Exxon Valdez Oil Spill
Restoration Project Final Report

Western Prince William Sound Human Use and Wildlife Disturbance Model

Restoration Project 99339
Final Report

Karen A. Murphy[1]
Glacier Ranger District
Chugach National Forest
P.O. Box 129
Girdwood, Alaska 99587

Lowell H. Suring[2]
Chugach National Forest
3301 C Street, Suite 300
Anchorage, Alaska 99503

Ali Iliff[3]
Alaska Department of Natural Resources
Division of Parks and Outdoor Recreation
Anchorage, Alaska 99503

August 2004

[1] Current address: U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, Alaska 99503.
[2] Current address: USDA Forest Service, Terrestrial Wildlife Ecology Unit, Forestry Sciences Laboratory, 316 East Myrtle Avenue, Boise, Idaho 83702
[3] Current address: 1600 West 11th Avenue, Number 33, Anchorage, Alaska 99501.

Exxon Valdez Oil Spill
Restoration Project Final Report

Western Prince William Sound Human Use and Wildlife Disturbance Model

Restoration Project 99339
Final Report

Karen A. Murphy[1]
Glacier Ranger District
Chugach National Forest
P.O. Box 129
Girdwood, Alaska 99587

Lowell H. Suring[2]
Chugach National Forest
3301 C Street, Suite 300
Anchorage, Alaska 99503

Ali Iliff[3]
Alaska Department of Natural Resources
Division of Parks and Outdoor Recreation
Anchorage, Alaska 99503

August 2004

[1] Current address: U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, Alaska 99503.
[2] Current address: USDA Forest Service, Terrestrial Wildlife Ecology Unit, Forestry Sciences Laboratory, 316 East Myrtle Avenue, Boise, Idaho 83702
[3] Current address: 1600 West 11th Avenue, Number 33, Anchorage, Alaska 99501.

Western Prince William Sound Human Use and Wildlife Disturbance Model

Restoration Project 99339
Final Report

Study History: Project 99339 was proposed in 1997 by the USDA Forest Service and the Alaska Department of Natural Resources as a pilot project covering western Prince William Sound. Funding for the initial year of the project was received in December 1997 from the *Exxon Valdez* Oil Spill Trustee Council. Chapter 1 of the final report (Western Prince William Sound Human Use and Wildlife Disturbance Model – Assessment of Current Human Use Patterns) was submitted to the *Exxon Valdez* Oil Spill Trustee Council for review in December 1999. That chapter includes a description of human use patterns in 1998, distribution of selected species injured as a result of the *Exxon Valdez* Oil Spill, results of a literature review on the effects of human disturbance on wildlife, and general management recommendations. A summary of this material was previously published as: *Murphy, K. A., L. H. Suring, and A. Iliff. 2001. Human use and wildlife disturbance – establishing the baseline for management in western Prince William Sound, Alaska. Proceedings of the 2nd Biennial Coastal GeoTools Conference, 8-11 January 2001, Charleston, South Carolina*. Chapter 2 of the final report (Western Prince William Sound Human Use and Wildlife Disturbance Model – Predictions of Future Human Use Patterns and Associated Wildlife Disturbance) was submitted to the *Exxon Valdez* Oil Spill Trustee Council for review in January 2004. That chapter includes predictions of future human use patterns, descriptions of potential areas of increased conflict with selected injured species, and specific management recommendations.

Abstract: We described human use in western Prince William Sound in 1998 through surveys of recreational boaters, Whittier Harbor records, and surveys of charter boat operators. We modeled future human use patterns and described their relationship with the distribution of harbor seals (*Phoca vitulina*) and pigeon guillemots (*Cepphus columba*). Predicted changes in monthly use in 2015 within 1,000 m of guillemot nesting sites ranged from 0 to increases > 4 times by kayakers and from 0 to increases approximating 20 times by motorized recreational boats. Predicted changes in monthly use within 1,000 m of haul-out sites for seals ranged from 0 to increases approximating 12 times by kayakers and from 0 to increases approximating 45 times by motorized recreational boats.

Disturbance of injured wildlife may result in decreased productivity exacerbating the effects of the spill. Education programs should be developed that identify situations and habitats to be avoided. New recreation sites should be developed to divert use away from sensitive areas. Consideration should be given to closing selected existing sites or discouraging their use. A greater presence in the Sound by management agencies is needed to implement education efforts, enforce existing regulations, and assure adherence to closed-area policies.

Key Words: Alaska, *Cepphus columba, EVOS, Exxon Valdez,* geographic information system, GIS, harbor seals, human use, *Phoca vitulina*, pigeon guillemots, Prince William Sound, wildlife disturbance.

Project Data: 1) Data describing vessel use of Whittier Harbor during 1997; stored in a MS Access database; held by Karen A. Murphy, U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, Alaska, 907-786-3501/907-786-3965, karen_a_murphy@fws.gov; are available upon request. 2) Monthly and cumulative use patterns of kayak, charter boat, cruise ship and State ferries, commercial fishing, and recreational motor boat user groups for western Prince William Sound for either 1996, 1997, or 1998; stored as ArcGIS geographic information system data files; held by Karin Preston, USDA Forest Service, Chugach National Forest, Anchorage, Alaska, 907-743-9574, kpreston@fs.fed.us, are available upon request as Arc export files. 3) Results of surveys of recreational motor boat operators and kayakers in western Prince William Sound; stored in a MS Assess database; held by Karen A. Murphy, U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, Alaska, 907-786-3501/907-786-3965, karen_a_murphy@fws.gov; are available upon request. 4) Predicted monthly and cumulative use data and use patterns of kayak and recreational motor boat user groups for western Prince William Sound for 2015 stored as MS Excel spreadsheets and ArcGIS geographic information system data files, respectively are held by Karin Preston, USDA Forest Service, Chugach National Forest, Anchorage, Alaska, 907-743-9574, kpreston@fs.fed.us. Spatial data are available upon request as Arc export files.

Citation: Murphy, K. A., L. H. Suring, and A. Iliff. 2004. Western Prince William Sound human use and wildlife disturbance model, *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 99339), USDA Forest Service, Chugach National Forest, Anchorage, Alaska.

Exxon Valdez Oil Spill
Restoration Final Report

Western Prince William Sound Human Use and Wildlife Disturbance Model – Assessment of Current Human Use Patterns

Restoration Project 99339
Final Report – Chapter 1

Karen A. Murphy[1]
Glacier Ranger District
Chugach National Forest
P.O. Box 129
Girdwood, Alaska 99587

Lowell H. Suring[2]
Chugach National Forest
3301 C Street, Suite 300
Anchorage, Alaska 99503

Ali Iliff[3]
Alaska Department of Natural Resources
Division of Parks and Outdoor Recreation
Anchorage, Alaska 99503

August 2004

[1] Current address: U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, Alaska 99503.
[2] Current address: USDA Forest Service, Terrestrial Wildlife Ecology Unit, Forestry Sciences Laboratory, 316 East Myrtle Avenue, Boise, Idaho 83702
[3] Current address: 1600 West 11th Avenue, Number 33, Anchorage, Alaska 99501.

Western Prince William Sound Human Use and Wildlife Disturbance Model

Restoration Project 99339
Final Report – Chapter 1

Study History: Project 99339 was proposed in 1997 by the USDA Forest Service and the Alaska Department of Natural Resources as a pilot project covering western Prince William Sound. Funding for the initial year of the project was received in December 1997 from the *Exxon Valdez* Oil Spill Trustee Council. This report constitutes Chapter 1of the final product and includes a description of current human use patterns, distribution of selected species injured as a result of the *Exxon Valdez* Oil Spill, results of a literature review on the effects of human disturbance on wildlife, and general management recommendations. Chapter 2 of the final product includes projections of future human use patterns, descriptions of potential areas of conflict with the selected injured species, and specific management recommendations.

Abstract: We used geographic information system techniques to describe current human use in western Prince William Sound. Current human use patterns were constructed from numerous sources, including: 1) a survey of recreational boaters using western Prince William Sound, 2) records from the Whittier Harbor Master's office, 3) interviews with and records of charter boat operators, and 4) information from the State of Alaska on commercial fishing use. Resulting use patterns were verified through aerial surveys of western Prince William Sound during the 1998 boating season. Digital maps of current use were incorporated with digital maps of the distribution of harbor seal, pigeon guillemot, and cutthroat trout. This provided a basis to identify areas where there may be conflicts between human use and wildlife concentrations resulting in disturbance. Disturbance of injured wildlife may result in decreased productivity exacerbating the effects of the spill and prolonging the time to recovery. Review of the published literature on the effects of human disturbance on wildlife allowed development of recommendations that may eliminate or minimize the negative effects of increasing human use. This information is expected to be useful to Federal, State, and private land managers in their land management planning efforts.

Key Words: Alaska, *Exxon Valdez*, geographic information system, human use, Prince William Sound, wildlife disturbance.

Project Data: 1) Vessel use of Whittier Harbor during 1997; stored in an Access database; held by Karen A. Murphy, U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, Alaska, 907-786-3501/907-786-3965, karen_a_murphy@fws.gov; data are available upon request. 2) Monthly and cumulative use patterns of kayak, charter boat, cruise ship and State ferries, commercial fishing, and recreational motor boat user groups for western Prince William Sound for either 1996, 1997, or 1998; stored as ArcGIS geographic information system data files; held by Karin Preston, USDA Forest Service, Chugach National Forest, Anchorage, Alaska, 907-743-9574, kpreston@fs.fed.us, data are available upon request as Arc export files. 3) Results of surveys of recreational motor boat operators and kayakers in western Prince William Sound; stored in an Assess database; held by Karen A. Murphy, U.S. Fish and Wildlife

Service, 1011 East Tudor Road, Anchorage, Alaska, 907-786-3501/907-786-3965, karen_a_murphy@fws.gov; data are available upon request.

Citation: Murphy, K. A., L. H. Suring, and A. Iliff. 2004. Western Prince William Sound human use and wildlife disturbance model – assessment of current human use patterns. Pages 4-199 *in* K. A. Murphy, L. H. Suring, and A. Iliff. 2004. Western Prince William Sound human use and wildlife disturbance model, *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 99339), USDA Forest Service, Chugach National Forest, Anchorage, Alaska.

TABLE OF CONTENTS

LIST OF TABLES

FIGURES

APPENDICES

EXECUTIVE SUMMARY

Ten years after the *Exxon Valdez* oil spill, only 2 injured species were considered to have recovered from the effects of the spill, while 12 species were believed to still be recovering. Populations of 8 species have shown little or no improvement and are listed as “not recovering," while an additional 4 species are in an unknown recovery status. Simple explanations for the different recovery responses shown by different species do not exist. The ability of a species to recover from the effects of an event like the spill depends on a multitude of factors, including breeding strategies, food availability, habitat quality, and other pressures that may exist on the population, in addition to any lingering effects of the spill. As human use in Prince William Sound (the Sound) increases, there is an increasing potential that human disturbance will play a major role in the distribution and population dynamics of many wildlife species. What effect this change may have on the recovery of species injured by the spill will depend on resource managers’ abilities to understand and mitigate the effects of human activity in areas important to the injured species.

While increased human activity in the Sound may affect the recovery of species injured by the spill, little information has been available to document and monitor the changing patterns of human use in the Sound. This project was designed as a tool for resource managers in the western Sound to help them understand the potential relationships between human activity and local wildlife populations. This information is particularly important because new access into the western Sound is expected to result in dramatic increases in recreation-based human activities. The goal of this project was to provide a foundation for displaying and understanding existing and future human use patterns in the western Sound, the potential disturbances these uses may have on injured resources, and to make management recommendations to minimize adverse effects of increased human use on wildlife populations.

Human activity in the western Sound is strongly tied to the water of the Sound. People participating in upland activities generally access upland sites via the water. The greatest potential for disturbance to injured species is also most likely to be from water-based activities. For these reasons, our project focused entirely on water-based human uses. We divided water-based activities into 5 user groups: kayaks, charter boats, cruise ships and Alaska State ferries, commercial fishing, and other recreational motor boats. Because the activities and movements of these different user groups are distinct from each other, and would presumably have different potentials to disturb wildlife, distribution use patterns were developed independently for each group. The extent of human use in the western Sound was described through a geographic information system (GIS) based analysis of the distribution of water craft in association with preferred destinations (e.g., recreational and commercial fishing areas, mooring buoys, camping sites, recreation cabins). To evaluate the projected distribution of vessels in each user group throughout the western Sound, aerial surveys were conducted during summer months in 1998 to record the density of water vessel use on weekends and weekdays.

To compare human use levels near concentrations of injured resources, distribution maps of concentration areas were created for 3 species. The 3 injured resources were used as examples to demonstrate how information on distribution of human use was relevant to the recovery of different species. Harbor seals, pigeon guillemots, and cutthroat trout were selected to represent 3 classes of animal species injured as a result of the spill. To understand how human activities may affect injured species and other wildlife populations in the western Sound, we examined studies published in the scientific literature pertaining to human disturbance of

wildlife. Our specific goal for this literature review was to summarize information that could be used by managers to understand the effects of human activity near wildlife populations. Information that identified distances at which disturbance occurred and that identified the consequences of the disturbance was of particular interest. We focused our search on taxa and forms of disturbance that may be relevant to current or future conditions in the western Sound.

There were 727 individual vessels, in 12 vessel classes, that docked in the Whittier Harbor during the summer months of 1997. Nearly 6800 trips were estimated to have originated from the Whittier harbor. The description of current use patterns for kayaks was based on 1368 occurrences of kayaks over 146 routes. Sixty-nine percent of the kayaks used charter services one way on their trip, while 15% were dropped off and picked up by a charter service, and 16% paddled their entire trip. Charter boat operators based in Whittier commonly used seventy-six destinations. Most of these destinations were used by water taxi charter services that transport kayakers to or from different parts of the study area. Six-hundred ninety two individual trips were considered in the distribution of existing use by charter boats; 447 of these were for water taxi operators, 245 were for other charter operations – primarily sport fishing and sightseeing. Three companies operated day cruises out of Whittier in 1997 and 1998. Large cruise ships (e.g., Princess and Holland lines) made trips through the western Sound 112 times during the summer of 1997. Voyages of the Alaska Marine Highway Ferries were also incorporated into this user group. During 1996, 19 commercial fishing subdivisions were fished in the western Sound. Nine hundred trips by commercial fishing vessels were estimated to have originated from the Whittier Harbor to these fishing areas; 50 originated from the Chenega Bay Harbor. There were 341 recreational motorboats and sailboats that docked in the Whittier harbor in 1997. These boats made 1,145 multi-day trips from the harbor, with an additional 1,612 trips that were estimated at less than 24 hrs. During June, July, and August, 1998, 36 recreation boats used the Chenega Bay village harbor. These data were combined with the results from the Alaska Department of Natural Resources user survey to estimate how the vessels were distributed throughout the study area.

Seventeen aerial surveys were flown from June through September to provide information necessary to evaluate patterns of use developed for water vessels in the western Sound. Two hundred recreational motor boats and 228 kayaks were observed during the surveys. Comparisons of the relative number of kayaks and recreational motor boats estimated to occur in the western Sound through our GIS analyses with the results of the aerial surveys revealed strong correlations.

Locations were obtained for 36 harbor seal haulout sites, 131 pigeon guillemot nesting areas, and 6 watersheds having cutthroat trout populations. To understand the relationship of population distributions of resources relative to estimated levels of human use, the mean level of human use by analysis area was compared to the population distribution.

Understanding the effects of human-caused disturbance to wildlife is extremely difficult. Activities without immediate effects may cause cumulative impacts that are not apparent until long after the disturbance, or until the disturbance has continued for some time. Conversely, disturbances that cause immediate effects may not necessarily result in cumulative effects over time. Unlike activities that physically alter a species' habitat, disturbance allows the habitat to remain physically intact, but reduces its ability to support wildlife. Whether or not disturbance will cause a change in the population of a particular species depends on a variety of factors that are specific to each situation. Factors that influence the vulnerability of a species to disturbance include seasonal factors and the biological activity occurring at that time, group size, species size, feeding location, and the general behavior of the species such as its intrinsic wariness and flight response. Similarly, the frequency and form of activity will influence the potential for disturbance.

For managers interested in understanding the potential effects of human activity on wildlife in Prince William Sound, it may be useful to ask the question “Who is most disturbed, by whom, where and when?” In reviewing the literature on human disturbance to marine mammals and birds, it is apparent that there are inter- and intra-specific variations in how animals respond to human activity. Because there is so much variation in the response of different species, and individuals, to different forms of human activities, managers must carefully consider the specific situation being addressed. While it is inappropriate to make generalizations about how a particular activity will affect nearby wildlife, there are some disturbance patterns that warrant consideration. For instance, fast-moving and erratic motion tends to be consistently more disturbing to a wide range of wildlife species than slow, steady motion. Aircraft activity is often very disturbing to many species of wildlife, and helicopters elicit an even greater response than fixed-winged aircraft. Juvenile animals are often more vulnerable to disturbance than are adults.

Many of the activities that are occurring in the Sound today, and probably for the foreseeable future, may not show immediate impacts to wildlife. Many people may think that the disturbance that they cause is inconsequential and will not directly harm the animals. While they may be correct, the combined effects of disturbance may often be significant or they may be disturbing an animal at a crucial time period, which could lead to the eventual loss of their offspring or other serious consequences. Many articles that presented approaches for managing people to reduce the effects of disturbance on wildlife identified the same range of protective measures. Potential protective measures included: (1) public education, (2) enforcement of existing laws and regulations, (3) exclusion of specific forms of transportation (ranging from cars to jet skis), (4) exclusion of dogs and the removal of other introduced predators, (5) excluding people from large or small areas, (6) redirecting public access, and (7) habitat manipulation. Because land management jurisdiction in the Sound is so complex, public education may be one of the strongest tools available to managers.

INTRODUCTION

Prince William Sound’s (the Sound) combination of rugged coastal mountains, glaciers, sheltered waters, and forested islands provide a mix of spectacular scenery and maritime habitats. The Sound provides essential habitat for thousands of seabirds, marine mammals, 5 species of salmon, as well as habitat for upland birds and mammals. It also provides an economically important fishery for salmon[1], blackcod, Pacific herring and other species. The wealth of abundant wildlife and fish and impressive scenery has drawn people to the area for thousands of years.

Over the last century, human activity in the Sound has changed from exclusively providing homes and sustenance to its Native Alaskan residents, to include the exploitation of marine mammals for Russian fur traders, to mining, and most recently to oil exportation, fisheries, tourism, and recreation. As human activities in the Sound have changed, so have the distribution and abundance of wildlife and fish populations that occur in the Sound. Over the last decade, the *Exxon Valdez* oil spill in 1989 was the most notable human-caused impact to the Sound's ecosystem. However, the opening of the Whittier Access road in the summer of 2000 is likely to bring new challenges to the Sound and to the species recovering from the spill as a result of increasing human use and associated development.

Thirteen years after the spill, only 6 injured species were considered to have recovered from the effects of the spill, while 5 species were believed to still be recovering (Table 1). Populations of 8 species have shown little or no improvement and are listed as “not recovering," while an additional 4 species are in an unknown recovery status (*Exxon Valdez* Oil Spill Trustee Council 2002). Simple explanations for the different recovery responses shown by different species do not exist. The ability of a species to recover from the effects of an event like the spill depends on a multitude of factors, including breeding strategies, food availability, habitat quality, and other pressures that may exist on the population, in addition to any lingering effects of the spill. As human use in the Sound increases, there is an increasing potential that human disturbance will play a major role in the distribution and population dynamics of many wildlife species. What effect this change may have on the recovery of species injured by the spill will depend on resource managers’ abilities to understand and mitigate the effects of human activity in areas important to the injured species.

The Whittier Access road was completed in 2000. Although Whittier is only approximately 76 km from Anchorage, the only access to the community had been via the Alaska railroad, by float plane, or by boat. The new road will provide another means of access to the western Sound for 73% of Alaska's population who may readily drive to Whittier. The new road will also serve the increasing number of visitors to Alaska. This improved access is expected to result in increased human use (Alaska Department of Transportation and Public Facilities and Federal Highway Administration 1995), which may have consequences for wildlife and fish populations in the Sound. Future management of the Sound should be made with an understanding of the human activity that occurs in that area and how that activity may relate to the local wildlife and fish populations. The anticipated changes associated with new road access are in addition to other changes in human use of the Sound that have been occurring over the last decade. Tourism patterns in the Sound have changed as cruise ships altered their routes and glacier tour operators added trips. While the extensive commercial fishery has remained at about

---

[1] Scientific names are listed in Appendix A.

Table 1. Recovery status of species injured by the 1989 *Exxon Valdez* oil spill (*Exxon Valdez* Oil Spill Trustee Council 2002).

Status Species (common name)	Scientific name
Not recovering	
Common loon	*Gavia immer*
Cormorants (3 spp.)	*Phalacrocorax spp.*
Harlequin duck	*Histrionicus histrionicus*
Pigeon guillemot	*Cepphus columba*
Harbor seal	*Phoca vitulina*
Pacific herring	*Clupea pallasii*
Recovering	
Marbled murrelets	*Brachyramphus marmoratus*
Sea otter	*Enhydra lutris*
Killer whale (AB pod)	*Orcinus orca*
Clams	Mollusca; Bivalvia
Mussels	Mollusca; Bivalvia
Recovered	
Black oystercatchers	*Haematopus bachmani*
Common murre	*Uria aalge*
Bald eagle	*Haliaeetus leucocephalus*
River otter	*Lutra canadensis*
Sockeye salmon	*Oncorhynchus nerka*
Pink salmon	*Oncorhynchus gorbuscha*
Recovery Unknown	
Kittlitz's murrelet	*Brachyramphus brevirostris*
Cutthroat trout	*Salmo clarkii*
Dolly varden	*Salvelinus malma*
Rockfish	Scorpaenidae

the same level in recent years, recreational boating and kayaking have increased dramatically in the last decade. For example, kayak use in the Sound has been increasing at an average rate of 6% per year since 1988 (P. Twardock, Alaska Pacific University, personal communication).

Increased human activity in the Sound may affect the recovery of species injured by the spill, but little information has been available to document and monitor the changing patterns of human use in the Sound. This project was designed as a tool for resource managers in the western Sound to help them understand the potential relationships between human activity and local wildlife populations. This information is particularly important because the new access into the western Sound is expected to result in dramatic increases in recreation-based human activities.

An extensive body of literature has established that many human activities near wildlife cause disturbance to individual animals. Since the early 1970s, biologists have been concerned about the increasing use of important wildlife habitats for human activities, such as recreation. This concern led to many studies that investigated whether recreation and other human activities caused disturbance to local wildlife. The results of these studies varied widely between species, season, and the intensity and form of human activity; however, the majority of the studies documented a disturbance effect on wildlife. In a literature review of human-caused disturbance to birds, Hockin et al. (1992) found 44 species in 50 reports that showed changes in breeding success as a result of human disturbance. At least 18 species in 14 reports showed changes in nest site choices; 24 species, ranging from waterfowl to songbirds, showed changes in distribution in response to disturbance. Similar studies have documented disturbance in marine mammals (e.g., Richardson et al. 1995). Unfortunately, for most forms of human activities, the consequences to wildlife populations of such disturbances are poorly understood. Short-term consequences have been documented for some species, but even less is known about long-term effects on populations.

In reviewing literature on human disturbance to wildlife, it becomes apparent that generalizations are difficult to make, especially since local policy and management practices can greatly alter the level of disturbance caused by human activity. We have provided a summary of information from the disturbance literature on the potential effects of different activities, consequences that have been shown for a variety of species, and management actions that have been used to minimize adverse effects. To demonstrate how human use in the western Sound may affect injured species, we examined the relationship of the existing use patterns relative to the general distribution patterns of nesting pigeon guillemots, harbor seal concentration sites, and watersheds with cutthroat trout. Both pigeon guillemots and harbor seals have been classified as ‘not recovered’ from the effects of the spill, and the recovery status of cutthroat trout is unknown (*Exxon Valdez* Oil Spill Trustee Council 2002).

This project was divided into two parts designed to provide information to managers and businesses interested in protecting the resources in the western Sound as human use increases. First, to provide a baseline for understanding the potential effects of human activity on injured resources, we must understand current human use patterns. Second, we wanted to explore how those human use patterns may change with new access and increasing use in the western Sound.

The goal of this project was to provide a foundation for displaying and understanding existing and future human use patterns in the western Sound, the potential disturbances these uses may have on injured resources, and to make management recommendations to minimize adverse effects of increased human use on wildlife populations. Because the scope of this project was larger than originally anticipated, we have divided our final report into 2 chapters. This report, chapter 1, presents the distribution of current human uses as baseline information, baseline information on the 3 injured species used as examples, the review of wildlife disturbance literature, and general management recommendations. Chapter 2 describes the methodology used to develop and the results from predictive models that explore potential human use patterns in the study area following the opening of the Whittier Access road. That chapter also provides more site-specific management recommendations by identifying areas where the intensity or pattern of human use is expected to change near important habitats for injured resources.

STUDY AREA

Prince William Sound is located in South-central Alaska. The Sound is sheltered from the Gulf of Alaska by Montague and Hinchinbrook islands, and is separated from interior Alaska by the Chugach and Kenai mountains. Our study area included the western half of the Sound. The line dividing the Sound for our study runs southwest between Point Freemantle on the southwestern edge of Valdez Arm through Montague Strait to Cape Puget at the southwestern corner of Port Bainbridge (Fig. 1). The study area covers 9,700 km^2 (5,044 km^2 of saltwater) and includes 1,754 km of mainland shoreline and an additional 2,108 km of shoreline along 146 islands. Of the 5 communities within the Sound, only Whittier and Chenega Bay are within the study area.

The Chugach National Forest manages the largest amount of upland areas within the study area (4,160 km^2); the State of Alaska manages additional public land (183 km^2), including the State Marine Park system. The Alaska Department of Natural Resources manages most of the submerged and tidal lands up to the mean high tide mark within the study area. Native Corporations manage approximately 265 km^2 of land primarily in the southwestern quarter of the study area. There is limited private ownership of lands outside of the communities, but private parcels do exist (6 km^2).

OBJECTIVES

Project objectives have been slightly modified to accommodate the focus of 2 chapters. The intent of the original objectives is still covered in the combination of the 2 chapters. There were 3 objectives originally identified for this project:

1. Describe existing and potential human-use patterns in western Prince William Sound,
2. Identify areas where human disturbance has a high potential to affect injured resources, and
3. Develop management recommendations for public agencies to minimize or eliminate the effects of disturbance on injured resources.

This chapter addresses the following objectives:

1. Describe existing patterns of human use,
2. Identify areas where existing human use patterns intersect with important areas associated with injured resources, and
3. Provide general management recommendations to reduce the effects of disturbance based on information provided in the published literature.

METHODS

Human activity in the western Sound is strongly tied to the water of the Sound. People participating in upland activities generally access upland sites via the water. The greatest potential for disturbance to injured species is also most likely to be from water-based activities. For these reasons, our project focused entirely on water-based human uses. We divided water-based activities into 5 user groups: kayaks, charter boats, cruise ships and Alaska State ferries,

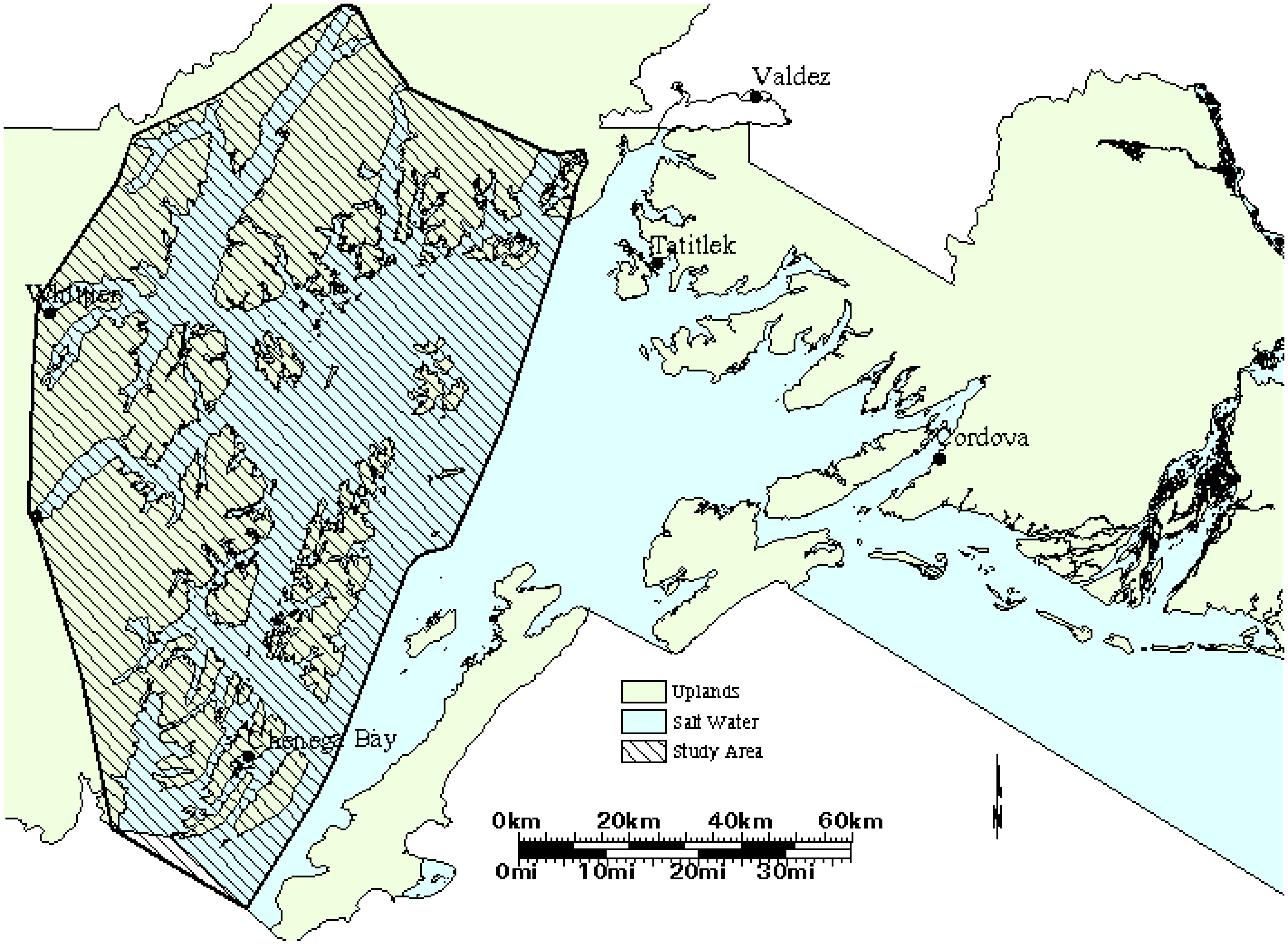


Fig. 1. Location of the study area in western Prince William Sound, Alaska, USA.

commercial fishing, and other recreational motor boats. Because the activities and movements of these different user groups are distinct from each other, and would presumably have different potentials to disturb wildlife, distribution use patterns were developed independently for each group. Although development of use patterns varied for each user group, there were some common steps (Fig. 2).

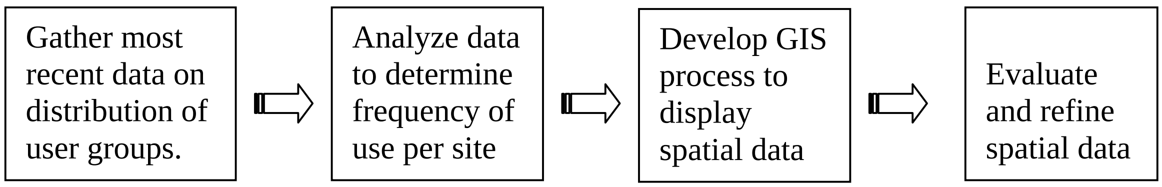


Fig. 2. Process for the development of use patterns for user groups in western Prince William Sound, Alaska.

To establish existing use patterns of different user groups in the western Sound, we collected the most recent data available for analysis. Because this project was initiated in January, 1998, the largest segments of our data are based on use levels in 1997 and 1996. Some additional data were collected in 1998, primarily for the cruise ship and Alaska State ferry user group. Only data for the months of May through September were considered, because most user groups were generally inactive in the western Sound during the remaining months.

When we developed distribution patterns for each user group, we usually doubled the count of vessels to represent that an individual vessel passed through a corridor twice to reach and return from a destination. We assumed that this would be a representative approach to assess the potential frequency of disturbance to wildlife.

Whittier Harbor Data

The staff at the Whittier Harbor provided data that were instrumental in providing a means to determine the number of boats and their temporal patterns in the western Sound. In 1997, harbor staff kept records of each boat docked in the harbor at 0600 every day. A record of every boat present in the harbor was entered into a computerized system by vessel registration number, name, and slip number. This database allowed the harbormaster to document harbor use on any given day throughout the year. In early 1998, the Whittier Harbor was switching computer systems and was unable to provide us with an electronic version of their data. However, they were able to supply a hardcopy of the records, which we entered into a Microsoft™ Access database. The harbor staff, and other local experts, identified the primary use and class of each vessel (Table 2). Some vessels, such as commercial fishing vessels, were also classified by their US Coast Guard number.

By searching the Access database for missing dates for individual vessels, we determined which boats were out of the harbor and when they were out of the harbor. Boats that were out of the harbor for up to 14 days were assumed to be on a trip in the western Sound. Boats absent longer than 14 days were assumed to have been pulled from the water or to have left for another harbor destination (e.g., Seward, Valdez, Cordova). To determine the number of boats making day trips from the harbor, these data were examined for changes in slip numbers that did not correspond to gaps in the sequence of dates. For example, at 0600 on 16 June 1997, a boat identified as “NoName” was berthed in slip Z-28; and on 17 June 1997 at 0600, the “NoName” was recorded berthed in slip D-18. Since the boat was moved during the 24 hour period, we assumed that it made a day trip into the western Sound. This process for determining day trips

Table 2. Classification used to describe vessels in Whittier Harbor and in Prince William Sound, Alaska.

User group	Vessel type classification
Kayaks	Single kayaks Double kayaks
Recreational motor boats	Inflatables (e.g. Zodiacs™) Skiffs Runabouts Cabin cruisers Motor yachts Sailboats
Commercial fishing	Purse seiners Drift netters Set netters Draggers Long liners
Charter	Charter boats Water taxies
Cruise ships and State ferries	Alaska Marine Highway ferries Cruise ships
Other (not considered in the analysis)	Commercial vessels (barges, landing craft) Coast Guard cutters Jet skies

only worked for those boats that were assigned a different slip by the harbormaster each time they entered the harbor. These harbor users are referred to as 'transient' slip holders in this report and represent slightly less than 50% of the records from the Whittier Harbor data. We were not able to calculate day-trips for berth holders with permanently assigned slips. Therefore, we applied the frequency and timing of day trips calculated for the transient slip holders to harbor users who have permanent slips to describe their frequency of day trips.

Kayaks

The Whittier Harbor data could not be used to determine the numbers of kayaks in the western Sound. Therefore, we requested data from water taxi operators who transport kayakers to destinations at the beginning and/or end of their trips. In 1997, there were 3 water taxi operators who primarily transported kayakers. Two of these operators provided us with their daily operation logs. These data described the number of kayakers in each group, the date, whether the kayakers were picked-up or dropped off, and the location. From these data, we determined the number of kayakers in a group, their point of origination, their destination, and their length of trip. Kayakers who only used a water taxi for one direction of their trip were assumed to have either come from, or returned to, Whittier to complete their trip. For these kayakers, we were unable to determine the duration of their trip.

Some kayakers who departed from Whittier do not use a water taxi service. To determine the number of kayakers who fell into this category, we sampled the number of kayaks transported into Whittier on the Whittier-Portage train (P. Twardock, Alaska Pacific University, personal communication). During the months of June, July, and August, 1998, a stratified, observer-selected sample was taken of the number of kayaks carried on trains arriving in Whittier. Each scheduled train, according to its arrival time and day of the week, was met once a month. For example, the train arriving in Whittier at Monday morning at 0800 hours was met once a month for a total of 3 times during the summer. The sample was designed to meet every train an equal number of times.

The observer met the train as it arrived in Whittier where she counted the kayaks unloaded from the train and determined how many people were associated with the kayaks. She also determined how many kayaks were double versus single boats and determined if the kayakers were associated with guided groups or rental parties. By comparing data collected from the train sample to records of chartered water taxi and guides on a daily basis, we were able to estimate the number of kayakers who traveled independent of a guide or charter service. To determine the total number of kayaks that would occur in the study area, we determined the number of people using single kayaks and double kayaks. During the counts of kayaks, being brought to Whittier on the train approximately 26% of the non-guided kayakers brought double kayaks for their trip. For simplicity, we multiplied the number of people kayaking in the western Sound by 75% to represent the total number of kayaks present.

An additional source of data for kayak use in the western Sound was the Chenega Bay IRA Council. In 1998, the Alaska Marine Highway began a “whistle stop” at Chenega Bay. During the summer of 1998, the Council recorded the number of arriving kayakers who used the ferry. They also identified any groups who arrived to Chenega Bay to catch the ferry for their return trip. All other kayak groups that departed from Chenega Bay were assumed to have used Whittier as their destination.

Once these data were summarized to show destination and pickup points for kayak groups around the western Sound, we consulted with local experts to develop trip routes for the individual groups. Professor Paul Twardock, Alaska Pacific University, assisted us by suggesting probable routes for trips of varying duration from and to locations throughout the western Sound. Based on his recommendations and on the assumption that kayakers generally paddle an average of 16 km/day, probable trip routes were developed for every group of kayakers in the database. One-hundred forty six unique trips were developed (Table 3). Trip routes for 192 kayaks that did not use guide or charter services were assumed to be roundtrips from Whittier. Because the average duration of all trips was 5.5 days, we allocated the majority of these trips to areas within a 3-day paddle from Whittier (i.e., 50 km).

Charter Boats

The charter boat user group includes water taxi operators, sport fishing charters, and small overnight charter boats. In 1997, there were 3 water taxi operators who primarily transported kayakers. Two of these operators provided us with their daily operation logs. These

Table 3. Assumed distribution of kayak trips, western Prince William Sound, Alaska.

Initiation point Name	Destination point Name	Number of days in trip	Total trips
13mile Blackstone	Storm Beach	4	6
13mile Blackstone	Round Trip	2	2
13mile Blackstone	Round Trip	3	12
13mile Blackstone	Round Trip	4	4
13mile Blackstone	17mile Blackstone	6	6
16mile Culross	Round Trip	7	3
16mile Culross	Storm Beach	13	10
16mile Culross	Whittier	--	16
17mile Blackstone	Round Trip	2	2
17mile Blackstone	13mile Blackstone	2	2
17mile Blackstone	13mile Blackstone	3	7
17mile Blackstone	Round Trip	4	11
17mile Blackstone	13mile Blackstone	6	4
17mile Blackstone	Whittier	--	61
Applegate	Darby's Cove	3	2
Applegate	Round Trip	3	3
Applegate	Long Bay	4	3
Applegate	Darby's Cove	4	3
Applegate	Darby's Cove	6	3
Applegate	Round Trip	7	6
Applegate	Deepwater Bay	8	3
Applegate	Whittier	--	14
Bainbridge	Whittier	--	2
Baker Beach	Whittier	--	3
Bald Head	Surprise Cove	13	5
Bettles Bay	Round Trip	4	1
Billings Glacier	Round Trip	4	2
Blacksand Beach	Whittier	--	8
Boomerang Beach	Whittier	--	1
Cannery Creek Hatchery	Whittier	--	5
Chenega Bay	Chenega Bay	7	4
Chenega Bay	Whittier	--	24

Table 3. Assumed distribution of kayak trips, western Prince William Sound, Alaska.

Initiation point Name	Destination point Name	Number of days in trip	Total trips
Coghill	Round Trip	11	2
Coghill	Whittier	--	14
Coghill	Round Trip	--	3
Culross Cove	Round Trip	4	2
Culross Cove	13mile Blackstone	4	6
Culross Cove	Whittier	--	33
Darby's Cove	Applegate	3	2
Darby's Cove	Long Bay	4	2
Darby's Cove	Round Trip	4	7
Darby's Cove	Round Trip	5	6
Darby's Cove	W.Twin Bay	5	3
Darby's Cove	Applegate	6	3
Darby's Cove	Derrickson Bay	7	3
Darby's Cove	Lighthouse Point	9	2
Darby's Cove	Derrickson Bay	10	2
Darby's Cove	Whittier	--	14
Daycare Bight	Whittier	--	4
Decision Point	Round Trip	4	3
Decision Point	Whittier	--	17
Deepwater Bay	Applegate	8	3
Derrickson Bay	Round Trip	4	8
Derrickson Bay	Round Trip	7	4
Derrickson Bay	Whittier	--	2
Dual Head	Whittier	--	2
Dual Head	Herring Bay	13	6
Dutch Group	Whittier (a) (via Barry Arm)	--	2
Dutch Group	Whittier (short)	--	2
E. Flank Island	N. Esther Island	3	6
E. Flank Island	Toboggan	7	5
E. Flank Island	Whittier	--	6
E. Upper Ingot Cove	Whittier	--	2
Eaglek	N. Esther Island	4	3

Table 3. Assumed distribution of kayak trips, western Prince William Sound, Alaska.

Initiation point Name	Destination point Name	Number of days in trip	Total trips
Eaglek	Round Trip	6	6
Eaglek	Whittier	--	12
Emerald Cove	Whittier	--	3
Entry Cove	Whittier	--	12
Esther Hatchery	Whittier	--	5
Esther Hatchery	Round Trip	--	2
Esther Island	Round Trip	10	2
Esther Pass	Whittier	--	2
Goose Bay	Whittier	--	3
Granite Bay	Whittier	--	4
Harrison Lagoon	Round Trip	3	6
Harrison Lagoon	Round Trip	6	7
Harrison Lagoon	Whittier	--	13
Herring Point	Whittier	--	2
Hidden Bay	Whittier	--	2
Hobo Bay	Kelly's Cove	2	5
Hobo Bay	Round Trip	3	5
Hobo Bay	Round Trip	5	4
Hobo Bay	Toboggan	6	3
Hobo Bay	Round Trip	7	6
Hobo Bay	Whittier	--	23
Icy Bay	Pt. Nowell	4	6
Icy Bay	Squire Island	7	13
Kelly's Cove	Round Trip	3	5
Kelly's Cove	Toboggan	6	9
Kelly's Cove	Round Trip	7	4
Kelly's Cove	Whittier	--	52
Knight Island Passage	Round Trip	1	2
Knight Island Passage	Whittier	--	4
Lawerence Glacier	Whittier	--	1
Lighthouse	Whittier	--	6
Long Bay	Round Trip	4	7

Table 3. Assumed distribution of kayak trips, western Prince William Sound, Alaska.

Initiation point Name	Destination point Name	Number of days in trip	Total trips
Long Bay (mouth)	Long Bay (head)	5	5
Long Bay (mouth)	Whittier	--	14
Long Bay(Head)	Long Bay (mouth)	1	4
Long Bay(Head)	Whittier	--	8
Lower Passage	Whittier	--	6
McClure Point	Whittier	--	3
Meares Point	Surprise Cove	3	10
Mid-Glacier	Round Trip	3	8
Mid-Glacier	Whittier	--	11
Naked Island	Whittier	--	5
Nasseau Fjord	Dual Head	3	4
Olsen Island	Round Trip	4	5
Olsen Island	Golden	6	3
Pakenham Point	Dutch Group	5	2
Pakenham Point	Whittier	--	4
Paulson Bay	Round Trip	4	8
Paulson Bay	Round Trip	8	3
Paulson Bay	Whittier	--	4
Picturesque Bight	Whittier	--	2
Pigot Bay	Round Trip	5	2
Pigot Bay	Round Trip	13	2
Pigot Bay	Whittier	--	12
Pt Nowell	Round Trip	4	5
Pt Nowell	Surprise Cove	13	5
S. Culross	Round Trip	3	9
S. Culross	Round Trip	5	3
S. Culross	Round Trip	8	3
S. Culross	Whittier	--	4
Shotgun Cove	Whittier	--	130
Squire Island	Whittier	--	7
Squirrel Island	Whittier	--	2
Storm Beach	Whittier	--	12

Table 3. Assumed distribution of kayak trips, western Prince William Sound, Alaska.

Initiation point Name	Destination point Name	Number of days in trip	Total trips
Surprise Cove	13mile Blackstone	3	4
Surprise Cove	17mile Blackstone	4	18
Surprise Cove	Round Trip	4	5
Surprise Cove	Derrickson Bay	5	3
Surprise Cove	Round Trip	6	2
Surprise Cove	Whittier	--	48
Tebenkof Cove	Round Trip	3	1
Toboggan	Round Trip	2	6
Toboggan	Round Trip	3	6
Toboggan	Round Trip	5	11
Toboggan	Whittier	--	20
Unakwik	Round Trip	9	3
W.Twin Bay	Round Trip	7	7
Whales Bay	Whittier	--	2
Whittier	13mile Blackstone	--	68
Willard Island	Round Trip	2	3
Willard Island	Whittier	--	5
Zeigler Cove	Whittier	--	6

logs identified each destination that the charter operator used to drop off or pick up kayakers in the western Sound. Each drop off or pick up point identified in the records became the destination for a trip from Whittier. Most charter boat operators, with the exception of those with sightseeing clients, took the most direct route to their destination. The GIS functions were designed to identify the most efficient path between Whittier and each destination. The use of each route used between Whittier and the destination point was doubled to represent that a charter boat had to return to Whittier once it reached its destination.

Descriptions of use patterns of other kinds of charter boats in the western Sound were based on information from charter operators in combination with data from the Whittier Harbor records. Well-known sport fishing locations in the western Sound used during each summer month were also identified. The number of trips made by charter boats out of the Whittier Harbor was used to establish the frequency of use of each location for each month. Because distribution and frequency of trips for this user group was based on trips from Whittier to specific destinations, each destination on was recorded separately as though it was a specific trip from Whittier. This overestimated the total number of trips for the vessels considered because more than 1 destination may have actually been visited on a specific trip. This over estimation was assumed to compensate for the fact that only 2 of several sightseeing charter vessels were used in the calculations.

Cruise Ships and State Ferries

This user group includes vessels in the Alaska Marine Highway ferry system, 3 day-cruise operations out of Whittier, large cruise ships (e.g., Princess and Holland lines), and smaller overnight cruises that followed consistent routes and schedules in the western Sound. Routes, number of vessels, and schedules for the day cruises and the Alaska Marine Highway ferry were based on information from 1998. Trip frequencies and routes for the overnight cruise ships, both large and small, were based on information from 1997.

Locations of trip routes were based largely on information provided by members of the Alaska Visitors Association (AVA) (P. McNees, AVA, personal communication). AVA members drew their vessel routes for day cruises and small overnight cruise ships on maps of the study area. Additional information was provided by the companies through their advertisement brochures or via telephone. The 3 day-cruise companies provided information on the number of days per week that the vessels operated and the length of season. Schedules for the large cruise ships were based on docking records for Valdez and Seward in 1997. Adjustments were not made for cancellations that may have been caused by inclement weather or mechanical problems.

The frequency of occurrence of an individual vessel was doubled along any portion of a route that required a vessel to return on the same route. For example, a day cruise ship that made daily round trips between Valdez and Whittier was assumed to travel along the route twice to represent each leg of the round trip. Vessels such as large cruise ships that did not make round trips within the western Sound were counted as occurring 1 time per trip.

Commercial Fishing

The Alaska Department of Fish and Game (ADF&G) commercial fishing districts and permit records for 1996 were used to determine the frequency and extent of commercial fishing use in the study area (Fig. 3) (Johnson and Merritt 1996). Permit records for 1996 were used because the 1997 records had not been summarized for each commercial fishing subdistrict when we compiled these data in early 1998, and we felt that the 1996 records would be more representative of the 1998 fishery. Only commercial salmon fisheries were considered in our analysis of distribution. Most other major fisheries in the western Sound occurred outside of our May–September study period.

Permit records were used to establish the number of boats fishing in each subdistrict for each opening. These data were then compiled for each month. Travel routes and frequency of use along the routes were developed based on Whittier Harbor data. We assumed that most fishing vessels would travel a direct route between the harbor and the fishing location. Vessel traffic along the routes was doubled to account for round trip traffic. Similarly, the Chenega IRA council provided records of the number of fishing vessels docked at Chenega Harbor and moored in Crab Bay. These vessels were assumed to travel to and from the subdistricts near Chenega Bay at a frequency similar to the trips out of Whittier Harbor.

We placed less emphasis on the commercial fishing activities in the study area because we assumed that the industry is unlikely to change as a result of the Whittier Road opening. Unlike the majority of other users in the Sound, ADF&G regulates this industry so there is an avenue to address potential indirect effects.

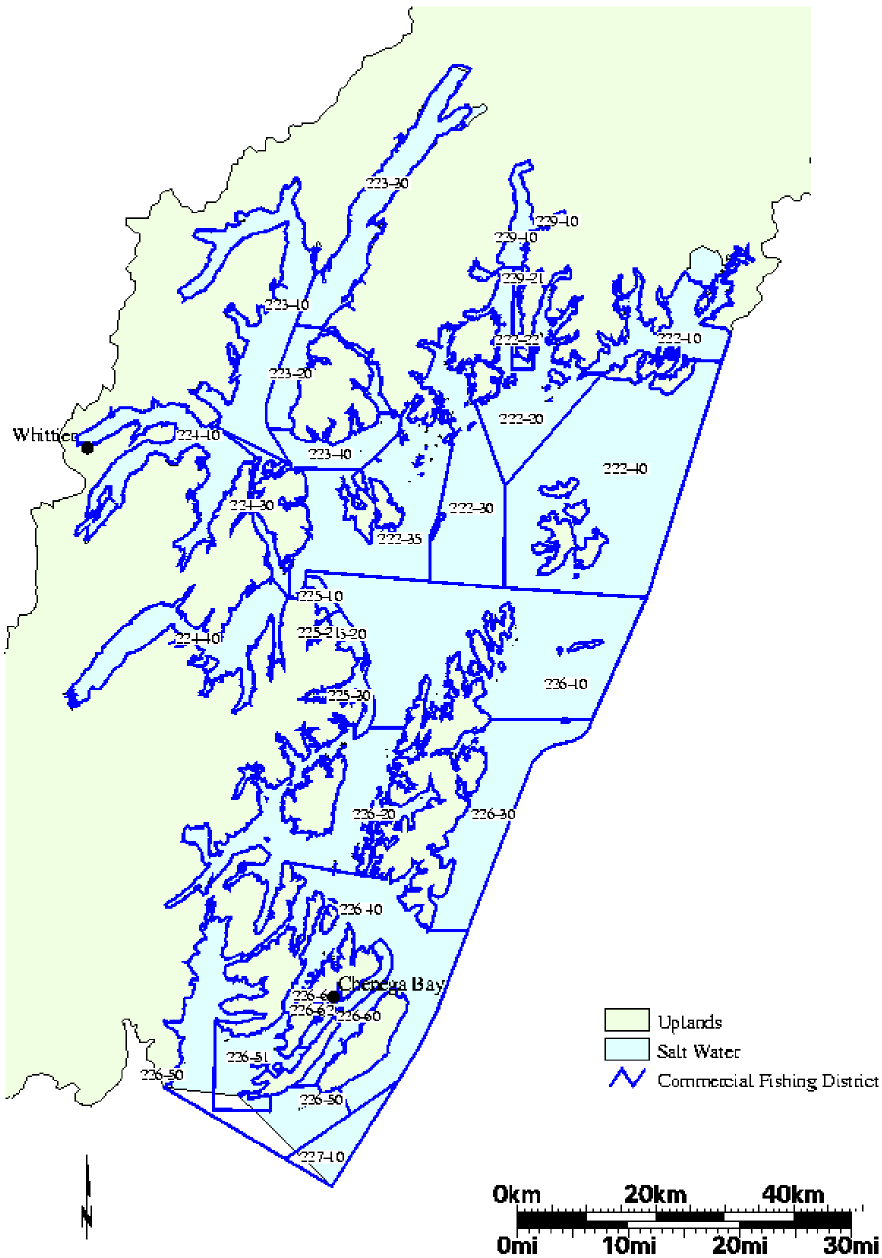


Fig. 3. Commercial fishing districts in western Prince William Sound, Alaska.

Recreational Motor Boats

This user group included all motorized recreational boats and sailboats. Using the Whittier Harbor data, we calculated the number of vessels out of the harbor, the duration of trips taken by individual boats, and by analyzing the slip occupancy records we estimated the number of day trips from the harbor. However, we did not have a direct method for determining where the boats traveled once they left Whittier. To characterize the destinations of this user group, the Alaska Department of Natural Resources sent a questionnaire in February, 1998 to slip holders at the Whittier Harbor (Appendix B). Three-hundred fifty questionnaires were mailed to permanent and temporary slip holders in Whittier. The questionnaire requested information about personal recreation use patterns and perceived changes in use patterns. Information received included types of recreation vessels used, number of trips made in the Sound, destinations of those trips, numbers of other boats seen and number of boats respondents were willing to see. We also learned how far respondents would travel to find desired conditions, and if their use patterns might change under certain conditions.

Responses from the user questionnaires were entered into an Access database, which was used to determine the frequency of use at destinations throughout the western Sound. We assumed that the responses were representative of Whittier Harbor recreational boaters and extrapolated the frequency of use to correspond to the number of boat trips known to have occurred in each month based on the harbor data. Rather than extrapolate trips to specific sites, we used the user responses to determine what percentage of the Whittier Harbor data should be assigned to a particular region of the western Sound. For example, in July the user survey data showed that 27 of 279 trips occurred around Knight Island, the harbor data analysis indicated that 675 multi-day trips occurred in July, so we assigned approximately 10% to the Knight Island area.

To estimate recreational boat use associated with Chenega Bay, the Chenega Bay IRA council recorded visitor use by recreational boaters to the village harbor for July–September, 1998. The Armin F. Koernig (AFK) Fish Hatchery staff also provided records of their recreational use for June–September, 1998. As a safety precaution, hatchery managers required their staff to record the destination, boat, and the expected return time for any trip out of the hatchery. Records were not always dated, but the hatchery manager attempted to assign undated trips to early or late month periods. Once distribution patterns for the hatchery data were entered into the GIS, we determined the distances traveled from the hatchery. These data were then used to estimate recreational boat use associated with the other 3 hatcheries located in the study area.

Description of Current Use Patterns

The extent of human use in the western Sound was described through an analysis of the distribution of water craft in association with preferred destinations (e.g., recreational and commercial fishing areas, mooring buoys, camping sites, recreation cabins). Cell-based modeling using the GRID feature of the ArcInfo GIS formed the basis of our approach to evaluate human-use patterns in the western Sound (Environmental Systems Research Institute, Inc. 1994). All processes used a 60 m cell size. Weighted distance functions were used to describe areas that were available to and used by vessel operators. Separate grids of the water portion of the western Sound were created for the analysis of dispersion of vessels in each class. For each vessel class a source grid was created which represented trip initiation points or sources (i.e., Whittier or Chenega). The COSTDISTANCE function was used to determine the minimum accumulative-travel cost from the source through each cell on the grid to a specific destination on the grid. This function allowed for the control of factors that influenced movement of water vessels. First source cells were identified. Then the cost to travel to each neighbor that adjoins a source cell was determined. Next, each of the neighbor cells was ordered from least costly to most costly. The cell location with the least cost was removed. Finally, the least-accumulative cost to each of the neighbors of the cell just removed was determined. This process was repeated until all cells on the grid were assigned an accumulative cost to reach a specific destination.

Corresponding cost grids were established for each vessel class. The cost grids assigned an impedance value to each cell that reflected choices involved in moving through any particular cell (e.g., avoidance of open water, avoidance of navigation risks). The value of each cell in the cost grid represented the ease of a particular vessel type passing through the cell (Environmental Systems Research Institute, Inc. 1994:253). Each cell location was given a weight proportional to the relative cost incurred by a vessel passing through a cell. ArcInfo GRID functions were then used to create grids that represented dispersion of water craft by vessel class the western Sound. These dispersion grids for each vessel class were combined through map algebra to describe density of use in the western Sound, by use class. The dispersion and density grids were then combined with grids of sensitive areas for injured species to identify those areas where conflict may occur.

Calculation of the Mean Level of Occurrence

With the exception of the cruise ships and State ferry user group, all analysis area maps of the mean occurrence of human use were generated in the same fashion (e.g., Fig 4). The

Analysis Area

"Raw" Data

10	10	6	2	2
10	10	10	7	3
7	10	10	10	3
0	6	10	10	10
0	0	5	10	10

Analysis Area

Zonal Mean

6.8	6.8	6.8	6.8	6.8
6.8	6.8	6.8	6.8	6.8
6.8	6.8	6.8	6.8	6.8
6.8	6.8	6.8	6.8	6.8
6.8	6.8	6.8	6.8	6.8

Fig. 4. Application of the "zonalmean" function to calculate mean use values in analysis areas in western Prince William Sound, Alaska.

ArcInfo CORRIDOR function defined the “most efficient” travel corridor from a source to a specific destination. The numbers of vessels projected to use a specific corridor during a specific month were entered into each cell within that corridor. All of the corridors used during a specific month were combined through map algebra to represent the cumulative use pattern for that user group. The resulting "raw" data number in each cell represented the number of times a vessel in a particular use class occurred in that cell during the period of interest. This process was not designed to present information at the resolution of individual cells. Rather, it was more appropriate to calculate the mean value of all of the cells in an analysis area for analysis and presentation. In the example, the mean value of the 25 cells in the analysis area is 6.8 occurrences.

This method was not appropriate for the Cruise Ship and State Ferry user group because the raw data represent use along a predetermined route line rather than a computer-generated corridor. For this use group, a total occurrence number for vessels was calculated for each analysis area by month and assigned to all cells in the analysis area.

Evaluation of Use Patterns

To evaluate the projected distribution of vessels in each user group throughout the western Sound, aerial surveys were conducted during summer months in 1998 to record the density of water vessel use on weekends and weekdays. A stratified random sample of the 40 analysis areas in the study area resulted in 13 analysis areas in 3 zones being selected for aerial surveys (Fig. 5). The goal was to conduct a survey during 1 weekday and 1 weekend in each zone during each month. To avoid long weekend effects, “weekday” flights were flown on Tuesday, Wednesday, or Thursday. Weekend flights were flown on Saturday or Sunday. Start locations for the surveys alternated among the survey sites to ensure variation in time of the day for surveys. Random pairs of dates were selected for the surveys from the first 3 weeks of each summer month. The last week and weekend of each month were used as back-up survey dates if we were weathered out of our original dates. We attempted to fly consecutive days so that the entire area was sampled during the same week or weekend. If we missed a scheduled flight date because of weather, we flew on the next available matching (weekend or weekday) date.

Aerial surveys were flown at 150 m elevation in either a Cessna 180 or 206 airplane. We completely surveyed each sample area. The airplane followed the shoreline so that the observer in the front passenger seat could observe small boats and kayaks near or on the shore. Generally, identification of boats in the open water was not difficult, but if the observer and pilot were uncertain of the appropriate boat class, or number of boats, additional passes were made. Recording forms included a map of each aerial survey area; a number was placed on the map in the location that each vessel was seen and a corresponding list was made to identify the boat class of each vessel. To reduce observer variation in spotting and classifying vessels, only 2 people were used as observers on all flights and 1 of 2 pilots were used for all but 2 of the survey flights.

To test the ability of an observer in an airplane to see and identify kayaks on the water, 3 flights were coordinated with boat-based surveys. The boat-based observers began surveying the sample area by paralleling the shoreline and recording all kayaks and motorized vessels observed. The aerial survey was conducted in the same fashion as other surveys except that observers were in radio contact with observers in the boat to coordinate the flight.

The aerial survey data were compared to projected densities of user groups through regression analyses to determine if predicted densities compared to observed number of vessels from the aerial surveys.

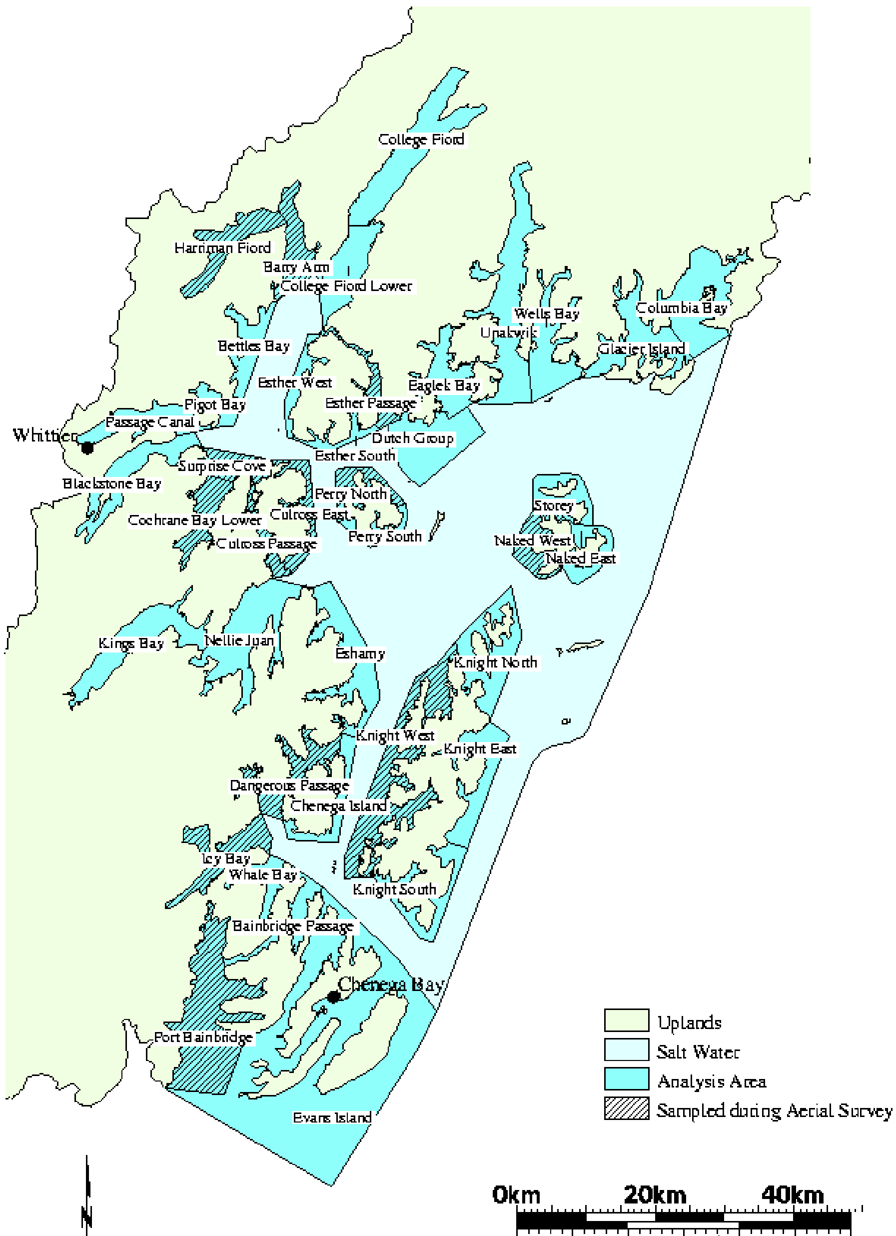


Fig. 5. Analysis Areas in western Prince William Sound, Alaska.

One weekend in August was also selected to monitor vessel traffic in 3 analysis areas for 12-15 hour periods. By positioning a vessel at a location that provided good visibility of an entire analysis area or its entrance, observers were able to record activity entering and departing each area throughout the day. In the afternoon, the observer vessel made a boat-based survey of the unit to document any vessels, which may have been anchored out of site of observers.

Resource Distribution

To compare human use levels near concentrations of injured resources, distribution maps of concentration areas were created for 3 species. The 3 injured resources were used as examples to demonstrate how information on distribution of human use was relevant to the recovery of different species. Harbor seals, pigeon guillemots, and cutthroat trout were selected to represent 3 classes of animal species injured as a result of the spill. At least one principal investigator for each species was contacted and asked to supply the most recent data for harbor seal haulout locations, pigeon guillemot nesting sites, and watersheds with cutthroat trout populations. The principal investigators were also asked to recommend a procedure for ranking the importance of sites to the species. While principal investigators could not easily rank sites, using sites with the largest number of animals was the most acceptable way to highlight importance of sites for harbor seals and pigeon guillemots (K. Frost, Alaska Department of Fish and Game; J. Burns, Living Resources Inc., D.Withrow, National Oceanic and Atmospheric Administration; S. Stephensen, US Fish and Wildlife Service; personal communication). For cutthroat trout, the inverse may be true because small population size could elevate the risk of over-fishing (D. Gillikin, Chugach National Forest, personal communication).

Harbor seals.--Latitude and longitude locations of harbor seal haulout sites were obtained from three sources (K. Frost, Alaska Department of Fish and Game; J. Burns, Living Resources Inc., D.Withrow, National Oceanic and Atmospheric Administration). All surveys were flown to observe the animals during molt from mid-August to early September. Sites were monitored with varying frequencies so population estimates may be based on 1996, 1997 or 1998 data. It also became apparent that each biologist used slightly different estimation techniques to estimate population size. For these reasons, the most recent location data were entered into the GIS, and a relative size index was developed to represent the most recent population estimates made for each location. All haulout sites were represented by point locations in the GIS. However, some sites, particularly those associated with ice from tidewater glaciers, cover areas larger than indicated by the point.

Pigeon guillemot.--Data for pigeon guillemot nest locations and associated population size were obtained from the U.S. Fish and Wildlife Service Berengia Seabird Colony Catalog (US Fish and Wildlife Service 1999). Population sizes were based on the number of adults at each site. We created an index of relative size to distinguish the size of colonies. Discussions with pigeon guillemot biologists provided additional insights into the disturbance potential for human activities at nesting colonies (G. Golet and J. Fischer, U.S. Fish and Wildlife Service; personal communication).

Cutthroat trout.—Locations of streams with cutthroat trout populations were provided by the USDA Forest Service based on information gathered from their oil spill restoration projects (D. Gillikin, Chugach National Forest, personal communication). Population data for cutthroat trout in these streams are largely unavailable. However, over-wintering populations in Alaska often consist of only a few hundred individuals (Schmidt 1997) and principal investigators in the western Sound believe the populations could consist of as few as 200 adults in some streams (D. Gillikin, Chugach National Forest, personal communication).

Literature Synthesis

To understand how human activities may affect injured species and other wildlife populations in the western Sound, we examined studies published in the scientific literature pertaining to human disturbance of wildlife. Our specific goal for this literature review was to summarize information that could be used by managers to understand the effects of human activity near wildlife populations. Information that identified distances at which disturbance occurred and that identified the consequences of the disturbance was of particular interest. We focused our search on taxa and forms of disturbance that may be relevant to current or future conditions in the western Sound.

A broad literature search was conducted to summarize disturbance studies on birds. While we placed particular emphasis on seabirds, sea ducks, and oystercatchers, we also reviewed literature on other species if the form of disturbance was relevant. Relevant disturbance types included any water-based disturbance, disturbance from aircraft, and shoreline activity of people on foot. Other forms of disturbance were summarized if the species studied were similar taxonomically to species found in the western Sound. We did not review studies that examined the effects of hunting or egging, except when the study was focused on the unintentional disturbance caused by these activities.

The literature was also searched for studies on disturbance to marine mammals. All marine mammal taxa were considered. However, studies on disturbance to Pinnipeds were emphasized both in our search and in the actual availability of information. As with our review of human disturbance on birds, we did not examine literature that addressed the effects of hunting on marine mammals.

Approximately 250 references were reviewed and 150 were summarized. Our summary focused on identifying the type of disturbance, the circumstances of the disturbance (such as frequency or intensity), the distance at which the disturbance occurred, and the consequences of the disturbance to either the individual or population. Very few studies covered all aspects of disturbance. To help make use of this information, the summarized elements were presented in a matrix.

RESULTS

This project developed a means to provide information about current human use patterns in the western Sound and how human activity may affect wildlife populations that are recovering from the effects of the spill. To achieve this, GRID-based spatial data files were developed in ArcInfo GIS for each of 5 user groups: kayaks, charter boats, commercial fishing, cruise ships and State ferries, and recreational boats. The focus of these human use distribution maps was to represent where people were going in the study area, and to represent how the levels of use compared among areas in the western Sound. While collecting data for each user group, we compiled a considerable amount of information that could be used for additional interpretation of each user group. For instance, data collected for kayaks could be used for an evaluation of kayaker user days. This information is interesting but not essential for the creation of the user distribution maps. Therefore, this report focuses on the results necessary to meet our objectives.

The GIS data, which illustrate existing use patterns in the study area, were created complex computer programs (see Arc Macro Language programs in Appendix C). However, we can illustrate the results from these processes with maps, figures, and tabular data. Developing the distributions of existing use initially required the development of spatial data files that contained raw data. These data files were then used to determine the mean occurrence of use by analysis area. Representation of use patterns by analysis areas is the most practical tool for managers, because the process we used was not designed to present detailed information for specific locations.

The following descriptions of the existing use distribution for each user group include maps presenting the raw distribution data, and user group densities by analysis area. The maps shown are examples of the spatial results generated when information is extracted to represent the distribution of use in the study area based on the following percentage-of-use ranges: <2, 3 to 9, 10 to 20 and >20%. Exceptions to this distribution were maps of cruise ship and State ferries use patterns, which were shown in 25% increments. These percentage ranges were selected based on the distribution of data throughout grid cells of spatial data files. Data were distributed such that the counts of cells representing very high boat densities were very small compared to the number of cells with low densities. The maps displayed show the distribution of use for the combined months of May through September. However, the GIS database contains data necessary to generate other maps for individual months, other combinations of months, or with different percentage-of-use ranges.

Whittier Harbor Data

There were 727 individual vessels, in 12 vessel classes, that docked in the Whittier Harbor during the summer months of 1997 (Table 4). Commercial fishing boats were the most common vessel in the harbor with a total summertime count of 280 individual boats. There were 67 boats that were not considered in the development of the user group distribution patterns because they could not be classified to a specific group. Nearly 6800 trips were estimated to have originated from the Whittier harbor. Of these, 4884 trips were identified directly from the harbor data. The additional 2000 trips were based on extrapolations to account for day trips by boats assigned to permanent slips at the harbor.

Kayaks

Based on the daily logs of 2 charter water taxi services that specialize in transporting kayakers, we estimated that they transported 1,969 people during May—September, 1997. There were 381 groups, with an average group size of 4.4 people. Kayak trips averaged 5.5 days in length. Twenty-two percent of trains arriving in Whittier were met during June, July and August to determine how many kayakers do not use the charter or guide services. Approximately 2,400 kayakers paddled out of Whittier in the summer of 1998; 84% used a charter service; 52% used a guide service.

The description of current use patterns for kayaks was based on 1368 occurrences of kayaks over 146 routes (Table 5, Figs. 6-7). Sixty-nine percent of the kayaks used charter services one way on their trip, while 15% were dropped off and picked up by a charter service, and 16% paddled their entire trip.

Charter Boats

Charter boat operators based in Whittier commonly used Seventy six destinations. Most of these destinations were used by water taxi charter services that transport kayakers to or from different parts of the study area. Six-hundred ninety two individual trips were considered in the distribution of existing use by charter boats; 447 of these were for water taxi operators, 245 were for other charter operations – primarily sport fishing and sightseeing (Table 6, Figs. 8-9). There were 95 multi-day trips taken by charter boats during the summer of 1997 and at least 150 day trips occurred.

Cruise Ships and State Ferries

Three companies operated day cruises out of Whittier in 1997 and 1998 (Table 7, Figs. 10-11). Two sightseeing vessels made daily trips to Barry Arm and College Fjord before returning to Whittier, while 1 vessel made daily trips to Barry Arm, but did not go into College Fjord. Only 1 vessel made daily trips into Blackstone Bay. However, other overnight cruises made trips into Blackstone Bay several times a month. A roundtrip day cruise operated between Whittier and Valdez 5 days a week in 1998; 2 additional vessels made daily cruises from Valdez into Columbia and Unakwik bays. Large cruise ships (e.g., Princess and Holland lines) made trips through the western Sound 112 times during the summer of 1997. Most of these large ships passed from Valdez to College Fjord, then back through the Sound to Seward. Two small overnight cruises operated in the study area. In general, these 2 vessels would visit various locations throughout the Sound 2 times a week. Finally, the Alaska Marine Highway Ferries were incorporated into this user group. In 1998, the MV Bartlett and MV Tustemena operated in the Sound. The Bartlett arrived in Whittier from Valdez and Cordova an average of 6 times a week, while the Tustemena made 4 roundtrips a week from Valdez to Seward. The Tustemena made whistle stops in Chenega Bay 3 times a month.

Table 4. Vessels that were present in Whittier Harbor, western Prince William Sound, Alaska, May—September, 1997.

Vessel class	n	Length of trip in days														Total trips
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Recreational																
Skiff	4	88	148	94	34	20	12	12	10	7	2	2	1	2	1	345
Runabout	23	3	43	15	6	5	0	1	1	1	0	0	0	0	0	72
Cruisers	161	154	356	162	39	17	8	7	6	5	5	2	1	1	4	613
Motor yacht	112	499	352	227	77	41	20	10	2	5	1	0	2	3	3	743
Sail	41	62	110	39	14	6	1	2	1	2	1	1	1	0	0	178
Nordic Tug	2	5	3	3	4	0	1	0	3	0	0	1	1	0	0	16
Commercial fishing																
Fishing boats	280	556	450	284	79	52	53	34	7	16	10	5	6	5	5	1006
Charter																
Charter/water taxi	24	75	78	38	17	9	9	4	1	3	1	3	1	0	1	165
Other																
Commercial	9	19	16	11	3	1	2	2	2	0	0	0	0	1	1	39
Landing craft	2	0	29	2	5	0	0	1	0	0	0	0	1	0	0	38
Tug	1	13	6	1	1	0	0	0	0	0	0	0	0	0	0	8
Unknown	67	14	113	38	7	4	1	2	3	2	2	0	0	1	0	173
Total trips		1488	1704	914	286	155	107	75	36	41	22	14	14	13	15	4884
Total boat days		1488	3408	2742	1144	775	642	525	288	369	220	154	168	169	210	12302

Table 5. Mean number of kayaks present by analysis area in western Prince William Sound, Alaska, May--September, 1997.

Analysis area	Trips by month											
	May		June		July		August		September		All months	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Bainbridge Passage	0	0	5	1	21	2	2	0	0	0	12	1
Barry Arm	16	9	46	7	39	5	48	9	13	10	147	7
Bettles Bay	3	2	33	5	36	4	32	6	8	6	91	5
Blackstone Bay	23	13	72	11	103	12	83	15	20	15	276	14
Chenega Island	0	0	11	2	13	2	9	2	0	0	24	1
Cochrane Bay Lower	5	3	9	1	13	2	4	1	0	0	21	1
College Fiord	0	0	2	0	6	1	11	2	0	0	17	1
College Fiord Lower	0	0	5	1	6	1	6	1	2	1	10	1
Columbia Bay	0	0	0	0	0	0	0	0	0	0	0	0
Culross East	5	3	6	1	25	3	11	2	3	2	38	2
Culross Passage	2	1	70	10	69	8	26	5	2	1	154	8
Dangerous Passage	0	0	4	1	14	2	6	1	0	0	28	1
Dutch Group	6	3	6	1	12	1	0	0	5	4	14	1
Eaglek Bay	6	3	4	1	12	1	0	0	5	4	11	1
Eshamy	0	0	5	1	18	2	5	1	0	0	29	1
Esther Passage	2	1	17	2	5	1	2	0	2	1	20	1
Esther South	2	1	12	2	14	2	5	1	6	4	32	2
Esther West	2	1	2	0	2	0	0	0	0	0	2	0
Evans Island	0	0	5	1	20	2	2	0	0	0	9	0
Glacier Island	0	0	0	0	0	0	0	0	0	0	0	0
Harriman Fiord	8	5	46	7	21	2	30	6	4	3	89	4
Icy Bay	0	0	10	1	10	1	0	0	0	0	17	1
Kings Bay	8	5	5	1	7	1	6	1	2	1	16	1
Knight East	0	0	6	1	0	0	0	0	0	0	6	0
Knight North	0	0	5	1	0	0	6	1	0	0	5	0
Knight South	0	0	6	1	0	0	0	0	0	0	6	0

Table 5. Mean number of kayaks present by analysis area in western Prince William Sound, Alaska, May--September, 1997.

Analysis area	Trips by month											
	May		June		July		August		September		All months	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Knight West	0	0	4	1	4	0	3	1	0	0	6	0
Naked East	0	0	0	0	5	1	0	0	0	0	5	0
Naked West	0	0	0	0	5	1	0	0	0	0	5	0
Nellie Juan	7	4	27	4	38	4	19	3	3	2	76	4
Passage Canal	52	30	108	16	143	17	106	19	27	20	383	19
Perry North	2	1	4	1	10	1	8	1	0	0	12	1
Perry South	5	3	3	0	26	3	17	3	0	0	34	2
Pigot Bay	3	2	63	9	46	5	61	11	14	10	159	8
Port Bainbridge	0	0	4	1	0	0	0	0	0	0	4	0
Storey	0	0	0	0	5	1	0	0	0	0	5	0
Surprise Cove	12	7	66	10	97	11	37	7	13	10	199	10
Unakwik	3	2	5	1	0	0	0	0	5	4	10	1
Wells Bay	3	2	0	0	0	0	0	0	0	0	3	0
Whale Bay	0	0	7	1	5	1	0	0	0	0	10	1
Total	175	100	683	100	850	100	545	100	134	100	1985	100

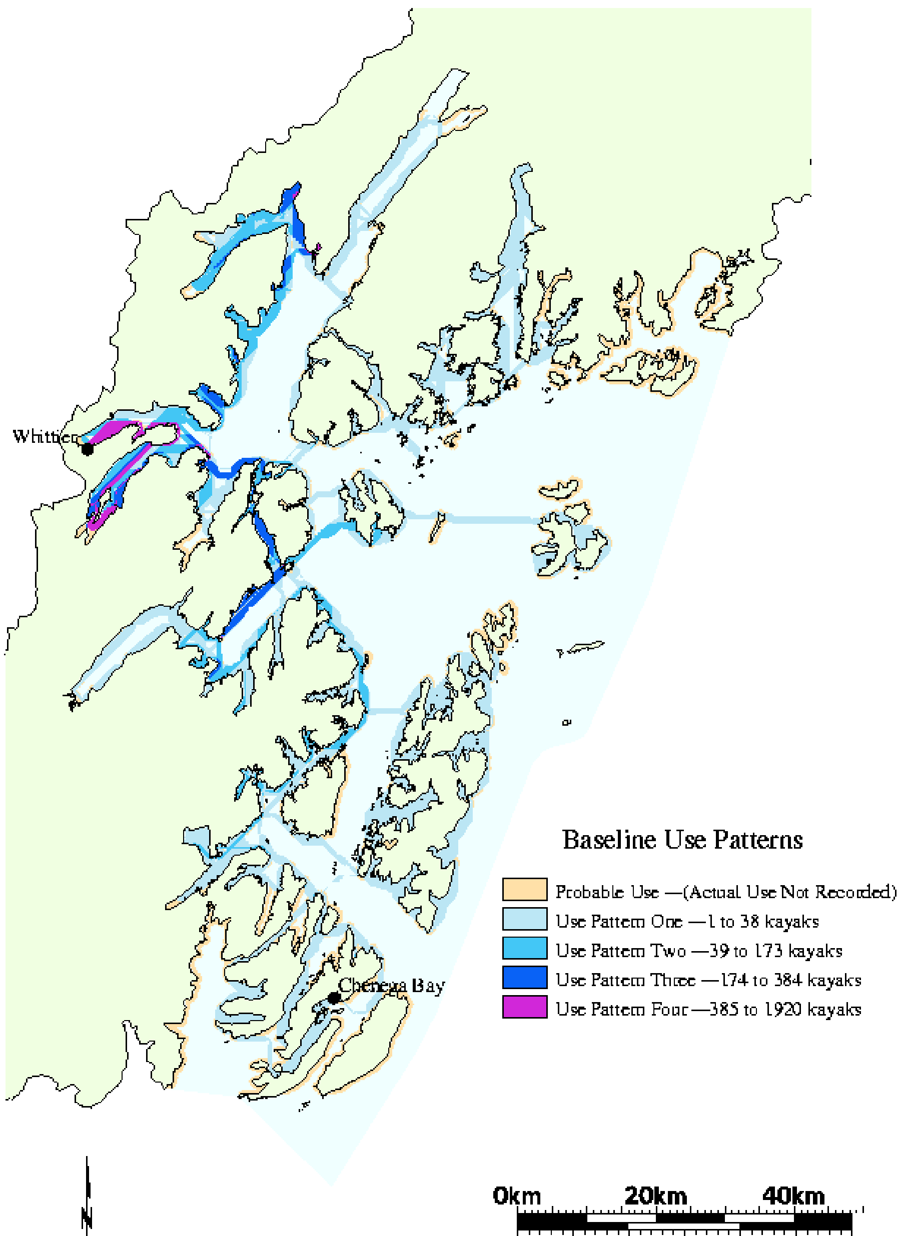


Fig. 6. Distribution of the kayak user group in western Prince William Sound, Alaska, May–September, 1998.

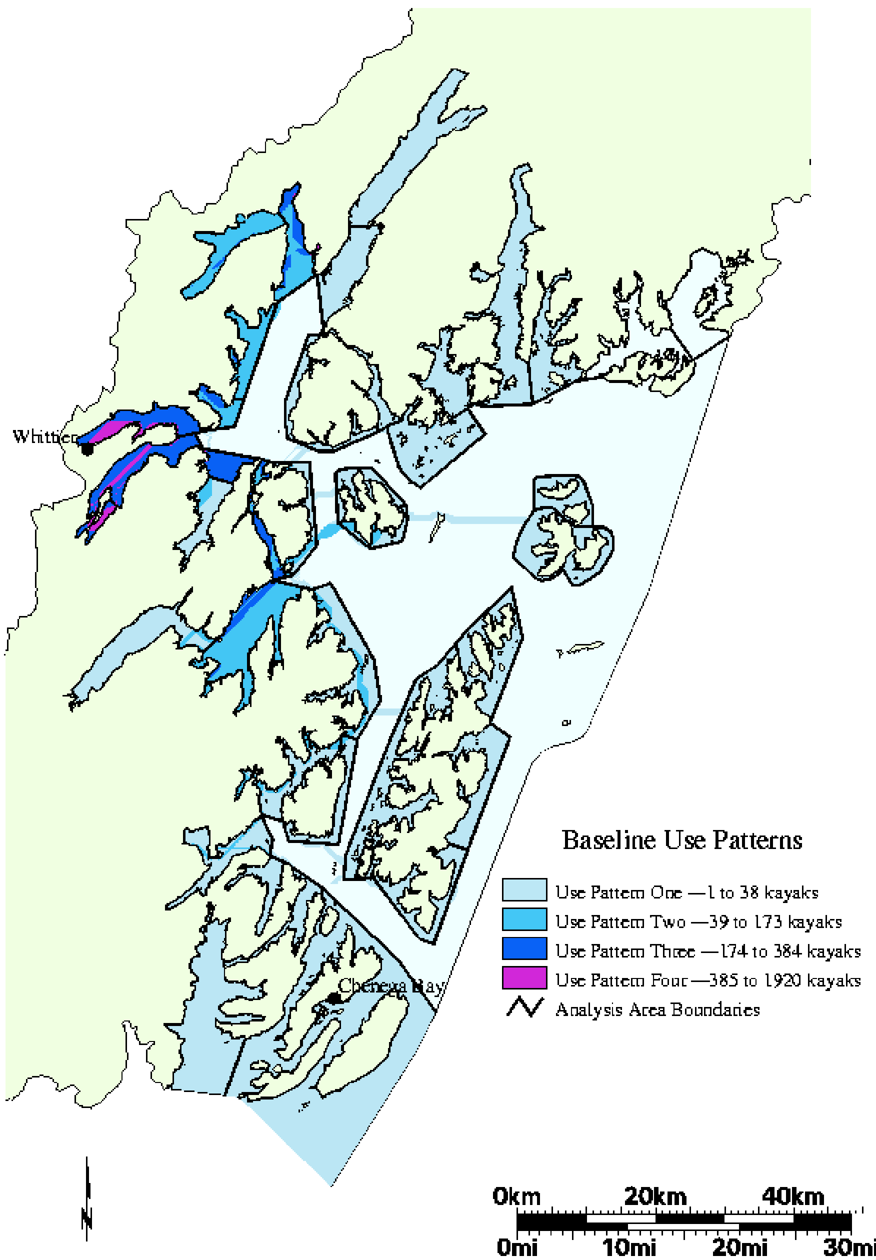


Fig. 7. Mean number of kayaks present by analysis area in western Prince William Sound, Alaska, May–September, 1998.

Table 6. Mean number of charter boat occurrences by analysis area in western Prince William Sound, Alaska, May--September, 1997.

Analysis area	Trips by Month											
	May		June		July		August		September		All Months	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Bainbridge Passage	0	0	5	0	2	0	2	0	2	1	12	0
Barry Arm	10	2	50	4	18	1	23	2	7	2	75	2
Bettles Bay	34	8	96	8	87	6	136	10	19	6	351	8
Blackstone Bay	16	4	53	4	110	8	60	4	18	6	204	5
Chenega Island	0	0	13	1	12	1	19	1	6	2	51	1
Cochrane Bay Lower	8	2	19	2	8	1	8	1	0	0	43	1
College Fiord	0	0	4	0	8	1	12	1	0	0	20	0
College Fiord Lower	0	0	5	0	17	1	25	2	0	0	47	1
Columbia Bay	0	0	0	0	2	0	2	0	0	0	2	0
Culross East	7	2	35	3	69	5	57	4	14	5	169	4
Culross Passage	21	5	93	7	175	12	124	9	28	10	440	10
Dangerous Passage	0	0	12	1	22	2	15	1	3	1	50	1
Dutch Group	16	4	15	1	10	1	8	1	0	0	37	1
Eaglek Bay	12	3	7	1	8	1	5	0	0	0	30	1
Eshamy	0	0	35	3	78	5	63	5	14	5	189	4
Esther Passage	7	2	11	1	3	0	7	1	3	1	25	1
Esther South	34	8	58	5	24	2	31	2	2	1	146	3
Esther West	20	5	31	2	15	1	21	2	5	2	71	2
Evans Island	0	0	6	0	6	0	15	1	4	1	26	1
Glacier Island	0	0	0	0	2	0	3	0	0	0	4	0
Harriman Fiord	4	1	36	3	5	0	16	1	0	0	30	1
Icy Bay	0	0	4	0	9	1	4	0	2	1	11	0
Kings Bay	0	0	0	0	4	0	0	0	0	0	4	0
Knight East	0	0	6	0	3	0	2	0	0	0	5	0
Knight North	0	0	5	0	8	1	4	0	0	0	14	0

Table 6. Mean number of charter boat occurrences by analysis area in western Prince William Sound, Alaska, May--September, 1997.

Analysis area	Trips by Month											
	May		June		July		August		September		All Months	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Knight South	0	0	2	0	2	0	4	0	0	0	6	0
Knight West	0	0	8	1	15	1	14	1	4	1	36	1
Naked East	0	0	4	0	0	0	0	0	0	0	4	0
Naked West	0	0	4	0	0	0	2	0	0	0	2	0
Nellie Juan	4	1	8	1	11	1	15	1	5	2	34	1
Passage Canal	135	31	280	22	306	21	288	22	76	26	1016	23
Perry North	8	2	10	1	23	2	14	1	13	4	46	1
Perry South	8	2	30	2	48	3	33	2	12	4	111	3
Pigot Bay	32	7	81	6	78	5	105	8	18	6	303	7
Port Bainbridge	0	0	2	0	0	0	0	0	0	0	2	0
Storey	0	0	4	0	0	0	0	0	0	0	4	0
Surprise Cove	49	11	193	15	241	17	190	14	38	13	708	16
Unakwik	8	2	20	2	6	0	5	0	0	0	16	0
Wells Bay	0	0	0	0	2	0	3	0	0	0	5	0
Whale Bay	0	0	4	0	8	1	4	0	0	0	12	0
Total	433	100	1249	100	1445	100	1339	100	293	100	4361	100

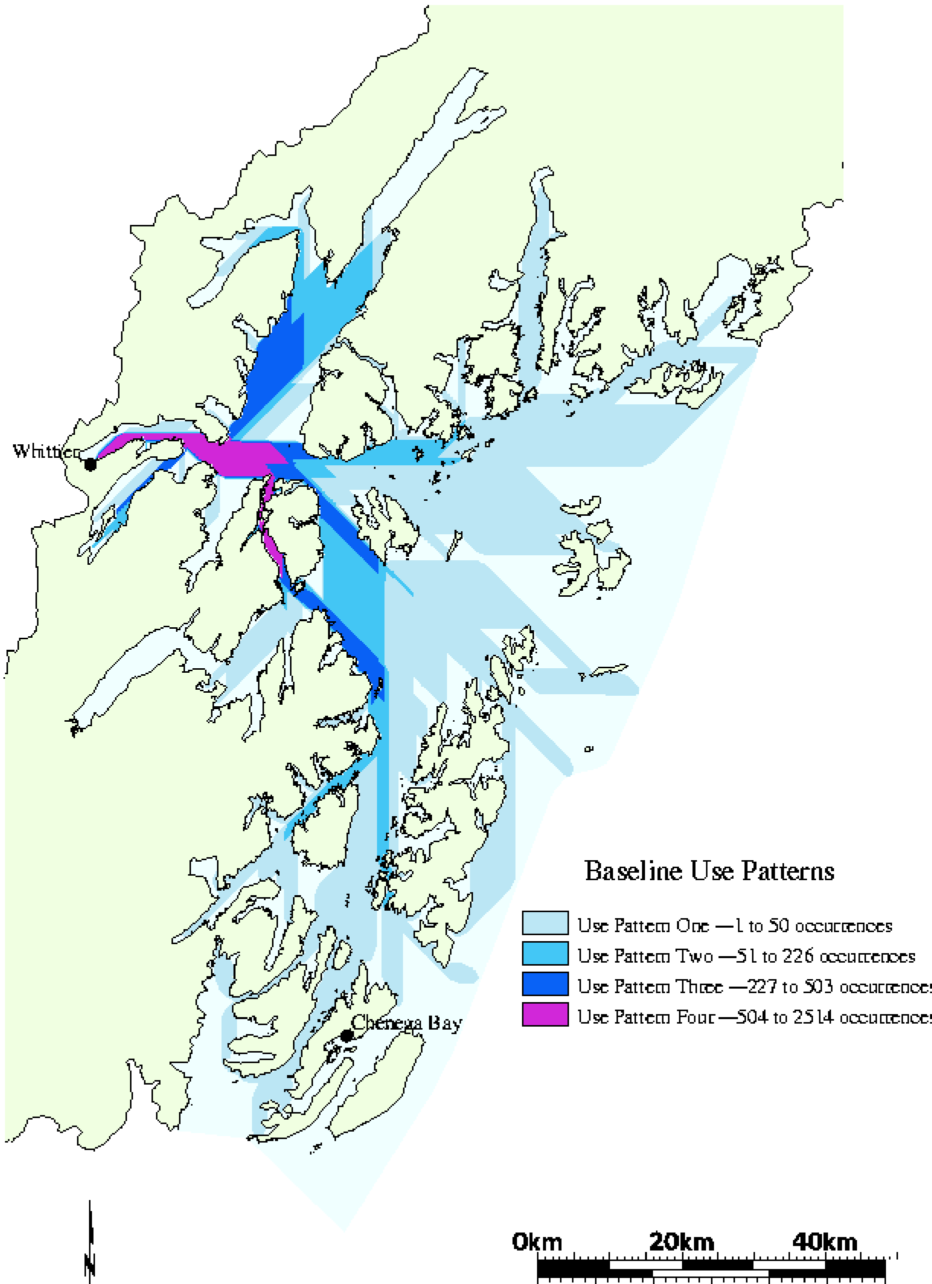


Fig. 8. Distribution of the charter boat user group in western Prince William Sound, Alaska, May–September, 1997.

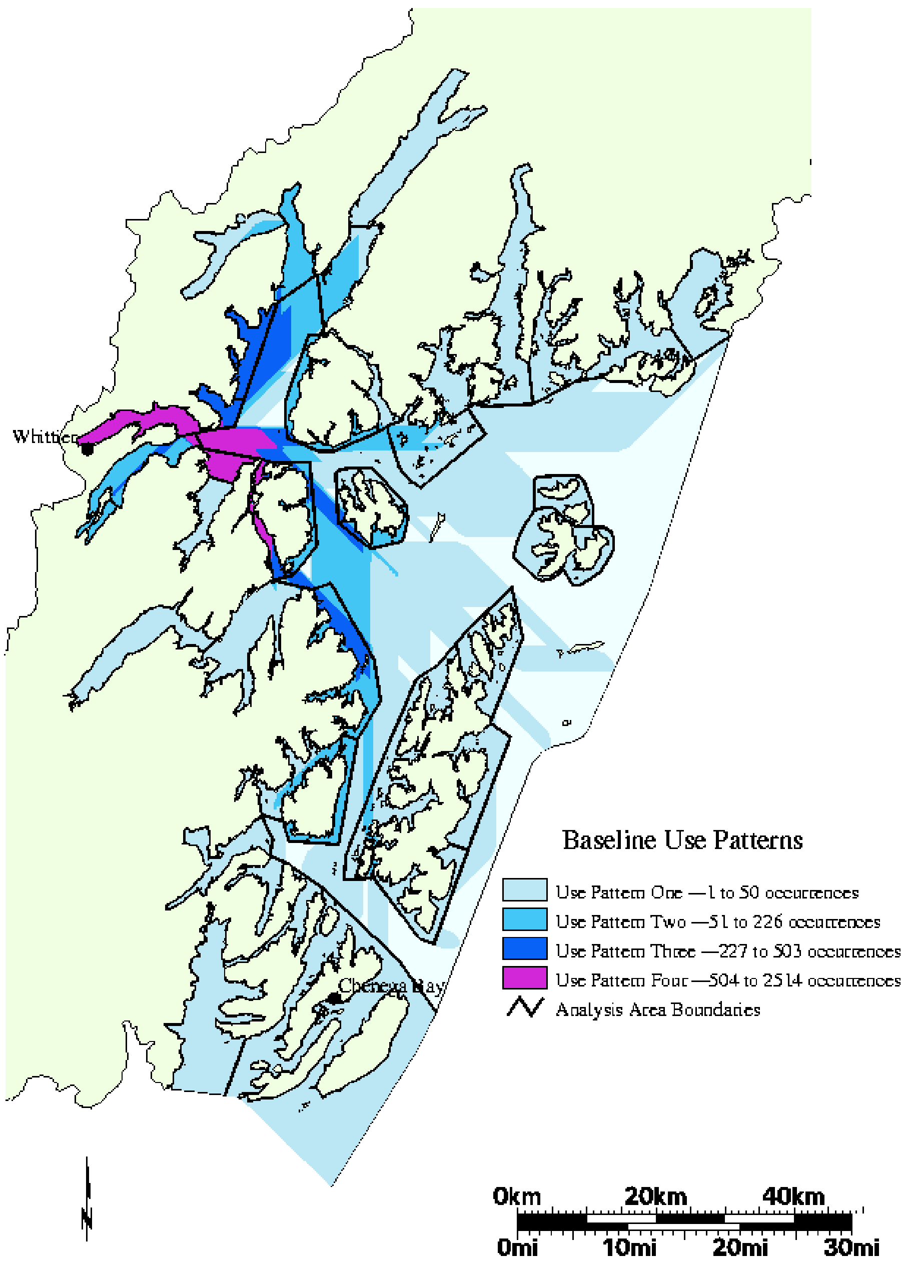


Fig. 9. Mean number of charter boat occurrences by analysis area in western Prince William Sound, Alaska, May–September, 1997.

Table 7. Total number of cruise ship and State ferry trips by analysis area in western Prince William Sound, Alaska, 1998

Analysis area	Trips by month											
	May		June		July		August		September		All months	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Bainbridge Passage	8	1	18	1	19	1	19	1	10	1	74	1
Barry Arm	100	8	180	7	186	7	186	7	100	9	752	7
Bettles Bay	66	5	120	5	124	5	124	5	70	6	504	5
Blackstone Bay	46	3	94	4	98	4	94	4	34	3	366	4
Chenega Island	4	0	16	1	16	1	16	1	8	1	60	1
Cochrane Bay Lower	0	0	0	0	0	0	0	0	0	0	0	0
College Fiord	98	7	202	8	210	8	204	8	84	7	798	8
College Fiord Lower	98	7	202	8	210	8	204	8	84	7	798	8
Columbia Bay	126	9	192	8	193	8	195	8	75	6	781	8
Culross East	0	0	0	0	0	0	0	0	0	0	0	0
Culross Passage	4	0	16	1	16	1	16	1	8	1	60	1
Dangerous Passage	4	0	16	1	16	1	16	1	8	1	60	1
Dutch Group	57	4	94	4	89	3	92	4	34	3	366	4
Eaglek Bay	10	1	36	1	34	1	34	1	4	0	118	1
Eshamy	4	0	16	1	16	1	16	1	8	1	60	1
Esther Passage	5	0	20	1	20	1	18	1	3	0	66	1
Esther South	0	0	0	0	0	0	0	0	0	0	0	0
Esther West	0	0	0	0	0	0	0	0	0	0	0	0
Evans Island	20	2	50	2	53	2	50	2	29	3	202	2
Glacier Island	126	9	192	8	193	8	195	8	75	6	781	8
Harriman Fiord	100	8	180	7	186	7	186	7	100	9	752	7
Icy Bay	4	0	16	1	16	1	16	1	8	1	60	1
Kings Bay	4	0	16	1	16	1	16	1	8	1	60	1
Knight East	0	0	0	0	0	0	0	0	0	0	0	0
Knight North	4	0	16	1	16	1	16	1	8	1	60	1
Knight South	0	0	0	0	0	0	0	0	0	0	0	0

Table 7. Total number of cruise ship and State ferry trips by analysis area in western Prince William Sound, Alaska, 1998

Analysis area	Trips by month											
	May		June		July		August		September		All months	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Knight West	4	0	16	1	16	1	16	1	8	1	60	1
Naked East	0	0	0	0	0	0	0	0	0	0	0	0
Naked West	0	0	0	0	0	0	0	0	0	0	0	0
Nellie Juan	4	0	16	1	16	1	16	1	8	1	60	1
Passage Canal	224	17	364	14	377	15	375	15	195	17	1535	15
Perry North	0	0	0	0	0	0	0	0	0	0	0	0
Perry South	0	0	0	0	0	0	0	0	0	0	0	0
Pigot Bay	105	8	198	8	203	8	203	8	102	9	811	8
Port Bainbridge	11	1	21	1	22	1	22	1	13	1	89	1
Storey	0	0	0	0	0	0	0	0	0	0	0	0
Surprise Cove	4	0	17	1	17	1	17	1	3	0	58	1
Unakwik	44	3	96	4	96	4	96	4	34	3	366	4
Wells Bay	44	3	96	4	96	4	96	4	34	3	366	4
Whale Bay	0	0	0	0	0	0	0	0	0	0	0	0
Total	1328	100	2516	100	2570	100	2554	100	1155	100	10123	100

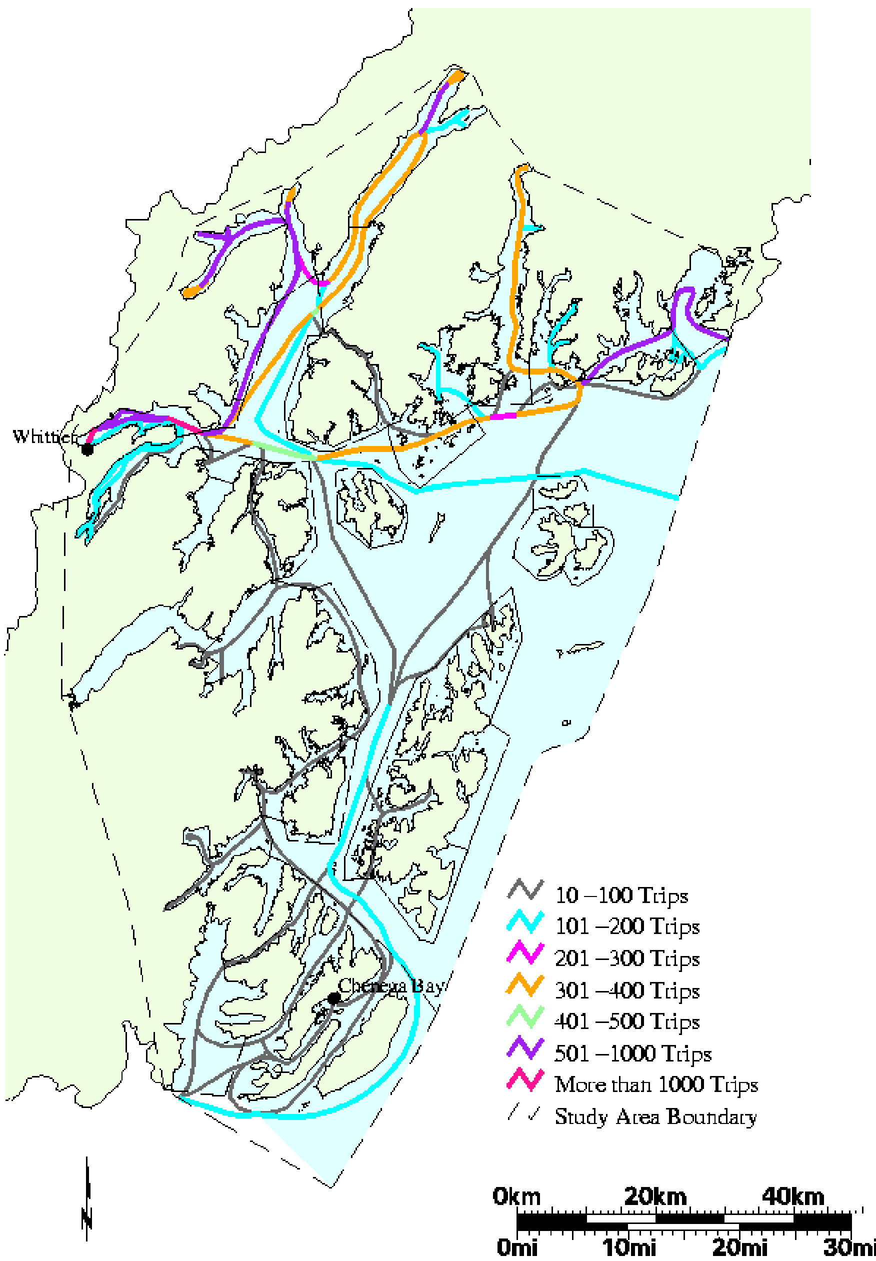


Fig. 10. Distribution of the cruise ship & State ferry user group in western Prince William Sound, Alaska, May–September, 1998.

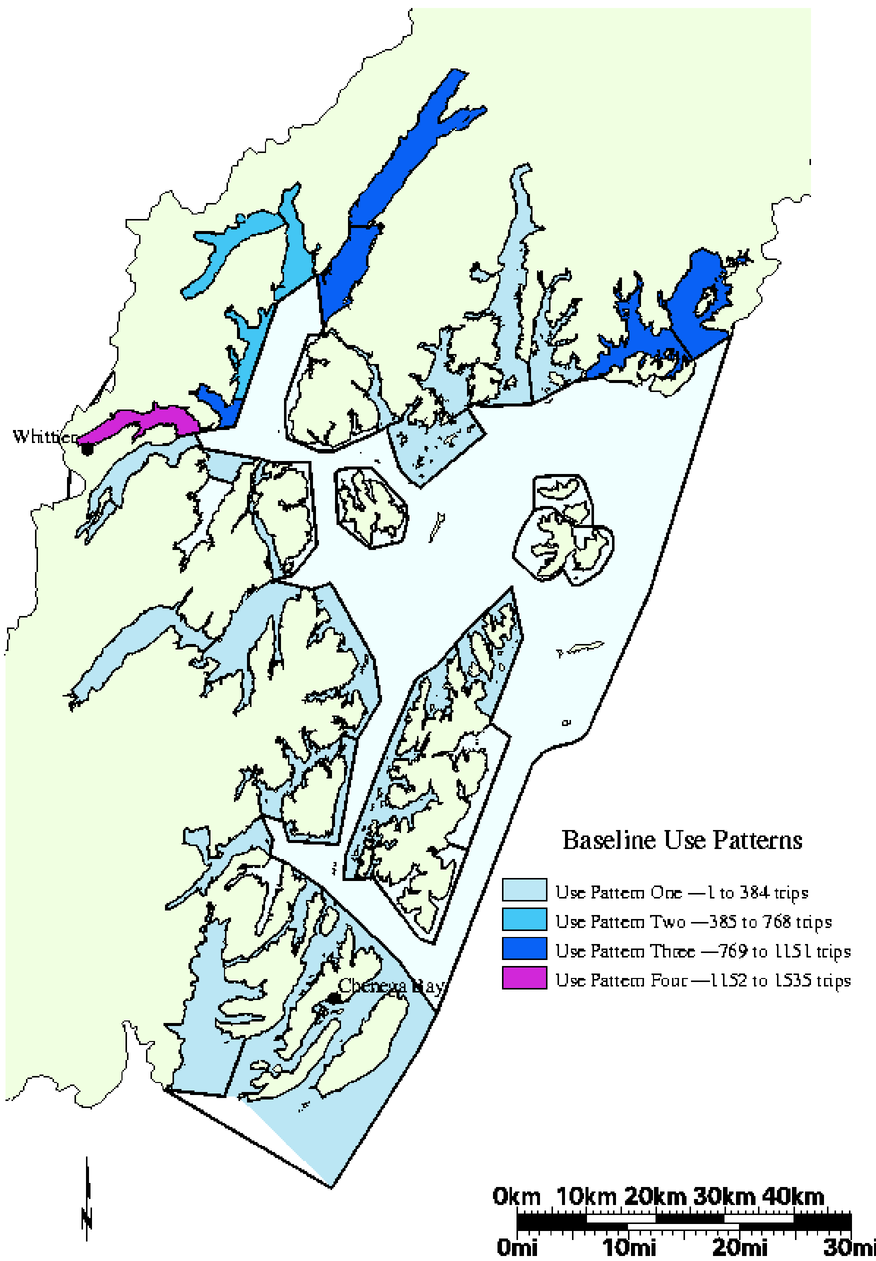


Fig. 11. Total number of cruise ship and State ferry trips by analysis area, using 25% increments, in western Prince William Sound, Alaska, May –September 1998.

Commercial Fishing

During 1996, 19 commercial fishing subdivisions were fished in the western Sound (Fig. 3). There were 389 openings that occurred over 86 days throughout the summer. Nine hundred trips by commercial fishing vessels were estimated to have originated from the Whittier Harbor to these fishing areas; 50 originated from the Chenega Bay Harbor (Table 8, Figs. 12-13).

Recreational Motor Boats

There were 341 recreational motorboats and sailboats that docked in the Whittier harbor in 1997. These boats made 1,145 multi-day trips from the harbor, with an additional 1,612 trips that were estimated at less than 24 hrs. The average trip length for recreational boats from the Whittier Harbor was 2.74 days (7,572 boatdays/2,757 trips of any length). These data were combined with the results from the Alaska Department of Natural Resources user survey to estimate how the vessels were distributed throughout the study area. One-hundred eighteen responses to the questionnaire were received (34% response rate). Respondents described 1,420 trips that they had taken during the summer of 1997 (Table 9).

During June, July, and August, 1998, 36 recreation boats used the Chenega Bay village harbor. The IRA Council was also able to determine the approximate trip route and destinations for these visitors. Recreational boat trips by the staff at the AFK Hatchery contributed 116 additional trips for June through September in the southwest portion of the study area. With these data we were able to represent boating activity around Chenega Bay and the hatchery, in addition to activity from vessels that departed from the Whittier harbor. After we determined how many boats to direct to different destinations in the western Sound, computer algorithms determined the most efficient path for recreation boats to travel between sources and destination (Fig. 14).

The data provided by the AFK hatchery were also used to represent resident activity from the other 3 hatcheries in the study area. The distances between the AFK hatchery and the destinations identified for their trips were calculated and separated into 4 distance categories: <8 km, 8-16 km, 16-32 km, and > 32 km from the hatchery. These categories were used to distribute the same number of trips made by the AFK Hatchery personnel to analysis areas surrounding the other hatcheries. These trips were then added to the mean value of the associated analysis areas (Table 10, Fig 15).

Model Evaluation

Seventeen aerial surveys were flown from June through September to provide information necessary to evaluate patterns of use developed for water vessels in the western Sound. Two-hundred recreational motor boats and 228 kayaks were observed during the surveys. Three analysis areas were surveyed simultaneously by boat to evaluate the "sightability" of kayaks during aerial surveys. Comparison of the results of the simultaneous surveys showed nearly identical results, indicating that it is likely that aerial surveys detected most kayaks present in sampled areas (Fig. 16). Comparisons of the relative number of kayaks and recreational motor boats estimated to occur in the western Sound with the results of the aerial surveys revealed strong correlations (Figs. 17-18).

Table 8. Mean number of commercial fishing trips by analysis area in western Prince William Sound, Alaska, June--September, 1996.

Analysis area	June No.	June %	July No.	July %	August No.	August %	September No.	September %	All months No.	All months %
Bainbridge Passage	0	0	15	0	22	1	87	3	37	0
Barry Arm	40	1	9	0	6	0	0	0	9	0
Bettles Bay	50	1	29	1	22	1	22	1	46	0
Blackstone Bay	0	0	0	0	0	0	0	0	0	0
Chenega Island	0	0	123	2	130	4	130	5	383	3
College Fiord	40	1	503	9	6	0	0	0	549	5
College Fiord Lower	40	1	503	9	6	0	22	1	550	5
Columbia Bay	0	0	1	0	0	0	0	0	1	0
Culross East	925	24	335	6	261	8	204	7	768	7
Culross Passage	0	0	485	9	244	8	243	8	965	9
Dangerous Passage	0	0	0	0	4	0	4	0	8	0
Dutch Group	91	2	32	1	144	4	21	1	200	2
Eaglek Bay	10	0	25	0	148	5	0	0	35	0
Eshamy	0	0	328	6	176	5	183	6	622	6
Esther Passage	287	8	343	6	201	6	224	8	730	6
Esther South	930	24	389	7	212	7	234	8	1767	16
Esther West	140	4	344	6	230	7	245	9	516	5
Evans Island	0	0	44	1	71	2	53	2	134	1
Glacier Island	0	0	1	0	0	0	0	0	1	0
Harriman Fiord	0	0	9	0	0	0	0	0	9	0
Knight East	0	0	1	0	1	0	4	0	2	0
Knight North	0	0	5	0	4	0	4	0	13	0
Knight South	0	0	9	0	14	0	60	2	25	0
Knight West	0	0	99	2	112	3	111	4	323	3
Naked East	0	0	2	0	5	0	0	0	7	0

Table 8. Mean number of commercial fishing trips by analysis area in western Prince William Sound, Alaska, June--September, 1996.

Analysis area	Trips by month									
	June		July		August		September		All months	
	No.	%	No.	%	No.	%	No.	%	No.	%
Naked West	0	0	2	0	5	0	4	0	7	0
Nellie Juan	0	0	387	7	207	6	197	7	392	3
Passage Canal	254	7	686	12	328	10	328	11	1514	13
Perry North	925	24	73	1	164	5	57	2	272	2
Perry South	0	0	118	2	186	6	135	5	258	2
Pigot Bay	50	1	61	1	51	2	51	2	115	1
Port Bainbridge	0	0	68	1	16	0	4	0	28	0
Storey	0	0	2	0	5	0	4	0	7	0
Surprise Cove	10	0	491	9	251	8	251	9	978	9
Unakwik	7	0	14	0	0	0	0	0	20	0
Wells Bay	0	0	6	0	0	0	0	0	6	0
Total	3799	100	5542	100	3232	100	2882	100	11297	100

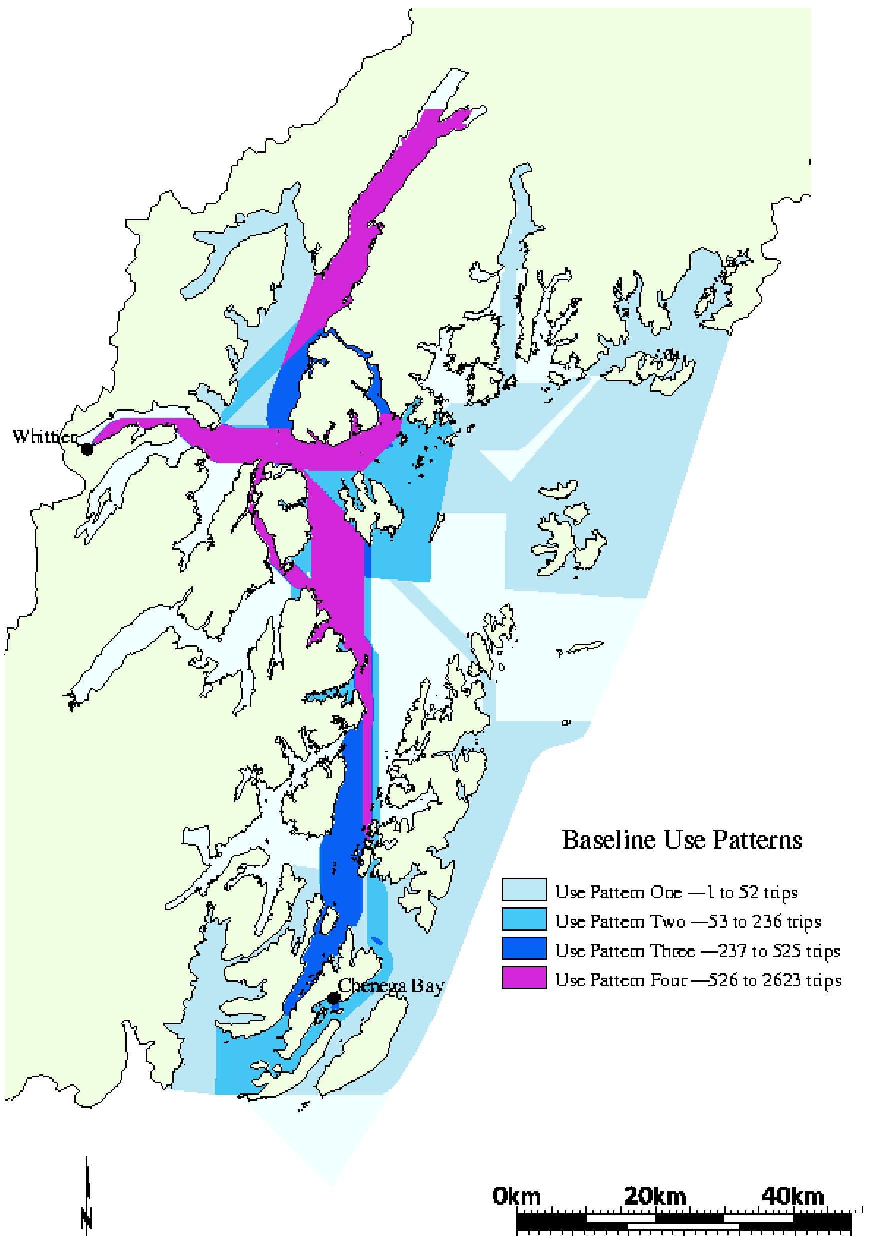


Fig. 12. Distribution of the commercial fishing user group in western Prince William Sound, Alaska, June–September, 1996.

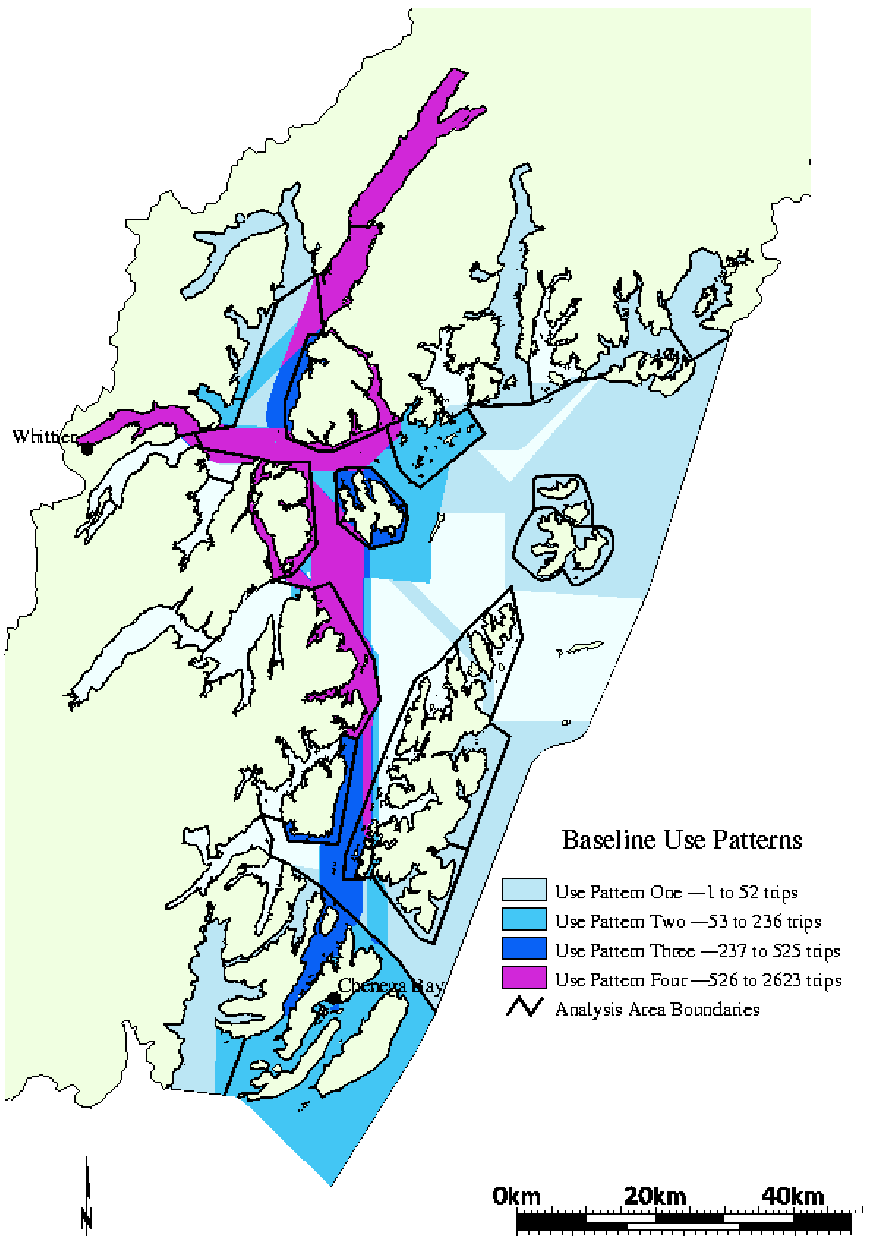


Fig. 13. Mean number of commercial fishing trips by analysis area in western Prince William Sound, Alaska, June–September, 1996.

Table 9. Trips reported by users of recreational motor boats in western Prince William Sound, Alaska, May—September, 1997.

Reported Destinations	Destinations used by month				
	May	June	July	August	September
Applegate		X	X	X	
Applegate Island	X				
Axel Lind Island	X	X	X		
Bainbridge				X	X
Bainbridge Glacier			X		
Bainbridge Passage		X	X		
Bainbridge Port		X	X		
Barns Cove			X		
Barry Arm		X	X	X	X
Barry Glacier			X		
Bass Harbor	X				
Bay Isles			X		
Bettles Bay	X	X	X	X	X
Bettles Lagoon		X			
Bishop Rock	X				
Blackstone Bay	X	X	X	X	X
Blackstone Glacier			X	X	X
Blackstone Pt.		X		X	
Blue Fiord		X		X	
Bush Banks			X	X	
Cabin Bay	X			X	X
Cake Bay				X	
Cedar Bay	X		X		X
Chenega Island		X	X		
Cochrane Bay	X	X	X	X	X
Coghill Pt.	X				
Coghill River/Port Wells		X	X		
College Fiord	X	X	X	X	X
College Fiord/Harriman		X	X	X	
Columbia Bay			X	X	
Constantine Har./Hinchinbrook		X			

Table 9. Trips reported by users of recreational motor boats in western Prince William Sound, Alaska, May—September, 1997.

Reported Destinations	Destinations used by month				
	May	June	July	August	September
Copper Bay		X		X	
Cordova		X	X	X	
Crafton Island/lower Herring Bay				X	
Crafton Island			X		
Culross	X				
Culross Bay	X	X	X	X	
Culross Cove/Perry Island			X		X
Culross Island		X		X	X
Culross Passage	X	X	X	X	X
Culross/Long Bay			X	X	X
Danger Island		X			
Dangerous Passage		X			
Deep Water Bay	X	X	X	X	X
Dickerson Bay			X	X	
Disk Island	X			X	
Drier Bay		X		X	
Dutch Grove		X	X		
Eaglek Bay	X	X	X	X	X
East Twin Bay					X
Eleanor Island	X		X		X
Elrington Island		X	X		X
Emerald Bay				X	
Eshamy Bay		X	X	X	X
Eshamy Lagoon				X	X
Eshamy Lake		X			
Esther Bay	X				
Esther Island	X	X	X	X	X
Esther Passage	X	X	X	X	X
Foul Bay				X	
Fox Farm			X	X	
Glacier Island				X	

Table 9. Trips reported by users of recreational motor boats in western Prince William Sound, Alaska, May—September, 1997.

Reported Destinations	Destinations used by month				
	May	June	July	August	September
Golden/Ester Island				X	
Goose Bay	X	X	X		X
Granite Bay		X	X		X
Granite Bay/Ester Island	X	X	X	X	X
Green Island				X	X
Green Island/Snug Harbor				X	
Harriman Fiord	X	X	X	X	X
Harriman Glacier		X	X		
Herring Bay				X	
Hidden Bay	X	X	X	X	
Hinchinbrook	X	X			
Hobo Bay	X	X	X		X
Hogg Bay			X	X	X
Homer				X	
Hummer Bay	X	X	X	X	X
Icy Bay		X	X		X
Ingot Cove	X				
Jackpot Bay		X	X	X	X
Kings Bay	X	X	X	X	X
Knight Island	X	X	X	X	X
Knight Island Passage		X	X		
Lake Bay	X	X	X	X	X
Latouche Island	X	X		X	
Logging Camp Bay	X				
Lone Island	X	X	X	X	X
Long Bay	X	X	X	X	X
Long Channel		X	X		
Lower Passage	X	X	X	X	
Main Bay	X	X	X	X	X
Marsha Bay			X		
Mask Bay			X		

Table 9. Trips reported by users of recreational motor boats in western Prince William Sound, Alaska, May—September, 1997.

Reported Destinations	Destinations used by month				
	May	June	July	August	September
McClure Bay	X	X	X	X	X
Miners Bay		X	X		
Mink Island	X	X	X	X	
Montague Island	X		X	X	X
Mummy Bay			X		
Naked Island	X	X	X	X	X
Nellie Juan glacier		X			
North Twin Bay			X		
North West Bay		X			X
Outside Bay	X		X		
Pakenham Point	X			X	
Passage Canal	X	X	X	X	X
Paulson Cove	X	X	X	X	
Perry Bay			X		
Perry Island	X	X	X	X	X
Perry Passage	X	X	X		X
Picturesque Cove		X			
Pigot Bay	X	X	X	X	X
Poe Bay				X	X
Point Decision			X	X	
Port Nellie Juan	X	X	X	X	X
Port Wells	X	X	X	X	X
Quillian Bay		X	X	X	X
Rocky Bay	X				
Saw Mill Bay				X	
Seward		X	X	X	X
Shady Cove			X		
Shallow Cove		X	X		
Shoestring Cove			X		
Shotgun Cove	X	X	X		X
Shrode Lake			X	X	

Table 9. Trips reported by users of recreational motor boats in western Prince William Sound, Alaska, May—September, 1997.

Reported Destinations	Destinations used by month				
	May	June	July	August	September
Siwash Bay	X	X	X	X	
Snug Harbor		X	X	X	X
Squaw Bay	X	X	X		X
Squire Island		X			
Squirrel Bay	X		X		
Surprise Cove		X	X	X	X
Tebenkof Glacier	X				X
Three Finger Cove					
Unakwik Inlet	X	X	X	X	X
Valdez	X	X	X	X	
Wells Passage	X	X	X	X	X
West Side	X	X	X	X	X
West Twin	X				
West Twin Bay		X	X	X	X
Whale Bay			X		
Whittier	X	X	X	X	
Ziegler Cove	X		X	X	

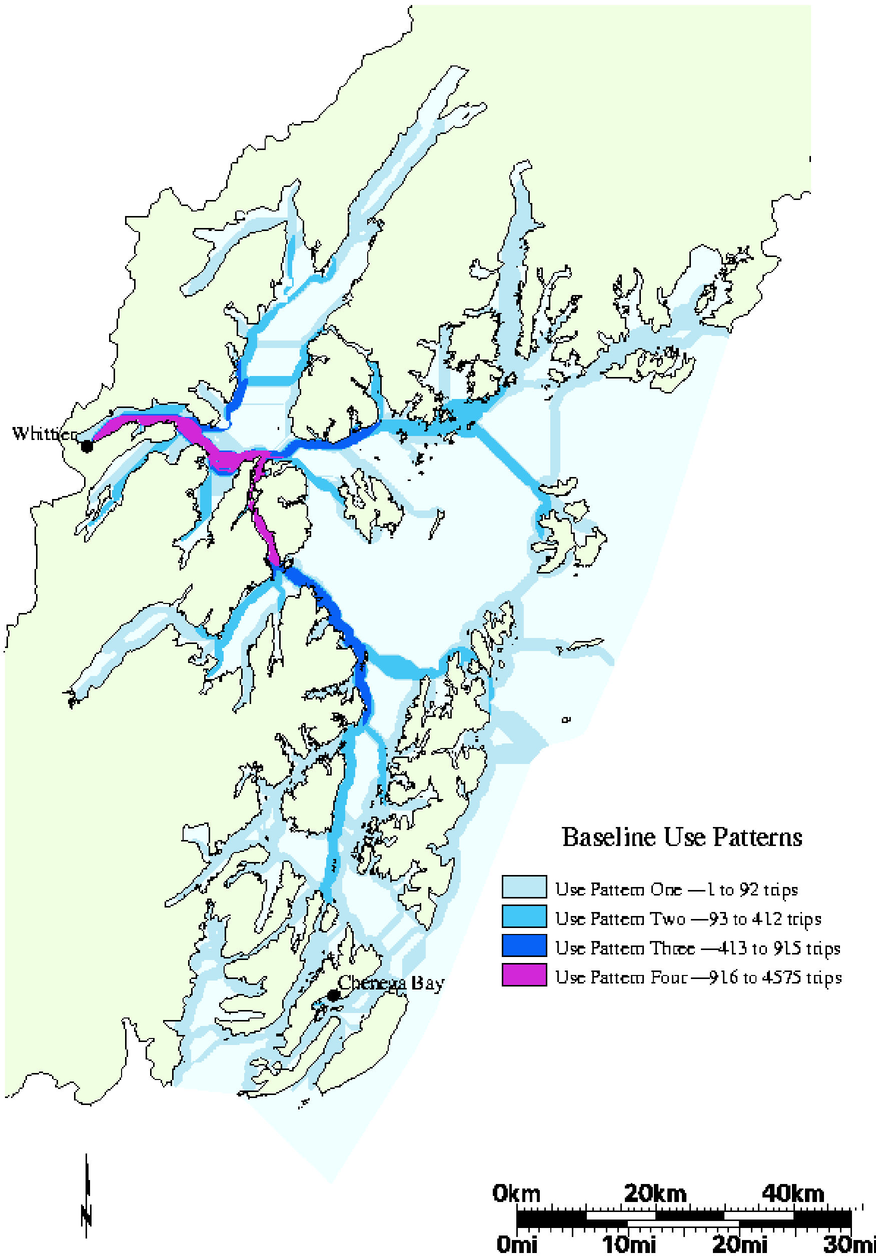


Fig. 14. Distribution of the recreation motor boat user group in western Prince William Sound, Alaska, May–September, 1997.

Table 10. Mean number of recreational motor boat trips by analysis area in western Prince William Sound, May--September, 1997—1998.

Analysis area	Trips by month											
	May		June		July		August		September		All months	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Bainbridge Passage	6	1	13	1	25	1	28	1	7	1	70	1
Barry Arm	5	1	20	1	33	1	28	1	9	1	78	1
Bettles Bay	23	2	50	3	121	4	78	3	31	3	300	4
Blackstone Bay	78	8	70	4	217	6	187	8	55	6	339	4
Chenega Island	11	1	41	2	73	2	45	2	15	2	187	2
Cochrane Bay Lower	20	2	19	1	22	1	27	1	11	1	78	1
College Fiord	3	0	5	0	10	0	9	0	5	1	29	0
College Fiord Lower	5	1	10	1	33	1	16	1	7	1	56	1
Columbia Bay	4	0	10	1	26	1	13	1	1	0	51	1
Culross East	11	1	24	1	61	2	47	2	10	1	143	2
Culross Passage	108	12	236	14	461	14	328	13	102	11	1213	14
Dangerous Passage	2	0	12	1	30	1	10	0	3	0	55	1
Dutch Group	20	2	24	1	72	2	34	1	26	3	144	2
Eaglek Bay	10	1	19	1	44	1	16	1	10	1	87	1
Eshamy	24	3	69	4	176	5	98	4	31	3	362	4
Esther Passage	22	2	22	1	47	1	42	2	9	1	119	1
Esther South	62	7	97	6	211	6	108	4	55	6	527	6
Esther West	13	1	20	1	33	1	36	1	17	2	113	1
Evans Island	3	0	6	0	12	0	9	0	2	0	28	0
Glacier Island	4	0	11	1	42	1	23	1	1	0	83	1
Harriman Fiord	6	1	16	1	20	1	26	1	8	1	63	1
Icy Bay	0	0	5	0	4	0	2	0	2	0	11	0
Kings Bay	2	0	9	1	12	0	4	0	3	0	31	0
Knight East	4	0	5	0	9	0	13	1	3	0	27	0
Knight North	4	0	5	0	14	0	14	1	8	1	42	0

Table 10. Mean number of recreational motor boat trips by analysis area in western Prince William Sound, May--September, 1997—1998.

Analysis area	Trips by month											
	May		June		July		August		September		All months	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Knight South	0	0	3	0	3	0	7	0	1	0	11	0
Knight West	5	1	10	1	17	0	14	1	5	1	48	1
Naked East	4	0	3	0	8	0	6	0	4	0	18	0
Naked West	7	1	7	0	13	0	13	1	11	1	50	1
Nellie Juan	15	2	23	1	40	1	31	1	15	2	114	1
Passage Canal	192	21	338	20	597	18	504	20	184	21	1647	19
Perry North	4	0	14	1	22	1	12	0	6	1	58	1
Perry South	2	0	8	0	18	1	7	0	2	0	37	0
Pigot Bay	30	3	46	3	100	3	79	3	27	3	284	3
Port Bainbridge	0	0	2	0	4	0	7	0	2	0	15	0
Storey	9	1	8	0	13	0	13	1	10	1	52	1
Surprise Cove	195	21	365	22	696	20	509	21	183	21	1849	22
Unakwik	4	0	8	0	40	1	6	0	5	1	63	1
Wells Bay	4	0	8	0	22	1	19	1	1	0	38	0
Whale Bay	0	0	1	0	5	0	2	0	0	0	8	0
Total	921	100	1662	100	3406	100	2470	100	887	100	8528	100

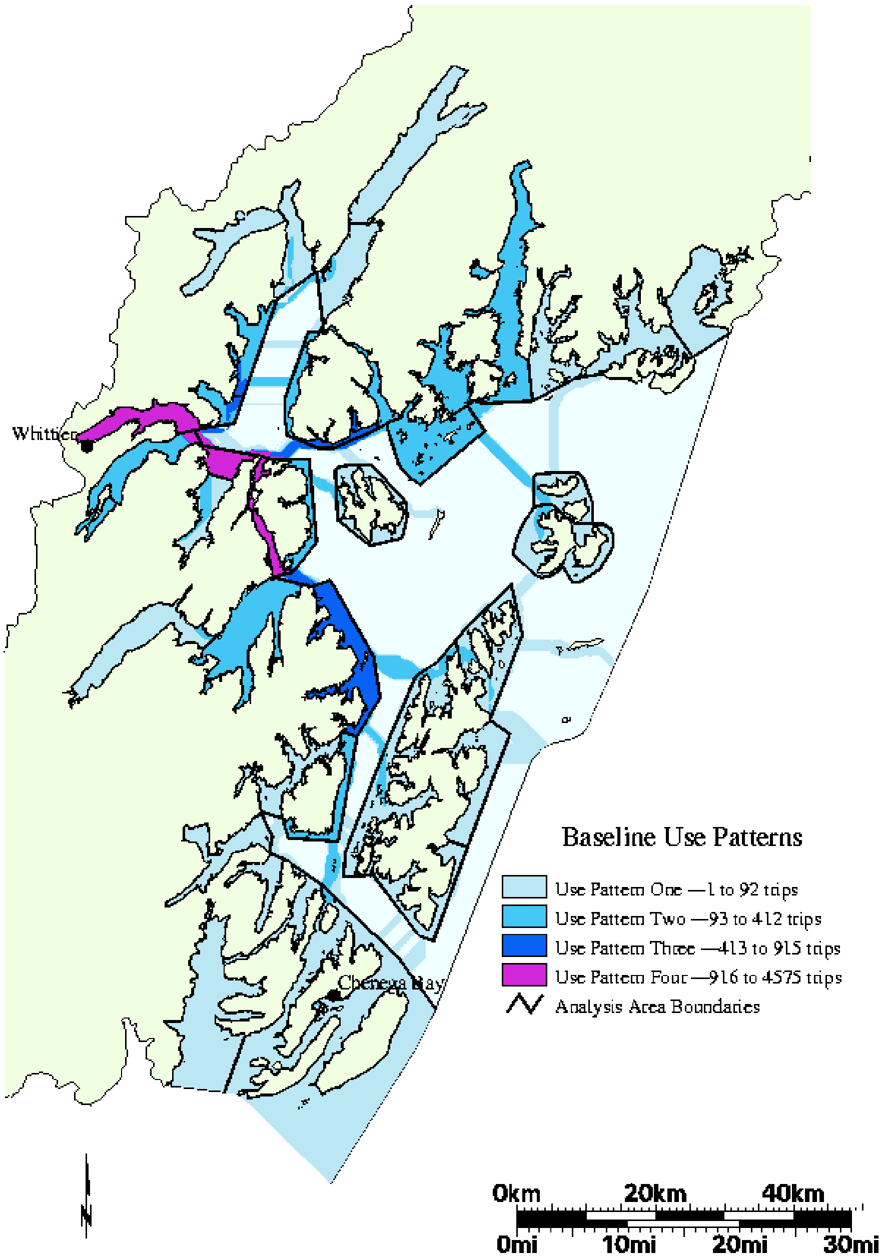


Fig. 15. Mean number of recreational motor boat trips by analysis area in western Prince William Sound, Alaska, May–September, 1997.

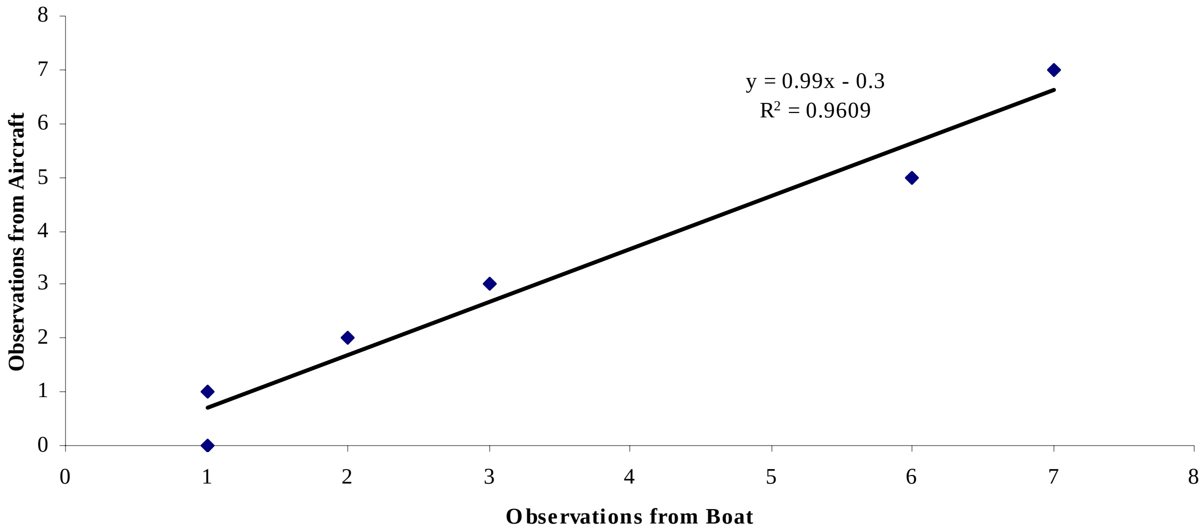


Fig. 16. Evaluation of the sightability of kayaks during aerial surveys in western Prince William Sound, Alaska, 1998.

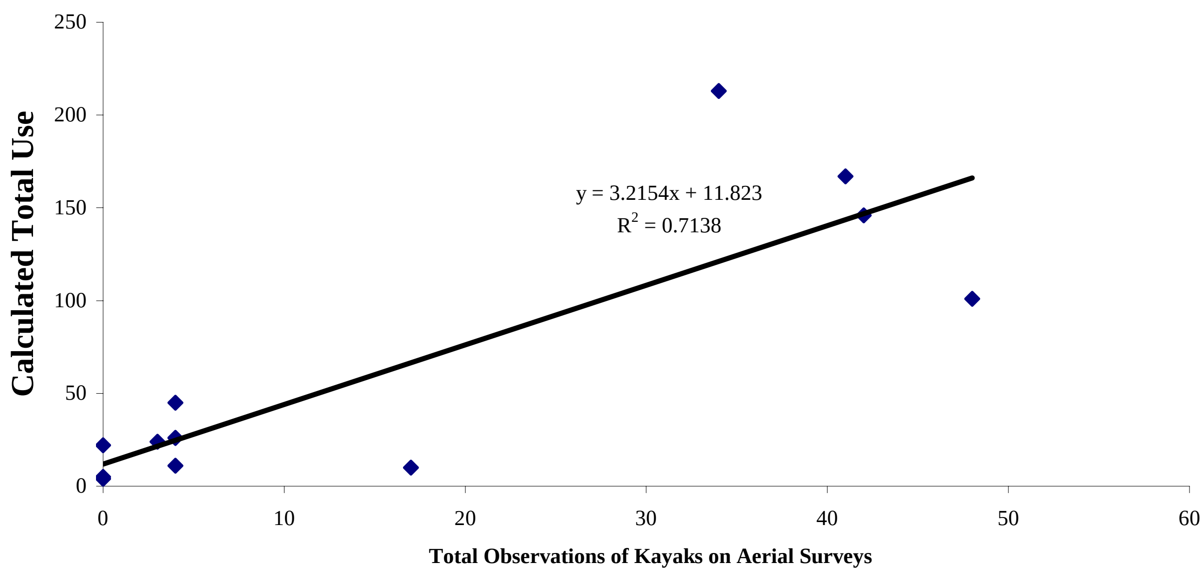


Fig. 17. Evaluation of the estimated density of kayaks during aerial surveys in western Prince William Sound, Alaska, June--September, 1998.

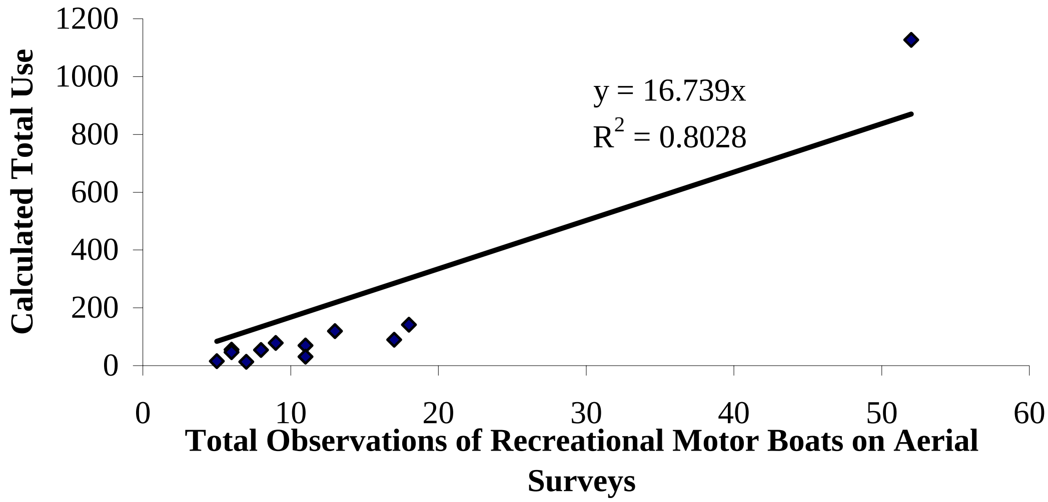


Fig. 18. Evaluation of the estimated density of recreational motor boats with aerial su western Prince William Sound, Alaska, 1998.

Resource Distribution

Locations were obtained for 36 harbor seal haulout sites, 131 pigeon guillemot nesting areas, and 6 watersheds having cutthroat trout populations (Table 11, Figs 19-21). To understand the relationship of population distributions of resources relative to estimated levels of human use, the mean level of human use by analysis area was compared to the population distribution. These data can be plotted to show the spatial relationship between human use in an area and the species concentrations (Figs. 22-24).

Literature Synthesis

Over 200 references were reviewed for disturbance effects on marine mammals and avian species. The literature varied widely on disturbance types and on disturbance response. We focused our review on the types of disturbance that could potentially occur in the western Sound and could potentially affect the recovery of species injured by the spill. We reviewed articles that documented disturbance on over 40 avian species and taxa. The types of disturbances and the identified consequences of disturbance for a variety of avian species were summarized (Table 12). To provide resource managers with a tool to understand how human activity may disturb bird populations throughout the year, the literature was summarized relative to disturbances to birds caused by people on foot, boats, and aircraft (Tables 13-15).

For marine mammals, we reviewed 74 articles that documented disturbance on over 22 species. The types of disturbances and the identified consequences of disturbance for a variety of marine mammal species were summarized (Table 16). To provide insight on how human activity may disturb marine mammal populations throughout the year, the literature was summarized relative to disturbances to these species caused by people on foot, boats and aircraft (Tables 17-19).

These tables are provided to managers as a quick reference to some of the available literature on disturbance effects to birds and marine mammals. Resource managers should recognize that these tables provide a starting point for a more in-depth analysis of the situation and species that they are managing. Although we focused on species or taxa, or on forms of

Table 11. Size and location of populations of harbor seals, pigeon guillemots, and watershed with cutthroat trout.

Analysis area	Number of pigeon guillemot nesting colonies by size class[1]			Number of harbor seal haul out sites by size class[2]										Number of watersheds with cutthroat trout populations	Percentage of human use
	1	2	3	1	2	3	4	5	6	7	8	9	10		
Bainbridge Passage	2	2			1										1
Barry Arm	1								1						3
Bettles Bay															5
Blackstone Bay	2	2	3												4
Chenega Island		1				1									2
Cochrane Bay Lower	1	1													0
College Fiord	1	1								1					2
College Fiord Lower															3
Columbia Bay													1		2
Culross East															3
Culross Passage															9
Dangerous Passage			1	1										1	0
Dutch Group	3	1		1				1							2
Eaglek Bay															1
Eshamy														1	4
Esther Passage														1	3
Esther South															8
Esther West															2

Table 11. Size and location of populations of harbor seals, pigeon guillemots, and watershed with cutthroat trout.

Analysis area	Number of pigeon guillemot nesting colonies by size class[1]			Number of harbor seal haul out sites by size class[2]										Number of watersheds with cutthroat trout populations	Percentage of human use
	1	2	3	1	2	3	4	5	6	7	8	9	10		
Evans Island	8	3	1		2	3	1								1
Glacier Island															2
Harriman Fiord	5	1	1												3
Icy Bay	3	1									1				0
Kings Bay															0
Knight East	1					1								2	0
Knight North	2			3											0
Knight South		1													0
Knight West				1	3										1
Naked East	6	1	1			1									0
Naked West	5	4	1												0
Nellie Juan				1											1
Passage Canal		1	1												17
Perry North	1														1
Perry South		1													1
Pigot Bay															5
Port Bainbridge	7	2	2	1											0
Storey	4	9	2	1											0

Table 11. Size and location of populations of harbor seals, pigeon guillemots, and watershed with cutthroat trout.

Analysis area	Number of pigeon guillemot nesting colonies by size class[1]			Number of harbor seal haul out sites by size class[2]										Number of watersheds with cutthroat trout populations	Percentage of human use
	1	2	3	1	2	3	4	5	6	7	8	9	10		
Surprise Cove															10
Unakwik				1					1					1	1
Wells Bay				1			1								1
Whale Bay	1														0
Open Water	11	11	1	2		2									
Total	64	43	14	13	6	8	2	1	2	1	1	0	1	6	100

[1]Size classes: 1 = 1-10; 2 = 11-20; 3 = >20.
[2]Size classes: 1 = 1-10; 2 = 11-25; 3 = 26-50; 4 = 51-100; 5 = 101-150; 6 = 151-200; 7 = 201-300; 8 = 301-500; 9 = 501-700; 10 = 701 - 1000.

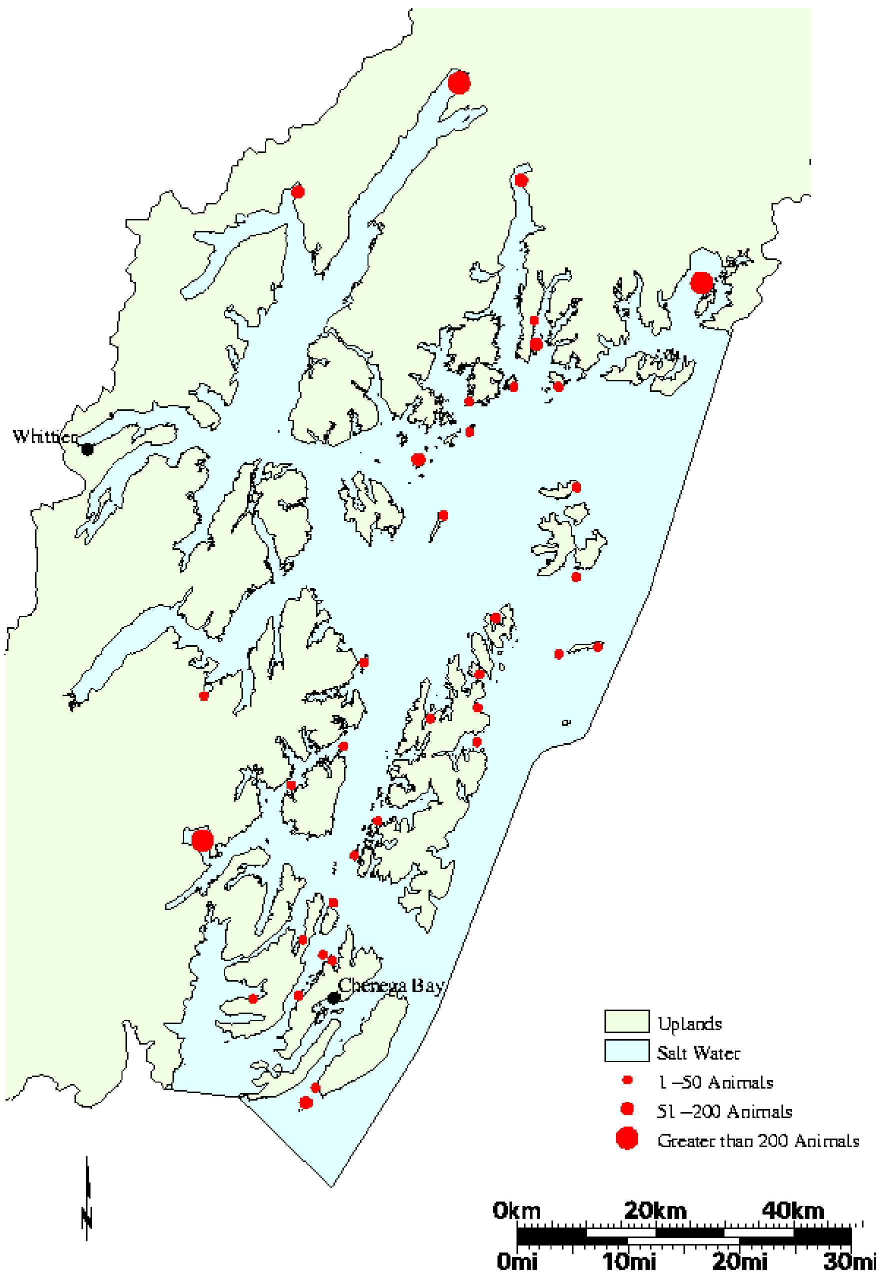


Fig. 19. Location of harbor seal haul out sites in western Prince William Sound, Alaska.

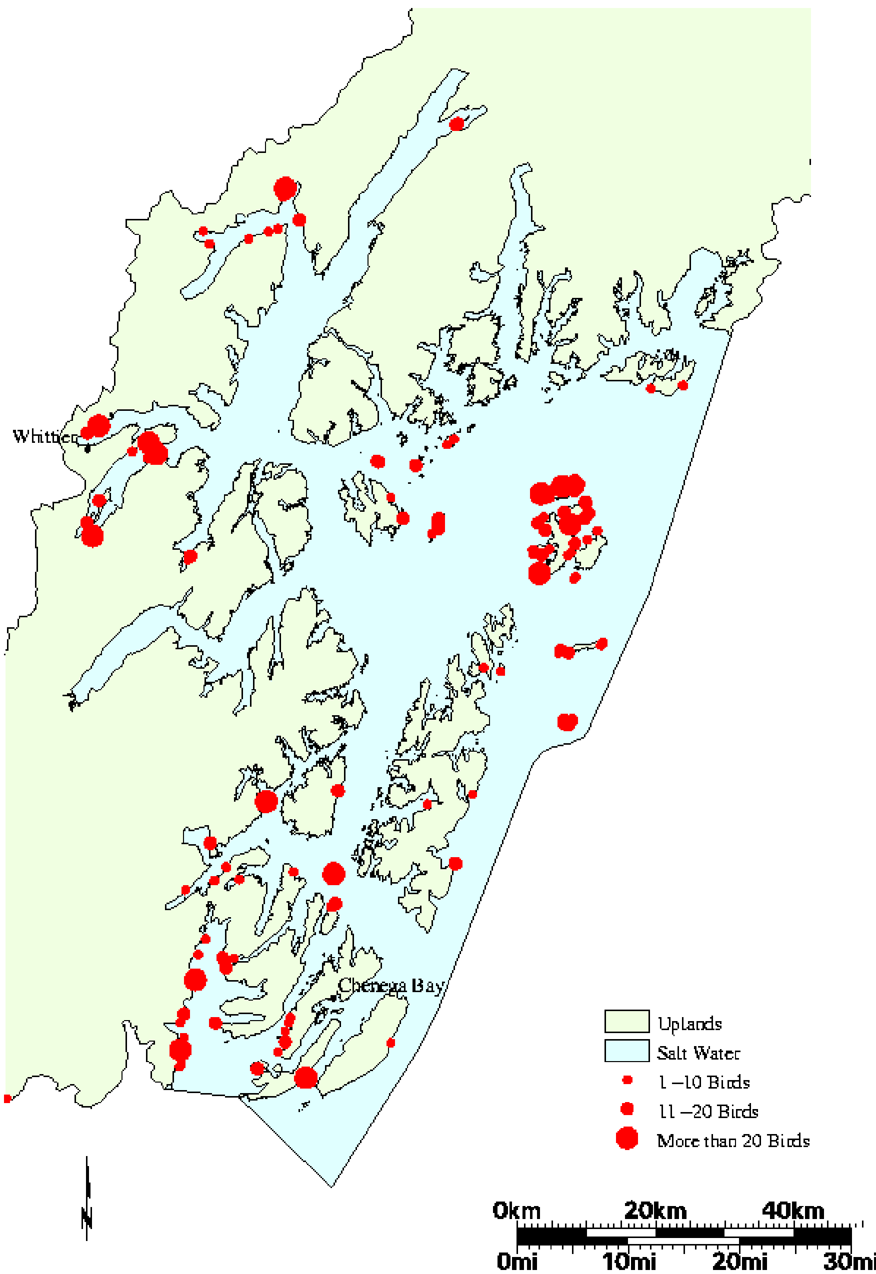


Fig. 20. Location of pigeon guillemot nesting areas in western Prince William Sound, Alaska.

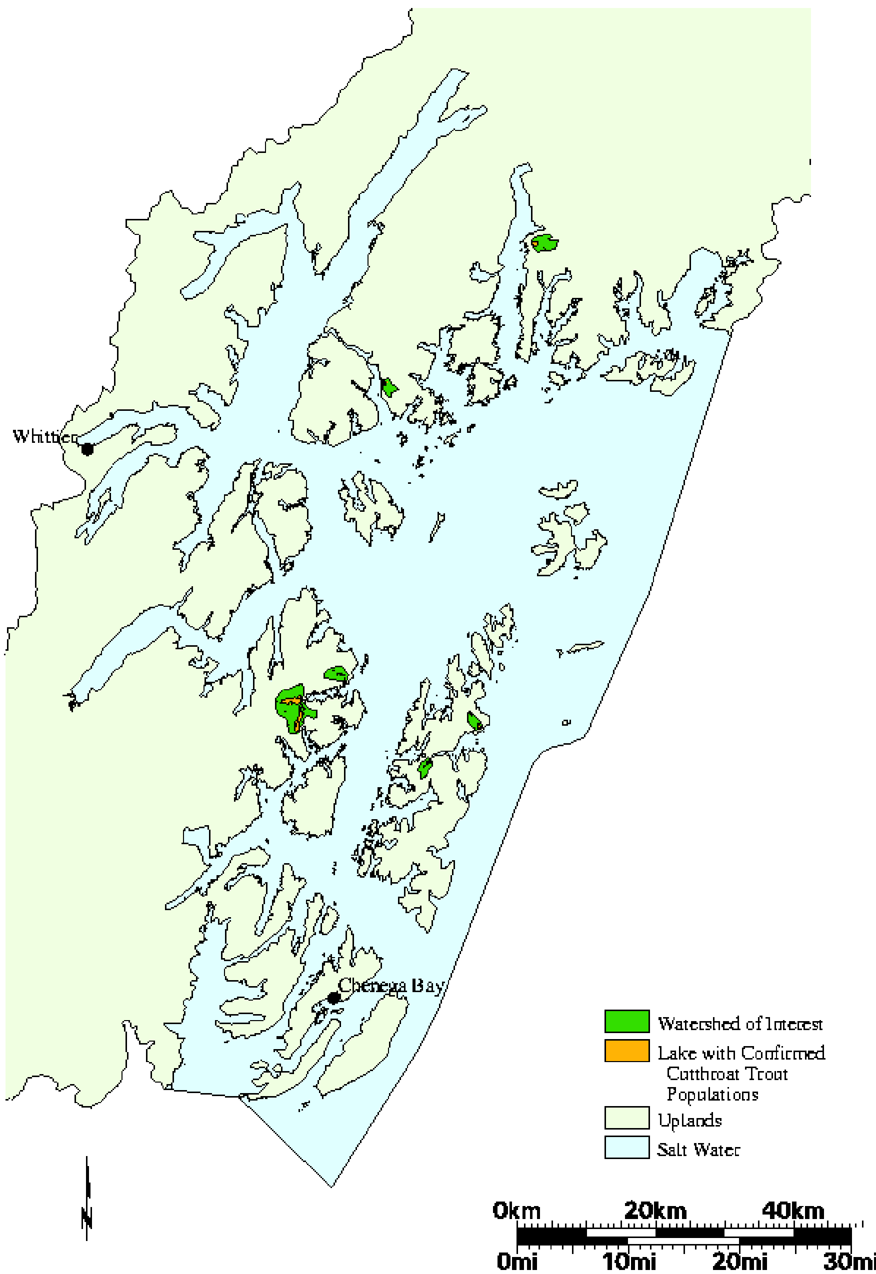


Fig. 21. Location of aquatic habitat with cutthroat trout in western Prince William Sound, Alaska.

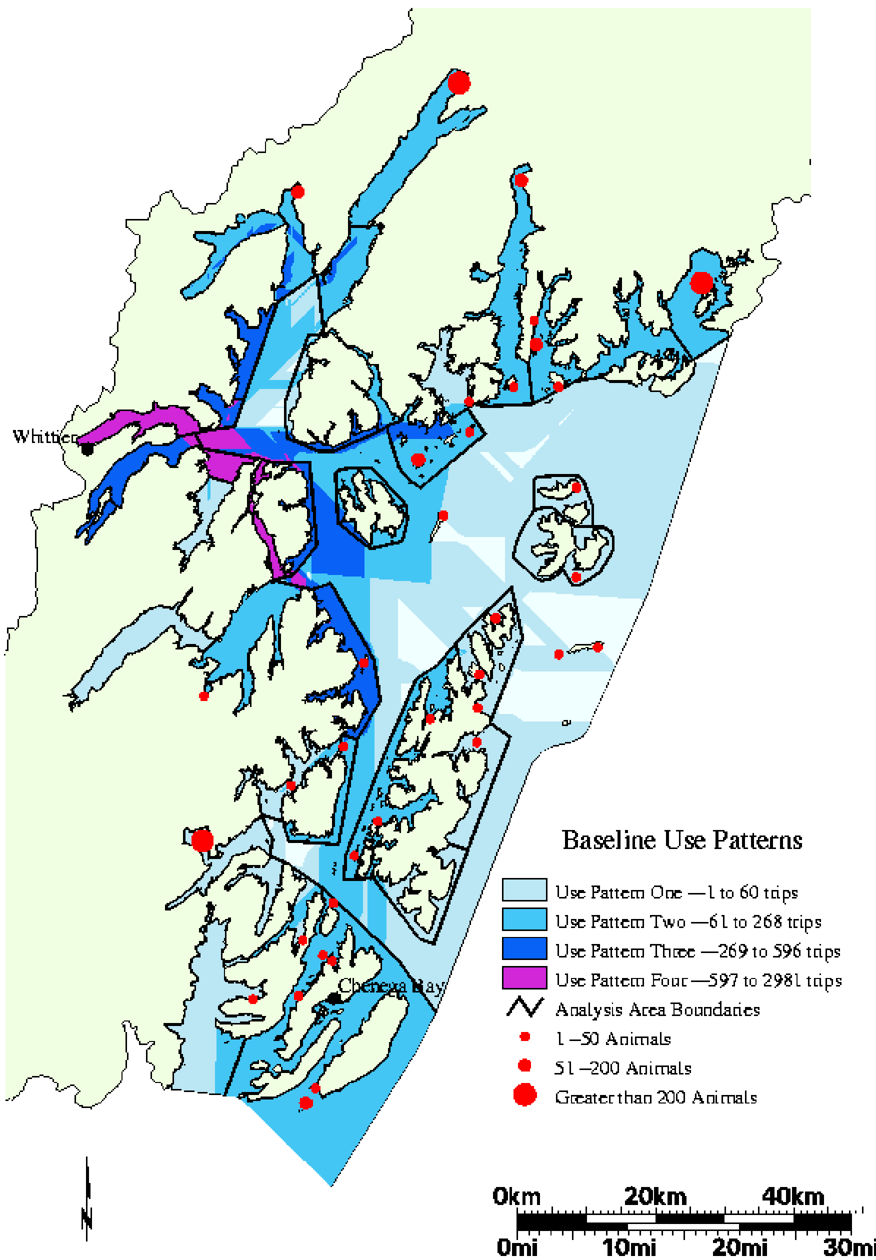


Fig. 22. Relationship of human use patterns and harbor seal haul out sites in western Prince William Sound, Alaska, during August.

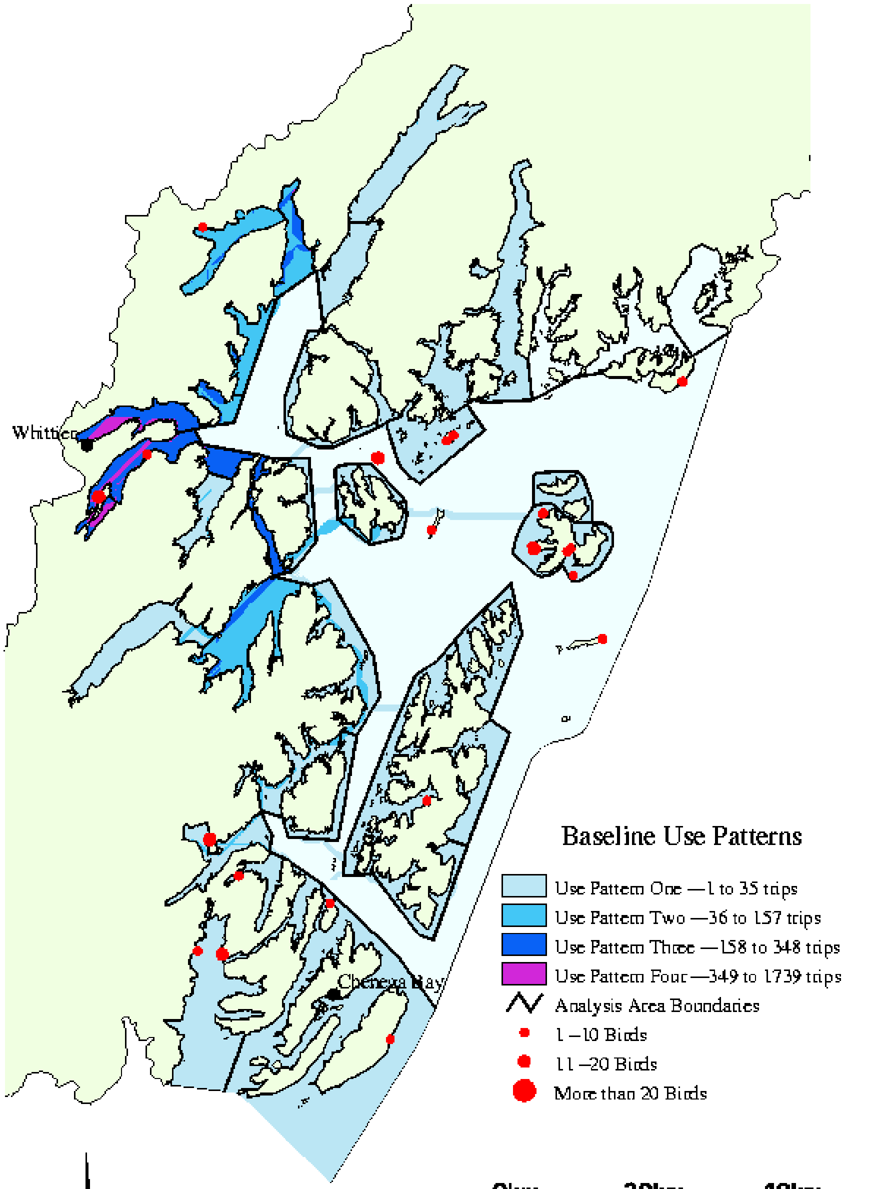


Fig. 23. Relationship of human use patterns and pigeon guillemot nesting areas in western Prince William Sound, Alaska, during June, July and August.

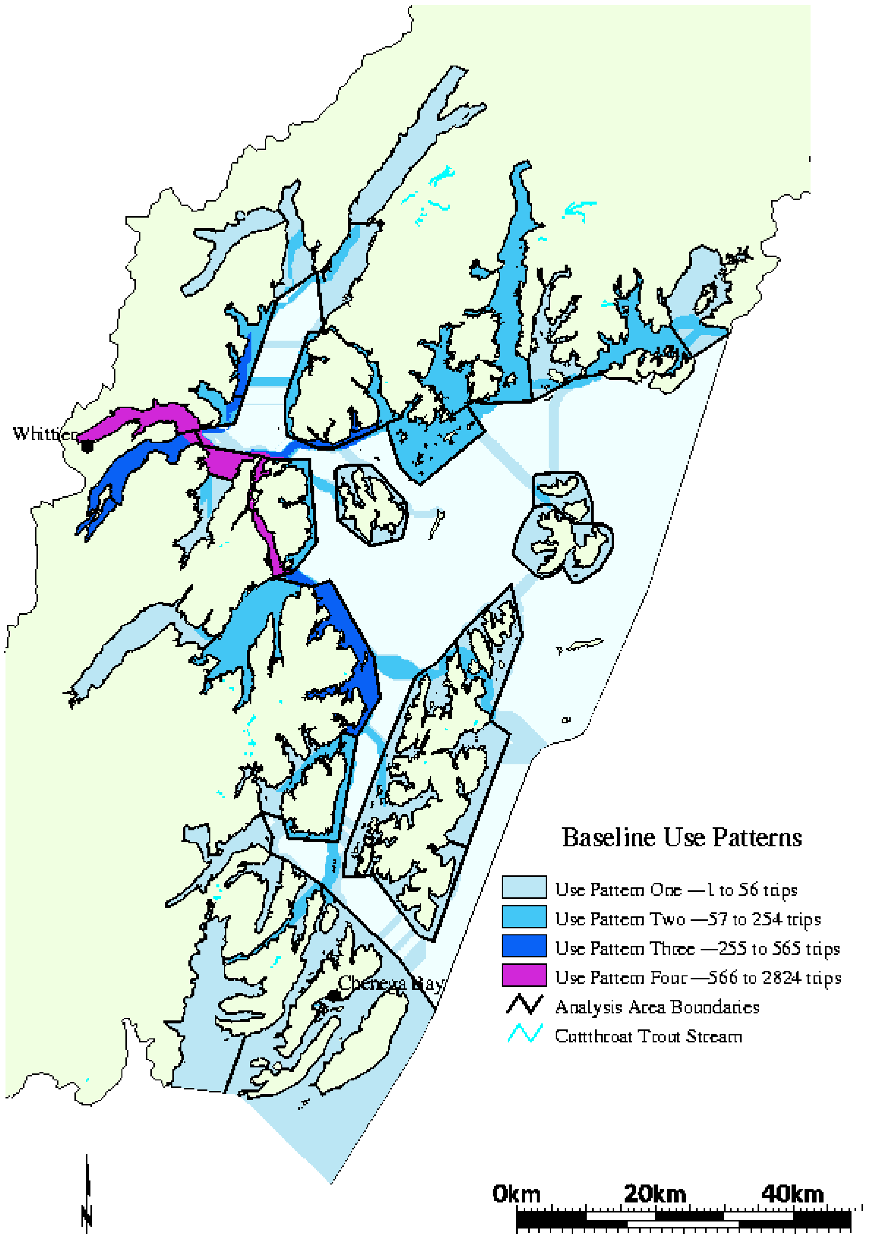


Fig. 24. Relationship of recreation motor boat user group patterns with cutthroat trout streams in western Prince William Sound, Alaska, during July and August.

Table 12. Types and effects of disturbance to avian species.

Source of disturbance	Documented effects of disturbance
Humans on foot	Egg damage; trampling of young
	Increased chick mortality
	Increased intraspecific aggression
	Increased predation
	Increased stress
	Interruption of feeding
	Nest abandonment
Watercraft	Delay in nesting
	Increased energy expenditure
	Increased stress
	Interruption of feeding
	Nest abandonment
Aircraft	Egg damage; trampling of young
	Increased energy expenditure
	Interruption of feeding
	Reduced nest attendance

disturbance that are relevant to the Sound, there are references from geographic areas and species that are different from those found in the Sound. Managers should use caution in directly relating the results of the studies cited in these tables to the effects of human disturbance in the Sound.

DISCUSSION

Natural resource management has become increasingly multi-jurisdictional and interdisciplinary over the last quarter century, and, as a result, is extremely complex. Diverse groups, representing a wide spectrum of interests are becoming increasingly involved in influencing State and Federal agencies' management of the natural lands and resources. For example, during the summer of 1999 the Kachemak Bay Coalition in Homer petitioned the State to regulate jet skis in portions of Kachemak Bay (Anchorage Daily News, 7/3/99). A group of

Table 13. Response of avian species to disturbance from humans on foot.

Species	Biological activity	Normal, birders, or research[1]	Disturbance response	Response distances	Consequences	Source
Auklet, crested	Reproduction	Research	High egg losses from abandonment and non-hatching correlated to intensive researcher activity	Not given	Reduced productivity from egg loss and non hatching	Piatt et al. 1990
Auklet, least	Reproduction	Research	High egg losses from abandonment and non-hatching correlated to intensive researcher activity	Not given	Reduced productivity from egg loss and non hatching	Piatt et al. 1990
Auklet, rhinoceros	Reproduction	Research	High disturbance reduced fledging success from 94 - 18 %, caused retarded chick development, nest abandonment and extended incubation (altered chronology)	Not given	Nest abandonment; reduced productivity, extended incubation	Manuwal 1978, Pierce and Simons 1986
Coot	Wintering	Normal (fly fishers)	Effects of fly fishermen. Anglers had no effect on distribution patterns	Not given	No effects	Cryer et al. 1987
Curlew	Foraging	Normal	Mean flight response was at 211 m people walking on tidal flats	211 m	Stress	Smit and Visser 1993

Table 13. Response of avian species to disturbance from humans on foot.

Species	Biological activity	Normal, birders, or research[1]	Disturbance response	Response distances	Consequences	Source
Duck, mallard	Wintering	Normal (fly fishers)	Effects of fly fishermen. Anglers did not change # of birds, but significantly changed distribution (temporal and spatial). Intensity of <1 vs. 3 anglers/area did not change response.	Not given	Changes in distribution patterns and feeding times.	Cryer et al. 1987
Duck, pochard	Wintering	Normal (fly fishers)	Effects of fly fishermen. Anglers did not change # of birds, but significantly changed distribution (temporal and spatial). Intensity of <1 vs. 3 anglers/area did not change response.	Not given	Changes in distribution patterns and feeding times.	Cryer et al. 1987
Duck, tufted	Wintering	Normal (fly fishers)	Effects of fly fishermen. Anglers had no effect on distribution patterns	Not given	No effects	Cryer et al. 1987
Duck, wigeon	Wintering	Normal (fly fishers)	Effects of fly fishermen. Anglers did not change # of birds, but significantly changed distribution (temporal and spatial). Intensity of <1 vs. 3 anglers/area did not change response.	Not given	Changes in distribution patterns and feeding times.	Cryer et al. 1987

Table 13. Response of avian species to disturbance from humans on foot.

Species	Biological activity	Normal, birders, or research[1]	Disturbance response	Response distances	Consequences	Source
Duck, wigeon	foraging	Normal	People walking on tidal flats causes birds to leave eel-grass foraging area		Stress; did not return until next tide if late in tidal cycle	Fox et al. 1993
Eider	Reproduction	Research	Greater human disturbance (#visits/ month) significantly decreased nesting success.	At nest site	Hypothesis = increased nest predation by gulls	Choate 1967
Eider	Reproduction	Normal	Eider creches on shore more sensitive than water (approx. 52 vs. 18 m respectively). Distances from people w/dogs were twice than without dogs. Increased predation & changed activity budgets	18 - 52 m	Mean number of predators approx. 4 times higher after disturbances; activity budgets changed may = stress	Keller 1991
Eider, common	Reproduction	Research	Examined predator response to research activity at eider nests. Hooded crow and magpie were repelled; great black-backed gull had slight increase and herring gull increased by 95% after disturbance but had no significant effect	At nest site	Egg and nest mortality not significantly changed by observers - probably due to covering nests. 43% of 7 uncovered nests were predated.	Gotmark and Ahlund 1984

Table 13. Response of avian species to disturbance from humans on foot.

Species	Biological activity	Normal, birders, or research[1]	Disturbance response	Response distances	Consequences	Source
Goose, brent	Wintering	Normal	Brent geese flushed from hunters at 500 m; but in non-hunting area allowed people to 150 m. Birds flew 33% of instances with people within 100 m in early winter but for only 12% of instances in late winter. Disturbance in quick succession increased flushing distances (1st = 200m; 2nd = 600m; 3rd = 800m in 20 min. span)	100 - 800 meters depending on hunting danger and freq. of disturbance	Increased energy expense; interruption of feeding	Owens 1977
goose, lesser snow	Staging/ migration	Birders / normal	Average seasonal disturbance of 0.5/hr would cause a 20.4% loss in energy reserves	Not given	Reduction in energy reserves	Davis and Wiseley 1974
Goose, snow	Staging/ migration	Birders / normal	Looked at all forms of disturbance. Disturbance rate of 0.5/hr approx. doubled flight time, 2.5/hr = 5-fold increase. Birds lost between 4 - 7.7 % of feeding time.	Not given	>2.0 disturb/hour may cause energy deficiency that can not be compensated for by night feeding or other mechanism.	Belanger and Bedard 1990
Guillemots, black	Reproduction	Research	Approach within 15 m daily vs. every 4th day significantly decreased hatching success but did not change fledging success	Within 15 m of nests within colony	Reduced productivity, nest abandonment, disrupted incubation, damage to eggs	Cairns 1980

Table 13. Response of avian species to disturbance from humans on foot.

Species	Biological activity	Normal, birders, or research[1]	Disturbance response	Response distances	Consequences	Source
Gull	Foraging/ roosting	Birders / normal	Generally returned to site after disturbances. Responses more severe for high speed & direct movement (joggers vs. birders)	Not given	Unknown - stress	Burger 1981a
Gull	Reproduction	Birders	6 yr study. birds closer to path when no people. Mean distances with and without disturbance were 90.4 vs. 29.3 m	90.4 m to 97.2 m	Changes in distribution patterns, reduced abundance	Burger et al. 1995
Gull	Reproduction	Normal	Found habitat shift in nesting birds under different disturbance regimes	Not given	Habitat shift could result in reduced productivity	Erwin 1980
Gull, black backed	Reproduction	Research	Aggression caused by disturbance varied with nesting stage. Lower during incubation than in hatching.	Within colony	Stress, reduced abundance	Burger 1981b
Gull, brown-hooded	Reproduction	Research	A single walk though undisturbed colony resulted in 2 of 30 chicks to disappear and 9 chicks in wrong nest. Increased brood size usually results in mortality.	Within colony	Stress, reduced productivity.	Burger 1981b

Table 13. Response of avian species to disturbance from humans on foot.

Species	Biological activity	Normal, birders, or research[1]	Disturbance response	Response distances	Consequences	Source
Gull, Franklin's	Reproduction	Research	A single walk though undisturbed colony resulted in 2 of 30 chicks to disappear and 9 chicks in wrong nest. Increased brood size usually results in mortality.	Within colony	Stress, reduced productivity.	Burger 1981b
Gull, glaucous-winged	Reproduction	Research	Walking through colony 2-3 times/day resulted in chick loss	Within colony	Chick mortality, reduced productivity	Gillett et al. 1975
Gull, Heermann's	Reproduction	Research / birders	Disturbance causes territorial displacement results in destruction of eggs and young by neighbors	Within colony	Chick mortality, egg loss to intraspecific aggression, trampling	Anderson and Keith 1980
Gull, herring	Reproduction	Research	Aggression caused by disturbance varied with nesting stage. Lower during incubation than in hatching. Aggression rates involving fights increased 75 % in Herring gulls after disturbance	Within colony	Stress, reduced abundance	Burger 1981b
Gull, herring	Reproduction	Research	Walking through colony 30 min/2 days gulls flew at 10-12 meters, undisturbed birds allowed approach to 5 meters suggesting some habituation.	5-12 m	Reduced productivity	Burger 1981b

Table 13. Response of avian species to disturbance from humans on foot.

Species	Biological activity	Normal, birders, or research[1]	Disturbance response	Response distances	Consequences	Source
Gull, herring	Reproduction	Research	Chicks handled daily moved further from nests than those handled less frequently.	Within colony	Chick loss, reduced productivity, increased intraspecific aggression	Burger 1981b
Gull, herring	Reproduction	Research	Males incubated more often after disturbance than expected.	Within colony	Disrupted incubation	Burger 1981b
Gull, western	Reproduction	Research	Different frequencies of walking in colony from 3/day to 1/wk and control. Egg loss and young chick mortality directly proportional to disturbance. Older chicks showed signs of habituation to frequent disturbance and more mortality found on less disturbed plots	Separation of 30 m between plots seemed sufficient to have no overlap	Reduced productivity, egg loss and chick mortality, some signs of older chicks habituating to disturbances	Robert and Ralph 1975
Gulls	Reproduction	Normal	Birds flushed at mean distances between 15 - 25 m. Recommends set-back distance of standard deviation + 40 m. Direct approach on foot - document all dist. response.	Recommend 180 m for gulls	Stress	Rodgers and Smith 1995
Heron	Reproduction	Birders	Daily visits to 50 meters = no effect; 1 visit into colony = 15 - 28 % mortality of 3 wk old chicks found 2 days later	50 m	None to chick mortality and reduced productivity	Burger et al. 1995

Table 13. Response of avian species to disturbance from humans on foot.

Species	Biological activity	Normal, birders, or research[1]	Disturbance response	Response distances	Consequences	Source
Heron, great blue	Reproduction	Normal	Some portion of birds flew from people in 68% of experimental disturbances. All birds flew from rookery in 8.5% of disturbances - more flight response during pre-laying period (mean distance = 152 m; later = 72 m).	Recommend 250 m buffer (max. disturb. distance + 50 m)	Disrupted incubation	Vos et al. 1985
Many species	Reproduction	All	Summary of human dist. and predation increase; 30 articles on introduced predators, 14 on increase in *Larus* sp.	Not given	Increased predation causing reduced productivity.	Burger and Gochfeld 1994
Murre, thick-billed	Reproduction	Normal	Firecrackers set off near colony caused nest abandonment and egg loss	Not given	Nest abandonment; reduced productivity	Curry 1995
Oystercatcher, black	Reproduction	Normal / research	Summarizes other research showing human dist. causing increase predation; reduced productivity	Not given	Reduced productivity	Warheit et al. 1984

Table 13. Response of avian species to disturbance from humans on foot.

Species	Biological activity	Normal, birders, or research[1]	Disturbance response	Response distances	Consequences	Source
Oystercatcher, European	Roosting	Normal	Documents increased disturbance 1986-94 speculates that this increase is responsible for decreased preference for site. 1.05 dist/hr compared to 0.33 in AK	Not given	Changes in distribution patterns, reduced abundance	Burton et al. 1996
Oystercatcher, European	foraging	Normal	Continued feeding if >75m; foraging time reduced by avg. of 20-25%. Despite inc. dist. Pop has increased	75 m	Stress; juvenile overall intake rate reduced by 65-75%	Goss-Custard and Verbovan 1993
Oystercatcher, European	Wintering	Normal	Increased disturbance caused increased density. Increased density increases interference, reducing intake rate by subordinates as much as 45%.	Not given	Interruption of feeding, reduced intake rates, increased intraspecific competition, changes in distribution	Goss-Custard and Durell 1990
Oystercatcher, European	Roosting	Normal	6 yr study; increases in disturb. from variety sources. Dogs (27-72% and walkers (20-34%) caused most disturb. in all yrs. Education successful in reduced disturbance		Stress, reduced abundance	Kirby et al. 1993
Oystercatcher, European	Foraging	Normal	Mean flight response was at 85 m people on tidal flats	85 m	Stress	Smit and Visser 1993

Table 13. Response of avian species to disturbance from humans on foot.

Species	Biological activity	Normal, birders, or research[1]	Disturbance response	Response distances	Consequences	Source
Oystercatcher, European	Reproduction	Normal	New access to area changed recreation intensity from 7.8 people/ha to 37.0 people/ha. Sign. neg. effect on 12 spp. Oystercatcher # reduced but not significant	Not given	Individual species response not significant but combined species response sign. that increased intensity reduced bird density	van der Zande and Vos 1984
Passerine	Reproduction	Research	Compared flushing distances for 17 spp in rural and suburban areas. 7 of 10 spp (with >10 obs) were sign. shorter distances in suburbs. Smaller birds more approachable	4.8-20 m in rural areas and 5.2-16 m in suburbs	None described - potential evidence of some habituation	Cooke 1980
Passerines	Reproduction	Normal	Experimental test of cumulative effects of solitary hikers over 5 yrs. No effect on abundance but species richness declined during 1st year followed by gradual recovery in later years	Variable	Community-wide displacement of some spp during 1st year followed by gradual recovery	Riffel et al. 1996
Pelican, brown	Reproduction	Research / birders	Nest abandonment and chick loss (<3 wks old) sign. increased with disturbance. Loss from predation, trampling.	Within colony	Chick mortality, nest abandonment	Anderson and Keith 1980

Table 13. Response of avian species to disturbance from humans on foot.

Species	Biological activity	Normal, birders, or research[1]	Disturbance response	Response distances	Consequences	Source
Pelican, brown	Reproduction	Birders	Locals walking on trails to view colony once every 1-2 wks caused nest abandonment within 600 m of trail	600 m	Nest abandonment and reduced productivity	Anderson 1988
Pelican, white	Reproduction	Birders	Pre-laying = reduced clutch size, early in incubation = dramatic egg loss; late in incubation = decreased # fledged young. Extremely sensitive to disturbance	Within colony	Reduced productivity	Bunnell et al. 1981
Petrel, fork-tailed storm	Reproduction	Research	High disturbance reduced fledging success from 94 - 18 %, caused retarded chick development, nest abandonment and extended incubation (altered chronology)	Not given	Nest abandonment; reduced productivity, extended incubation	Manuwal 1978, Pierce and Simons 1986
Plover, golden	Reproduction	Normal	Plovers react to disturb. within 200 m of chicks. Pre-laying birds flushed; time incubating decreased by 4 % (much worse when dogs were present), over 1/2 flushed at <10 m; Post hatching birds flushed and alarm called at 200 m	200 m	Reduced productivity, chicks lost foraging and brooding time	Yalden and Yalden 1990

Table 13. Response of avian species to disturbance from humans on foot.

Species	Biological activity	Normal, birders, or research[1]	Disturbance response	Response distances	Consequences	Source
Plover, Kentish	Reproduction	Normal	Significant difference showing clutch loss increasing with increased disturbance intensity. Veg cover loss also = more clutch loss. Losses from increase predation (avian & dogs)	Not given	Reduced productivity	Schulz and Stock 1993
Plover, piping	Reproduction	Normal	1.8 young/pair in low disturbance versus 0.5 young/pair in high disturb. Adults flushed avg. 40 m (some at 210m) chicks began reacting at 160 m. People caused more reactions than did predators	40 m (adults) 160 m (chicks)	Significant decrease in feeding & brooding for chicks in high disturbance area. Chick loss especially between 10 and 17 days old	Flemming et al. 1988
Puffin, tufted	Reproduction	Research	High disturbance reduced fledging success from 94 - 18 %, caused retarded chick development, nest abandonment and extended incubation (altered chronology)	Not given	Nest abandonment; reduced productivity, extended incubation	Manuwal 1978, Pierce and Simons 1986
Shearwater, short-tailed	Reproduction	Research	Sensitivity to disturbance by researchers highest during incubation, less to no effect at post hatching. {study not designed to investigate disturbance}		Nest abandonment, reduced breeding productivity	Serventy and Curry 1984

Table 13. Response of avian species to disturbance from humans on foot.

Species	Biological activity	Normal, birders, or research[1]	Disturbance response	Response distances	Consequences	Source
Shorebird	Reproduction	Birders	6 yr study. birds closer to path when no people. Mean distances with and without disturbance were 97.2 vs 33.6	90.4 m to 97.2 m	Changes in distribution patterns, reduced abundance	Burger et al. 1995
Shorebird	Roosting	Normal	Documents increased disturbance 1986-94 speculates that this increase is responsible for decreased preference for site	Not given	Changes in distribution patterns, reduced abundance	Burton et al. 1996
Shorebirds	Foraging/ roosting	Birders / normal	Generally flew to new site and did not return	Not given	Changes in distribution patterns, reduced abundance	Burger 1981a
Shorebirds	Migration	Normal	Children and joggers caused most flight responses. % of birds that flew was inversely related to flock size. Almost 1/2 leave completely	Not given	Changes in distribution patterns, reduced abundance	Burger 1986
Skimmer	Foraging/ roosting	Birders / normal	Generally returned to site after disturbances. Responses more severe for high speed & direct movement (joggers vs birders)	Not given	Unknown - stress	Burger 1981a
Skimmer	Reproduction	Normal	Found habitat shift in nesting birds under different disturbance regimes	Not given	Habitat shift could result in reduced productivity	Erwin 1980

Table 13. Response of avian species to disturbance from humans on foot.

Species	Biological activity	Normal, birders, or research[1]	Disturbance response	Response distances	Consequences	Source
Skimmer	Reproduction	Normal	Skimmers flushed at mean distances of 60 m. Recommends set-back distance of standard deviation + 40 m. Direct approach on foot - document all dist. response.	Recommend 100 m for wading colonies	Stress	Rodgers and Smith 1995
Skimmer, black	Reproduction	Research	Males incubated more often after disturbance than expected.	Within colony	Disrupted incubation	Burger 1981b
Skimmer, black	Reproduction	Research	Determined chick response to observer presence/handling. Chicks most likely to run when handled and when weather is cooler. Skimmers more sensitive.	Direct or close contact	Potential chick mortality from predation, displacement, inclement weather	Gochfeld 1981
Tern	Foraging/ roosting	Birders / normal	Generally returned to site after disturbances. Responses more severe for high speed & direct movement (joggers vs birders)	Not given	Unknown - stress	Burger 1981a
Tern	Reproduction	Normal	Found habitat shift in nesting birds under different disturbance regimes	Not given	Habitat shift could result in reduced productivity	Erwin 1980

Table 13. Response of avian species to disturbance from humans on foot.

Species	Biological activity	Normal, birders, or research[1]	Disturbance response	Response distances	Consequences	Source
Tern	Reproduction	Normal	Terns flushed at mean distance of 60 m. Recommends set-back distance of standard deviation + 40 m. Direct approach on foot - document all dist. response.	Recommend 180 m for terns	Stress	Rodgers and Smith 1995
Tern, common	Reproduction	Normal	Recommend buffer of 175-200 m from nest to eliminate disturbance	175-200 m	Reduced productivity, stress	Erwin 1989, Rogers and Smith 1991
Tern, common	Reproduction	Research	Determined chick response to observer presence/handling. Chicks most likely to run when handled and when weather is cooler. Skimmers more sensitive.	Direct or close contact	Potential chick mortality from predation, displacement, inclement weather	Gochfeld 1981
Variety	All	Birders	Literature summary - 21 articles on impacts from observation/ photography activities. 2 showed no effect; 19 had negative effects	Not given	All forms	Boyle and Samson 1985
Variety	All	Normal	Literature summary - 27articles on impacts from hiking and camping activities. 6 showed no effect; 17 had negative effects and 4 had positive effects	Not given	All forms	Boyle and Samson 1985

Table 13. Response of avian species to disturbance from humans on foot.

Species	Biological activity	Normal, birders, or research[1]	Disturbance response	Response distances	Consequences	Source
Waders (general)	Roosting	Normal	6 yr study; increases in disturb. from variety sources. Dogs (27-72% and walkers (20-34%) caused most disturb. in all yrs. Education successful in reduced disturbance		Stress, reduced abundance	Kirby et al. 1993
Waders (general)	Foraging/ roosting	Normal	People with dogs most serious. When disturb. level increased site use changed from 50% to 11% with 4 of 7 spp moving. Red knot and short-billed dowitcher most severe.	Not given	Changes in distribution patterns, reduced abundance	Pfister et al. 1992
Waders (general)	Foraging	Normal	Plovers, godwit, dunlin and turnstones mean response to people on tidal flats range 124 m for grey plovers to 47 m for turnstones	47 - 124 m	Stress	Smit and Visser 1993
Waterfowl	Foraging/ roosting	Birders / normal	Landed nearby after disturbance but delayed return	Not given	Unknown - stress	Burger 1981a

[1]Normal indicates activity not directly associated with the birds of interest; birder indicates activity associated with viewing birds; research indicates activity associated with scientific study.

Table 14. Response of avian species to disturbance from water vessels.

Species	Biological activity	Motorboats or canoes /kayaks	Disturbance response	Response distances	Consequences	Source	Notes
Coot	Foraging/ breeding	Sailing dinghies	Coots took little notice of boats until they approached closely.	50 m	Interrupt feeding; potentially reduce feeding chick	Batten 1977	May suggest similar changes to boat visits
Cormorant	Reproduction	Motorboats	Approximately. 6 recreational boats/day began visiting island in San Juan chain when all birds abandoned their nests	Not given	Nest site abandonment	Henny et al. 1989	
Duck, canvasback	Migration	Motorboats	83-98% of all spring disturbance from sport fishing boats; 33% in fall. Hunting caused 64-67% of disturbance in fall. Boating caused flights every 1.1/hour or 13-14 times/day. Avg. flight from disturbance 11-31 min/day with energetic cost of 14-42 kcal/flight	Not given	Increased energy expense; changes in distribution, interruption of feeding	Kahl 1991	
Duck, canvasback	Staging	Motorboats	Sport fishers caused 41.8% of disturbances; hunters and researchers caused the rest. Avg. of 17.2 boats/day = 5.2 dist/day to flocks. Disturbance caused approx. 1 hr/day extra flying which requires extra 75 kcal/day for maintenance	Up to 1 km	Increased energy expense; interruption of feeding	Korschgen et al. 1985	

Table 14. Response of avian species to disturbance from water vessels.

Species	Biological activity	Motorboats or canoes /kayaks	Disturbance response	Response distances	Consequences	Source	Notes
Duck, diving	Staging/ wintering	Motorboats & barges	Boating activity for sport and commercial fishing caused most disturbance on Miss. river, hunting was next most disturbing and barges were the least. Birds were more sensitive during hunting season.	Rafting birds 450 m	Changes in distribution, interruption of feeding	Havera et al. 1992	
Duck, mallard	Wintering	Sailboats	In evaluating effects of fly-fishermen. Two days were open to sailing on the reservoirs. Sailing interrupted feeding of all species	Not given	Interruption of feeding, changes in distribution	Cryer et al. 1987	Rec. distance based on distance of any disturbance response
Duck, pochard	Wintering	Sailing dinghies	Larger flocks flew at greater distances. Pochards flew at 275 m (100 birds/flock) and at 450 m (300/flock).	Small flocks at 230 - 275 m; large flocks at 350-450 m.	Interrupt feeding - stress	Batten 1977	Unpredictable movement was worse than kayaks
Duck, pochard	Wintering	Sailboats	In evaluating effects of fly-fishermen. Two days were open to sailing on the reservoirs. Sailing interrupted feeding of all species - Pochards were most sensitive	Not given	Interruption of feeding, changes in distribution	Cryer et al. 1987	Rec. distance based on distance of any disturbance response

Table 14. Response of avian species to disturbance from water vessels.

Species	Biological activity	Motorboats or canoes /kayaks	Disturbance response	Response distances	Consequences	Source	Notes
Duck, tufted	Wintering	Sailing dinghies	Larger flocks flew at greater distances. Tufted duck flew at 275 m (100 birds/flock) and at 450 m (300/flock).	small flocks at 230 - 275 m; large flocks at 350-450 m.	Interrupt feeding - stress	Batten 1977	Unpredictable movement was worse than kayaks
Duck, wigeon	Wintering	Sailboats	In evaluating effects of fly-fishermen. Two days were open to sailing on the reservoirs. Sailing interrupted feeding of all species	Not given	Interruption of feeding, changes in distribution	Cryer et al. 1987	Rec. distance based on distance of any disturbance response
Eagle, bald	Reproduction	All	Evaluated the effects of a new road on bald eagle nesting activity. Significant decline in active nests within 4 km of access areas.	Not given	Changes in nesting distribution - no overall affect on population size	Gerrard et al. 1983	
Eagle, bald	Wintering	Canoe	Compared flushing distance on river with a lot of boating activity to one with little activity. Eagles perched flushed less often on high use river (mean = 168 m). Eagles in groups and on ground flew at greater distances than solitary birds.	450 m buffer from eagles on ground would protect 99% of birds from disturbance	Increased energy expense; interruption of feeding	Knight 1984	

Table 14. Response of avian species to disturbance from water vessels.

Species	Biological activity	Motorboats or canoes /kayaks	Disturbance response	Response distances	Consequences	Source	Notes
Eider	Reproduction	Motorboats	Documented mean rate of gull encounters on chicks at least 200 times undisturbed creches. 1 in 10 boat disturbances resulted in successful gull attack	2-200 m	Increased chick mortality from 8 - 18%, from increased predation	Ahlund and Gotmark 1989	
Eider	Reproduction	Rowboats	Eider creches showed little disturbance response to rowboats		None	Keller 1991	
Goose, brent	Wintering	Motorboats	Large boats & yachts rarely caused disturbance, but noisy outboard engines on smaller boats made the birds fly. Flight response to disturbance decreased through winter.	Not given	Increased energy expense; interruption of feeding	Owens 1977	
Grebe, great-crested	Reproduction	Rowboats/ canoes	Examined flushing distances on 3 lakes with different disturbance levels and activities. Lowest disturbance: flush at 50-100 m covered eggs 93% of times; Middle disturbance: flush at 0-20 m covered eggs 48%; Highest: flush at 0-10 m, covered eggs 16%	0 - 100 m from rowboat depending on disturbance exposure	Increased predation resulting in clutch loss	Keller 1989	

Table 14. Response of avian species to disturbance from water vessels.

Species	Biological activity	Motorboats or canoes /kayaks	Disturbance response	Response distances	Consequences	Source	Notes
Grebe, great-crested	Foraging/ breeding	Sailing dinghies	Grebes: singles and pairs tend to dive, small flocks flew at 100 m	100 m	Interrupt feeding; potentially reduce feeding chick	Batten 1977	May suggest similar changes to boat visits
Grebe, little	Foraging/ breeding	Sailing dinghies	Grebes: singles and pairs tend to dive, small flocks flew at 100 m	100 m	Interrupt feeding; potentially reduce feeding chick	Batten 1977	May suggest similar changes to boat visits
Gull	Reproduction	Canoe and motorboats	Birds flushed at mean distances between 10 - 45 m with cormorants highest. Recommends set-back distances of standard deviation + 40 meters	Recommend 100 m for wading colonies and 180 for terns/gulls	Stress	Rodgers and Smith 1995	
Heron	Reproduction	Motorboats	4 colonies visited weekly to within 100 m showed no effects	100 m	None	Burger et al. 1995	If boating occurs when chicks are older = less problem
Heron, great blue	Reproduction	Motorboats	Experimental test of disturbance. Rookery tolerant to small motorboats. Only 8% of boat dist caused birds to fly and mostly when directly beneath rookery	Recommend 150 m (max. disturb distance + 50 m)	High tolerance to boat-based disturbance	Vos et al. 1985	

Table 14. Response of avian species to disturbance from water vessels.

Species	Biological activity	Motorboats or canoes /kayaks	Disturbance response	Response distances	Consequences	Source	Notes
Loon, common	Reproduction	Motorboats	Examined species composition relative to boat use & shoreline development. Loons and Eastern kingbirds had reduced nesting success in disturbed areas	Not given	Reduced productivity	Robertson and Flood 1980	
Loon, common	Reproduction	Canoes	Behavioral differences found on lakes with canoe use versus control. Displays and flushing distances were significantly closer in canoe use areas than controls. {low sample sizes}	Mean flushing distance = 8.5 m in dist vs 112.6 m in control area	Showed signs of habituation.	Smith 1981	
Loon, common	Reproduction	Motorboats	Intense motorboat activity in early May delayed nest initiation.	Flushing dist = 11.2 m	Delayed nesting	Titus and VanDruff 1981	
Loon, common	Reproduction	Canoes	High use areas compared to low use lakes. No sig. difference in hatching success but sig. more juveniles lived to 2 wks old in low use areas	Mean = 27.8 m (closer in high use areas than low use areas)	Reduced productivity	Titus and VanDruff 1981	
Murrelet	Feeding	Motorboats	For boats 19-44 feet in length, murrelets dove when boats were within 59 m (behind birds)	59 m	Interrupt feeding; potentially reduce feeding chick	Thompson et al. 1998	

Table 14. Response of avian species to disturbance from water vessels.

Species	Biological activity	Motorboats or canoes /kayaks	Disturbance response	Response distances	Consequences	Source	Notes
Murrelet, marbled	Foraging/ breeding	Motorboats	Boats < 200 m counted with birds. # birds neg. correlated to # boats. No birds found when 5 + boats/day on transect	200 m	Changes in distribution patterns	Kuletz 1996	
Oystercatcher, Black	Reproduction	Cars	14 yrs of nest/fledging data, sharp decline in both loosely tied to 4x4 vehicle sales in area	None	Reduced productivity	Jeffrey 1987	
Oystercatcher, European	Roosting	Boats	Documents increased disturbance 1986-94 speculates that this increase is responsible for decreased preference for site. All disturbance = 1.05/hr compared to 0.33 in AK sites	Not given	Changes in distribution patterns, reduced abundance	Burton et al. 1996	
Oystercatcher, European	Roosting	Kayaks and windsurfers	Birds left area when approached at 50 m for kayaks and 175 m from windsurfers	50 - 175 m	Birds left area	Koepff and Dietrich 1986 in Smit and Visser 1993	
Shorebird	Roosting	Boats	Increased disturbance 1986-94 speculates that this increase is responsible for decreased preference for site - caused consistent departures.	Not given	Changes in distribution patterns, reduced abundance	Burton et al. 1996	Rowboats vs motorboats

Table 14. Response of avian species to disturbance from water vessels.

Species	Biological activity	Motorboats or canoes /kayaks	Disturbance response	Response distances	Consequences	Source	Notes
Tern	Reproduction	Canoe and motorboats	Birds flushed at mean distances between 10 - 45 m with cormorants highest. Recommends set-back distances of standard deviation + 40 meters	Recommend 100 m for wading colonies and 180 for terns/gulls	Stress	Rodgers and Smith 1995	
Tern	Reproduction	Motorboats	Restricted water borne disturbance increased breeding least terns from 0 to 162 pairs	Restricted landings	Reduced productivity	Hirons and Thomas 1993	
Wader	Roosting	All	Found kayaks + sailboats most disturbing because of closer approaches. Unpredictable movement of windsurfers very bad	Not given	Birds left area	Koepff and Dietrich 1986 in Smit and Visser 1993	
Wader	Wintering	Cars	Showed that threshold distances for 19 spp changed with number of car visits.	Varied from 0 to 100	Changes in distribution patterns	Klein et al. 1995	
Wader	Reproduction	Canoe and motorboats	Birds flushed at mean distances between 10 - 45 m with cormorants highest. Recommends set-back distances of standard deviation + 40 meters	Recommend 100 m for wading colonies and 180 for terns/gulls	Stress	Rodgers and Smith 1995	

Table 14. Response of avian species to disturbance from water vessels.

Species	Biological activity	Motorboats or canoes /kayaks	Disturbance response	Response distances	Consequences	Source	Notes
Waterfowl	Wintering	Cars	Showed that threshold distances for 19 spp changed with number of car visits.	Varied from 0 to 100	Changes in distribution patterns	Klein et al. 1995	
Waterfowl	Wintering	All	Found recreation intensity inversely correlated to bird abundance. All but one species moved from preferred areas. 4 spp. made little use of lakes when levels > 75 boat/people hours (8-10 boats on lake at once)	Not given	Increased energy expense; displacement from preferred feeding areas; interruption of feeding	Tuite et al. 1983	
Waterfowl	Wintering	All	Compared all lakes > 4 ha in England and Wales, physical traits, # birds and recreation types. Coarse fishing, sailing, rowing appeared to have largest negative effect	Not applicable	Displacement	Tuite et al. 1984	

Table 15. Response of avian species to disturbance from aircraft.

Species	Biological activity	Helicopter or fixed-wing	Disturbance response	Response distances	Consequences	Source
Cormorant	Reproduction	Helicopter	Compared helicopters to fixed wing. In 75% of 220 obs. 90% birds showed no reaction or simply looked up all birds returned within 5 minutes	120 m and 60 m	None	Kushlan 1979
Curlew	Foraging	Helicopter	Mean flight response was at 200 m	200 m	Stress	Smit and Visser 1993
Egret	Reproduction	Helicopter	Compared helicopters to fixed wing. In 75% of 220 obs. 90% birds showed no reaction or simply looked up all birds returned within 5 minutes	120 m and 60 m	None	Kushlan 1979
Goose, brant	Staging/ migration	Fixed-wing	Aircraft caused 22% of all interruption time. Flocks took flight to 26% of overflights. 50% of flocks flew when planes within 0.8 km. Planes ≤ 0.8 km and below 610 m were twice as likely to make flocks fly.	50% of flocks flew when planes ≤0.8 km and below 610 m	Increased energy expense; interrupted feeding	Ward et al. 1994
Goose, brant	Staging/ migration	Helicopter	Of all aircraft types; helicopters caused the longest interruption time. Helicopters, hunting and boating caused the greatest proportion of flocks to depart area.	Not given	Increased energy expense; interrupted feeding; displacement	Ward et al. 1994

Table 15. Response of avian species to disturbance from aircraft.

Species	Biological activity	Helicopter or fixed-wing	Disturbance response	Response distances	Consequences	Source
Goose, brant	Wintering	Fixed-wing	Any plane below 500 m and up to 1.5 km away would cause flight response. Slow, noisy aircraft were worst. Very slow to habituate, though eventually ignored jets.	< 500 m above flock and up to 1.5 km distance	Increased energy expense; interrupted feeding	Owens 1977
Goose, brant	Wintering	Helicopter	Of all aircraft types; helicopters caused most disturbance. Authors described as "widespread panic."	No specifics for helicopters but all planes < 500 m	Increased energy expense; interrupted feeding	Owens 1977
Gull, black backed	Reproduction	Jet	Supersonic airplanes (108 dB-A) caused increase flights and aggression than regular airplanes (88 dB-A) and no disturbance.	Noise level	Stress, reduced productivity from reduced nest attendance	Burger 1981b
Gull, herring	Reproduction	Jet	Supersonic airplanes (108 dB-A) caused increase flights and aggression than regular airplanes (88 dB-A) and no disturbance.	Noise level	Stress, reduced productivity from reduced nest attendance	Burger 1981b
Heron	Reproduction	Helicopter	Compared helicopters to fixed wing. In 75% of 220 obs. 90% birds showed no reaction or simply looked up all birds returned within 5 minutes	120 m and 60 m	None	Kushlan 1979

Table 15. Response of avian species to disturbance from aircraft.

Species	Biological activity	Helicopter or fixed-wing	Disturbance response	Response distances	Consequences	Source
Kittiwake	Reproduction	Helicopter	Varied by breeding status. Birds not actively brooding responded at 1.5 - 6 km distance while only 2.5% of departing birds were actively brooding. No habituation after 10 flights.	Recommended 2 - 3 km buffer (3 km to reduce mass - panic flights)	Potential chick loss (though none observed), reduced productivity	Mehlum and Bakken 1994
Murre	Reproduction	Fixed-wing	Moderate to loud overflights of at least 2 DC6 aircraft/day caused significant behavior changes (flushes)	Not given	Stress	Curry 1995
Murre	Reproduction	Helicopter	Varied by breeding status. Birds not actively brooding responded at 1.5 - 6 km distance while only 2.5% of departing birds were actively brooding. No habituation after 10 flights.	Recommended 2 - 3 km buffer (3 km to reduce mass - panic flights)	Potential chick loss (though none observed), reduced productivity	Mehlum and Bakken 1994
Oystercatcher, European	Roosting	Helicopter	Documents increased disturbance 1986-94 speculates that this increase is responsible for decreased preference for site. All disturbance = 1.05/hr compared to 0.33 in AK sites	Not given	Changes in distribution patterns, reduced abundance	Burton et al. 1996

Table 15. Response of avian species to disturbance from aircraft.

Species	Biological activity	Helicopter or fixed-wing	Disturbance response	Response distances	Consequences	Source
Oystercatcher, European	Foraging	Fixed-wing	After single pass at 360 m bird # returned to normal in 10 minutes; a plane passing twice (450 and 360 m) only 67 and 87% of original # returned in 45 minutes	360 m	Stress, reduced abundance at site	Glimmerveen and Went 1984 in Smit and Visser 1993
Oystercatcher, European	Roosting	Fixed-wing	Mean flight response was at 500 m	500 m	Stress	Smit and Visser 1993
Oystercatcher, European	Foraging	Helicopter	Birds flew 27% of instances when aircraft within 250 m	250 m	Stress	Smit and Visser 1993
Pelican, white	Reproduction	Fixed-wing	Aircraft > 610 m if early during incubation increased egg loss (crushing) by 88%, if later increased nestling loss moderately to 61%	> 610 m	Stampeding adults crush eggs = reduced productivity	Bunnell et al. 1981
Shorebird	Roosting	Helicopter	Documents increased disturbance 1986-94 speculates that this increase is responsible for decreased preference for site - caused consistent departures.	Not given	Changes in distribution patterns, reduced abundance	Burton et al. 1996
Tern, crested	Reproduction	Fixed-wing	Sound $\geq$ 85 dB(A) produced by a recording of Beaver on floats caused birds to fly off nest	Not given	increased predation	Brown 1990

Table 15. Response of avian species to disturbance from aircraft.

Species	Biological activity	Helicopter or fixed-wing	Disturbance response	Response distances	Consequences	Source
Wader	Roosting	Helicopter	Response ranges from looking up to abandoning site. Compared small airplanes, motor gliders and helicopters. Response rates were 56%, 50% and 100% respectively	Not given	Stress, reduced abundance at site	Heinen 1986 in Smit and Visser 1993

Table 16. Types and effects of disturbance to marine mammal species.

Source of disturbance	Documented effects of disturbance
Humans on foot	Feeding of young disrupted Haul-out sites avoided Mating activities are disrupted Separation of mother and young Young are deserted and die
Watercraft	Collisions and injury Communication impaired Displacement for feeding areas Hearing capability damaged Increased stress Separation of mother and young
Aircraft	Separation of mother and young Young are deserted and die Young are trampled

residents in Skagway organized an appeal to the State's decision to continue a permit for commercially operated canoe-trips at Glacier Point, Alaska (Anchorage Daily News, 8/12/99).

Through the 1990s out-of-state tourism in Alaska has increased from approximately 608,000 visitors to approximately 1,135,000 visitors (or 87%) for the summer months (Alaska Visitors Association 1999). Many of these businesses market Alaska's scenery and wildlife to their customers. The challenge for natural resource managers is to provide opportunities for both commercial and recreational use of the environment, without causing irreparable harm to wildlife resources. This is particularly important for resources, such as those injured by the spill that may not be resilient to changes in their environment. Indirect effects, such as disturbance, are much more difficult to document or understand than are direct effects such as fisheries harvest or activities that disturb the ground.

With the upcoming opening of the Whittier Road, the one certainty about the future of the western Sound is that human use will change. In order to make informed decisions about how to respond to, or how to manage the change in human use, it is important to have some understanding of today's use patterns. Ideally an on-site assessment of both human and biological activity should be completed around each bay or island in the Sound. The Sound's

Table 17. Response of marine mammal species to disturbance from humans on foot.

Species	Biological activity	Normal, observation, or research[1]	Disturbance response	Response distances	Consequences	Source
Seal, fur	Hauled out	Normal	Humans drive seals into the water		Some pups are deserted and die; mating activities are disrupted leading to reduced pup production	Wickens et al. 1992
Seal, harbor	Hauled out	Observation	Response not discernable			Renouf et al. 1981
Seal, harbor	Hauled out	Normal	Disturbance by beach combers separated mothers and pups		A lower percentage of weaned pups occurred in the population with higher levels of human disturbance	Slater and Markowitz 1983
seal, harbor	Hauled out	Normal	Seals left haul out sites.	100 m	Potential change in behavior from diurnal to nocturnal haul outs and increased pup mortality.	Allen et al. 1984

Table 17. Response of marine mammal species to disturbance from humans on foot.

Species	Biological activity	Normal, observation, or research[1]	Disturbance response	Response distances	Consequences	Source
Seal, harp	Hauled out	Observation	Most female left pups and entered the water for up to 2 hrs. For females that stayed, pups were nursed less and less social interaction occurred. Pups spent less time resting in the presence of humans	Humans were directly adjacent to seals.	Specific consequence were not observed. Desertion and injury to pups may occur.	Kovacs and Innes 1990
Seal, monk	Whelping	Normal	Humans drive seals into the water		Beaches where they have been disturbed often are avoided	Kenyon 1972
Seal, monk		Normal	Repeated interruption of nursing and stress reduced the amount of milk received by pups		Recurring human activity results in lowered likelihood of pup survival	Gerrodette and Gilmartin 1990
Seal, ringed	Hauled out in ice lairs.	Normal	Seals left haul out sites.	200 m	Abandonment of lairs; increased pup mortality	Kelly et al. 1986
Walrus, Atlantic	Hauled out	Normal	Humans drive walruses into the water		Walruses do not return to land for 3-4 days	Mansfield and St. Aubin 1991
Walrus, Pacific	Hauled out	Research	Alertness and displacement behaviors increased 10 fold during capture and tagging of individual walrus. Departing walruses moved 10-20 m away from capture crew.			Jay et al. 1998.

Table 17. Response of marine mammal species to disturbance from humans on foot.

Species	Biological activity	Normal, observation, or research[1]	Disturbance response	Response distances	Consequences	Source
Walrus, Pacific	Hauled out	Research	Handling activities resulted in >10-fold increase in alertness, displacement, and dispersal.		Predisturbance levels returned within 40 min	Jay et al. 1998.

[1]Normal indicates activity not directly associated with the species of interest, observation indicates activity associated with viewing marine mammals; research indicates activity associated with scientific study.

Table 18. Response of marine mammal species to disturbance from water vessels.

Species	Biological activity	Motorboat, kayak or canoe	Disturbance response	Response distances	Consequences	Source
Dolphin, bottlenose	At sea	Motorboat	Collisions between recreational boats and dolphins increased greatly during summer months. Heavy boat traffic, increased underwater noise, and high speed of boats contributed to high incident of collisions.			Wells and Scott 1997

Table 18. Response of marine mammal species to disturbance from water vessels.

Species	Biological activity	Motorboat, kayak or canoe	Disturbance response	Response distances	Consequences	Source
Dolphin, bottlenose	At sea		Dolphins ingested recreational fishing gear.		The dolphins died as a result.	Gorzelany 1998
Narwhal	At sea	Large vessels	Slow movement, submergence, silent	40 km		Finley et al. 1984; Miller and Davis 1984
Orca	At sea	Motorboat	Vessel noise impaired the ability of orcas to detect low frequency signals		Vessel noise is expected to impair communication among orcas and may lead to increased difficulty in finding food.	Bain and Dahlheim 1994
Orca	At sea	Motorboat	Orcas responded to approaching boats by swimming faster and swimming toward open water.	400 m	Increased stress	Kruse 1991
Otters, sea	At sea	Motorboat	Sea otters avoided areas with frequent boat traffic but reoccupied those areas during seasons with less traffic.			Garshelis and Garshelis 1984
Otters, sea	At sea	Motorboat	15% of sea otters moved away from survey vessels so they were not detected			Udevitz et al. 1995

Table 18. Response of marine mammal species to disturbance from water vessels.

Species	Biological activity	Motorboat, kayak or canoe	Disturbance response	Response distances	Consequences	Source
Otters, sea	On shore	Motorboat	Sea otters moved into the water when the motorboat approached the shore.	100 m		Garrott et al. 1993
Porpoise, harbor	At sea	Motorboat	Changed direction to avoid ships.	1.0-1.5 km		Barlow 1988
Porpoise, harbor	At sea	Motorboat	Strong reaction by changing direction to avoid ships.	400 m		Polacheck and Thorpe 1990
Sea lion	Hauled out	Motorboat	Sea lions left the haul out site.	100-200 m		Bowles and Stewart 1980
Seal, harbor	Hauled out	Motorboat	Response not discernable			Renouf et al. 1981
Seal, harbor	Hauled out	Canoe, motorboat	Seals left haul out sites in response to canoes more so than in response to motorboats.	100 m	Potential change in behavior from diurnal to nocturnal haul outs and increased pup mortality.	Allen et al. 1984.

Table 18. Response of marine mammal species to disturbance from water vessels.

Species	Biological activity	Motorboat, kayak or canoe	Disturbance response	Response distances	Consequences	Source
Seal, harbor	Hauled out	Motorboat	Females left the haul out site and entered the water	40 m	Separation of pups from mothers	Murphy and Hoover 1981
Seal, harbor	Hauled out	Motorboat	Seals entered the water.	100-300 m		Calambokidis et al. 1983
Seal, harbor	Hauled out	Motorboat	When in the presence of many fishing vessels response varied depending on distance to boat.	>200 m limited response; 150-200 m become alert; 60 m vacate the haul out site		Johnson et al. 1989
Seal, harbor	Hauled out	Motorboat	Seals left haul out sites in response to the motorboats and entered the water.	264 m detected potential disturbance source; 144 m entered the water		Suryan and Harvey 1999
Seal, harp	At sea	Motorboat	Upon arrival of vessels seal vocal activity ceased. Seals either left the area or changed vocalization patterns.	2 km	Increased stress	Terhune et al. 1979.

Table 18. Response of marine mammal species to disturbance from water vessels.

Species	Biological activity	Motorboat, kayak or canoe	Disturbance response	Response distances	Consequences	Source
Seal, harp	At sea	Large vessels	Communications distance between seals is reduced by masking sounds of the vessel. The following relationship exists: communications distances at 1, 10, 25, and 50 km from a vessel will be about 50, 80, 650, and 1400 m.		In addition to interfering with communication, prolonged exposure to high ambient noise levels may result in damage to hearing capabilities	Mansfield 1983
Seal, ringed	At sea	Large vessels	Communications distance between seals is reduced by masking sounds of the vessel. The following relationship exists: communications distances at 1, 10, 25, and 50 km from a vessel will be about 10, 50, 80, and 100 m.	40 km	In addition to interfering with communication, prolonged exposure to high ambient noise levels may result in damage to hearing capabilities	Mansfield 1983
Walrus, Atlantic	Hauled out	Motorboat	Responses were not detectable.	1.8-7.7 km		Salter 1979
Whale, Baird's beaked	Migration	Large vessels	Migration routes altered as a result of increased boat traffic.			Nishiwaki and Sasao 1977

Table 18. Response of marine mammal species to disturbance from water vessels.

Species	Biological activity	Motorboat, kayak or canoe	Disturbance response	Response distances	Consequences	Source
Whale, beluga	At sea	Large vessels	Rapid movement, loss of pod integrity, asynchronous diving, alarm calls, long distance movement (I.e., up to 85 km)	40 km	Displacement from feeding areas	Finley et al. 1984; Miller and Davis 1984
Whale, beluga	At sea	Motorboat	Avoidance behavior: prolonged intervals between surfacing, speed increased, bunched into groups. Avoidance behavior intensifies with increasing number of boats.		Searching and travel-searching belugas resumed activity; feeding and traveling belugas terminated activity	Blane and Jaakson 1994.
Whale, beluga	At sea	Motorboat	Vocalization response changed.	<1 km		Lesage et al. 1999
Whale, bowhead	At sea	Motorboat	Whales changed their headings, speeds, surface times, and number of respirations per surfacing in response to approaching vessels.	4 km	Displacement from feeding areas; breakup of (family) groups	Richardson and Malme 1993; Richardson et al. 1985a; Richardson et al. 1985b
Whale, bowhead	At sea	Large vessels	Communications between individuals may be masked by sounds of the vessel.	300 km		Mansfield 1983

Table 18. Response of marine mammal species to disturbance from water vessels.

Species	Biological activity	Motorboat, kayak or canoe	Disturbance response	Response distances	Consequences	Source
Whale, bowhead	At sea	16 and 60 m vessels	When approached, whales attempted to outrun the boats; when overtaken the whales moved at right angles to the boats. Disturbed whales spent less time at the surface, blew fewer times during surfacing, and made briefer dives.	0.8 - 3.0 km		Fraker et al. 1982
Whale, bowhead	At sea	Motorboat	Whales moved away to avoid ships approaching them	400-600 m		Kibal'chich et al. 1986
Whale, fin	At sea	Motorboat	Initially whales avoided ships and equipment, especially those with low-frequency sounds. Over the years they appeared undisturbed by passing vessels or vessels with observers.	30 m	Vocalizations were discontinued; feeding not affected	Watkins 1986
Whale, gray	Migration	Motorboat	Whales changed course to avoid ships in their path.	200-300 m		Wyrick 1954
Whale, gray	Summering	Motorboat	Whales moved away to avoid ships approaching them	350-550 m		Bogoslovskaya et al. 1981

Table 18. Response of marine mammal species to disturbance from water vessels.

Species	Biological activity	Motorboat, kayak or canoe	Disturbance response	Response distances	Consequences	Source
Whale, humpback	At sea	Motorboat	Initially whales avoided ships and equipment. Over the years they appeared undisturbed by passing vessels or vessels with observers and at time approached vessels.		Vocalizations were discontinued	Watkins 1986
Whale, humpback	At sea	Motorboat	Disturbance by vessels resulted in a decrease in interval between blows, an increase in total dive time, and a decrease in whale speeds.	Vertical avoidance from 0 to 2000 m; greatest effect within 400 m	Displacement from preferred feeding sites, interruption of feeding including nursing of calves	Baker et al. 1982; Baker et al. 1983; Baker and Herman 1989
Whale, humpback	At sea	Motorboat	Disturbance by vessels resulted in a decrease in dive times, longer blow intervals, and an increase in whale speeds.	Horizontal avoidance from 2000 to 4000 m	Displacement from preferred feeding sites	Baker et al. 1982; Baker et al. 1983; Baker and Herman 1989
Whale, humpback	Wintering	Motorboat	Measures of respiration, diving, swimming speed, social exchange, and aerial behaviors were correlated with vessel numbers, proximity, speed, and direction changes. Whales attempted to avoid vessels and directed threats toward them.	0.5-1.0 km	Increased stress	Bauer 1986; Bauer and Herman 1986; Bauer et al. 1993
Whale, minke	Migration	Large vessels	Migration routes altered as a result of increased boat traffic.			Nishiwaki and Sasao 1977

Table 18. Response of marine mammal species to disturbance from water vessels.

Species	Biological activity	Motorboat, kayak or canoe	Disturbance response	Response distances	Consequences	Source
Whale, minke	At sea	Motorboats	Initially whales investigated ships and equipment. Over the years they appeared undisturbed by passing vessels or vessels with observers.			Watkins 1986
Whale, right	At sea	Motorboat	Throughout the period of study right whales generally avoided vessels but moved away slowly.		Vocalizations were discontinued	Watkins 1986
Whale, white	At sea	Large vessels	Adult females and young moved away from vessel	2.4 km		Fraker 1977a
Whale, white	At sea	Large vessels	Migration movements were disrupted by frequent vessel traffic possibly because the wakes of these vessels contained many small air bubbles which may have disrupted the whales' echolocation systems			Fraker 1977b

Table 19. Response of marine mammal species to disturbance from aircraft.

Species	Biological activity	Helicopter or fixed-wing	Disturbance response	Response distances	Consequences	Source
Dolphin	At sea	Bell 204 helicopter	Limited reaction	366-549 m		Au and Perryman 1982; Hewitt 1985
Dolphin, spinner	Resting in nearshore bays	Cessna 172 fixed wing	Dove abruptly	300 m		Richardson et al. 1995:248
Narwhal	At sea	Bell 206 helicopter	Quickly dove.	<244 m		Kingsley et al. 1994
Narwhal	At sea	Fixed wing	Dove	305 m altitude; within 0.5-1 km		Born et al 1994
Porpoise, Dall's	At sea	Bell 205 helicopter	Porpoises dove, moved erratically, or rolled to look upward.	215-365 m		Withrow et al. 1985
Sea lion, California	Hauled out	Jet aircraft	Limited movement; no major reaction.	<305 m		Bowles and Stewart 1980
Sea lion, California	Hauled out	Fixed wing	Alert reactions and movement.	<150-180 m		Richardson et al. 1995:245

Table 19. Response of marine mammal species to disturbance from aircraft.

Species	Biological activity	Helicopter or fixed-wing	Disturbance response	Response distances	Consequences	Source
Sea lion, California	Hauled out	Helicopter	1000+ animals stampeded of a beach in response to a Bell 205 helicopter.	>1.6 km lateral distance		Withrow et al. 1985
Seal, harbor	hauled out	Jet aircraft	Seals left haul out sites.	>244 m		Bowles and Stewart 1980
Seal, harbor	hauled out	Helicopter overflight	Seals left haul out sites.	<305 m		Bowles and Stewart 1980
Seal, harbor	hauled out	Helicopter turning or hovering	Seals left haul out sites.	>300 m; >1.6 km lateral distance		Bowles and Stewart 1980
Seal, harbor	hauled out	Fixed wing	Overflight caused alert reaction; some seals left the haul out site.	150 m		Osborn 1985
Seal, harbor	Hauled out, birthing	Helicopter, fixed wing	Seals left the beach after flights above 300 m but total desertions were rare. Flights at 120--300 m had varying effects; effects were greater on calm days than on stormy days. Flights at <120 m nearly always resulted in large-scale disturbance. Helicopters and large airplane were more disturbing than small planes.	Large-scale movements into the water.	If disturbance occurred during pupping season many new-born pups are separated from their mothers and die.	Johnson 1977

Table 19. Response of marine mammal species to disturbance from aircraft.

Species	Biological activity	Helicopter or fixed-wing	Disturbance response	Response distances	Consequences	Source
Seal, harbor	Hauled out	Fixed wing	Females left the haul out site and entered the water	60 m altitude	Separation of pups from mothers	Murphy and Hoover 1981; Hoover 1988
Seal, northern elephant	Hauled out	Jet aircraft	Limited movement; no major reaction.	<305 m		Bowles and Stewart 1980
Seal, northern elephant	Hauled out	Fixed wing	Alert reactions.	<150-180 m		Richardson et al. 1995:245
Seal, ringed	Hauled out in ice lairs.	Helicopter	Seals left haul out sites.	300 m altitude within 2 km	Abandonment of lairs; increased pup mortality	Kelly et al. 1986
Seal, spotted	Hauled out	Fixed wing	Seals left haul out sites.	305-760 m; 1 km lateral distance		Frost et al. 1993
Walrus	Hauled out	Fixed wing (IL-14)	Animals stampeded into the water	150 m	21 calves crushed, 2 fetuses aborted	Tomilin and Kibal'chich 1975 in Fay 1981
Walrus	Hauled out	Fixed wing	Animals stampeded into the water	800 m	102 walruses killed	Ovsyanikov et al. 1994

Table 19. Response of marine mammal species to disturbance from aircraft.

Species	Biological activity	Helicopter or fixed-wing	Disturbance response	Response distances	Consequences	Source
Walrus, Atlantic	Hauled out	Bell 206 helicopter	Initial response to a Bell 206 occurred when aircraft was >2.5 km away (I.e., raised heads). Movement towards and water entry occurred as aircraft approached closer.	<150 m altitude; within 1.3 km		Salter 1979
Walrus, Atlantic	Hauled out	DeHavilland Otter (piston engine)	Adult females, calves, and immatures more likely to enter the water when disturbed than adult males when disturbed.	1000-1500 m altitude; within <1 km		Salter 1979
Whale, beluga	At sea	Unspecified	Belugas dove for longer periods, had shorted surface intervals, and occasionally swam away; feeding animals were less prone to disturbance.	150-200 m		Bel'kovich 1960 in Richardson et al. 1995:247
Whale, bowhead	At sea	Fixed wing	Blow interval was reduced when aircraft descended to 300 m altitude. At 300 m or below whales dispersed from circling aircraft including a quick dive or swimming away.	<300 m altitude		Richardson and Malme 1993; Richardson et al. 1985a; Richardson et al. 1985b
Whale, bowhead	At sea	Helicopter	Limited response to helicopter overflights at 150 m altitude and greater.			Richardson and Malme 1993; Richardson et al. 1985a; Richardson et al. 1985b

Table 19. Response of marine mammal species to disturbance from aircraft.

Species	Biological activity	Helicopter or fixed-wing	Disturbance response	Response distances	Consequences	Source
Whale, bowhead	At sea	P-3 patrol fixed wing	Dove	150-250 m		Ljungblad 1986 in Richardson et al. 1995:249
Whale, gray	At sea	Fixed wing	Mother-calf pairs sensitive to over flight by positioning the mother between the calf and the air craft.	335 m		Clarke et al. 1989
Whale, gray	At sea	Fixed wing	Mating group had limited initial reaction but dispersed after aircraft circled	366 m initial; circled at 670 m		Clarke et al. 1989
Whale, gray	Migrating	Fixed wing	Limited detectable reaction to an overflight.	60 m		Green et al. 1992 in Richardson et al. 1995:250
Whale, gray	Migrating	Bell 212 helicopter	Course changes in response to playbacks of recorded underwater sound. Response was to helicopter noise, vision was not involved.			Malme et al. 1983, 1984 in Richardson et al. 1995:250
Whale, gray	Migrating	Bell 212 helicopter	Abrupt turns, dives, or both.	>425 m no reaction; 305-365 m occasional reaction; <250 usually reacted		SRA 1988 in Richardson et al. 1995:250

Table 19. Response of marine mammal species to disturbance from aircraft.

Species	Biological activity	Helicopter or fixed-wing	Disturbance response	Response distances	Consequences	Source
Whale, gray	Calving	Fixed wing	Dove	<75 m	Mothers and calves separated	Withrow 1983
Whale, minke	At sea	H-52 turbine helicopter	Whales changed course, rolled onto their side, or dived slowly	230 m		Leatherwood et al. 1982.
Whale, right	At sea	Fixed wing	Limited disturbance	<150 m		Watkins and More 1983

vast size makes that task impossible – especially over a short period of time. Our approach was to gather data on existing use and to graphically represent the information. Through one aspect of this project we have developed a tool that may be used to create a variety of images to convey information. Maps are powerful tools because they visually convey information to people. The challenge is to make people understand, and appropriately use, the tool that we have created. The mapping capability through GIS provides opportunity to display very different images depending on how the system is queried to display data. It is possible to give the impression that there is virtually no human use in the western Sound, or that there is overwhelming activity.

In order for this compilation of information to be a useful tool for managers, they need to understand its capabilities and limitations. To demonstrate these capabilities and limitations we responded to questions from Prince William Sound land and resource managers. While our focus has been towards providing a tool to understand the relationship between wildlife populations and human use, many of the questions we received were more focused on understanding the many facets of human use.

What is the cumulative human use level in the Sound?

For some species it may be important to look at the total amount of boat traffic in an area, rather than the use patterns of a particular user group. With our data, distributions for each user group can be added together for any month or combination of months. Using the same display categories (i.e., <2%, 3-10%, 11-20%, >20%) that we have shown for the individual user groups, we illustrated the use distribution patterns in the analysis areas for the 5 user groups over the entire summer season (Fig. 25, Table 20). From these data we can see that Passage Canal, Culross Passage and South Esther Island receive the highest levels of boat activity. Passage Canal will always have the highest level of use because our distributions are based on traffic from Whittier. Culross Passage is the primary transportation corridor to access the southern half of the Sound, and is also a destination for kayakers, visitors to Long Bay and the Shrode Lake cabin, and for sport fishermen who fish in Long Bay. Similar to Culross Passage, South Esther Island receives both vessels passing through the analysis area as part of an East-West travel corridor, and activity as a destination for commercial fishing and other user groups.

How does use vary over time?

Our data provides at least 3 options for addressing this question. First, by analyzing the Whittier Harbor data, we can look at the daily use levels for the boats that use the harbor. For recreational motor boats we can see that the peak in use during the summer of 1997 occurred on 16 July (Fig. 26). When evaluating the spatial illustrations of use patterns for recreation motor boats and sailboats, it is important to keep the daily use levels in mind. The GRID maps were compiled at a monthly scale; we did not consider use patterns at time steps less than the monthly use level. By analyzing the Whittier harbor data for June it is indicated that the mean number of recreation motor boats in the Sound on weekends ($x = 76$) is significantly higher than the mean number of boats in the Sound on weekdays ($x = 43$; $P < 0.001$).

A second approach is to look at the monthly distribution patterns for an individual user group. All the use maps that we have displayed show the use levels based on the percentages of the total use for each individual user group during a specific time period. These percentages (i.e., <2%, 3-10%, 11-20%, >20%) were based on the data distribution that included very small areas with amounts of boat use close to the total number of boats known to have traveled to and from Whittier. In other words, once boats left the Whittier harbor and Passage Canal, where use was concentrated, they dispersed rapidly. We believe that the distribution patterns based on these

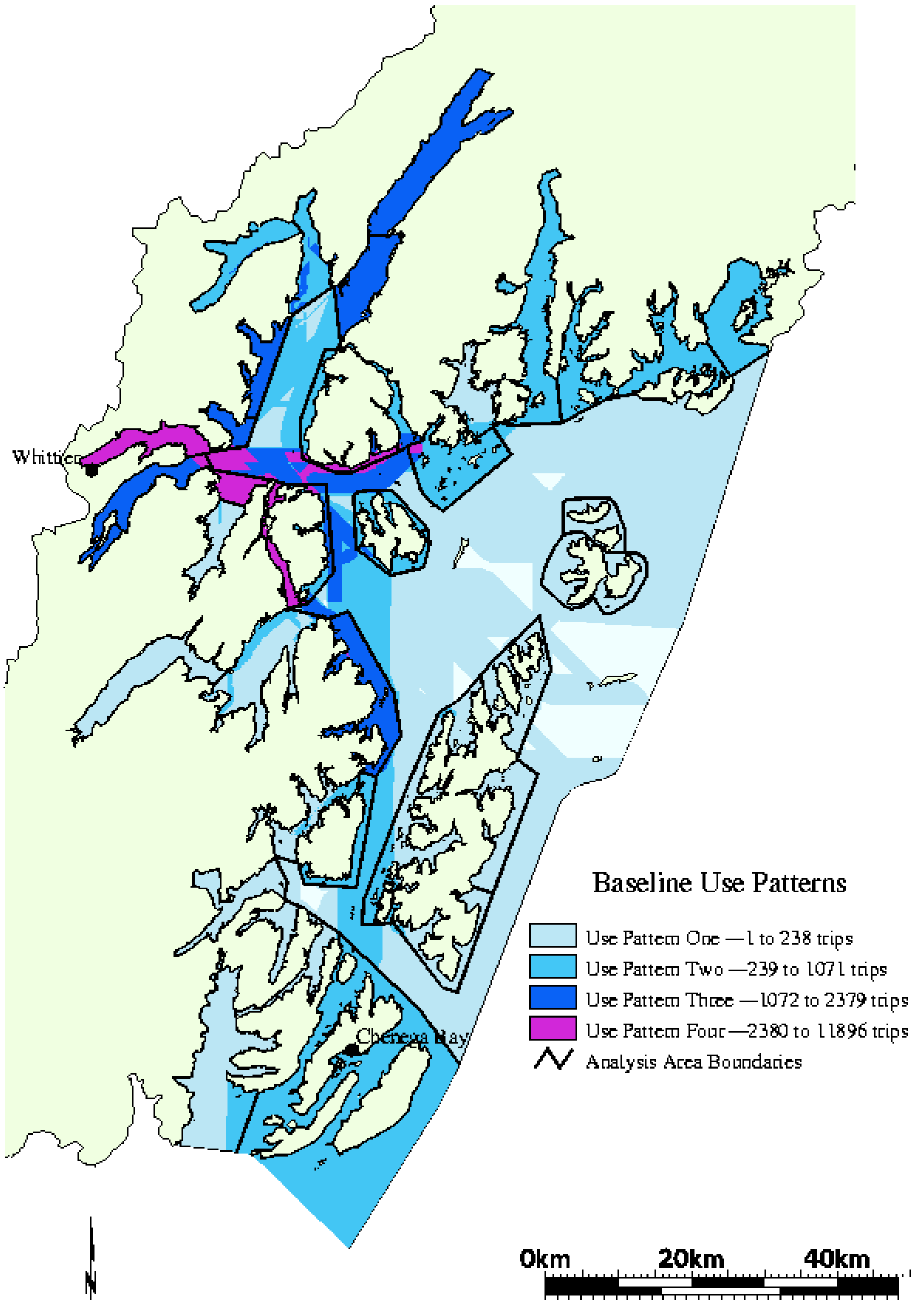


Fig. 25. Distribution of all user groups in western Prince William Sound, Alaska, May–September.

Table 20. Mean number of occurrences of vessels in all user groups by analysis area in western Prince William Sound, Alaska, May—September.

Analysis area	Occurrences by month											
	May		June		July		August		September		All months	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Bainbridge Passage	10	0	35	1	59	1	58	1	17	1	180	1
Barry Arm	115	6	243	4	246	2	241	4	111	3	962	3
Bettles Bay	141	7	322	5	379	4	359	5	144	4	1340	5
Blackstone Bay	113	6	267	4	379	4	299	4	107	3	1168	4
Chenega Island	11	1	49	1	169	2	180	3	140	4	509	2
Cochrane Bay Lower	24	1	25	0	28	0	28	0	11	0	90	0
College Fiord	31	2	75	1	439	4	54	1	13	0	613	2
College Fiord Lower	31	2	90	1	564	6	76	1	14	0	776	3
Columbia Bay	111	5	150	2	161	2	152	2	49	2	625	2
Culross East	12	1	167	3	351	4	307	4	201	6	917	3
Culross Passage	127	6	391	6	1095	11	675	10	341	10	2592	9
Dangerous Passage	0	0	0	0	0	0	0	0	0	0	0	0
Dutch Group	60	3	134	2	138	1	198	3	42	1	575	2
Eaglek Bay	21	1	48	1	56	1	41	1	9	0	176	1
Eshamy	24	1	80	1	503	5	283	4	188	6	1040	4
Esther Passage	21	1	333	5	391	4	90	1	61	2	898	3
Esther South	76	4	1048	17	583	6	324	5	283	9	2321	8
Esther West	16	1	160	3	367	4	60	1	43	1	618	2
Evans Island	20	1	39	1	70	1	83	1	35	1	249	1
Glacier Island	80	4	116	2	139	1	122	2	51	2	510	2
Harriman Fiord	108	5	230	4	222	2	226	3	106	3	886	3
Icy Bay	0	0	11	0	15	0	3	0	2	0	29	0
Kings Bay	3	0	12	0	16	0	6	0	3	0	39	0
Knight East	4	0	7	0	9	0	9	0	3	0	26	0
Knight North	4	0	8	0	19	0	16	0	9	0	51	0

Table 20. Mean number of occurrences of vessels in all user groups by analysis area in western Prince William Sound, Alaska, May—September.

Analysis area	Occurrences by month											
	May		June		July		August		September		All months	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Knight South	0	0	6	0	11	0	21	0	7	0	40	0
Knight West	5	0	13	0	51	1	61	1	51	2	141	1
Naked East	4	0	5	0	5	0	5	0	4	0	14	0
Naked West	7	0	8	0	11	0	13	0	11	0	43	0
Nellie Juan	14	1	33	1	58	1	46	1	21	1	148	1
Passage Canal	410	20	1013	16	1615	16	1216	18	545	17	4796	17
Perry North	7	0	69	1	64	1	182	3	55	2	337	1
Perry South	6	0	20	0	96	1	212	3	86	3	346	1
Pigot Bay	140	7	329	5	394	4	363	5	154	5	1372	5
Port Bainbridge	13	1	23	0	38	0	41	1	13	0	130	0
Storey	14	1	14	0	19	0	21	0	14	0	84	0
Surprise Cove	209	10	500	8	1090	11	699	10	302	9	2798	10
Unakwik	30	1	69	1	93	1	58	1	11	0	263	1
Wells Bay	17	1	54	1	58	1	53	1	6	0	190	1
Whale Bay	0	0	7	0	8	0	2	0	0	0	17	0
Total	2039	100	6203	100	10009	100	6883	100	3263	100	27909	100

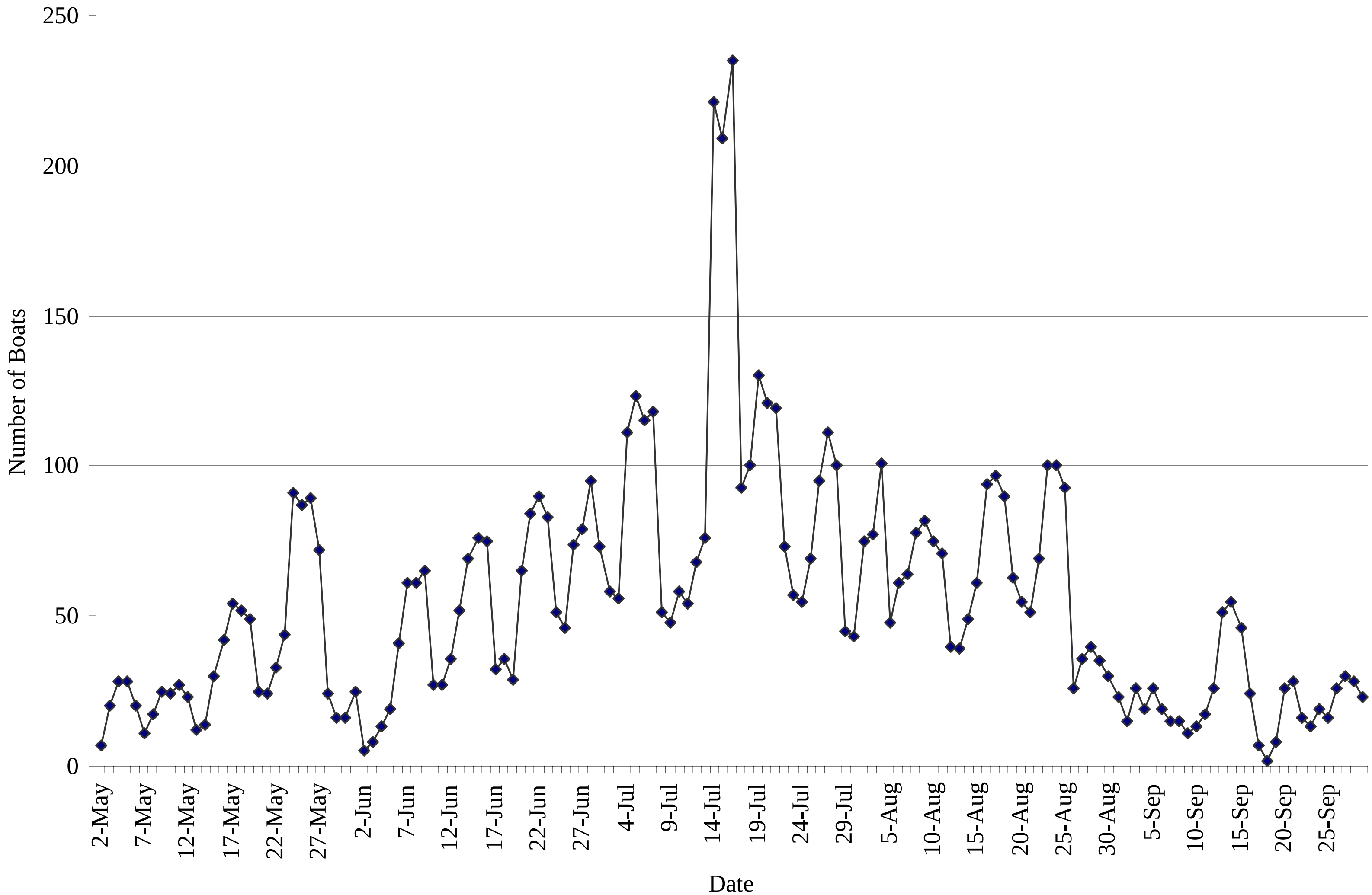


Fig. 26. Number of recreational motor boats leaving Whittier Harbor by day from May through September, 1997.

percentages provide a reasonable representation of how the study area was used by an individual user group for a given time period. Because we used a percentage-based system to define each category, the number of boats in each display pattern varies with the total number of boats considered for that user group and time period. To determine how a user group's patterns changes between months, the number of boats represented by each use category needed to be held constant. To demonstrate this we used the same percentages to define the use levels for the month of July, then held the number of boats in each category constant for May and June (Fig 27).

This same information can be displayed graphically by analysis area. As an example, the mean numbers of kayaks in Barry Arm were plotted for each of the 5 months (Fig. 28). Similar data displays may be generated for all user groups in each analysis area. However, these data cannot be used to establish past use trends in western Prince William Sound. Because we collected only the most recent data that was available in 1998, we are unable to provide an analysis of growth patterns from prior use levels for the different user groups.

How can these data be used to protect injured resources?

Understanding the effects of human-caused disturbance to wildlife is extremely difficult. Activities without immediate effects may cause cumulative impacts that are not apparent until long after the disturbance, or until the disturbance has continued for some time. Conversely, disturbances that cause immediate effects may not necessarily result in cumulative effects over time (Riffel et al. 1996). Unlike activities that physically alter a species' habitat, disturbance allows the habitat to remain physically intact, but reduces its ability to support wildlife (Goss-Custard and Durell 1990). Whether or not disturbance will cause a change in the population of a particular species depends on a variety of factors that are specific to each situation. Factors that influence the vulnerability of a species to disturbance include seasonal factors and the biological activity occurring at that time, group size, species size, feeding location, and the general behavior of the species such as its intrinsic wariness and flight response (Burger et al. 1995). Similarly, the frequency and form of activity will influence the potential for disturbance (Fig. 29).

For managers interested in understanding the potential effects of human activity on wildlife in Prince William Sound, it may be useful to ask the question "Who is most disturbed, by whom, where and when?" (Davidson and Rothwell 1993). In reviewing the literature on human disturbance to marine mammals and birds, it is apparent that there are inter- and intra-specific variations in how animals respond to human activity. From a broad perspective it may be difficult to determine which species is more disturbed by human activity without considerably more information than is currently available.

Our approach was to provide a quick reference to the literature on the effects of disturbance on birds and marine mammals (Tables 13-15; 17-19). These tables are meant to provide enough information so that managers have an understanding of the potential effects that people on shore, or in boats, or aircraft may have on different species. Because there is so much variation in the response of different species, and individuals, to different forms of human activities, managers must carefully consider the specific situation being addressed. While it is inappropriate to make generalizations about how a particular activity will affect nearby wildlife, there are some disturbance patterns that warrant consideration. For instance, fast-moving and erratic motion tends to be consistently more disturbing to a wide range of wildlife species than slow, steady motion (e.g. Burger 1981, Smit and Visser 1993). Aircraft activity is often very disturbing to many species of wildlife, and helicopters elicit an even greater response than fixed-

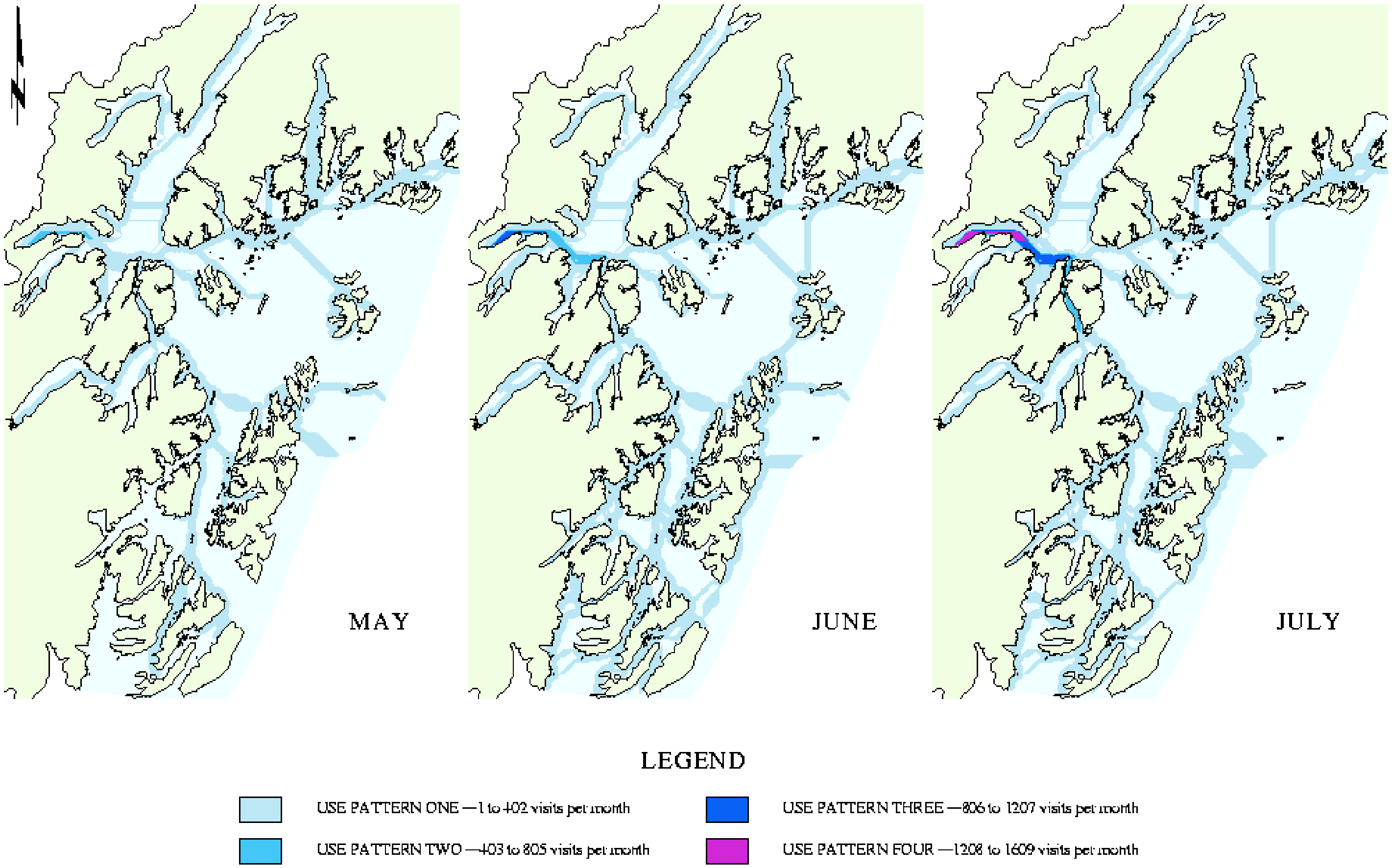


Fig. 27. Comparison of distribution patterns for the recreation motor boat user group in western Prince William Sound, Alaska, for the months of May, June and July 1997.

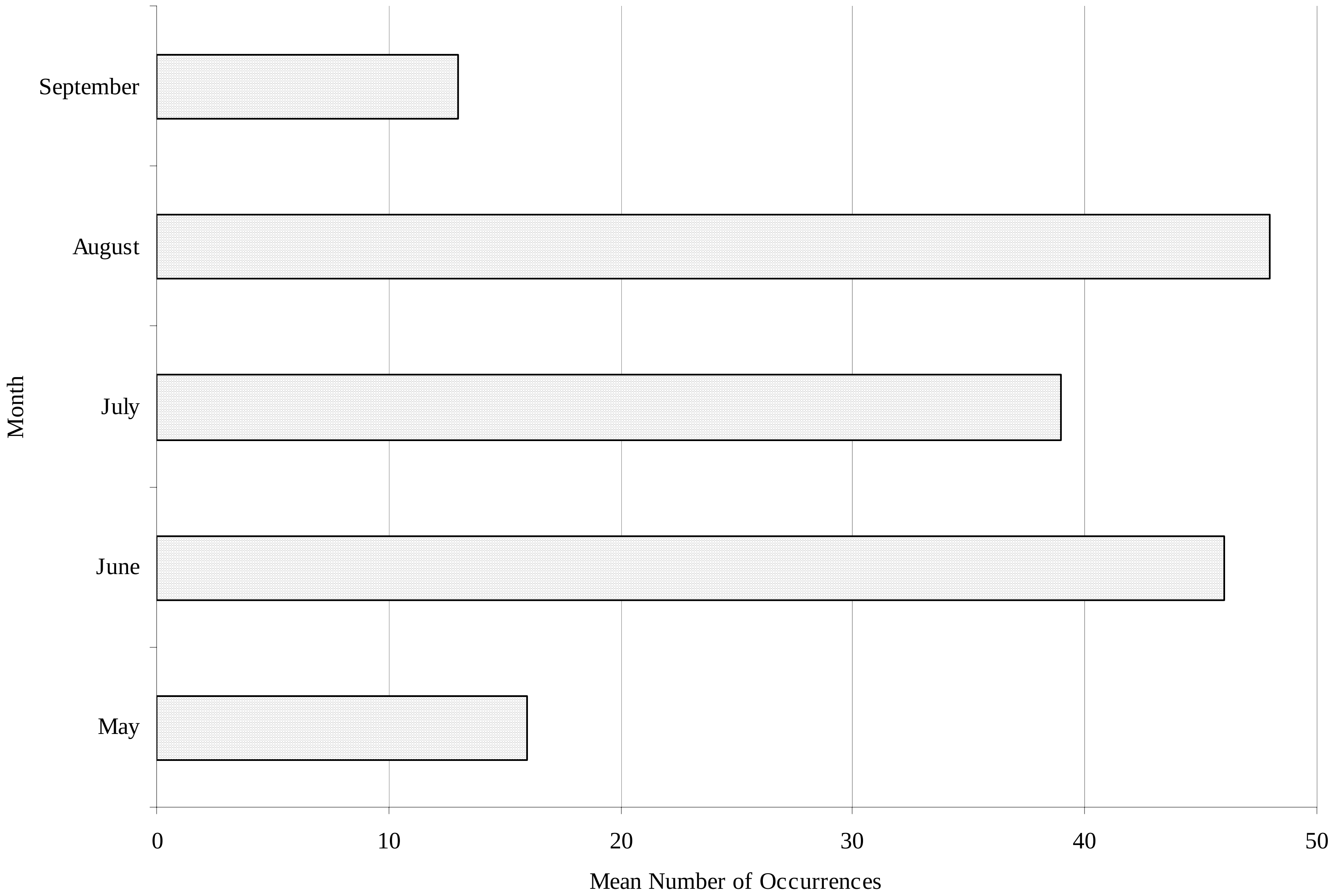
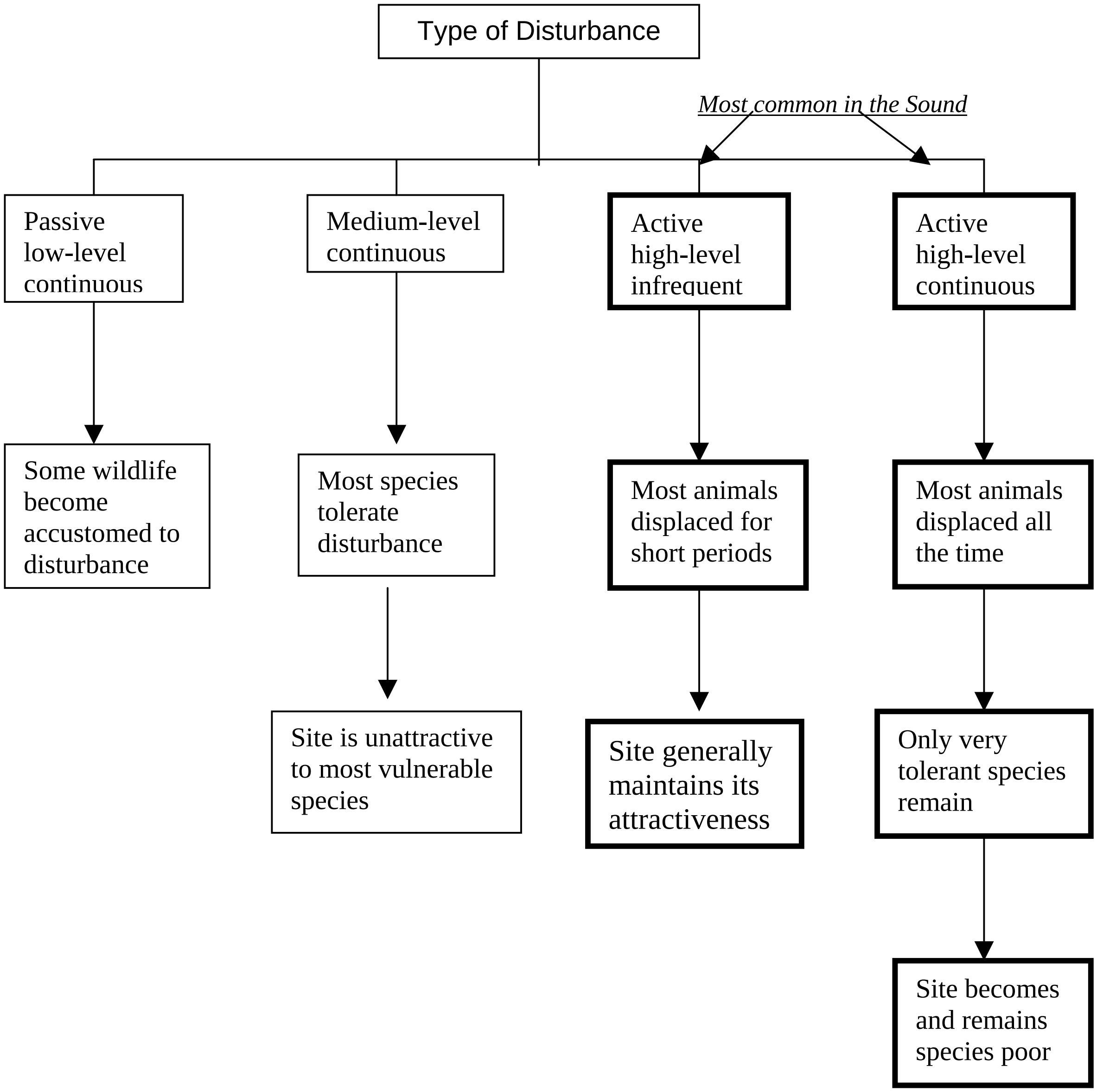


Fig. 28. Mean number of kayak occurrences in Barry Arm, Prince William Sound, Alaska, 1998.



Examples:

Pumping station with no visible human presence	Humans screened in vehicles	Fishing People walking near nest site once/week	Frequent power boating Popular campsite with people walking on beach daily

Fig. 29. Types of disturbance, likely responses from wildlife, and some examples (adapted from Hockin et al. 1992).

winged aircraft (e.g. Mehlum and Bakken 1994, Smit and Visser 1993). Juvenile animals are often more vulnerable to disturbance than are adults (e.g. Goss-Custard and Durell 1990).

Many of the activities that are occurring in the Sound today, and probably for the foreseeable future, may not show immediate impacts to wildlife. Many people may think that the disturbance that they cause is inconsequential and will not directly harm the animals. While they may be correct, the combined effects of disturbance may often be significant or they may be disturbing an animal at a crucial time period that could lead to the eventual loss of their offspring or other serious consequences. Belanger and Bedard (1990) calculated the energetic cost of flight for staging greater snow geese. They determined that a disturbance rate of 0.5/hour approximately doubled the amount of time the geese spent in flight. A rate of more than 2.0 disturbances/hour could cause an energy deficit that would exceed the ability of the birds to compensate for the lost feeding time and increased energy expense. Similar energetic costs should be expected for other species that are required to expend energy, or lose feeding time as a result of disturbance.

Harbor Seals.—Richardson et al. (1995) provided a thorough review of the responses of marine mammals to factors of disturbance. Seals that are hauled out on land or ice react to both the sound and sight of aircraft by becoming alert and often by entering the water. Aircraft that fly low and overhead with sudden changes in sound cause the greatest reaction in harbor seals. Repeated exposure of harbor seals to aircraft disturbance often increases the seals' reaction to subsequent disturbance. Although harbor seals in water do react to boat-based disturbance, there is a paucity of definitive studies defining the effects of that response on seals. Although stress may increase in harbor seals as a result of boat-based disturbance, there is an indication that seals have a high level of tolerance for the presence of boats. Harbor seals may become habituated to human presence in the absence of hunting or active harassment (Bonner 1982, Thompson 1992).

For harbor seals, human activity may be most disturbing during pupping and during the molt. Disturbance that causes a female to be separated from her newborn pup can endanger the pup. Johnson (1977) has shown that pair bonds between a female and her pup are fragile during the first few days of a pup's life. Separation can result in the pup becoming lost or abandoned. Because harbor seals do not have a synchronous pupping period, it may be difficult to use our data. However, since the majority of pups are born in the 1st half of June in the Sound (Frost 1996), an examination of the human activity near some of the primary haulout sites during this time may be useful. Forced movement into the water may be a particular problem for pups which may need to remain hauled out for long periods of time to maintain adequate body temperatures (e.g., Fay and Ray 1968).

The peak period for harbor seals to molt occurs in late July and August in the Sound (Pitcher and Calkins 1979). During this period they must rest out of the water in order to maintain their body heat (e.g., Fay and Ray 1968). New hair may also grow faster when seals are out of the water and the skin is warmer (Hoover-Miller 1994). Human activity that forces the seals to return to the water during this time is likely to increase the amount of energy that an animal must expend to stay warm.

We did not find an indication that a particular user group is likely to be more disturbing to seals at haulout sites than other user groups (Allen et al. 1984, Osborn 1985, Swift and Morgan 1993). Disturbance to the seals is more from proximity, speed and approach (direct line or parallel) to the haulout sites (Hoover 1988). The Marine Mammal Protection Act provides regulations that should prevent vessels from disturbing the seals, however, individuals in any user group could violate these rules and disturb the animals.

Pigeon Guillemots.—Pigeon guillemots in western Prince William Sound typically establish nest sites in May (Kuletz 1998). During this time the adults display on the water adjacent to the colony and make frequent trips to and from the potential nest site. Pigeon guillemots generally nest in rock crevices on cliffs or in talus boulders, or in labyrinth tree root systems. Although we did not find published literature describing disturbance effects on pigeon guillemot nesting colonies, observations by researchers in Prince William Sound have shown that the birds are extremely wary of people on shore. Results of recent observations in 2 regions of the Sound show the same behavior of adult birds returning to their nest sites. Prior to returning to their nests, the adult birds land on nearby waters and apparently look for on-shore activity. Biologists have observed that birds will not return to their nests when people are on shore in close proximity to nest sites (G. Golet and J. Fischer, Fish and Wildlife Service; personal communication). Adult birds delivering fish to their hatchlings tend to wait offshore until the perceived danger has left. Alternatively, adults may swallow or drop the fish rather than deliver them to their young. The effects of these types of disturbances have not been quantified for pigeon guillemots. However, if the frequency or duration of human activity on shore prevents the birds from incubating or feeding their young, it is reasonable to expect that reproductive success will be reduced. Also, if birds are repeatedly flushed, the likelihood of detection of the nest location by predators (e.g., mink) is increased.

Researchers studying pigeon guillemots in Prince William Sound are aware of the birds' sensitivity to people on shore. To minimize the potential for disturbance they use blinds and other techniques during their research. Unfortunately, people who are unaware of pigeon guillemot biology or the location of nesting colonies may disturb the breeding birds. Pigeon guillemot nests tend to be cryptic so visitors to nest sites may not even know they are causing disturbance. In 1999, Jackpot Island, one of the largest pigeon guillemot nesting colonies in the western Sound, had complete reproductive failure (G. Golet, U.S. Fish and Wildlife Service, personal communication). This small island has two beaches suitable for landing boats and is occasionally used as a tent site by kayakers (Sanger and Cody 1994). Although it is unknown if human disturbance caused the nesting failure in 1999, tents were observed on the island during the incubation period. Because kayakers use the shoreline more than any of the other 4 user groups, biologists believe that this user group holds the greatest potential for disturbance to pigeon guillemot colonies (e.g., Fig. 23). If biologists are interested in examining the effects of human disturbance on pigeon guillemot colonies, our data may provide information on the relative numbers of kayaks that use areas near different colonies. This information may provide an initial screen to determine the potential levels of disturbance at colonies. During the development of the distribution patterns for the different user groups, we identified over 435 destinations throughout the study area (Fig 30). These destinations included everything from recreation cabins and fish hatcheries to campsites. An evaluation of the availability of campsites relative to pigeon guillemot colonies could provide additional insights into the potential for disturbance.

Evaluation of human disturbance on species closely related to pigeon guillemots provided additional insights to the effects of human disturbance during nesting on productivity. During studies of black guillemots nesting colonies, researchers determined that colonies that were visited daily by humans had significantly lower hatching success than colonies visited once every 4 days (Cairns 1980). Although fledging success was not significantly different between colonies, chicks in the heavily disturbed colonies were heavier but had narrower wingspans. The author believed that disturbance led to decreased incubation attentiveness, nest abandonment, and damage to eggs during panic departures from the nest, all of which could contribute to the reduced hatching success. Human disturbance has also been shown to reduce hatching success in least auklets (Piatt et al. 1990). Hatching success was significantly decreased by intensive

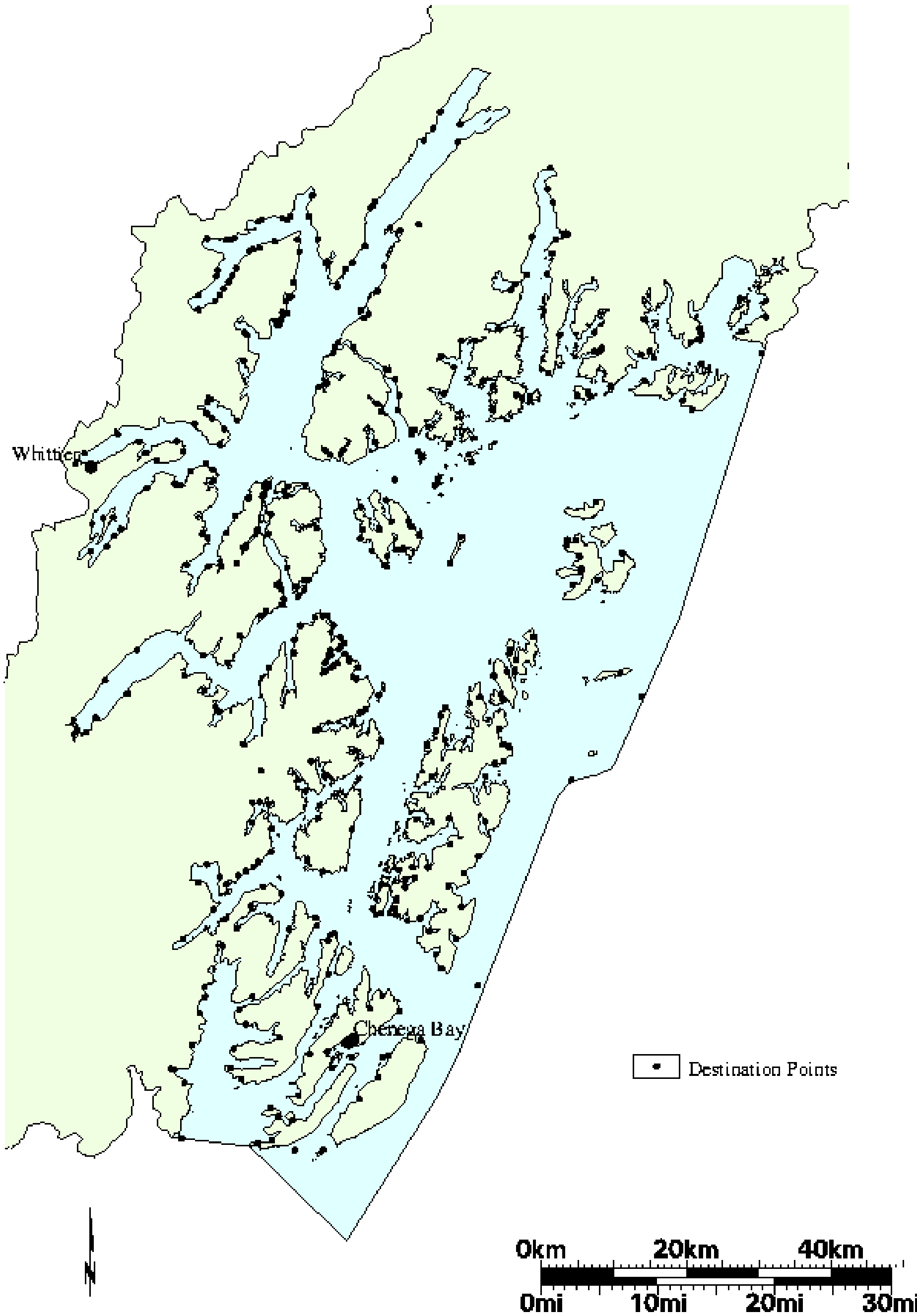


Fig. 30. Identified destinations for recreation and other uses thoughtout western Prince William Sound, Alaska.

research activity. Researchers noted increased numbers of abandoned nests and unhatched eggs in the high disturbance areas.

Reduced fledging success has also been documented for other species of alcids that experienced disturbance during nesting. Pierce and Simons (1986) varied the frequency of researcher visits to tufted puffin nests on the Barren Islands, Alaska. They estimated that the fledging rate was reduced from 94% in undisturbed portions of the colony to 18% in the high disturbance area. They also found that chicks in the high disturbance area were significantly lighter and had shorter wings than less disturbed chicks.

These research studies examined the effects of research activities on nesting alcids. While the type of disturbance caused by researchers may differ from disturbance caused by people not actively studying the birds, these studies identify the potential effects of any form of disturbance. According to Schulz and Stock (1993) "when studying the effects of disturbances, one of the major questions to be answered is whether or not a disturbance is significant to a bird. In population terms this means whether or not the population can withstand a certain reduction in productivity to secure a population level or not." Disturbance to breeding birds can have an immediate effect. Eggs and young chicks must be incubated to keep warm. If the adult birds are absent for too long of a period the eggs and chicks may perish because they cannot maintain the proper temperature; they are also more vulnerable to predation. Disturbance to non-breeding birds is more difficult to quantify. Disturbance is harmful if it results in birds losing more energy than can be made up by food intake (Owens 1977). Disturbance may also result in increased competition because of increased density at feeding or nesting areas (Goss-Custard and Durell 1990).

Cutthroat Trout.--Cutthroat trout in the western Sound include both anadromous and resident populations. Over-wintering populations in Alaska often consist of only a few hundred fish (Schmidt 1997), and the western Sound populations may consist of as few as 200 adults in some streams (D. Gillikin, Chugach National Forest, personal communication). Our study area supports the most northern extent of the species range in North America. Biologists generally agree that populations at the extreme limits of a species' range are particularly vulnerable to environmental change. Researchers believe that the spill affected both the survival and growth rates of sea-run populations of cutthroat trout (Hepler et al. 1996). The recovery status of these injured populations 10 yrs after the spill are currently unknown (*Exxon Valdez* Oil Spill Trustee Council 1999). Small populations, potential continuing effects from the spill, and the environment constraints limiting the species' range, all contribute to an increased vulnerability of cutthroat trout in the western Sound.

Unlike many species of birds and mammals, the effects of indirect human-caused disturbance to fish have not been investigated. The effects of human-use on cutthroat trout are less likely to be tied to the number of vessels and people in a particular area than to the popularity of trout fishing and to the management of the sport fishery. Cutthroat trout are believed to be among the most vulnerable salmonid species to capture by anglers (Gresswell and Harding 1997). While this vulnerability may make them an attractive species for sport fishing, it has led to the over harvest of many populations of resident cutthroat trout populations in the western United States (Gresswell 1988). The Alaska Department of Fish and Game has closed sport fishing for cutthroat trout in Prince William Sound from 15 April to 14 June to protect the fish during spawning. Only 2 fish/day are allowed to be harvested during the remainder of the year.

Understanding the existing use patterns of recreation boaters within the study area provides limited information to the direct management of the cutthroat trout species. The sport fishing harvest records gathered by the Alaska Department of Fish and Game provide more direct information than the general use patterns described in this report. However, these patterns do provide a broader understanding of activity relative to the streams with cutthroat trout (e.g., Fig. 24). Managers may consider these patterns to prioritize areas to monitor for habitat changes from human use that may affect the quality of the habitat for cutthroat trout and the fishing pressure that these populations receive. This information can facilitate interagency coordination of human use management in these important habitat areas.

What are the competing/conflicting areas between user groups?

While the focus of the work reported here was to synthesize baseline data on human use in order to provide a basis for understand existing or potential disturbance pressure on injured species, this information may be even more valuable as a tool to managers interested in understanding the competing interests of user groups throughout the Sound. The Chugach National Forest revises its land management plan that guides land management on a 10-15 year interval. Many different user groups typically work with the National Forest and with the State Department of Natural Resources through a cooperative process to ensure that their concerns are addressed during the revision process.

Blackstone Bay is one of the areas that are of concern to many people. Its nearness to Whittier and its tidewater glacier make it a popular location for kayakers, recreational boaters, cruise ships (e.g., day cruises), and charter boats. The mean number of occurrences of vessels in each user group for May through September may be presented (Fig. 31). Although this information provides a useful comparison of relative use in Blackstone Bay by the different user groups, it also highlights some of the limitations of our data. There are 3 obvious weaknesses. First, our information for recreation motor boats is based on estimates of the number of boats that choose Blackstone Bay as their destination for their trip into the Sound. We were unable to estimate the number of recreation motor boats that may make a side trip into Blackstone Bay (or any other analysis area) as part of their trip to reach their final destination in an analysis area further into the Sound. Therefore, we feel that this user group is probably under represented in many of the analysis areas – especially for those areas close to Whittier. Similarly, commercial fishing boats are not shown in this analysis area because it is not a commercial fishing location. We were unable to document how commercial fishers may use the Sound outside of their commercial fishing activities.

Unlike the other user groups, the vessels in the cruise ship and State ferries user group had a predictable route and schedule. Therefore, barring mechanical failures or cancellations due to weather, the number of occurrences for this user group are expected to be accurate. Thus, while our results probably under represent the recreation and commercial fishing user groups, they are more accurate for the cruise ships that use the bay (Fig. 31). For all user groups, except kayaks, the number of estimated vessels for each user group was doubled to represent that a boat makes a trip into the bay and an associated trip out of the bay.

CONCLUSIONS

Our review of the literature and description of current human-use patterns provide a basis to summarize recommendations to managers that a variety of authors have made in the course of

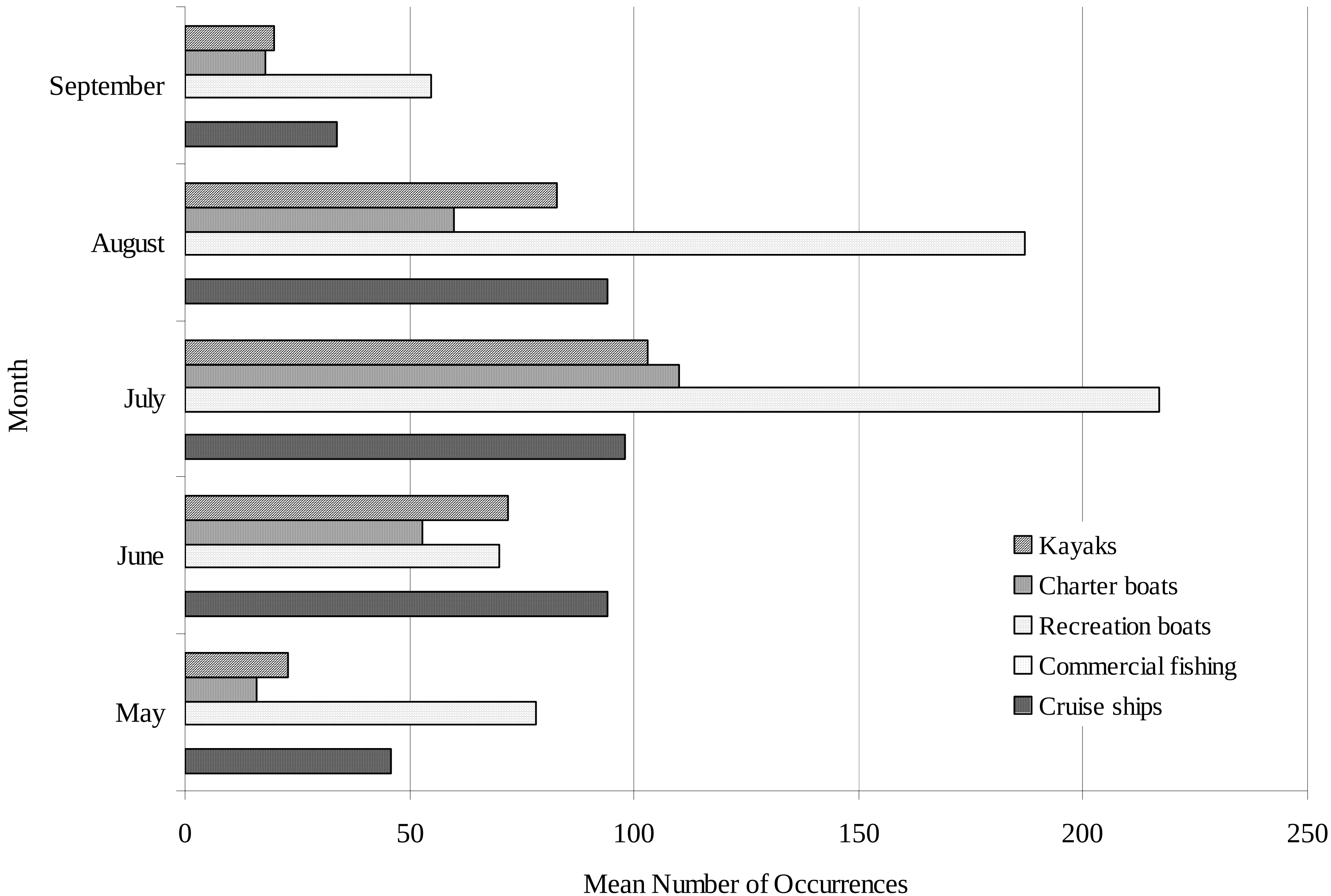


Fig. 31. Distribution of user groups in Blackstone Bay, Prince William Sound, Alaska, May--September, 1998.

their specific studies. In considering the appropriate management strategy for a specific situation, the following questions from Duffy and Schneider (1994:33) should be considered.

> "First, what are the consequences of believing there is no interaction when there actually is (i.e., 'Type II error' to the statistician)? Are there endemic or endangered species that might be lost if nothing is done? Or are most of the species common and widely distributed? […are the animals feeding in a few areas,] so that local food demand and thus competition might be focalized and severe? […or is a population dispersed] so competition is likely to be diffuse? Second, what are the consequences if the manager believes an interaction is occurring when in fact there is none (i.e., 'Type I error')? Should the manager make a decision not to be right, but to minimize the cost of being wrong? Which type of error would cost more? Which is the 'least worst'!"

Understanding the effects of disturbance is even more problematic when: 1) species of interest remain in the area but the disturbance unpredictably changes their rates of survival, reproduction, or dispersal, and 2) where the populations being affected are migratory so their year-round dynamics are difficult to study (Goss-Custard and Durell 1990). From an ecosystem perspective, the effects of disturbance are especially severe if they affect the density or distribution of species that functionally dominate the system (Cole and Landres 1995). For instance, studies have shown that the removal of sea otters from areas can result in an enormous increase in urchins. Urchins, in turn, eat the kelp forests, which provide food and shelter for whole communities of sea life. Thus, the removal or reduction of sea otters can result in a dramatic change in the ecosystem (Reidman and Estes 1990).

Many articles that presented approaches for managing people to reduce the effects of disturbance on wildlife identified the same range of protective measures. Potential protective measures included (1) public education, (2) enforcement of existing laws and regulations, (3) exclusion of specific forms of transportation (ranging from cars to jet skis), (4) exclusion of dogs and the removal of other introduced predators, (5) excluding people from large or small areas, (6) redirecting public access, and (7) habitat manipulation (e.g. Pienkowski 1993, Velarde and Anderson 1994). Because land management jurisdiction in the Sound is so complex, public education may be one of the strongest tools available to managers. Tershy et al. (1997) studied the effects of human disturbance on San Pedro Martir Island in the Gulf of California. They examined the effects of different user groups on the populations of birds and marine mammals that depend on the island. They found that the ecotourism groups that visited the island caused one of the lowest levels of disturbance to the local wildlife – probably due to a combination of a well designed education program and permit regulations. While other studies have documented reduced productivity and other negative effects as a result of disturbance from ecotourism groups (e.g., Burger et al. 1995), Tershy et al. (1997) indicated that education can effectively reduce disturbance.

ACKNOWLEDGEMENTS

This project could not have been completed without the support of many other people. We are particularly grateful to the people and companies who provided information and data on activities in the Sound. C. Beck, C. Buchholdt, the Heddells, E. Huffines, P. McNees, C. Pratt, G. Sanger, the von Wichmans, and the Whittier Harbor staff provided data and advice that formed much of the core of our knowledge about current activity patterns in the Sound. P.

Twardock and D. Wheeler worked with us to refine information on kayak activity from Whittier. The Chenega Bay IRA Council gathered additional information on activities in the southwestern portion of the Sound.

The Chugach National Forest GIS staff provided invaluable expertise in developing the spatial distributions of human use activity. Karin Preston and Linda Kelly were instrumental in developing the GIS programs used in this project. We would also like to thank other Chugach National Forest and Alaska Department of Natural Resources employees for contributing their time and expertise to this project. We are grateful to D. Gillikin, B. Kitto, E. Lance, S. Oehlers, D. Strehle, and J. Urbanus of the Chugach National Forest, and J. Gilpin and K. Reed of the Alaska Department of Natural Resources who all contributed substantial amounts of time and energy.

LITERATURE CITED

Ahlund, M., and F. Gotmark. 1989. Gull predation on eider ducklings *Somateria mollissima*: effects of human disturbance. Biological Conservation 48:115-127.

Alaska Department of Natural Resources. 1999. Alaska's outdoor legacy, Statewide comprehensive outdoor recreation plan (SCORP), 1997-2002. Division of Parks and Outdoor Recreation, Department of Natural Resources, Anchorage, Alaska, USA.

Alaska Department of Transportation and Public Facilities and Federal Highway Administration. 1995. Whittier access project. Final environmental impact statement and final section 4(f) evaluation. Federal Highway Administration and Alaska Department of Transportation and Public Facilities, FHWA-AK-EIS-94-02-DR, Anchorage, Alaska, USA.

Alaska Visitors Association. 1999. Tourism wise. Alaska Visitors Association, Anchorage, Alaska, USA

Allen, S. G., D. G. Ainley, G. W. Page, and C. A. Ribic. 1984. The effect of disturbance on harbor seal haul out patterns at Bolinas Lagoon, California. Fishery Bulletin 82:493-500

Anderson, D. W. 1988. Dose-response relationship between human disturbance and brown pelican breeding success. Wildlife Society Bulletin 16:339-345.

Anderson, D. W., and J. O. Keith. 1980. The human influence on seabird nesting success: conservation implications. Biological Conservation 18:65-80.

Au, D., and W. Perryman. 1982. Movement and speed of dolphin schools responding to an approaching ship. Fishery Bulletin 80:371-379.

Bain, D. E., and M. E. Dahlheim. 1994. Effects of masking noise on detection thresholds of killer whales. Pages 243-256 *in* T.R. Loughlin, editor. Marine Mammals and the Exxon Valdez. Academic Press, San Diego, California, USA.

Baker, C. S., and L. M. Herman. 1989. Behavorial responses of summering humpback whales to vessel traffic: experimental and opportunistic observations. NPS-NR-TRS-89-01. Kewalo Basin Marine Mammal Laboratory, University of Hawaii, Honolulu for National Park Service, Anchorage, Alaska, USA.

Baker, C. S., L. M. Herman, B. G. Bays, and G. Bauer. 1983. The impact of vessel traffic on the behavior of humpback whales in southeast Alaska: 1982 season. Kewalo Basin Marine

Mammal Laboratory, University of Hawaii, Honolulu for National Marine Fisheries Service, National Marine Mammal Laboratory, Seattle, Washington, USA.

Baker, C. S., L. M. Herman, B. G. Bays, and W. F. Stifel. 1982. The impact of vessel traffic on the behavior of humpback whales in southeast Alaska. Contract No. 81-ABC-00114. Kewalo Basin Marine Mammal Laboratory, University of Hawaii, Honolulu for National Marine Fisheries Service, Seattle, Washington, USA.

Banks, R. C., R. W. McDiarmid, and A. L. Gardner. 1987. Checklist of vertebrates of the United States, the U.S. Territories, and Canada. United States Department of the Interior Fish and Wildlife Service Resource Publication 166

Barlow, J. 1988. Harbor porpoise, *Phocoena phocoena*, abundance estimation for California, Oregon, and Washington: I. Ship survey. Fishery Bulletin 86:417-432.

Batten, L. A. 1977. Sailing on reservoirs and its effects on waterbirds. Biological Conservation 15:49-58.

Bauer, G. B. 1986. The behavior of humpback whales in Hawaii and modifications of behavior induced by human interventions. Dissertation, University of Hawaii, Honolulu, USA.

Bauer, G.B., and L.M. Herman. 1986. Effects of vessel traffic on the behavior of humpback whales in Hawaii. Kewalo Basin Marine Mammal Laboratory, University of Hawaii, Honolulu for National Marine Fisheries Service, Honolulu, Hawaii.

Bauer, G. B., J. R. Mobley, and L. M. Herman. 1993. Responses of wintering humpback whales to vessel traffic. Journal of the Acoustic Society of America 94:1848.

Belanger, L., and J. Bedard. 1990. Energetic cost of man-induced disturbance to staging snow geese. Journal of Wildlife Management 54:36-41.

Bel'kovich V. M. 1960. Some biological observations on the white whale from the aircraft. Zoological Journal 39:1414-1422.

Blane, J. M., and R. Jaakson. 1994. The impact of ecotourism boats on the St. Lawrence beluga whales. Environmental Conservation 21:267-269.

Bogoslovskaya, L. S., L. M. Votrogov, and T. N. Semenova. 1981. Feeding habits of the gray whale off Chukotka. Report of the International Whaling Commission 31:507-510.

Bonner, W. N. 1982. Seals and man. A study of interactions. University of Washington Press, Seattle, Washington, USA.

Born, E. W., M. P. Heide-Jorgensen, F. Larsen, and A. R. Martin. 1994. Abundance and stock composition of narwhals (*Monodon monoceros*) in Inglefield Breding (NW Greenland). Meddelelser om Gronland. Bioscience 39:51-68.

Bowles, A., and B. S. Stewart. 1980. Disturbances to the pinnipeds and birds of San Miguel Island, 1979-1980. Pages 99-137 *in* J.R. Jehl, Jr., and C.F. Cooper, editors. Potential effects of space shuttle sonic booms on the biota and geology of the California Channel Islands: research reports. Technical Report 80-1. Center for Marine Studies, San Diego State University, and Hubbs/Sea World Research Institute, San Diego , California, USA.

Boyle, S. A., and F. B. Samson. 1985. Effects of nonconsumptive recreation on wildlife: a review. Wildlife Society Bulletin 13:110-116.

Brown, A. L. 1990. Measuring the effect of aircraft noise on seabirds. Environmental International 16: 587-592.

Bunnell, F. L., D. Dunbar, L. Koza, and G. Ryder. 1981. Effects of disturbance on the productivity and numbers of white pelicans in British Columbia - observations and models. Colonial Waterbirds 4:2-11.

Burger, J. 1981a. The effect of human activity on birds at a coastal bay. Biological Conservation 19:231-241.

Burger, J. 1981b. Effects of human disturbance on colonial species, particularly gulls. Colonial Waterbirds 4:28-36.

Burger, J. 1986. The effect of human activity on shorebirds in two coastal bays in Northeastern United States. Environmental Conservation 13:123-130.

Burger, J., and M. Gochfeld. 1994. Predation and effects of humans on island nesting seabirds. BirdLife Conservation 1:39-67.

Burger, J., M. Gochfeld, and L. J. Nikes. 1995. Ecotourism and birds in Coastal New Jersey: contrasting responses of birds, tourists, and managers. Environmental Conservation 22:56-65.

Burton, N. H. K, P. R. Evans, and M. A. Robinson. 1996. Effects on shorebird numbers of disturbance, the loss of a roost site and its replacement by an artificial island at Hartlepool, Cleveland. Biological Conservation 77:193-201.

Cairns, D. 1980. Nesting density, habitat structure and human disturbance as factors in black guillemot reproduction. Wilson Bulletin 92:352-361.

Calambokidis, J., G. H. Steiger, and L. E. Healey. 1983. Behavior of harbor seals and their reaction to vessels in Glacier Bay, Alaska. Page 16 *in* Abstracts 5th Biennal Conference on Biology of Marine Mammals, Boston, Massachusetts, USA.

Choate, J. S. 1967. Factors influencing nesting success of eiders in Penobscot Bay, Maine. Journal of Wildlife Management 31:769-777.

Clarke, J. T., S. E. Moore, and D. K. Ljungblad. 1989. Observations on gray whale (*Eschrichtius robustus*) utilization patterns in the northeastern Chukchi Sea, July-October 1982-1987. Canadian Journal Zoology 67:2646-2654.

Cole, D. N., and P. B. Landres. 1995. Indirect effects of recreation on wildlife. Pages 183-202 *in* R.L. Knight, and K.J. Gutzwiller, editors. Wildlife and recreationists--coexistence through management and research. Island Press, Washington, D.C., USA.

Cooke, A. S. 1980. Observations on how close certain passerine species will tolerate an approaching human in rural and suburban areas. Biological Conservation 18:85-88.

Cryer, M., N. W. Linley, R. M. Ward, J. O. Stratford, and P. F. Randerson. 1987. Disturbance of overwintering wildfowl by anglers at two reservoir sites in South Wales. Bird Study 34:191-199.

Curry, T. L. 1995. Effects of aircraft overflights on behavior and reproductive success of thick-billed murres (*Uria lomvia*) on St. George Island, Alaska. Thesis, University of Alaska, Fairbanks, Alaska, USA.

Davidson, N. C., and P. I. Rothwell. 1993. Human disturbance to waterfowl on estuaries: conservation and coastal management implications of current knowledge. Wader Study Group Bulletin 68:97-106.

Davis, R. A., and A. N. Wiseley. 1974. Normal behavior of snow geese on the Yukon-Alaska North Slope and the effects of aircraft-induced disturbance on this behavior, September, 1973. Pages 1-85 *in* W. W. H. Gunn, W. J. Richardson, R. E. Schweinsburg, and T. D. Wright, editors. Studies of snow geese and other waterfowl in the North-west Territories, Yukon Territory and Alaska, 1973. Arctic Gas Biological Report Series 27.

Duffy, D. C., and D. C. Schneider. 1994. Seabird-fishery interactions: a manager's guide. BirdLife Conservation 1:26-38

English, D. B. K., C. J. Betz, J. M. Young, J. C. Bergstrom, and H. K. Cordell. 1993. Regional demand and supply projections for outdoor recreation. United States Department of Agriculture Forest Service, General Technical Report RM-230.

Environmental Systems Research Institute, Inc. 1994. Cell-based modeling with GRID. Environmental Systems Research Institute, Inc., Redlands, California, USA.

Erwin, M. R. 1980. Breeding habitat use by colonially nesting waterbirds in two mid-Atlantic US regions under different regimes of human disturbance. Biological Conservation 18:39-51.

Erwin, M. R. 1989. Response to human intruders by birds nesting in colonies: experimental results and management guidelines. Colonial Waterbirds 12:104-108.

Exxon Valdez Oil Spill Trustee Council. 2002. Exxon Valdez oil spill restoration plan. Update on injured resources and services. *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska, USA.

Fay, F. H. 1981. Modern populations, migrations, demography, trophics, and historical status of the Pacific walrus. Pages 191-234 *in* Outer Continental Shelf Environmental Assessment Program, Final Report of Principal Investigators, National Oceanic and Atmospheric Administration, Boulder, Colorado, USA.

Fay, F. H. and C. Ray. 1968. Influence of climate on the distribution of walruses, *Odobenus rosmarus* (Linnaeus) I. Evidence from thermoregulatory behavior. Zoologica 53:1-18.

Finley, K. J., G. W. Miller, R. A. Davis, and C. R. Green. 1984. Responses of narwhals (*Monodon monoceros*) and belugas (*Delphinapterus leucas*) to ice-breaking ships in Lancaster Sound-1983. Unpublished report submitted to Northern Environmental Protection Branch Canada Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada.

Fisher, A. C., and J. V. Krutilla. 1972. Determination of optimal capacity of resource-based recreation facilities. Natural Resources Journal 12:417-444.

Flemming, S. P.; R. D. Chiasson, and P. C. Smith. 1988. Piping plover status in Nova Scotia related to its reproductive and behavioral responses to human disturbance. Journal of Field Ornithology 59:321-330.

Fox, A. D., D. V. Bell, and G. P. Mudge. 1993. A preliminary study of the effects of disturbance on feeding wigeon grazing on eel-grass Zostera. Wader Study Group Bulletin 68:67-71.

Fraker, M. A. 1977a. The 1976 white whale monitoring program, Mackenzie Estuary, N.W.T. F.F. Slaner & Co. Ltd., Vancouver, British Columbia for Imperial Oil, Ltd., Calgary, Alberta, Canada.

Fraker, M. A. 1977b. The 1977 whale monitoring program/Mackenzie Estuary, N.W.T. F.F. Slaner & Co. Ltd., Vancouver, British Columbia for Imperial Oil, Ltd., Calgary, Alberta, Canada.

Fraker, M. A., W. J. Richardson, and B. Wursig. 1982. Disturbance responses of bowheads. Pages 145-248 *in* W.J. Richardson, editor. Behavior, disturbance responses and feeding of bowhead whales *Balaena mysticetus* in the Beaufort Sea, 1980-81. LGL Ecological Research Associates, Inc., Bryan, Texas, USA for USDI Bureau of Land Management, Washington, D.C., USA.

Frost, K. J. 1996. Harbor seal *Phoca vitulina richardsi*. Restoration Notebook. *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska, USA.

Frost, K. J., L. F. Lowry, and G. Carroll. 1993. Beluga whale and spotted seal use of a coastal lagoon system in the northeastern Chukchi Sea. Arctic 46:8-16.

Garrott, R. A., L. L. Eberhardt, and D. M. Burn. 1993. Mortality of sea otters in Prince William Sound following the Exxon Valdez oil spill. Marine Mammal Science 9:343-359.

Garshelis, D. L., and J. A. Garshelis. 1984. Movements and management of sea otters in Alaska. Journal Wildlife Management 48:665-678.

Gerrard, P. N., J. M. Gerrard, and G. R. Bartolotti. 1983. The impact of road development and tourist access on a bald eagle population at Besnard Lake Saskatchewan. Pages 160-165 *in* J. M. Gerrard and T. N. Ingram, editors. The bald eagle in Canada. Proceedings of bald eagle days, 1983.

Gerrodette, T. and W. G. Gilmartin. 1990. Demographic consequences of changed pupping and hauling sites of the Hawaiian monk seal. Conservation Biology 4:423-430.

Gillett, W. H., Hayward, J. L. Jr., and J. F. Stout. 1975. Effects of human activity on egg and chick mortality in a glaucous-winged gull colony. Condor 77:492-495

Glimmerveen, U., and W. Went. 1984. Dossis-effect relatie bij verstoring van wadvogels. Unpublished Report, Inst. Landschapsoecologie en Natuurbeheer R.U. Utrecht.

Gochfeld, M. 1981. Differences in behavioral responses of young common terns and black skimmers to intrusion and handling. Colonial Waterbirds 4:47-53.

Gorzelany, J. F. 1998. Unusual deaths of two free-ranging Atlantic bottlenose dolphins (*Tursiops truncatus*) related to ingestion of recreational fishing gear. Marine Mammal Science 14:614-617.

Goss-Custard, J.D., and N. Verbovan. 1993. Disturbance and feeding shorebirds on the Exe estuary. Wader Study Group Bulletin 68:59-66.

Goss-Custard, J. D., and SEA Le V. dit. Durell. 1990. Bird behavior and environmental planning: approaches in the study of wader populations. Ibis 32:273-289.

Gotmark, F., and M. Ahlund. 1984. Do field observers attract nest predators and influence nesting success of common eiders? Journal of Wildlife Management 48:381-387.

Green, G. A., J. J. Brueggeman, R. A. Grotefendt, C. E. Bowlby, M. L. Bonnell, and K. C. Balcomb, III. 1992. Cetacean distribution and abundance off Oregon and Washington, 1989-1990. Chapter I *in* J. J. Brueggeman, editor. Oregon and Washington marine mammal and seabird surveys. Report from EBASCO Environmental and Ecological Consulting Inc. to U.S. Minerals Management Service, Pacific Outer Continental Shelf Region, OCS Study MMS 91-0093, Los Angeles, California, USA.

Gresswell, R. E., editor. 1988. Status and management of interior stocks of cutthroat trout. American Fisheries Society Symposium 4.

Gresswell, R. E., and R. D. Harding. 1997. The role of special angling regulations in management of coastal cutthroat trout. Pages 151-156 *in* J. D. Hall, P. A. Bisson, and R. E. Gresswell, editors. Sea-run cutthroat trout: biology, management, and future considerations. Oregon Chapter, American Fisheries Society, Corvallis, Oregon, USA.

Heberlein, T. A., G. E. Alfano, L. H. Ervin. 1986. Using a social carrying capacity model to estimate the effects of marina development at the Apostle Islands National Lakeshore. Leisure Sciences 8:257-274.

Hammitt, W. E., C. D. McDonald, and F. P. Poe. 1984. Use level and encounters: important variables of perceived crowding among nonspecialized recreationists. Journal of Leisure Research 16:1-8.

Havera, S., L. R. Boens, M. M. Georgi, and R. T. Shealy. 1992. Human disturbance of waterfowl on Keokuk Pool, Mississippi River. Wildlife Society Bulletin 20:290-298.

Heinen, R. 1986. Untersuchung uber den Einfluss des Flugverhehrs auf brutende und rastende Kustenvogel an ausgewahlten Stellen des niedersachsischen Wattenmeergebietes. Unpublished Report, (Diplomarbeit) University Essen.

Henny, C. J., L. J. Blus, S. P. Thompson, and U. W. Wilson. 1989. Environmental contaminants, human disturbance and nesting of double crested cormorants in northwestern Washington. Colonial Waterbirds 12:198-206.

Hepler, K. R., P. A. Hansen, and D. R. Bernard. 1996. Impact of oil spilled from the *Exxon Valdez* on survival and growth of Dolly Varden and cutthroat trout in Prince William Sound. American Fisheries Society Symposium 18:645-658.

Hewitt, R. P. 1985. Reaction of dolphins to a survey vessel: effects on census data. Fisheries Bulletin 83:187-193.

Hirons, G., and G. Thomas. 1993. Disturbance on estuaries: RSPB nature reserve experience. Wader Study Group Bulletin 68:72-78.

Hockin, D., M. Ounsted, M. Gorman, D. Hill, V. Keller, and M. A. Barker. 1992. Examination of the effects of disturbance on birds with reference to its importance in ecological assessments. Journal of Environmental Management 36:253-286.

Hoover, A. A. 1988. Harbor seal *Phoca vitulina*. Pages 125-157 *in* J.W. Lentfer, editor. Selected marine mammals of Alaska. Species accounts with research and management recommendations. U.S. Marine Mammal Commission, Washington, D.C., USA.

Hoover-Miller, A. A. 1994. Harbor seal (*Phoca vitulina*) biology and management in Alaska. Contract T75134749. Marine Mammal Commission, Washington, D.C., USA.

Jay, C. V., T. L. Olson, G. W. Garner, B. E. Ballachey. 1998. Response of Pacific walruses to disturbances from capture and handling activities at a haul-out in Bristol Bay, Alaska. Marine Mammal Science 14:819-828.

Jeffrey, R. G. 1987. Influence of human disturbance on the nesting success of African black oystercatchers. South African Journal of Wildlife Research 17:71-72.

Johnson, B. W. 1977. The effects of human disturbance on a population of harbor seals. Pages 422-432 *in* Environmental Assessment of the Alaskan Continental Shelf, Volume I. Receptors--Mammals. Outer Continental Shelf Environmental Assessment Program, Boulder, Colorado, USA.

Johnson, J. and L. Merritt. 1996. Commercial salmon catch statistics for the Prince William Sound management area, 1996. Alaska Department of Fish and Game Regional Information Report 2A96-39, Anchorage, Alaska, USA.

Johnson, S. R., J. J. Burns, C. I. Malme, and R. A. Davis. 1989. Synthesis of information on the effects of noise and disturbance on major haulout concentrations of Bering Sea pinnipeds. U.S. Minerals Management Services, Alaskan Outer Continental Shelf Region, Contract 14-12-0001-30361. LGL Alaska Research Associates, Anchorage, Alaska, USA.

Kahl, R. 1991. Boating disturbance of canvasbacks during migration at Lake Poygan, Wisconsin. Wildlife Society Bulletin 19:242-248.

Keller, V. E. 1989. Variations in the response of great crested grebes *Podiceps cris*tatus to human disturbance - a sign of adaptation? Biological Conservation 49:31-45.

Keller, V. E. 1991. Effects of human disturbance on eider ducklings *Somateria mollissima* in an estuarine habitat in Scotland. Biological Conservation 58:213-228.

Kelly, B. P., L. T. Quakenbush, and J. R. Rose. 1986. Ringed seal winter ecology and effects of noise disturbance. Pages 447-536 *in* Outer Continental Shelf Environmental Assessment Program, Final Report of Principal Investigators, National Oceanic and Atmospheric Administration OCS Study MMS 89-0026, Anchorage, Alaska, USA.

Kenyon, K. W. 1972. Man versus the monk seal. Journal of Mammalogy 53:687-696.

Kibal'chich, A. A., G. A. Dzhamanov, and M. V. Ivashin. 1986. Records of bowhead and gray whales in early winter in the Bering Sea. Report of the international Whaling Commission 36:291-292.

Kingsley, M. C. S., H. J. Cleator, and M. A. Ramsay. 1994. Summer distribution and movements of narwhals (*Monodon monoceros*) in Eclipse Sound and adjacent waters, north Baffin Island, N.W.T. Meddelelser om Gronland. Bioscience 39:163-174.

Kirby, J. S., C. Clee, and V. Seager. 1993. Impact and extent of recreational disturbance to wader roosts on the Dee estuary: some preliminary results. Wader Study Group Bulletin 68:53-58.

Klein, M. L., S. R. Humphrey, and H. F. Percival. 1995. The effects of ecotourism on distribution of waterbirds in a wildlife refuge. Biological Conservation 9:1454-1464.

Knight, R. L. 1984. Responses of wintering bald eagles to boating activity. Journal of Wildlife Management 48:999-1004.

Koepff, C., and K. Dietrich. 1986. Storungen von Kustenvogeln durch Wasserfahrzeuge. Vogelwarte 33:232-248.

Korschgen, C. E., L. S. George, and W. L. Green. 1985. Disturbance of diving ducks by boaters on a migrational staging area. Wildlife Society Bulletin 13:290-296.

Kovacs, K. M. and S. Innes. 1990. The impact of tourism on harp seals (*Phoca groenlandica*) in the Gulf of St. Lawrence, Canada. Applied Animal Behavioral Science 26:15-26.

Kruse, S. 1991. The interactions between killer whales and boats in Johnstone Strait, B.C. Pages 149-159 *in* K. Pryor and K.S. Norris, editors. Dolphin societies: discoveries and puzzles. University of California Press, Berkeley, California, USA.

Kuletz, K. 1996. Marbled murrelet abundance and breeding activity at Naked Island, Prince William Sound, and Kachemak Bay, Alaska, before and after the Exxon Valdez oil spill. American Fisheries Society Symposium 18:770-784.

Kuletz, K. 1998. Pigeon Guillemot (*Cepphus columba*). Restoration Notebook, Exxon Valdez Oil Spill Trustee Council, Anchorage, Alaska, USA.

Kushlan, J. A. 1979. Effects of helicopter censuses on wading bird colonies. Journal of Wildlife Management 43:756-760.

Leatherwood, S., F. T. Awbrey, and J. A. Thomas. 1982. Minke whale response to a transiting survey vessel. Report International Whaling Commission 32:795-802.

Lesage, V., C. Barrette, C., M. C. S. Kingsley, and B. Sjare. 1999. The effect of vessel noise on the vocal behavior of belugas in the St. Lawrence River Estuary, Canada. Marine Mammal Science 15:65-84.

Ljungblad, D. K. 1986. Endangered whale aerial surveys in the Navarin Basin and St. Matthew Hall planning areas, Alaska. U.S. Naval Ocean Systems Center, NOSC TR 1111, San Diego, California, USA.

Lucas, R. C. 1980. Use patterns and visitor characteristics, attitudes, and preferences in nine wilderness and other roadless areas. United States Department of Agriculture Forest Service Research Paper INT-253.

Malme, C. I., P. R. Miles, C. W. Clark, P. Tyack, and J. E. Bird. 1983. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior. Report from Bolt Beranek & Newman Inc. to U.S. Minerals Management Service, BBN Rep. 5366, Anchorage, Alaska, USA.

Malme, C. I., P. R. Miles, C. W. Clark, P. Tyack, and J. E. Bird. 1984. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior. Phase II: January 1984 migration. Report from Bolt Beranek & Newman Inc. to U.S. Minerals Management Service, BBN Rep. 5586, Anchorage, Alaska, USA.

Mansfield, A.W. 1983. The effects of vessel traffic in the Arctic on marine mammals and recommendations for future research. Canadian Technical Report of Fisheries and Aquatic Sciences 1186.

Mansfield, A. W., and D. J. St. Aubin. 1991. Distribution and abundance of the Atlantic walrus, *Odobenus rosmarus rosmarus*, in the Southhampton Island-Coats Island region of northern Hudson Bay. Canadian Field-Naturalist 105:95-100.

Manuwal, D. A. 1978. Effect of man on marine birds: a review. Pages 140-160 *in* J. S. Wright, editor. Wildlife and people. Purdue Research Foundation, West Lafayette, Indiana, USA.

Mehlum, F., and V. Bakken. 1994. Seabirds in Svalbad (Norway): status, recent changes and management. Pages 155-171 *in* D. N. Nettleship, J. Burger, and M. Gochfeld, editors. Seabirds on islands: threats, case studies and action plans. BirdLife International, Cambridge, England, United Kingdom.

Menefee, W., and S. Hennig. 1994. Prince William Sound recreation project. *Exxon Valdez* Oil Spill Restoration Final Report (Restoration Projects 93065 and 94217), Alaska Department of Natural Resources, Anchorage, Alaska, USA.

Miller, G. W., and R. A. Davis. 1984. Distribution and movements of narwhals and beluga whales in response to ship traffic at the Lancaster Sound ice edge - 1984. LGL Limited Environmental Research Associates report to Northern Environmental Protection Branch, Canada Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada.

Murphy, E. C., and A. A. Hoover. 1981. Research study of the reactions of wildlife to boating activity along Kenai fjords coastline. Final Report to National Park Service Contract CX-9000-8-0151. Alaska Cooperative Park Studies Unit, University of Alaska, Fairbanks, Alaska, USA.

Nishiwaki, M., and A. Sasao. 1977. Human activities disturbing natural migration routes of whales. Scientific Report of Whales Research Institute 29:113-120.

Osborn, L. S. 1985. Population dynamics, behavior, and the effect of disturbance on haulout patterns of the harbor seal *Phoca vitulina rechardsi*. Elkhorn Sough, Monterey Bay, California. Thesis, University of California, Santa Cruz, Califronis, USA.

Ovsyanikov, N. G., L. L. Bove, and A. A. Kochnev. 1994. The factors causing mass death of walruses on coastal rookeries. Zoological Journal 73:80-87 (in Russian with English summary).

Owens, N. W. 1977. Responses of wintering brent geese to human disturbance. Wildfowl 28:5-14.

Pfister, C., B. A. Harrington, and M. Lavine. 1992. The impact of human disturbance on shorebirds at a migration staging area. Biological Conservation 60:115-126.

Piatt, J. F., B. D. Roberts, W. W. Lidster, J. L. Wells, and S. A. Hatch. 1990. Effects of human disturbance on breeding least and crested auklets at St. Lawrence Island, Alaska. Auk 107:342-350.

Pienkowski, M. W. 1993. The impact of tourism on coastal breeding waders in western and southern Europe: an overview. Wader Study Group Bulletin 68:92-96.

Pierce, D. J., and T. R. Simons. 1986. The influence of human disturbance on tufted puffin breeding success. Auk 103:214-216.

Pitcher, K. W., and D. G. Calkins. 1979. Biology of the harbor seal, *Phoca vitulina richardsi*, in the Gulf of Alaska. Pages 231-310 *in* Outer Continental Shelf Environmental Assessment Program, Final Report of Principal Investigators, National Oceanic and Atmospheric Administration, Boulder, Colorado, USA.

Polacheck, T., and L. Thorpe. 1990. The swimming direction of harbor porpoise in relationship to a survey vessel. Report International Whaling Commission 40:463-470.

Renouf, D., L. Gaborko, G. Galway, and R. Finlayson. 1981. The effect of disturbance on the daily movements of harbour seals and grey seals between the sea and their hauling grounds at Miquelon. Applied Animal Ethnology 7:373-379.

Richardson, W. J., and C. I. Malme. 1993. Man-made noise and behavioral responses. Pages 631-700 *in* J.J. Burns, J.J. Montague, and C.J. Cowles, editors. The bowhead whale. Special Publication 2, Society for Marine Mammalogy, Lawrence, Kansas, USA.

Richardson, W. J., M.A ., Fraker, B. Wursig, and R .S. Wells. 1985a. Behavior of bowhead whales *Balaena mysticetus* summering in the Beaufort Sea: reactions to industrial activities. Biological Conservation 32:195-230.

Richardson, W. J., C. R. Greene, and B. Wursig. 1985b. Behaviour, disturbance responses and distribution of bowhead whales *Balaena mysticetus* in the eastern Beaufort Sea, 1980-84: a summary. LGL Ecological Research Associates, Inc., Bryan, Texas for U.S. Minerals Management Service, Reston, Virginia, USA. Contract 14-12-0001-29051.

Richardson, W. J., C. R. Greene, Jr., C. I. Malme, and D. H. Thompson. 1995. Marine mammals and noise. Academic Press, New York, New York, USA.

Riedman, M. L., and J. A. Estes. 1990. The sea otter (*Enhydra lutris*): behavior, ecology, and natural history. United States Fish and Wildlife Service Biological Report 90(14).

Riffel, S. K., K. J. Gutzwiller, and S. H. Anderson. 1996. Does repeated human intrusion cause cumulative declines in avian richness and abundance. Ecological Applications 6:492-505.

Robert, H. C., and C. J. Ralph. 1975. Effects of human disturbance on the breeding success of gulls. Condor 77:490-495.

Robertson, R. J., and N. J. Flood. 1980. Effects of recreational use of shorelines on breeding bird populations. Canadian Field Naturalist 94:131-138.

Rodgers, J. A., Jr, and H. T. Smith. 1991. Minimum buffer zone requirement to protect nesting bird colonies from human disturbance. Page 55 *in* D.P. Jennings, editor. Proceedings of the Coastal Nongame Workshop, Southeast Region.

Rodgers, J. A., Jr, and H. T. Smith. 1995. Set-back distances to protect nesting bird colonies from human disturbance in Florida. Biological Conservation 9:89-99.

Salter, R. E. 1979. Site utilization, activity budgets, and disturbance responses of Atlantic walruses during terrestrial haul-out. Canadian Journal of Zoology 57:1169-1180.

Sanger, G. A., and M. B. Cody. 1994. Survey of pigeon guillemot colonies in Prince William Sound, Alaska. *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 93034), U.S. Fish and Wildlife Service, Anchorage, Alaska, USA.

Schmidt, A. E. 1997. Status of sea-run cutthroat trout stocks in Alaska. Pages 80-83 *in* J. D. Hall, P. A. Bisson, and R. E. Gresswell, editors. Sea-run cutthroat trout: biology, management, and future considerations. Oregon Chapter, American Fisheries Society, Corvallis, Oregon, USA.

Schulz, R., and M. Stock. 1993. Kentish plovers and tourists: competitors on sandy coasts? Wader Study Group Bulletin 68:83-91.

Serventy, D. L. and P. J. Curry. 1984. Observations on colony size, breeding success, recruitment and inter-colony dispersal in a Tasmanian colony of short-tailed shearwaters, *Puffinus tenuirostris* over a 30-year period. Emu 84:71-79.

Shelby, B. 1980. Crowding models for backcountry recreation. Land Economics 56:43-55.

Shelby, B., and T.A. Heberlein. 1986. Carrying capacities in recreation settings. Oregon State University Press, Corvallis.

Shon, L. A. 1981. Wilderness use and perceptions of crowding on the Kenai canoe routes, Alaska. Thesis, University of Alaska Fairbanks, Fairbanks, Alaska, USA.

Slater, L. M. and H. Markowitz. 1983. Spring population trends in *Phoca vitulina richardi* in two central California coastal areas. California Fish and Game 69:217-226.

Smit, C. J., and G. J. M. Visser. 1993. Effects of disturbance on shorebirds: a summary of existing knowledge from Dutch Wadden Sea and Delta area. Wader Study Group Bulletin 68:6-19.

Smith, E. L. 1981. Effects of canoeing on common loon production and survival on the Kenai National Wildlife Refuge, Alaska. Thesis, Colorado State University, Fort Collins, Colorado, USA.

SRA. 1988. Results of the 1986-1987 gray whale migration and landing craft, air cushion interaction study program. Report from SRA Southwest Research Associates to Naval Facilities Engineering Commission, U.S. Navy Contribution N62474-86-M-0942, San Bruno, California, USA.

Suryan, R. M., and J. T. Harvey. 1999. Variability in reactions of Pacific harbor seals, Phoca vitulina richardsi, to disturbance. Fishery Bulletin 97:332-339.

Swift, R., and L. Morgan. 1993. The effect of disturbance on harbor seal haul out in Bolinas Lagoon, California. Page 105 *in* Abstracts 10th Biennial Conference on the Biology of Marine Mammals, Galveston, Texas, USA.

Terhune, J. M., R. E. A. Stewart, and K. Ronald. 1979. Influence of vessel noises on underwater vocal activity of harp seals. Canadian Journal of Zoology 57:1337-1338.

Tershy, B. R., D. Breese, and D. A. Croll. 1997. Human perturbations and conservation strategies for San Pedro Martir Island, Islas del Golfo de California Reserve, Mexico. Environmental Conservation 24:261-270.

Thompson, C. W., K. Brennan, T. Hamer, C. Stron, and J. L. Laake. 1998. Behavior of marbled murrelets in response to survey vessels during at sea surveys: implications for use of line transects. Abstracts for the Pacific Seabird Group Twenty-6th annual meeting.

Thompson, P. M. 1992. The conservation of marine mammals in Scottish waters. Proceedings of the Royal Society of Edinburgh, Section B 100:123-140.

Titus, J. R., and L. W. VanDruff. 1981. Response of the common loon to recreational pressure in the Boundary Waters Canoe Area, Northeastern Minnesota. Wildlife Monograph 79.

Tomilin, A. G., and A. A. Kibal'chich. 1975. Walruses of the Wangel Island region. Zoological Journal 54:266-272.

Tuite, C. H., M. Owen, and D. Paynter. 1983. Interaction between wildfowl and recreation on Llangorse Lake and Talybont Reservoir, South Wales. Wildfowl 34:48-63.

Tuite, C. H., P. R. Hanson, and M. Owen. 1984. Some ecological factors affecting winter wildfowl distribution on inland waters in England and Wales, and the influence of water-based recreation. Journal of Applied Ecology 21:41-62.

Udevitz, M. S., J. L. Bodkin, and D. P. Costa. 1995. Detection of sea otters in boat-based surveys of Prince William Sound, Alaska. Marine Mammal Science 11:59-71.

U.S. Fish and Wildlife Service. 1999. Beringian seabird colony catalog – computer database. U.S. Fish and Wildlife Service, Migratory Bird Management, Anchorage, Alaska, USA.

van der Zande, A. N., and P. Vos. 1984. Impact of a semi-experimental increase in recreation intensity on the densities of birds in groves and hedges on a lake shore in the Netherlands. Biological Conservation 30:237-259.

Velarde, E., and W. Anderson. 1994. Conservation and management of seabird islands in the Gulf of California: setbacks and successes. BirdLife Conservation 1:229-243.

Vos, D. K., R. A. Ryder, and W. D. Graul. 1985. Response of breeding great blue herons to human disturbance in North-central Colorado. Colonial Waterbirds 8:13-22.

Ward, D. H., R. A. Stehn, and D. V. Derksen. 1994. Response of staging brant to disturbance at the Izembeck Lagoon, Alaska. Wildlife Society Bulletin 22:220-228.

Warheit, K .I., D. R. Lindberg, and R. J. Boekelheide. 1984. Pinniped disturbance lowers reproductive success of black oystercatchers *Haematopus bachmani* (Aves). Marine Ecology Program Series 17:101-104.

Watkins, W. A. 1986. Whale reactions to human activities in Cape Cod waters. Marine Mammal Science 2:251-262.

Watkins, W. A., and K. E. Moore. 1983. Three right whales (*Eubalaena glacialis*) alternating at the surface. Journal of Mammalogy 64:506-508.

Wells, R. S., and M. D. Scott. 1997. Seasonal incidence of boat strikes on bottlenose dolphins near Sarasota, Florida. Marine Mammal Science 13:475-480.

Wickens, P. A., D. W. Japp, P. A. Shelton, F. Kriel, P. C. Goosen, B. Rose, C. J. Augustyn, C. A. R. Bross, A. J. Penney, and R. G. Krohn.. 1992. Seals and fisheries in South Africa—competition and conflict. South African Journal of Marine Science 12:773-789.

Withrow, D .E. 1983. Gray whale research in Scammon's Lagoon (Laguna Ojo de Liebre). Cetus 5:8-13.

Withrow, D. E., G. C. Bouchet, and L. L. Jones. 1985. Response of Dall's porpoise (*Phocoenoides dalli*) to survey vessels in both offshore and nearshore waters: results of 1984 research. International North Pacific Fisheries Commission Document. U.S. National Marine Mammal Laboratory, Seattle, Washington. USA.

Wyrick, R. F. 1954. Observations on the movements of the Pacific gray whale *Eschrichtius glaucus* (Cope). Journal of Mammalogy 35:596-598.

Yalden, P. E. and D. W. Yalden. 1990. Recreational disturbance of breeding golden plovers *Pluvialis apricarius*. Biological Conservation 51:243-262.

APPENDIX A

Common and scientific names of birds, mammals, and fish mentioned in this report.[1]

Table A1. Common and scientific names of birds, mammals, and fish mentioned in this report.

Common name	Scientific name
Birds	
Short-tailed shearwater	*Puffinus tenuirostris*
Fork-tailed storm petrel	*Oceanodroma furcata*
Snow goose	*Chen caerulescens*
American white pelican	*Pelecanus erythrorhynchos*
Brown pelican	*Pelecanus occidentalis*
American wigeon	*Anas americana*
Eider	*Somateria* spp.
Piping plover	*Charadruis melodus*
Kentish plover	*Chardrius alexandrinus*
Golden plover	*Pluvialis* spp.
Black oystercatcher	*Haematopus bachmani*
European oystercatcher	*Haematopus ostralegus*
Red knot	*Calidris canutus*
Short-billed dowitcher	*Limnodromus griseus*
Curlew	*Numenius* spp.
Herring gull	*Larus argentatus*
Lesser black-backed gull	*Larus fuscus*
Heermann’s gull	*Larus heermanni*
Franklin’s gull	*Larus pipixcan*
Brown-headed gull	*Larus maculipennis*
Common tern	*Sterna hirundo*
Black skimmer	*Rynchops niger*
Crested auklet	*Aethia cristatella*
Marbled murrelet	*Brachyramphus marmoratus*
Pigeon guillemot	*Cepphus columba*
Black guillemot	*Cepphus grylle*
Least auklet	*Aethia pusilla*
Rhinoceros auklet	*Cerorhinca monocerata*
Tufted puffin	*Fratercula cirrhata*
Thick-billed murre	*Uria lomvia*

[1] Scientific nomenclature for birds and mammals follows Banks et al. 1987.

Table A1. Common and scientific names of birds, mammals, and fish mentioned in this report.

Common name	Scientific name
Mammals	
Mink	*Mustela vison*
Sea otter	*Enhydra lutris*
Northern fur seal	*Callorhinus ursinus*
Northern sea lion	*Eumetopias jubatus*
California sea lion	*Zalophus californianus*
Walrus	*Odobenus rosmarus*
Hawaiian monk seal	*Monachus schauinslandi*
Harp seal	*Phoca groenlandica*
Ringed seal	*Phoca hispida*
Harbor seal	*Phoca vitulina*
Long-snouted spinner dolphin	*Stenella longirostris*
Bottle-nosed dolphin	*Tursiops truncatus*
Harbor porpoise	*Phocoena phocoena*
Dall’s porpoise	*Phocoenoides dalli*
White whale	*Delphinapterus leucas*
Narwhal	*Monodon monoceros*
Baird’s beaked whale	*Mesoplodon*
Gray whale	*Eschrichtius robustus*
Minke whale	*Balaenoptera acutorostrata*
Fin whale	*Balaenoptera physalus*
Humpback whale	*Megatera novaeangliae*
Black right whale	*Balaena glacialis*
Bowhead whale	*Balaena mysticetus*
Fish	
Salmon	*Oncorhynchus* spp.
Blackcod	*Anoplopoma fimbria*
Pacific herring	*Clupea pallasii*
Cutthroat trout	*Oncorhynchus clarki*

APPENDIX B

Survey of recreational motor boat and kayak users in western Prince William Sound, Alaska, 1998.

These surveys were implemented to provide background information necessary to describe existing and potential human use patterns in the western Sound. The surveys were designed to describe current human use patterns, attitudes, and perceptions of how an individual's use patterns may change as overall use patterns change. Information generated from the surveys was integrated with other data to describe current human use patterns and to project changes in those patterns that may result from additional development in the Sound (e.g., increased access).

Previous user surveys specific to the Sound generally focused directly on the effects of the spill (e.g., Menefee and Hennig 1994). Others included a broader land base area, and dealt with attitudes about recreation in general (e.g., Chugach National Forest, unpublished data). Similar studies, primarily conducted as oral interviews, addressed user attitudes and perceptions (e.g., Shon 1981). Public comments that had been received on the Whittier Road Access Project were incorporated into the Final Environmental Impact Statement (Alaska Department of Transportation and Public 1995). Prior to the recreational boat and kayak surveys described here, there had not been surveys that specifically asked about recreation use and perceptions of use in the Sound based on increased access. Published studies from other parts of the country reinforced the need for baseline data, and showed that similarities among study areas are often more common than different (e.g., Lucas 1980).

METHODS

In the fall of 1997, the Alaska Department of Natural Resources, Division of Parks and Outdoor Recreation (i.e., Alaska State Parks), in conjunction with other agencies conducting planning for the Sound, developed these surveys. Before asking Sound users about existing patterns of human use, perceptions of use, and how use patterns might change, we examined 19 previous surveys related to the Sound, and published literature reporting recreation-related user studies (e.g., Chugach National Forest, unpublished data, Menefee and Hennig 1994, Alaska Department of Natural Resources 1999). Our purpose was to determine if survey questions had recently been asked that might be applicable to this project's objectives, might provide additional data for the model, and might provide management-related suggestions. We also wanted to examine similar work done elsewhere that might provide a comparative basis for this project effort.

Alaska State Parks staff, and other state and federal officials who have conducted surveys assisted in preparing, clarifying the direction for, and field testing these user surveys, based on their needs for addressing management concerns (J. Sinclair, W. Menefee, and K. Kruse, Alaska Department of Natural Resources, personal communication). Review and discussion of a US Forest Service customer visitor survey also provided a basis for comparison of baseline data (P. Reid, Chugach National Forest, unpublished data and personal communication).

Recreational motor boat users.—Based on previous experiences with surveys and public comment processes it was suggested that mail contact works better to quickly reach potential respondents, rather than personal contact when they are out recreating. A mail-out survey was determined to be the most efficient and expedient format. In addition, given limitations in staff, time, and budget, a mail out survey was much more practical than trying to conduct one-on-one interviews. Length of survey was short, to encourage response (Fig. B1). The largest target group available was permanent and temporary slip holders in the Whittier harbor. Because survey length was limited, and because the over-all project objectives were to describe the extent of human use through analysis of distribution of recreational boats in association with preferred destinations, demographic questions were not applicable, and therefore, were not included. A standardized set of vessel descriptions was incorporated into the survey for categorizing types of recreational boats based on size and function (Table B1). A cover letter was developed to provide instructions for respondents to follow. A map of the western Sound was included with the survey instrument to facilitate and standardize identification of destinations. The survey was field-tested with agency personnel, to anticipate possible responses, and to develop procedures for entering responses into the database.

On 27 February 1998, the cover letter, map, and survey were mailed to 350 permanent and transient slip holders having boats in Whittier. Names and addresses of slip holders were obtained from the Whittier Harbormaster. The survey form did not ask for the respondent's name. Respondents were asked to return their completed surveys by 16 March 1998. Return postage was provided. A general reminder was sent to non-respondents the 2nd week in March.

Kayakers.—To reach the largest number of individual kayakers possible, a broadcast email was sent in the fall of 1998 from several agencies to known recreational kayakers, asking them to respond if they might be willing to participate in a survey. They were also asked to forward the request on to other kayakers they knew. The request was also sent to several canoe and kayak clubs, asking them to disseminate the request to their members. The 70 individuals who responded were put on a master email list.

The survey was designed to gather information from kayakers who had actually kayaked in the Western Sound within the past 10 yrs, so that their perceptions about the Sound would be based on actual experience in the Sound. The email cover memo included instructions for participants to follow. It encouraged them to forward the form electronically to other known kayakers before completing the survey on line. The survey questions were grouped by existing/current use, perceptions of change due to increased access, and some demographic questions. Anonymity was assured when results were reported.

On 27 November 1998, the email cover memo and survey were electronically sent to 70 participants (Fig. B2). Another 10 surveys were emailed over the next 2 wks to additional participants who requested a copy. It is not known how many survey forms participants forwarded on. Participants were asked to return their completed surveys by 14 December 1998, either on line or by regular mail. A general reminder was emailed the 2nd week in December.

Data entry.—Prior to being entered in a Micro Soft Access database, survey responses were coded by Alaska State Parks staff. Codes were developed to include all responses, to allow the database to incorporate as much specificity as possible, and to include ranges of responses and open-ended responses. Responses were coded to capture both general and specific destination names (e.g., Blackstone Bay, Blackstone Glacier, Blackstone), single and multiple destination trips, and categories of the purpose of the trip. For example, "recreation" included the following specific purposes: relaxing, getting away, vacation, exploring, pleasure, overnighting, picnicking, fun, and seeing the scenery. Open-ended comments were categorized. In addition, unclear answers or answers outside of consistent coding categories were identified and coded for retrieval and evaluation. After coding, responses were entered into an Access database (Tables B2 and B3). Macros or modules were not included in the database.

Alaska State Parks, 3601 C Street, #1200, Anchorage, AK 99503

February 27, 1998

DEAR PRINCE WILLIAM SOUND BOAT OWNER,

Alaska State Parks is cooperating with several agencies on an *Exxon Valdez* Oil Spill Restoration project to develop a Geographic Information System model for Western Prince William Sound. The purpose of the project is to look at human use patterns and how they relate to Prince William Sound resources. The results will help resource managers and users learn about changing use patterns in the Sound.

We re interested in how you use the Sound and your perceptions of use. We re collecting information in various ways from recreational boaters, harbors in the Sound, charter and commercial fishing operations, ferries, cruise boats, and other Sound users. Please take a few minutes to complete both sides of the enclosed form. RETURN POSTAGE IS PROVIDED!

INSTRUCTIONS: Please answer all questions based on recreational use of your own boat in the Sound from May-Sept. 1997, and expectations for use in 1998 (if you are a commercial operator or your boat fits a commercial category, do not include commercial use or commercial operations, only your personal recreational use of the boat).

For Question.1: Most boat types are self-explanatory, but use the following to distinguish these 4 types of motorboats, if they apply to you (if you are a charter/water taxi operator, use the charter/water taxi category).

> Runabout: 16-27' long, cabin/cockpit not permanently enclosed/no solid cabin roof (may have awnings).
> Cruiser: 22-35' long, enclosed cabin/hard roof, may have a flying bridge.
> Motoryacht: 40+ long, enclosed cabin/hard roof, may have a flying bridge.
> Commercial: barges, tugs, tenders, landing craft (NOT commercial fishing boats).

For Question 2: For destination, write in your trip primary destination; if your trip did not have a primary destination, write in the name of the farthest place from Whittier that you reached on the trip.

Use the place names on the map on the back of this sheet as the names of your trip destinations (you may write in more specific names if you wish).
Count partial days of a trip as one day.
If you made more than one trip per month to the same destination, use an average number of days for those trips, and an average number of hours on shore.

PLEASE COMPLETE AND MAIL YOUR SURVEY BY **MARCH 16, 1998**. If you have questions, please contact Ali Iliff, Alaska State Parks, Anchorage (phone 269-8699; fax 269-8907; e-mail: Alice_Iliff@dnr.state.ak.us). Thank you!

(over for map)

Fig. B1. Form for survey of recreational boaters in western Prince William Sound, Alaska, 1998.

Table B1. Classification used to describe vessels in Whittier Harbor and in Prince William Sound, Alaska.

User group	Vessel type classification
Kayaks	Single kayaks Double kayaks
Recreational motor boats	Inflatables (e.g. Zodiacs™) Skiffs Runabouts Cabin cruisers Motor yachts Sailboats
Commercial fishing	Purse seiners Drift netters Set netters Draggers Long liners
Charter	Charter boats Water taxies
Cruise ships and State ferries	Alaska Marine Highway ferries Cruise ships
Other (not considered in the analysis)	Commercial vessels (barges, landing craft) Coast Guard cutters Jet skies

RESULTS

Recreational motor boat users.--One hundred eighteen (34%) surveys were returned. Almost all surveys returned contained complete, usable information. Respondents answered most questions, and often wrote additional qualifying information in the margins or in the comment section. There were very few cynical or glib remarks, which implied willingness on the part of participants to provide information. Because most surveys were returned completed, and most included open-ended comments, we felt that this was a good response, both for content and for number of respondents. Similar surveys reported in the literature and in personal communications often had a lower response rate than this survey (e.g., Heberlein et al. 1986).

Name: Ali Iliff (E-mail: Ali Iliff <Alice_Iliff@dnr.state.ak.us>

November 27, 1998

WESTERN PRINCE WILLIAM SOUND KAYAK SURVEY

Hello, Kayaker, Thanks for volunteering to help us with our project on human use patterns and how they relate to Sound resources. We have decided to limit this data collection portion to kayakers who HAVE KAYAKED IN WESTERN PWS IN THE PAST 10 YEARS. Feel free to forward this email on to other PWS kayakers before you fill it out.

This survey is not meant to be statistically valid -- the data you provide will help us get our project up and running; respondents names will not be identified in the results. Please answer based on your personal kayak use in the western half of the Sound. There are 17 questions, some with places for you to specify answers further.

How you can respond: use your "forward" key, and then enter your responses right on this email (in most cases, put an X in front of the applicable answer; don't worry if the spacing shifts!); forward the completed email to: Alice_Iliff@dnr.state.ak.us

Or, print out the email or the attachment (a wordperfect document), hand mark your responses, and mail or fax to Ali Iliff, AK State Parks, 3601 C. Street, #1200, Anchorage, AK 99503;
fax 269-8907. (Call Ali at 269-8699 if questions.)

PLEASE RESPOND BY DECEMBER 14, 1998. Thanks!

1. In the past 10 years, how many times have you have kayaked in Prince William Sound? (put an X in front of one answer)

__ 1-4 times
__ 5-10 times
__ 10+ times

2. What is the average length, in days, of your kayaking trip(s) in the Sound? (do not count driving time to and from the Sound; count partial days as one day)

_____ # days

3. Where is your PRIMARY access to reach the western Sound? (check one)
__ Whittier
__ Valdez
__ Other (specify:)

4. Do you tend to kayak to (or at) the same destination (or a favorite area) of the western Sound?

__ Yes (name of favorite bay or destination:)
__ No, it varies (list up to 3 favorites:)

5.Do you usually paddle from your access point or do you use drop off/water taxi services? (check one)

__ Usually paddle entire way (both ways)
__ Usually paddle one way/use drop off or water taxi one way
__ Usually use drop off/water taxi both ways
__ Other (specify:)

6. With the opening of the Whittier Road, do you expect YOUR kayak use patterns (eg.trip length/purpose/destinations)in the western Sound to change in the next 10 years?

__ My use will increase (specify why/how)

__ My use will decrease (specify why/how)

__ My use will stay the same (specify why)

7. On future trips, do you think you will use drop off/water taxi services more often than before?

__ More (why?)

__ Less (why?)

__ Same (why?)

8. In the next 10 years, do you anticipate changing from kayaking in the Sound to some other primary form of recreational boating?

__ Yes (specify what type:)
__ No, I plan to remain a kayaker, primarily.
__ No, I already have another type of boat/do other kinds of recreational boating

9. What 3 factors most influence your choice of kayaking trip or destination in the Sound? (check up to 3; do not prioritize)

__ Reasonable cost
__ Reasonable time frame
__ Lack of crowds
__ Lack of other boat traffic
__ Scenic experience
__ Availability of campsites
__ Other (specify:)

10. What is the average number of boats (other than your group) that you have seen on your trips in the western Sound (give average number for past 5 years or less)

_____ # per day while kayaking
_____ # using your camping destination

11. How many boats (other than your group) would you tolerate seeing in the future?

_____ # per day while kayaking
_____ # using your camping destination

11a. If the number of boats exceeds the number you'd tolerate in 11 above, what would you do (paddle farther to another area, avoid that location in the future, try the area at a different time, etc.)?

12. Please suggest/identify any locations for more kayak campsites:

a.

b.

c.

d.

13. What is your age?

___ Under 25
___ 25-35
___ 36-50
___ 50+

14. What is your gender?

__ Male
__ Female

15. What is your highest educational level?

__ High school grad/some high school
__ Some college/trade school/certificate program
__ College grad/some post grad work
__ Graduate degree

16. What is your annual family income before taxes?

__ Under $30,000
__ $30,000-$50,000
__ $50,000+

17. Please use the space below if you have any other comments about kayaking in western Prince William Sound:

Thanks for your help! (End)

Fig. B2. Form for survey of kayakers in western Prince William Sound, Alaska, 1998.

Table B2. MS Access database design for the results of the survey of recreational boaters, Prince William Sound, Alaska, 1998.

Table name	Brief description of tables
Alilab	Mailing list of 350 names
Annlab	Mailing list of 100 names of annual slip holders
Permlab	mailing list of 250 names of permanent slip holders
Main	Information from questions 1, 4 and parts of 6 and 7 plus Survey ID field
Trip recreation	Most information from question 2 plus Survey ID and Recreation ID fields
Q67Occatg	Categorization of opened ended questions 6, 7 and comments, plus Survey ID field
Purpose	Part of question 2 plus Purpose ID field, associates Recreation ID with purpose
Purpose code	Associates purpose name with a number
Destination	Part of question 2 plus Dest ID field, associates Recreation ID with destination
Destination code	Associates destination name with a number
Vessel code	Associates a vessel type with a number
Month code	Associates a month with a number
Origin trip	Associates place of origin with a number

Table B3. Detailed description of MS Access tables for the results of the survey of recreational boats, Prince William Sound, Alaska, 1998.

Table name	Brief description of table fields	
Alilab	FirstName	text
	LastName	text
	Address	text
	Address2	text
	City	text
	State	text
	PostalCode	text
	Perm/annual	text
	Boat(s)	text
	MailingListID	autonumber, key in table
Annlab	same fields as Alilab except MailingListID, which is now text and is associated with the number and information in Alilab.	
Permlab	same fields as Alilab except MailingListID, which is now text and is associated with the number and information in Alilab.	
Main Table	SurveyID	#; is associated with number on survey
	Original Trip	#; origins of trip, correlates from Origin Trip Table, info from ?
	Survey Date	date/time; date of survey
	1stVessel	#; vessel type, correlates from Vessel Code Table, from question 1
	1stVessel	Name text, vessel type by name, correlates from 1stVessel field
	2ndVessel	#; 2nd vessel type, correlates from Vessel Code Table, from question 1
	NumberofBoats	#; # of boats seen, from question 4
	NumberAddMiles	#; # of boats willing to see, from question 4
	PreferReserve	Yes/No; if could reserve mooring, willing to see more boats, from question 4

	NumberAddMiles	#; # of additional miles willing to travel if too many boats, from question 4
	BoatUseChange	Yes/No; boat pattern changes, from question 6
	AddFuel	Yes/No; if fuel available, would boat pattern change, from question 7
	Comment6	#; not used, see Q67OCcatg Table
	Comment7	#; not used, see Q67OCcatg Table
	Comment	#; not used, see Q67OCcatg Table
	Destination	#; not used, for ?
Trip Recreation Table	RecreationID	autonumber; key to table
	RecreationDesc	text; empty, not used
	SurveyID	#; # assigned to survey
	Month	#; # associated with month name from Month Code Table
	TripLength	# ; trip length in # of days, from question 2
	NoOfTrips	#; # of trips here this month, from question 2
	NoHrsAshore	#; # of hours ashore, from question 2
Q67Occatg	SurveyID	#; # assigned to survey
	Q6-1	#, 1 indicates positive, go farther (distance)
	Q6-2	#, 1 indicates positive, Longer trips (time)
	Q6-3	#, 1 indicates positive, less use/fewer trips/stop using, leave Sound
	Q6-4	#, 1 indicates positive, avoid crowds/avoid crowded times (weekends)
	Q6-5	#, 1 indicates positive, other
	Q7-1	#, 1 indicates positive, go farther/more range/go more places
	Q7-2	#, 1 indicates positive, longer trips
	Q7-3	#, 1 indicates positive, use lower sound
	Q7-4	#, 1 indicates positive, get there faster
	Q7-5	#, 1 indicates positive, get away from crowds/congestion/other boats
	OC1	#, 1 indicates positive, too much crowding will result; will ruin experience; can't accommodate crowds; deteriorating experience;
	OC2	#, 1 indicates positive, user conflicts; inexperienced vs good boaters;

	OC3	#, 1 indicates positive, need facilities & services/improvements
	OC4	#, 1 indicates positive, use will increase closer to Whittier
	OC5	#, 1 indicates positive, restrictions/rules will be necessary and may not like
	OC6	#, 1 indicates positive, no facilities/improvements; keep area pristine
Purpose Table	PurposeID	autonumber; key for table, NOT RELATED to PurposeID in Purpose Code Table
	RecreationID	#; from RecreationID field in Trip Recreation Table
	Purpose	#; purpose of trip from question 2, correlates from Purpose Code Table
Purpose Code Table	PurposeID	autonumber; number to correlate with purpose name, also key of table
	PurposeDesc	text; purpose name
Destination Table	DestID	autonumber; key for table, NOT RELATED to DescID in Destination Code Table
	RecreationID	#; from RecreationID field in Trip Recreation Table
	DestCode	#, destination from question 2, correlates from Destination Code Table
Destination Code Table	DestID	autonumber; number to correlate with destination, also key of table
	Destination	text; destination name
Vessel Code	VesselID	autonumber; number to correlate with vessel type, also key of table
	VesselDesc	text; vessel type
Month Code Table	MonthID	number; number to correlate with month name, also key of table
	MonthDesc	text; name of month
Origin Trip Table	TripID	autonumber; number to correlate with place of trip origin
	TripDesc	text; place of trip origin

Most respondents fell into three major categories of recreational motor boat users: 1) cruisers, 2) motor yachts, or 3) sailboats (Table B4). In addition, the Access database was queried to describe use patterns by vessel type and site/destination, number of trips by month, duration, destinations/purpose, and crowding tolerance. Future use, such as what users might do when access changes or use increased, was assessed. Comparisons of what users see to what they desire to see in the Sound were also made.

Kayakers.—Sixty completed surveys were returned; 45 were submitted electronically, 15 were mailed in (80 surveys were sent out, and we estimate that 20 more were forwarded to others by participants), for an estimated 60% return. Almost all surveys returned contained complete, usable information. Respondents answered most questions, and often wrote additional qualifying information in the comment sections. There were very few cynical or glib remarks, which implied willingness on the part of participants to provide information. Because most surveys were returned completed, and most included open-ended comments, we felt that this was an excellent response rate, both for content and for number of respondents. Most respondents fell into the same age and income demographic categories (Table B5).

DISCUSSION

These surveys were not designed for the application of statistical analyses to the results. However, when compared with other surveys and results reported in the literature our surveys were very similar (Table B6). These comparisons point to possible management recommendations or suggestions. Readers are urged to use caution when developing specific management recommendations from the findings of our surveys. However, these results do suggest trends in recreation uses of which resource managers should be aware. Managers can focus on managing people as they change, as well as managing activities (R. Haynes, USDA Forest Service, personal communication).

The results of the surveys were used primarily to document existing use patterns in the Sound and provide a basis for computer applications that mapped those use patterns. The results were also used to provide insight on how those use patterns may change with changing use levels and to provide a basis for modelling and mapping those changing patterns. Survey data will also be useful in future recreation assessments. This survey did not address, in depth, the motivations that led to use of specific areas of the Sound. Additional study with larger populations of boaters is necessary to determine motives, desires, and values associated with social and economic demographics of users.

Table B4. Results of the survey of motor boat operators in western Prince William Sound, Alaska, 1998.

1. First column is the count by type of primary recreation vessel. The second column is the count of any other boat types owned and used recreationally in the Sound.

4 - Runabout	2 - Runabout
67 - Cruiser	0 - Cruiser
19 - Motoryacht	0 - Motoryacht
1 - Commercial	0 - Commercial
18 - Sailboat	1 - Sailboat

4 - Charter/Water Taxi	2 - Charter/Water Taxi
0 - Open Skiff	10 - Open Skiff
1 - Inflatable	31 - Inflatable
0 - Sea Kayak	2 - Sea Kayak
3 - Commercial Fishing	1 - Commercial Fishing
0 - Other	4 - Other
1 - None Given	52 - None Given
0 - Multiple Boats	13 - Multiple Boats

2. List all personal recreation trips you made in the Sound in 1997 for the following months.
   Note: Destination and purpose information not given in this summary.
   Trip length in number of days:
   - 2.7 - Average
   - 21 - Maximum
   - 0 - Minimum

   Number of trips by month:
   - 264 - May
   - 331 - June
   - 390 - July
   - 297 - August
   - 138 - September

   Number of hours ashore:
   - 6.7 - Average
   - 168 - Maximum
   - 0 - Minimum

3. The survey did not have a question 3.

4. When boating to a favorite destination or frequently visit a destination:
   How many other boats were seen at that destination:
   - 2.9 - Average
   - 20 - Maximum
   - 0 - Minimum

   How many boats was the user willing to see and still go there:
   - 5.6 - Average
   - 100 - Maximum
   - 0 - Minimum

   If the user could reserve a mooring or campsite at that destination, would the user mind seeing more boats:
   - 42 - NO
   - 76 - YES

   If there are too many boats at desired destination, how many miles from Whittier would the user be willing to travel to find desired destination conditions:
   - 42.2 - Average
   - 100 - Maximum
   - 0 - Minimum

5. The survey did not have a question 5.

6. Assuming increasing boat traffic in the Sound, did the user expect their recreation boating use patterns to change in the next 3 years.

   Note: comments put into 5 categories, more than one comment could be given per survey.

   34 - NO
   84 - YES

   If yes, then:

   46 - go farther (distance)
   12 - longer trips (time)
   16 - less use/fewer trips/stop using, leave sound
   35 - avoid crowds/avoid crowded times (weekends)
   1 - other

7. If fuel were available at locations that would extend the users distance capability, would the users' boating use patterns change?

   Note: comments put into 5 categories, more than one comment could be given per survey.

   68 - NO
   50 - YES

   If yes, then:

   34 - go farther/more range/go more places
   18 - longer trips
   6 - use lower sound
   3 - get there faster
   2 - get away from crowds/congestion/other boats

Additional Comments

Note: comments were put into 6 categories, more than 1 comment could be given per survey.

16 - too much crowding will result; will ruin experience; can't accommodate crowds; deteriorating experience;
10 - user conflicts; inexperienced vs. good boaters;
14 - need facilities & services/improvements
3 - use will increase closer to Whittier
4 - restrictions/rules will be necessary and may not like
2 - no facilities/improvements; keep area pristine

Table B5. Results of the survey of kayakers in western Prince William Sound, Alaska, 1998.

---

1. In the past 10 years, how many times have you have kayaked in Prince William Sound? (put an X in front of one answer)

   24 - 1-4 times
   21 - 5-10 times
   15 - 10+ times

2. What is the average length, in days, of your kayaking trip(s) in the Sound? (do not count driving time to and from the Sound; count partial days as one day)

Trip length in number of days

7.5 – Average
30 - Maximum
2 – Minimum

3. Where is your PRIMARY access to reach the western Sound? (check one)

55 - Whittier
2 - Valdez
3 - Other (2 - use both; 1 - Seward/Chenega)

4. Do you tend to kayak to (or at) the same destination (or a favorite area) of the western Sound?

2 - No Response
11 - Yes (3 - Blackstone; 3 - Harriman; 1 - SW Sound; 4 - no response)
47 - No, it varies (received 32 destinations, plus no response, listed below)

3-Surprise Cove, 2-Port Wells, 14-Culross, 14-Harriman, 14-Blackstone, 11-Port Nellie Juan, 3-Columbia Glacier, 2-College Fjord, 1-Eshamy, 2-Shoup Bay, 1-Jack Bay, 3-Unakwik, 5-Knight, 1-Whale, 2-Esther, 1-Squire, 1-Hidden, 1-Passage Canal, 1-Landlocked Bay, 1-Paulson Bay, 1-Harrison Lagoon, 2-Derickson, 2-Perry, 3-Icy, 3-Bainbridge, 1-Axel Lind, 1-Cochrane, 1-Whittier, 3-Chenega, 1-Dangerous Passage, 1-Montague, 2-Pigot, 9-no response

5. Do you usually paddle from your access point or do you use drop off/water taxi services?(check 1)

19 - Usually paddle entire way (both ways)
18 - Usually paddle one way/use drop off or water taxi one way
17 - Usually use drop off/water taxi both ways
6 - Other (5 - use a combination; 1 - use my own boat)

6. With the opening of the Whittier Road, do you expect YOUR kayak use patterns (e.g. trip length/purpose/destinations)in the western Sound to change in the next 10 years?

9 - My use will increase (2 - more time/money; 7 - easier access; 1 - kids can paddle farther; 1 - no response)
30 - My use will decrease (4 - more noise; 19 - more crowds; 5 - higher cost; 2 - don't want to use road; 6 - use different areas)
20 - My use will stay the same (2 - easier access; 10 - road won't affect; 1 - won't like traffic; 1 - change destination; 1 - go farther/fewer-longer trips; 5 - no response)
1 - No Response

7. On future trips, do you think you will use drop off/water taxi services more often than before?

31 - More (1 - avoid noise; 25 - get away from crowds; 3 - see different areas; 3 - accommodate young kids; 2 - no response)
4 - Less (2 - only paddle close by; 1 - use Sound less; 1 - no response)

24 - Same (3 - prefer to paddle; 8 - use by interest/time-not road; 1 - have own boat;
1 - avoid crowds; 12 - no response)
1 - No Response

8. In the next 10 years, do you anticipate changing from kayaking in the Sound to some other primary form of recreational boating?
5 - Yes (2 - sail boat; 2 - small motor boat; 0 - canoe; 2 - no response)
45 - No, I plan to remain a kayaker, primarily.
8 - No, I already have another type of boat/do other kinds of recreational boating
2 - Other (1 - no response; 1 - remain kayaker and have another boat)

9. What 3 factors most influence your choice of kayaking trip or destination in the Sound? (check up to 3; do not prioritize)
19 - Reasonable cost
17 - Reasonable time frame
41 - Lack of crowds
26 - Lack of other boat traffic
51 - Scenic experience
9 - Availability of campsites
14 - Other (1 - no noise/solitude; 2 - know cabins/campsites; 2 - friends organize trips; 2 - remoteness; 3 - wildlife viewing; 2 - safety; 2 - try new sites)

10. What is the average number of boats (other than your group) that you have seen on your trips in the western Sound (give average number for past 5 years or less)
Number per day while kayaking:
8.7 - Average
50 - Maximum
0 – Minimum

Number using your camping destination:
1.6 - Average
10 - Maximum
0 – Minimum

11. How many boats (other than your group) would you tolerate seeing in the future?
Number per day while kayaking:
12.2 - Average
75 - Maximum
0 – Minimum

Number using your camping destination - 1.5 ave; 0 min; 10 max;
1.5 - Average
10 - Maximum
0 – Minimum

11a. If the number of boats exceeds the number you'd tolerate in 11 above, what would you do (paddle farther to another area, avoid that location in the future, try the area at a different time, etc.)?

41 - avoid area
8 - avoid the Sound
24 - try area at different time
2 - use other access
28 - go farther
1 - share the beach
8 - no response

12. Please suggest/identify any locations for more kayak campsites:

26 choices given, plus no response, listed below

1-Pigot, 9-Blackstone, 1-Cascade, 5-Decision Point, 1-College Fjord, 4-Shotgun Cove, 1-Willard Island, 1-Port Wells, 2-Hidden Bay, 3-Whittier, 3-Culross, 1-Split Point, 1-Mink Island, 2-Granite Bay/Esther, 5-Harriman, 3-Port Nellie Juan, 1-Valdez, 2-Knight Island, 1-Unakwik, 1-Applegate, 1-Kayak Island, 1-Copper River Delta, 1-Eaglek Bay, 1-Dangerous Passage, 2-Cochrane Bay, 1-Derrickson Bay, 36-no response

13. What is your age?

0 - Under 25
6 - 25-35
49 - 36-50
5 - 50+

14. What is your gender?

21 - Male
39 - Female

15. What is your highest educational level?

0 - High school grad/some high school
2 - Some college/trade school/certificate program
26 - College grad/some post grad work
32 - Graduate degree

16. What is your annual family income before taxes?

8 - Under $30,000
11 - $30,000-$50,000
38 - $50,000+
3 - no response

17. Please use the space below if you have any other comments about kayaking in western Prince William Sound:

9 - motorized use displaces non-motorized
5 - motorized use impacts on resources are greater

13 - separate users by areas and boats
6 - more public cabins
1 - access is fly-in
6 - maintain wilderness feeling
1 - no fuel docks
4 - limit group size
3 - more tent platforms/hardened sites
8 - educate all users on use and resource protection
3 - need monitoring, enforcement and management
25 - no response

Table B6. Comparison of findings of a survey of recreational boaters in western Prince William Sound, Alaska with other surveys.

Findings of this survey of Western Prince William Sound users	Findings of other surveys	Citations for other surveys
Similarities		
Recreation patterns in the Sound have been changing and will continue to change.	Similar	Menefee and Hennig 1994
More people will be using the Sound.	Similar	Alaska Department of Natural Resources 1999
More user education and management are needed.	Similar	Menefee and Hennig 1994
Trip purposes in Western Prince William Sound are primarily for recreation, sightseeing, and fishing.	Similar	Menefee and Hennig 1994, Alaska Department of Natural Resources 1999, Chugach National Forest unpublished data

Table B6. Comparison of findings of a survey of recreational boaters in western Prince William Sound, Alaska with other surveys.

Findings of this survey of Western Prince William Sound users	Findings of other surveys	Citations for other surveys
Placement of recreational facilities, such as mooring buoys, would enhance a recreational experience.	Similar	Menefee and Hennig 1994, Chugach National Forest unpublished data
Visitors may continue to use crowded areas even if they dislike heavy use.	Similar	Lucas 1980
There is a higher value for solitude at campsites than along the way to the campsite.	Similar	Lucas 1980
If visitors who perceive conditions as deteriorating have already stopped visiting an area, the situation could be worse than reported.	Similar	Lucas 1980
Travel costs are a primary determinant of site availability (cost determines the increase/decrease of number of trips and frequency of use).	Similar	English et al. 1993
Use densities differ by user groups (the degree of specialization of activity is a contributor, as is the level of commitment/investment in gear) .	Similar	Hammitt et al. 1984

Table B6. Comparison of findings of a survey of recreational boaters in western Prince William Sound, Alaska with other surveys.

Findings of this survey of Western Prince William Sound users	Findings of other surveys	Citations for other surveys
Crowding perceptions are more highly correlated with preferences/expectations than with actual densities.	Similar	Shelby 1980
Users look at the overall experience, not just crowding.	Similar	Shelby 1980
To obtain a more wilderness-like experience, people wait longer to take a trip, pay more, or go at a different time.	Similar	Shelby 1980
There is a belief that fewer contacts will occur as one travels farther and as people spread out; there is an expectation of greater numbers of encounters closer in.	Similar	Shon 1981
Differences		
Fourteen kayak survey respondents stated in various open ended comments that a permit system would be preferable to more campsites.	Placement of recreational facilities, such as campsites, would enhance a recreational experience.	Menefee and Hennig 1994, Chugach National Forest unpublished data

Table B6. Comparison of findings of a survey of recreational boaters in western Prince William Sound, Alaska with other surveys.

Findings of this survey of Western Prince William Sound users	Findings of other surveys	Citations for other surveys
Our survey found that 68% of respondents using motor boats said additional availability of fuel would not change their patterns. Large boats can carry large amounts of fuel.	Additional availability of fuel in the Sound would enhance use and change recreation patterns.	Menefee and Hennig 1994
Our survey showed that crowding was a major concern of recreational motor boaters, but litter and the area being worn did not appear as concerns. This may be because most of our respondents said they hardly spent any time on shore. Our survey also showed that crowding was a major concern of kayakers, but litter and the area being worn did not appear as concerns.	Most common complaints (among canoeists) were of crowding and the area being worn/littered.	Shon 1981

APPENDIX C

Arc Macro Language (AML) programs used in the Arc/INFO geographic information system to generate user group use patterns in western Prince William Sound, Alaska.

make_grid.aml

```
/*
/* This AML creates a grid for each destination point.
/*
&severity &error &routine exit
/*
/* Open file containing list of destination points
/*
&s filer [open id.list status -read]
  &if %status% ne 0 &then
    &type 'Could not open' list'
/*
/* Read first record
/*
&s i [locase [read %filer% readstat]]
/*
/* Process each record until file is empty
&do  &while %readstat% ne 102
/*
/* Start ArcEdit module
  display 1040
    ae
/* Open point coverage contining destination points
    edit destpts lab
/* Select point and put into new coverage
    sel id# = %i%
    weedt 0
    grain 0
    put rs%i%_cov
    q
/*
  build rs%i%_cov point
/*
/* Start the GRID module and create grid of each destination point
  display 1040
    grid
    setcell 60
    setwindow rs_wpws_grd
    rs%i% = pointgrid (rs%i%_cov)
    q
```

```
/*
/* Remove individual point coverages
  kill rs%i%_cov all
/*
/* Read  next record from text file
&s i [locase [read %filer% readstat]]
/*
&end
&ret
/*
/* Error routine
/*
&routine exit
&severity &error &ignore
&s closew = [close -all]
&ret &error An error has occurred.
&ret
```

corridor.aml

```
/* This aml was designed to utilize GRID functions to provide information that
/* would allow determination of the most efficient travel corridor between
/* potential destination points in western Prince William Sound and Whittier.
/*
/* Using different cost grids, this aml is used to produce corridors for the recreation,
/* commercial fishing, and charter boats.
/*
/* The ID# item of the destination points coverage provides a link to the points of interest
/* through a list of numbers in a flat file called id.list.  A separate aml is
/* used to create a grid for each of the destination points of interest called
/* rs%i%.  The COSTDISTANCE function is run for each point in sequence.  The
/* output of that process, cost%i% is used in the CORRIDOR function along with
/* a Whittier cost distance grid to provide a grid (corr%i%) of all potential corridors
between
/* Whittier and the point of interest and the associated "cost" of using each corridor.
/*
/* The cost grid for the commercial fishing and charter boats was the salt water
/* portion of  western Prince William Sound.  Each cell was assigned a value of 1.  A cost
/* distance grid for Whittier was created using this same cost grid.
/*
/* The cost grid for the recreation boats took this grid and converted  the "nodata"
/* (land) values were converted to a value of 500 to relieve the problem of some destination
/* points falling in nodata areas and not being included in the model.  The shoreline was
buffered
/*and assigned a value of 1, the outside of Culross Island was assigned a value of 2,
```

```
/* open saltwater was assigned a value of 3.  A cost distance grid for Whittier was created
using
/* this same cost grid.
/*
/* Lowell H. Suring; 8 September 1998., Karin E. Preston 4/21/99
/*
&severity &error &routine exit
/*
/* Start the GRID module
display 1040
grid
/*
/* Open file containing list of destination points
/*
&s filer [open id.list status -read]
  &if %status% ne 0 &then
    &type 'Could not open' id.list'
/*
/* Read first record
/*
&s i [locase [read %filer% readstat]]
/*
/* Process each record until file is empty
&do  &while %readstat% ne 102
/*
&type 'Processing COSTDISTANCE for destination' %i%
/*
/* Copy grid containing destination point to this directory
copy rec_points/rs%i%
/*
/* Create costdistance grid for destination point
cost%i% = costdistance (rs%i%,cost_distance_grid)
  &if [exists cost%i% -grid] &then
     kill rs%i%
/*
/* CORRIDOR function
/*
&type 'Processing CORRIDOR for destination' %i%
/*
/* Determine corridor between destination point and Whittier
corr%i% = corridor (Whittier_cost_distance_grid,cost%i%)
&if [exists corr%i% -grid] &then
   kill cost%i%
/*
/* Read  next record from text file
/*
```

```
&s i [locase [read %filer% readstat]]
/*
&end
/* Close all files
&s closer = [close -all]
&messages &on
quit
&ret
/*
/* Error routine
/*
&routine exit
&severity &error &ignore
&s closew = [close -all]
&ret &error An error has occurred.
quit
&ret
```

cumulative.aml

```
/* This aml provides a process to develop a grid of the total number of "trips"
/* through a corridor from Whittier to a destination over a period of time.
/* It is used to produce monthly totals for the recreation, commercial fishing, and charter
boats.
/*
/* Each point is initially identified through its ID# item from the id.list.
/* The number of trips via the corridor is included in a corresponding
/* trip.list.
/*
/* Each corridor and the number of trips for each corridor serve as one
/* iteration in this process.  When the destination list (id.list) and the
/* number of trips list (trip.list) are exhausted a final grid is created
/* using a name provided when the aml initiates its run.
/*
/* Lowell H. Suring  8 Sept. 1998
/*
&severity &error &routine exit
/*
/* Start the GRID module
display 1040
grid
/*
/* Set up the GRID environment and create "starting" grid
setcell 60
setwindow /fsfiles/unit/res/evos_gis/model/costgrids/costv3_1grd
totalgrd1 = 0
```

```
/*
/* Initialize counters for current and previous grid
&sv c = 0
&sv t = 1
/*
/* Ask for name of final GRID to create
&s name = [Response 'Enter the name of the final grid']
/*
/* Open file with list of destination points for month being processed
/*
&s filer [open month.list status -read]
  &if %status% ne 0 &then
    &type 'Could not open' month.list'
/*
&s trips [open month.trips status2 -read]
  &if %status2% ne 0 &then
    &type 'Could not open month.trips'
/*
/* Read first record
/*
&s i [locase [read %filer% readstat]]
/*
&s n [locase [read %trips% readstat2]]
/*
/* Process each record until file is empty
&do  &while %readstat% ne 102
/*
&type 'Processing corridor' %i%
/*
/* Multiply trip by the number of times it occurred during that month
corrtrips%i% = lccorr%i% * %n%
/*
/* Increment counters by 1
&sv c = %c% + 1
&sv t = %t% + 1
/*
&type 'Proceeding with iteration' %c%
/*
/* Make running total
totalgrd%t% = totalgrd%c% + corrtrips%i%
/*
&type 'Removing interim grids'
/*
   kill totalgrd%c%
   kill corrtrips%i%
/*
```

```
/*
/* Read next record from id.list and trip.list files
/*
&s n [locase [read %trips% readstat2]]
&s i [locase [read %filer% readstat]]
/*
&end
/*
/* Rename grid to the name of the month it represents
rename totalgrd%t% %name%grd
/*
/* Close all files
&s closer = [close -all]
&messages &on
&ret
/*
/* Error routine
/*
&routine exit
&severity &error &ignore
&s closew = [close -all]
&ret &error An error has occurred.
&ret
```

corridor_kayak.aml

```
/* Modified version of corridor.aml to create corridors for kayak trips
/*
/* This aml calculates the corridor between two destinations (i.e., ID# from
/* id.list1 and id.list2) by first running the COSTDISTANCE function for each
/* destination and then running the CORRIDOR function between the two
/* destinations.  corr%i%_%ii% is the resulting grid for each destination
/* pair.
/*
/* The cost grid for the kayaks  took the salt water portion of  western Prince William Sound
/*  and coded  the "nodata" (land) cells to 500 to relieve the problem of some destination
/* points falling in nodata areas and not being included in the model.  The shoreline was
buffered
/* and assigned a value of 1, the outside of Culross Island was assigned a value of 2,
/* open saltwater was assigned a value of 3.   Additional restrictions to avoid known hazard
areas
/* were also made.
/*
/* Lowell H. Suring & Karin E. Preston
/*
&severity &error &routine exit
```

```
/*
/* Start the GRID module
display 1040
grid
/*
/* Open file containing points of origin
/*
&s file1 [open id.list1 status -read]
  &if %status% ne 0 &then
    &type 'Could not open id.list1'
/*
/* Read first record
/*
&s i [locase [read %file1% readstat]]
/*
/* Process each record until point of origin file is empty
/* &do  &while %readstat% ne 102
/*
/* Open file containing list of destination points
&s file2 [open id.list2 status -read]
  &if %status% ne 0 &then
     &type 'Could not open id.list2'
/*
/* Read first record
/*
&s ii [locase [read %file2% readstat]]
/*
/* See if corridor grid already exists and read next two records if it does
&if [exists  corr%i%_%ii% -grid] &then
  &do &until ^ [exists  corr%i%_%ii% -grid]
    &s i [locase [read %file1% readstat]]
    &s ii [locase [read %file2% readstat]]
  &end
/*
vix read.me
/* Process each record until destination points file is empty
&do  &while %readstat% ne 102
/*
&type 'Processing COSTDISTANCE for destination' %i%
/*
/* Copy grids containing origin & destination point to this directory
copy /fsfiles/unit/res/evos_gis/model/rec_use3_v2/rec_points/rs%i%
copy /fsfiles/unit/res/evos_gis/model/rec_use3_v2/rec_points/rs%ii%
/*
* Create costdistance grids for point of origin
costi%i% = costdistance (rs%i%,cost_distance_grid)
```

```
/*
&type 'Processing COSTDISTANCE for destination' %ii%
/*
* Create costdistance grids for destination point
costii%ii% = costdistance (rs%ii%,cost_distance_grid)
/*
/* CORRIDOR function
/*
&type 'Processing CORRIDOR for destinations' %i% 'and' %ii%
/*
/* Determine corridor between point of origin and destination
corr%i%_%ii% = int (corridor (costi%i%,costii%ii%))
/*
/* If corridor grid successfully created, delete preliminary grids
 &if [exists corr%i%_%ii% -grid] &then
   kill (!costi%i% costii%ii% rs%i% rs%ii%!)
/*
/* Read  next records from text files
/*
&s i [locase [read %file1% readstat]]
/*
&s ii [locase [read %file2% readstat]]
/*
/* See if corridor grid already exists and read next two records if it does
&if [exists  corr%i%_%ii% -grid] &then
  &do &until ^ [exists  corr%i%_%ii% -grid]
    &s i [locase [read %file1% readstat]]
    &s ii [locase [read %file2% readstat]]
  &end
/*
&end
/* Close all files
&s closer = [close -all]
&messages &on
quit
&ret
/*
/* Error routine
/*
&routine exit
&severity &error &ignore
&s closew = [close -all]
&ret &error An error has occurred.
quit
&ret
```

leastcost.aml

```
/* The corridor.aml produces a grid of all possible corridors and their
/* associated "costs" to travel from Whittier to a potential destination in
/* western Prince William Sound.  This aml uses the DESCRIBE function to
/* determine the minimum cost in the grid of interest.  It then adds 0.005 of
/* that minimum value to the minimum value and considers that the "least cost
/* corridor."  All other values in the grid are reduced to 0.  This process
/* results in a reasonable "real world" corridor between the two points that
/* may be used to represent travel paths in western Prince William Sound.
/*
/* The ID# item of each destination is used to identify that destination
/* through a list of ID# in the id.list.
/*
/* Lowell H. Suring  8 September 1998.
/*
&severity &error &routine exit
/*
/* Start the GRID module
display 1040
grid
/*
/* Open file containing list of destination points
&s filer [open id.list status -read]
  &if %status% ne 0 &then
    &type 'Could not open' id.list'
/*
/* Read first record
/*
&s i [locase [read %filer% readstat]]
/*
/* Process each record until file is empty
&do  &while %readstat% ne 102
/*
&type 'Processing minimum corridor for destination' %i%
/*
/* Find minimum cost, add 0.005 to it and find least cost corridor
&describe corr%i%
/*
/* Use internal variable %grd$zmin% to get minimum value
lccorr%i% = con(corr%i% < (%grd$zmin% + (%grd$zmin% * 0.005)), 1, 0)
/*
/* Read  next record from text file
/*
&s i [locase [read %filer% readstat]]
/*
```

```
&end
/* Close all files
&s closer = [close -all]
&messages &on
&ret
/*
/* Error routine
/*
&routine exit
&severity &error &ignore
&s closew = [close -all]
&ret &error An error has occurred.
&ret
```

leastcost_kayak.aml

```
/* This aml uses the output from corridor_kayak.aml, i.e., corr%i%_%ii%, to
/* create a "minimum" corridor between two destinations from id.list1 and
/* id.list2.  The result is a least cost corridor with the name in the form
/* lck%i%_%ii%.
/*
/* Lowell H. Suring  & Karin E Preston
/*
&severity &error &routine exit
/*
/* Start the GRID module
display 1040
grid
/*
/* Open file containing points of origin
&s file1 [open id.list1 status -read]
  &if %status% ne 0 &then
    &type 'Could not open id.list1'
/*
/* Read first record
/*
&s i [locase [read %file1% readstat]]
/*
/* Process each record until point of origin file is empty
/* &do  &while %readstat% ne 102
/*
/* Open file containing list of destination points
&s file2 [open id.list2 status -read]
  &if %status% ne 0 &then
     &type 'Could not open id.list2'
/*
```

```
/* Read first record
/*
&s ii [locase [read %file2% readstat]]
/*
/* See if least cost grid exists, and read next 2 records if it does
&if [exists lck%i%_%ii% -grid] &then
  &do &until ^ [exists lck%i%_%ii% -grid]
    &s i [locase [read %file1% readstat]]
    &s ii [locase [read %file2% readstat]]
  &end
/*
/* Process each record until destination points file is empty
&do  &while %readstat% ne 102
/*
&type 'Processing the minimum corridor for destinations' %i% 'and' %ii%
/*
/* Find minimum cost, add 0.005 to it and find least cost corridor
&describe corr%i%_%ii%
/*
/* Use internal variable %grd$zmin% to get minimum value
lck%i%_%ii% = con(corr%i%_%ii% < (%grd$zmin% + (%grd$zmin% * 0.005)), 1, 0)
/*
/* Read  next records from text files
/*
&s i [locase [read %file1% readstat]]
/*
&s ii [locase [read %file2% readstat]]
/*
/* See if least cost grid exists, and read next 2 records if it does
&if [exists lck%i%_%ii% -grid] &then
  &do &until ^ [exists lck%i%_%ii% -grid]
    &s i [locase [read %file1% readstat]]
    &s ii [locase [read %file2% readstat]]
  &end
/*
&end
/* Close all files
&s closer = [close -all]
&messages &on
quit
&ret
/*
/* Error routine
/*
&routine exit
&severity &error &ignore
```

```
&s closew = [close -all]
&ret &error An error has occurred.
quit
&ret
```

kayak_trips_parcer.aml

```
/* This aml produces separate origin and destination files for each trip.
/* NOTE that id.list1 and id.list2 must have 99999 as the break between
/* individual trips.  kep 9/98
/*
/* Individual trip files are necessary before the cumulative_kayak.aml can be run.
/* Files created are idlist1_%list1% (points of origin for trip),
/* idlist2_%list2% (destination points for trip), & trip_%grd% (names of
/* lck%i%_%ii% grids that make up trip).
/*
&severity &error &routine exit
/*
/* Initialize counters
/* grd contains the sequential number for the least cost grid names
&s grd = 1
/* list1 contains the sequential number for the point of origin
&s list1 = 1
/* list2 contains the sequential number for the destination point
&s list2 = 1
/*
/* Open master list files
/*
/* Open origin file
&s file1 [open id.list1 status -read]
  &if %status% ne 0 &then
    &type 'Could not open id.list1'
/*
/* Open destination file
&s file2 [open id.list2 status -read]
  &if %status% ne 0 &then
     &type 'Could not open id.list2'
/*
/* Open individual list files to write to.  Create files first.  Delete them if they exist.
/*
&if [exists idlist1_%list1% -file] &then
  &sys \rm idlist1_%list1%
&sys touch idlist1_%list1%
/*
```

```
&s filew1 [open idlist1_%list1% wstatus -append]
  &if %wstatus% ne 0 &then
    &type 'Could not open' idlist1_%list1%
/*
&if [exists idlist2_%list2% -file] &then
  &sys \rm idlist2_%list2%
  &sys touch idlist2_%list2%
/*
&s filew2 [open idlist2_%list2% wstatus -append]
  &if %wstatus% ne 0 &then
    &type 'Could not open' idlist1_%list2%
/*
/* Open file to write grid names to.
/*
&if [exists trip_%grd% -file] &then
  &sys \rm trip_%grd%
  &sys touch trip_%grd%
/*
&s filew3 [open trip_%grd%  wstatus -append]
  &if %wstatus% ne 0 &then
    &type 'Could not open' trip_%grd%
/*
/* Read first records from origin & destination files
/*
&s i [locase [read %file1% readstat]]
&s ii [locase [read %file2% readstat]]
/*
/* Process each record until file is empty
&do &while %readstat% = 0
/*
/* Write origin, destination and least cost grid name to separate files
&s origin  = %i%
 &s writestat = [write %filew1% [quote %origin%]]
&s destin = %ii%
 &s writestat = [write %filew2% [quote %destin%]]
&s grdname = lck%i%_%ii%
 &s writestat = [write %filew3% [quote %grdname%]]
/*
/* Read next records
&s i [locase [read %file1% readstat]]
&s ii [locase [read %file2% readstat]]
/*
/* If end of trip (99999), close files, increment counters and open new files
  &if %i% = 99999 &then
    &do
      &s closer = [close %filew1%]
```

```
      &s closer = [close %filew2%]
      &s closer = [close %filew3%]
      &s list1 = %list1% + 1
      &s list2 = %list2% + 1
      &s grd = %grd% + 1
      &s filew1 [open idlist1_%list1% wstatus -append]
        &if %wstatus% ne 0 &then
          &type 'Could not open' idlist1_%list1%
      &s filew2 [open idlist2_%list2% wstatus -append]
        &if %wstatus% ne 0 &then
          &type 'Could not open' idlist1_%list2%
      &s filew3 [open trip_%grd%  wstatus -append]
        &if %wstatus% ne 0 &then
          &type 'Could not open' trip_%grd%
/*
/* Read next records
      &s i [locase [read %file1% readstat]]
      &s ii [locase [read %file2% readstat]]
    &end
&end
/*
/* Close all files
&s closer = [close -all]
&messages &on
&ret
/*
/* Error routine
/*
&routine exit
&severity &error &ignore
&s closew = [close -all]
&ret &error An error has occurred.
&ret
```

cumulative_kayak.aml

```
/* This aml uses the output from leastcost_kayak.aml, i.e., lck%i%_%ii%.
/* It adds the legs of a trip together and produces a grid named for the
/* number of days the trip lasted and the origin and destination in the form
/* day%d%_%i%_%ii%.
/*
/* It is necessary to run the kayak_trips_parcer.aml first to produce origin and
/* destination files for each individual trip.
/*
/* Two other files are also necessary:  trip.days contains the number of
/* days the trip lasted and trip.num contains the number of times the trip occurred.
```

```
/*
/* Lowell H. Suring & Karin E. Preston
/*
&severity &error &routine exit
/*
/* Start the GRID module
display 1040
grid
/*
/* Initialize counters
/* grd contains the sequential number for the least cost grid names
&s grd = 1
/* list1 contains the sequential number for the point of origin
&s list1 = 1
/* list2 contains the sequential number for the destination point
&s list2 = 1
/* zz is the total number of trips
&s zz = 155
/*
/* Open file with number of days in trip
/*
&s file4 [open trip.days status -read]
      &if %status% ne 0 &then
        &type 'Could not open trip.days'
/*
/* Open file with number of times each trip occurred
/*
&s file5 [open trip.num  status -read]
      &if %status% ne 0 &then
        &type 'Could not open trip.num '
/*
/* Loop until all trips processed
&do &while %zz% le 155
/* NOTE: zz will change according to the number of uniques trips being
/* processed.  Check for the highest number created by the kayak_trips_parcer.aml.
/*
/* Initialize counters to separate grids from current and previous loops
&s y = 3
&s z = 2
/*
/* Open origin file
/*
&s file1 [open idlist1_%list1% status -read]
  &if %status% ne 0 &then
    &type 'Could not open idlist1_%list1%'
/*
```

```
/* Open destination file
/*
&s file2 [open idlist2_%list2% status -read]
  &if %status% ne 0 &then
     &type 'Could not open idlist2_%list2%'
/*
/* Open file with least cost grid names
/*
&s file3 [open trip_%grd% status -read]
  &if %status% ne 0 &then
    &type 'Could not open trip_%grd%'
/*
/* Read point of origin
/*
&s i [locase [read %file1% readstat]]
/*
/* Read destintion
&s ij [locase [read %file2% readstat]]
/*
/* Process each record until point of origin file is empty
&do  &while %readstat% eq 0
/*
/* Check to see if destination point is the end of file
&if %ij% ne 99999 &then
   &s ii = %ij%
&s ij [locase [read %file2% readstat]]
/*
&end
/*
/* Read number of days in trip
/*
&s d [locase [read %file4% readstat]]
/*
/* Read number of trips for 1st trip
/*
/*&s n = [read %file5% readstat]
/*
/* Read name of first least cost grid
/*
&s lcgrd [locase [read %file3% readstat]]
&s lcgrd1 = %lcgrd%
/*
/* Read second least cost grid
&s lcgrd [locase [read %file3% readstat]]
&s lcgrd2 = %lcgrd%
/*
```

```
/* Add first two grids together
leg%z% = %lcgrd1% + %lcgrd2%
/*
&s leg%z% = [locase leg%z%]
/*
/* Read third least cost grid
&s lcgrd [locase [read %file3% readstat]]
/*
/* Process each record until file is empty
&do &while %readstat% = 0
/*
/* Add grids together
  leg%y% = leg%z% + %lcgrd%
/*
/* Increment counters
  &s y = %y% + 1
  &s z = %z% + 1
  &s leg%y% = leg%z%
/*
/* Read  next least cost grid
/*
&s lcgrd [locase [read %file3% readstat]]
/*
&end
/*
/* Increment counters to next trip number
&s list1 = %list1% + 1
&s list2 = %list2% + 1
&s grd = %grd% + 1
&s zz = %zz% + 1
/*
&s y = %y% - 1
rename leg%y% day%d%_%i%_%ii%
/*
&end
/* Close all files
&s closer = [close -all]
&messages &on
quit
&ret
/*
/* Error routine
/*
&routine exit
&severity &error &ignore
&s closew = [close -all]
```

```
&ret &error An error has occurred.
quit
&ret
```

buffer_kayak.aml

```
/* An area 500 meters from the shoreline was coded 1 wherever the original value was 0.
/* Areas inside buffer and between the shore and a higher corridor value were manually
coded
/* with the higher value according to manuscripts prepared by Lowell Suring.  This was
account
/* for incidental use that was not documented.
/*
/* Start the GRID module
display 1040
grid
/*
/* Set up loop to process all months
&do i &list ~
  may june july aug allmon
&s outgrid = %i%
/*
/* If the original grid has a value of 0 and the buffer grid has a value of 1, code the outgrid
1.
/* Otherwise the value of the outgrid will be the same as the original grid.
if (%outgrid%grd == 0 and buffer_grd == 100 )
   %outgrid%buf = 1
else
   %outgrid%buf = %outgrid%grd
endif
&end
quit
&ret
```

mean_combine.aml

```
/* This aml takes the monthly outputs from the cumulative.aml or the cumulative_kayak.aml
/* and, in it's simplist form, determines the mean value for each analysis area.  If the value
in
/* the original grid is greater than the mean value, the mean value is replaced with the
original
/* value.   The  analysis area grid is combined with the mean grid so mean values/analysis
area
/* can be reported.
/*
```

```
/* For the charter boats, this is all that is done.
/*
/* Extra steps for the commercial fish boats:
/* those analysis areas where no fishing was allowed were zeroed out.  The values in them
/* were errors caused when a corridor corridor crossed an analysis area boundary.
/* There were no trips in May for the commercial fish boats.
/*
/* Extra steps for the recreation boats:
/* The Chenega and hatchery trips were added to the rest of the recreation boats.
/*
 /* Extra steps for the kayaks:
/* The 500 meter buffer was removed.
/*
/* Lowell H. Suring & Karin E. Preston
/*
/* Start the GRID module
display 1040
grid
/*
/* Set up a loop to process cumulative totals for each month
&do i &list ~
  may june july aug sept allmon
&s outgrid = %i%
/*
/* Areas outside the corridors must be NODATA for the ZONALMEAN command
/* to work properly.
%outgrid%null = setnull (%outgrid%grd == 0, %outgrid%grd)
/*
/* Determine the mean value for each analysis area.
%outgrid%zone = int (zonalmean (analysis_areas_grid, %outgrid%null))
/*
/* In order to replace the mean values with the corridor values (if they are
/* higher), the NODATA must be changed to 0.
%outgrid%zero = con (isnull (%outgrid%zone), 0, %outgrid%zone)
%outgrid%grd2 = con (isnull (%outgrid%grd ), 0, %outgrid%grd )
/*
/* If the value in the corridor grid is higher than the mean value, write
/* the value of the corridor grid to the outgrid.  Otherwise write the mean.
/* NOTE: this grid is for display only.
if (%outgrid%grd2 le %outgrid%zero)
   %outgrid%comb = %outgrid%zero
else
   %outgrid%comb = %outgrid%grd2
endif
/*
/* Change to an integer grid
```

```
%outgrid%mean = int(%outgrid%comb)
/*
/* Get rid of the intermediate grids
kill (!%outgrid%zero  %outgrid%comb %outgrid%grd2!)
/*
/* Combine the analysis area grid with the zone grid so you can report the
/* mean value for each analysis area.
%outgrid%vat = combine (%outgrid%zone, ../analysis_areas/an_area_null)
/*
/* Make sure the corridor grid is integer and doesn't have NODATA.  (for easier
/* plotting).
rename %outgrid%grd %outgrid%1
%outgrid%grd = int (con (isnull (%outgrid%1), 0, %outgrid%1))
kill %outgrid%1
/*
/* Make sure the mean grid is integer and doesn't have NODATA.  (for easier
/* plotting.
rename %outgrid%mean %outgrid%1
%outgrid%mean = int (con (isnull (%outgrid%1), 0, %outgrid%1))
kill %outgrid%1
/*
&end
quit
&ret
```

combined_use.aml

```
/* This aml adds all the trip classes together.  It creates totals by month and for all months
/* for both the raw data and the mean values.
/*
/* Prepare the individual grids so they can be added together
/*
/* Kayak trips
/* Set up a loop to process kayak trips
&do i &list ~
  may june july aug sept allmon
&s outgrid = %i%
/*
/* remove buffers on shoreline
%outgrid%0 = con (../kayak_use3/%outgrid%buf == 1, 0, ../kayak_use3/%outgrid%buf)
/*
/* Get rid of NODATA so can add grids
%outgrid%zero = con (isnull (%outgrid%0), 0, %outgrid%0)
rename %outgrid%zero %outgrid%k
kill %outgrid%0
/* allmonk is the total for all months for kayaks
```

```
&end
/*
/* Charter boats
/*
/* Set up a loop to process charter boats
&do i &list ~
  may june july aug sept
&s outgrid = %i%wc
/*
/* Get rid of NODATA so can add grids
%outgrid%zero = con (isnull (../charter/%outgrid%grd), 0, ../charter/%outgrid%grd)
rename %outgrid%zero %outgrid%
&end
/*
/* Add monthly grids together
cumwc = maywc + junewc + julywc + augwc + septwc
/*
/* Com Fish
/* Set up a loop to process commercial fishing boats
&do i &list ~
  june july aug sept
&s outgrid = %i%cf
/*
/* Get rid of NODATA so can add grids
%outgrid%zero = con (isnull (../com_fish/%outgrid%grd), 0, ../com_fish/%outgrid%grd)
rename %outgrid%zero %outgrid%
&end
/* Add up all Com Fish use
cumcf = junecf + julycf + augcf + septcf
/*
/* Rec boats
/* Set up a loop to process recreation boats
&do i &list ~
  may june july aug sept
&s outgrid = %i%rb
/*
/* Get rid of NODATA so can add grids
%outgrid%zero = con (isnull (../analysis_areas/%outgrid%grd), 0,
../analysis_areas/%outgrid%grd)
rename %outgrid%zero %outgrid%
&end
/* Add up all recreation boat use
cumrb = mayrb + junerb + julyrb + augrb + septrb
/*
/* Add all trips & monthly trips together
maycuttl = mayk + maywc + mayrb
```

```
junecuttl = junek + junewc + junecf + junerb
julycuttl = julyk + julywc + julycf + julyrb
augcuttl = augk + augwc + augcf + augrb
septcuttl = septk + septwc + septcf + septrb
grndcuttl = cumrb + cumcf + allmonk + cumwc
/*
/* Create means for the monthly totals by class and combined
&do i &list ~
  cumrb cumcf allmonk cumwc grndcuttl maycuttl junecuttl julycuttl augcuttl septcuttl
&s outgrid = %i%
/*
/* Areas outside the corridors must be NODATA for the ZONALMEAN command
/* to work properly.
%outgrid%null = setnull (%outgrid% == 0, %outgrid%)
/*
/* Determine the mean value for each analysis area.
%outgrid%zone = zonalmean (/fsfiles/unit/res/evos_gis/model/analysis_areas/an_area_null,
%outgrid%null)
/*
/* In order to replace the mean values with the corridor values (if they are
/* higher), the NODATA must be changed to 0.
%outgrid%zero = con (isnull (%outgrid%zone), 0, %outgrid%zone)
%outgrid%grd = con (isnull (%outgrid%null ), 0, %outgrid%null)
/*
if (%outgrid%grd le %outgrid%zero)
  %outgrid%comb = %outgrid%zero
else
  %outgrid%comb = %outgrid%grd
endif
/*
/* Change to an integer grid
%outgrid%mean = int(%outgrid%comb)
/*
/* Get rid of the intermediate grids
kill (!%outgrid%zero %outgrid%comb %outgrid%null!)
/*
/* Combine the analysis area grid with the zone grid so you can report the
/* mean value for each analysis area.
%outgrid%vat = combine (%outgrid%zone,
/fsfiles/unit/res/evos_gis/model/analysis_areas/an_area_null)
/*
/* Make sure the corridor grid is integer and doesn't have NODATA.  (for easier
/* plotting.
rename %outgrid%grd %outgrid%1
%outgrid%grd = int (con (isnull (%outgrid%1), 0, %outgrid%1))
kill %outgrid%1
```

```
/*
/* Make sure the mean grid is integer and doesn't have NODATA.  (for easier
/* plotting.
rename %outgrid%mean %outgrid%1
%outgrid%mean = int (con (isnull (%outgrid%1), 0, %outgrid%1))
kill %outgrid%1
/*
&end
/*
/* Add the mean values for the ferry & cruise routes to the mean values
/* for the total of all other trips and the total for each month.
/*
/* Set up a loop to create new mean grids that have the  ferry & cruise routes added in
&do i &list ~
   may june july aug sept grnd
&s outgrid = %i%
/*
/* Add ferry & cruise routes
rename %outgrid%cuttlmean outgrid2
%outgrid%cuttlmean = outgrid2 + %.wfte%/analysis_areas/aa_%outgrid%_grd
kill outgrid2
&end
&ret
```

Exxon Valdez Oil Spill
Restoration Project Final Report

Western Prince William Sound Human Use and Wildlife Disturbance Model – Predictions of Future Human Use Patterns and Associated Wildlife Disturbance

Restoration Project 99339
Final Report – Chapter 2

Lowell H. Suring[1]
Chugach National Forest
3301 C Street, Suite 300
Anchorage, Alaska 99503

Karen A. Murphy[2]
Glacier Ranger District
Chugach National Forest
P.O. Box 129
Girdwood, Alaska 99587

Ali Iliff[3]
Alaska Department of Natural Resources
Division of Parks and Outdoor Recreation
Anchorage, Alaska 99503

Shay Howlin
Western EcoSystems Technology, Inc.,
Cheyenne, Wyoming 82001

Karin Preston
Chugach National Forest
3301 C Street, Suite 300
Anchorage, Alaska 99503

August 2004

[1] Current address: USDA Forest Service, Terrestrial Wildlife Ecology Unit, Forestry Sciences Laboratory, 316 East Myrtle Avenue, Boise, Idaho 83702
[2] Current address: U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, Alaska 99503.
[3] Current address: 1600 West 11th Avenue, Number 33, Anchorage, Alaska 99501.

Western Prince William Sound Human Use and Wildlife Disturbance Model – Predictions of Future Human Use Patterns and Associated Wildlife Disturbance

Restoration Project 99339
Final Report – Chapter 2

Study History: Project 99339 was proposed in 1997 by the USDA Forest Service and the Alaska Department of Natural Resources as a pilot project covering western Prince William Sound. Funding for the initial year of the project was received in December 1997 from the *Exxon Valdez* Oil Spill Trustee Council. Part A of the final product was submitted to the *Exxon Valdez* Oil Spill Trustee Council for review in December 1999. That report included a description of human use patterns in 1998, distribution of selected species injured as a result of the *Exxon Valdez* Oil Spill, results of a literature review on the effects of human disturbance on wildlife, and general management recommendations. This report constitutes Part B of the final product and includes predictions of future human use patterns, descriptions of potential areas of increased conflict with selected injured species, and specific management recommendations.

Abstract: We described the relationship of modeled future human use patterns with the distribution of harbor seals (*Phoca vitulina*) and pigeon guillemots (*Cepphus columba*) in western Prince William Sound. Predicted monthly use in 2015 within 1,000 m of individual pigeon guillemot nesting sites ranged from no change to increases > 4 times use in 1998 by kayakers and from no change to increases approximating 20 times by motorized recreational boats. Predicted monthly use in 2015 within 1,000 m of individual haul-out sites for harbor seals ranged from no change to increases approximating 12 times by kayakers and from no change to increases approximating 45 times by motorized recreational boats.

We recommend that education programs be developed that identify situations and habitats that should be avoided. New camp sites and upland recreation sites should be developed to help divert use away from sensitive areas. Consideration should be given to closing existing sites or discouraging their use in the vicinity of sensitive areas. A greater presence in the Sound by personnel of management agencies is needed to implement education efforts, enforce existing regulations, and assure adherence to closed area policies.

Key Words: Alaska, *Cepphus columba, Exxon Valdez*, geographic information system, GIS, harbor seals, human use, *Phoca vitulina*, pigeon guillemots, Prince William Sound, wildlife disturbance.

Project Data: Predicted monthly and cumulative use data and use patterns of kayak and recreational motor boat user groups for western Prince William Sound for 2015 stored as MS Excel spreadsheets and ArcGIS geographic information system data files, respectively are held by Karin Preston, USDA Forest Service, Chugach National Forest, Anchorage, Alaska, 907-743-9574, kpreston@fs.fed.us. Spatial data are available upon request as Arc export files.

Citation: Suring, L. H., K. A. Murphy, A. Iliff, S. Howlin, and K. Preston. 2004. Western Prince William Sound human use and wildlife disturbance model – predictions of future human use patterns and associated wildlife disturbance. Pages 200-269 *in* K. A. Murphy, L.

H. Suring, and A. Iliff. 2004. Western Prince William Sound human use and wildlife disturbance model, *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 99339), USDA Forest Service, Chugach National Forest, Anchorage, Alaska.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Fig. 13. Predicted use by kayaks in 2015 within 1,000 m of 36 harbor seal haulout sites evaluated from June through August (low levels = 0 – 15 more vessels per season; moderate levels = 16 – 100 more vessels per season; high levels = >100 more vessels per season).

Fig. 14. Spatial distribution of kayak use levels in 2015 within 1,000 m of harbor seal haulout sites in western Prince William Sound, Alaska.

Fig. 15. Mean number of motorized recreation boats within 1,000 m of harbor seal haul-out sites in western Prince William Sound, Alaska (error bars represent standard error).

Fig. 16. Predicted use by recreation boats in 2015 within 1,000 m of 36 harbor seal haulout sites evaluated from June through August (low levels = 0 – 15 more vessels per season; moderate levels = 16 – 100 more vessels per season; high levels = >100 more vessels per season).

Fig. 17. Spatial distribution of recreation boat use levels in 2015 within 1,000 m of harbor seal haulout sites in western Prince William Sound, Alaska.

EXECUTIVE SUMMARY

Prince William Sound provides spectacular scenery and essential habitat for thousands of seabirds, marine mammals, 5 species of salmon, as well as habitat for upland birds and mammals. It also provides an economically important fishery for salmon, blackcod, Pacific herring and other species. As human activities in the Sound have changed, so have the distribution and abundance of wildlife and fish populations that occur in the Sound. Over the last 15 years, the *Exxon Valdez* oil spill in 1989 was the most notable human-caused impact to the Sound's ecosystem. However, the opening of the Whittier Access road in the summer of 2000 is likely to bring new challenges to the Sound and to the species recovering from the spill as a result of increasing human use and associated development. Prior to construction of this road, access to western Prince William Sound was limited to float planes, the Alaska Railroad, Alaska State Ferries, and other boat traffic from Seward and Valdez. The new road provides easy and immediate access to the Sound for ½ of the State's population.

As human use in Prince William Sound increases, there is an increasing potential that human disturbance will play a major role in the distribution and population dynamics of many wildlife species. What effect this change may have on the recovery of species injured by the spill will depend on resource managers' abilities to understand and mitigate the effects of human activity in areas important to the injured species. While increased human activity in the Sound may affect the recovery of species injured by the spill, little information has been available to document and monitor the changing patterns of human use in the Sound. This project was designed as a tool for resource managers in the western Sound to help them understand the potential relationships between human activity and local wildlife populations.

Human activity in the western Sound is strongly tied to the water of the Sound. People participating in upland activities generally access upland sites via the water. The greatest potential for disturbance to injured species is also most likely to be from water-based activities. For these reasons, this portion of our project focused entirely on kayakers and recreational motor boat users. We gathered information on use levels and distribution of use for each of the user groups through examination of public and private records. We incorporated this information with the results of user surveys and developed GIS techniques to assist us in describing use patterns. We also evaluated the resulting patterns with field data.

To evaluate the projected distribution of vessels in each user group throughout the western Sound, aerial surveys were conducted during summer months in 1998 to record the density of water vessel use on weekends and weekdays. Members of user groups were also surveyed to better describe current use patterns and to determine what their likely response would be to increased use of the Sound and potential crowding. To compare human use levels near concentrations of sensitive species, distribution maps of concentration areas were created for 2 species. Harbor seals and pigeon guillemots were selected to represent 2 classes of animal species injured as a result of the *Exxon Valdez* oil spill. We also evaluated current human activity patterns associated with cutthroat trout (*Oncorhynchus clarki*) habitat and decided that our data were not sufficient to evaluate potential future use of this resource.

Seventeen aerial surveys were flown from June through September 1998 to provide information necessary to evaluate patterns of use developed for water vessels in the western

Sound. We also conducted simultaneous aerial and water-based surveys to evaluate the sightability of water vessels during aerial surveys. Comparisons of the relative number of water vessels predicted to occur in the western Sound through our GIS analyses with the results of the aerial surveys revealed strong correlations. These results are presented in Part A of this report.

Generalized linear models of current use by month were fit for kayakers and recreational motorboat users. The number of occurrences of each user group was assumed to follow a Poisson distribution. Twenty-eight variables describing distance to and density of sites and characteristics of interest to water-borne recreationists in the western Sound were available to develop models of human use patterns. Values for explanatory variables were derived through GIS techniques and were used to model the number of occurrences of each user group from a sample of grid cells throughout western Prince William Sound. Explanatory variables described distance to and density of features assumed to affect human distribution in the Sound, such as scenic features, recreation opportunities, and campsites. The candidate variable set for each month for each user group was reduced to 7 variables by ranking the univariate models by the lowest Akaike's Information Criterion value.

Univariate analyses relating each of the 28 individual variables to existing-use patterns showed similarity in top-ranked variables among months for distribution of kayaks and motorized recreation boats. Minimizing the distance to harbor, distance to shore (that is, avoiding open water), and distance to camp sites were consistently important to kayakers. Other characteristics that influenced distribution of kayakers were glaciers, wildlife viewing opportunities, and upland recreation sites (including access to trails). Minimizing distance to the harbor was also important for motorized recreation boat users, as was distance to anchor buoys and safe anchorage sites. Distance to shore was less important to this user group. Glaciers and upland recreation sites also attracted these users. Sport fishing opportunities consistently influenced distribution patterns of motorized recreation boat users. Opportunities for hunting black bear in the spring and Sitka black-tailed deer in the late summer and fall also had limited influence.

Multivariate model selection using these variables involved selecting the top 7 models from all possible models for each month. Final multivariate model selection attempted to minimize bias and variance and was based on model predictions made using a test data set. Separate distributions of the number of existing occurrences of each user group for each month were calculated for the entire dataset for the western Sound using the regression equations of the top 7 final models from the model fitting dataset. Spatial use patterns resulting from each of these models were compared with the spatial pattern of existing use. The models that best matched the spatial pattern of existing use for each month were selected for use in the process to estimate future use patterns.

Variables that entered these selected models to estimate monthly use patterns of kayakers included distance to campsites, shore, tidewater glaciers, upland recreation opportunities, and Whittier. As distance to these sites and characteristics increased, use decreased. The magnitude of the individual effect of each of these variables remained relatively constant among months. Distance to Whittier had a moderate effect on use levels predicted by models selected for all of the months. Distance to camp sites had a greater effect in all models. Distance to shore had a large effect in the models for June and July.

Variables that entered selected models to estimate monthly use patterns of motorized recreational boaters included distance to upland recreation opportunities, upland glaciers, safe anchorage sites, sport fishing opportunities, and Whittier. As distance to these sites and characteristics increased, use decreased. The magnitude of the individual effect of each of these variables also remained relatively constant among months. Distance to Whittier had a large effect on use levels predicted by models selected for all of the months. Upland recreation opportunities affected use patterns in May and June. Safe anchorage sites had a large influence on use patterns in July. Sport fishing opportunities influenced use in August and September.

Predicted monthly use in 2015 of kayaks within 1,000 m of individual Pigeon guillemot nesting sites ranged from no change to increases > 4 times current use. Mean monthly increases at all sites ranged from 150 to 250%. Predicted monthly use in 2015 of motorized recreational boats within 1,000 m of individual nesting sites ranged from no change to increases approximating 20 times current use. Mean monthly increases ranged from 380 to 660%. Predicted monthly use in 2015 of kayaks within 1,000 m of individual haul-out sites for Harbor seals ranged from no change to increases approximating 12 times current use. Mean monthly increases at all sites ranged from 110 to 290%. Predicted monthly use in 2015 of motorized recreational boats within 1,000 m of individual haul-out sites ranged from no change to increases approximating 45 times current use. Mean monthly increases ranged from 340 to 390%.

Many authors that presented approaches for managing people to reduce the effects of disturbance on wildlife identified the same range of protective measures including (1) public education, (2) enforcement of existing laws and regulations, (3) exclusion of specific forms of transportation, (4) exclusion of dogs and the removal of other introduced predators, (5) excluding people from large or small areas, (6) redirecting public access, and (7) habitat manipulation. Because land management jurisdiction in the Sound is so complex, public education may be one of the strongest tools available to managers.

We recommend that specific education materials be developed for distribution to recreational boaters in the Sound that identify the situations and general habitats that should be avoided to minimize disturbance to sensitive wildlife. Education programs should also be developed and delivered to ecotourism guides and to water taxi operators to ensure their operations do not result in increased disturbance. Efforts should be made for areas in the vicinity of nesting or haulout sites that are predicted to receive large increases of human use to redirect this potential increase in use. Camp sites appear to affect distribution of kayaks through out the months when pigeon guillemots and harbor seals are sensitive to disturbance. New camp sites should be developed in areas that will help divert use away from identified nest sites and haulout sites (and other sensitive areas). Consideration should be given to closing existing camp sites or otherwise discouraging their use in the vicinity of sensitive areas. Upland recreation sites appear to affect distribution of both kayakers and motorized recreation boat users during portions of the season when wildlife is vulnerable to disturbance. Developing new upland recreation sites and closing old sites should also be given consideration. Restricting use by kayakers and motorized recreation boat users in particularly sensitive areas should also be given consideration if use patterns cannot be redirected. A greater presence in the Sound by personnel of management agencies will also help with implementation of education efforts, enforcement of existing regulations, and adherence to closed area policies (if necessary).

INTRODUCTION

Prince William Sound’s (the Sound) combination of rugged coastal mountains, glaciers, sheltered waters, and forested islands provide a mix of spectacular scenery and maritime habitats. The Sound provides essential habitat for thousands of seabirds, marine mammals, 5 species of salmon, as well as habitat for upland birds and mammals. It also provides an economically important fishery for salmon, blackcod, Pacific herring and other species. The wealth of abundant wildlife and fish and impressive scenery has drawn people to the area for thousands of years.

Over the last century, human activity in the Sound has changed from exclusively providing homes and sustenance to its Native Alaskan residents, to include the exploitation of marine mammals for Russian fur traders, to mining, and most recently to oil exportation, fisheries, tourism, and recreation. As human activities in the Sound have changed, so have the distribution and abundance of wildlife and fish populations that occur in the Sound. In recent years, the *Exxon Valdez* oil spill in 1989 has been the most notable human-caused impact to the Sound's ecosystem. However, the opening of the Whittier Access road in the summer of 2000 is likely to bring new challenges to the Sound and to the species recovering from the spill as a result of increasing human use and associated development (Brooks and Haynes 2001).

Thirteen years after the spill, only 6 injured species were considered to have recovered from the effects of the spill, while 5 species were believed to still be recovering (Table 1). Populations of 8 species have shown little or no improvement and are listed as “not recovering," while an additional 4 species are in an unknown recovery status (*Exxon Valdez* Oil Spill Trustee Council 2002). Simple explanations for the different recovery responses shown by different species do not exist. The ability of a species to recover from the effects of an event like the spill depends on a multitude of factors, including breeding strategies, food availability, habitat quality, and other pressures that may exist on the population, in addition to any lingering effects of the spill. As human use in the Sound increases, there is an increasing potential that human disturbance will play a major role in the distribution and population dynamics of many wildlife species. What effect this change may have on the recovery of species injured by the spill will depend on resource managers’ abilities to understand and mitigate the effects of human activity in areas important to the injured species.

The Whittier Access road was completed in 2000. Although Whittier is only approximately 76 km from Anchorage, the only access to the community had been via the Alaska railroad, by floatplane, or by boat. The new road provides another means of access to the western Sound for 73% of Alaska's population who may readily drive to Whittier. The new road also serves the increasing number of visitors to Alaska. This improved access is expected to result in increased human use (Alaska Department of Transportation and Public Facilities and Federal Highway Administration 1995), which may have consequences for wildlife and fish populations in the Sound. Future management of the Sound should be made with an understanding of the human activity that occurs in that area and how that activity may relate to the local wildlife and fish populations. The anticipated changes associated with new road access are in addition to other changes in human use of the Sound that have been occurring over the last decade. Tourism patterns in the Sound have changed as cruise ships altered their routes and glacier tour operators added trips. While the extensive commercial fishery has remained at about the same level in recent years,

Table 1. Recovery status of species injured by the 1989 *Exxon Valdez* oil spill (*Exxon Valdez* Oil Spill Trustee Council 2002).

Status Species (common name)	Scientific name
Not recovering	
Common loon	*Gavia immer*
Cormorants (3 spp.)	*Phalacrocorax spp.*
Harlequin duck	*Histrionicus histrionicus*
Pigeon guillemot	*Cepphus columba*
Harbor seal	*Phoca vitulina*
Pacific herring	*Clupea pallasii*
Recovering	
Marbled murrelets	*Brachyramphus marmoratus*
Sea otter	*Enhydra lutris*
Killer whale (AB pod)	*Orcinus orca*
Clams	Mollusca; Bivalvia
Mussels	Mollusca; Bivalvia
Recovered	
Black oystercatchers	*Haematopus bachmani*
Common murre	*Uria aalge*
Bald eagle	*Haliaeetus leucocephalus*
River otter	*Lutra canadensis*
Sockeye salmon	*Oncorhynchus nerka*
Pink salmon	*Oncorhynchus gorbuscha*
Recovery Unknown	
Kittlitz's murrelet	*Brachyramphus brevirostris*
Cutthroat trout	*Salmo clarkii*
Dolly varden	*Salvelinus malma*
Rockfish	Scorpaenidae

recreational boating and kayaking have increased dramatically in the last decade and are expected to continue increasing (Bowker 2001). For example, kayak use in the Sound has been increasing at an average rate of 7.5% per year since 1988 (Twardock and Monz 2000).

While recreation impacts generally directly affect only a small percentage of natural areas, the effects are usually distributed unevenly primarily due to visitor use patterns (Lucas 1990), with intensive disturbance in some areas and less intensive disturbance in other areas. Knowledge of the magnitude of impacts is needed to evaluate their ecological and social significance and acceptability, and to prioritize management and maintenance needs (Leung and Marion 2000). The magnitude of recreation impacts is often evaluated by describing the intensity and spatial qualities of associated recreation activities (Leung and Marion 2000).

Increased human activity in the Sound may affect the recovery of species injured by the spill, but little information has been available to document and monitor the changing patterns of human use in the Sound. This project was designed as a tool for resource managers in the western Sound to help them understand the potential relationships between human activity and local wildlife populations. This information is particularly important because the new access into the western Sound is expected to result in dramatic increases in recreation-based human activities.

An extensive body of literature has established that many human activities near wildlife cause disturbance to individual animals. Since the early 1970s, biologists have been concerned about the increasing use of important wildlife habitats for human activities, such as recreation. This concern led to many studies that investigated whether recreation and other human activities caused disturbance to local wildlife. The results of these studies varied widely between species, season, and the intensity and form of human activity; however, the majority of the studies documented a disturbance effect on wildlife. In a literature review of human-caused disturbance to birds, Hockin et al. (1992) found 44 species in 50 reports that showed changes in breeding success as a result of human disturbance. At least 18 species in 14 reports showed changes in nest site choices; 24 species, ranging from waterfowl to songbirds, showed changes in distribution in response to disturbance. Similar studies have documented disturbance in marine mammals (e.g., Richardson et al. 1995). Unfortunately, for most forms of human activities, the consequences to wildlife populations of such disturbances are poorly understood. Short-term consequences have been documented for some species, but even less is known about long-term effects on populations.

In reviewing literature on human disturbance to wildlife, it becomes apparent that generalizations are difficult to make, especially since local policy and management practices can greatly alter the level of disturbance caused by human activity. We have provided a summary of information from the disturbance literature on the potential effects of different activities, consequences that have been shown for a variety of species, and management actions that have been used to minimize adverse effects (Murphy et al. 2004). To demonstrate how human use in the western Sound may affect injured species, we examined the relationship of existing use and predicted future human use patterns relative to the general distribution patterns of nesting pigeon guillemots and harbor seal concentration sites. Both pigeon guillemots and harbor seals have been classified as ‘not recovered’ from the effects of the spill (*Exxon Valdez* Oil Spill Trustee Council 2002).

This project was conducted in 2 phases designed to provide information to managers and businesses interested in protecting the resources in the western Sound as human use increases. First, to provide a baseline for understanding the potential effects of human activity on injured resources, we must understand current human use patterns. Second, we wanted to explore how those human use patterns may change with new access and increasing use in the western Sound.

The goal of this project was to provide a foundation for displaying and understanding existing and predicted future human use patterns in the western Sound, the potential disturbances these uses may have on injured resources, and to make management recommendations to minimize adverse effects of increased human use on wildlife populations. Because the scope of this project was larger than originally anticipated, we divided our final report into 2 chapters. Chapter 1 presented the distribution of current human uses as baseline information, baseline information on 3 injured species used as examples, the review of wildlife disturbance literature, and general management recommendations. This chapter describes the methodology used to develop predictive models and their results to explore potential human use patterns in the study area after the Whittier Access road was opened. This second chapter also provides more site-specific management recommendations by identifying areas where the intensity or pattern of human use is expected to change near important habitats for injured resources.

OBJECTIVES

Project objectives have been slightly modified to accommodate the focus of 2 chapters. The intent of the original objectives is still covered in the combination of the 2 chapters. There were 3 objectives originally identified for this project:

1. Describe existing and potential human-use patterns in western Prince William Sound,
2. Identify areas where human disturbance has a high potential to affect injured resources, and
3. Develop management recommendations for public agencies to minimize or eliminate the effects of disturbance on injured resources.

This chapter addresses the following objectives:

1. Model and describe potential future patterns of human use,
2. Identify areas where potential future human use patterns intersect with important areas associated with injured resources, and
3. Provide specific management recommendations to reduce the effects of disturbance.

METHODS

Prince William Sound is located in South-central Alaska. The Sound is sheltered from the Gulf of Alaska by Montague and Hinchinbrook islands, and is separated from interior Alaska by the Chugach and Kenai mountains. Our study area included the western half of the Sound. The line dividing the Sound for our study runs southwest between Point Freemantle on the southwestern edge of Valdez Arm through Montague Strait to Cape Puget at the southwestern corner of Port Bainbridge (Fig. 1). The study area covers 9,700 km^2 (5,044 km^2 of saltwater) and includes 1,754 km of mainland shoreline and an additional 2,108 km of shoreline along 146 islands. Of the 5 communities within the Sound, only Whittier and Chenega Bay are within the study area.

The Chugach National Forest manages the largest amount of upland areas within the study area (4,160 km^2); the State of Alaska manages additional public land (183 km^2), including the State Marine Park system. The Alaska Department of Natural Resources

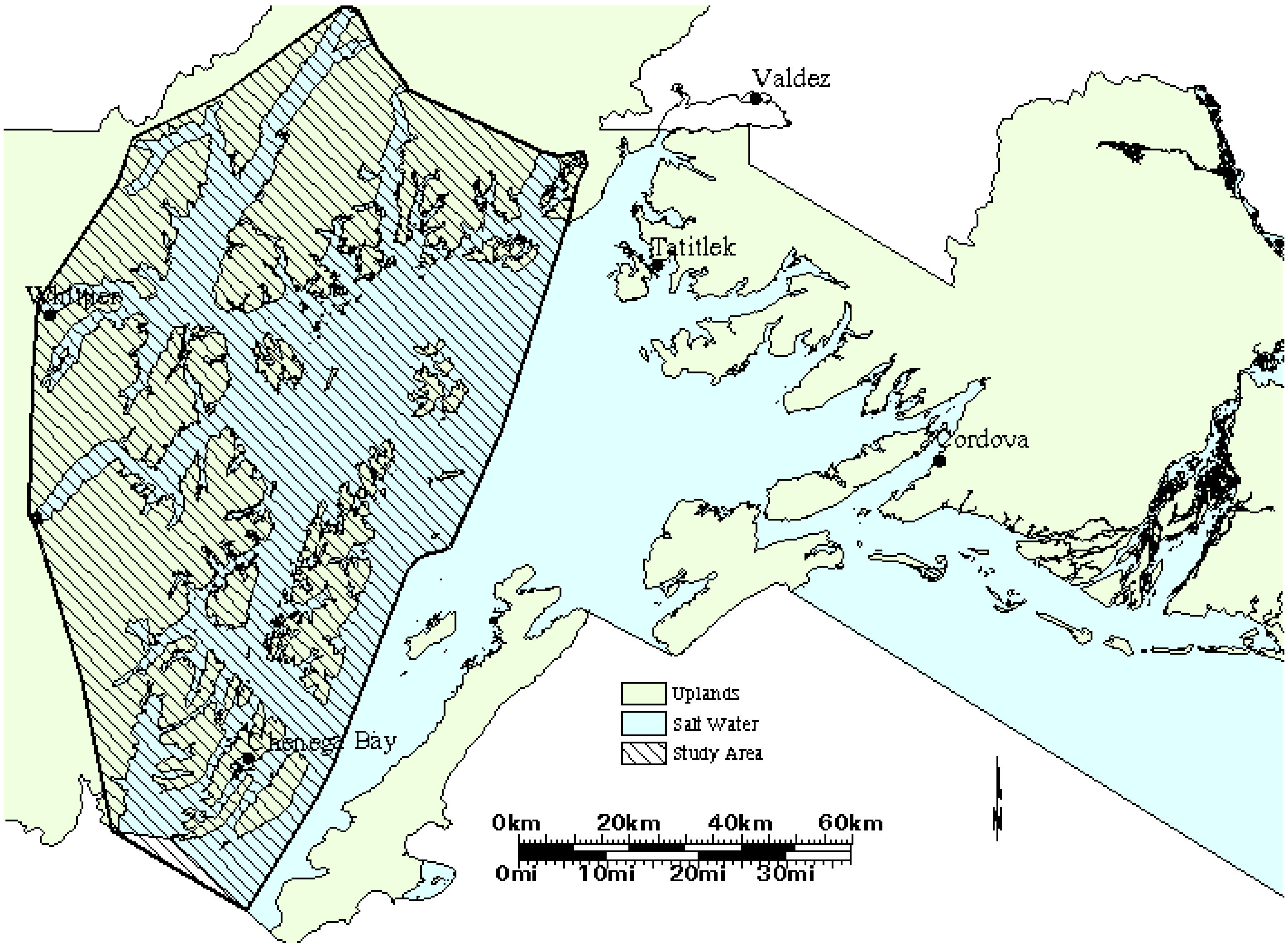


Fig. 1. Location of the study area in western Prince William Sound, Alaska, USA.

manages most of the submerged and tidal lands up to the mean high tide mark within the study area. Native Corporations manage approximately 265 km^2 of land primarily in the southwestern quarter of the study area. There is limited private ownership of lands outside of the communities, but private parcels do exist (6 km^2 total).

Simulation modeling has been characterized as the imitation of processes and events that occur in the real world over time. It requires the development of base data, which describe the system, and the evaluation of those data to develop deductions about how the real world system operates. This approach is especially suited to analyses that are too complex for direct observation or manipulation (Law and Kelton 1991). Wang and Manning (1999) used simulation modelling to describe visitor travel patterns and subsequent use levels to aid planning for National Park units. We developed an assessment of amount and distribution of current use patterns for selected injured resources and for a number of human uses in the Sound. We used the patterns of human use to develop models that simulated those use patterns, modified the models to estimate future human use patterns, and used that information to describe potential disturbance problems for the injured resources.

Resource Distribution

To compare human use levels near concentrations of injured resources, distribution maps of concentration areas were created for 2 species. The 2 injured resources were used as examples to demonstrate how information on distribution of human use was relevant to the recovery of different species. Harbor seals and pigeon guillemots were selected to represent 2 classes of animal species injured as a result of the spill. At least 1 principal investigator for each species was contacted and asked to supply the most recent data for harbor seal haulout locations and pigeon guillemot nesting sites.

Pigeon guillemot.—Data for pigeon guillemot nest locations and associated population size were obtained from the U.S. Fish and Wildlife Service Berengia Seabird Colony Catalog (U.S. Fish and Wildlife Service 1999).

Harbor seals.—Latitude and longitude locations of harbor seal haulout sites were obtained from three sources (K. Frost, Alaska Department of Fish and Game; J. Burns, Living Resources Inc., D. Withrow, National Oceanic and Atmospheric Administration). All surveys were flown to observe the animals during molt from mid-August to early September. Sites were monitored with varying frequencies so population estimates may be based on 1996, 1997 or 1998 data. All haulout sites were represented by point locations in the GIS. However, some sites, particularly those associated with ice from tidewater glaciers, cover areas larger than indicated by the point.

Model Development

GIS Database Development.—The ArcInfo GIS grids representing our approximation of use patterns in 1998 (from Murphy et al. 2004) contained approximately 1.4 million 60 m x 60 m cells. Grids existed for kayakers and motorized recreational boat users, for each month from May through September, and for total season use. Each cell in the grids contained a value representing the amount of use that cell received during each time period. Fourteen thousand grid cells (i.e., a 1% sample) were randomly selected as samples to represent use patterns during the model building process.

Spatial databases were prepared in the GIS for point locations of 14 characteristics known or assumed to influence use patterns of kayakers and/or recreational boaters in the western Sound (Table 2). Sources for the locations of these characteristics included USDA Forest Service (unpublished information, Glacier Ranger District, Gridwood, Alaska), S. Hennig (unpublished information, Chugach National Forest, Anchorage, Alaska), Alaska Department of Natural Resources (1997), and NOAA (2000). A 1-km^2 moving-window GIS routine was used to calculate the density of 12 of the characteristics in number/km^2 for each pixel in the study area. These density values were then associated with each of the 14,000 sample grid cells. Distances from each of the 14,000 sample grid cells to the nearest occurrence of each of the 14 characteristics were also calculated. Distances were also calculated from each of the 14,000 sample grid cells to the nearest shore and to the harbor in Whittier.

Table 2. Variables evaluated for modeling distribution of kayaks and motorized recreation boats in western Prince William Sound, Alaska. Distances were in meters and densities were counts per km^2.

Characteristic	Number of Sites	Form of variable and models considered[a]	
		Distance	Density
Safe anchorage	199	RB[b]	RB
Known sites suitable for camping	30	K[c], RB	K, RB
Known sites preferred for sport fishing	18	RB[b]	RB
Location of upland glaciers	14	K, RB[b]	K, RB
Location of fish hatcheries	5	RB	
Known sites preferred for black bear or Sitka black-tailed deer hunting	32	RB	RB
Location of lodges open to the public	3	RB	
Sites known to have outstanding or remarkable scenery	22	K, RB	K, RB
Location of tidewater glaciers	13	K[c], RB	K, RB
Sites adjacent to upland areas providing recreation opportunities	85	K[c], RB[b]	K, RB
Areas with a diversity of wildlife resources		K, RB	K, RB
Sites known to provide consistent wildlife viewing opportunities	18	K[c], RB	K, RB
Locations of anchor buoys		RB	RB
Locations of recreation cabins available to the public	6	K, RB	K, RB
Distance to shore	--	K, RB	
Distance to harbor	--	K[c], RB[b]	

[a] Considered for motorized recreation boat (RB) models and/or kayak (K) models.
[b] Included in models to estimate use by motorized recreation boats.
[c] Included in models to estimate use by kayaks.

Statistical Model.—A generalized linear model of use in 1998 was fit for 10 response variables: the number of kayaks for each month from May through September, and the number of motorized recreational boats for each month from May through September. The number of occurrences of each user group was assumed to follow a Poisson distribution and observations in each grid cell were assumed to have been obtained with equal effort. The Poisson model is a log linear model where the log of the mean number of occurrences is modeled as a linear function of the explanatory variables:

$$\log(\mu) = \beta_o + X_1\beta_1 + ... + X_p\beta_p$$

The 16 GIS-derived explanatory variables were used to develop predictive models of the number of occurrences of each user group from the sample of grid cells in the western Sound.

Model Selection.—The solution to a Poisson regression equation is obtained by maximizing the likelihood function. Model selection in this situation was facilitated using the likelihood statistic and the Akaike's Information Criterion (AIC) (Burnham and Anderson 1998). The candidate variable set was reduced to 7 variables by ranking the univariate models for each variable by the lowest AIC and selecting the top 7 variables. This was done for each month in the analysis. The multivariate model selection process using these top 7 variables involved selecting the best models (without interactions or higher order terms) created from the set of 127 possible models. The dataset was split into a model fitting dataset and a model testing dataset. Final multivariate model selection was based on comparisons of the predictions from each of these models with the model testing dataset.

We estimated the bias of each model by calculating the average size of the difference between the predicted use and the actual use as represented by the model testing dataset. We also calculated the average standard error of the linear predictor as an estimate of variance of each model. We standardized the bias and variance estimates to have a mean of 0 and variance of 1 and took the absolute value of the difference. This approach is similar to that recommended in Burnham and Anderson (1998), and depicts desired models as those having low bias and low variance.

Using Models to Estimate Mean Use.—Predictions of the number of occurrences of each user group for each month in 1998 were calculated for the entire dataset for the western Sound using the regression equations of the top 7 final models from the model fitting dataset. Spatial use patterns resulting from each of these models were compared with the spatial pattern of existing use from Murphy et al. (2004). The models that generated the spatial pattern that best matched the spatial pattern of existing use for each month were selected for use in the process to estimate future use patterns.

An annual percentage of increase of use to year 2015 for kayakers was applied to the 5 grids from Murphy et al. (2004) (i.e., May through September) representing existing use. This annual rate of increase was assumed to be 7.5% based on growth patterns from 1987 to 1998 (Twardock and Monz 2000). This increase in use has been facilitated by a large increase in opportunity for guided trips and water taxi services (Colt et al. 2002). Calculated over 18 years (i.e., 1998 to 2015), this resulted in a total increase of 242%. Additional increases over this time period were expected as a result of increased access via the Whittier road. This additional increase was assumed to be an additional 100% based on the findings of the Alaska Department of Transportation and Public Facilities and Federal Highway Administration (1995). The 5 grids representing monthly kayak use resulting from applying both of these increases in use were multiplied by 0.54 to represent the proportion of kayakers that are not expected to increase their distance traveled in response to additional use (Murphy et al. 2004). Next, the coefficients for the variable representing distance to Whittier were modified in all equations to reflect the willingness of a portion of the kayakers to travel additional distance (e.g., twice as far) to avoid crowding (Murphy et al. 2004). These modified models were applied and the results multiplied by 0.46 (i.e., the proportion of kayakers that are expected to increase their distance traveled in response to additional use). Grids resulting from each of these processes (i.e., increased use and associated increase in travel distance) were combined, by month, to represent total use of kayakers in the western Sound in 2015.

An annual percentage of increase of use to year 2015 for motorized recreation boat users was applied to the 5 existing use grids (i.e., May through September). This annual rate of increase is assumed to be 3.5% (based on analyses by the Alaska Department of Transportation and Public Facilities and Federal Highway Administration [1995]). Over 18 years (i.e., 1998 to 2015) this resulted in a total increase of 80%. Additional increases over this time period were also expected as a result of increased access via the Whittier road. Total boat mooring capacity increase associated with Whittier harbor expansions and trailered boats was assumed to be an additional 100% (estimates of increase by the Alaska Department of Transportation and Public Facilities and Federal Highway Administration [1995] ranged from 112% to 182%). The 5 grids representing monthly motorized recreation boat use resulting from applying both of these increases in use were multiplied by 0.46 to represent the proportion of motorized recreation boat users that are not expected to increase their distance traveled in response to additional use (Murphy et al. 2004). Next, the coefficients for the variable representing distance to Whittier were modified in all equations to reflect willingness of a portion of the motorized recreation boat users to travel additional distance (e.g., twice as far) to avoid crowding (Murphy et al. 2004). These modified models were applied and the results multiplied by 0.54 (the proportion of motorized recreation boat users that will increase their distance traveled in response to additional use). Grids resulting from each of these processes (i.e., increased use and associated increase in travel distance) were combined, by month, to represent total use of motorized recreation boat users in the western Sound, by month, in 2015.

Effects of Increased Use

GIS techniques were used to place 1,000-m buffers around mapped locations of all identified pigeon guillemot nesting areas and harbor seal concentration areas. The ZONALMEAN function in ArcInfo was used to calculate mean use by kayakers and motorized recreation boat users within the salt-water portions of these buffers by month (i.e., May through September) for 1998 and 2015. Data for the months May through August were summarized for potential effects on pigeon guillemots. This time period encompasses the breeding season for pigeon guillemots in southcentral Alaska (Ewins 1993, Kuletz 1998). Data for the months June through August were summarized for potential effects on harbor seals. This time period encompasses the peak pupping season in June through peak molting in August for harbor seals in southcentral Alaska (Pitcher and Calkins 1979, Frost 1997).

RESULTS

Resource Distribution

Locations were obtained for 133 pigeon guillemot nesting areas and 36 harbor seal haulout sites (Figs. 2 and 3).

Model Development

Twenty-eight variables describing distance to and density of sites and characteristics of interest to water-borne recreationists in the western Sound were available to model human use patterns (Table 2). Univariate analyses relating individual variables to existing-use patterns showed similarity in top-ranked variables among months for distribution of kayaks (Table 3) and motorized recreation boats (Table 4). Minimizing the distance to harbor, distance to shore (i.e., avoiding open water), and distance to camp sites were consistently important to kayakers. Other characteristics that influenced distribution of kayakers were glaciers, wildlife viewing opportunities, and upland recreation sites (e.g., access to trails). Minimizing distance to harbor was also important for motorized recreation boat users, as was distance to anchor buoys and safe anchorage sites. Distance to shore was less important to this user group. Glaciers and upland recreation sites also attracted these users. Sport fishing opportunities consistently influenced distribution patterns of motorized recreation boat users. Opportunities for hunting black bear in the spring and Sitka black-tailed deer in the late summer and fall also had limited influence.

Variables that entered models to estimate monthly use patterns of kayakers included distance to campsites, shore, tidewater glaciers, upland recreation opportunities, and Whittier (Tables 1 and 4). As distance to these sites and characteristics increased, use decreased. During May, distance to wildlife viewing opportunities also entered the model, but with increased use associated with increasing distance. The magnitude of the individual effect of each of these variables remained relatively constant among months (Figs. 4a – 4e). Distance to Whittier had a moderate effect on use levels predicted by models selected for all of the months. Distance to camp sites had a greater effect in all models. Distance to shore had a large effect in the models for June and July.

Variables that entered models to estimate monthly use patterns of motorized recreational boaters included distance to upland recreation opportunities, upland glaciers, safe anchorage sites, sport fishing opportunities, and Whittier (Tables 1 and 5). As distance to these sites and characteristics increased, use decreased. The magnitude of the individual effect of each of these variables also remained relatively constant among months (Figs. 5a – 5e). Distance to Whittier had a large effect on use levels predicted by models selected for all of the months. Upland recreation opportunities affected use patterns in May and June. Safe anchorage sites had a large influence on use patterns in July. Sport fishing opportunities influenced use in August and September.

Magnitude and Location of Increased Use

Pigeon guillemot.—Predicted monthly use in 2015 of kayaks within 1,000 m of individual nesting sites ranged from no change to increases > 4 times current use (Table 5). Mean monthly increases at all sites ranged from 150 to 250% (Fig. 6). Of 133 nest sites evaluated from May through August, 67% are predicted to experience low levels (0 – 15 more vessels per season) of increased use within their vicinity by 2015; 20% are predicted

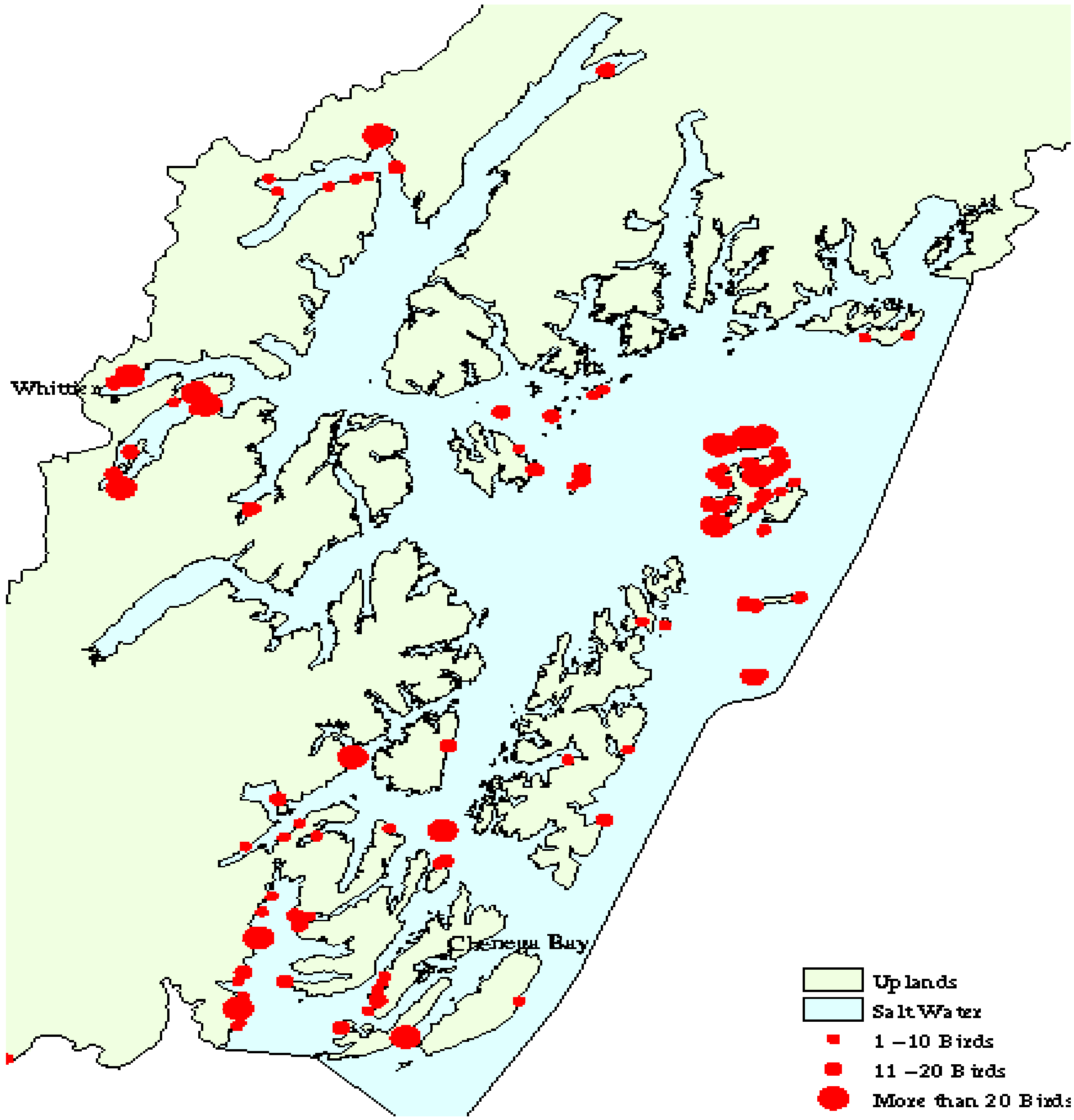


Fig. 2. Location of pigeon guillemot nesting sites in western Prince William Sound, Alaska, USA.

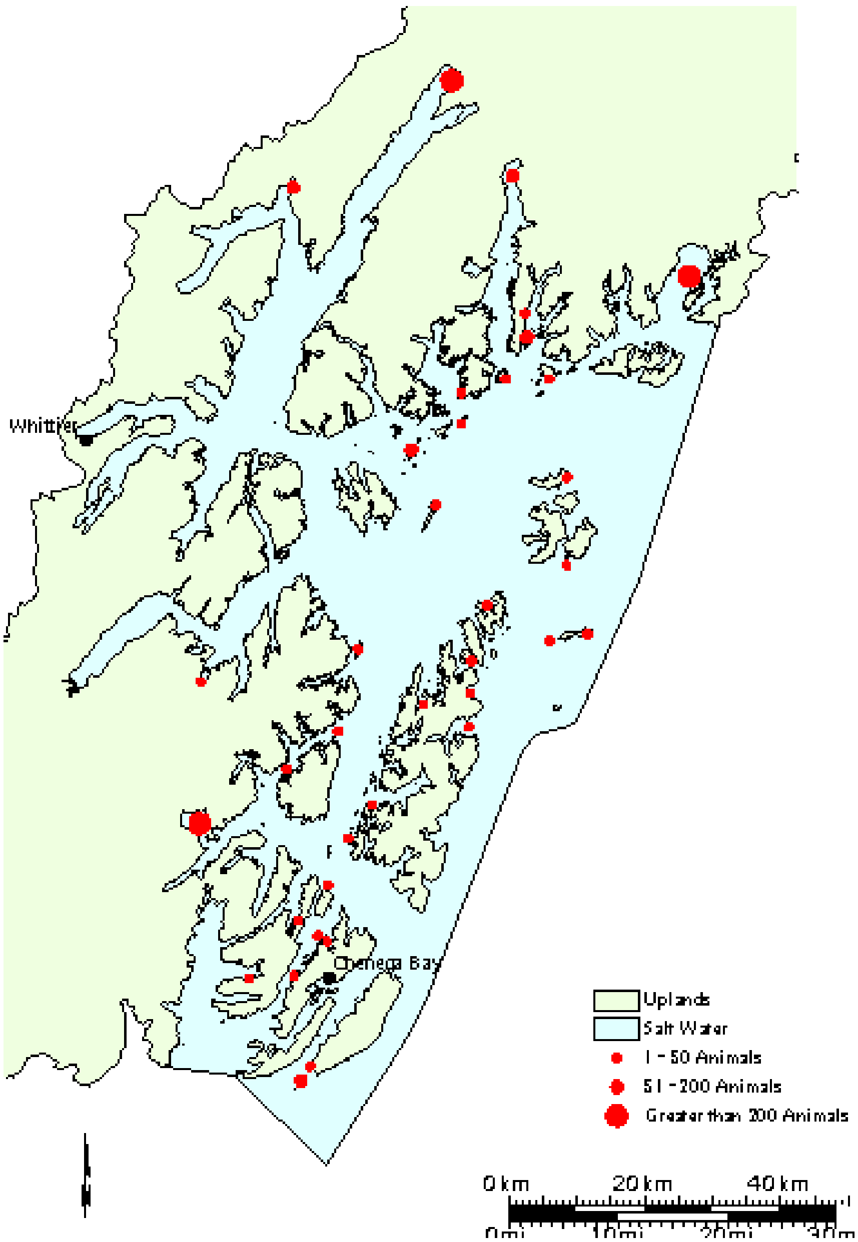


Fig. 3. Location of harbor seal haulout sites in western Prince William Sound, Alaska, USA.

Table 3. Variables associated with distribution of kayaks in western Prince William Sound determined through univariate analyses and ranked with Akaike's Information Criterion (AIC).

AIC Rank	Distance variables by month				
	May	June	July	August	September
1	Harbor	Harbor	Harbor	Harbor	Harbor
2	Shore	Shore	Shore	Upland glacier	Shore
3	Upland glacier	Upland glacier	Upland glacier	Shore	Upland glacier
4	Upland recreation site	Camp site	Camp site	Camp site	Upland recreation site
5	Tidewater glacier	Upland recreation site	Upland recreation site	Tidewater glacier	Camp site
6	Camp site	Tidewater glacier	Tidewater glacier	Upland recreation site	Tidewater glacier
7	Wildlife viewing	Wildlife viewing	Wildlife viewing	Wildlife viewing	Wildlife viewing
8	Scenery	Cabin	Scenery	Cabin	Cabin
9	Cabin	Scenery	Cabin	Scenery	High wildlife diversity

Table 4. Variables associated with distribution of motorized recreation boats in western Prince William Sound determined through univariate analyses and ranked with Akaike's Information Criterion (AIC).

AIC Rank	Distance Variables by Month May	June	July	August	September
1	Harbor	Harbor	Harbor	Harbor	Harbor
2	Anchor buoy	Anchor buoy	Anchor buoy	Anchor buoy	Anchor buoy
3	Anchorage site	Shore	Shore	Shore	Sport fishing
4	Upland glacier	Sport fishing	Upland recreation site	Sport fishing	Shore
5	Shore	Upland glacier	Anchorage site	Upland recreation site	Upland recreation site
6	Upland recreation site	Upland recreation site	Upland glacier	Upland glacier	Anchorage site
7	Sport fishing	Anchorage site	Sport fishing	Anchorage site	Upland glacier
8	Hunting site	Fish hatchery	Fish hatchery	Hunting site	Cabin
9	Cabin	Cabin	Cabin	Cabin	Hunting site

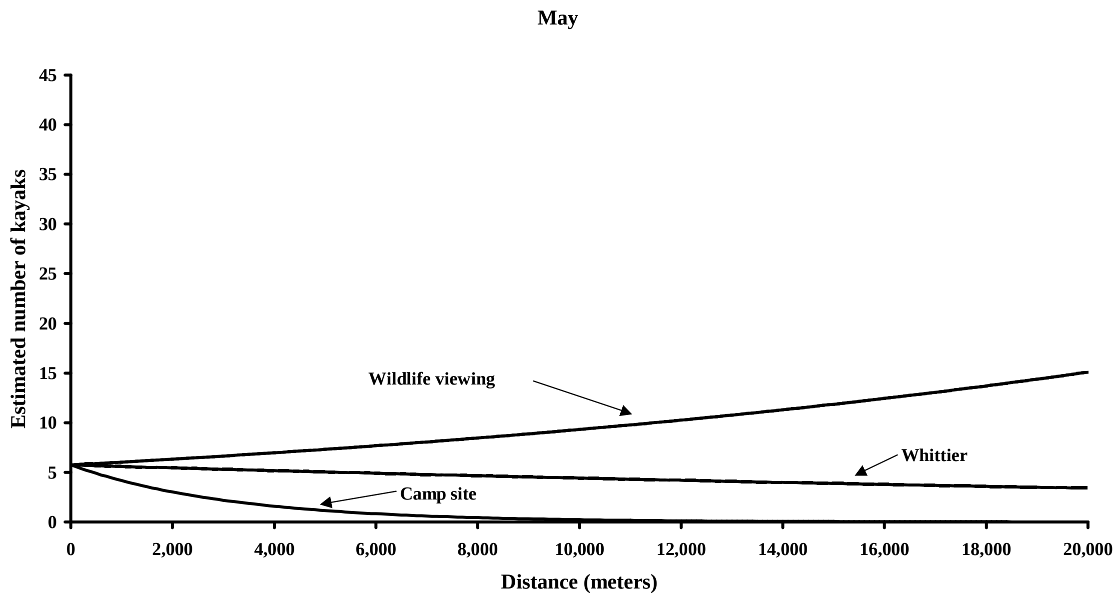


Fig. 4a. Effects of individual variables on the predicted number of kayaks during May in western Prince William Sound.

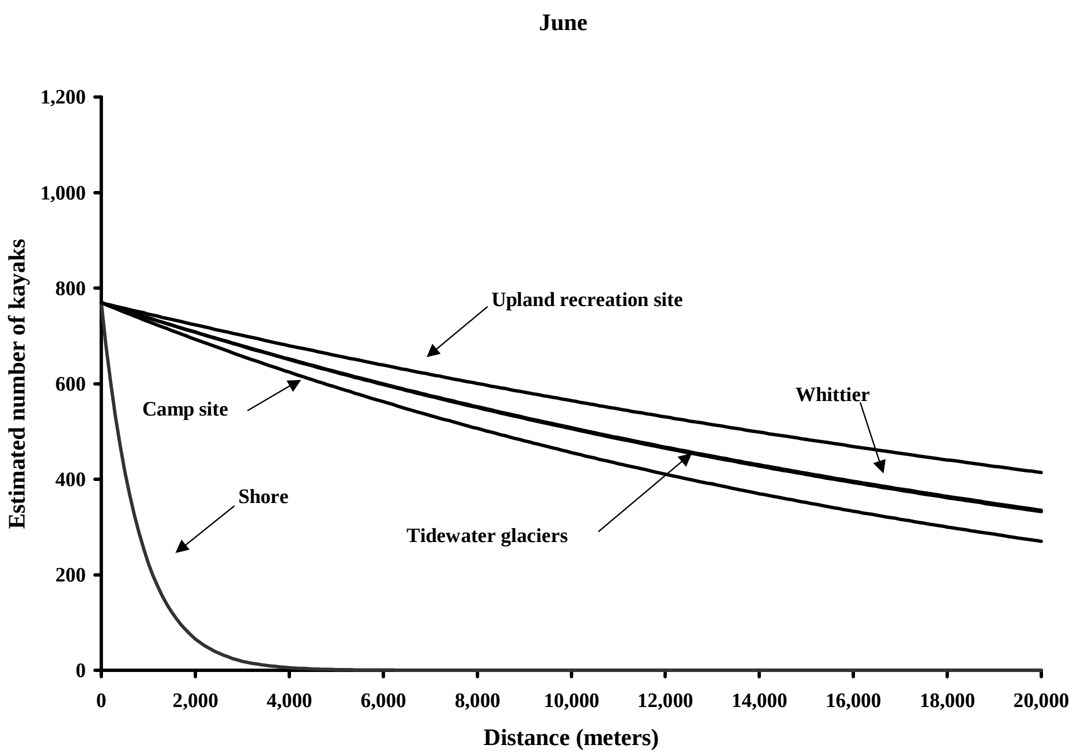


Fig. 4b. Effects of individual variables on the predicted number of kayaks during June in western Prince William Sound.

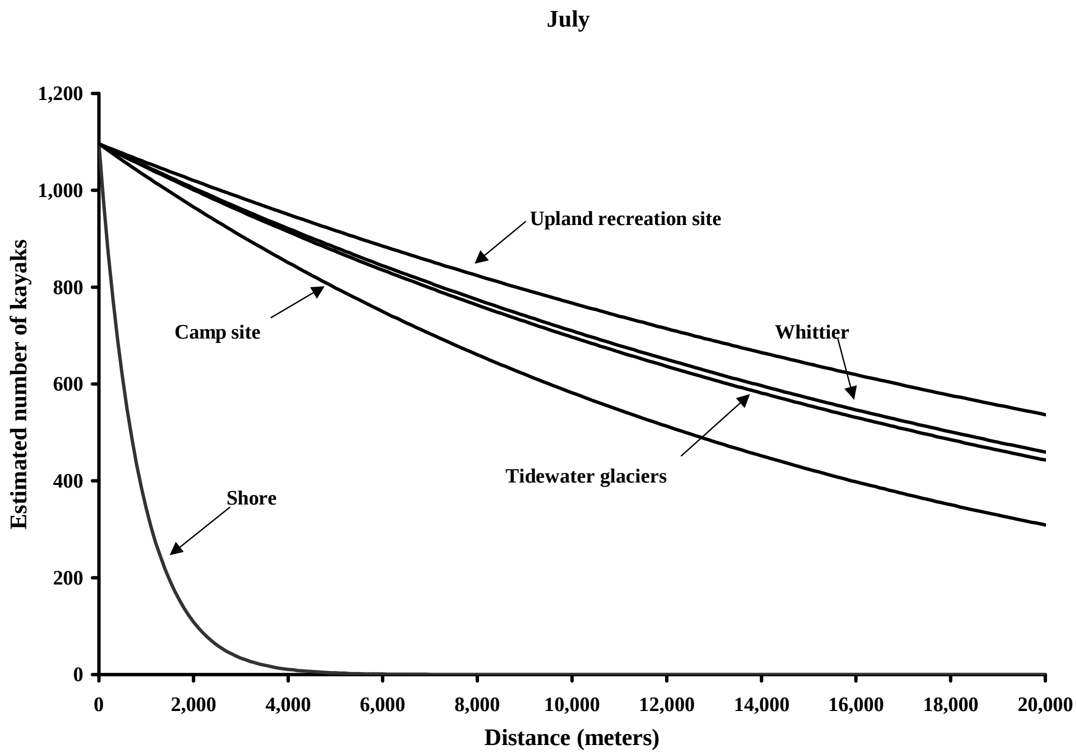


Fig. 4c. Effects of individual variables on the predicted number of kayaks during July in western Prince William Sound.

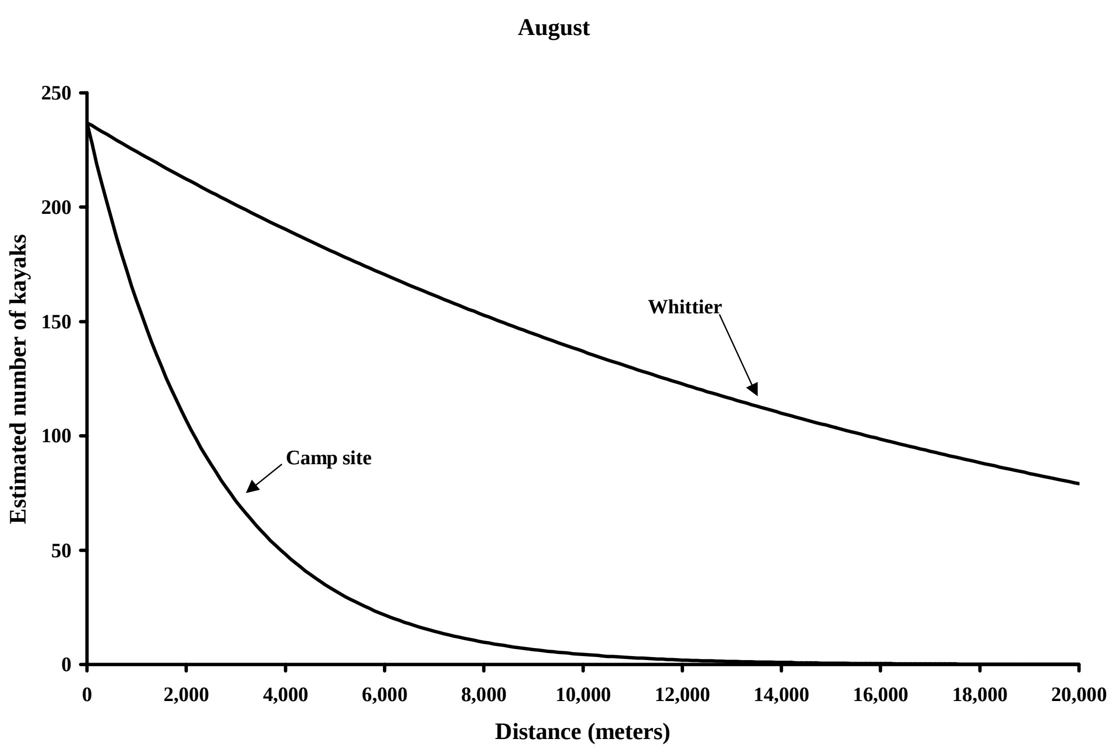


Fig. 4d. Effects of individual variables on the predicted number of kayaks during August in western Prince William Sound.

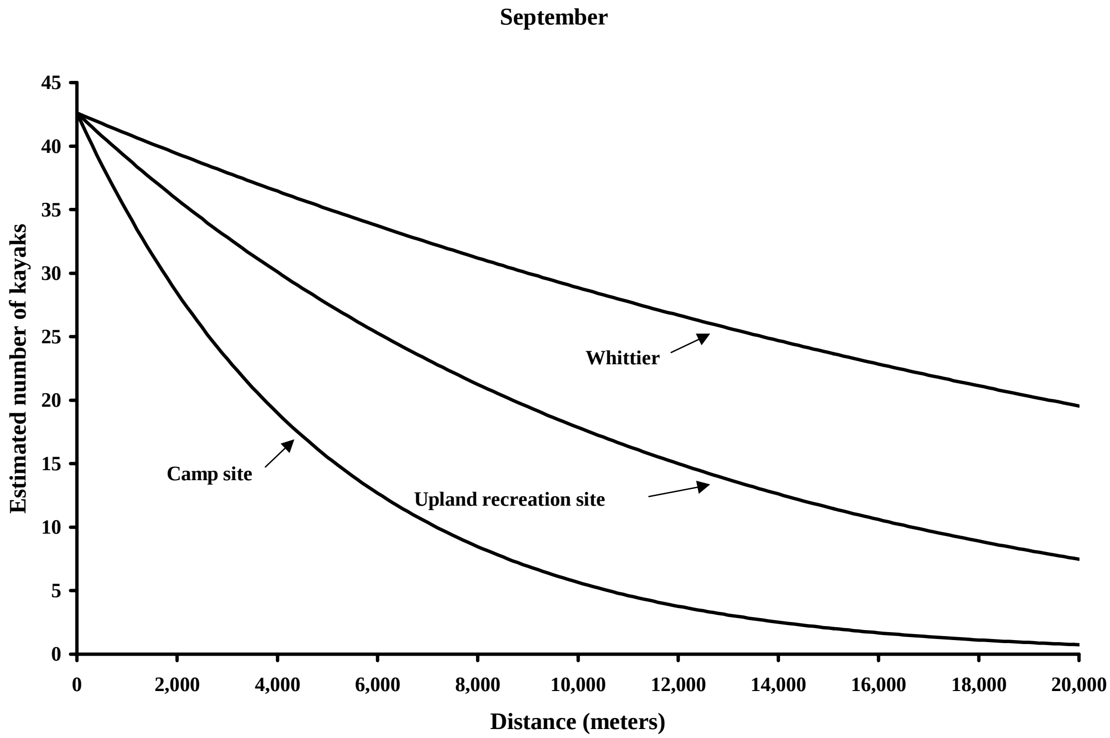


Fig. 4e. Effects of individual variables on the predicted number of kayaks during September in western Prince William Sound.

Table 5. Existing and predicted use patterns of kayaks in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest site	Distance to Whittier (km)	Mean number of kayaks by month											
		May		June		July		August		September		All months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
Twin Falls, Passage Canal	1.8	22	53	102	244	114	274	90	215	25	60	568	846
Passage Canal	3.5	22	53	102	244	114	274	90	215	25	60	568	846
W of Xeno, Blackstone Bay	20.0	18	44	52	124	63	150	57	137	10	26	337	481
North Blackstone Bay	20.8	18	44	52	124	63	150	57	137	10	26	337	481
S of Zircon, Blackstone Bay	21.6	18	44	52	124	63	150	57	137	10	26	337	481
Section 22, Blackstone Bay	23.4	18	44	54	130	69	165	83	199	17	41	440	579
Willard Island, Blackstone Bay	31.4	27	76	89	262	150	420	104	264	17	44	651	1,066
Northland Glacier, Blackstone Bay	35.5	25	98	86	389	145	582	94	265	17	48	632	1,382
Beloit Glacier, Blackstone Bay	36.1	4	45	10	208	18	276	12	68	2	14	114	611
Jello, Cochrane Bay	36.9	1	17	1	36	1	40	1	24	1	10	29	127
Blackstone Glacier	37.2	25	98	86	389	145	582	94	265	17	48	632	1,382
S of Jello, Cochrane Bay	37.2	1	17	1	36	1	40	1	24	1	10	29	127
NW point of Fool Island	45.5	0	2	0	12	0	13	0	24	0	4	24	55
NW Fool Island	45.7	0	2	0	12	0	13	0	24	0	4	24	55

Table 5. Existing and predicted use patterns of kayaks in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest site	Distance to Whittier (km)	Mean number of kayaks by month											
		May		June		July		August		September		All months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
North, Fool Island	45.7	0	2	0	12	0	13	0	24	0	4	24	55
SW point of Fool Island	45.7	0	2	0	12	0	13	0	24	0	4	24	55
Fool, Fool Island	45.7	0	2	0	12	0	13	0	24	0	4	24	55
South Fool Island	45.7	0	2	0	12	0	13	0	24	0	4	24	55
N of Daycare Cove, Perry Island	50.0	1	5	4	17	8	24	5	28	1	3	47	77
South Dutch Group (N side)	51.4	0	2	6	10	0	10	0	19	0	2	25	43
South Dutch Group (W side)	51.7	0	2	6	10	0	10	0	19	0	2	25	43
Billings Point, Perry Island	53.9	1	4	3	15	11	31	7	23	1	3	46	76
E Axel Lind Island	55.1	1	3	1	11	1	11	1	14	1	3	19	42
E of Point Doran	55.2	17	43	69	227	52	199	58	151	11	32	358	652
SW of Point Doran	56.9	4	10	42	148	26	120	33	91	3	9	199	378
SW Axel Lind Island	56.9	1	3	1	11	1	11	1	14	1	3	19	42
Section 9, W of Point Doran	57.6	4	10	42	148	26	120	33	91	3	9	199	378
Cascade Glacier	58.6	7	17	15	82	42	164	64	52	14	36	194	351
North Barry Arm	58.6	7	17	15	82	42	164	64	52	14	36	194	351
NW Section 19, Lone Island	58.8	1	3	1	6	1	8	1	7	1	2	12	26

Table 5. Existing and predicted use patterns of kayaks in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest site	Distance to Whittier (km)	Mean number of kayaks by month											
		May		June		July		August		September		All months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
Midwest Section 19, Lone Island	58.8	1	3	1	6	1	8	1	7	1	2	12	26
N of Raven, Lone Island	58.8	1	3	1	6	1	8	1	7	1	2	12	26
Coxe Glacier	60.5	1	3	2	66	43	176	67	15	15	37	143	297
Section 30, Lone Island	60.8	1	3	1	6	1	8	1	7	1	2	12	26
Toboggan Glacier	60.9	11	25	73	213	29	114	47	123	5	14	288	489
South Surprise Inlet	66.5	2	5	2	31	2	37	8	20	2	6	36	99
North Surprise Inlet	67.2	1	2	1	32	1	37	9	26	3	8	41	105
E of Storey, Storey Island	71.3	1	3	1	4	1	4	1	3	1	2	8	16
Outpost Island	72.5	0	2	0	5	0	5	0	2	0	0	2	14
Nomad, Naked Island	72.6	1	3	1	4	3	8	1	6	1	2	13	23
Row, Naked Island	72.7	1	3	1	4	3	8	1	6	1	2	13	23
Row Annex, Naked Island	73.1	1	3	1	4	3	8	1	6	1	2	13	23
S of Lily, Storey Island	74.0	1	3	1	4	1	4	1	3	1	2	8	16
Cocos, Storey Island	74.0	1	3	1	4	1	4	1	3	1	2	8	16
N of Quest, Storey Island	74.0	1	3	1	4	1	4	1	3	1	2	8	16

Table 5. Existing and predicted use patterns of kayaks in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest site	Distance to Whittier (km)	Mean number of kayaks by month											
		May		June		July		August		September		All months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
Dixie, Storey Island	74.0	1	3	1	4	1	4	1	3	1	2	8	16
Quest, Storey Island	74.0	1	3	1	4	1	4	1	3	1	2	8	16
N Cabin Bay, Naked Island	74.1	1	3	1	4	3	8	1	6	1	2	13	23
South Cabin Bay, Naked Island	74.6	1	3	1	4	4	12	1	4	1	2	12	25
West Point of Naked Island	74.6	1	3	1	4	4	12	1	4	1	2	12	25
Section 34, Naked Island	74.6	1	3	1	4	4	12	1	4	1	2	12	25
Section 3, Naked Island	74.6	1	3	1	4	4	12	1	4	1	2	12	25
Foul Pass, Ingot Island	74.8	1	4	6	19	1	7	1	8	1	4	18	42
Hook, Naked Island	75.2	1	3	1	4	4	12	1	4	1	2	12	25
Folly, Storey Island	75.4	1	3	1	4	1	4	1	3	1	2	8	16
N of Jason, Peak Island	75.7	1	2	1	3	3	9	1	2	1	2	9	18
NW of Major, Storey Island	76.3	1	3	1	4	1	4	1	3	1	2	8	16
Igloo, Naked Island	76.4	1	2	1	3	3	9	1	2	1	2	9	18
N of Tuft, Naked Island	76.6	1	2	1	3	3	9	1	3	1	2	10	19
Bass Harbor - W. Naked I.	76.6	1	2	1	3	3	9	1	3	1	2	10	19

Table 5. Existing and predicted use patterns of kayaks in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest site	Distance to Whittier (km)	Mean number of kayaks by month											
		May		June		July		August		September		All months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
Major, Storey Island	76.7	1	3	1	4	1	4	1	3	1	2	8	16
E of Major, Storey Island	76.9	1	3	1	4	1	4	1	3	1	2	8	16
Clove Triangle	77.9	1	2	1	2	1	2	1	2	1	2	7	10
Sphinx Island	77.9	1	2	1	4	1	4	1	2	1	2	7	14
Elk Head Point	78.4	1	2	1	3	1	3	1	2	1	2	7	12
Yale Glacier Island-SE	79.3	1	2	1	11	1	12	1	2	1	2	7	29
S of Elk Head Pt, Peak I	79.3	1	2	1	3	1	3	1	2	1	2	7	12
Yale Glacier Island-SW	79.7	1	2	1	11	1	12	1	2	1	2	7	29
S of Balmy, Peak Island	80.0	1	2	1	3	1	3	1	2	1	2	7	12
S Section 16, Peak Island	80.0	1	2	1	3	1	3	1	2	1	2	7	12
Abner, Naked Island	80.4	1	3	1	2	4	11	1	3	1	2	11	21
Ball, Bass Island	81.2	1	2	1	2	2	5	1	2	1	2	8	13
Agnes, Bass Island	81.3	1	2	1	2	2	5	1	2	1	2	8	13
E.Point Naked Island	81.4	1	3	1	2	4	11	1	3	1	2	11	21
Edgar, Naked Island	81.4	1	3	1	2	4	11	1	3	1	2	11	21
Glory Annex, Naked Island	81.7	1	3	1	2	4	11	1	3	1	2	11	21

Table 5. Existing and predicted use patterns of kayaks in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest site	Distance to Whittier (km)	Mean number of kayaks by month											
		May		June		July		August		September		All months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
NW Bass Harbor, Naked Island	81.9	1	3	1	2	4	11	1	3	1	2	11	21
W Bass Harbor, Naked Island	82.6	1	3	1	2	4	11	1	3	1	2	11	21
North Little Smith Island	84.5	0	0	0	0	0	0	0	0	0	0	0	0
W tip of Smith Island	84.5	0	0	0	0	0	0	0	0	0	0	0	0
West Little Smith Island	84.5	0	0	0	0	0	0	0	0	0	0	0	0
N of Lint, Chenega Island	86.6	1	2	1	5	1	5	1	3	1	2	8	17
Cave Point, Glacier Island	87.9	1	3	1	5	1	5	1	3	1	2	8	18
S. Glacier Island	88.4	1	3	1	5	1	5	1	3	1	2	8	18
East Tip of Smith Island	89.2	0	0	0	0	0	0	0	0	0	0	0	0
Southeast Smith Island	89.6	0	0	0	0	0	0	0	0	0	0	0	0
Light, Seal Island	89.7	0	0	0	0	0	0	0	0	0	0	0	0
Rocks E of Seal Island	89.7	0	0	0	0	0	0	0	0	0	0	0	0
West Seal Island	89.7	0	0	0	0	0	0	0	0	0	0	0	0
SW Point of Seal Island	89.9	0	0	0	0	0	0	0	0	0	0	0	0
Weather Station, Seal Island	90.2	0	0	0	0	0	0	0	0	0	0	0	0

Table 5. Existing and predicted use patterns of kayaks in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest site	Distance to Whittier (km)	Mean number of kayaks by month											
		May		June		July		August		September		All months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
NE of Bull Head, Glacier Island	92.7	1	2	1	4	1	4	1	2	1	2	7	14
Jackpot Island	93.9	1	2	5	7	13	21	1	2	1	2	23	34
Outer Marsha Bay, Knight I.	94.4	1	2	4	10	1	2	1	2	1	2	10	18
Barnes Cove, Knight Island	94.4	1	2	1	3	4	10	0	2	1	2	9	19
Pleiades Islands	99.0	0	0	0	2	0	2	2	4	0	0	6	8
NW of Point Countess	101.0	1	2	12	28	12	28	1	2	1	2	29	62
Gage Island	103.1	1	2	2	5	4	8	1	2	1	2	11	19
Flemming Island	103.8	1	2	2	5	4	8	1	2	1	2	11	19
Section 30, Icy Bay	105.1	1	2	2	9	6	20	1	2	1	2	13	35
S of Discovery Pt, Knight Island	105.4	1	2	4	10	1	2	1	2	1	2	10	18
Whale Bay	106.9	1	2	11	30	2	8	1	2	1	2	18	44
West Arm of Whale Bay	107.1	1	2	11	30	2	8	1	2	1	2	18	44
Near Zeus, Icy Bay	107.5	1	2	2	11	4	17	1	2	1	2	11	34
Will, Nassau Fiord	107.7	1	2	1	13	3	17	1	2	1	2	9	36
Chenega Glacier	109.7	1	2	4	17	7	25	1	2	1	2	16	48
Icy Bay	111.1	1	2	1	7	6	20	1	2	1	2	12	33
S of Pt Waters, Port Bainbridge	120.3	1	2	2	5	1	2	1	2	1	2	8	13
Near Hydro, Bainbridge Passage	120.3	1	2	2	5	1	2	1	2	1	2	8	13
N of Hogg Point	120.3	1	2	2	5	1	2	1	2	1	2	8	13

Table 5. Existing and predicted use patterns of kayaks in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest site	Distance to Whittier (km)	Mean number of kayaks by month											
		May		June		July		August		September		All months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
N of Isle, Evans Island	122.3	1	2	1	2	1	2	1	4	1	2	9	12
Bainbridge Glacier	124.5	1	2	1	2	1	2	1	2	1	2	7	10
N of Aluklik Bay, Evans I.	124.6	1	2	1	2	1	2	1	4	1	2	9	12
Port Bainbridge	124.8	1	2	1	2	1	2	1	2	1	2	7	10
Brid, Port Bainbridge	125.1	1	2	1	2	1	2	1	2	1	2	7	10
E side of Latouche Island	125.3	1	2	1	2	1	2	1	2	1	2	7	10
West of Hogg Bay	125.4	1	2	1	2	1	2	1	2	1	2	7	10
SW of Aluklik Bay, Evans I.	125.7	1	2	1	2	1	2	1	4	1	2	9	12
N Squirrel Bay, Evans Island	125.7	1	2	1	2	1	2	1	4	1	2	9	12
Mid Squirrel Bay, Evans I.	125.7	1	2	1	2	1	2	1	4	1	2	9	12
SW Pt of Squirrel Bay, Evans I.	125.7	1	2	1	2	1	2	1	4	1	2	9	12
Point Pyke, Bainbridge Island	129.2	1	2	3	8	1	2	1	2	1	2	9	16
South of North Auk Bay	130.6	1	2	1	2	1	2	1	2	1	2	7	10
North Point, Auk Bay	130.6	1	2	1	2	1	2	1	2	1	2	7	10
Mid Section 33, Elrington I.	132.2	1	2	1	2	1	2	1	2	1	2	7	10
Section 33,	132.9	1	2	1	2	1	2	1	2	1	2	7	10

Table 5. Existing and predicted use patterns of kayaks in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest site	Distance to Whittier (km)	Mean number of kayaks by month											
		May		June		July		August		September		All months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
Elrington Island													
North Twin Bay	133.0	1	2	1	2	1	2	1	2	1	2	7	10
S Pt of Auk Bay	133.2	1	2	1	2	1	2	1	2	1	2	7	10
Gray Bowl, Port Bainbridge	135.2	1	2	1	2	1	2	1	2	1	2	7	10
S Gray Bowl, Port Bainbridge	135.5	1	2	1	2	1	2	1	2	1	2	7	10
Point Elrington	136.0	1	2	1	2	1	2	1	2	1	2	7	10
Section 27, Port Bainbridge	137.1	1	2	1	2	1	2	1	2	1	2	7	10
S Section 27, Port Bainbridge	137.7	1	2	1	2	1	2	1	2	1	2	7	10
Total		345	1,007	1,115	3,950	1,424	5,006	1,226	3,099	314	818	7,523	13,880

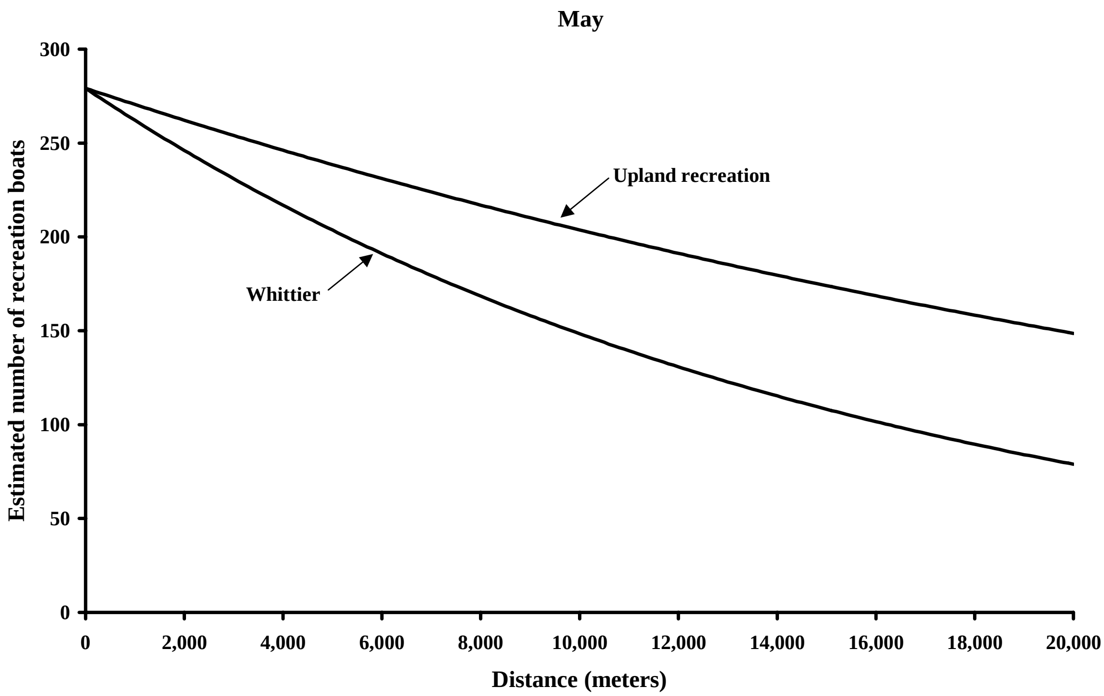


Fig. 5a. Effects of individual variables on the predicted number of recreational motor boats during May in western Prince William Sound.

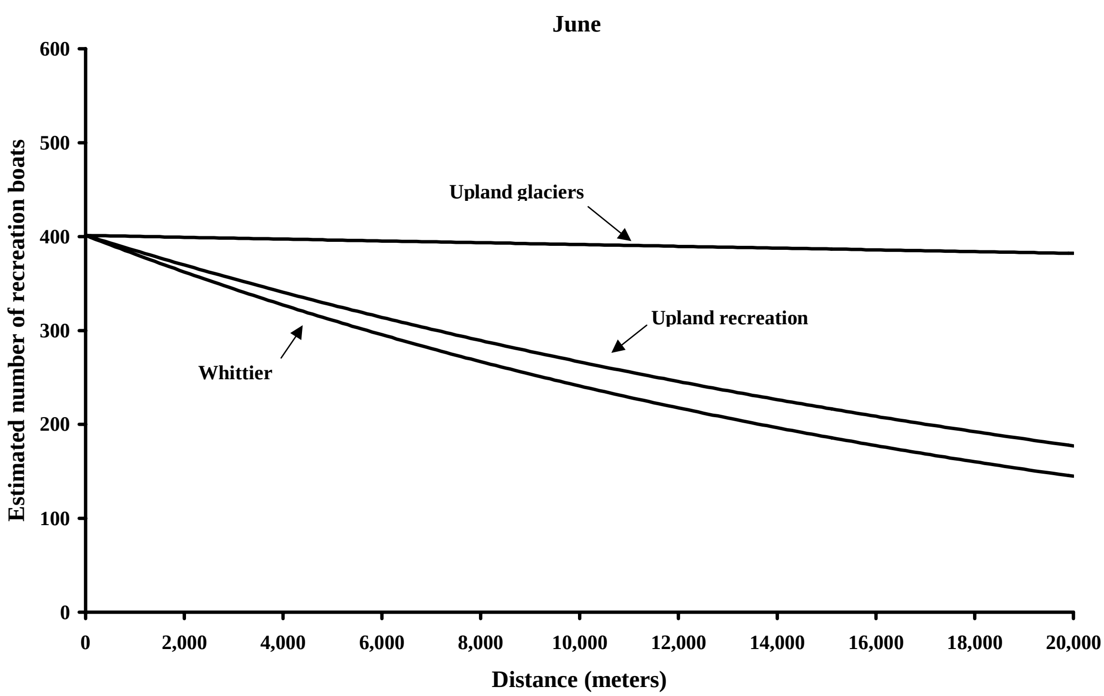


Fig. 5b. Effects of individual variables on the predicted number of recreational motor boats during June in western Prince William Sound.

July

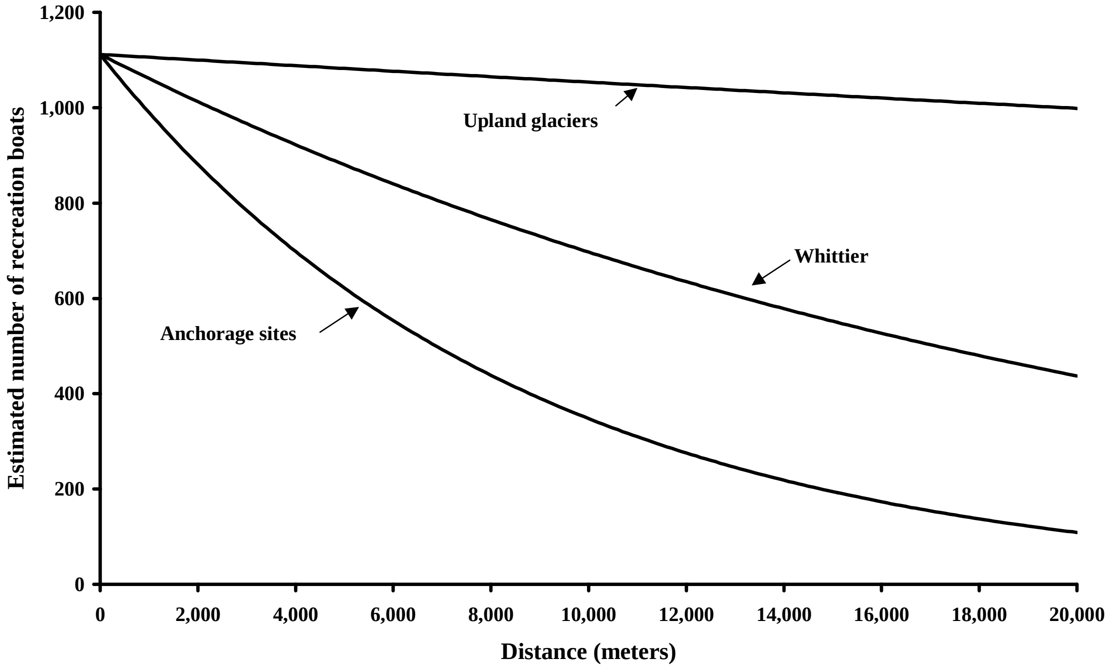


Fig. 5c. Effects of individual variables on the predicted number of recreational motor boats during July in western Prince William Sound.

August

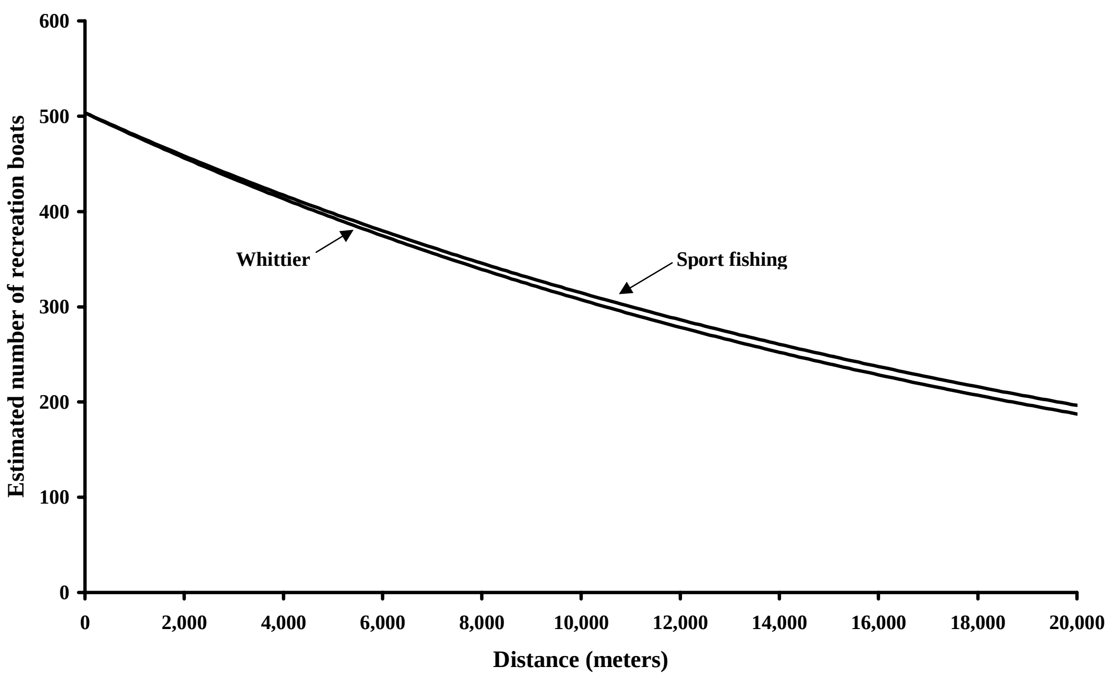


Fig. 5d. Effects of individual variables on the predicted number of recreational motor boats during August in western Prince William Sound.

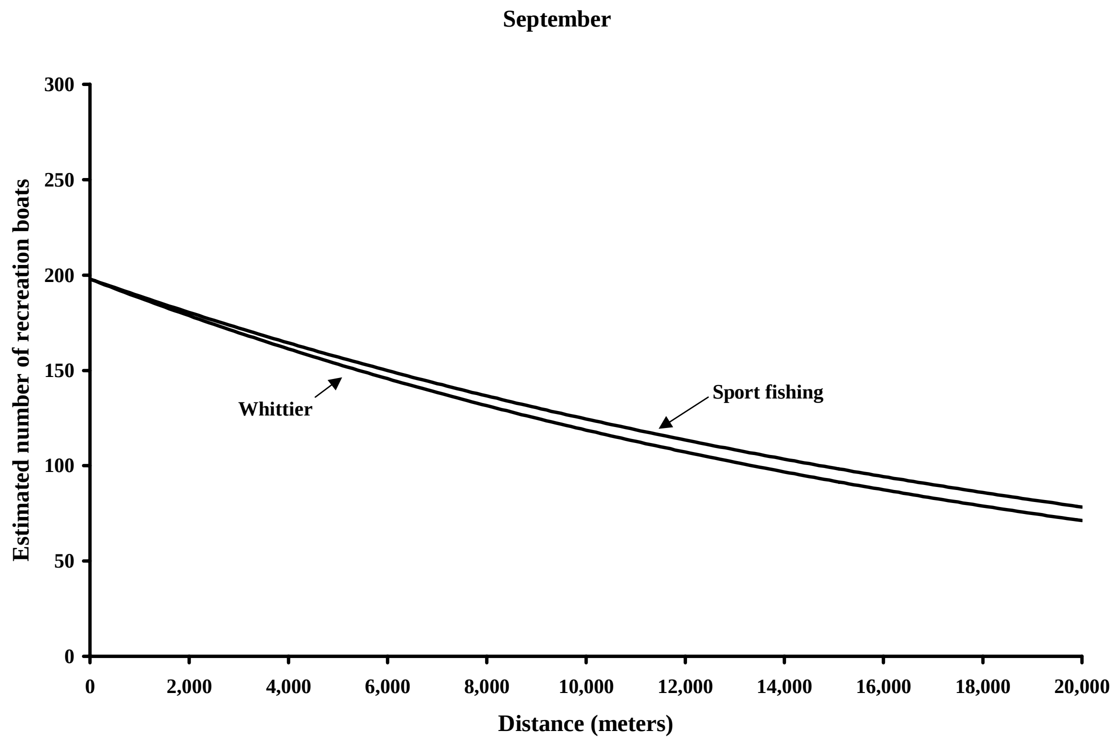


Fig. 5e. Effects of individual variables on the predicted number of recreational motor boats during September in western Prince William Sound.

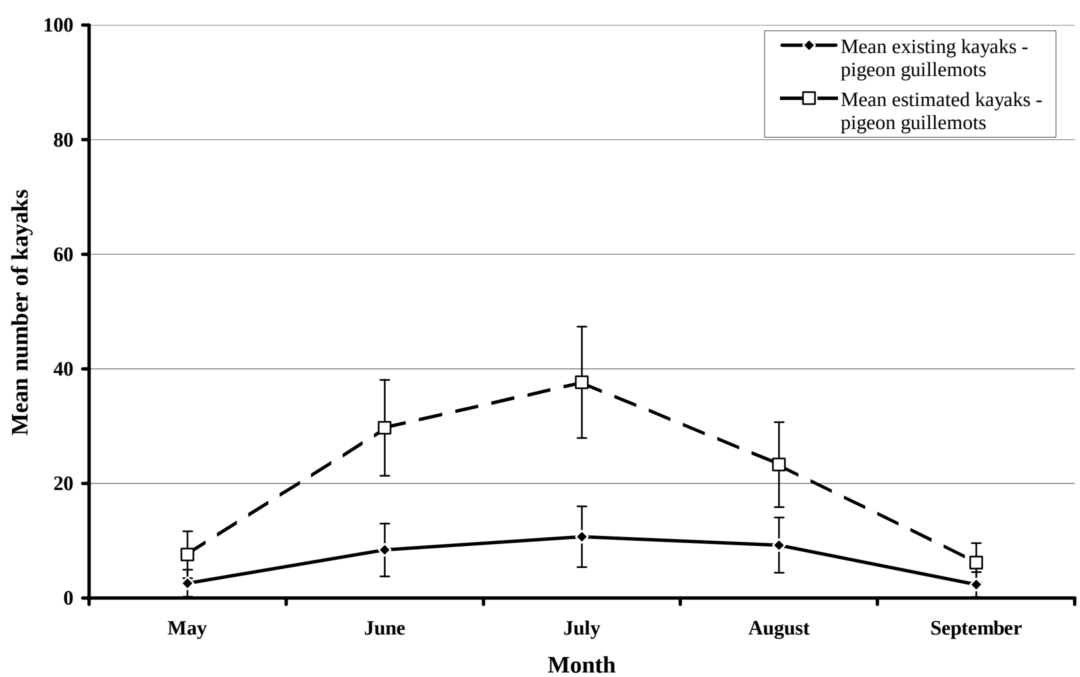


Fig. 6. Mean number of kayaks within 1,000 meters of pigeon guillemot nesting sites in western Prince William Sound, Alaska (error bars represent standard error).

to experience moderate levels (16 – 100 more vessels) of increase; and 13% are expected to experience high levels (>100 more vessels) of kayak use (Fig. 7). The nest sites we expect to receive high levels of increased use are concentrated in Passage Canal, Blackstone Bay, Barry Arm, and lower Harriman Fiord (Fig. 8).

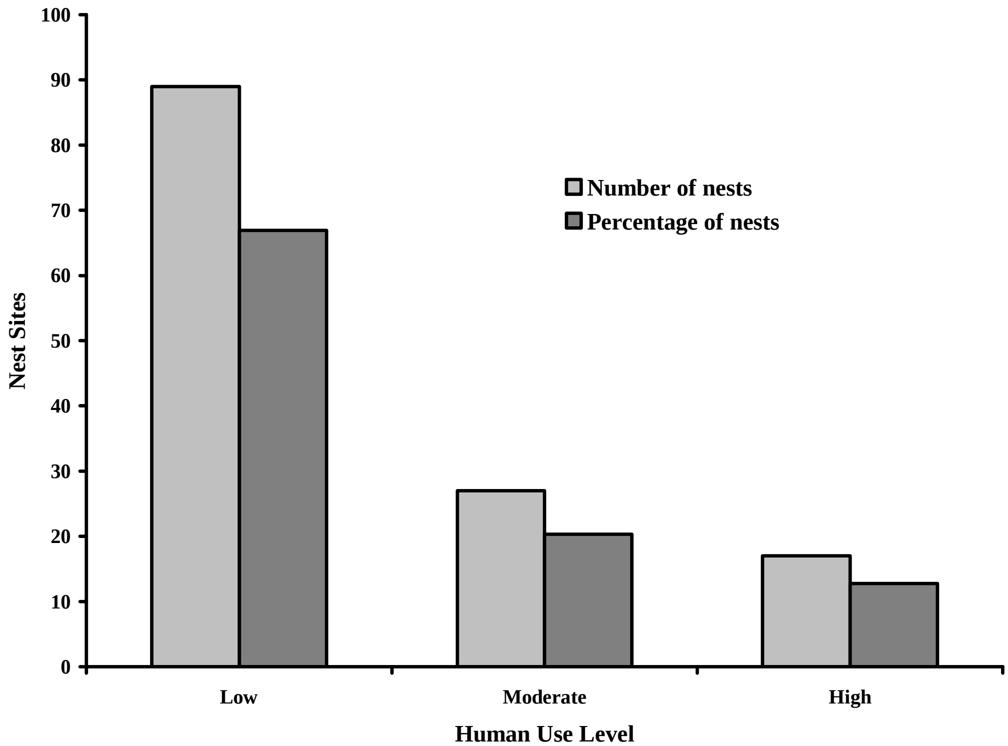


Fig. 7. Predicted use by kayaks in 2015 within 1,000 m of 133 pigeon guillemot nest sites evaluated from May through August (low levels = 0 – 15 more vessels per season; moderate levels = 16 – 100 more vessels per season; high levels = >100 more vessels per season).

Predicted monthly use in 2015 of motorized recreational boats within 1,000 m of individual nesting sites ranged from no change to increases approximating 20 times current use (Table 6). Mean monthly increases ranged from 380 to 660% (Fig. 9). Twenty percent of the 133 nest sites evaluated from May through August are predicted to experience low levels (0 – 15 more vessels per season) of increased use within their vicinity by 2015; 24% are predicted to experience moderate levels (16 – 100 more vessels) of increase; and 56% are expected to experience high levels (>100 more vessels) of use by motorized recreational boats (Fig. 10). We expect high levels of increased use to occur at nest sites throughout the western Sound with concentrated use in Passage Canal, Blackstone Bay, lower Harriman Fiord, from Perry Island to Naked Island, Knight Island, Knight Island Passage, Icy Bay, and Evans Island (Fig. 11).

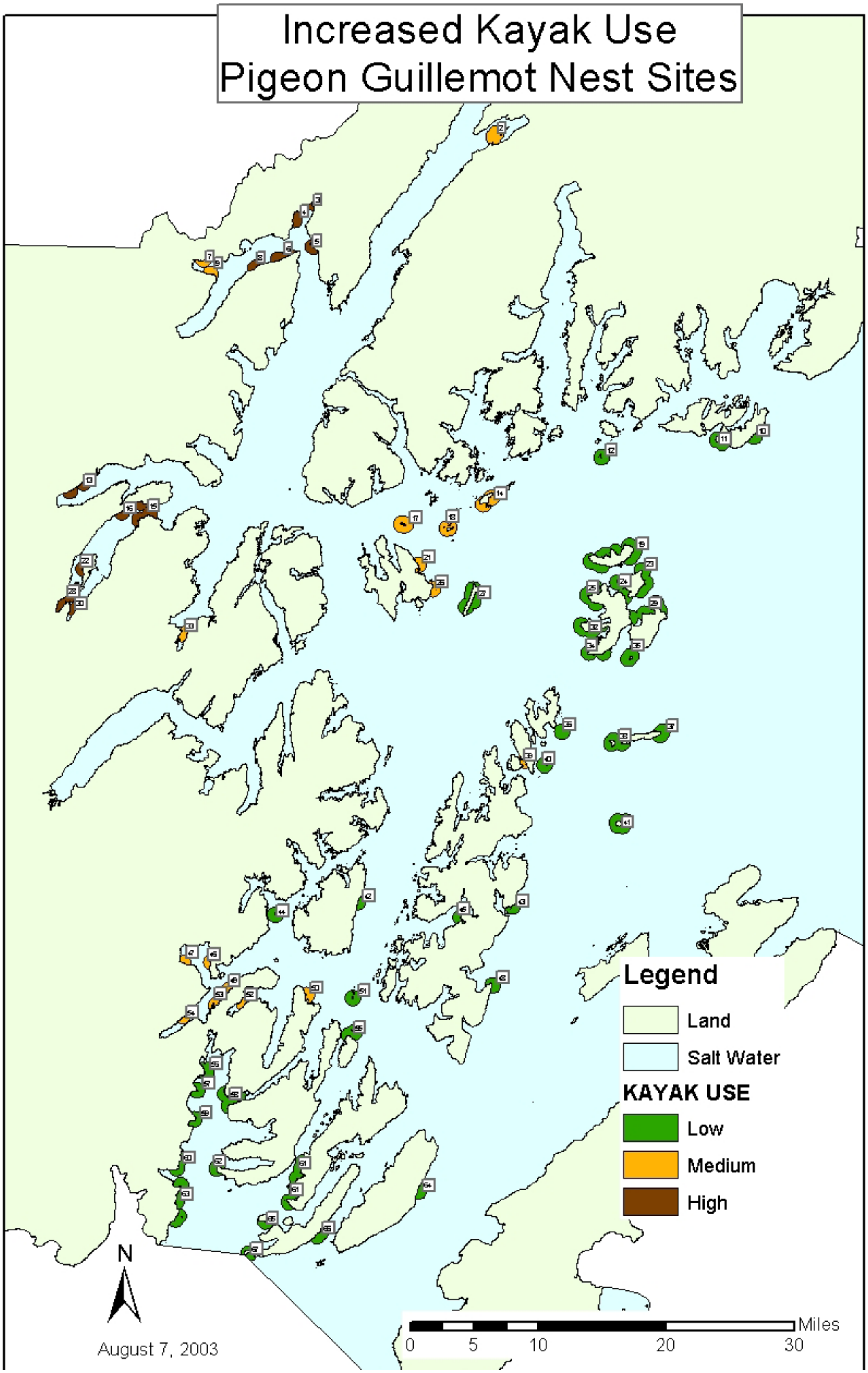


Fig. 8. Magnitude and location of predicted kayak use levels in 2015 within 1,000 m pigeon guillemot nest sites in western Prince William Sound, Alaska.

Table 6. Existing and predicted use patterns of motorized recreation boats in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest Site	Distance to Whittier (km)	Mean number of motorized recreation boats by month											
		May		June		July		August		September		All Months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
Twin Falls, Passage Canal	18.2	12	365	34	523	66	623	48	669	18	262	178	2,442
Passage Canal	35.4	12	365	34	523	66	623	48	669	18	262	178	2,442
W of Xeno, Blackstone Bay	200.3	30	200	20	267	76	439	64	492	22	186	212	1,584
North Blackstone Bay	208.0	30	200	20	267	76	439	64	492	22	186	212	1,584
S of Zircon, Blackstone Bay	216.1	30	200	20	267	76	439	64	492	22	186	212	1,584
Section 22, Blackstone Bay	233.6	0	0	2	242	0	0	0	0	0	0	2	242
Willard Island, Blackstone Bay	314.3	0	0	2	227	0	0	0	0	0	0	2	227
Northland Glacier, Blackstone Bay	354.6	30	147	34	228	76	142	64	314	22	116	226	947
Beloit Glacier, Blackstone Bay	361.0	0	0	0	0	0	0	0	0	0	0	0	0
Jello, Cochrane Bay	369.3	0	0	0	0	0	0	0	0	0	0	0	0
Blackstone Glacier	371.9	30	147	34	228	76	142	64	314	22	116	226	947
S of Jello, Cochrane Bay	372.3	0	0	0	0	0	0	0	0	0	0	0	0
NW point of Fool Island	455.3	0	0	0	0	0	0	0	0	0	0	0	0

Table 6. Existing and predicted use patterns of motorized recreation boats in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest Site	Distance to Whittier (km)	Mean number of motorized recreation boats by month											
		May		June		July		August		September		All Months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
NW Fool Island	457.2	0	0	0	0	0	0	0	0	0	0	0	0
North, Fool Island	457.2	0	0	0	0	0	0	0	0	0	0	0	0
SW point of Fool Island	457.2	0	0	0	0	0	0	0	0	0	0	0	0
Fool, Fool Island	457.2	0	0	0	0	0	0	0	0	0	0	0	0
South Fool Island	457.2	0	0	0	0	0	0	0	0	0	0	0	0
N of Daycare Cove, Perry Island	500.4	4	60	15	107	16	145	11	152	7	60	53	524
South Dutch Group (N side)	514.3	0	0	2	90	4	165	0	0	0	0	6	255
South Dutch Group (W side)	516.8	0	0	2	90	4	165	0	0	0	0	6	255
Billings Point, Perry Island	539.0	4	49	10	82	8	169	4	145	3	57	29	502
E Axel Lind Island	550.7	10	58	13	94	35	224	20	113	24	63	102	552
E of Point Doran	552.3	0	0	0	0	4	68	0	0	0	0	4	68
SW of Point Doran	568.7	6	58	20	119	20	77	26	95	8	33	80	382
SW Axel Lind Island	569.1	10	58	13	94	35	224	20	113	24	63	102	552
Section 9, W of Point Doran	575.6	6	58	20	119	20	77	26	95	8	33	80	382

Table 6. Existing and predicted use patterns of motorized recreation boats in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest Site	Distance to Whittier (km)	Mean number of motorized recreation boats by month											
		May		June		July		August		September		All Months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
Cascade Glacier	585.6	0	0	0	0	4	47	0	0	0	0	4	47
North Barry Arm	585.9	0	0	0	0	4	47	0	0	0	0	4	47
NW Section 19, Lone Island	587.7	4	40	10	68	8	104	4	113	4	45	30	370
Midwest Section 19, Lone Island	587.7	4	40	10	68	8	104	4	113	4	45	30	370
N of Raven, Lone Island	587.7	4	40	10	68	8	104	4	113	4	45	30	370
Coxe Glacier	604.6	0	0	0	0	4	36	0	0	0	0	4	36
Section 30, Lone Island	608.0	4	40	10	68	8	104	4	113	4	45	30	370
Toboggan Glacier	609.0	6	46	20	97	20	55	26	79	8	27	80	304
South Surprise Inlet	665.2	0	0	0	0	0	0	0	0	0	0	0	0
North Surprise Inlet	672.0	0	0	0	0	0	0	0	0	0	0	0	0
E of Storey, Storey Island	713.3	13	36	11	45	19	163	19	65	15	34	77	343
Outpost Island	724.7	0	0	3	49	1	101	8	38	1	12	13	200
Nomad, Naked Island	726.5	12	33	12	43	20	160	20	74	18	41	82	351
Row, Naked Island	727.2	12	33	12	43	20	160	20	74	18	41	82	351

Table 6. Existing and predicted use patterns of motorized recreation boats in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest Site	Distance to Whittier (km)	Mean number of motorized recreation boats by month											
		May		June		July		August		September		All Months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
Row Annex, Naked Island	730.5	12	33	12	43	20	160	20	74	18	41	82	351
S of Lily, Storey Island	740.5	13	36	11	45	19	163	19	65	15	34	77	343
Cocos, Storey Island	740.5	13	36	11	45	19	163	19	65	15	34	77	343
N of Quest, Storey Island	740.5	13	36	11	45	19	163	19	65	15	34	77	343
Dixie, Storey Island	740.5	13	36	11	45	19	163	19	65	15	34	77	343
Quest, Storey Island	740.5	13	36	11	45	19	163	19	65	15	34	77	343
N Cabin Bay, Naked Island	740.5	12	33	12	43	20	160	20	74	18	41	82	351
South Cabin Bay, Naked Island	745.9	6	26	6	40	11	179	9	69	11	35	43	349
West Point of Naked Island	745.9	6	26	6	40	11	179	9	69	11	35	43	349
Section 34, Naked Island	745.9	6	26	6	40	11	179	9	69	11	35	43	349
Section 3, Naked Island	745.9	6	26	6	40	11	179	9	69	11	35	43	349
Foul Pass, Ingot Island	747.8	6	41	6	74	40	102	25	135	10	50	87	402
Hook, Naked	751.6	6	26	6	40	11	179	9	69	11	35	43	349

Table 6. Existing and predicted use patterns of motorized recreation boats in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest Site	Distance to Whittier (km)	Mean number of motorized recreation boats by month											
		May		June		July		August		September		All Months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
Island													
Folly, Storey Island	753.7	13	36	11	45	19	163	19	65	15	34	77	343
N of Jason, Peak Island	757.2	4	18	4	27	8	139	6	42	4	17	26	243
NW of Major, Storey Island	762.6	13	36	11	45	19	163	19	65	15	34	77	343
Igloo, Naked Island	763.8	4	18	4	27	8	139	6	42	4	17	26	243
N of Tuft, Naked Island	766.3	4	23	3	36	1	137	8	73	1	25	17	294
Bass Harbor - W. Naked I.	766.3	4	0	3	0	1	0	8	0	1	0	17	0
Major, Storey Island	767.4	13	36	11	45	19	163	19	65	15	34	77	343
E of Major, Storey Island	769.2	13	36	11	45	19	163	19	65	15	34	77	343
Clove Triangle	778.9	2	25	4	49	1	33	6	80	1	28	14	215
Sphinx Island	779.1	2	30	7	63	1	31	8	104	1	36	19	264
Elk Head Point	784.0	4	15	4	22	8	142	6	35	4	15	26	229
Yale Glacier Island-SE	792.7	0	0	0	0	0	0	0	0	0	0	0	0
S of Elk Head Pt, Peak I	793.1	4	15	4	22	8	142	6	35	4	15	26	229
Yale Glacier Island-SW	796.5	0	0	0	0	0	0	0	0	0	0	0	0

Table 6. Existing and predicted use patterns of motorized recreation boats in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest Site	Distance to Whittier (km)	Mean number of motorized recreation boats by month											
		May		June		July		August		September		All Months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
S of Balmy, Peak Island	799.8	4	15	4	22	8	142	6	35	4	15	26	229
S Section 16, Peak Island	800.5	4	15	4	22	8	142	6	35	4	15	26	229
Abner, Naked Island	804.3	4	17	3	22	8	151	6	33	4	14	25	237
Ball, Bass Island	811.6	0	0	0	0	0	0	0	0	0	0	0	0
Agnes, Bass Island	812.5	0	0	0	0	0	0	0	0	0	0	0	0
E.Point Naked Island	814.1	4	17	3	22	8	151	6	33	4	14	25	237
Edgar, Naked Island	814.1	4	17	3	22	8	151	6	33	4	14	25	237
Glory Annex, Naked Island	817.1	4	17	3	22	8	151	6	33	4	14	25	237
NW Bass Harbor, Naked Island	818.6	4	17	3	22	8	151	6	33	4	14	25	237
W Bass Harbor, Naked Island	825.6	4	17	3	22	8	151	6	33	4	14	25	237
North Little Smith Island	844.8	2	18	4	34	0	0	0	0	0	0	6	52
W tip of Smith Island	844.8	2	18	4	34	0	0	0	0	0	0	6	52
West Little Smith Island	844.8	2	18	4	34	0	0	0	0	0	0	6	52

Table 6. Existing and predicted use patterns of motorized recreation boats in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest Site	Distance to Whittier (km)	Mean number of motorized recreation boats by month											
		May		June		July		August		September		All Months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
N of Lint, Chenega Island	866.2	13	33	48	96	82	153	51	111	17	38	211	431
Cave Point, Glacier Island	879.1	0	0	0	0	0	0	0	0	0	0	0	0
S. Glacier Island	884.0	0	0	0	0	0	0	0	0	0	0	0	0
East Tip of Smith Island	891.6	2	13	4	25	0	0	0	0	0	0	6	38
Southeast Smith Island	895.5	2	13	4	25	0	0	0	0	0	0	6	38
Light, Seal Island	897.4	0	0	0	0	0	0	0	0	0	0	0	0
Rocks E of Seal Island	897.4	0	0	0	0	0	0	0	0	0	0	0	0
West Seal Island	897.4	0	0	0	0	0	0	0	0	0	0	0	0
SW Point of Seal Island	899.3	0	0	0	0	0	0	0	0	0	0	0	0
Weather Station, Seal Island	901.7	0	0	0	0	0	0	0	0	0	0	0	0
NE of Bull Head, Glacier Island	927.4	0	0	0	0	0	0	0	0	0	0	0	0
Jackpot Island	938.8	0	0	6	48	4	89	2	67	2	25	14	229
Outer Marsha Bay, Knight I.	944.3	0	0	6	36	10	38	16	65	3	20	35	159
Barnes Cove, Knight Island	944.3	2	11	6	25	18	154	8	45	0	0	34	235
Pleiades Islands	989.7	8	19	30	58	54	125	46	107	12	32	150	341

Table 6. Existing and predicted use patterns of motorized recreation boats in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest Site	Distance to Whittier (km)	Mean number of motorized recreation boats by month											
		May		June		July		August		September		All Months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
NW of Point Countess	1,009.8	0	0	1	21	2	53	0	0	0	0	3	74
Gage Island	1,031.5	5	14	17	38	24	81	22	67	4	19	72	219
Flemming Island	1,038.3	5	14	17	38	24	81	22	67	4	19	72	219
Section 30, Icy Bay	1,051.1	0	0	6	38	3	107	0	0	2	15	11	160
S of Discovery Pt, Knight Island	1,053.6	0	0	2	31	2	8	6	39	1	11	11	89
Whale Bay	1,068.9	0	0	1	16	2	90	2	37	0	0	5	143
West Arm of Whale Bay	1,070.6	0	0	1	16	2	90	2	37	0	0	5	143
Near Zeus, Icy Bay	1,075.4	0	0	8	37	4	76	0	0	2	13	14	126
Will, Nassau Fiord	1,077.3	0	0	0	0	0	0	0	0	0	0	0	0
Chenega Glacier	1,097.3	0	0	1	31	2	57	0	0	0	0	3	88
Icy Bay	1,111.4	0	0	8	31	4	48	0	0	2	10	14	89
S of Pt Waters, Port Bainbridge	1,203.4	0	0	10	23	18	57	21	50	5	15	54	145
Near Hydro, Bainbridge Passage	1,203.4	0	0	10	23	18	57	21	50	5	15	54	145
N of Hogg Point	1,203.4	0	0	10	23	18	57	21	50	5	15	54	145
N of Isle, Evans Island	1,223.2	3	10	2	20	12	73	5	35	1	12	23	150

Table 6. Existing and predicted use patterns of motorized recreation boats in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest Site	Distance to Whittier (km)	Mean number of motorized recreation boats by month											
		May		June		July		August		September		All Months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
Bainbridge Glacier	1,245.3	0	0	2	12	6	42	2	21	2	8	12	83
N of Aluklik Bay, Evans I.	1,246.0	3	10	2	20	12	73	5	35	1	12	23	150
Port Bainbridge	1,247.8	0	0	2	10	6	52	3	22	2	8	13	92
Brid, Port Bainbridge	1,250.6	0	0	2	10	6	52	3	22	2	8	13	92
E side of Latouche Island	1,253.1	0	0	0	0	0	0	0	0	0	0	0	0
West of Hogg Bay	1,254.1	0	0	4	15	6	34	10	30	4	10	24	89
SW of Aluklik Bay, Evans I.	1,256.8	3	10	2	20	12	73	5	35	1	12	23	150
N Squirrel Bay, Evans Island	1,256.8	3	10	2	20	12	73	5	35	1	12	23	150
Mid Squirrel Bay, Evans I.	1,256.8	3	10	2	20	12	73	5	35	1	12	23	150
SW Pt of Squirrel Bay, Evans I.	1,256.8	3	10	2	20	12	73	5	35	1	12	23	150
Point Pyke, Bainbridge Island	1,292.5	0	0	2	14	3	25	4	25	0	0	9	64
South of North Auk Bay	1,306.4	0	0	2	12	5	23	10	29	2	7	19	71
North Point, Auk	1,306.4	0	0	2	12	5	23	10	29	2	7	19	71

Table 6. Existing and predicted use patterns of motorized recreation boats in 2015 within 1,000 m of pigeon guillemot nesting sites in western Prince William Sound, Alaska.

Nest Site	Distance to Whittier (km)	Mean number of motorized recreation boats by month											
		May		June		July		August		September		All Months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
Bay													
Mid Section 33, Elrington Island	1,321.7	0	0	1	12	1	18	0	0	0	0	2	30
Section 33, Elrington Island	1,328.5	0	0	1	12	1	18	0	0	0	0	2	30
North Twin Bay	1,330.4	0	0	2	16	8	40	0	0	2	11	12	67
S Pt of Auk Bay	1,331.8	0	0	2	12	4	17	7	24	2	7	15	60
Gray Bowl, Port Bainbridge	1,352.0	0	0	2	12	4	17	7	24	2	7	15	60
S Gray Bowl, Port Bainbridge	1,354.7	0	0	2	12	4	17	7	24	2	7	15	60
Point Elrington	1,359.9	0	0	2	13	8	28	0	0	2	9	12	50
Section 27, Port Bainbridge	1,371.4	0	0	2	12	4	17	7	24	2	7	15	60
S Section 27, Port Bainbridge	1,377.1	0	0	2	12	4	17	7	24	2	7	15	60
Total		571	3,341	863	6,402	1,626	12,382	1,362	8,129	682	3,260	5,104	33,514

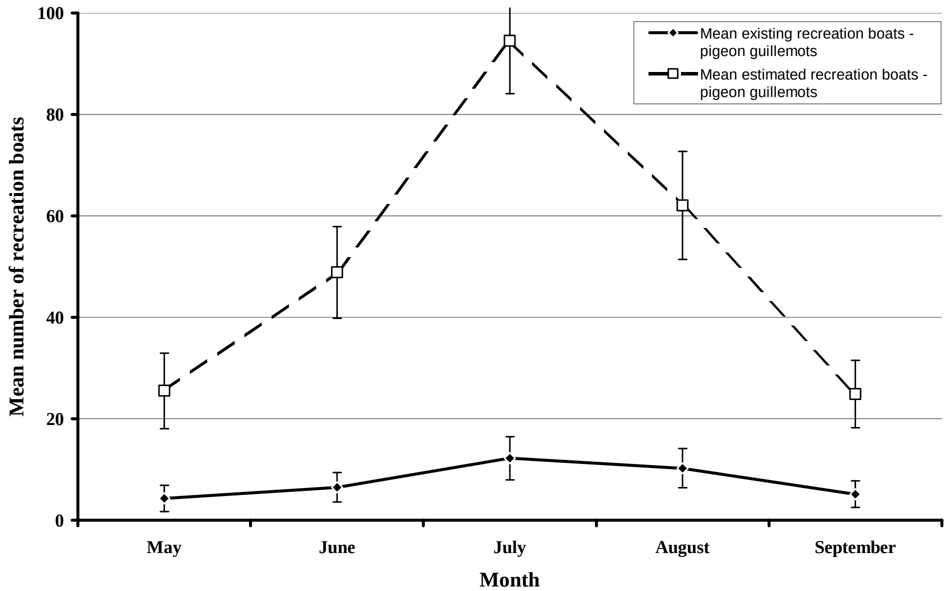


Fig. 9. Mean number of motorized recreation boats within 1,000 meters of pigeon guillemot nesting sites in western Prince William Sound, Alaska (error bars represent standard error).

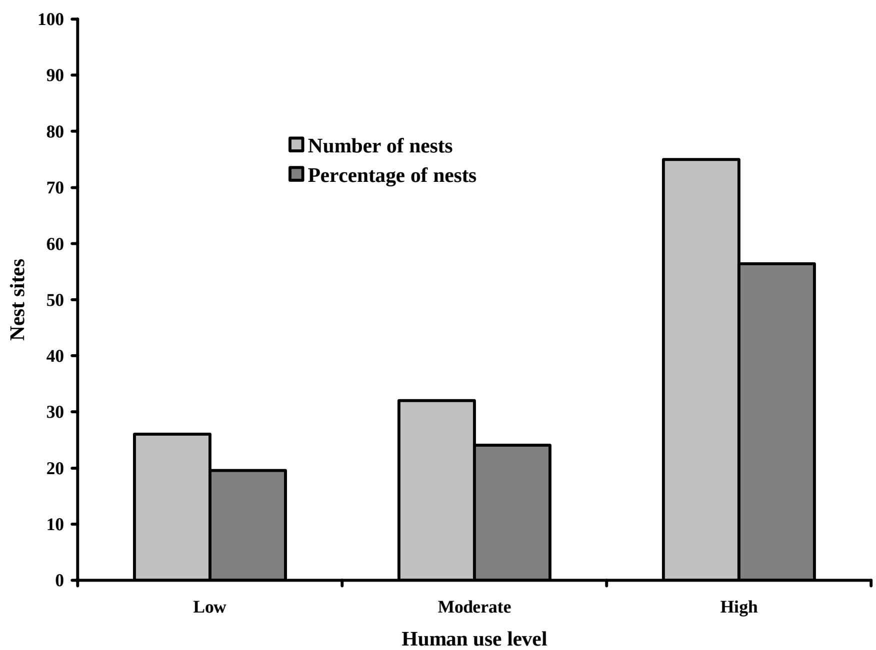


Fig. 10. Predicted use by recreation motor boats in 2015 within 1,000 m of 133 pigeon guillemot nest sites evaluated from May through August (low levels = 0 – 15 more vessels per season; moderate levels = 16 – 100 more vessels per season; high levels = >100 more vessels per season).

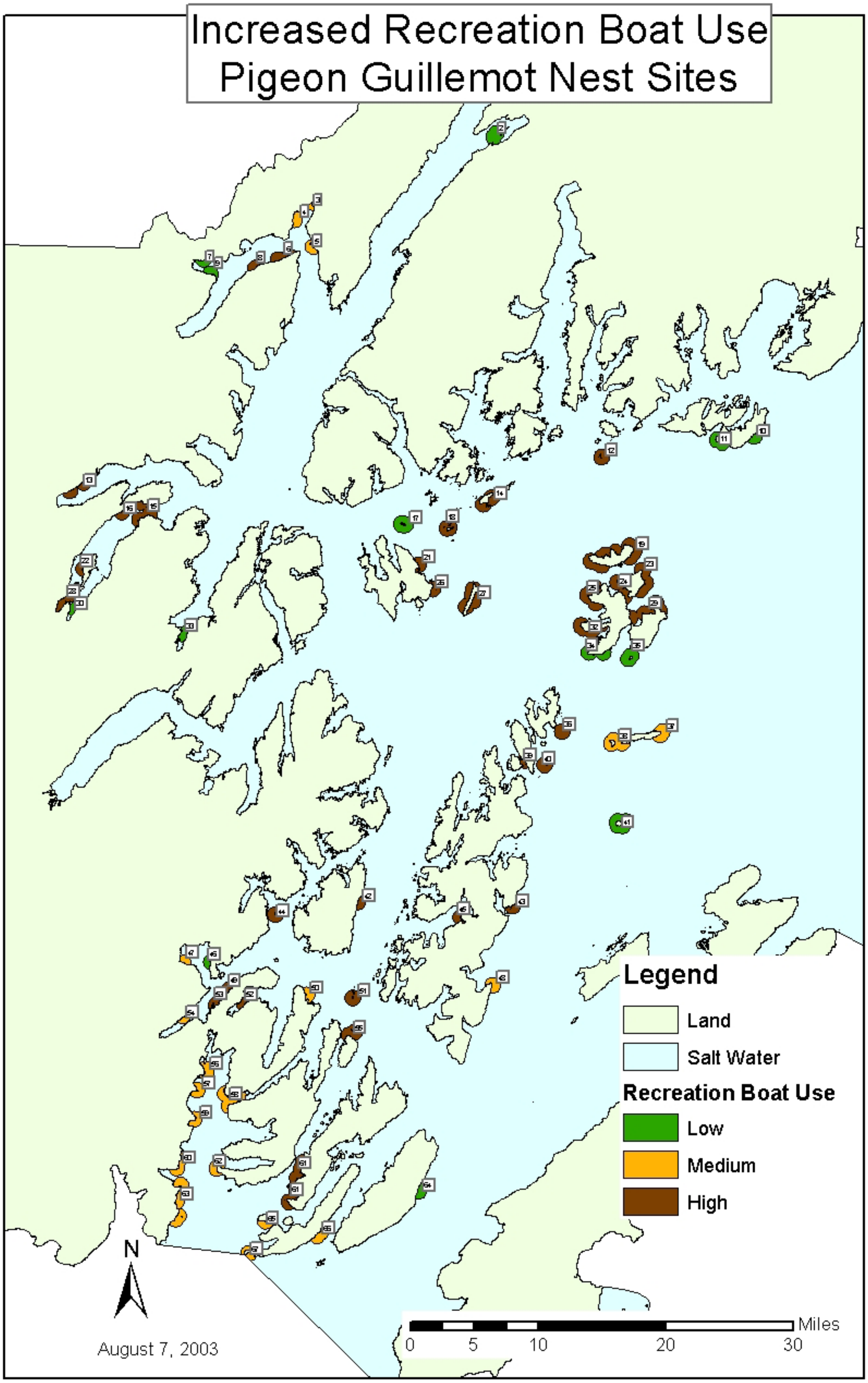


Fig. 11. Magnitude and location of predicted recreation boat use levels in 2015 within 1,000 m of pigeon guillemot nest sites in western Prince William Sound, Alaska.

Harbor seals.— Predicted monthly use in 2015 of kayaks within 1,000 m of individual haul-out sites ranged from no change to increases approximating 12 times current use (Table 7). Mean monthly increases at all sites ranged from 110 to 290% (Fig. 12). Of 36 haulout sites evaluated during June, July, and August; 61% are predicted to experience low levels (0 – 15 more vessels per season) of increased use within their vicinity by 2015; 33% are predicted to experience moderate levels (16 – 100 more vessels) of increase; and 6% are expected to experience high levels (>100 more vessels) of kayak use (Fig. 13). The limited high level of increased kayak use is expected to be concentrated at haulout sites in Barry Arm and Port Nellie Juan (Fig. 14).

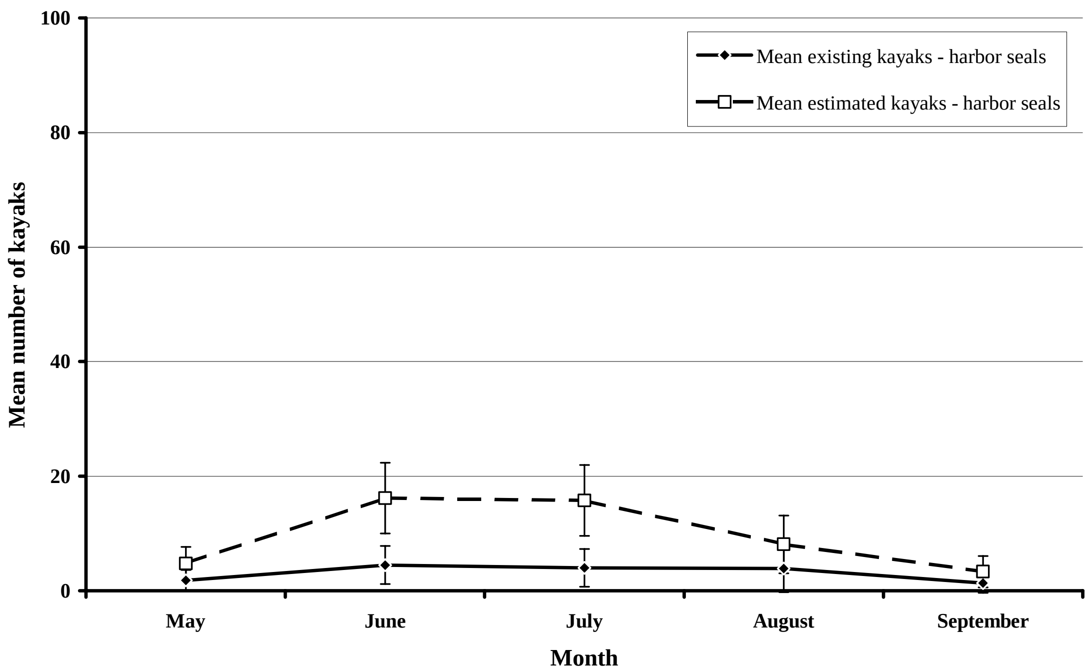


Fig. 12. Mean number of kayaks within 1,000 meters of harbor seal haul-out sites in western Prince William Sound, Alaska (error bars represent standard error).

Predicted monthly use in 2015 of motorized recreational boats within 1,000 m of individual haul-out sites ranged from no change to increases approximating 45 times current use (Table 8). Mean monthly increases ranged from 340 to 390% (Fig. 15). Twenty-two percent of the 36 haulout sites evaluated during June, July, and August are predicted to experience low levels (0 – 15 more vessels per season) of increased use within their vicinity by 2015; 22% are predicted to experience moderate levels (>16 – 100 more vessels) of increase; and 56% are expected to experience high levels (>100 more vessels) of use by motorized recreational boats (Fig. 16). High levels of increased recreation boat use at haulout sites is expected to occur across The islands of the north central Sound, Knight Island, Knight Island Passage, and Dangerous Passage (Fig. 17).

Table 7. Existing and predicted use patterns in 2015 of kayaks within 1,000 m of harbor seal haulout sites in western Prince William Sound, Alaska.

Haulout site	Distance to Whittier (km)	Mean number of kayaks by month										All months	
		May		June		July		August		September			
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
Dutch Group	51.4	0	2	6	13	0	10	0	18	0	2	6	45
Lone Island group	58.4	1	2	1	5	3	10	1	3	1	2	7	22
Little Axel Lind Island	59.1	0	0	0	8	0	8	0	4	0	2	0	22
Harriman Fjord	59.6	17	42	62	200	62	213	102	154	18	46	261	655
Point Pellew	60.9	7	18	2	15	1	13	1	3	3	7	14	56
Crafton Island	66.2	1	3	3	17	16	46	2	12	1	3	23	81
Olsen Island	68.2	1	3	1	9	1	9	1	5	1	2	5	28
Port Nellie Juan	68.8	10	23	30	133	8	95	0	4	1	5	49	260
Northwest Bay	72.6	1	3	1	4	1	4	1	4	1	2	5	17
Fairmount Island	74.7	1	3	1	8	1	8	1	4	1	2	5	25
Disk Island	75.5	1	4	6	19	1	6	1	6	1	4	10	39
Wells Bay	75.6	2	7	1	7	1	8	1	3	1	2	6	27
Storey Island	76.8	1	3	1	4	1	4	1	3	1	2	5	16
Herring Bay	78.6	1	2	4	10	1	4	0	0	1	2	7	18

Table 7. Existing and predicted use patterns in 2015 of kayaks within 1,000 m of harbor seal haulout sites in western Prince William Sound, Alaska.

Haulout site	Distance to Whittier (km)	Mean number of kayaks by month											
		May		June		July		August		September		All months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
Payday	79.0	2	9	1	7	1	8	1	5	1	2	6	31
Junction Island	79.8	1	2	4	9	20	30	6	15	1	2	32	58
Unnamed Cove	80.9	1	3	6	15	1	4	1	4	1	2	10	28
Agnes Island	81.5	1	2	1	2	2	5	1	2	1	2	6	13
Little Smith Island	84.1	0	0	0	0	0	0	0	0	0	0	0	0
Bay of Isles	86.5	1	2	6	14	1	2	1	2	1	3	10	23
Delenia Island	89.3	1	2	2	10	8	28	5	12	1	2	17	54
Big Smith Island	89.9	0	0	0	0	0	0	0	0	0	0	0	0
Schooner Rocks	90.1	1	2	1	4	1	6	1	3	1	2	5	17
Squire Island	94.9	1	2	1	2	1	2	1	4	1	2	5	12
Unakwik Inlet	97.9	4	15	7	29	1	13	1	2	1	2	14	61
Columbia Bay	102.8	1	2	1	4	1	4	1	2	1	2	5	14
Gage Island	103.1	1	2	1	2	1	2	1	2	1	2	5	10

Table 7. Existing and predicted use patterns in 2015 of kayaks within 1,000 m of harbor seal haulout sites in western Prince William Sound, Alaska.

Haulout site	Distance to Whittier (km)	Mean number of kayaks by month											
		May		June		July		August		September		All months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
Unnamed site	108.5	1	2	2	11	3	14	1	2	1	2	8	31
Bainbridge Passage	110.3	1	2	1	2	1	2	1	2	1	2	5	10
Iktua Rocks	111.2	1	2	1	2	1	2	1	2	1	2	5	10
Iktua Bay	111.5	1	2	1	2	1	2	1	2	1	2	5	10
Prince of Wales Passage	118.6	1	2	1	2	1	2	1	4	1	2	5	12
Hogg Bay	127.6	1	2	5	12	1	2	1	2	1	2	9	20
Latouche Island	133.1	1	2	1	2	1	2	1	2	1	2	5	10
College Fjord		0	0	0	0	0	0	0	0	0	0	0	0
Danger Island		0	0	0	0	0	0	0	0	0	0	0	0
Total		66	172	162	583	144	568	139	292	49	120	560	1,735

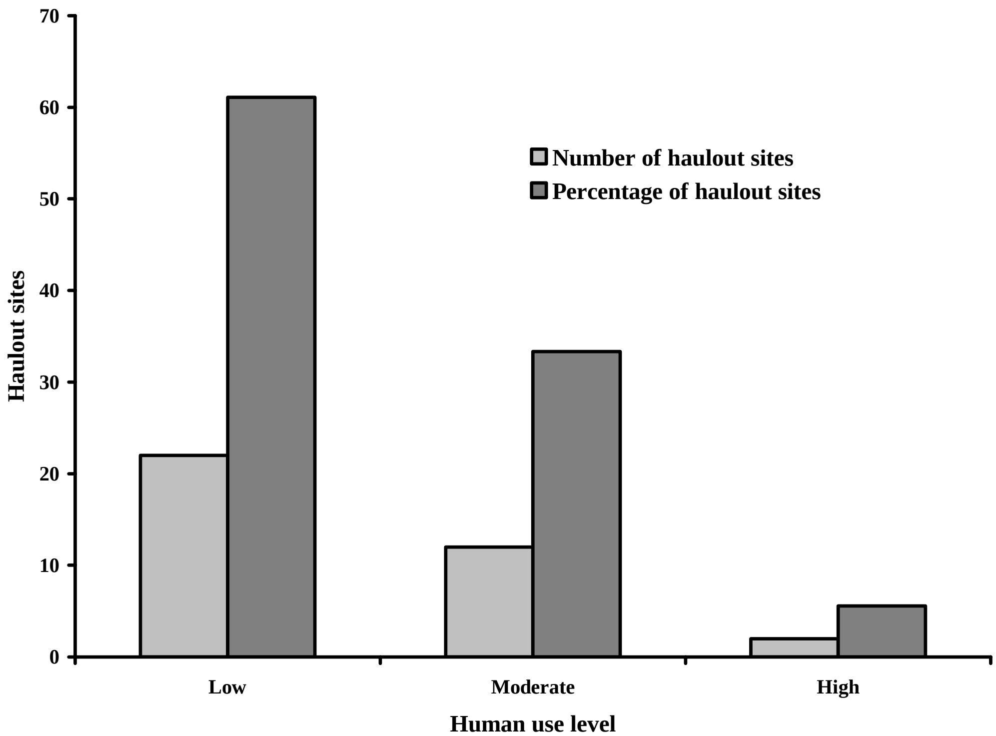


Fig. 13. Predicted use by kayaks in 2015 within 1,000 m of 36 harbor seal haulout sites evaluated from June through August (low levels = 0 – 15 more vessels per season; moderate levels = 16 – 100 more vessels per season; high levels = >100 more vessels per season).

DISCUSSION

Natural resource management has become increasingly multi-jurisdictional and interdisciplinary over the last quarter century, and, as a result, is extremely complex. Diverse groups, representing a wide spectrum of interests are becoming increasingly involved in influencing State and Federal agencies' management of the natural lands and resources. Adding to the complexity, many businesses market Alaska's scenery and wildlife to their customers. The challenge for natural resource managers is to provide opportunities for both commercial and recreational use of the environment, without causing irreparable harm to wildlife resources. This is particularly important for resources injured by the spill that may not be resilient to changes in their environment. Indirect effects, such as disturbance, are much more difficult to document or understand than are direct effects such as fisheries harvest or activities that disturb the ground. The tradeoffs associated with decisions regarding levels of use by various user groups in the western Sound are often difficult to quantify. Management to encourage higher levels of use will help to ensure that large numbers of visitors have access to outdoor recreation resources and that vendors are able to develop and conduct traditional and innovative commercial operations that are economically viable (Brooks and Haynes 2001). Choices

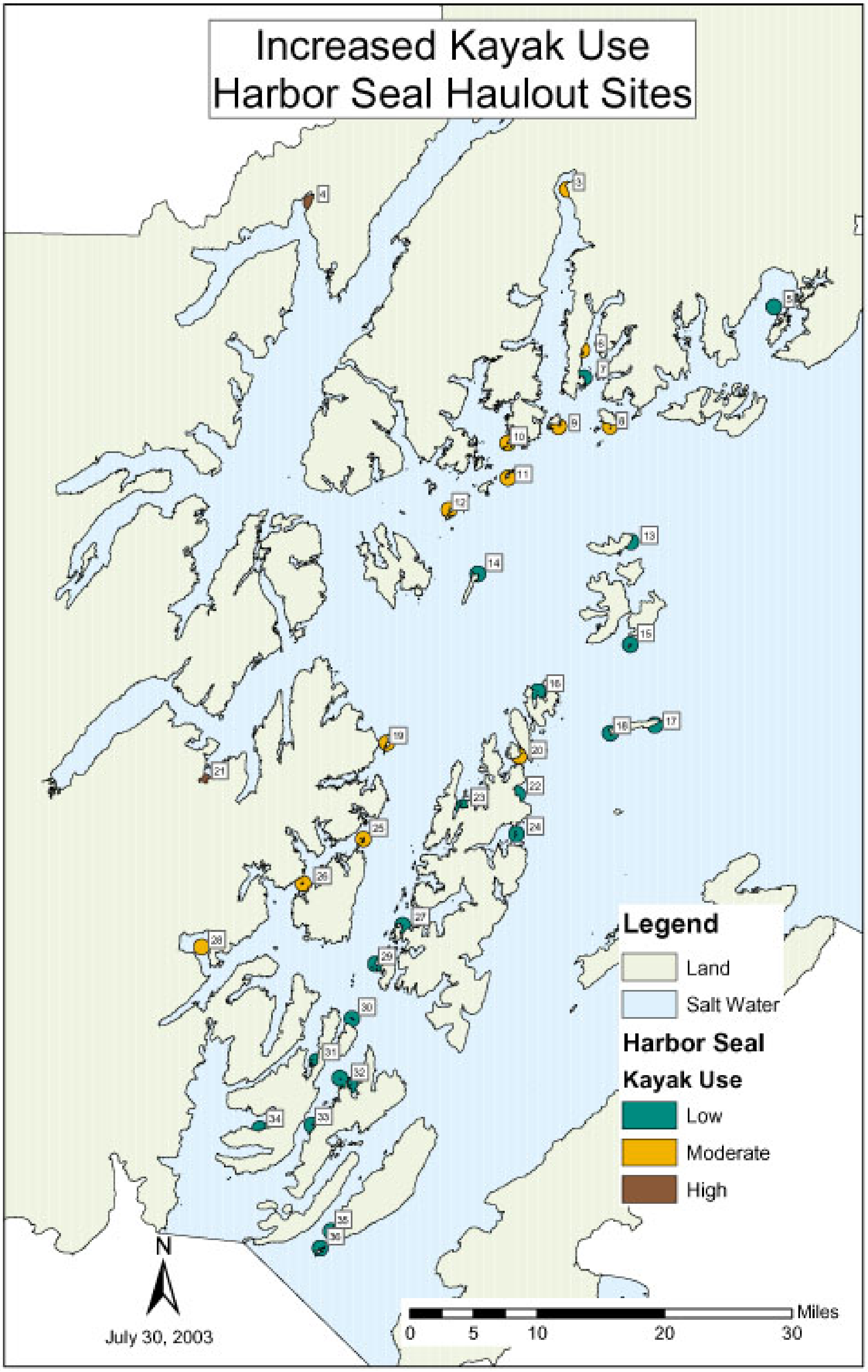


Fig. 14. Magnitude and location of predicted increase in kayak use in 2015 in the vicinity of harbor seal haul out sites in western Prince William Sound, Alaska.

Table 8. Existing and predicted use patterns in 2015 of motorized recreation boats within 1,000 m of harbor seal haulout sites in western Prince William Sound, Alaska.

Haulout Site	Distance to Whittier (km)	Mean Number of Recreation Boats											
		May		June		July		August		September		All Months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
Dutch Group	51.4	0	0	2	91	4	174	0	0	0	0	6	265
Lone Island group	58.4	4	40	10	67	8	97	4	109	4	43	30	356
Little Axel Lind Island	59.1	21	70	19	100	53	253	26	108	25	60	144	591
Harriman Fjord	59.6	0	0	0	0	4	40	0	0	0	0	4	40
Point Pellew	60.9	13	64	21	114	94	409	25	98	7	34	160	719
Crafton Island	66.2	20	61	66	148	157	341	94	256	27	84	364	890
Olsen Island	68.2	6	37	8	64	46	256	17	61	2	16	79	434
Port Nellie Juan	68.8	0	0	0	0	0	0	0	0	0	0	0	0
Northwest Bay	72.6	0	0	3	55	3	55	6	108	10	49	22	267
Fairmount Island	74.7	4	29	8	57	42	180	20	49	1	10	75	325
Disk Island	75.5	5	40	5	73	40	97	24	133	10	50	84	393
Wells Bay	75.6	4	33	0	0	8	192	0	0	2	10	14	235
Storey Island	76.8	0	0	0	0	0	0	0	0	0	0	0	0
Herring Bay	78.6	0	0	0	0	0	0	0	0	0	0	0	0
Payday	79.0	0	0	0	0	0	0	0	0	0	0	0	0
Junction Island	79.8	11	39	50	116	95	227	52	127	16	42	224	551
Unnamed Cove	80.9	4	30	2	53	30	87	21	117	8	43	65	330
Agnes Island	81.5	0	0	0	0	0	0	0	0	0	0	0	0
Little Smith Island	84.1	2	19	4	35	0	0	0	0	0	0	6	54

Table 8. Existing and predicted use patterns in 2015 of motorized recreation boats within 1,000 m of harbor seal haulout sites in western Prince William Sound, Alaska.

Haulout Site	Distance to Whittier (km)	Mean Number of Recreation Boats											
		May		June		July		August		September		All Months	
		Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted	Existing	Predicted
Bay of Isles	86.5	0	0	3	55	12	97	10	97	3	33	28	282
Delenia Island	89.3	0	0	17	62	43	196	12	80	3	27	75	365
Big Smith Island	89.9	2	14	4	25	0	0	0	0	0	0	6	39
Schooner Rocks	90.1	4	17	18	48	18	119	18	78	2	23	60	285
Squire Island	94.9	0	0	10	31	14	82	7	61	1	19	32	193
Unakwik Inlet	97.9	2	16	6	41	36	56	4	9	6	9	54	131
Columbia Bay	102.8	0	0	0	0	4	25	4	8	0	0	8	33
Gage Island	103.1	6	15	19	39	25	82	23	70	4	20	77	226
Unnamed site	108.5	0	0	1	33	2	66	0	0	0	0	3	99
Bainbridge Passage	110.3	4	11	2	16	16	78	4	30	2	11	28	146
Iktua Rocks	111.2	3	10	2	16	15	93	4	31	2	11	26	161
Iktua Bay	111.5	3	10	2	16	15	93	4	31	2	11	26	161
Prince of Wales Passage	118.6	4	11	2	17	16	53	5	37	2	13	29	131
Hogg Bay	127.6	0	0	0	0	4	71	10	27	2	7	16	105
Latouche Island	133.1	0	0	1	12	0	0	0	0	0	0	1	12
College Fjord		0	0	0	0	0	0	0	0	0	0	0	0
Danger Island		0	0	0	0	0	0	0	0	0	0	0	0
Total		122	566	285	1,384	804	3,519	394	1,725	141	625	1,746	7,819

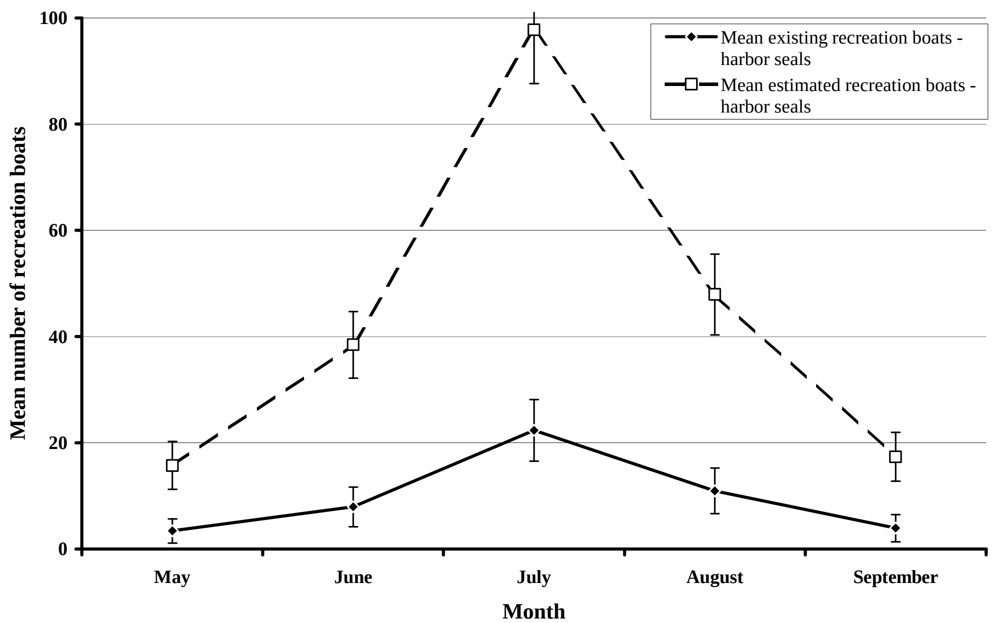


Fig. 15. Mean number of motorized recreation boats within 1,000 meters of harbor seal haul-out sites in western Prince William Sound, Alaska (error bars represent standard error).

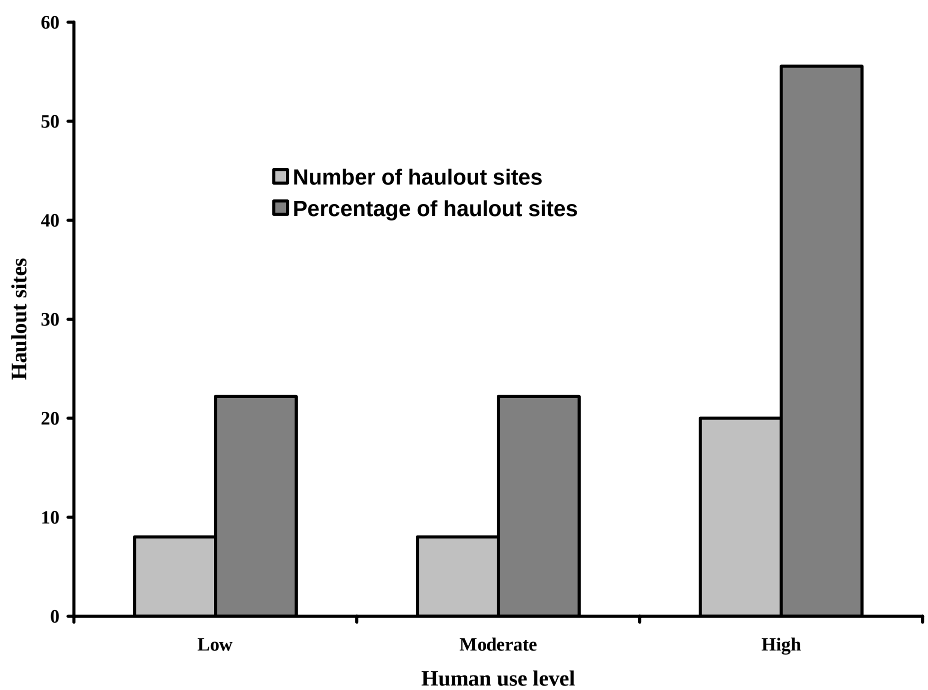


Fig. 16. Predicted use by recreation boats in 2015 within 1,000 m of 36 harbor seal haulout sites evaluated from June through August (low levels = 0 – 15 more vessels per season; moderate levels = 16 – 100 more vessels per season; high levels = >100 more vessels per season).

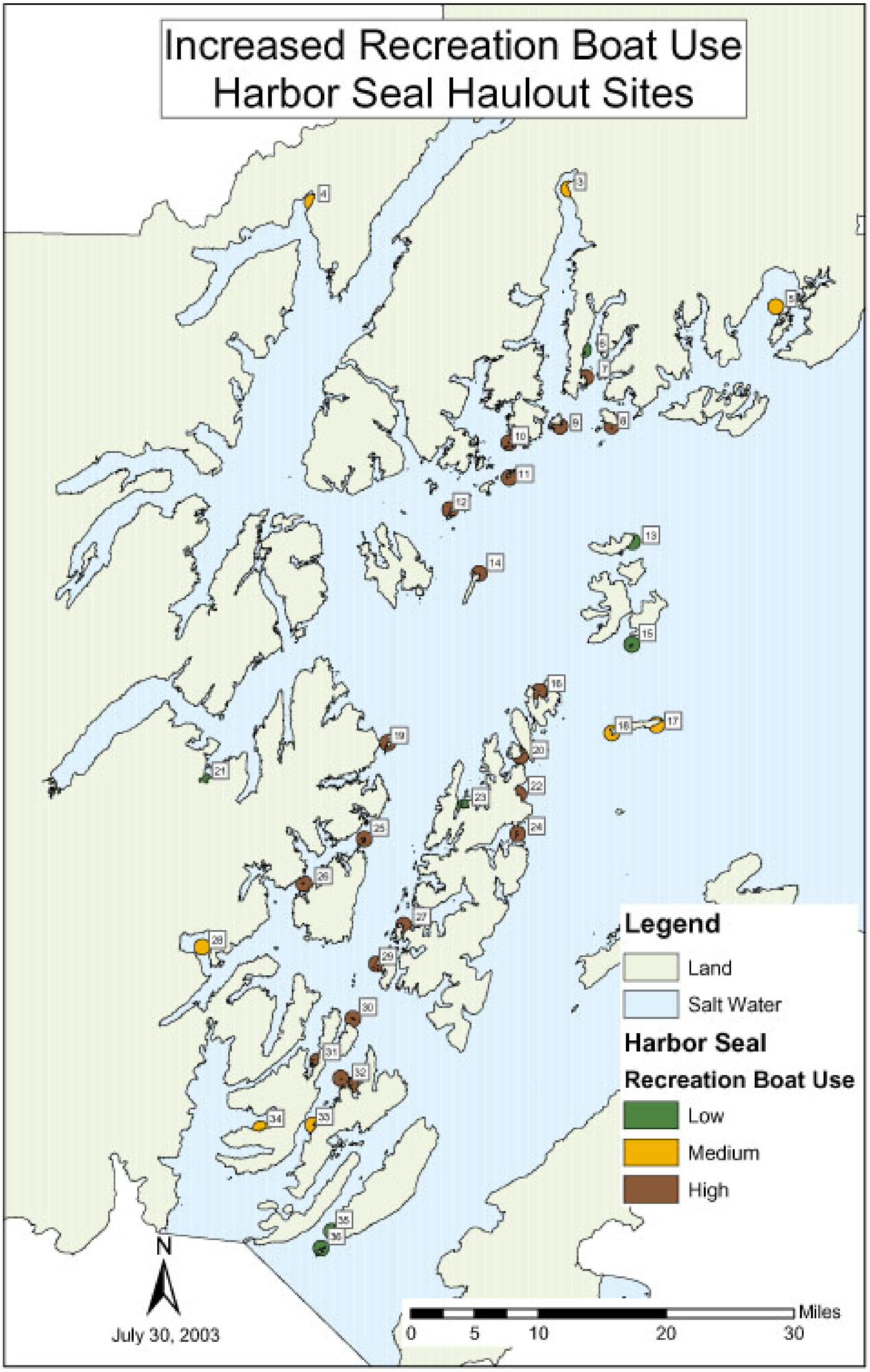


Fig. 17. Magnitude and location of predicted increase in motorized recreation boat use in 2015 in the vicinity of harbor seal haul out sites in western Prince William Sound, Alaska.

will need to be made between limiting visitor use to ensure the well being of injured and other species and allowing higher levels of use (Lawson and Manning 2001, 2002).

The opening of the Whittier Road provided the impetus to plan for the future of the western Sound and the change in human use patterns. In order to make informed decisions about how to respond to, or how to manage the change in human use, it is important to have an understanding of current human use patterns, predicted future use patterns, and their potential impact on injured resources.

Kayak Users

Distance to camp sites and upland recreation sites consistently entered into equations explaining the distribution of kayakers from May through September (Table 3, Fig. 4). Although location of cabins did not enter into equations explaining distributions, it was of some importance when considered as an individual variable (Table 3). These findings offer opportunity to manage the distribution of kayakers through the distribution of these sites. Construction of new facilities should be planned in areas that offer access to other attractions for kayakers (e.g., glaciers) but that are well away from pigeon guillemot nest sites, harbor seal haulout sites, and other areas with sensitive wildlife present. Existing sites that are in close proximity to sensitive sites may need to be removed or closed during specific times of the year.

Recreational Motorboat Users

Variables influencing the distribution of motorized recreation boat users included sport fishing opportunities, black bear *(Ursus americanus*) hunting in the spring, Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) hunting in late summer and fall, anchor buoys, and upland recreation sites (Table 3, Fig. 4). The response of motorized recreation boat users to these factors also offers opportunities to manage their distribution in relation to pigeon guillemot nest sites, harbor seal haulout sites, and other areas with sensitive wildlife present (e.g., Ocean Resources Management Task Force 1990). Areas may be closed to sport fishing and hunting if they are in close proximity to sensitive areas. Placement of anchor buoys may have great potential for directing motorized recreation boat users to other attractions for this user group (e.g., glaciers) but that are well away from sensitive areas. Construction of upland recreation sites should be planned in areas that will not draw users to the vicinity of sensitive sites.

Pigeon Guillemots

Golet et al. (2002) demonstrated that seabird populations cannot always be expected to rebound to preperturbation levels in the short term following a mass mortality event such as that associated with an oil spill. They also suggested that recovery times following oil spills might be considerably longer for certain species than a few yrs, which was considered typical for marine birds (Wiens et al. 1996, Day et al. 1997). Reproductive effort in seabirds reduces adult body condition and survival (Golet et al. 1998, Golet and Irons 1999) this also makes them more vulnerable to the effects of disturbance.

Pigeon guillemots in the western Sound typically begin to return to breeding grounds in April and initiate courtship and nest site establishment in May (Kuletz 1998). During this time the adults display on the water adjacent to the colony and make frequent trips to and from the potential nest site. Pigeon guillemots generally nest in rock crevices on cliffs or in talus boulders, or in labyrinth tree root systems. They remain on nest sites through fledging of the young which peaks during the first 2 weeks of August in southcentral Alaska (Kuletz 1998).

The potential for disturbance of pigeon guillemots extends throughout much of the recreational kayak and motorized boating season. We do not expect the predicted increase in kayak use to add greatly to current disturbance levels at pigeon guillemot nest sites (Figs. 6, 7, 8). However, we estimate that high levels of increased use of motorized recreation boats will occur at nest sites throughout the western Sound with concentrated use in Passage Canal, Blackstone Bay, lower Harriman Fiord, from Perry Island to Naked Island, Knight Island, Knight Island Passage, Icy Bay, and Evans Island (Figs. 9, 10, 11). This pattern of use is similar to that reported by Colt et al. (2002). These areas should be targeted for potential closure of facilities and restricted use. These areas should also receive greater attention by resource management agencies to ensure closures are being observed.

Harbor Seals

Richardson et al. (1995) provided a thorough review of the responses of marine mammals to factors of disturbance. Although harbor seals in water do react to boat-based disturbance, there is a paucity of definitive studies defining the effects of that response on seals. Although stress may increase in harbor seals as a result of boat-based disturbance, there is an indication that seals have a high level of tolerance for the presence of boats. Harbor seals may become habituated to human presence in the absence of hunting or active harassment (Bonner 1982, Thompson 1992).

For harbor seals, human activity may be most disturbing during pupping and during the molt. The majority of pups are born in the 1st half of June in the Sound (Frost 1996). Disturbance that causes a female to be separated from her newborn pup can endanger the pup. Johnson (1977) has shown that pair bonds between a female and her pup are fragile during the first few days of a pup's life. Separation can result in the pup becoming lost or abandoned. Forced movement into the water may be a particular problem for pups, which may need to remain hauled out for long periods of time to maintain adequate body temperatures (e.g., Fay and Ray 1968).

The peak period for harbor seals to molt occurs in late July and August in the Sound (Pitcher and Calkins 1979). During this period they must rest out of the water in order to maintain their body heat (e.g., Fay and Ray 1968). New hair may also grow faster when seals are out of the water and their skin is warmer (Hoover-Miller 1994). Human activity that forces the seals to return to the water during this time is likely to increase the amount of energy that an animal must expend to stay warm.

The Marine Mammal Protection Act (MMPA) provides regulations intended to prevent vessels from disturbing seals. Human actions that merely have the potential to disturb a seal are defined as an unlawful "taking." Individuals in either user group that we examined could violate these rules and disturb the animals. With increasing human use in the vicinity of haulout sites, the potential for disturbance increases. While the MMPA has been used successfully to deter human activity that may directly and immediately harm seals, penalties have not been imposed to prevent harassment by boaters (Lelli and Harris 2001). This suggests that education of boaters and clear regulations may be a reasonable first step in reducing the impact of boaters on harbor seals, but that enforcement of regulations will need specific emphasis.

CONCLUSIONS

Managers have responded to potential problems associated with increased use with a variety of visitor and resource management practices (Manning 1979, Manning et al. 1996). Three basic recreation management strategies are among those traditionally used to address conflicts associated with use of natural areas (e.g., Pienkowski 1993, Velarde and Anderson 1994):

1. The supply of natural areas may be increased to accommodate additional demand,
2. The use of natural areas may be limited through restrictions on public access, and
3. The character of recreation use may be modified to reduce its adverse impact.

Although the resources of the Sound are finite and cannot be expanded, management practices may be implemented to make currently little-used or unused areas with limited potential for disturbance of injured resources more available or desirable to users. This may included development and advertisement of facilities that attract users (e.g., camp sites, cabins, upland recreation sites, anchor buoys).

Efforts should be made in areas in the vicinity of nesting or haulout sites that are predicted to receive large increases of human use to redirect this use. Camp sites appear to affect distribution of kayaks throughout the months when pigeon guillemots and harbor seals are sensitive to disturbance. If efforts to divert use away from identified nest sites and haulout sites (and other sensitive areas) are not fully successful, consideration should be given to closing existing camp sites or otherwise discouraging their use in the vicinity of sensitive areas during these months. Upland recreation sites appear to affect distribution of both kayakers and motorized recreation boat users during portions of the recreation season when wildlife is vulnerable to disturbance. Closing sites in particularly sensitive areas should be given consideration. Restricting use by kayakers and motorized recreation boat users in particularly sensitive areas should also be given consideration if use patterns cannot be redirected.

Because land management jurisdiction in the Sound is so complex, public education may be one of the strongest tools available to managers. The character of recreation use and its associated impact may be modified through education of the users and those providing services to the users. Tershy et al. (1997) studied the effects of human disturbance on San Pedro Martir Island in the Gulf of California. They examined the effects of different user groups on the populations of birds and marine mammals that depend on the island. They found that the ecotourism groups that visited the island caused one of the lowest levels of disturbance to the local wildlife – probably due to a combination of a well designed education program and permit regulations. While other studies have documented reduced productivity and other negative effects as a result of disturbance from ecotourism groups (e.g., Burger et al. 1995), Tershy et al. (1997) indicated that education can effectively reduce disturbance. We recommend that specific education materials be developed for distribution to recreational boaters in the Sound that identify the situations and general habitats that should be avoided to minimize disturbance to sensitive wildlife. Education programs should also be developed and delivered to ecotourism guides and to water taxi operators to ensure their operations do not result in increased disturbance. Education efforts may be particularly effective since they can be concentrated at the origin of most use in Whittier. A greater presence in the Sound by personnel of management agencies will also help with implementation of education efforts, enforcement of existing regulations, and adherence to closed area policies (if necessary).

ACKNOWLEDGEMENTS

This project could not have been completed without the support of many people. We are particularly grateful to the people and companies who provided information and data on activities in the Sound. C. Beck, C. Buchholdt, the Heddells, E. Huffines, P. McNees, C. Pratt, G. Sanger, the von Wichmans, and the Whittier Harbor staff provided data and advice that formed much of the core of our knowledge about current activity patterns in the Sound. P. Twardock and D. Wheeler worked with us to refine information on kayak activity from Whittier. The Chenega Bay IRA Council gathered additional information on activities in the southwestern portion of the Sound.

The Chugach National Forest GIS staff provided invaluable expertise in developing the spatial distributions of human use activity. Linda Kelly was instrumental in developing the GIS programs used in this project. We would also like to thank other Chugach National Forest and Alaska Department of Natural Resources employees for contributing their time and expertise to this project. We are grateful to D. Gillikin, B. Kitto, E. Lance, S. Oehlers, D. Strehle, and J. Urbanus of the Chugach National Forest, and J. Gilpin and K. Reed of the Alaska Department of Natural Resources who all contributed substantial amounts of time and energy.

LITERATURE CITED

Alaska Department of Natural Resources. 1997. Alaska's outdoor legacy, statewide comprehensive outdoor recreation plan (SCORP), 1997-2002. Division of Parks and Outdoor Recreation, Department of Natural Resources, Anchorage, Alaska, USA.

Alaska Department of Transportation and Public Facilities and Federal Highway Administration. 1995. Whittier access project. Final environmental impact statement and final section 4(f) evaluation. Federal Highway Administration and Alaska Department of Transportation and Public Facilities, FHWA-AK-EIS-94-02-DR, Anchorage, Alaska, USA.

Bonner, W. N. 1982. Seals and man. A study of interactions. University of Washington Press, Seattle, Washington, USA,

Bowker, J. M. 2001. Outdoor recreation by Alaskans: projections for 2000 through 2020. USDA Forest Service General Technical Report PNW-GTR-527.

Brooks, D. J., and R. W. Haynes. 2001. Recreation and tourism in south-central Alaska: synthesis of recent trends and prospects. USDA Forest Service General Technical Report PNW-GTR-511.

Burger, J., M. Gochfeld, and L. J. Nikes. 1995. Ecotourism and birds in Coastal New Jersey: contrasting responses of birds, tourists, and managers. Environmental Conservation 22:56-65.

Burnham, K. P., and D. R. Anderson. 1998. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, New York, USA.

Colt, S., S. Martin, J. Mieren, M. Tomeo. 2002. Recreation and tourism in south-central Alaska: patterns and prospects. USDA Forest Service General Technical Report PNW-GTR-551.

Day R. H., S. M. Murphy, J. A Wiens, G. D. Hayward, E. J. Harner, and L. N. Smith. 1997. Effects of the *Exxon Valdez* oil spill on habitat use by birds in Prince William Sound, Alaska. Ecological Applications 7:593-613.

Ewins, P. J. 1993. Pigeon Guillemot (*Cepphus columba*). *in* A. Poole and F. Gill editors, The birds of North America 49. The Academy of Natural Sciences, Philadelphia, Pennsylvania, USA, The American Ornithologists' Union, Washington, D.C., USA.

Exxon Valdez Oil Spill Trustee Council. 2002 Exxon Valdez oil spill restoration plan. Update on injured resources and services. *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska, USA.

Fay, F. H., and C. Ray. 1968. Influence of climate on the distribution of walruses, *Odobenus rosmarus* (Linnaeus) I. Evidence from thermoregulatory behavior. Zoologica 53:1-18.

Frost, K. J. 1996. Harbor seal *Phoca vitulina richardsi*. Restoration Notebook. *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska, USA.

Golet, G. H., and D. B. Irons. 1999. Raising young reduces body condition and fat stores in black-legged kittiwakes. Oecologia 120:530-538.

Golet, G. H., D. B. Irons, and J. A. Estes. 1998. Survival costs of chick rearing in black-legged kittiwakes. Journal of Animal Ecology 67:827-841.

Golet, G. H., P. E. Seiser, A. D. McGuire, D. D. Roby, J. B. Fischer, K. J. Kuletz, D. B. Irons, T. A. Dean, S. C. Jewett, and S. H. Newman. 2002. Long-term direct and indirect effects of the *Exxon Valdez* oil spill on pigeon guillemots in Prince William Sound, Alaska. Marine Ecology Progress Series 241:287-304.

Hockin, D., M. Ounsted, M. Gorman, D. Hill, V. Keller, and M. A. Barker. 1992. Examination of the effects of disturbance on birds with reference to its importance in ecological assessments. Journal of Environmental Management 36:253-286.

Hoover-Miller, A.A. 1994. Harbor seal (*Phoca vitulina*) biology and management in Alaska. Contract T75134749. Marine Mammal Commission, Washington, D.C., USA.

Johnson, B. W. 1977. The effects of human disturbance on a population of harbor seals. Pages 422-432 *in* Environmental Assessment of the Alaskan Continental Shelf, Volume I. Receptors—Mammals. Outer Continental Shelf Environmental Assessment Program, Boulder, Colorado, USA.

Kuletz, K. 1998. Pigeon Guillemot (*Cepphus columba*). Restoration Notebook. *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska, USA.

Law, A. M., and W. D. Kelton. 1991. Simulation modeling and analysis. McGraw-Hill, New York, New York, USA.

Lawson, S. R., and R. E. Manning. 2001. Solitude versus access: a study of tradeoffs in outdoor recreation using indifference curve analysis. Leisure Sciences 23:179-191.

Lawson, S. R., and R. E. Manning. 2002. Tradeoffs among social, resource, and managerial attributes of the Denali wilderness experience: a contextual approach to normative research. Leisure Sciences 24:297-312.

Lelli, B., and D. E. Harris. 2001. Human disturbances affect harbor seal haul-out behavior: can the law protect these seals from boaters? Macalester Environmental Review [http://www.macalester.edu/~envirost/MacEnvReview/harbor_seal.htm].

Leung, Y.-F., and J. L. Marion. 2000. Recreation impacts and management in wilderness: a state-of-knowledge review. Pages 23-48 *in* D. N. Cole, S. F. McCool, W. T. Borrie, and J. O'Loughlin, compilers. Wilderness science in a time of change conference—Volume 5: wilderness ecosystems, threats, and management. USDA Forest Service Rocky Mountain Research Station Proceedings RMRS-P-15-VOL-5.

Lucas, R. C. 1990. Wilderness use and users: trends and projections. Pages 355-398 *in* J. C. Hendee, G. H. Stankey, and R. C. Lucas, editors. Wilderness management. Second edition. North American Press, Golden, Colorado, USA.

Manning. R. E. 1979. Strategies for managing recreation use of national parks. Parks 4:13-15.

Manning, R. E., N. L. Ballinger, J. Marion, and J. Roggenbuck. 1996. Recreation management in natural areas: problems and practices, status and trends. Natural Areas Journal 16:142-146.

Murphy, K. A., L. H. Suring, and A. Iliff. 2004. Western Prince William Sound human use and wildlife disturbance model – assessment of current human use patterns. Pages 4-199 *in* K. A. Murphy, L. H. Suring, and A. Iliff. 2004. Western Prince William Sound human use and wildlife disturbance model, *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 99339), USDA Forest Service, Chugach National Forest, Anchorage, Alaska.

National Oceanic and Atmospheric Administration (NOAA). 2000. Sensitivity of coastal environments and wildlife to spilled oil. Prince William Sound. National Ocean Service, National Oceanic and Atmospheric Administration, Seattle, Washington, USA.

Ocean Resources Management Task Force. 1990. Oregon ocean resources management plan. Oregon Land Conservation and Development Commission, Eugene, Oregon, USA. [http://www.lcd.state.or.us/coast/offshore/otsp_3-g.pdf]

Pienkowski, M. W. 1993. The impact of tourism on coastal breeding waders in western and southern Europe: an overview. Wader Study Group Bulletin 68:92-96.

Pitcher, K. W., and D. G. Calkins. 1979. Biology of the harbor seal, *Phoca vitulina richardsi*, in the Gulf of Alaska. Pages 231-310 *in* Outer continental shelf environmental assessment program, final report of principal investigators, National Oceanic and Atmospheric Administration, Boulder, Colorado, USA.

Richardson, W. J., C. R. Greene, Jr., C. I. Malme, and D. H. Thompson. 1995. Marine mammals and noise. Academic Press, New York, New York, USA.

Tershy, B. R., D. Breese, and D. A. Croll. 1997. Human perturbations and conservation strategies for San Pedro Martir Island, Islas del Golfo de California Reserve, Mexico. Environmental Conservation 24:261-270.

Thompson, P. M. 1992. The conservation of marine mammals in Scottish waters. Proceedings of the Royal Society of Edinburgh, Section B 100:123-140.

Twardock, P., and C. Monz. 2002. Recreational kayak visitor use, distribution, and financial value of beaches in western Prince William Sound, Alaska, between 1987 and 1998. Pages 175-180 *in* D. N. Cole, S. F. McCool, W. T. Borrie, and J. O'Loughlin, compilers. Wilderness science in a time of change conference—Volume 4: Wilderness visitors, experiences, and visitor management. USDA Forest Service Rocky Mountain Research Station Proceedings RMRS-P-15-VOL-4.

U.S. Fish and Wildlife Service. 1999. Beringian seabird colony catalog – computer database. U.S. Fish and Wildlife Service, Migratory Bird Management, Anchorage, Alaska, USA.

Velarde, E., and W. Anderson. 1994. Conservation and management of seabird islands in the Gulf of California: setbacks and successes. BirdLife Conservation 1:229-243.

Wang, B., and R. E. Manning. 1999. Computer simulation modeling for recreation management: a study on carriage road use in Acadia National Park, Maine, USA. Environmental Management 23:193-203.

Wiens J. A., T. O. Crist, R. H. Day, S. M. Murphy, G. D. Hayward. 1996. Effects of the *Exxon Valdez* oil spill on marine bird communities in Prince William Sound, Alaska. Ecological Applications 6:828–841.