CHAPTER 2

RECOMMENDATIONS TO THE *EXXON VALDEZ* TRUSTEE COUNCIL

Part A: General Recommendations

In the following chapters we describe general restoration techniques and outline specific projects aimed at restoring populations of seabirds. Although the activities associated with some of these techniques address larger-scale issues, such as ecosystem dynamics (e.g., seabird-fish-fisheries interactions), the purpose of these techniques is to restore specific populations of seabirds. The workshop also addressed general issues or recommendations, not necessarily related to particular restoration techniques, but relevant to the overall approach to the restoration and recovery of seabird populations affected by the *Exxon Valdez* oil spill. The recommendations fall into two general categories, (1) policy and (2) research, and are discussed below.

POLICY RECOMMENDATIONS

1. Enlarge the oil spill impact area for seabirds beyond the immediate oil spill zone. – The *Exxon Valdez* oil spill area is currently defined as the "maximum extent of oiled shorelines, severely affected communities and their immediate human-use areas, and adjacent uplands to the watershed divide" (Trustee Council 1994b:map). Furthermore, the Trustee Council's Mission Statement Number 8 indicates that "[r]estoration activities will occur primarily within the spill area" (Trustee Council 1994b:14). The Trustee Council did make allowances for restoration work outside the spill area "when the most effective restoration actions for an injured migratory population are in part of its range outside the spill area." But they limited those activities by requiring that "the *vast majority* of restoration funds be focused on the spill area, where the *most serious injury* occurred and the *need for restoration* is greatest" (Trustee Council 1994b:14; emphasis added). The consensus of the workshop participants was that the current definition of the spill area excludes the larger geographic area in which seabird populations (as opposed to individual seabirds) were injured, and severely limits restoration options for those affected populations.

   First, the spill area appears to be defined by the extent of injury to shoreline habitat. Such a definition is most efficacious, since the presence or absence of oil on the beach is irrefutable evidence of contamination. However, from a biological perspective the definition is problematic. Although shoreline habitat is an integral and important part of coastal ecosystems, it represents only a portion of the habitat used by populations of mobile species. Individuals from populations breeding outside the oiled area may and probably do spend part of the year (e.g., migratory birds or marine mammals) or part of their life (e.g., plankton larvae of relatively sedentary marine invertebrates) within the spill zone. If sufficient numbers were present in the spill area at the time of the spill, there is a real potential that these populations experienced "serious injury."

Second, there currently are no data to support the position that the "most serious injury" to all seabird species occurred within this narrowly defined spill zone. In fact, there are no data on the geographic affinities of the seabirds killed during the spill, and to assume that seabird mortality was limited to breeding populations or colonies within the spill zone is premature. Arctic and subarctic seabirds typically undertake considerable seasonal migration. The spill occurred prior to the breeding season for all species of seabirds breeding in Alaska, and the birds occurring within the spill zone at the time of the spill may have included individuals from breeding populations outside the spill zone. Although there is considerable seasonal (Harrison 1982) and year-to-year variability, Prince William Sound and adjacent areas in the Gulf of Alaska can support significant concentrations of wintering seabirds (Gould *et al.* 1982, Piatt *et al.* 1990, Agler *et al.* 1994 and 1995b, Piatt and Anderson 1996). The origin and status of these birds are not known. At the time of the spill, pelagic and nearshore seabirds in this area could be expected to include local breeding birds, breeding birds from distant localities that had not yet returned to their breeding colonies, and nonbreeding birds from any number of localities, some within and some outside the spill area. While the relative abundance of each of these groups within the spill area is not known, because most of the central and northern Bering Sea, the Chukchi Sea, and essentially all of the Arctic Ocean are usually covered with ice in March and into April, the number of birds from populations breeding outside the spill zone may be relatively high. Significant injury to any population with individuals wintering in the spill zone is conceivable.

Third, even if all the mortality resulting from the spill occurred to colonies within the spill zone, restoration of those colonies may be facilitated by activities outside the spill zone. By requiring that most restoration projects take place within the spill zone, the Trustee Council assumes a particular demographic structure to the "populations" within the spill zone. Currently there are little or no data indicating that seabirds breeding within the spill zone are genetically isolated from those outside the zone. Moreover, based on genetic research (e.g., Birt-Friesen *et al.* 1992, Friesen *et al.* 1997) and dispersal studies elsewhere (e.g., Halley and Harris 1993, Harris and Wanless 1991), there is no reason to assume that they are. Immigration among colonies for each species may occur, and the recovery of a colony in the spill area *may* result, in part, from immigrants from colonies outside the area. Similarly, colonies inside the spill area may be important sources of immigrants for colonies outside the spill area. While there are no data suggesting that this immigration-emigration process occurs in this region, studies from other regions indicate that some seabirds regularly disperse hundreds of kilometers from their natal colony (Halley and Harris 1993, Harris and Wanless 1991, Coulson and de Mévergnies 1992). Limiting restoration activities to colonies within the spill area, and thereby assuming that these colonies are demographically and genetically isolated from colonies outside the spill area, may also limit the potential for restoring affected colonies.

In summary, the composition of the winter/spring aggregation of seabirds in Prince William Sound and the Gulf of Alaska is unknown, as are the geographic structure and demography of the breeding populations within the spill. For this reason, no evidence supports the assumption that populations breeding inside the "spill area" sustained the most serious injury or that the greatest restoration needs are in the oiled area. Limiting active restoration activities to the spill area may restrain the potential for recovery by excluding populations that may have been severely injured by the spill. We recommend that the Trustee Council increase the spill area for seabirds to include Middleton Island, all of the Alaskan Peninsula, and the Aleutian Islands.

2. Improve the process by which resources are included, reclassified, or removed from the "Injured Resources" list. – The Trustee Council, along with its scientific advisors, has established a list of species, populations, and habitats that were injured by the spill and that may be appropriate for restoration actions (Trustee Council 1994b). A species, population, community, or habitat included in this list was determined by the Trustee Council to have been injured by the spill, and to have not yet recovered. Conversely, resources reclassified from "not recovering" to "recovering" or "recovered" have been found by the Trustee Council to be recovering or recovered from the spill. With the aid of public review and comment (Trustee Council 1994a, 1994b:29-30), the Trustee Council established the criteria used to determine if a species, population, or habitat was injured early in the restoration planning process. Although the Trustee Council is correct in including sublethal effects and degradation of habitat as part of the injury criteria, the workshop participants determined that these criteria must also include data on basic population demographics, community dynamics, and ecosystem health. Furthermore, to ensure that the decision to place or decline to place a species, population, community, or habitat on the injured resources list is based on biological data, we recommend a process that is more open to scientific scrutiny and review. We acknowledge that the Trustee Council adopted this approach in 1995. We also advocate a uniform policy for determining injury to any resource, noting, however, that injury determination for seabirds may require a different set of criteria than those for fish or shoreline habitats. We recommend that the Trustee Council implement the criteria that we discuss in Chapter 4 to determine which seabird species/populations sustained significant injury from any oil spill and should be the focus for restoration activities.

3. Register new toxicants. – The control or eradication of introduced exotic predators or competitors is a proven and most effective method of restoring local populations of seabirds. However, the implementation of eradication programs may be hampered by federal restrictions on the use of certain toxicants on federal land. We recommend that the relevant trustee agencies (e.g., Department of Interior) first determine what toxicants are most effective at controlling or eradicating target species without having secondary or residual negative effects to the ecosystem, and then determine if it is legal to use such toxicants on federal or state land. If it is not, we recommend that the Trustee Council take steps to register those toxicants for use on federal land, permitting their use as a means of control of predators and competitors.

RESEARCH RECOMMENDATIONS

In determining which *species* of seabirds were injured as a direct result of the *Exxon Valdez* oil spill, and which species are priority candidates for restoration, the Trustee Council has made assumptions about which *populations* were injured, as well as additional assumptions about the demographic structure of the injured populations. Likewise, in recommending specific restoration projects aimed at restoring these populations, we have made similar assumptions about the populations, as well as assumptions about the structure and functions of the community or ecosystem to which these populations belong. Ultimately, we concluded that to realistically determine which assumptions and restoration options, if any, are appropriate for a particular population, information is needed to determine how that population was affected by the spill, and how particular restoration options will affect that population. We recommend that research be conducted to help to (1) delineate the geographic and demographic structures of populations, (2) determine which populations were affected by the spill, (3) estimate the probability of natural recovery through dispersal or recruitment, and (4) understand community and ecosystem effects that may help or hinder recovery. Most participants agreed that a mechanism to fund this research could be the endowment of chairs in marine ornithology at the University of Alaska, which would serve as a long-term catalyst to conduct the research projects that we have identified.

1. Collect population demographic information. – In Chapter 3, we define populations and outline why it is important to determine the geographic boundaries and understand the demographic parameters of populations. In particular, the recovery of a seabird colony following a natural or anthropogenic disturbance will depend, in part, on the geographic and demographic structure of that colony's population. Small, isolated populations with low rates of immigration will recover more slowly than populations that are part of a larger metapopulation or that have higher rates of immigration or gene flow. There is little or no dispersal among genetically isolated colonies or subpopulations, and recovery following disturbance must be through local recruitment. Dispersal among colonies that are part of a larger population or metapopulation should be relatively high, and natural recovery following a disturbance should be relatively rapid due to the influx of immigrants.

Knowledge of the rates and distance of immigration and genetic structure of these colonies or populations would allow for a better assessment of whether active hands-on restoration is needed and, if so, what types of restoration are best prescribed. Natural recovery through immigration or high local production would indicate that no active hands-on restoration other than monitoring is needed. Furthermore, demographic analyses of populations (including genetic analyses as well as data on dispersal gathered mainly through banding efforts and annual measures of colony growth) may point to a colony or geographic region on which to concentrate restoration efforts (e.g., identification of "source" populations) or may help set restoration goals (see Chapter 3 for further discussion of seabird populations, and Chapter 6 for restoration goals).

Studies on the genetic or morphometric structure of seabird populations may identify population markers (e.g., DNA sequences or unique relative proportions of skeletal elements) that would make it possible to identify the origin of individuals killed by oils spills. Finally, complete demographic analyses would include collecting data on the age-structure of a population (estimated through banding returns), survival of birds from all age classes, age at first breeding, and reproductive success. In order to collect most of these data, birds must be banded and permanent study sites established. These data are essential to adequately model populations so that the relative effects of different restoration options can be evaluated.

We recommend that the Trustee Council fund research on (1) the genetic and morphometric structure of seabird colonies in Prince William Sound, the Gulf of Alaska, and the Aleutian Islands, (2) population structure at representative colonies (these studies should include the banding of chicks for individual and cohort identification and the collecting of reproductive success data), and (3) modeling of the populations to help predict if natural recovery is possible, or to assess the utility of particular restoration techniques (see Chapter 11 for discussion of population models). These demographic studies should be conducted on the seabird species determined by the Trustee Council to be not recovering[1].

2. Analyze carcasses for population information. – Wiens and Parker (1995) and Wiens (1995) review methods by which oil spill impacts can be measured with some statistical rigor. Each method is based on determining statistically significant differences between affected sites and reference or control sites. In some methods, reference "sites" are the affected sites prior to the spill (i.e., baseline studies), while in others, reference sites are single or replicated sites not in the affected area, or series of sites with a gradient of effects—from no disturbance to heavily oiled. The Trustee Council also measured injury or impact by comparing prespill and postspill numbers and trends. The methods prescribed by Wiens, and Wiens and Parker, and the Trustee Council assume that the affected populations were in the oil spill area. In other words, comparing pre- and postspill data, or affected versus unaffected sites for seabird colonies within the oil spill area (see also Erikson 1995), assumes that the mortality associated with the spill is restricted to the oil spill area. We have argued above that this assumption may be incorrect and the assessment premature.

The only existing direct evidence for seabird mortality associated with *Exxon Valdez* oil spill is the oiled carcasses salvaged from beaches within the oil spill area. The majority of these carcasses have been destroyed. However, representative samples have been obtained by a few museums in North America, principally the Burke Museum, University of Washington. If populations or subpopulations of the seabirds nesting in Prince William Sound, the Gulf of Alaska, or the Aleutian Islands differ genetically and/or morphometrically (see above), it may be possible to identify what populations or subpopulations were injured by the spill (see Anker-Nilssen *et al.* 1988 and Warheit 1996 for analyses associated with the 1981 Skagerrak and the 1991 *Tenyo Maru* oil spills, respectively). By analyzing these remaining carcasses, not only will the Trustee Council have a more concrete basis by which to determine *what* populations may have been affected by the oil spill, it will also be able to estimate *how* these

[1] At the time of the workshop, the common murre, pigeon guillemot, marbled murrelet, and harlequin duck were the species of birds listed by the *Exxon Valdez* Trustee Council to be not recovering. In spring 1996, the Trustee Council moved the common murre to the "recovering" list, but added Kittlitz's murrelet, common loon, and double-crested, pelagic, and red-faced cormorants to the "not recovering" list.

populations were affected and *where* to target restoration projects. We recommend that the remaining carcasses (especially those of the common murre, pigeon guillemot, marbled murrelet, Kittlitz's murrelet, and pelagic cormorant) be analyzed for morphometric and genetic population markers (see above) to help determine their source populations. Furthermore, the age class (i.e., juvenile, subadult, adult) and sex of each carcass should be ascertained to help determine the demographic impacts of the injury.

3. Examine trophic interactions, impacts of net fisheries, and community structure. – Although we consider managing seabird food to be a potentially viable restoration option (see Chapter 9), there is a lack of data on trophic interactions and food availability for seabirds in the EVOS area, and on how altering such interactions and availability might enhance seabird populations. The underlying assumption in "enhancing food" as a restoration option is that the current population size for some or all of the seabird species of interest to the Trustee Council is limited by the abundance and availability of prey (see Chapters 9, 12, and 13; Piatt and Anderson 1996). One potential method of enhancing the food supply of seabirds is to reduce competition by altering commercial fishery and/or fish hatchery activities (see Chapter 9 for details). If food availability is limiting recovery, the production or maintenance of trophic competition through hatchery and fishery practices could significantly affect the ability of seabird populations to increase. Little is known about the relationships among seabird consumption of prey, fishery catch of seabird prey, and the production of salmon in local hatcheries.

Not only do humans act as competitors with seabirds for a limited food supply (i.e., direct competition through fishing and indirect competition through the production of direct competitors such as hatchery-reared salmon), they also act as predators on seabirds. Although the entanglement of seabirds in fishing nets is unintentional, its effects on seabird populations can be profound (see Chapter 9c and references therein). Much more must be learned about entanglement of seabirds in the net fisheries in Prince William Sound. We recommend that the Trustee Council provide funds to examine how modifications to the activities of fisheries (including net fisheries) and hatcheries may enhance seabird populations by increasing their food supplies, or by decreasing mortality as a result of gillnet bycatch.

In addition to those anthropogenic activities that may alter the availability of food to seabirds, natural competitors may also affect this availability and foraging success. For example, one of the goals of the EVOS restoration plan is to restore the sea otter populations in Prince William Sound. Although this goal is worthy, a growing sea otter population may affect the food availability and foraging success of local pigeon guillemots and marbled murrelets, owing to the altered subtidal and intertidal habitats that may result from otter restoration (see Chapter 12 for details on how community factors may affect restoration). Little is known on the nearshore community structure in Prince William Sound, and if interspecific competition for food resources is high, the restoration of one species (e.g., sea otters) may compromise he restoration of other species (e.g., guillemots and murrelets). We recommend that the Trustee Council continue to fund research on the nearshore community structure and food availability (e.g., the Alaska Predator Ecosystem Experiment and Nearshore Vertebrate Predator projects).

4. Examine sources or causes of predation at marbled murrelet nests. – Later in this chapter we describe restoration options for marbled murrelets. Although reducing habitat loss either by altering forest practices or by preserving or purchasing land is singularly the most effective option for preventing further declines in marbled murrelet populations, small-scale activities, such as reducing human disturbance at campsites, may be effective in increasing marbled murrelet populations. Human disturbance at campsites (e.g., accumulation of trash) may attract corvids (crows, ravens, jays, and magpies) to the local area. Corvids are chick and egg predators of marbled murrelets, and human activity near marbled murrelet nest sites may increase corvid predation on nest contents (Singer *et al.* 1991). We recommend that the Trustee Council fund projects to determine if corvid predation associated with human activities decreases marbled murrelet reproductive success, and if such human disturbance can be controlled.

5. Develop resource sensitivity maps. – One of the concerns of those in charge after a disaster is to ensure that every effort is made to prevent any further accidents that could worsen the situation. Another oil spill in the EVOS area could set back the recovery of some or all of the resources injured by EVOS and could complicate or even negate all the restoration efforts implemented so far. Therefore, there is a need for a system to rank the seabird use (and the use by other resources) of different waters of Alaska according to their vulnerability to environmental hazards (see King and Sanger 1979, Carter *et al.* 1993, Williams *et al.* 1995). Oil vulnerability maps for the EVOS area could be used to delineate shipping routes, assign fishing areas, design oil managing facilities, deploy booms, allocate skimmers, and conduct all the other actions that would protect critical seabird areas from injury associated with another oil spill.

In the early to mid-1980s, the National Oceanic and Atmospheric Administration (NOAA) produced environmental sensitivity index atlases for many of the regions that later were affected by EVOS (e.g., RPI 1983). These indices ranked shorelines in terms of their vulnerability to detrimental effects associated with toxic substance spills, including oil, and incorporated both the physical and biological features of shoreline habitats. In 1978, the U.S. Fish and Wildlife Service (USFWS) published an Alaska seabird catalog (Sowls *et al.* 1978), which is periodically updated and maintained in a USFWS database. However, these indices, catalogs, and maps (as well as other databases) need to be revised *and integrated* before they can serve as an easily usable product that would help protect critical seabird areas (or other resources) from further injury. For this reasons we recommend that the Trustee Council provide funds to update, integrate, and publish new versions of the environmental sensitivity index atlases that include seabird breeding and at-sea areas.

6. Monitor all restoration activities. – The only way to determine if a population is naturally recovering or if restoration is required is to monitor the population under consideration and,

in some cases, reference or control[2] populations. In Chapter 7 we outline the monitoring activities that should be implemented as part of a restoration plan. We note here that these monitoring activities are an essential part of the plan and should be emphasized.

7. Fund multi-year projects. – Single-year funding cycles make it difficult to plan and implement cost-effective and scientifically justifiable projects. The workshop recommends that projects be funded on a multi-year basis whenever possible.

Part B: Species-Specific Recommendations

INTRODUCTION

In the following chapters we describe specific restoration techniques and identify their assumptions, advantages, and deficiencies. We also discuss seabird restoration in an ecosystem context and demonstrate how the recovery of seabirds following a perturbation, such as an oil spill, may be enhanced or hampered by large-scale effects. This information is provided (1) to describe what types of restoration activities are available to the Trustee Council, (2) to describe what particular restoration techniques would be favored in Alaska, and (3) to consider community and ecosystem functions when designing a restoration plan. It is in this larger ecosystem framework that the recovery of seabird populations occurs and within which we evaluate particular restoration techniques for common murres, marbled murrelets, and pigeon guillemots (this workshop did not completely address harlequin ducks) in Prince William Sound, the Gulf of Alaska, and the Aleutian Islands.

For each restoration technique we judged the probability of success for a particular species based on the goals of the technique, the current status of that species in Alaska, and the species' life history. We then ranked the restoration techniques using a four-part scale ranging from "do not consider" (= 0) to "best probability of success—should be applied" (= 3) (Table 1).

Comparison of Techniques Among Species

Based on the distribution of scores shown in Table 1, there are more viable restoration options available (techniques receiving scores of either 2 or 3) for common murres than for either pigeon guillemots or marbled murrelets. Discounting restoration techniques Numbers 3 and 5 (see Table 1), the modal and median scores for common murres, pigeon guillemots, and marbled murrelets are 2, 1, and 0, respectively. In other words, more than half the restoration techniques listed in Table 1 (discounting Numbers 3 and 5) can be applied to common murre populations, while most of the techniques are of little use in restoring marbled murrelet populations.

[2] Restoration activities should be funded only when the restoration plan incorporates appropriate controls or reliable baseline data, so that the success of the restoration can be measured.

With the exception of the techniques that reduce fisheries bycatch and colony disturbance, restoration options that show a relatively high probability of success for common murres also show a high probability of success for pigeon guillemots. There is very little correspondence between these two species and marbled murrelets. The general restoration category that shows the most agreement among these three species is Management of Seabird Habitat. However, even within this "family" of techniques the species differ in that restoration for marbled murrelets should focus on the protection of large tracts of land, while pigeon guillemot restoration should be focused at a smaller spatial scale; even enhancing individual nest sites offers a high probability of success. Common murres may benefit from restoration aimed at either small or large spatial scales, from establishing habitat preserves to protecting nest sites.

Categories of Restoration Techniques That Offer the Highest Probability of Success

Among all the restoration techniques described in Chapter 9, and listed in Tables 1 and 2, the categories that offer the highest probability of success are designed to reduce both the direct and indirect effects of *human disturbance*, rather than to directly manipulate seabird population demographics. In addition, techniques that *reduce mortality of adult birds* show the greatest promise in increasing the rate of growth of a disturbed colony (see also discussion of models in Chapter 11). Two restoration techniques stand out in this regard. First, the removal of introduced exotic predators from seabird colonies (an indirect or lingering form of human disturbance) and the prevention of their introduction or reintroduction are perhaps the techniques with the longest history and highest overall probability of success (see Chapter 9 and references therein). Second, reducing the number of seabirds inadvertently killed in net fisheries (direct disturbance, akin to predation) should have a substantial positive effect on common murre and marbled murrelet populations by increasing the survival of birds in all age classes. *These are broad-based techniques that benefit a suite of species. The removal of introduced exotic species from islands has the potential to restore an entire ecosystem, not just one species of seabird, while the effective management of net fisheries bycatch will benefit all species that are inadvertently taken in fishing nets.*

Categories of Restoration Techniques That Offer the Lowest Probability of Success

The addition of birds to wild populations through captive rearing, translocation, and rehabilitation offers the lowest probability of success of all restoration techniques considered in this workshop, owing to a variety of problems (Table 2). Among the major shortcomings of these techniques are that they are extremely labor intensive, there is a relatively high risk of failure or low level of success, and they are expensive. Furthermore, these techniques are most appropriate when whole colonies have been extirpated or when populations are close to extinction (see Table 2 and Chapter 9 for discussion). Options that involve reduction of human interactions with the resource (Table 2: Management of Human Impacts) may be problematic because they involve alteration of lifestyles, and may therefore receive political or public opposition. Some of these options may pit jobs against the resource.

TABLE 1. RANKING[1] OF POTENTIAL RESTORATION TECHNIQUES FOR COMMON MURRE, PIGEON GUILLEMOT, MARBLED MURRELET, AND HARLEQUIN DUCK POPULATIONS AFFECTED BY THE *EXXON VALDEZ* OIL SPILL

RESTORATION TECHNIQUE	COMU	PIGU	MAMU	HADU[2]
1. Management of Predators and Herbivores	**3***	**3**	**1+**	**3**
a) Remove introduced exotics*	3	3*	0	?
b) Remove indigenous species	2	3?	0	?
c) Manage indigenous species	2	3	1	?
2. Management of Human Impacts	**2**	**1**	**3**	**3**
a) Reduce fisheries bycatch	3	1	2+	?
b) Reduce habitat loss	0	0	3	3
c) Reduce colony disturbance	3	0	0	?
d) Reduce at-sea disturbance	1	1	1	1
e) Prevent predator introduction	3	3	0	3*
f) Minimize marine pollution	?	?	?	?
g) Reduce subsistence harvest	0	0	0	1
3. Management of Food	**?**	**?**	**?**	**?**
a) Manage fisheries	?	?	?	?
i) Salmon hatcheries	?	?	?	?
ii) Pollock harvest	?	?	?	?
iii) Herring harvest	?	?	?	?
b) Enhance nearshore habitat	?	?	?	?
i) Sand lance spawning	?	?	?	?
ii) Blennies/sculpins	?	?	?	?
4. Management of Seabird Habitat	**2**	**2**	**3**	**3**
a) Preserve habitat or purchase land	2	1	3	3
b) Improve nest sites	2*	3	0	0
c) Deploy social attractants	2*	1	0	0
d) Reduce predator/competitor interactions	1 (gulls)	1 (puffins)	0	0
e) Create habitat	0	1	0	0
5. Supplement Wild Populations	**0**	**0**	**0**	**1**
a) Release captive-raised juvenile birds	0	0	0	1
b) Translocate juvenile birds	0	0	0	0
c) Rehabilitate injured birds	0	0	0	0

[1] = 0: Do not consider. 1: Likely not to succeed. 2: Appropriate for feasibility studies; moderate level of success. 3: **Best probability of success; should be applied.**

[2] = Workshop did not adequately address harlequin ducks.

* = Outside official "spill area."

TABLE 2. POTENTIAL OR ACTUAL DEFICIENCIES OF SEABIRD RESTORATION TECHNIQUES

	High Financial Costs	Excessive or Extended Logistics or Labor	Enforcement Required	Stakeholder Resistance	Potential Public or Political Opposition	Potential Injury to Source Population	Other
MANAGEMENT OF PREDATORS AND HERBIVORES							
Control predators and herbivores		●			●		Potential for injury to nontarget species
MANAGEMENT OF HUMAN IMPACTS							
Reduce fisheries bycatch	●		●	●	●		Untested techniques
Reduce habitat loss				●			
Reduce disturbance	●		●	●	●		
Reduce predator introductions	●		●				
Reduce chronic pollution			●				Difficult to monitor
Reduce harvest by humans			●		●		
Reduce aquaculture conflicts				●	●		
MANAGEMENT OF FOOD							
Manipulate fisheries, hatcheries, or habitats	●			●		●	Uncertain outcome
MANAGEMENT OF SEABIRD HABITAT							
Acquire habitat preserves or corridors	●				●		Hard to find tracts of land
Create or enhance nest sites		●			●		
Deploy social attractants		●				●	New method
Reduce competitive interactions	●	●					
SUPPLEMENT WILD POPULATIONS							
Release captive-raised juvenile birds	●	●	●				High chance of failure
Translocate juvenile birds	●	●	●			●	High chance of failure
Rehabilitate injured birds	●	●				●	Low returns for effort
NATURAL RECOVERY							
Allow unassisted recovery to occur					●		Potentially of long duration

Enhancing Food

We have proposed several restoration techniques that involve the enhancement of the prey base for seabirds. These techniques are divided into two categories: (1) fisheries management and (2) nearshore habitat enhancement (Tables 1, 2). Enhancing food through altering fisheries practices or improving nearshore forage fish spawning habitat may be very useful; however, not much is known about how these techniques may be implemented or what effect they will have on seabird populations. For example, will further attempts to enhance salmon production in Prince William Sound, which is already at an all-time high level (Francis and Hare 1994), have a detrimental effect on other marine vertebrates, including seabirds, that compete with salmon for forage fish resources? Unfortunately, little research has been done to assess the impacts of large-scale salmon enhancement projects on local marine ecosystems. Conversely, would encouraging a larger harvest of pollock in Prince William Sound have a beneficial effect on seabirds and other marine predators and enhance their recovery? Links between environmental change, pollock abundance, and fisheries and stocks of forage fish have been examined in some detail (e.g., Laevastu 1984, Springer 1992), but a link to seabird populations is missing. As a result, we scored all food enhancement techniques as question marks; but we do consider these techniques promising and recommend that research be conducted to determine not only their feasibility but also their potential effects.

In the following sections, we discuss in detail our recommended restoration techniques for marbled murrelets, common murres, and pigeon guillemots, and provide restoration suggestions for Kittlitz's murrelets, common loons, and double-crested, pelagic, and red-faced cormorants.

Part C: Recommended Marbled Murrelet Restoration Techniques

INTRODUCTION

Most of the world's population of marbled murrelets breeds in Alaska (Mendenhall 1992, Ralph *et al.* 1995), and some of the highest nesting densities of murrelets occur in the area affected by the *Exxon Valdez* oil spill (Piatt and Ford 1993). An estimated 8,400 murrelets were killed by the spill, possibly 7% of the total summer population in the spill area (Kuletz 1996). Marbled murrelets spend most of their lives at sea but breed inland in old-growth forest. Attempts to restore or conserve murrelet populations require that we consider both terrestrial and marine aspects of their biology. Marbled murrelets are widely dispersed and loosely colonial, and concentrations may occur at forested breeding locations and at sea. Their nesting behavior is secretive, except for vocalizations, and their nests are typically widely dispersed and concealed (review in Ralph *et al.* 1995). All these factors make it difficult to census breeding populations or obtain the demographic information needed to develop a restoration plan.

In California, Oregon, and Washington, where the marbled murrelet is listed as threatened under the Endangered Species Act, loss of old-growth forest nesting habitat is considered the primary cause of the population decline (Stein and Miller 1992). Recovery plans in these states have emphasized the protection of nesting habitats. Similarly, habitat preservation has been the main approach to murrelet restoration following the *Exxon Valdez* oil sp although this acts to prevent further injury due to loss of habitat rather than restore the populations. This approach also provides habitat protection for other species.

Following the *Exxon Valdez* oil spill, the first step in murrelet restoration was to identify the characteristics of the birds' nesting habitat, because historical data suggested that it differed from habitats used in southern regions. Prior to 1989, only one tree nest had been discovered in southeast Alaska (Quinlan and Hughes 1990), and six ground nests had been located in south-central and southwest Alaska (Day *et al.* 1983). Between 1991 and 1993, studies funded by the Trustee Council led to the discovery of 22 murrelet nests and the characterization of nesting habitats.

Reducing human impacts on murrelets, in both the terrestrial and marine environments, is likely the best approach to restore murrelet populations (Table 3). On land we can protect large tracts of nesting habitat and, on a smaller scale, minimize the effects of artificially enhanced predator populations. In nearshore habitats, important foraging areas or habitats vital to prey can be protected, and gillnet bycatch of murrelets can be reduced or eliminated by modifying net characteristics or fishing seasons (e.g., Melvin and Conquest 1996). In this section we discuss primary restoration options, consider less viable options, and discuss the benefits of monitoring programs.

TABLE 3. RECOMMENDATIONS FOR RESTORATION OF MARBLED MURRELET POPULATIONS

Primary	*Protect Nesting Habitat:*
	1. Acquire and protect prime nesting habitat as suggested by habitat studies.
	2. Establish habitat database on a geographic information system, and contribute murrelet data.
	3. Survey potential lands available for purchase and rank their value to murrelets.
	4. Continue research on use of marine habitat and relationship to terrestrial habitat.
	5. Change management and logging practices to minimize impact to murrelets.
	Reduce Mortality:
	6. Reduce nest predation by reducing human-caused increase in predators.
	7. Institute active predator control in problem areas.
	8. Evaluate scope of gillnet mortality and factors influencing bycatch.
Secondary	9. Evaluate human disturbance at critical marine areas and reduce if necessary.
	10. Implement efforts to conserve or increase food resources.
	11. Continue to research methods that may increase survival of rehabilitated birds.
	12. Develop procedures to more effectively aid recovery of injured juvenile birds.

TABLE 3. CONTINUED

Monitoring	13. Monitor populations during summer and winter. 14. Monitor productivity using at-sea surveys during fledging period. 15. Monitor inland activity to gauge relative breeding attempts. 16. Monitor annual mortality: bycatch data, beach census, investigation of events. 17. Maintain database on birds collected, trapped and released, or rehabilitated.

PRIMARY RECOMMENDATIONS

Protect Nesting Habitat

Because murrelet nesting density increases with forest stand size (Paton and Ralph 1990, Marks *et al.* 1995, Raphael *et al.* 1995) and is highest in major watersheds (Miller and Ralph 1995), conservation of large tracts of suitable habitat is perhaps the most significant method for conserving murrelet populations in Alaska. Current knowledge suggests that prime habitats within the spill zone are composed of old-growth forests with the largest trees in the region, including lands around the heads of bays, and with slopes protected from prevailing summer winds (Kuletz *et al.* 1995a, 1995c; Naslund *et al.* 1995). Although most nests found adjacent to the spill zone were less than 1 kilometer from the ocean, two ground nests were 2 and 6 kilometers inland (Kuletz *et al.* 1995b), and suitable forest habitat exists farther inland along river valleys. The best predictors of murrelet occupation include tree-branch size, potential number of nesting platforms per tree, and epiphyte cover (Kuletz *et al.* 1995a, 1995c; Naslund *et al.* 1995, Hamer 1995).

There are few data that allow us to assess the amount of land needed to preserve a given number of murrelet nests. Nesting density may vary in different habitats or with proximity to prime marine habitats. There is evidence that marbled murrelets are loosely colonial. At Naked Island, Prince William Sound, 7 to 12 pairs of murrelets used a 17.5-hectare stand, and 2 to 3 pairs used a nearby 3 to 6-hectare stand (Naslund *et al.* 1995). Thus, densities ranged from 0.4 to 0.8 pairs per hectare of suitable forest. In one fjord, three radio-tagged birds were nesting in trees less than 1 kilometer from each other at the head of a small bay. In contrast, three ground-nesting birds were separated by 6 to 12 kilometers in different drainages of the main fjord (Kuletz *et al.* 1995b).

Highly fragmented forest may create an "edge effect," resulting in reduced murrelet nesting success due to predation, adverse weather, and tree blowdowns (review in Ralph *et al.* 1995). Conversely, Raphael *et al.* (1995) found that forest patches with more complex edges had higher murrelet activity. However, long, narrow buffer strips along streams or shoreline may not be suitable (Kuletz *et al.* 1995a, Marks *et al.* 1995). Forests of lower quality may provide adequate buffer around high-quality forest patches (Kuletz *et al.* 1995a).

Suitable land parcels should be evaluated for murrelet activity by conducting dawn surveys, and their relative value should be ranked in terms of murrelet occupation. This would assure that the parcels being considered for purchase are valuable to murrelets. If the potential parcels are too extensive, dispersed, or inaccessible to survey, as is often true in the *Exxon Valdez* spill zone, then habitat-use techniques can predict where optimal nesting habitat may occur.

The best habitat-use studies employ geographic information system databases that incorporate vegetation and landform features. The results of murrelet dawn surveys, which measure nesting activity of murrelets, can then be overlaid with habitat data to ascertain optimal nesting habitat. In the *Exxon Valdez* spill zone, nesting habitat studies for murrelets have compared U.S. Forest Service timber-type databases and on-site measurements to murrelet dawn activity (Kuletz *et al.* 1995a, 1995c; Marks *et al.* 1995). Similar results have been derived in other regions through the use of geographic information system landscape-level databases (Raphael *et al.* 1995) and forest vegetation databases (Grenier and Nelson 1995, Burger 1995). With the geographic information system it is also possible to incorporate the habitat requirements of other species into land purchase decisions. For example, harlequin ducks may nest in valleys that are also important to marbled murrelets.

Murrelet nesting habitat may also be defined by a combination of terrestrial and marine features. In 1993 and 1994, radio-tagged murrelets in Prince William Sound foraged an average of 20 kilometers from their nests (Burns *et al.* 1994, Kuletz *et al.* 1995b), suggesting that good foraging areas are relatively close to nest sites. Murrelets in Prince William Sound and elsewhere can forage up to 120 kilometers (75 miles) from nests if necessary (Kuletz *et al.* 1995b, Hamer and Nelson 1995). Hypothetically, marginal nesting habitat near predictable foraging "hot spots" may be preferred over "optimum" forests far removed from good foraging area. In general, little is known about the relationship between murrelet foraging behavior and nesting habitat selection in Alaska. Further research in this area would be useful.

Finally, public and private lands can be managed to minimize the disturbance to nesting areas and reduce the concentration of predators. We recommend the following forestry practices:

1. Increase the width of buffers along streams and shoreline.
2. Practice selective cutting and, where possible, removal by helicopter. Selective cutting ensures that some older trees will remain available for murrelet nesting.
3. Leave a percentage of large trees during selective cutting, particularly those with large numbers of "platforms" or branches with large moss patches. Older trees with substantial core-rot can be valuable as nest trees.
4. Leave buffers of lower-quality forests around prime nest trees.
5. Minimize the creation of roads that eliminate nest trees and create more edges through and around the stands.
6. Use harvest methods that minimize the spread of disease-carrying insects such as the bark-beetle.

Reduce Mortality

Reduce predation

The breeding plumage and behavior of murrelets appear to be adaptations that minimize predation, but murrelets still experience high losses of eggs, young, and even adults at the small number of nests that have been discovered (Nelson and Hamer 1995). Adult murrelets may be taken at the nest, or in transit to or from the nest, by sharp-shinned hawks (Marks and Naslund 1994) or peregrine falcons (J. Hughes, Alaska Department of Fish and Game, pers. com.). Bald eagles may attack murrelets at sea (K. Kuletz, pers. obs.) and have been observed feeding on murrelet carcasses, but whether they scavenged or killed the birds was uncertain (Burns *et al.* 1994, Kuletz *et al.* 1995b).

Of 32 murrelet nests with known outcomes, 43% were lost to predation (Nelson and Hamer 1995). The most common predators on eggs or chicks are corvids, such as Steller's jays, magpies, northwestern crows, and common ravens. These predators tend to concentrate and expand their population around human habitation. To minimize predation, human trash should be controlled at cleanup sites (in the case of oil spills), campsites, permanent shelters, villages, and coastal towns. The public should also be educated about proper disposal of food waste and discouraged from hand-feeding all predatory species.

Squirrels and small mustelids may also be nest predators (Marzluff *et al.* 1995). As with corvids, squirrels are attracted to human habitation and are best controlled by minimizing human activities that draw them. If concentrations of predators become unmanageable, we recommend predator extermination or translocation in especially important murrelet nesting areas.

Reduce gillnet bycatch

The loss of adults due to natural annual mortality or gillnet bycatch is of much greater consequence to the population than is the loss of juveniles (Beissinger 1995). Murrelets are susceptible to gillnet mortality for several reasons. They forage by diving underwater and usually feed less than 1 kilometer from shore. Both behaviors bring them into contact with salmon gillnets. In addition, murrelets frequently feed in low light conditions, when it may be difficult to see and avoid gillnets. Finally, oceanographic conditions that concentrate commercial fish also attract the forage fish on which murrelets feed, thus increasing encounter rates with gillnets (Carter and Sealy 1984).

Little is known about the importance of gillnet mortality to the Alaska murrelet population, but it is known that elsewhere murrelets are caught in all continental shelf areas with many types of gear (Carter *et al.* 1995). Murrelets were the seabird most commonly caught in salmon gillnets during a bycatch study conducted in Prince William Sound in 1990 and 1991, with an estimated 1,231 and 298 murrelets killed in those years, respectively (Wynne *et al.* 1991, 1992). Extrapolating to other areas of Alaska, Piatt and Naslund (1995) estimated that as many as 3,300 murrelets die annually in Alaska gillnets. This is almost half of the minimum estimated mortality from the *Exxon Valdez* oil spill, and may represent a significant proportion of total adult mortality for this population.

A comprehensive survey of seabird bycatch in gillnets, including set nets, should be conducted to determine which areas have the highest mortality and which factors contribute to high mortality rates (see also Wynne *et al.* 1991, 1992). In British Columbia, murrelet bycatch was found to be highest at night (Carter and Sealy 1984), and commercial fisherman Pete Isleib reported a similar pattern in Prince William Sound (Carter *et al.* 1995). If murrelet bycatch is concentrated temporally or spatially, it may be possible to restrict fishing activity with minimal impact on commercial fisheries. Additionally, experiments could be conducted with different types of fishing gear to determine which gear minimizes seabird bycatch (see Melvin and Conquest 1996 for experiments in Puget Sound, Washington).

SECONDARY RESTORATION TECHNIQUES

The following restoration techniques may be difficult to implement, but are included here to indicate potential options that may become feasible as our knowledge of murrelets and the ecosystem improves or as our ability to manipulate survival of the species increases.

Reduce Human Disturbance

Boat traffic may keep murrelets from critical foraging areas (Kuletz 1996). During the breeding season, limiting boat traffic in key feeding areas may benefit murrelets. Studies should be done to determine if murrelets habituate to some levels or types of traffic. Additionally, low-level pollution associated with boat traffic, particularly small oil and diesel discharges, could be causing habitat degradation or direct mortality. Chronic pollution may directly reduce use of a foraging area if the birds avoid oil, or it can harm birds that ingest oil or suffer reduced insulation from light oiling. Indirectly, pollution can affect murrelets by altering the abundance or distribution of prey. Many of the species on which murrelets depend are intertidal spawners and/or sediment dwellers during periods of their diel cycle (i.e., sand lance). These species are highly susceptible to nearshore pollution (Trasky *et al.* 1977).

Increase Food Resources

Diet studies of marbled murrelets in Prince William Sound (Oakley and Kuletz 1979, Kuletz *et al.* 1996b), like those of pigeon guillemots (Hayes 1996, Hayes and Kuletz 1996), suggest that the prey base has changed since the 1970s. Murrelets' consumption of sand lance, in particular, has decreased as their consumption of gadid species (e.g., pollock, cod) has increased. Because sand lance has been associated with high reproductive success for seabirds (Harris and Hislop 1978, Vermeer 1979, Monaghan *et al.* 1989a, 1989b), murrelets may benefit from increased sand lance availability. The spawning areas and habitat requirements for species like sand lance and capelin are not well known, but should be identified and protected to assure a healthy prey base for all seabirds.

Although ecosystem changes may be responsible for changes in the prey base (Hollowed and Wooster 1995, Piatt and Anderson 1996), studies of key prey such as sand lance and capelin may identify management practices or coastal planning strategies that enhance forage fish abundance. Juvenile clupeids (e.g., herring) and gadid species may also be important in the murrelet diet (Carter 1984, Sealy 1975, Krasnow and Sanger 1986, Sanger 1987); juvenile salmon may be significant as well (Carter and Sealy 1986). These commercial fish species are already a focus of studies funded by the Trustee Council. Because the apparent decline in certain forage fish species was concurrent with the introduction of salmon hatcheries into Prince William Sound, research could examine the effects of hatchery-reared fish on native forage fish abundance.

Currently, hatcheries may provide a temporary and limited resource to murrelets. In 1994, several radio-tagged birds visited the Main Bay hatchery (Kuletz *et al.* 1995b). In 1995, D. Scheel (pers. com.) noted that the number of murrelets at a hatchery increased for four days after release of salmon smolt. Although hatcheries are probably of minimal benefit to murrelets, these observations suggest they may provide a short-term supplement to the murrelet diet.

Rehabilitation

Capture and rehabilitation of oiled murrelets appears to be of little value in enhancing the viability of marbled murrelet populations. In 1989 a relatively small proportion of murrelets were brought to rehabilitation centers (less than 3% of all birds rescued during EVOS), and few birds survived. Only 3 of 33 marbled murrelets (9%) survived (M. Wood, International Bird Rescue, unpubl. data), compared to 51% of the 1,630 birds treated (Wood and Heaphy 1991). However, International Bird Rescue (Berkeley, California) continues to research techniques that would improve the survival rates of small alcids.

The rehabilitation of murrelets under other conditions could be encouraged through public outreach and education. Although oiled adults are not currently good candidates for rehabilitation, temporarily stunned adults, as well as chicks and newly fledged juveniles, have survived to be released. Adults found on the forest floor following unknown injury or downing of their nest tree have been treated and released (G. van Vliet, Alaska Department of Fish and Game, pers. com.; K. Sundet, Alaska Department of Fish and Game, pers. com.). Downy chicks that have fallen from nests and completely feathered juveniles that have not reached the ocean also have been successfully reared and released (Anchorage Bird Treatment and Learning Center, unpubl. data). A secondary benefit from these events has been community involvement and education about this little-known seabird.

MONITORING ACTIVITIES

Estimate Population Trends

It is not practical by conventional means to directly monitor the breeding population of murrelets because they are not colonial, and their nests are difficult to locate. However, their at-sea populations can be monitored using standard USFWS survey protocols (Klosiewski and Laing 1994, Agler *et al.* 1994). Because murrelets are widely distributed, population estimates can be calculated with relatively narrow confidence intervals, making them good candidates for monitoring population trends at sea (Klosiewski and Laing 1994).

Monitor Murrelet Productivity at Sea

Productivity should be monitored to enable natural resource trustees to respond quickly to a negative trend in the murrelet population. Little is known about the demography of marbled murrelets, but based on their body size, their single-egg clutch, and information extrapolated from other alcids, they probably depend on high adult survival to offset their low reproductive potential (Beissinger 1995).

Because it is not financially practical to measure the reproductive success of large numbers of murrelet nests, a productivity index has been developed (Ralph and Long 1995, Strong *et al.* 1995, Kuletz *et al.* 1996a). This method relies on the ratio of adults to juveniles counted at sea during the fledging period. In south-central Alaska, surveys for juvenile birds can be conducted from late July through August. This period does not coincide with that currently used for the Prince William Sound population surveys and will require a separate effort. Baseline adult-to-juvenile ratios should be obtained for areas of concern and monitored before and after a catastrophic event.

Monitor Murrelet Terrestrial Activity

While at-sea surveys can provide an index of reproductive success, they do not measure reproductive effort. For colonial seabirds, the percentage of birds attempting to breed can be estimated in order to gauge the proportion of breeding birds in the population and annual fluctuations in the size of the breeding population. For marbled murrelets, an analogous survey might be the dawn watch, where inland activity is measured by the number of murrelet detections. There is circumstantial evidence that dawn watches are an index of breeding effort. At Naked Island, Prince William Sound, detections increased from 1989 to 1991, concurrent with a decrease in spill-related disturbance and increasing numbers of juveniles at sea (Kuletz 1996). In Oregon (K. Nelson, pers com.) and British Columbia (Burger 1995), murrelet detections decreased during years with higher than normal sea surface temperatures associated with El Niño. Selected murrelet nesting sites, preferably adjacent to marine areas surveyed for juveniles, could be monitored to determine if birds are visiting nest sites and to detect long-term trends in breeding activity.

Monitor Annual Mortality

The population will not recover even with stable reproductive success if other sources of mortality offset annual recruitment. For example, winter can be a time of food stress, resulting in low overwinter survival. Postfledging survival is normally low for seabirds (Lack 1966) and can be decreased by reduced food availability in late summer. Other sources of mortality may be identified by periodic and regular monitoring of gillnet bycatch, by conducting beached-bird censuses at selected sites, and by opportunistically obtaining dead or weakened birds.

Part D: Recommended Common Murre Restoration Techniques

INTRODUCTION

The common murre is a circumpolar species of boreal and low Arctic habitats (Nettleship and Evans 1985). On the Pacific coast of North America, common murres breed in dense colonies from mainland northwestern Alaska and the Bering Sea south to central California (American Ornithologists' Union 1983).

About 1.4 million common and thick-billed murres nested in the Gulf of Alaska prior to EVOS, with common murres comprising 80-85% of that total (Sowls *et al.* 1978; but see Erikson 1995). Where both species nest at the same colonies, thick-billed murres prefer narrow nesting ledges, and common murres favor wide nesting ledges and larger, flatter areas (Tuck 1961). About 1.2 million murres nest in the western Gulf of Alaska on the Semidi Islands. Before the spill the largest colonies in the EVOS area were located at the Chiswell Islands, near Seward; at the Barren Islands, at the mouth of Cook Inlet; and in three colonies on the Alaska Peninsula (Sowls *et al.* 1978; see Boersma *et al.* 1995, Erikson 1995, and USFWS unpubl. data for population estimates both before and after EVOS).

Common murres form breeding colonies on seaward-facing cliffs, where they are highly social and lay only one egg (Tuck 1961). Timing of breeding within a breeding group is synchronized, and breeding success is variable, with a maximum of 70-90% of young fledged per breeding pair (Birkhead 1977, Hedgren 1980, Ainley and Boekelheide 1990). Common murres are long-lived, with adult survival averaging over 89% per year (Birkhead 1974, Hudson 1985, Harris and Wanless 1988, Hatchwell and Birkhead 1991, Sydeman 1993); banded murres have lived as long as 32 years.

In spring and summer, common murres are distributed in Alaska mainly over the continental shelf (Gould *et al.* 1982, Harrison 1982). In late fall and winter, they often migrate to protected coastal bays and fjords of the Gulf of Alaska, including the area around Kodiak Island (Forsell and Gould 1981), Prince William Sound (Agler *et al.* 1994), and Cook Inlet (Agler *et al.* 1995b).

In summer, common murres in the Gulf of Alaska forage mainly on fish over the continental shelf (Sanger 1987), while their winter diet also includes euphausids (Krasnow and Sanger 1986). Murres are among the deepest-diving alcids (Piatt and Nettleship 1985), and have been caught in crab pots at 110-130 meters near Kodiak Island (Forsell and Gould 1981).

Murres are particularly vulnerable to floating oil (King and Sanger 1979) and have been determined by respective natural resource trustees to be an injured species in the *Apex Houston, Nestucca, Tenyo Maru,* and EVOS spills. In fact, common murres comprised 61%, 60%, 73%, and 74% of the total number of seabird carcasses recovered from these spills, respectively (Page *et al.* 1990, Warheit 1996; USFWS, unpubl. data). Piatt *et al.* (1990) estimated that EVOS killed 120,000-134,000 breeders, mostly from the Chiswell Islands and the Barren Islands, while Piatt and Anderson (1996) used a figure of 185,000 for common murre mortality.

PRIMARY RECOMMENDATIONS

Reduce or Prevent Mortality

Restoration activities that reduce or prevent the direct mortality of common murres (juvenile, subadult, or adult birds, but particularly established breeders) were considered by the workshop participants as the most promising of all murre restoration options. We considered five different restoration alternatives designed to reduce or prevent common murre mortality.

Remove introduced predators

Restoration projects designed to *remove introduced* predators from nesting habitats both within and outside the spill areas have the highest potential for succeeding on islands. Releasing nesting populations from predation pressures caused by introduced species should result in an almost immediate increase in population numbers. Furthermore, because the recovery of a colony of common murres within the spill area may result, in part, from immigrants from colonies outside the spill area, we advocate predator removal from colonies outside the spill zone as a potentially effective restoration option for colonies within the spill zone. Programs to remove introduced foxes from Alaskan islands have been conducted successfully by the USFWS for several years (see Bailey 1993), and we recommend that these programs be implemented at islands where common murres are most vulnerable to predation by introduced predators. These programs should also be designed as experiments with adequate postremoval monitoring (e.g., EVOS-sponsored Projects 94041 and 95051). Finally, although predator removal projects are widely applicable to many seabird species, they are effective in restoring murre colonies only where such colonies contain nesting habitats accessible to predators (e.g., flat or less precipitous rubble-type habitats easily accessible to foxes).

Prevent introduction of predators

Because introduced wild or domestic predators negatively affect common murre populations (see above), preventing their introduction helps ensure that a colony remains viable and is a potential source of emigrants. Furthermore, because a small number of predators can result in high seabird mortalities at colonies (e.g., red foxes; see Peterson 1982), it is prudent to design and implement programs that will prevent the introduction of even one individual. As with projects for removing introduced predators (particularly rats, but also other rodents, canids, mustelids, and felids), projects designed to prevent their introduction have the highest potential for succeeding on islands. Prevention programs are species specific and may employ a variety of methods. For example, programs that prevent the introduction of rats to islands with seabird colonies may include an immediate and organized response to ship-grounding, the placing of poison bait stations, developing/supporting programs to inspect vessels for rats, and educating vessel operators about the dangers of rat introductions to island habitats. Rat response and educational programs have been recently developed by the USFWS for use on the Pribilof Islands, and also can be employed on the Aleutians and in the Gulf of Alaska. Finally, as with the removal of predators, preventing their introduction is an effective mechanism for maintaining viable murre colonies only where such colonies contain nesting habitats accessible to the potential predator.

Reduce gillnet mortality

Little is known about the effects of drift- and set-net gillnet fisheries on common murre populations in Alaska, and there is a great need for research in this area. DeGange *et al.* (1993) summarized the effects of coastal gillnet fisheries on seabirds in Alaska and reported that common murres are among the species most frequently caught. Furthermore, data from other regions, such as California, indicate that coastal gillnet activities can have a drastic effect on common murre populations. For example, between 1983 and 1986, 50-97% of all seabirds killed in gillnets in the Gulf of Farallones and Bodega Bay, California, were common murres, and their estimated mortality in central California from 1979 to 1987 was 70,000-75,000 birds and included the extirpation of one colony (Takekawa *et al.* 1990). The resulting decline in the central California population may have been as high as 52.6% (Takekawa *et al.* 1990, reported in DeGange *et al.* 1993). Wynne *et al.* (1992) estimated that 432 common murres died in gillnets in the Prince William Sound and Copper River fishing districts in May and June 1991. If common murres are being caught in high numbers in gillnets in coastal Prince William Sound, Cook Inlet, and the Gulf of Alaska, the effects on their populations may be severe. We recommend that research be conducted to determine the effects of gillnet bycatch on common murre populations in the extended EVOS area, and that programs be developed and implemented to reduce or eliminate the drowning of common murres in gillnets. Furthermore, we recommend that partnerships be developed among state and federal agencies, fishing associations, and native corporations to modify fishing gear or the timing and location of gillnet activities in the vicinity of nesting colonies and foraging areas.

Reduce Human Disturbance

Humans can disturb seabird colonies unintentionally through such activities as recreation (e.g., hiking, hunting, kayaking, boating) and aircraft overflights, and this disturbance may negatively affect common murre recruitment and productivity. We recommend that projects be designed and implemented to reduce or eliminate this type of disturbance at and near common murre colonies.

The responses of common murres to human disturbance are difficult to quantify because reactions depend on a series of potentially confounding variables. First, responses may depend on the stage of breeding when the birds are disturbed (e.g., prelaying, laying, incubation, hatching, chick-rearing). Second, responses may vary markedly among individuals and colonies depending on local conditions and circumstances. Birds exposed to regular, ongoing disturbing activities may react differently from birds exposed to the same activities on an intermittent basis (e.g., birds at colonies with histories of close-flying aircraft may respond differently from individuals in populations where this form of disturbance is rare or nonexistent). Third, older, more experienced breeders may tolerate disturbance better than younger, less experienced breeders; individuals incubating eggs or brooding chicks may tolerate events better than roosting off-duty mates or nonbreeders (e.g., Denlinger *et al.* 1994). Also, the effects of disturbance may be cumulative over time (e.g., several years); however, these types of effects are extremely difficult to measure because local abundance and breeding phenology may differ among years as a result of differing environmental conditions.

Population size and local habitat conditions (e.g., configuration and stability of nesting substrates) should be considered when designing programs that eliminate or reduce the negative effects of human disturbance. For example, protecting small colonies where negative effects are likely to be proportionally larger may be of greater value than protecting large colonies where the same human activity may not be a disturbance. Furthermore, the disturbance may be of little or no consequence to large populations before an oil spill, but the same level of disturbance may become biologically important if the populations are markedly reduced in size or are under stress by the event. Finally, preventing or reducing specific forms of disturbance, such as noise and vibration from low-flying aircraft, is likely to be more beneficial at colonies with unstable nesting substrates or densely packed concentrations of nesting birds than at colonies with more stable or less densely populated nesting substrates. In designing projects to reduce human disturbance at nesting colonies, we offer the following recommendations:

- Projects should be site-specific and tailored to address local circumstances and needs.
- Projects should be developed in close cooperation with local user groups (e.g., sport, commercial, and subsistence hunters and fishermen; charter vessel and aircraft companies and associations; guiding and tourism businesses and associations), and appropriate state and federal agencies (e.g., Alaska Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, National Park Service, U.S. Forest Service, Bureau of Land Management). Specific concerns regarding vessel and aircraft activities should be discussed with the U.S. Coast Guard and the Federal Aviation Agency, respectively.

Conduct Research on Fish and Fisheries Management Practices

The workshop identified at least four management areas where there were insufficient data to determine if common murres are being negatively affected by fisheries activities. In particular, we recommend that research be conducted on what effects particular fisheries management practices may have on common murre productivity and survival. Research may be directed toward a variety of issues on an as-needed basis, but the following topics should be given priority:

Hatchery-raised salmon

Investigate and evaluate the effects that large-scale releases of hatchery-raised salmon may be having on marine food webs. During the past 10 to 15 years, hundreds of millions of salmon fry have been raised and released into western Pacific marine ecosystems annually by private and government-sponsored hatchery programs. These programs, for the most part, have been developed to support, maintain, and enhance local and regional commercial fishing industries and are particularly well developed in Alaska. Hatchery-reared salmon present a twofold problem that may ultimately depress food resources for common murres: competition with, and then predation on, forage fish. In Alaska there are concerns that *young* hatchery-reared fish may be competing for zooplankton stocks needed to support and sustain forage fish populations (e.g., sand lance, capelin) important to fish-eating seabirds and marine mammals (e.g., common murres, young seals and sea lions). In addition, as these hatchery-reared fish grow they no longer compete with the forage fish but become their predators, and the artificially inflated at-sea populations of released salmon may reduce local and regional availability of forage fish to seabirds and marine mammals. The need to develop and implement studies that can address these concerns appears to be particularly important in Prince William Sound and parts of the northwestern Gulf of Alaska where large-scale hatchery programs are operating annually. We recommend that food-web interactions between hatchery-reared salmon and forage fish and the effects of these interactions on the stocks of forage fish important to common murres be investigated.

Commercial harvest of walleye pollock

Large-scale harvests of walleye pollock in the northern Gulf of Alaska may reduce the numbers of young-of-the-year pollock available to common murres at some colonies in some years. Pollock harvests may also be altering marine food webs in unknown ways. We recommend that research be conducted to investigate the relationships between pollock harvests and seabird productivity.

Nearshore/shore habitats

Sand lance are an important prey item for common murres in the areas affected by EVOS. We recommend that research be conducted on how the nearshore and beach habitats can be *protected or modified* to protect or enhance sand lance spawning. If research determines that modification techniques are feasible, it should also be determined whether it would be too difficult or expensive to modify enough habitat to significantly alter sand lance productivity to the degree that it would benefit murres and other fish-eating seabirds.

<u>*Residual oil on forage fish*</u>

Residual oil from EVOS is present on certain beaches and may be inhibiting spawning activities of forage fishes such as sand lance and capelin. We recommend that research be conducted to determine (1) if residual oil is present along spawning beaches and (2) if the oil is affecting the productivity of those forage fish that are an important part of common murre diets.

SECONDARY RECOMMENDATIONS

Social Attraction

Social attraction may be a useful technique for assisting recovery of common murres *at certain colonies* both inside and outside the EVOS area, but the workshop determined that this technique should be restricted to sites where the entire nesting population has been eradicated (the cause of the eradication at an individual colony is not important if the purpose in conducting restoration is to return birds to a particular region). Social attraction may also be useful when employed in combination with predator control or removal programs (see above) at sites that no longer support populations of birds (e.g., western Gulf of Alaska and the Aleutian Islands, where colonies have been extirpated by introduced predators). In most cases, though, social attraction techniques may be of little value for at least five reasons:

- Birds still present at injured colonies likely serve as better attractants than any manmade decoys or sound recordings.
- The number of decoys that can be effectively deployed at an injured colony may be limited by available funds and physical factors. That is, placing decoys in many typical cliff-nesting habitats may be costly, time-consuming, and dangerous.
- Decoys placed at injured but nonextirpated colonies will occupy space (i.e., potential nest sites) more appropriately used by the remaining birds or new recruits.
- Attracting birds to one colony may preclude recruitment to others.
- Common murres have shown the ability to find and colonize suitable nesting habitat without human-assisted social attraction.

Enhancement of Existing Nesting Habitats

<u>*Habitat modification*</u>

Improving nesting habitats has some potential to increase murre productivity at injured colonies by providing areas that may be less susceptible to egg and chick loss. Techniques might include modifying nesting ledges (e.g., altering widths and slopes) to prevent egg loss, shoring up areas to prevent or reduce the number of natural rockfalls, or creating overhangs to provide better shelter for eggs and chicks during inclement weather conditions. To help ensure positive results, programs proposing to use these techniques should be required to evaluate whether certain types of nesting habitats are preferred by the birds, or are measurably superior in terms of increasing productivity and survival. Also, projects proposing to use these methods should be required to identify if the abundance of any particular habitat is limiting recovery, and then determine if this habitat can be constructed efficiently and cost-effectively by modifying existing habitats or substrates in nearby adjacent areas. Furthermore, the habitat to be modified must not be required by other naturally occurring animals or plants in the region.

Habitat protection

A different class of nesting habitat enhancement is the removal (or the prevention of the introduction of) exotic or domestic species *that have the potential to damage common murre nesting habitats* both within and outside of spill zones (e.g., cattle, sheep, goats). These types of projects have the highest potential for succeeding on islands. They are usually of greater benefit to burrow-nesting species (e.g., puffins, petrels), but they may also be relevant to common murres if birds are nesting (or previously nested) on flat, accessible terrain. One possible method for accomplishing this would be to purchase privately owned land that is currently being affected by the grazing activities of domestic species, and place this land into the public trust.

Captive Management

Captive management (e.g., captive rearing and release of birds) is a technique that should be considered only in extreme cases when all other possibilities have been exhausted and common murre numbers have dropped to the point at which they are endangered over an entire region. There are several problems in using captive management as a restoration tool for common murres:

- Rearing enough chicks to positively influence injured populations would be technically difficult and extremely costly (Fry 1991).
- Postfledging survival of chicks released at injured colonies would require that chicks be adopted and fed by unrelated adult males for the extended period of postfledging care (approximately 60 days) or kept in captivity until adult age is reached (Kress and Carter 1991).

Translocation of Birds

Translocation of common murres is another potential restoration technique that should be considered only in extreme cases when all other possibilities have been exhausted. This method involves the capturing of chicks at noninjured, healthy colonies and releasing them at injured or extirpated colonies. Although this method has not been tried, it suffers from the same problems as captive rearing of common murres. That is, common murres have extended postfledging parental care, and the successful translocation of chicks would require that the chicks be adopted by chickless adults or kept in captivity until independent (Kress and Carter 1991). If chicks are being translocated to colonies that have been extirpated, there will be no adults in the area to adopt the chicks.

Rehabilitation of Oiled Birds

Rehabilitation of oiled seabirds may have intangible benefits in terms of public support for restoration. However, the survival of rehabilitated common murres, once released back to sea, is low, while the cost of rehabilitation is high (Sharp 1996, Fry 1991). Furthermore, the rehabilitation of oiled birds may give the public false perceptions about the impacts of spills and the subsequent probabilities of recovery. In general, we recommend that rehabilitation of oiled birds be used only with small populations of common murres where the survival of individual birds is important to the viability of the population. We also recommend that the public be educated about the fact that the rehabilitation of *most* seabirds, including common murres, is costly and generally not successful. Finally, if rehabilitation is to be used, we recommend that effective triage procedures be developed and employed (see Chapter 9f).

MONITORING ACTIVITIES

Monitoring activities associated with seabird restoration projects are discussed in Chapter 7. We list here important activities associated with monitoring common murre colonies, and emphasize that such studies should be designed for both the target (injured) and reference (uninjured) colonies (see Wiens and Parker 1995, Wiens 1995). We recommend that the following population parameters be monitored.

Productivity

Data on murre productivity (chicks per nesting attempt) should be collected from a series of plots at each colony in an effort to monitor reproductive success. Preferably, monitoring should be conducted annually at several colonies within the affected region until it can be demonstrated that productivity has remained within normal limits for several consecutive years (e.g., four to five consecutive years; see Chapter 6 for other ways of measuring success). These data also can be used to monitor nesting phenology should that be an issue.

Size of Breeding Population

Data on population numbers at breeding colonies should be based on at least five separate counts made on different days during the nesting season at a statistically adequate set of monitoring plots (see Gerrodette 1987, Byrd 1989, Hatch and Hatch 1989, Wanless *et al.* 1982, Harris *et al* 1985). These activities should be conducted annually at several sites within the affected region until significant positive trends are clearly apparent. In the event that numbers show little change for several years (e.g., five to six years), monitoring efforts may be modified to census colonies about every two to three years until trends are evident. To calibrate counts, the diel attendance patterns must be determined in conjunction with total counts. This will show what proportion of the population is present at a given time of day, thus allowing comparison of counts conducted at different times of day.

Survival

Survival is one of the most difficult population parameters to monitor, and requires repeated observations of banded birds. Therefore, our first recommendation is that studies be implemented to band both common murre adults and chicks at breeding colonies with continued monitoring for resightings of banded birds. High breeding fidelity in common murres allows survival to be monitored by observing the rates of return to the breeding colony.

Additionally, implementing long-term beached bird surveys can provide estimates of "normal" postfledging and winter mortality in a region, and can identify those years and events that result in unusually high mortality. Although this method does not provide an estimate of average survival rates for individual birds, it may help provide data on the demographic impact of unusually high fall and winter mortalities (especially if sex, relative age, and area of origin [via genetic or morphometric markers] are determined for each bird).

Part E: Recommended Pigeon Guillemot Restoration Techniques

The pigeon guillemot is a cavity- or crevice-nesting alcid with a broad geographic range extending from Arctic Alaska south to southern California (American Ornithologists' Union 1983). The species forages in nearshore waters, usually within 5 kilometers of the nest (Drent 1965). The pigeon guillemot breeds solitarily or in loose colonies (as do the black and spectacled guillemots), and the distribution and abundance of breeding pairs is often dependent on nest-site availability (Storer 1952). The typical clutch size is two eggs.

The pigeon guillemot population in Prince William Sound decreased from about 15,000 birds in the 1970s to less than 5,000 in the 1990s (Agler *et al.* 1994, Sanger and Cody 1994). Over 600 pigeon guillemot carcasses were recovered after the spill, and may represent 10-30% of the total mortality resulting from the spill (Piatt *et al.* 1990). Although there is evidence suggesting that the Prince William Sound population was in decline at the time of the spill, relative declines in populations were greater along oiled than unoiled shorelines (Oakley and Kuletz 1996).

Reasons for the decline and lack of recovery are not clear and could be related to changes in prey availability and/or increased predation at the nest. Schooling fishes, particularly sand lance, account for a smaller proportion of food returned to chicks now than before the spill. Also, predation on guillemot eggs and chicks was minimal before the spill but now is a major factor influencing breeding productivity (Hayes 1995, Oakley and Kuletz 1996).

PRIMARY RECOMMENDATIONS

Predator Removal or Control

The most efficacious restoration technique for pigeon guillemots in Prince William Sound is likely to involve the eradication or control of predators on eggs and chicks. Control of terrestrial predators has been shown to benefit guillemot populations in the Aleutian Islands, where populations rebounded dramatically after eradication of foxes (Byrd *et al.* 1994). The species that prey on guillemot eggs and chicks in Prince William Sound are many: they include northwest crow, common raven, black-billed magpie, Steller's jay, gray jay, mink, and river otter. Mink and river otters will also prey upon adults in the nest cavities. Adults and fledglings may be taken by bald eagles and peregrine falcons. There is evidence that predation on guillemots on Naked Island has increased since the late 1970s and early 1980s (Oakley and Kuletz 1996). More than 25% of the nests monitored on Naked Island were depredated in 1994 (Hayes 1995).

Any reduction in the number of predators would almost certainly increase guillemot productivity. Besides negatively affecting productivity, the presence of these predators could be acting to reduce recruitment at the affected colonies. Islands outside the spill zone that have introduced animals should be considered for predator control or eradication. Any colonies in the northern Gulf of Alaska that can be increased through predator eradication may be a source of potential recruits for Prince William Sound colonies. Rates of immigration in pigeon guillemots may be high; recent work in Arctic Alaska has shown that black guillemots will regularly disperse more than 500 kilometers and that over half the recruits at one colony were immigrants (G. Divoky, unpubl. data).

The control or eradication of indigenous predators is more problematic, and is not generally recommended given both the potential ecological effects and public opposition. USFWS has made exceptions, however, and indigenous predators (e.g., gulls) have been eradicated to protect or enhance another species (e.g., Atlantic puffin; Kress and Nettleship 1988). For terrestrial predators, fencing of high-density nesting areas, rather than trapping or poisoning, may be a sufficient predator control measure.

Nest Site Enhancement and Artificial Nest Sites

Guillemots are cavity nesters that can use a variety of nest types; their only nesting requirement is overhead cover (Storer 1952). Artificial nest sites have been used successfully by several burrow-nesting species of seabird (Priddle and Carlile 1995 and references therein). The use of artificial nest sites has been documented for pigeon guillemots in Washington (M. Mahaffy, pers. com.) and on the Farallon Islands (Ainley and Boekelheide 1990), and for its congener, the black guillemot, in Arctic Alaska (Divoky *et al.* 1974). In the latter instance, artificial nest sites increased a population of black guillemots from 15 to 225 pairs over a period of 15 years.

In Prince William Sound guillemots nest in rock crevices in cliffs, in talus piles at the base of cliffs, and beneath cavernous tree-root systems at the edge of cliffs. On Naked Island, and probably on many other islands in Prince William Sound, suitable cavities are probably not limiting to the population. On Naked Island, many sites used by guillemots in the late 1970s and early 1980s currently are not being used, possibly because of increased predation pressure from corvids and mustelids. However, on Jackpot Island (1.6 hectares with little shoreline), nests may be limiting and only one type of nest site (tree roots) is available. If the abundance or availability of prey is not limiting the numbers of guillemots at this location, creating high-quality nesting cavities might be a viable restoration technique.

Artificial nest sites for pigeon guillemots would need to be designed to exclude predators while appealing to prospecting guillemots. Crows, mink, and magpies can probably enter most openings that allow access to guillemots. However, a tight entrance and several baffles might deter corvids. The location of the nest box, rather than the dimensions of its entrance, would be more important for preventing mink from getting to eggs or chicks. River otters could be excluded by a small entrance. By varying the size and shape of entrances and passageways and monitoring rates of prospecting and occupation, it may be possible to develop a functional and predator-free nest site. Occupation of the sites by breeding birds will increase the sample size of nests for ongoing studies (assuming that they attract nonbreeders and not experienced birds abandoning nearby natural sites) or, at the very least, allow for better monitoring of nesting success and chick growth rates. An alternative to providing nest sites at available islands would be the provision of nest sites on offshore pilings and "dolphins" (a group of pilings, often with a platform) created for the express purpose of providing guillemot nesting habitat. Such structures would lack terrestrial predators and could support a cluster of artificial nest sites with easy access for monitoring.

An alternative to providing entirely artificial nest sites is the enhancement of natural nesting cavities. Some existing crevices might attract guillemots if they were slightly more concealed or simply offered some additional protection from the elements. Enhancement techniques would not require the purchase of any new materials (boulders and flat rocks at the colony could be used), and such work could be done coincidentally with normal field work during nest visits.

Control of Anthropogenic Factors

The effects of human disturbance at seabird colonies are legion; examples come from around the world (see Manuwal 1978, Burger and Gochfeld 1994 for reviews). Because pigeon guillemots generally breed in small, scattered colonies, the potential for catastrophic population effects caused by human disturbance at the colony is not high. Disturbance of birds rafting just offshore from a colony is not likely to harm their breeding efforts unless the disturbance is chronic. However, camping and other on-land activities that disturb breeding birds at the nest could result in abandonment (Drent 1965), a reduction in breeding success (Cairns 1980), decreased recruitment, and increased breeding dispersal.

Guillemots successfully occupy working docks and other locations where human activity occurs daily during the breeding season. Thus the species can habituate to the presence of humans if their nesting cavities offer security to the incubating adults. In Prince William Sound, Jackpot

Island may be most vulnerable to the effects of human disturbance because of the high density of nests there. Colonies of concern should be identified and, when possible, access to these colonies prevented during the breeding season. Alternatively, a public information campaign, targeted at recreational and commercial boaters, could identify the areas and activities to be avoided during the breeding season.

Gillnetting operations in Monterey Bay, California, have drowned large numbers of pigeon guillemots (King 1984). In Alaska, pigeon guillemots are caught in set gillnets (K. Kuletz, pers. com.). A study should be undertaken to identify the magnitude of the guillemot bycatch mortality in Prince William Sound, with the goal of decreasing mortality associated with these fisheries (see discussion of bycatch in Chapter 2c).

SECONDARY RESTORATION TECHNIQUES

Enhancing Food Supplies

Sand lance has declined in the diet of pigeon guillemot chicks at the nest, while apparently lesser-quality prey has increased (Hayes 1995). This apparent change in abundance and availability of a preferred prey may be part of an ecosystem shift and could be a factor in the lack of recovery of pigeon guillemots. However, there may be methods that modify nearshore habitats or shorelines that will increase prey abundance for this species (see Chapter 9d). The lack of known techniques and the uncertainty of the role that prey abundance or composition is playing in the lack of recovery makes this a low-priority restoration option. Studies of the nearshore ecosystem (e.g., the Alaska Predator Ecosystem Experiment, EVOS Restoration Project 95163) may provide some understanding regarding the lack of recovery by pigeon guillemots. In addition to the possibility that an ecosystem shift has occurred, prey populations may still be affected by EVOS. Although it is unlikely that direct ingestion of oil is affecting the birds seven years after the spill, indirect effects of oil might be important. Hemosiderosis has been observed in demersal fish collected from oiled eelgrass beds in Herring Bay, Knight Island; these fish were in poor condition as judged by lipid and glycogen stores (S. Jewett, pers. com.). The incidence of hemosiderosis would likely be less of a factor with time.

Monitoring Activities

As with all nonrecovering species, the monitoring of the population is necessary to provide information that will allow assessment of the need for or success of various restoration techniques. Monitoring should consist of censuses of affected colonies and populations in known oiled locations as well as censuses in unaffected (i.e., unoiled) areas. The latter will provide important reference sites to allow the determination of whether population trends at affected colonies reflect natural regional trends or impacts of the spill, and will also help determine the effects of the restoration effort. Population size, as measured by the number of breeding pairs or, less ideally, total number of birds (breeders and nonbreeders), is the most important parameter. Populations are best sampled before the beginning of egg laying when both members of a pair are visible during the daily periods of colony attendance (Vermeer *et al.* 1993). General population estimates could be obtained with minimal field time. The percentage of nonbreeders associated with a breeding colony ranges from 0 to 50% (Ewins 1985, Hilden 1994; G. Divoky, unpubl. data). Only at colonies where intensive work is conducted can we obtain accurate estimates of the number of breeding pairs or detect trends in the breeding population. A colony with 50% nonbreeders, for instance, could have its number reduced by half and still have had no change in the breeding population. For those populations where the size of both the breeding and nonbreeding populations can be monitored, changes in the nonbreeding population can act as important indicators of the condition of a population (Klomp and Furness 1991).

In addition to the number of adult birds, the productivity of target and reference colonies should be monitored. For nonrecovering colonies or populations, breeding success and the factors that limit hatching and fledging success should be monitored annually. The possibility of monitoring productivity through the use of nearshore censuses of adult/young ratios, as is being tried with marbled murrelets (Kuletz 1996), should be examined. If successful, the technique would reduce the need to locate nests for productivity studies. Banding of chicks and adults can help elucidate the reasons for a lack of recovery and should be part of a monitoring program. At a minimum, all fledging chicks at target colonies should be banded so that the percentage of fledglings that survive and return to breed at their natal colony is known. Banding at reference colonies or any colony in the northern Gulf of Alaska could provide information on immigration to the target colonies and should be conducted when possible. In northern Alaska, immigrants made up well over half the recruits at a black guillemot colony (G. Divoky, unpubl. data), showing the importance of productivity at adjacent colonies in rates of colony growth.

Banding and individual marking of adults is more logistically complex than banding chicks, but should be done if target colonies fail to recover. If banding shows that adult mortality is a factor contributing to the lack of recovery, then manipulation of the sources of adult mortality (i.e., gillnet bycatch and predation) could provide additional avenues of restoration. Monitoring studies should also include studies of the chick provisioning and growth rates at target and reference colonies. If low fledging weights caused by low-quality prey are contributing to a lack of recovery, then food enhancement restoration techniques may be worth pursuing.

REJECTED TECHNIQUES

The workshop deemed captive breeding, translocation, and social attraction to be last-resort techniques, appropriate for use only when a pigeon guillemot population is on the brink of extinction. Captive breeding and translocation could be employed only where there is little or no possibility of immigration from adjacent colonies. Because guillemot chicks are independent at fledging, young could be released into the wild from captive breeding or after translocation. Additionally, because they lay two eggs and are able to re-lay if the initial clutch is removed early in incubation, it might be possible to obtain eggs from wild populations for raising chicks in captivity without harming source populations.

Part F: Recommendations Regarding Restoration and Monitoring of Other Marine Bird Species

At the time of the workshop, the Trustee Council listed common murres, harlequin ducks, marbled murrelets, and pigeon guillemots as nonrecovering injured species. This judgment was based on the quantified injury resulting from the spill and the status of each species. However, several species of marine birds were not listed as injured because there were no data detailing how the spill affected populations or the status of those populations. For example, Kittlitz's murrelet was not initially considered an injured species, mainly because this species is rare, local, and difficult to study, and few data were available about its abundance and distribution. In the absence of data, the Trustee Council was unable to determine if this and other species were injured.

In 1996, the Trustee Council added Kittlitz's murrelet, common loon, and double-crested, pelagic, and red-faced cormorants to the nonrecovering injured species list (Trustee Council 1996). In this subchapter, we review the status and restoration/research options for these species.

KITTLITZ'S MURRELET

Introduction

Kittlitz's murrelet breeds from northeast Siberia and the Commander Islands to southeast Alaska, with its center of abundance extending from southeast Alaska to Kodiak Island (Harrison 1983). The primary breeding areas for Kittlitz's murrelets are the southern Kenai Peninsula, Prince William Sound, and Glacier Bay in southeast Alaska (Isleib and Kessel 1973; USFWS, unpubl. data). Its population probably numbers in the tens of thousands, but little is known about its abundance or its biology. Kittlitz's murrelet coexists with its more abundant and widespread congener, the marbled murrelet, and is similarly noncolonial, nests inland, and has cryptic breeding plumage. However, unlike the marbled murrelet, Kittlitz's murrelet nests exclusively on the ground, usually at high elevations in barren scree (Day *et al.* 1983).

It is difficult to distinguish between marbled and Kittlitz's murrelets during at-sea surveys, and the two species are frequently combined as *Brachyramphus* murrelets in survey estimates. In Prince William Sound, *Brachyramphus* murrelets have declined 67% since the 1970s (Klosiewski and Laing 1994), and approximately 10% of the identified *Brachyramphus* murrelets in the area were Kittlitz's murrelets (Agler *et al.* 1994). The *Brachyramphus* murrelet population in Prince William Sound is currently estimated at 89,000 to 138,000, which would suggest that Kittlitz's murrelet numbers approximately 9,000 to 14,000.

In general, during the breeding season, Kittlitz's murrelets are found near tidewater glaciers at the heads of bays and fjords in Prince William Sound. Although these areas were not directly oiled, murrelets breeding in these areas were probably affected by oil southwest of Prince William Sound before arriving at their breeding grounds (Kuletz 1996). Only 72 Kittlitz's murrelet carcasses were recovered and identified from EVOS; as a result, this species was not included in the initial list of injured species. However, we know little about the abundance, distribution, and productivity of Kittlitz's murrelet. The actual mortality from the spill may have been considerably higher than the 72 carcasses recovered (Kuletz 1996), perhaps as high as 3% of its total population (van Vliet 1993). Because the spill occurred in the center of Kittlitz's murrelet's range, and because there is a legitimate question as to the status of this species following the spill, the Trustee Council added Kittlitz's murrelet to the list of injured species (Trustee Council 1996). Furthermore, beginning in 1996 the Trustee Council funded a study to investigate the life history of and habitat use by Kittlitz's murrelet.

Research Recommendations

Determine abundance and distribution

There is a need for more precise data on the population size and distribution of Kittlitz's murrelet in the spill zone. Since the local distribution of Kittlitz's murrelets is rather patchy, we recommend that at least one complete shoreline survey of Prince William Sound be conducted to locate all major concentrations. This information should be used to modify the current protocol used to monitor the Prince William Sound population.

Similar surveys could be conducted along the outer coast of the Kenai Peninsula and Kachemak Bay/lower Cook Inlet and compared with historical data in the southern Kenai Peninsula. Sites of particular interest along the southern Kenai include the upper portions of East Nuka, Harris, and Aialik Bays and, in Kachemak Bay, the Grewingk Glacier runoff. Kittlitz's murrelets also occur around Kodiak Island and the Alaska Peninsula, but USFWS surveys suggest that their numbers in these areas are too low to warrant a large census effort.

To estimate the effects of EVOS on Kittlitz's murrelet, comparisons can be made among Prince William Sound, Kenai Fjords, and Kachemak Bay. Although Kachemak Bay is in the designated zone, the inner bay where Kittlitz's murrelets congregate was relatively unoiled, with little apparent effects on *Brachyramphus* murrelets (Kuletz 1996). Kittlitz's murrelets occur in several large fjords in northern Prince William Sound that were not oiled, and comparative studies on long-term population trends within Prince William Sound should be conducted.

Investigate breeding phenology, habitat use, and diet

There is little information on the marine habitat use, diet, or productivity of Kittlitz's murrelets. Information on seasonal and diel activity patterns would improve monitoring protocols. These types of intensive studies are best done at multiple sites. The breeding phenology of Kittlitz's murrelets is not well known, but observations suggest that they arrive at breeding areas later and leave earlier than marbled murrelets (K. Kuletz, unpubl. data). Replicate surveys from April to September would document dates of arrival and departure from the breeding area. Late summer counts of fledglings at sea could define the fledging period and provide an index of productivity.

Kittlitz's murrelets are usually found near tidewater glaciers and glacial runoff, and therefore use less true marine habitat than marbled murrelets. Because Kittlitz's murrelets forage near glaciers, they may depend on physical and biological properties associated with tidewater glaciers, such as upwelling and turbulence where macroplankton productivity is high. Kittlitz's murrelets feed on the same fish as marbled murrelets, but may also eat more crustacea and euphausids (Krasnow and Sanger 1986). However, a chick monitored by video camera inland of Kachemak Bay was fed exclusively Pacific sand lance, capelin, and other forage fish (Naslund *et al.* 1994). Diet should be recorded by observations of adults with fish, by stomach samples, or by stable isotope analysis.

Investigate the food limitation hypothesis

Because both species of *Brachyramphus* murrelets have declined, Kittlitz's murrelets should be included in studies investigating the effects of prey resources on seabird populations. Changes in fjord or glacial regimes might impact the productivity and abundance of Kittlitz's murrelets, either positively or negatively. The highly localized occurrences of Kittlitz's murrelets could promote studies that compare the abundance of fish with the abundance and productivity of Kittlitz's murrelets.

Define nesting habitat

Few Kittlitz's murrelet nests have been found, and little is known about their nesting habitat or behavior, conspecific associations, or foraging range. As with the marbled murrelet, radio-telemetry is probably the best method of discovering Kittlitz's murrelet nests in an unbiased manner. Tagged birds would also provide data on the distances between nesting and feeding areas. Ground searches in potential nesting habitat could be conducted in association with dawn watches, although a protocol for surveying upland activity of Kittlitz's murrelets needs to be developed. Kittlitz's murrelets do not appear to be vocal during dawn flights to the nest (Naslund *et al.* 1994), but several nests have been found by sighting a departing bird (Day *et al.* 1983, Day 1995, Naslund *et al.* 1994). Once a nest is found, time-lapse cameras can provide information on nesting behavior and fledging success (Naslund *et al.* 1994).

Restoration Recommendations

Minimize disturbance at nest sites

Most Kittlitz's murrelet nests have been found above 300 meters, and all have been found in unforested habitat. Therefore, the nesting habitat of Kittlitz's murrelet would not likely be affected by logging; however, mining operations, construction of roads or power lines, or similar activities may negatively affect breeding activities. Until more is known about the nesting habitat of Kittlitz's murrelet and about the distribution of nests in a breeding area, we cannot make specific recommendations.

Reduce disturbance at foraging sites

There are no data on the effects of boat traffic or noise on the foraging activities of Kittlitz's murrelets. However, the birds' association with tidewater glaciers makes them susceptible to disturbance from tour boats and glacial ice harvest. Both operations occasionally use horns or explosives to cause glacial calving. Once areas of Kittlitz's murrelet activity are identified, disturbance should be minimized or restricted during the breeding season. We recommend a study on the effects of boats and noise on Kittlitz's murrelets and their potential to habituate to disturbance.

Investigate and reduce gillnet mortality

The few data on the gillnet mortality of Kittlitz's murrelets suggest that mortality associated with their incidental bycatch is a serious problem. In Prince William Sound, Kittlitz's murrelets constituted 5% of the total identified murrelets killed in gillnets in 1990 (Wynne *et al.* 1991). However, in 1991 they accounted for approximately 30% of murrelet bycatch (Wynne *et al.* 1992). By extrapolating from net permits and data from Wynne *et al.* (1991), Piatt and Naslund (1995) estimated that *Brachyramphus* annual mortality was between 813 and 2,043 murrelets (±95% confidence intervals) in Prince William Sound and 1,100 murrelets in lower Cook Inlet. Because Kittlitz's murrelets averaged 16% of the total murrelet bycatch, between 130 and 323 Kittlitz's murrelets may be killed annually in Prince William Sound. An additional 100 Kittlitz's murrelets may be taken in lower Cook Inlet (based on the 9% proportion of the Kittlitz's murrelet in the *Brachyramphus* population).

In Prince William Sound, the estimated annual bycatch of the Kittlitz's murrelet is approximately 2% of the population. Although most murrelets were caught in the Copper River district, three northern fishery districts—Coghill, Unakwik, and Eshamy—overlap with areas of very high Kittlitz's murrelet densities. Fishing in Unakwik and Coghill in particular may have affected local Kittlitz's murrelet populations since the 1970s.

Further study is needed to determine the extent of gillnet bycatch and factors affecting bycatch rate. The effect of bycatch in the Coghill and Unakwik areas can be determined by surveying specifically for Kittlitz's murrelets and focusing bycatch studies in those areas. Limited data suggest that Kittlitz's murrelets may leave Prince William Sound by early August, which may preclude them from being caught in nets located in the northern districts. However, nothing is known about their postbreeding dispersal, and the late summer fishery in the Copper River district may overlap with postbreeding congregations of murrelets.

COMMON LOON

At least 216 of the 395 oiled loons recovered in Prince William Sound following EVOS were common loons (J. Piatt, unpubl. data). The Trustee Council recently placed the common loon on the injured species list (Trustee Council 1996).

Subadult and adult birds from one or more unidentified breeding populations were killed by EVOS. Efforts to restore the injured populations would first require the identification of nesting geography of common loons found in Prince William Sound in mid-March. Evers *et al.* (1996) have captured and color leg-banded 867 common loons in Prince William Sound and sighted 148 of these birds on their breeding grounds using a night spot-lighting technique. Recent efforts in wintering areas indicate that this technique can be adapted for identifying individual common loons in coastal wintering groups (D. Evers, pers. com.). Although color marking research is feasible, it may not result in a large-scale determination of common loon breeding grounds. Satellite-tracking of radio-tagged individuals appears to be a better technique to identify the breeding areas of wintering or migratory loons. A pilot project using the adapted capture technique on winter coastal waters and experimental implantation of satellite telemetry appears promising.

Once identified, an injured population should be assessed for restoration needs. Primary criteria used to identify the need for restoration are population density and productivity rates (chicks fledged per territorial loon pair). These data could be compared with densities in adjacent areas or similar habitats and with reported productivity rates such as those summarized by McIntyre (1988). Monitoring is discussed below. Nesting frequency may also reflect injury (Field *et al.* 1993, McIntyre 1992).

Restoration efforts for a common loon breeding population may be direct or indirect. Indirect restoration techniques include those designed to enhance the productivity of the remaining breeding loon pairs by reducing the effects of limiting factors on nesting success and chick survival. Factors limiting the productivity of North American common loons include human disturbance, direct killing or harvest, egg and chick predation, habitat loss, water-level fluctuations, fishing line and net entanglement, fishhook and lead sinker ingestion, and environmental contamination (McIntyre 1988, Loon Preservation Committee 1990, Evers *et al.* 1996). Management and mitigation techniques specific to individual factors include management of gillnetting, public education, warning signs, employment of artificial nesting islands, nest covers, breeding habitat protection, and improvement of water-level management regimes (e.g., Sutcliffe 1979, Loon Preservation Committee 1990, Fair and Poirier 1993). Other mitigation techniques may include reduction of illegal hunting, additional protection from predators, and alteration of fish harvest techniques and management.

Successful indirect restoration efforts require significant return of subadults to natal areas. D. Evers (pers. com.) reports a 5-30% return of subadults to natal lakes; dispersal and mortality rates of nonreturning loons are unknown. However, intensive indirect restoration management appears to successfully enhance common loon populations. The threatened New Hampshire common loon population has doubled in number during two decades of intense management

(Loon Preservation Committee 1995). Common loon populations of multiple-pair reservoirs have increased after 5 to 14 years of intensive management (Fair and Poirier 1993). Because natural colonization is slow, translocation is potentially valuable in areas where loons have been extirpated. This technique, however, has not yet been attempted. Translocation of independent nonfledged juveniles appears feasible, and experimental development of this reintroduction technique has been proposed in the Anchorage area (Evers *et al.* 1995). This technique assumes that subadults return to transplanted fledging areas. Return data from approximately 350 juvenile common loons color-banded from 1989 through 1995 will more accurately indicate return rates over the next several years (D. Evers, pers. com.).

In the context of restoration, common loon populations are monitored on the breeding grounds to determine significance of injury, investigate limiting factors of production, and assess effects of restoration efforts. Loon monitoring techniques on the breeding grounds (Belant *et al.* 1993, Lanctot and Quang 1994) and on wintering areas (Jodice 1992) have been described and evaluated. Determination of injury may begin with less intensive ground or aerial surveys of adult populations, nesting frequency, and possibly chick production. Determination of limiting factors and effects of restoration efforts require more intensive monitoring (e.g., Loon Preservation Committee 1990, Evers *et al.* 1996).

Preventive efforts include development of techniques to determine the geography of injured common loon breeding populations, development of direct restoration techniques, and improvement of oil transport systems to reduce wildlife injuries caused by oil spills.

PELAGIC, DOUBLE-CRESTED, AND RED-FACED CORMORANTS

Three species of cormorants nest throughout the spill area, with the exception of the inside waters of Prince William Sound (USFWS 1996). In the Gulf of Alaska, cormorants generally nest in relatively small colonies of less than 100 nests (Baird *et al.* 1983). Cormorants eat bottom-dwelling and midwater-schooling fishes (Ainley *et al.* 1981). In the Gulf of Alaska, schooling fishes such as Pacific sand lance and capelin are important prey species (Ainley *et al.* 1981, Baird *et al.* 1983).

Injury to cormorants resulting from the spill was documented for nonbreeding birds that spend their summer in Prince William Sound (Klosiewski and Laing 1994, Day *et al.* 1995) and for birds breeding along the south coast of the Kenai Peninsula (Vequist 1990, Day *et al.* 1995). The number of breeding pelagic cormorants also declined at Gull Island in lower Cook Inlet in 1989 (Slater *et al.* 1995). Although the Trustee Council now lists cormorants as injured, it has funded no studies specific to cormorant restoration. However, biannual marine bird surveys in Prince William Sound have documented the lack of recovery of the nonbreeding cormorants (Agler *et al.* 1994). It is not known if cormorants along the Kenai Peninsula have recovered, because data have not been collected since 1991 (Day *et al.* 1995). Before restoration activities can be designed, the nonrecovering populations must be identified. Recommendations for restoration of cormorants would be similar to the recommendations for restoration of murres (see Chapter 2d).

OTHER MARINE BIRD SPECIES

The oil spill affected the abundance and habitats of several marine bird species in Prince William Sound and along the south coast of the Kenai Peninsula that were not included in the Trustee Council's injured species list (Klosiewski and Laing 1994, Day *et al.* 1995). Along the Kenai Peninsula, these species include red-necked phalarope, mew and glaucous-winged gulls, rhinoceros auklet, tufted puffin, and common merganser. In Prince William Sound, these species include Arctic tern, mew and glaucous-winged gulls, scoters, horned and red-necked grebes, Barrow's goldeneye, bufflehead, and common and red-breasted mergansers. Based on marine bird surveys in Prince William Sound, none of these species seem to have recovered significantly. In addition, Irons (1996) demonstrated that the oil spill affected the productivity of black-legged kittiwakes in Prince William Sound and that their productivity had not recovered by 1995; further, goldeneyes and mergansers are not increasing in the oiled area as fast as they are increasing in the unoiled area, which may indicate an oil spill effect (Agler *et al.* 1994, Agler *et al.* 1996). Day *et al.* (1995) concluded that by 1991 some of these species were using oiled habitat no differently than they used unoiled habitat, while other species continued to avoid the oiled areas (see also Day *et al.* 1997).

FOOD AS A LIMITING FACTOR

Food may be an important factor limiting seabird populations (Ashmole 1963, Birt *et al.* 1987, Cairns 1992). There is evidence that the recovery of injured piscivorous marine birds in the Gulf of Alaska and Prince William Sound may be limited by food (Duffy 1996). Population sizes of several piscivorous marine birds in Prince William Sound and along the Kenai Peninsula coast had declined before the oil spill (Nishimoto and Rice 1987, Klosiewski and Laing 1994, Agler *et al.* 1995a). Diets of some seabirds in Prince William Sound and the Gulf of Alaska have shifted during the last two decades from energy-rich prey (e.g., Pacific sand lance and capelin) to lower-energy prey (e.g., gadid species) (Hayes 1996, Hayes and Kuletz 1996, Piatt and Anderson 1996), and evidence of food stress has been noted in some birds (Piatt and Anderson 1996).

MONITORING

Following an oil spill, the abundance and productivity of marine bird populations need to be monitored first, to ascertain which populations have been injured, and second, to determine the degree to which the injured populations have recovered. The Trustee Council has funded specific studies designed to measure the abundance and productivity of species identified by the Trustee Council as being injured. However, for species only recently identified as being injured, and for those species whose status is unknown, monitoring activities have not been extensive. Monitoring studies can include colony monitoring for some species and at-sea monitoring for all species. Currently the Trustee Council is funding an at-sea survey that assesses the status of all species in Prince William Sound every two years. These surveys have been conducted since the spill and are being compared to prespill surveys. In addition, the Trustee Council has funded sustained monitoring of common murre colony attendance and productivity in the Barren Islands every year since 1990. Other areas in the spill region have not been monitored since 1990 or 1991.

We recommend that, in addition to common murre sites on the Barren Islands, index colonies and at-sea areas outside Prince William Sound be monitored to determine marine bird population trends throughout the spill area. Areas that are monitored should be selected based on historical data so that recovery can be quantified; one such area is the south side of the Kenai Peninsula. We also recommend that forage fish abundance be monitored regularly in index areas throughout the spill area.