pass area of the Kenai Peninsula. Much of the following discussion on large woody debris, erosion, and stream shading is summarized from this analysis.

Cover (in the form of overhanging vegetation, undercut banks, logs and rocks in the stream, water pools and turbulence) is an essential element in the life cycle of salmonids. Studies have demonstrated, for instance, that the biomass of cutthroat trout in a stream increases with the amount of cover available (Pauley et al. 1989a).

Large trees in the riparian area provide a source of large woody debris (LWD) which forms cover in the stream channel. Trees fall into streams as a result of windthrow, bank undercutting, and mortality from insects, disease, or fire. LWD forms up to 73% of the pool rearing habitat for salmonids in small streams (Heifetz et al. 1986). Pools created by LWD are preferred by juvenile salmon because they provide better hiding cover and more diversity than pools created by boulders. Woody debris in streams also collects sediment during high water flows, helping maintain quality spawning gravels.

In the short term, beetle tree mortality will cause an increase in the amount of large woody debris entering streams. In the Moose Pass area, the peak period of LWD entering streams is anticipated to be 5-10 years after riparian spruce are attacked by beetles (Wenger 1994a). The downed spruce trees will then influence stream morphology and provide cover habitat for rearing and migrating juvenile salmon until the wood decays or is flushed out by high flows. Based on studies of the persistence of LWD in southeast Alaska (Murphy and Koski 1989), beetle-killed spruce would be expected to provide productive habitat in streams for at least 20-30 years. If spruce were the sole source of LWD in a given area and if all mature spruce were killed in a single outbreak, a gap period could occur between the disappearance of the downed debris in the streams and the time it takes to reestablish spruce of sufficient size to contribute new LWD to the system (estimated at 50 - 70 years). Most of the streams in the beetle epidemic zone would not meet these assumptions, however. In mixed riparian stands (i.e., containing cottonwood, birch, hemlock), the effect of spruce mortality from beetles would be minimal since other tree species would sustain a future source of LWD.

Erosion/bank integrity: Streambank integrity is maintained by healthy streamside vegetation. The root structure of trees, woody shrubs and grasses serve as a net which binds streambank materials. The loss of root structure associated with dying spruce could destabilize the soil and lead to increased surface erosion and sedimentation in the streams (Bishop and Stevens 1964). Survival of salmon eggs within the spawning redds decreases rapidly as the percentage of fine sediments exceeds 10%. This reaction would be greatest in areas susceptible to mass wasting, i.e., along high gradient streams with steep side slopes that drain into spawning streams. Such sedimentation can have major impacts on local populations of salmon and trout. On the other hand, salmon streams with moderate to low gradients and gradually sloping sides would not experience as much sedimentation from tree kill. In addition, understory vegetation and other tree species would continue to protect surface soils from erosion in many areas. The severity of the impact would depend on whether mass wasting could occur along steep banks, its location in relation to spawning areas, and the percentage of spruce in the riparian vegetation (Wenger 1994a).

Stream shading: In many regions healthy streamside vegetation also plays an important role in fish habitat by providing shade. In southcentral Alaska, however, stream shading during summer months is not critical to achieve suitable water temperatures since they rarely reach lethal levels. In this area, a reduction in large trees along stream margins would likely have a greater effect in the winter by influencing snow accumulation. Added snow accumulation on the surface insulates the channel, preventing formation of extensive anchor ice and keeping eggs in spawning gravels from freezing (Swanston 1991). During winters of low snow fall, reduced tree canopy could have the opposite effect since more thermal energy would be allowed to escape the stream. These effects would be greatest in riparian zones dominated by spruce, where it could take decades to reestablish large spruce trees along stream margins. In mixed canopy riparian stands, other vegetation would continue to shade and buffer temperatures and intercept snow, and no significant changes in stream temperature or icing would be expected (Wenger 1994a).



## B. Salvage Logging Impacts

The potential effects of timber harvest on salmonid and other fish populations have been well documented (Chamberlin et al. 1991, Furniss et al. 1991). The amount of impact depends largely on the harvesting techniques used and activity level in the riparian areas, but generally the effects on fish are associated with: increased sedimentation; disruption of fish migrations from road crossing of streams; removal of potential sources of large woody debris in the streamside area; decreased stream shading; and changes in bank stability and channel morphology over time. As stated above, stream shading does not appear to play a critical role in regulating fish habitat in southcentral Alaska.

**Sedimentation:** Stream sediment loads are increased by both harvesting along streams and constructing timber access roads. Fine sediments in salmonid rearing areas can clog fish gills, reduce feeding, block access to some areas, lower survival of eggs or alevins and/or destroy food sources such as insect larvae (Pauley et al. 1989b). Sedimentation negatively affects spawning conditions and the early fry stage, causing fewer adults to return, and run populations to decline. Cutthroat trout can be particularly hard hit by logging impacts because they spawn and rear in small tributaries and isolated headwater streams, where the stream system has the least capacity to buffer these effects on fish populations. As is the case for most salmonids, survival of cutthroat embryos has been shown to decrease as the percentage of fine sediments in the substrate increases (Pauley et al. 1989a).

**Disruption of fish migrations:** Disturbances or complete blockages to adult and juvenile salmon migrations can occur from poorly designed road crossings. An inadequately sized or poorly installed culvert can block fish by acting as either a physical, velocity, or elevational barrier (i.e., perched culverts). Minimizing the number of stream crossings and employing bridges and/or pipe arched culverts can reduce these dangers.

**Removal of sources of large woody debris:** As discussed above, large woody debris is an essential element of productive salmonid habitat. The bark beetle epidemic and any salvage operations in the riparian zone would affect the present and future supply of LWD. A long-term continuous state of slow LWD additions is the optimal situation. Too much at one time (as in a riparian community made up almost exclusively of beetle-killed spruce trees) could destabilize the creek bank and/or impede fish passage. However, it is a far more common error to allow for too little LWD recruitment over time, resulting in channel incision and consequent loss of the diversity of water depth and flow types needed for productive spawning and rearing. If salvage logging were to be proposed in a predominantly spruce riparian zone, a percentage of standing dead trees should be left to supply a short-term source of LWD (Wenger 1994b).

**Channel stability:** In addition to removing sources of LWD, logging activities can influence channel morphology in other ways. Adverse impacts to fish populations would include dispersing spawning gravels, altering access for migrating juveniles and adults, and reducing the number of resting pools (used during migration) and rearing ponds through changes in stream bank stability, lateral scouring (widening and shallowing), and changes in sediment and bedload routing. The amount of harvest near the stream affects the watershed's ability to retain storm

runoff and dampen flood waters, which would also affect sediment and bedload movement (U.S.D.A. Forest Service and Foster Wheeler Environmental Corporation 1995).

Summary of spruce bark beetle impacts on fish: Any potentially adverse effects on fisheries resources from timber salvage efforts can be significantly decreased by avoiding timber harvest and road construction in riparian areas and by designing adequate stream crossings. However, if an objective of spruce bark beetle management actions were to remove affected spruce within the riparian zone, there could be serious consequences for fish habitat productivity in the area, as described above. Arguments against any tree harvest in riparian areas point to the impacts associated with accessing and harvesting beetle-killed spruce through ground based operations, and suggest that these impacts would prove far more damaging than allowing the trees to die. For the proposed Moose Pass salvage timber sale, fisheries biologists responded to a request for information with almost exclusive recommendations that no salvage logging be done in riparian areas (Wenger 1994b). Fisheries biologists justified this recommendation based on the following points: the expected additions of downed wood to the stream from beetle-killed trees are generally beneficial to fish habitat; there is no documentation to support the contention that the infestation could result in too much downed wood, which would degrade fish habitat; and that therefore salvage logging in the riparian zone would likely cause significantly more damage to fish habitat than leaving the trees where they are.

## CONCLUSIONS

Studies examining the specific effects of a large spruce die-off on the injured species are non-existent. The few studies that have addressed wildlife impacts of similar infestations in other states may have limited applicability in southcentral Alaska due to different climatic factors (rainfall and decay rates) and natural forest succession patterns. Alaskan studies are needed to address the secondary impacts of an infestation in this climatic zone. The combined assessment of many professional biologists, ecologists, and foresters together with the most relevant available literature yields the following anticipated effects.

In general, the effect of spruce bark beetle infestations on the injured species would vary directly with the percentage of spruce composing the mature forest canopy in a given area. In an area of mixed forest canopy species, the remaining live canopy trees would be expected to continue to provide essential functions such as cover and recruitment of large woody debris into streams. Some of the injured species, such as harlequin ducks and river otters, might experience positive short-term benefits from the increase in potential nesting and denning sites afforded by the downed wood and subsequent dense understory vegetation. Others, such as the bald eagle and marbled murrelet, would experience a decrease in the number of suitable nesting sites in areas where spruce are the dominant nesting tree. This is the case along Kachemak Bay; less impact would be anticipated for these tree nesters in other portions of the current bark beetle infestation within the oil spill zone. The effect of the spruce bark beetle infestation on fisheries resources is anticipated to be minimal, especially in mixed stands where other tree species can maintain riparian functions when spruce trees die.

Silvicultural management options for the control of spruce bark beetles involving road construction and/or salvage logging resulting in the widespread loss of much of the forest canopy will likely prove detrimental to all of the injured species mentioned above. When, and if, the Trustee Council considers retaining or purchasing parcels of forest land as habitat protection for injured species, the importance of spruce in the forest canopy and any past timber management actions should be central considerations. They should consider addressing the following questions: 1) what proportion of the mature forest is comprised of spruce; 2) are the injured species dependent on spruce particularly for nesting sites, denning sites, or cover in that area; 3) has the parcel been assessed for its susceptibility to SBB attack and likelihood of infestation (Reynolds et al. 1994); and 4) have any management actions been initiated on the land for the control of the bark beetle? In general, a land parcel affected by the spruce bark beetle will have the highest remaining habitat values for the injured species if spruce is just one component of a mixed forest canopy, and if no management actions involving road construction or large-scale timber harvesting of mature forest have been conducted in the area. These key points, along with the synthesis of information provided above for the injured species should be utilized by the Trustee Council in making habitat management decisions that would retain important habitat values and prevent further injury to fish and wildlife resources already impacted by the spill.

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APPENDIX: Sampling of Literature Collected on Database

REF#: 3614

TI: Effects of logging on winter habitat of juvenile salmonids in Alaskan streams

AU: Heifetz, J; Murphy, ML; Koski, KV

SO: N. Amer. J. Fish. Mgmt. 6, pp. 52-58.

PY: 1986

AB: Effects of logging on preferred winter habitats of juvenile salmonids in southeastern Alaskan streams were assessed by comparing the area of preferred winter habitat in 54 reaches of 18 streams. Three types of streams were sampled at each of six locations: a stream in a mature, undisturbed forest; a stream in a clear-cut area but logged on at least one bank; and a stream in a clear-cut area with strips of forest (buffer strips) along the stream bank. To identify preferred winter habitats, we classified stream areas in 12 of 18 streams into discrete habitat types and compared the density of salmonids within these habitat types with average density of the entire reach. Most wintering coho salmon, Dolly Varden, and steelhead occupied deep pools with cover (i.e., upturned tree roots, accumulations of logs, and cobble substrate). Riffles, glides, and pools without cover were not used. 73% of all pools were formed by large organic debris. Reaches in clear-cut areas without buffer strips had significantly less area of pool habitat than old-growth reaches. Buffer strips protected winter habitat of juvenile salmonids by maintaining pool area and cover within pools. In some cases, blowdown from buffer strips added large organic debris to the stream and increased the cover within pools.

KW: COHO SALMON; DOLLY VARDEN; FISH HABITAT IMPACTS; LARGE WOODY DEBRIS; LOGGING; SOUTHEAST ALASKA; STEELHEAD; WINTER HABITAT

REF#: 3624

TI: Comparison of White, Sitka, and Lutz Spruce as Hosts of the Spruce Beetle in Alaska

AU: Holsten, EH; Werner, RA

SO: Can. J. For. Res. 20, pp. 292-297.

PY: 1990

AB: When white spruce is infected with spruce beetle broods, more beetles are produced than when Lutz and Sitka spruce are infested. In spite of the host susceptibility differences, outbreaks of the spruce beetle have been more frequent and severe in stands of Lutz spruce than in white or Sitka spruce. Host suitability may be as important as host susceptibility and weather conditions in the development of spruce beetle outbreaks in south central Alaska. Cool summer temperatures and high precipitation limit the rate of development and growth of beetles in maritime Sitka spruce stands of southeast Alaska, but in white spruce stands of interior Alaska, cold winter temperatures usually help to maintain endemic levels. When these factors are ameliorated, however, spruce beetle populations increase rapidly to epidemic levels.

KW: ALASKA; LUTZ SPRUCE; RISK RATING; SITKA SPRUCE; SOUTHCENTRAL ALASKA; SPRUCE BEETLE; WHITE SPRUCE

REF#: 3605

TI: Inland Habitat Suitability for the Marbled Murrelet in Southcentral Alaska

AU: Kuletz, KJ; Marks, DK; Naslund, NL; Goodson, NJ; Cody, MB

SO: pp. 141-149 In: Ecology and Conservation of the Marbled Murrelet, edited by Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; Albany, CA.

PY: 1995

AB: The majority of marbled murrelets nest in Alaska, where they sometimes nest on the ground, and their nesting habitat requirements are not well understood. The inland activity of murrelets was surveyed, and habitat features measured, between 1991 and 1993 in Prince William Sound, Kenai Fjords National Park and Afognak Island, Alaska (n= 262 sites). We used these data to develop statistical models that explain variation in murrelet activity levels and predict the occurrence of occupied behaviors (indicative of nesting) based on temporal, geographic, topographic, weather and habitat characteristics. Multiple regression analyses explained 52% of the variation in general murrelet activity levels ( $p < 0.0001$ ). The best model included survey date, location relative to the head of a bay, elevation, slope, aspect, % of forest cover, tree diameter, and epiphyte cover on tree branches. The highest activity levels were associated with late July surveys at the heads of bays where there was high epiphyte cover on trees. Stepwise logistic regression was used to identify variables that could predict the probability of detecting occupied behaviors at a survey site. The best model included survey method (from a boat, shore, or upland), location relative to the head of a bay, tree diameter, and number of potential nesting platforms on trees. The best predictors for observing occupied behaviors were tree diameter and number of platforms. In a jackknife procedure, the logistic function correctly classified 83% of the occupied sites. Overall, the features indicative of murrelet nesting habitat include low elevation locations near heads of bays, with extensive forest cover of large old-growth trees. Our results were derived from surveys designed to estimate murrelet use of forested habitat and may not accurately reflect use of nonforested habitat. Therefore, caution should be exercised when extrapolating observed trends on a broad scale across the landscape.

KW: BRACHYRAMPHUS MARMORATUS; MARBLED MURRELET; NESTING HABITAT; SOUTHCENTRAL ALASKA

REF#: 5423

TI: Estimating the southern pine beetle's hydrologic impact

AU: Leuschner, WA; Shore, DG; Smith, DW

SO: Bulletin of the Entomological Society of America 25 (2), pp. 147-150.

PY: 1979

AB: Infestations with *Dendroctonus frontalis* Zimm. alter forest watershed dynamics by killing trees and consequently forming openings in forests. This tends to increase water yield because the trees no longer transpire or intercept precipitation. The further an opening is located from a stream the more attenuated is the flow. These effects are reduced and subsequently offset completely as new vegetation occupies the growing space. The authors attempted to develop a methodology for estimating the hydrological impact of the beetle. Preliminary estimates indicated that changes in water yield caused

by infestations were insignificant forest-wide and generally did not need to be considered in control decisions. Similarly, water quality was not adversely affected, because there was insignificant soil disturbance and because infestation spots were characteristically small and scattered.

**KW:** AGRICULTURAL ENTOMOLOGY; ARTHROPODS; DENDROCTONUS FRONTALIS; ECONOMICS; HYDROLOGIC IMPACT; INSECT PESTS; PLANT WATER RELATIONS; TREES

**REF#:** 4984

**TI:** A qualitative analysis of the southern pine beetle's wildlife impact

**AU:** Maine, JD; Leuschner, WA; Tipton, AR

**SO:** Publication, School of Forestry and Wildlife Resources, Virginia Polytechnic Institute and State University. 1980., No. FWS-1-80, iii + 48 pp.; 84 ref.

**PY:** 1980

**AB:** The likely impact of *Dendroctonus frontalis* in the southern USA was assessed by considering each component change produced by an outbreak and reviewing the literature relating to its effect on different species groups. The components analysed were: increased bird food (insects); increased browse and other plant food; increased stream temp. and sedimentation; increased edge effects; changes in availability of nest sites; and changes in shelter and cover. *D. frontalis* has a positive impact on numbers of woodpeckers, quail (*Colinus virginianus*), rabbit (*Sylvilagus floridanus*), deer (*Odocoileus virginianus*), small mammals, and other birds, with increases in edge and food being the most important components; turkey (*Meleagris gallopavo*), squirrel, fish and other mammal numbers are unaffected. It is argued that the positive impacts on wildlife should be considered as an additional cost of beetle control, which could play an important role in decision making, especially when the benefits of a control programme are expected to be small.

**KW:** COLINUS VIRGINIANUS; DENDROCTONUS FRONTALIS; ECOLOGY; FORESTRY; MELEAGRIS GALLOPAVO; ODOCOILEUS VIRGINIANUS; SYLVILAGUS FLORIDANUS; USA; WILDLIFE

**REF#:** 3611

**TI:** Nest Success and the Effects of Predation on Marbled Murrelets

**AU:** Nelson, SK; Hamer, TE

**SO:** pp. 89-97 In: Ecology and Conservation of the Marbled Murrelet, edited by Ralph, C.J.; Hunt, G.L.; Raphael, M.G.; Piatt, J.F. Gen. Tech. Rept. PSW-GTR-152. Pacific Southwest Research Station, Forest Service, U.S. Dept. of Agriculture; Albany, CA.

**PY:** 1995

**AB:** By summarizing the information known on tree nests in North America, we found that 72% (23 of 32) nests were unsuccessful. The major cause of nest failure was predation (56%). Predators included common ravens and Steller's jays, predation by a great horned owl was suspected. We believe that changes in the forested habitat, such as increased amounts of edge, are affecting murrelet productivity. Successful nests were significantly further from edges and were better concealed than unsuccessful nests. We hypothesize that because this seabird has a low reproductive rate (one egg clutch), small increases in

predation will have deleterious effects on population viability. Further studies, such as testing the effects of various habitat features on recruitment and demography should be developed.

KW: BRACHYRAMPHUS MARMORATUS; MARBLED MURRELET; NEST SUCCESS;  
PREDATION

*Info to be included with diskettes of database:*

**System Requirements:**

Papyrus may be installed to run on an IBM-PC compatible computer under MS-DOS, Windows, and DESQview. In the future, it will be available for use in a full Windows environment. The Papyrus program requires approximately 470K of free RAM memory to run. Papyrus's program files take up approximately 2 megabytes of hard disk. The spruce bark beetle database files take up approximately 7.6 megabytes. For those who request the database that do not own Papyrus, a stripped-down, "read-only" version of the program called "Papyrus Retriever" may be obtained from us on one additional diskette. As described in the Papyrus manual (Version 7.0, page 2), the retriever is capable of searching a Papyrus database and outputting the results, but does not allow changes or additions to the database.