Common murre

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September 14, 1991

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To: Meeting participants

From: Bob Spies, Chief Scientist

Re: Review of Notes from Murre Meeting, 8/27/91

Please review and comment on the meeting summary below and return your comment to me by October 1, 1991.

ABSTRACT

A meeting was held at the Anchorage offices of Preston, Thorgrimson, Shidler, Gates and Ellis to review spill damages to murres in the Gulf of Alaska and to plan tasks necessary to complete the damage assessment and restoration planning. These were the major subjects considered: (1) murre life history, (2). initial losses, as determined by modeling or population census, (3) disruption of production by the spill in several seabird colonies, and (4) recovery and restoration of the populations. The following data were supplied mostly by the principal investigator, Dr. David Nysewander and are found mainly in the 1990 NRDA annual report (Nysewander, 1990). Questions and issues in regard to these data were raised by the peer reviewers and others at the meeting. These are summarized and listed as items to be addressed by further enquiry.

Life History Characteristics of Murres

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Murres are very common sea birds in the Gulf of Alaska, forming large breeding colonies on coastal sea cliffs. Both species, common and thick-billed murres, occur in Alaska. Thick-billed murres are primarily arctic and sub-arctic in distribution, while common murres occur and form breeding colonies in temperate regions. Because the two species tend to nest in the same areas and are extremely similar in appearance, they are often counted together when census is done from sea, while in land-based

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counts they can be differentiated by experienced observers. Murres forage mainly on the continental shelf, with their major prey being capelin, sandlance, and juvenile herring and pollock. Murres may live for more than 20 years. Breeding may starts as at 4 years of age, and by 5 years of age 80% of birds are breeding. Experienced adults arrive on the breeding colonies in the Gulf of Alaska in May and eggs are laid in late June. Younger birds arrive in the colonies later in the season (Birkhead and Hudson, 1977). Generally only one egg is laid per season, but a second egg may be layed if the first is lost There is a 32-d incubation period. After hatching the chicks stay in the colony for about 3 weeks. They then leave the colonies with an adult or, sometimes, a pair of adults. Often it is only the adult male that accompanies the fledgling chick. Sufficient densities of incubating adults are needed on colonies to fend off predators, such as gulls, falcons and eagles. Also, eggs must be laid early enough in the summer to allow sufficient growth of the chicks before autumn storms occur in the Gulf of Alaska. Since inexperienced breeders mate and lay their eggs later than experienced breeders, their chicks are less likely to survive early autumn storms in the Gulf.

Murres are counted both from land and from the sea during the breeding period. Replicate land-based counts are preferred to reduce variability. Ideally these counts should be corrected by a factor of about 1.4 or so to account for the foraging members (at sea) of the pairs incubating the eggs or attending the chicks on the colonies. This correction factor does not account for the non-breeding birds.

Murre populations in the Gulf of Alaska

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It is estimated that the total population of murres in Alaska is 10 million (Alaskan Seabird Colony Catalog, 1991), although this number is more likely to account only for breeding population. Of these there are about 1.4 million in the Gulf of Alaska. Approximately 1.2 million of these birds belong to the Semidi Islands colonies, which were not directly impacted by the spill, although it is possible that non-breeding birds from these colonies were in the area of the spill. Within the spill area it is estimated that there were 319,000 murres on breeding colonies (Piatt, 1990), although this estimate is based on OCSEAP counts of selected at-sea areas and may be conservative . Prespill populations on particular colonies will be discussed below.

Calculation of Initial losses

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As mentioned above, calculation of initial losses is based on two general approaches: (1) modeling of total losses from the number of birds recovered from beaches in the spill area, and (2) changes in populations on breeding colonies after the spill. To the extent that these two estimates are similar each estimate is strengthened. Bird study No. 1, which modeled losses of all birds from the spill calculated that there 316,000 murres killed by the spill. This is based on an estimate that 78% of 405,000 total birds calculated to be killed at sea were murres.

The second method of determining losses of murres depends on comparison of birds in breeding colonies before and after the spill. The baseline data are considered on a colony-by-colony basis for the spill area.

Middleton Island

This island is located 60 mi south of the Hitchinbrook entrance to PWS. There are both pre- and postspill data on this island colony, however oil did not come close to this island and the 31 dead, oiled birds found on this island may have come from sources of oiling other than the spill. Middleton Island was considered as a possible candidate for a control site, however changes in geomorphology of the island during the 1964 earthquake may have set in motion a long-term decline of the colony. The chicks must travel a much longer distance now to the water as they fledge, making them much more vulnerable to predators (Hatch, 19). Fry has recommended, however, that because there are prespill data that indicate a stable population, and post-spill counts indicating a decline, that some consideration be given to using this colony as a control. More statistical testing of the prespill data would, therefore, be in order.

Chiswell Islands

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There is no doubt that the Chiswell Island colony was heavily impacted by the spill, as there were virtually no birds nesting there in 1989. However, a one-time boat count (total of 2384) was taken there in 1989 (Bailey and Rice, 1989); this count included both birds on the islands and birds on the water The number of birds nesting on these islands in 1990, 4371 (based on repetitive counts on land and water), was probably not substantially different than the estimated number of birds on the islands in 1986, 3387 . The 1976 data indicated that there were 6030 birds at the time, probably a significantly larger number than in 1986. However, all the data were not taken using USFWS methods (instituted in the early 1980s) and included birds on the water as well as on the island. Therefore, the totals are not comparable to those of other sites that were surveyed using USFWS

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standard methods. Birds on the water are not now counted using the standard USFWS methods for assessing colonial sea birds. It has been recommended that some of the earlier data based on land and water counts be reanalyzed to compare only the land counts or water counts.

Barren Islands

One-time counts of murres on the Barren Islands in 1975 and 1979 were about 130,000 birds (USFWS computer archives, 1986). However, an aerial census by bird study #2 taken just before the spill showed about 97 thousand murres on the Barren Islands (Piatt et al., 1990). Actually 48, 780 were counted and this number was doubled to account for birds at sea. Counts taken during the 1970's indicated about 30 thousand murres on Nord Island and 20 thousand on East Amatuli Light. Replicate counts taken after the spill in 1989 showed about 12 thousand murres were on Nord Island and 6 to 7 thousand birds were on east Amatuli Light. In addition there are replicate aerial count data taken in late April 1989 that need to be analyzed before the assessment is complete.

Puale Bay

Single counts of murres on Puale Bay colonies in 1976 and 1981 were 92 thousand and 74 thousand murres, respectively. Postspill counts were 37 thousand and 32 thousand in 1989 and 1990, respectively. It could be argued that there has been a continuing decline in murres in this colony since 1976 based on this data, due, perhaps, to the increasing populations of bald eagles in Alaska during this period. However, the prespill unreplicated counts are not enough to establish a prespill population trend. The post-spill 1989 to 1990 change is within the range of variation of murre colonies. It could be further argued that the long-term population record at the Semidi Islands and other colonies, where replicated counts have been taken, does not indicate a downward trend of Murres in the Gulf of Alaska.

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The Triplets

The triplets colony on the Kodiak Archipelago had 1197 birds in 1977 and 1300 birds in 1984 (unreplicated counts). In 1989 after the spill the following replicated counts were made in July: 913 on 7/23, 630 on 7/24 and 987 on 7/25. For 95% confidence, the probability the pre and post-spill counts are different is 0.06.

Ugaiushak Island

This island was oiled. The PI observed shoreline oiling at this island in 1990 and areas to the west of this island were also oiled. A careful census of this island was last made in 1976, and there were between 8 and 10 thousand murres found during the breeding season. A less thorough count from the water was made in 1977 before the breeding season and it was estimated that there were between 12 and 15 thousand birds on the colony. The first post-spill assessment was made in august of 1990--about 5 to 6 thousand murres. Since both the pre and post-spill counts were unreplicated Dr. Nysewander feels that evidence for loss, taken by itself, is somewhat weak for Ugaiushak Island.

Semidi Islands

This serves as a control site, since little or no oil reached these islands. As mentioned above, this is the largest island colony in the Gulf of Alaska with in excess of a million murres (USFWS computer archives, 1986). The prespill data on these islands is quite good with surveys carried out during 7 breeding seasons between 1977 and 1990. During each survey 10 land-based plots were counted. The interyear variance for this colony is relatively low, with total numbers in the 10 plots ranging between 2308 and 2980 murres.

Total initial losses

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Brian Sharp has examined Dr. Nysewander's data for calculation of initial losses in the affected colonies (see below). On advice of Dr. Nysewander Middleton Island and Ugaiushak Island are deleted from the calculations of total losses.

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Murre spill losses from colony counts in 1989 and 1990

Location	Losses individuals	percent
Chiswell's	0	0
Barrens	81,250	60-70
Puale Bay (low)	37,468	50-60
Puale Bay (high)	55,768	50-60
Triplets	457	35

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Total losses low 119,175
high 134,475

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If these values are multiplied by a factor of 1.4 to account for foraging mates at sea then the low value is 167,896 and the high values is 189,316. This does not include non-breeding murres away from the colony.

Loss of production

Murres depend on social interactions for reproductive success and the colony plays an important role in this. The gathering of large numbers of birds in the spring at the colonies may help to induce ovulation. Certainly after egg laying, the adults on the colony that will not leave when predators threaten, creating a common mass defense against loss of young. After the spill certain colonies, such as those on the Barren Islands and at Puale Bay that suffered very heavy losses of breeding age adults, experienced massive reproductive failure. Some reproduction took place, but it was delayed by about a month, producing chicks that were not likely to survive the autumn storms as in normal years. The most likely explanation of the phenomenon of late breeding is that many of the breeders were young inexperienced birds, which tend to arrive at the colonies later in the season lay later than experienced birds. A contributing factor to low chick production was the low density of birds tending successful nests on the colonies, with a subsequent loss of the mass defense against predators. The individual colonies are reviewed below for the impact of this phenomenon on chick production in the spill area in 1989 and 1990.

Chiswell Islands--There was an almost complete lack of egg laying on the Chiswell Islands in 1989; only a few birds layed eggs on the top of Barwell Island. There were large numbers of murres seen on the Chiswell Islands in 1990, but they had not begun to lay eggs in any numbers at the time these Islands were visited (Dave, date?). Thus egg laying was delayed beyond the normal period in 1990 on the Chiswell Islands.

Barren Islands--In 1989 murres did not begin laying eggs until late July (a month late). In 1990 egg laying was again asynchronous, based on information gathered on two dates: 12 to 20th July and 13 to 19th August. There were no eggs or chicks present on land-based plots on Nord Island on the 18th August, suggesting another year of massive reproductive failure. Studies being conducted by Dr. Boursma, University of Washington, may have more detailed records of specific locations on E. Amatouli Light.

Puale Bay--In 1989 egg laying was at least a month late, similar to the situation on the Barren islands. In 1990 egg laying was again 30 to 45 days late (C. Berkman, pers. comm. to B. Sharp). Some chicks were hatched, but very few were fledged. Many chicks perished in a large storm.in mid-September 1990 (Dave, we should put these data on chicks in the report. What were the numbers?).

Semidi Islands--There was normal timing and production in the Semidi Islands in both 1989 and 1990. For common murres 0.54 young were fledged per breeding pair, and for thick-billed murres, 0.42 young per breeding pair. (Dave we need these data for the Barrens and Puale Bay.)

[A question that needs to be resolved: If reproductive failure is due to a large extent to delayed breeding won't those birds (presumably inexperienced in 1989 and 1990) be experienced within the next few years and breed earlier? Won't this phenomenon be expected to make recovery much quicker than it would be otherwise?]

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Birkhead, T.R. and P.J. Hudson. 1977. Population parameters for the common guillemot *Uria aalge*. Ornis Scand. 145-154.

Nysewander, D. 1990. Population surveys of seabird nesting colonies in Prince William Sound, the Outside Coast of the Kenai Peninsula, Barren Islands, and other nearby colonies, with emphasis on the changes in numbers and reproduction of murres. Bird Study Number 3. An unpublished report, US Fish and Wildlife Service, Homer Alaska. 48 pp.

Possible restoration measures

1. Since the discharge of firearms near the breeding colonies scares breeding birds off their nests, making eggs and chicks vulnerable to predators, fisherman should be encouraged to avoid this, especially halibut fisherman near the Chiswell Islands.

2. The possible exclusion of seining activities near colonies.

3. Ground squirrels are an introduced predator at some island sites. These could be removed or controlled.

4. Possible transport of immature eagles from Barren Islands to other areas.

5. Construction of baffles at close intervals on some breeding colonies would discourage predators but probably not interfere with murres.

Activities needed to complete the damage assessment and for restoration planning:

1. Dr. Tony Gaston will review the estimate of the prespill population in 1989. It was thought that this was in bird study No. 2, but it is not. The data are available from USFWS (Karen Bollinger, Bill Butler). Also, Brian Sharp has examined these data sheets.

2. More information is needed on the rate of production on murre colonies from elsewhere to see if production in the Semidi Islands was higher than at other large murre colonies. Brian sharp to do this. This would increase our confidence in the suitableness of the Semidi Islands as a control site.

3. The USFWS will investigate the availability of funds to conduct some aging of the carcasses in the morgues. There is a proposal from Dr. Furness from the University of Glascow to conduct the aging. These data would be crucial to determine how many of the killed murres were young and how many were breeding adults. This would help in reconciling the estimates of total losses from Bird Study No. 1 and from Bird Study No. 3. Carol Gorbics will review this. If funds are limited and only a small sample of birds can be aged, it would be preferable to to focus on a smaller geographical area over a short period of time.

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4. Dr. Nysewander will make a second visit to the Barren Islands, especially East Amatuli Light, as soon as possible to better document chick production there in 1991.

5. Dr. Heineman will coordinate with Dr. Gaston in the development of a model for recovery of murres.

6. Data from other murre colonies in the Gulf of Alaska, such as the Shumagin Islands, should be examined to see if they indicate any pre-spill population trends or for average rates of chick production--Dave Nysewander.

8. The incidental take of murres by fishing in the Gulf of Alaska needs to be documented. Apparently Pat Gould at USFWS Anchorage has some of these data.--Brian Sharp has looked into this preliminarily and it appears to be relatively insignificant, but we will need to obtain any available documentation.

9. An effort should be made to obtain pre-spill productivity data on the Barren Islands. Apparently Dr. Boersma of the University of Washington has such data. Dave Nysewander is to find out the funding sources for the data, and then Brian Sharp will try to obtain any existing prespill data.

cc:	Gertler	Fry	Sharp
	Freedman	Gaston	Senner (for RPWG)
	Belt	Gorbics	Swiderski

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CONFIDENTIAL MEMORANDUM

ANNOTATED LIST OF RESTORATION OPTIONS FOR

COMMON MURRES IN THE AFTERMATH OF THE EXXON VALDEZ SPILL

Prepared by

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17 December 1991

Introduction

Common Murres (Uria aalge) suffered the greatest direct mortality from the Exxon Valdez spill of any species of higher vertebrate. Some spill-affected murre colonies have suffered declines of up to 70% and experienced near total reproductive failure during the three breeding seasons since the spill. This indicates the potential need for restoration activities to encourage, enhance, and/or supplement natural recovery processes. It is not clear at the time of writing whether all damaged colonies have begun the recovery process, and continued monitoring will be crucial in order to detect colony declines in a timely manner so that restoration efforts can be initiated prior to colony extirpation. The loss of a few small breeding colonies of Common Murres is not significant for the statewide population, but some of the colonies decimated by the spill are also some of the most accessible to nonconsumptive users (Chiswell Islands, Barren Islands).

Common Murres are highly colonial nesters and there is evidence that reproductive success is positively density-dependent (i.e., larger colonies experience higher reproductive success). Murre populations are characterized by low intrinsic rate of increase; even under optimal conditions, murre population increase rarely exceeds 10%/year. Recovery of some colonies to pre-spill levels may require 75-100 years. However, recruitment of subadults from other murre colonies could substantially enhance natural recovery rate.

I have divided the restoration options listed below into three groups: (1) direct on-site restoration, (2) indirect on-site restoration, and (3) off-site restoration, both direct and indirect. By direct restoration, I mean activities that are directed specifically at murres, as opposed to their food supply or predators. By on-site, I mean restoration activities conducted at breeding colonies where damaged from the spill has been documented. Off-site restoration is either regional or directed at murre populations outside the spill area.

I have spoken by phone or in person with the following experts regarding potential restoration techniques for murres: David Ainley (Point Reyes Bird Observatory), Michael Fry (U.C. Davis), Anthony Gaston (CWS), Stephen Kress (Cornell Lab. of Ornithology), Christopher Mead (BTO), David Nettleship (CWS), Ian Nisbet, Nadav Nur (PRBO), David Nysewander (USF&WS), Raymond O'Connor (U. of Maine), and John Piatt (USF&WS). In addition, I have corresponded with C. Swennen (Netherlands Institute for Sea Research), William Montevecchi (Memorial U.), and John Croxall (British Antarctic Survey). George Hunt (U. C. Irvine) provided written comments on an earlier draft of this memo. I am grateful to these individuals for freely sharing their ideas and expertise with me. In the discussion that follows, I have tried to credit them for their input on particular restoration options.

Direct restoration of murres is a novel and somewhat controversial endeavor. Although murre populations have been previously damaged by oil spills and other human-related perturbations, I have found no evidence of previous direct restoration activities that targeted murres. Proponents of direct restoration of murres cite (1) the slow pace of murre colony recovery in the absence of human intervention, (2) the need to prevent extirpation of decimated murre colonies should natural recovery fail, (3) long-term benefits that may derive from development of murre restoration technology, (4) the opportunity afforded by the spill to test the feasibility of various direct restoration options using controlled experimentation, and (5) an obligation to expend restoration resources on species most damaged by the spill. Detractors of direct restoration for murres voice all or some of the following concerns: (1) technology for direct restoration of murres is in its infancy and there is a high risk of failure; (2) there is risk of unanticipated negative side effects from direct restoration; (3) direct restoration will not provide significant benefits to damaged murre colonies at a reasonable cost; (4) the limited funds available for restoration should be spent on habitat restoration or protection that will benefit more than a single species.

The success of murre restoration, whether direct or indirect, will depend on the continued monitoring of spill-affected colonies, particularly those that may be involved in on-site restoration activities. Generating data on the factors influencing murre survival and productivity at these sites is crucial to any restoration effort. Murre restoration poses a three-pronged challenge: (1) determine the factors currently limiting murre survival and productivity, (2) devise techniques to mitigate those factors, and (3) evaluate the efficacy of restoration techniques.

I. DIRECT ON-SITE RESTORATION

A. Social Stimulus Enhancement

1. Playback of recorded murre calls
   - use solar-powered tape players to continuously play recordings of murre calls at breeding colonies (Kress)

2. Painted murre decoys
   - place wood decoys on breeding ledges in an attempt to attract more adults to nest sites (Kress)
   - place styrofoam decoys on water beneath breeding cliffs (Montevecchi)

3. Mirrors
   - create the illusion of larger numbers of murres in attendance on breeding ledges (Gaston)

4. Dummy murre eggs
   - place painted wooden or plaster eggs on breeding ledges to provide a visual stimulus for laying (Gaston)

Notes: Productivity at colonies affected by the spill is suffering from delayed phenology, lack of reproductive synchrony, low hatching success, and low survival of pre-fledging chicks (Nysewander). The late timing of fledging probably also results in poor post-fledging survival. Surprisingly, these problems have persisted at some spill-affected colonies for three breeding seasons after the spill. Social factors are the most likely cause of these effects (Fry, Nisbet, O'Connor, Piatt, Swennen), but other factors may be involved (see below). There are probably few experienced breeders at those colonies where extensive adult mortality occurred following the spill. Also, breeding adults that did survive probably lost their mate and were forced to pair with inexperienced individuals (Nisbet). Those subadults that survived the spill and replaced breeding adults that died would be expected to breed later and be less synchronized (Nettleship, Gaston). Even for experienced breeders, there may be a critical number or density of other breeding adults necessary to stimulate ovulation. The persistence of reproductive impairment following the spill suggests that the vast majority of experienced breeders at certain colonies were killed (Gaston).

An increase in social stimuli may increase colony attendance, stimulate earlier onset of egg-laying, and increase egg-laying synchrony. All of these changes would be expected to result in improved production of young. Social stimulation of reproduction (using playbacks of murre calls and painted wooden decoys in the colony) has proved effective in attracting Atlantic Puffins to nest on islands off the coast of Maine where they have been absent for over a century (Kress). Providing an auditory "super stimulus" (high volume playbacks of murre calls recorded at a large colony) may serve as a strong attractant for prospecting murres that periodically visit colonies other than their natal colony (Mead).

Use of decoys, recordings, mirrors, and dummy eggs may be effective in the case of murre colonies that were severely affected by the spill and where breeding synchrony and reproductive success are chronically impaired. However, if poor reproductive success is primarily an artifact of the young age and inexperience of most of the survivors, then recovery may require time regardless of restoration efforts (Hunt). If a colony is declining with little prospect of recruiting additional breeders, then this restoration option may be effective in maintaining the colony as an active breeding site (Kress). However, if recruitment is limited by the availability of recruits, then there will be little that can be done to enhance colony growth by decoying new individuals to the colony (Hunt). This restoration activity is experimental, and the feasibility of stimulating breeding using decoys, recordings, dummy eggs, and mirrors should be tested prior to implementation on a large scale. Negative effects are possible for several of these options. Some examples: (1) painted decoys on breeding ledges may cause gaps between nesting murres that predators can use for access to the colony center; (2) decoys on the water may initially attract birds, but may then hold them on the water and decrease movements to nest sites; (3) mirrors on breeding ledges may elicit endless aggressive displays by birds toward their reflection, interfere with already present nest site fidelity, and birds may even fly into them; (4) dummy eggs might attract predators, occupy otherwise useful nest sites, or confuse incubating murres; (5) if playbacks of murre calls include alarm and /or aggressive, they may disrupt normal breeding behavior (Hunt).

The oil spill offers an opportunity to test restoration techniques for enhancing productivity following decimation of a murre colony (Gaston). However, in order to evaluate the efficacy of any novel and direct restoration technique, it is vital to carefully establish and monitor control sites. Also, some of the most severely decimated murre colonies (e.g., the Barren Islands) are some of the most difficult to work on in Alaska. Access to the murre breeding ledges is hampered by the lack of accessible beaches below, the unstable condition of cliff faces, and the paucity of unshore vantage points (Nysewander). Some of the most workable sites on the Barrens (e.g., East Amatuli Light) are also sites where some incipient recovery appears to be taking place.

Conclusions: This restoration option should receive careful consideration for feasibility studies during the 1992 breeding season. The techniques are amenable to tests of effectiveness by designating portions of decimated colonies as control and experimental sites. Experimental and control sites must be carefully selected so that differences in site characteristics do not confound interpretation of results. If nest site occupancy, onset of laying, egg production, laying synchrony, and fledging success are significantly enhanced in experimental sites compared to controls, then efforts to employ these techniques could be expanded. However, it should be emphasized that this restoration option can not be practically employed on a sufficiently large scale to produce substantial increases at all or even most of the spill-affected murre colonies.

B. Nest Site Improvement

1. Provide breeding ledges with sills
   - sills would mitigate egg loss due to eggs rolling off the breeding ledge (Gaston)

2. Construct partitions and/or roofs on nesting ledges
   - enhance security of nest sites from avian predators (i.e., bald eagles, gulls, ravens) (Gaston, Nysewander)

3. Blanket-off or cover portions of breeding cliffs
   - exluding murres from portions of cliffs that offer few large ledges may induce aggregations on a few broad ledges that provide the best opportunity for successful breeding (Mead)

4. Enlarge nesting ledges on cliff faces
   - dense aggregations of breeding murres on broad ledges are conducive of high production (Gaston)

5. Clearing debris, soil, and vegetation from otherwise suitable nest sites (Tuck, Uspenski)

Notes: All of the above restoration techniques are experimental. But experiences of biologists in the field suggest that these techniques may be effective in enhancing murre nesting success. All modifications to cliff nesting sites should, of course, be accomplished during the non-breeding season. The simple technique of providing nesting ledges with a sill to prevent murre eggs from rolling off the ledge may considerably improve hatching success. At some murre colonies egg breakage accounts for 60% of egg losses (Gaston). However, Common Murres prefer to nest on broad ledges where egg breakage may be less of a problem than it is for Thick-billed Murres, which usually nest on narrow ledges (Hunt). Murre eggs that pile up at sills constructed on broad ledges may not be retrieved by adults (Hunt). Protection of nest sites from avian predators would be enhanced by construction of partitions and/or roofs on nesting ledges (Gaston). Avian predators on murre adults, chicks, or eggs normally approach nesting ledges from above (eagles) or from the side (gulls), whereas adult murres approach their nest sites from below. Partitions and roofs may inhibit predators without detering use of nest sites by murres. Partitions spaced at 2'- 3' intervals may provide the greatest benefits without impairing murre reproduction (Gaston). However, these structures may also provide perches for avian predators to launch attacks on murre eggs or chicks (Hunt). Partitions, roofs, and sills in conjunction with decoys, mirrors, dummy eggs, and playbacks could attract murres to safe nest sites that would otherwise go unused due to a lack of social stimuli.

Excluding murres from suboptimal nest sites may improve occupancy on better ledges and enhance reproductive success (Mead), but it is difficult in practice because of the strong nest site tenacity of murres (Gaston). Forcing breeding murres to occupy new nest sites may also disrupt breeding pairs and contribute to delayed and unsynchronized laying, particularly if the most favored breeding sites are inadvertently covered. By providing larger nesting ledges, larger aggregations of breeding murres may form and thereby increase social stimulation for breeding. L.M. Tuck, in his book The Murres (1960), reported on several successful attempts to enhance murre nesting habitat by paving ledges in order to combine and strengthen them. He even recommended construction of artificial concrete ledges. He also reported successful attempts to establish or enhance murre breeding populations through habitat improvement, consisting variously of removing debris, small rocks, soil, and/or vegetation.

These restoration techniques may enhance reproductive success and colony occupancy at sites where reproduction is chronically impaired. But the practical aspects of effectively modifying cliff nesting habitat to achieve the desired results are largely unproven. Also, modification of breeding ledges runs the risk of displacing breeding pairs that are attempting to nest (Nettleship). Murres display strong nest site fidelity and displacement from nest sites may seriously disrupt breeding.

Conclusions: This restoration option carries some risk of negative side effects and may not produce a detectable increase in colony numbers. However, modifications of particular breeding cliff may provide significant enhancement of productivity. The cost-effectiveness of this restoration approach can not be ascertained based on current knowledge. While some experts question whether this restoration option will provide appreciable and cost-effective enhancement of breeding populations affected by the spill, I believe that it warrants consideration for a feasibility study. Murre restoration technology that could be developed in this area would be valuable. It will be critical to the success of any feasibility studies that all experiments be controlled.

C. Construction of Artificial Nesting Habitat

1. Modify cliff faces
    - relatively minor alterations of cliffs otherwise suitable for murre nest sites to render them inaccessible to mammalian predators
    - use scaffolding to provide nesting ledges on sheer cliffs

2. Construct artificial cliffs
    - masonry cliff faces to provide nest sites at locales where steep slopes or cliffs do not exist

3. Create cliff nest sites using explosives
    - blast out cliffs from slopes over-looking the sea

Notes: This restoration option seeks to enhance local productivity by increasing the availability of nest sites (cliff ledges) where they are limiting or lacking. This technique can vary from inobtrusive and minor modifications of cliff faces so as to eliminate access points by mammalian predators to use of explosives to produce cliff faces suitable for murre nesting. In some instances, fairly minor modifications to a site may render it inaccessible to foxes and other potential egg and chick predators. However, none of the spill-affected colonies are apparently subject to significant mammalian predation. At sites where sheer cliffs rise from cobble beaches, scaffolding might be used to provide broad nesting ledges where they are otherwise absent. Use of explosives or construction of artificial ledges may be necessary to provide suitable nesting habitat where none currently exist, but there is no assurance that new nesting habitat would be occupied. These restoration options are unlikely to be effective if suitable nesting habitat is not limiting (Nettleship). In addition, these modifications are provide mostly temporary benefits and are viewed by some as measures of desperation (Hunt).

Conclusions: It is unlikely that this restoration option will provide appreciable and cost-effective enhancement of breeding populations affected by the spill. Also, there is no indication that suitable nest sites are limiting, particularly for populations decimated by the spill. Finally, some of these options may result in permanent alteration of coastal landscapes to benefit murres, but detract from the pristine character of the landscape. I do not recommend this murre restoration option for consideration in 1992.

D. Release of Captive-reared Murres

1. Captive propagation of murres
   - use captive adult murres to obtain murre fledglings for release at target colonies (Swennen)

2. Captive rearing of murre eggs/chicks
   - collect fresh eggs from healthy murre colonies, hatch and raise chicks in captivity, transfer chicks to target colony for imprinting and release

3. Transfer of chicks between colonies
   - transfer young chicks caught at healthy murre colonies to colonies where reproduction is impaired, hold in pens until imprinted, and release (Kress)

Notes: This option makes use of the natural tendency of many colonial seabirds to return to their natal colony to breed. Transfer of chicks between colonies has been successfully employed to reestablish extirpated Atlantic Puffin colonies in the Gulf of Maine, and has been suggested as a potential method to enhance murre recruitment at colonies where reproduction is chronically impaired (Kress). Successful propagation of Common Murres in captivity has been accomplished by the Netherlands Institute for Sea Research, Texel, where captive adult murres produced fertile eggs that were then successfully raised by hand (Swennen). Captive-reared murres were released at Texel and later returned to the site where they had been raised and released, apparently prospecting for nest sites. This demonstrated for the first time that captive-reared murres could survive in the wild and would return to their natal area.

Annual egg production of captive adult murres is low, and using captive adults as a source of young for release is not cost-effective (Swennen). Alternatively, young murre chicks could be captured at healthy murre colonies and transferred to damaged ones. However, collecting chicks at murre colonies would impair recruitment at the donor colony due to: (1) removal of chicks, (2) egg loss resulting from breakage and predation when parents were not guarding their eggs, and (3) chick mortality resulting from premature fledging (Nettleship). The best option for obtaining chicks to release at a target colony is to collect fresh eggs from healthy donor breeding colonies. Wild murres will usually relay if their egg is removed or destroyed shortly after laying, so collection of eggs in the wild may have little or no effect on donor colony productivity. Eggs would be placed in incubators for hatching and hatchlings would be fed by hand until 4-5 weeks old.

The young do well in captivity on a diet of frozen fish (Swennen). Beginning at 4-5 weeks, murre fledglings will feed themselves if provided with fish in a tank or swimming area (Swennen). At three weeks post-hatching, murre chicks would be transported to the release site and held in outdoor pens with access to seawater. Murre feathers are easily fouled with excrement and waste food, causing lose of water repellancy, so providing fresh seawater is critical (Swennen). At approximately 8 weeks of age, fledgling murres would be released in groups of several dozen individuals. Murre fledglings normally go to sea with their male parent at about three weeks of age and receive considerable post-fledging parental care. Captive-reared fledglings released in groups when nearly full-grown may survive at nearly the rate of natural fledglings.

Common Murres normally breed for the first time at 4 years, so it would be several years before the survival of released murres could be determined through resightings of color-banded individuals at the release colony. If the release site had been completely abandoned by breeding adults, captive-reared birds would presumably search out other active colonies in which to breed. Artificial social stimuli (decoys, playbacks, dummy eggs, mirrors) would be necessary to attract captive-reared subadults to an abandoned colony, but these efforts may not be effective.

Captive-rearing and release is a highly experimental restoration method. Development of the technology for reestablishing extirpated murre colonies would be valuable, regardless of whether it is used to restore colonies affected by the spill. Plans are underway to use captive-rearing and release techniques to reestablish decimated murre colonies in California (Kress). But conducting such a feasibility study at spill-affected colonies in the Gulf of Alaska would be expensive and logistically difficult (Swennen).

If one or more murre colonies are eventually completely abandoned, releasing captive-reared young should be given consideration as a restoration option (Kress). However, the captive propagation and release option would only produce relatively small numbers of potential recruits (100's). The low predicted survival of released young to adulthood (< 10%, Nettleship), high cost of captive rearing, and potential negative impact on colonies that serve as sources for eggs (Nettleship) led some experts to recommend against this restoration option (Nettleship, Swennen).

Conclusion: The captive-rearing and release is, in my opinion, not justified as a technique to enhance recruitment at active murre colonies. However, if a breeding colony has been completely extirpated, this technique may be the sole option for reestablishing a colony. To date no murre breeding colonies are known to have been abandoned as a result of the Exxon Valdez spill. Even in cases of complete abandonment, this technique is experimental, risky, and expensive. It would be valuable to develop the technology for successful reestablishment of extirpated colonies or enhancement of decimated colonies, but Gulf of Alaska colonies seem a poor choice for feasibility assessment. This restoration option is not recommended for implementation or feasibility study during the 1992 breeding season.

II. Indirect On-site Restoration

A. Avian Predator Control

1. Control populations of gulls and ravens using lethal means (Nysewander)
   - DRC-1339 poison bread baits
   - shooting
   - oiling eggs

2. Live-trap and remove juvenile Bald Eagles
   - transport problem eagles to sites in the lower 48 where eagle restoration programs are underway (Nysewander)

Notes: Glaucous-winged Gulls and Northern Ravens are the most frequent predators on murre eggs and young at spill-affected colonies (Nysewander). Gulls can be a major source of egg mortality, accounting for 40% of egg losses at some colonies (Gaston). Gulls also take chicks from nesting ledges or as they attempt to fledge. Gull colonies are associated with most of the murre colonies in the northern GOA. Gulls have a much higher reproductive potential than murres and populations in the Gulf of Alaska are generally increasing. Temporary gull control measures could enhance murre productivity without threatening gull populations. Gulls and ravens nest earlier than murres, so control activities could be timed so as not to disrupt murre nesting (Nysewander, Kress). Gull control has been used successfully to enhance nesting success at some seabird colonies and has been an integral part of attempts to reestablish extirpated seabird colonies in the Gulf of Maine (Kress). Bread baits treated with the avicide DRC-1339 are an effective means of controlling gulls and pose no risk to other piscivorous seabirds (Kress). However, poisoned gulls might be a source of secondary poisoning for Bald Eagles. Shooting is another effective means of gull control with little chance of affecting non-target species. Another method of controlling gull populations is to oil gull eggs so that they fail to hatch, but the parents continue to attend the eggs until it is too late in the season to renest. However, this control technique may have little affect on the size of the gull population for some years and is considered too slow to be useful (Hunt). Destructive gull control is the only proven effective technique for mitigating the impact of gulls on seabird reproductive success (Kress) (but see I-D above).

Bald Eagles, unlike gulls and ravens, are known to take adult murres (Nysewander). Eagles elicit a strong panic response from adult murres on nesting ledges and indirectly result in losses of eggs and young to other avian predators. Some juvenile Bald Eagles are resident at murre colonies during the breeding season and cause significant disruption of breeding activities (Nysewander). Bald Eagles have apparently increased significantly in the northwestern GOA during the last few decades and are causing considerably more losses at murre colonies than in the past (Nysewander). Destructive control of problem Bald Eagles is certainly not feasible, but removing them to remote locations from which they are unlikely to return is an option.

Conclusions: Where decimated murre colonies are experiencing consistently poor reproductive success, it may be advisable to control gulls, eagles, and/or ravens on a temporary basis as a means to enhance natural recovery. However, this restoration option creates public relations problems. Before any avian predator control is instituted, it is crucial that intensive field studies be conducted to document prevalence and intensity of mortality and reproductive failure associated with avian predators (Piatt). A clear justification for predator control needs to be obtained prior to initiation of control measures (Kress). I recommend that the effects of avian predators on murre survival and reproductive success at spill-affected colonies be investigated in 1992, as a prelude to potential predator control measures.

B. Mammalian Predator Control

1. Eliminate introduced foxes from islands that support murre colonies

2. Eliminate or control other introduced mammals (e.g., ground squirrels on the Barren Islands) on breeding islands

3. Control native mammalian predators on islands and headlands where murre colonies exist

Notes: Elimination of arctic foxes that were intentionally introduced to the Aleutian Islands has been shown to be a very effective seabird restoration activity. Although murres generally nest on inaccessible cliff ledges, foxes are adept at reaching some ledges and preying on large numbers of eggs, chicks, and even adults (pers. obs.). However, there are apparently no colonies in the spill-affected area that are subject to fox predation (Nysewander, Piatt). Arctic ground squirrels have been introduced to the Barren Islands, but apparently pose no threat to murres, their eggs, or their young, mostly affecting burrow-nesting seabirds (Nysewander). In cases where native mammalian predators (e.g., otter, mink) are contributing to egg and chick losses, temporary predator control may be warranted. However, I know of no murre colonies in the spill-affected area that suffer significant losses to mammalian predators.

Conclusions: Current knowledge indicates that this is not a restoration option for murre colonies in the oil spill area. However, mammalian predation on murre eggs, chicks, or adults may not be apparent without fairly intensive on-site investigations, so it is possible that this is a viable restoration option for some spill-affected colonies. As with restoration option II-A, it is critical to acquire more site-specific information on the effects of predators on murre nesting success prior to initiation of any predator control measures.

C. Reduction of Human Disturbance at Breeding Colonies

1. Prohibit discharge of firearms near murre colonies during the breeding season
   - use of firearms to kill halibut has been noted near colonies in the spill-affected area, resulting in disturbance of breeding murres (Nysewander)

2. Prohibit use of explosive devices near murre colonies during the breeding season
   - use of firecrackers to drive salmon into gill nets has been noted near colonies in the spill-affected area and resulted in disturbance of breeding murres (Nysewander)

3. Prohibit over-flights of colonies by helicopters and fixed-wing aircraft during the breeding season
   - breeding murres respond to aircraft with panic flights that are at least as disruptive as those elicited by avian predators

4. Prohibit close approach to colonies by tour boats and other watercraft during the breeding season
   - on occasion tour boats may approach murre colonies so closely that breeding adults may leave nest ledges

Notes: This restoration option seeks to minimize disturbance that may cause adult murres to leave the breeding ledges in panic flights, thus causing eggs to roll off ledges or expose eggs and chicks to avian predation. The potential detrimental effects of shooting in proximity to murre colonies has been recognized for some time, and in the Faeroe Island and Iceland shooting within a mile or two of murre colonies is prohibited. Breeding murres are more sensitive to loud noises and aircraft than the close approach of vessels. Consequently, it may be possible to eliminate losses due to disturbance from tour boats by educating operaters about the effects of certain activities at critical times on murre nesting success. Keeping and maintaining a public constituency for marine birds is a worthwhile benefit from tour boat excursions in the area (Nysewander).

The evidence that any of the above factors result in significant nesting failure in the spill-affected area is anecdotal at best, and needs better documentation. Regulations limiting any or all of the potentially injurious activities listed above should be feasible and of considerable value (Hunt). But some enforcement, perhaps in conjunction with monitoring activities will be essential. Enforcement and compliance may be limited in the absence of documentation of damages related to these activities.

Conclusions: Another advantage of the kind of intensive colony-based investigations required to document murre losses to predators is to document losses resulting from human disturbance. Without Nysewander's observations on the effects of firearms and firecrackers on murre colonies, these activities would not be suspected as factors contributing to reproductive failure. Regulations restricting disruptive human activities near murre colonies during the breeding season (particularly C-1, C-2, and C-3 above) should receive careful consideration as restoration options for 1992.

D. Monitor Recovery, Including from Restoration Actions

1. Regular population monitoring at several selected colonies
   - use standardized census techniques to monitor population size at colonies affected by the oil spill
   - determine recovery rates of damaged colonies
   - compare population trends with colonies outside the spill-affected area (i.e., Semidi Islands, Middleton Island)
   - compare population trends with model populations based on best estimates of age structure, reproductive success, and recruitment (Hunt)

2. Colony-based monitoring of reproductive output
   - investigate factors responsible for persistent reproductive failure at some murre colonies
   - determine ratio of attending adults that produce eggs (breeders) to nonbreeders (Hunt)
   - determine age class distribution of attending murres (Hunt)
   - determine numbers of local murres available for recruitment to affected colonies (Hunt)
   - determine timing of hatching, hatching success, and hatching synchrony
   - determine chick survival and fledging success

3. Monitor results from on-site restoration activities
   - determine cost-effectiveness of restoration options

Notes: Monitoring recovery is an important information need. The extent and persistence of damages to particular murre colonies should determine the type and intensity of murre restoration activities. A major information need is for data to improve our understanding of the underlying causes of continued colony decline, reproductive failure, or failure of some colonies to recover in the aftermath of the spill. We still do not know what factors (e.g., social disruption, food supply, food contamination) are responsible for the unexpected persistence of reproductive failure at some spill-affected colonies. Most experts expressed serious concern that the underlying causes of continued reproductive impairment at some murre colonies are not understood. Restoration activities designed to provide social facilitation for reproduction will fail if reproduction is limited by food supply (Nettleship). In addition,

Murres are long-lived and it would require reproductive failure over an extended period to lose the tradition of nesting at a particular breeding colony, providing the surviving adults did not abandon the colony first. Modest increases in colony attendance would be expected for several years after the spill, even in colonies experiencing complete reproductive failure, as surviving subadults are recruited into the the breeding population (Hunt). This underlines the importance of monitoring all affected colonies for an extended period of 10-15 years, not just the largest or most accessible. A major information need is to known if and when colonies that have experienced reproductive failure resume laying, hatching young, and successfully fledging young. Colony attendance should be monitored to determine if certain colonies are eventually lost due to attrition of breeding adults. If a trend toward declining colony attendance and little or no reproductive success is documented over a period of several years, then restoration activities should be directed at the threatened colony.

Conclusions: Monitoring recovery, identifying factors affecting recovery, and monitoring effects of restoration activities are critical components of restoration. Current monitoring activities for murres should be expanded to include more intensive investigations at colonies that experienced severe losses of breeding adults and that have shown no indication of natural recovery. The establishment and monitoring of study plots, where feasible, should be used to quantify breeding phenology and reproductive success.

III. Off-site Restoration

A. Mitigate Incidental Take

1. Restrict use of salmon gill nets near murre breeding colonies in the spill area

2. Restrict fishing practices that result in a significant by-catch of Common Murres in the northern GOA

Notes: Incidental take of murres by commercial fisheries in the Gulf of Alaska portion of the EEZ is unknown but probably small (Piatt). Salmon gill net fisheries in West Greenland were responsible for huge losses of Thick-billed Murres, but there is no indication of a comparable by-catch in Alaska. For a long-lived species with low fecundity, such as the Common Murre, an increase in adult mortality would have a greater population-level effect than a decline in productivity. Mitigating losses of adults may be one of the most effective means of enhancing natural recovery.

Conclusions: This potential restoration option identifies an important information need: the extent of incidental take of murres by commercial fisheries in the northern Gulf of Alaska. Restoration options designed to mitigate incidental take are not recommended in the absence of evidence that significant mortality occurs.

B. Enhance Forage Fish Availability

1. Restrict commercial harvest of forage fish, i.e., capelin and sandlance

2. Mitigate by-catch of forage fish by commercial fisheries

3. Restrict production of hatchery salmon
   - hatchery salmon may compete directly with murres and other seabirds for forage fish stocks

Notes: The continued reproductive failure at some murre colonies affected by the spill is probably caused by the loss of most of the experienced adult breeders in those colonies and the resultant social disruption (Nisbet, Nysewander, Gaston). However, delayed onset of laying, lack of laying synchrony, and poor reproductive success are also indicators of inadequate food supply within foraging distance of the breeding colony (Nettleship). Several experts considered forage fish availability to be a reasonable alternative explanation for persistent reproductive failure (Hunt, Mead, Nettleship, O'Connor). There is considerable circumstantial evidence that a lack of available forage fish has had a negative impact on both marine birds and mammals (Hunt). This explanation was given more credence by experts from the U.K. and Maritime Canada, where there is a well-documented history of commercial over-harvest of forage fish coupled with poor seabird reproductive success. The forage fish explanation is less favored by Alaska experts.

Waiting until four or five years of reproductive failure have elapsed before investigating alternative explanations for reproductive failure is ill-advised (O'Connor). Food supply can be investigated by monitoring the type, size, and frequency of prey delivered by parents to their chicks, as well as the growth rates of chicks. Although murre breeding success has remained normal at the Semidi Islands and Middleton Island (Nysewander), colonies to the west and east of the oil spill area, respectively, these colonies are also influenced by different currents (Piatt). The concensus among Alaska seabird experts seems to be that commercial harvest or incidental take of forage fish (i.e., capelin and sandlance) in the northern GOA is not sufficient to warrant concern (Nysewander, Piatt). However, the large production of hatchery salmon may be responsible for reductions in forage fish stocks, possibly resulting in poor reproduction and population declines in a variety of seabirds and marine mammals. Murres are relatively tolerant of reductions of forage fish compared to surface-feeding seabirds, such as kittiwakes (Gaston). Kittiwakes have been suffering mediocre-poor reproductive success in much of the northern GOA for the last decade.

Persistent contamination of the food supply is a third potential explanation for continued reproductive failure at some murre colonies. Sandlance in particular may be a dietary source of petroleum hydrocarbons for murres (Nisbet). Effects of petroleum ingestion on reproduction have persisted for two years in some seabirds (Fry). However, the concensus among seabird experts seems to be that persistent contamination of the food supply is an unlikely explanation for three years of reproductive failure following the spill (Fry, Gaston, Nysewander, Piatt).

Conclusions: Forage fish availability may be limiting reproductive success at spill-affected murre colonies. Information is badly needed to address food supply and food contamination as potential causes of persistent reproductive failure in murres. Food supply problems may offer few options for murre restoration. But if food is limiting, otherwise effective restoration options may fail to expedite natural recovery. Shortages of forage fish appear to be affecting a variety of piscivorous marine birds and mammals in the PWS/GOA ecosystem. Murres are but one of the species that would benefit from a better understanding of the factors limiting forage fish. Without better information, it will be impossible to take effective measures to restore forage fish stocks. A year or so of planning would be appropriate before any major studies addressing the availability of forage fish are initiated. However, this should not preclude the timely collection of information on diet and feeding rates at successful and unsuccessful colonies in the interim (Hunt).

C. Predator Control

1. Eradication of introduced arctic foxes on seabird breeding islands

2. Gull control at murre colonies

Notes: Eradication of introduced arctic foxes from some islands in the Aleutian Chain has resulted in dramatic increases of breeding seabirds. Some Aleutian Islands still support fox populations, but none of the islands in question were affected by the oil spill. Nevertheless, restoration of large numbers of murres (and other seabirds) could be realized at a relatively low cost from fox eradication programs. Eradication could be achieved by a combination of shooting, poisoning, and gasing dens, followed by dropping of poisoned baits from aircraft during late winter when food is limiting for foxes and they spend most of their time foraging for food along the beach.

Another potential means of enhancing recovery is to mitigate factors that impair fledging success at murre colonies within the oil spill area, but not severely affected by the spill. For example, the Chisik Island colony of about 24,000 murres in Cook Inlet was not affected by the oil spill, but murres raised on Chisik may be recruited to nearby colonies decimated by the spill. Gull control at Chisik Island may be a means of helping restore the murre population on the Barrens.

Conclusions: Fox eradication projects on the Aleutian Islands are extremely worthwhile and should receive consideration, despite the absence of benefits to the spill area.

D. Protect/Acquire Breeding Colonies

1. Purchase murre breeding colonies that are currently in private ownership

Notes: Gull Rock in Kachemak Bay, The Triplets off Kodiak Island, and Ugaiushak Island off the Alaska Peninsula are examples of murre breeding colonies in the oil spill area that are currently or may soon be in private ownership. Most murre colonies are in federal ownership as part of the Alaska Maritime National Wildlife Refuge. Those not in federal ownership do not appear to be in imminent danger, but inclusion in the Refuge would assure that future developments would not threaten the resource. Gull Rock in particular is in a high visibility location with considerable tourist visitation and nonconsumptive use. It is also close to the Refuge office in Homer.

The Triplets are located near Kodiak Island and are currently in private ownership (Nysewander). Pre-spill murre population estimates were about 1,300 and the population is apparently down 35% in the aftermath of the spill (Nysewander). Ugaiushak, off the Alaska Peninsula, supported about 9,200 breeding murres prior to the spill. Losses due to the oil spill are thought to be minor (Nysewander). The island has been selected by a native corporation and future ownership is uncertain.

Conclusions: I recommend that attempts be made to acquire Gull Rock for inclusion in the Alaska Maritime N.W.R. Because this murre colony was apparently not significantly affected by the spill, it can potentially provide new recruits for the decimated colonies in the Barren Islands. Because of its location it could provide to the public an accessible example of the kinds of wildlife resources and habitats protected by the Refuge. Prospects for acquiring The Triplets and Ugaiushak Island should be investigated.

SUMMARY OF CONCLUSIONS

The most feasible options for direct restoration are enhancement of social stimuli (I-A), with its various permutations, and nest site improvement (I-B). These two approaches could be tested in concert. However, direct restoration activities may prove too costly and ineffective for appreciably enhancing recruitment at damaged colonies. The most promising potential method of indirect restoration is control of avian predators, but no control program should be initiated without prior studies to assess the severity of the problem. Such research could also provide information on the impact of mammalian predation and human disturbance. The latter option holds considerable promise as a means of effective indirect restoration.

The best off-site restoration options appear to be eradication of introduced arctic foxes from islands in the Aleutians and acquisition/protection of seabird breeding colonies that are currently in private ownership. Enhancement of forage fish stocks and mitigation of incidental take of murres by commercial fisheries are both potentially effective restoration techniques, but current knowledge of these factors as they affect murre survival and reproduction are inadequate to judge potential efficacy. The efficacy of any and all restoration options is dependent on continued monitoring of spill-affected and control murre populations and the factors limiting those populations. Monitoring efforts must remain the foundation of any attempts to restore murre populations to pre-spill levels.

Stan's copy

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Cooperative Wildlife Research Laboratory
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MEMORANDUM DATE: 29 November 1991

CONFIDENTIAL

TO: Stanley E. Senner
Oil Spill Restoration Planning Office
Alaska Department of Fish and Game

FROM: Daniel D. Roby FAX: 618-453-6944
Cooperative Wildlife Research Laboratory
Southern Illinois University

Daniel D. Roby

RE: Review of Murre Restoration Options

In response to your memo of 20 September, I have reviewed potential murre restoration options, paying particular attention to those options that may be feasible for implementation or study in 1992. Common Murres (Uria aalge) suffered the greatest direct mortality from the Exxon Valdez spill of any species of higher vertebrate. Murre populations are characterized by low intrinsic rate of increase. Some spill-affected colonies have apparently experienced near total reproductive failure during the three breeding seasons since the spill. These considerations indicate the need for restoration activities to encourage, enhance, and/or supplement natural recovery processes. It is not clear at the time of writing whether all damaged colonies have begun the recovery process, and results from continued monitoring may indicate that extirpation of some colonies can only be avoided by direct restoration efforts. The loss of a few small breeding colonies of Common Murres is not significant for the statewide population, but some of the colonies decimated by the spill are also some of the most accessible to nonconsumptive users (Chiswell Islands, Barren Islands).

I have divided the restoration options listed below into three groups: (1) direct on-site restoration, (2) indirect on-site restoration, and (3) off-site restoration, both direct and indirect. By direct restoration, I mean activities that are directed specifically at murres, as opposed to their food supply or predators. By on-site, I mean restoration activities conducted at breeding colonies that were damaged by the spill. Off-site restoration is either regional or directed at murre populations outside the spill area.

I have spoken by phone with the following experts regarding potential restoration techniques for murres: Michael Fry (U.C. Davis), Anthony Gaston (CWS), Stephen Kress (Cornell Lab. of Ornithology), Christopher Mead (BTO), David Nettleship (CWS), Ian Nisbet, David Nysewander (USF&WS), Raymond O'Connor (U. of Maine), John Piatt (USF&WS). In addition, I have corresponded with C. Swennen (Netherlands Institute for Sea Research), William Montevecchi (Memorial U.), and John Croxall (British Antarctic Survey). I am grateful to these individuals for freely sharing their ideas and expertise with me. In the discussion that follows, I have tried to credit them for their input on particular restoration options.

Direct restoration of murres is a novel and somewhat controversial endeavor. Although murre populations have been previously damaged by oil spills and other human-related perturbations, I have found no evidence of previous direct restoration activities that targeted murres. Proponents of direct restoration of murres cite (1) the slow pace of murre colony recovery in the absence of human intervention, (2) the need to prevent extirpation of decimated murre colonies should natural recovery fail, (3) long-term benefits that may derive from development of murre restoration technology, (4) the opportunity afforded by the spill to test the feasibility of various direct restoration options using controlled experimentation, and (5) an obligation to expend restoration resources on species most damaged by the spill. Detractors of direct restoration for murres voice all or some of the following concerns: (1) technology for direct restoration of murres is in its infancy and there is a high risk of failure; (2) there is risk of unanticipated negative side effects from direct restoration; (3) direct restoration will not provide significant benefits to damaged murre colonies at a reasonable cost; (4) limited restoration funds should be spent on habitat restoration or protection that will benefit more than a single species.

The success of murre restoration, whether direct or indirect, will depend on the availability of data on the factors influencing murre survival and productivity. Indirect restoration techniques, such as predator control, protection of breeding colonies from human disturbance, and reduction of forage fish harvest, have been used in attempts to restore or expedite natural recovery of seabird populations. But the success of these efforts has varied, depending on the extent to which these factors are limiting for any particular seabird population. Murre restoration poses a three-pronged challenge: (1) determine the factors currently limiting murre survival and productivity, (2) devise techniques to mitigate those factors, and (3) evaluate the effectiveness of restoration techniques.

I will fax a copy of the Annotated List directly to Tony Gaston for his comments. Please provide copies to Mike Fry and Dave Nysewander when you see them. Based on their responses and yours, I will finalize the memorandum and fax it to you before I depart for the south.

CONFIDENTIAL

DRAFT ANNOTATED LIST OF RESTORATION OPTIONS FOR COMMON MURRES IN THE AFTERMATH OF THE EXXON VALDEZ SPILL

I. DIRECT ON-SITE RESTORATION

A. Social Stimulus Enhancement

DRAFT

1. Playback of recorded murre calls
   - use solar-powered tape players to continuously play recordings of murre calls at breeding colonies (Kress)

2. Painted murre decoys
   - place wood decoys on breeding ledges in an attempt to attract more adults to nest sites (Kress)
   - place styrofoam decoys on water beneath breeding cliffs (Montevecchi)

3. Mirrors
   - create the illusion of larger numbers of murres in attendance on breeding ledges (Gaston)

4. Dummy murre eggs
   - place painted wooden or plaster eggs on breeding ledges to provide a visual stimulus for laying (Gaston)

Notes: Productivity at colonies affected by the spill is suffering from delayed phenology, lack of reproductive synchrony, low hatching success, and low survival of pre-fledging chicks (Nysewander). The late timing of fledging probably also results in poor post-fledging survival. Surprisingly, these problems have persisted at some spill-affected colonies for three breeding seasons after the spill. Social factors are the most likely cause of these effects (Fry, Nisbet, O'Connor, Piatt, Swennen), but other factors may be involved (see below). There are probably few experienced breeders at those colonies where extensive adult mortality occurred following the spill. Also, breeding adults that did survive probably lost their mate and were forced to pair with inexperienced individuals (Nisbet). Those subadults that survived the spill and replaced breeding adults that died would be expected to breed later and be less synchronized (Nettleship, Gaston). Even for experienced breeders, there may be a critical number or density of other breeding adults necessary to stimulate ovulation. The persistence of reproductive impairment following the spill suggests that the vast majority of experienced breeders at certain colonies were killed (Gaston).

An increase in social stimuli may increase colony attendance, stimulate earlier onset of egg-laying, and increase egg-laying synchrony. All of these changes would be expected to result in improved production of young. Social stimulation of reproduction (using playbacks of murre calls and painted wooden decoys in the colony) has proved effective in attracting Atlantic Puffins to nest on islands off the coast of Maine where they have been absent for over a century (Kress). Providing an auditory "super stimulus" (high volume playbacks of murre calls recorded at a large colony) may serve as a strong attractant for prospecting murres that periodically visit colonies other than their natal colony (Mead).

Use of decoys, recordings, mirrors, and dummy eggs may be effective in the case of murre colonies that were severely affected by the spill and where breeding synchrony and reproductive success are chronically impaired. If a colony is declining with little prospect of recruiting additional breeders, then this restoration option may be effective in maintaining the colony as an active breeding site (Kress). This restoration activity is experimental, and the feasibility of stimulating breeding using decoys, recordings, dummy eggs, and mirrors should be tested prior to implementation on a large scale. The oil spill offers an excellent opportunity to test restoration techniques for enhancing productivity following decimation of a murre colony (Gaston). However, in order to evaluate the effectiveness of any novel and direct restoration technique, it is vital to carefully establish and monitor control sites.

Conclusions: This restoration option should receive careful consideration for feasibility studies during the 1992 breeding season. The techniques are amenable to tests of effectiveness by designating portions of decimated colonies as control and experimental sites. Experimental and control sites must be carefully selected so that differences in site characteristics do not confound interpretation of results. If nest site occupancy, onset of laying, egg production, laying synchrony, and fledging success are significantly enhanced in experimental sites compared to controls, then efforts to employ these techniques could be expanded.

B. Nest Site Improvement

1. Provide breeding ledges with sills
   - sills would mitigate egg loss due to eggs rolling off the breeding ledge (Gaston)

2. Construct partitions and/or roofs on nesting ledges
   - enhance security of nest sites from avian predators (i.e., bald eagles, gulls, ravens) (Gaston, Nysewander)

3. Blanket-off or cover portions of breeding cliffs
   - exluding murres from portions of cliffs that offer few large ledges may induce aggregations on a few broad ledges that provide the best opportunity for successful breeding (Mead)

4. Enlarge nesting ledges on cliff faces
   - dense aggregations of breeding murres on broad ledges are conducive of high production (Gaston)

Notes: All of the above restoration techniques are experimental. But experiences of biologists in the field suggest that these techniques may be effective in enhancing murre nesting success. All modifications to cliff nesting sites should, of course, be accomplished during the non-breeding season. The simple technique of providing nesting ledges with a sill to prevent murre eggs from rolling off the ledge could considerably improve hatching success. At some murre colonies egg breakage accounts for 60% of egg losses (Gaston). Protection of nest sites from avian predators would be enhanced by construction of partitions and/or roofs on nesting ledges (Gaston). Avian predators on murre adults, chicks, or eggs normally approach nesting ledges from above (eagles) or from the side (gulls), whereas adult murres approach their nest sites from below. Partitions and roofs would inhibit predators without detering use of nest sites by murres. Partitions spaced at 2'- 3' intervals may provide the greatest benefits without impairing murre reproduction (Gaston). Partions, roofs, and sills in conjunction with decoys, mirrors, dummy eggs, and playbacks could attract murres to safe nest sites that would otherwise go unused due to a lack of social stimuli.

Excluding murres from suboptimal nest sites may improve occupancy on better ledges and enhance reproductive success (Mead), but it is difficult in practice because of the strong nest site tenacity of murres (Gaston). Forcing breeding murres to occupy new nest sites may also disrupt breeding pairs and contribute to delayed and unsynchronized laying. By providing larger nesting ledges, larger aggregations of breeding murres may form and thereby increase social stimulation for breeding.

These restoration techniques may enhance reproductive success and colony occupancy at sites where reproduction is chronically impaired. But the practical aspects of effectively modifying cliff nesting habitat to achieve the desired results have not been worked out. Also, modification of breeding ledges runs the risk of displacing breeding pairs that are attempting to nest (Nettleship). Murres display strong nest site fidelity and displacement from nest sites may seriously disrupt breeding.

Conclusions: This restoration option carries some risk of negative side effects and may not produce a detectable increase in colony numbers. However, modifications of particular breeding cliff may provide significant enhancement of productivity. The cost-effectiveness of this restoration approach can not be ascertained based on current knowledge. While some experts question whether this restoration option will provide appreciable and cost-effective enhancement of breeding populations affected by the spill, I believe that it warrants consideration for a feasibility study. Murre restoration technology that could be developed in this area would be valuable. It will be critical to the success of any feasibility studies that all experiments be controlled.

C. Construction of Artificial Nesting Habitat

1. Modify cliff faces
   - relatively minor alterations of cliffs otherwise suitable for murre nest sites to render them inaccessible to mammalian predators
   - use scaffolding to provide nesting ledges on sheer cliffs

2. Construct artificial cliffs
   - masonry cliff faces to provide nest sites at locales where steep slopes or cliffs do not exist

3. Create cliff nest sites using explosives
   - blast out cliffs from slopes over-looking the sea

Notes: This restoration option seeks to enhance local productivity by increasing the availability of nest sites (cliff ledges) where they are limiting or lacking. This technique can vary from inobtrusive and minor modifications of cliff faces so as to eliminate access points by mammalian predators to use of explosives to produce cliff faces suitable for murre nesting. In some instances, fairly minor modifications to a site may render it inaccessible to foxes and other potential egg and chick predators.

However, none of the spill-affected colonies are apparently subject to significant mammalian predation. At sites where sheer cliffs rise from cobble beaches, scaffolding might be used to provide broad nesting ledges where they are otherwise absent. Use of explosives or construction of artificial ledges may be necessary to provide suitable nesting habitat where none currently exist, but there is no assurance that new nesting habitat would be occupied. These restoration options are unlikely to be effective if suitable nesting habitat is not limiting (Nettleship).

Conclusions: It is unlikely that this restoration option will provide appreciable and cost-effective enhancement of breeding populations affected by the spill. Also, there is no indication that suitable nest sites are limiting, particularly for populations decimated by the spill. Finally, some of these options may result in permanent alteration of coastal landscapes to benefit murres, but detract from the pristine character of the landscape. I do not recommend this murre restoration option for consideration in 1992.

D. Release of Captive-reared Murres

1. Captive propagation of murres
   - use captive adult murres to obtain murre fledglings for release at target colonies (Swennen)

2. Captive rearing of murre eggs/chicks
   - collect fresh eggs from healthy murre colonies, hatch and raise chicks in captivity, transfer chicks to target colony for imprinting and release

3. Transfer of chicks between colonies
   - transfer young chicks caught at healthy murre colonies to colonies where reproduction is impaired, hold in pens until imprinted, and release (Kress)

Notes: This option makes use of the natural tendency of many colonial seabirds to return to their natal colony to breed. Transfer of chicks between colonies has been successfully employed to reestablish extirpated Atlantic Puffin colonies in the Gulf of Maine, and has been suggested as a potential method to enhance murre recruitment at colonies where reproduction is chronically impaired (Kress). Successful propagation of Common Murres in captivity has been accomplished by the Netherlands Institute for Sea Research, Texel, where captive adult murres produced fertile eggs that were then successfully raised by hand (Swennen). Captive-reared murres were released at Texel and later returned to the site where they had been raised and released, apparently prospecting for nest sites. This demonstrated for the first time that captive-reared murres could survive in the wild and would return to their natal area.

Annual egg production of captive adult murres is low, and using captive adults as a source of young for release is not cost-effective (Swennen). Alternatively, young murre chicks could be captured at healthy murre colonies and transferred to damaged ones. However, collecting chicks at murre colonies would impair recruitment at the donor colony due to: (1) removal of chicks, (2) egg loss resulting from breakage and predation when parents were not guarding their eggs, and (3) chick mortality resulting from premature fledging (Nettleship). The best option for obtaining chicks to release at a target colony is to collect fresh eggs from healthy donor breeding colonies. Wild murres will frequently (usually?) relay if their egg is removed or destroyed shortly after laying (pers. obs.), so collection of eggs in the wild may have little affect on donor colony productivity. Eggs would be placed in incubators for hatching and hatchlings would be fed by hand until 4-5 weeks old. The young do well in captivity on a diet of frozen fish (Swennen). Beginning at 4-5 weeks, murre fledglings will feed themselves if provided with fish in a tank or swimming area (Swennen). At three weeks post-hatching, murre chicks would be transported to the release site and held in outdoor pens with access to seawater. Murre feathers are easily fouled with excrement and waste food, causing lose of water repellancy, so providing fresh seawater is critical (Swennen). At approximately 8 weeks of age, fledgling murres would be released in groups of several dozen individuals. Murre fledglings normally go to sea with their male parent at about three weeks of age and receive considerable post-fledging parental care. Captive-reared fledglings released in groups when nearly full-grown may survive at nearly the rate of natural fledglings.

Common Murres normally breed for the first time at 4 years, so it would be several years before the survival of released murres could be determined through resightings of color-banded individuals at the release colony. If the release site had been completely abandoned by breeding adults, captive-reared birds would presumably search out other active colonies in which to breed. Artificial social stimuli (decoys, playbacks, dummy eggs, mirrors) would be necessary to attract captive-reared subadults to an abandoned colony.

Captive-rearing and release is a highly experimental restoration method. Development of the technology for reestablishing extirpated murre colonies would be valuable, regardless of whether it is used to restore colonies affected by the spill. Plans are underway to use captive-rearing and release techniques to reestablish decimated murre colonies in California (Kress). But conducting such a feasibility study at spill-affected colonies in the Gulf of Alaska would be expensive and logistically difficult (Swennen).

If one or more murre colonies are eventually completely abandoned, releasing captive-reared young should be given consideration as a restoration option (Kress). However, the captive propagation and release option would only produce relatively small numbers of potential recruits (100's). The low predicted survival of released young to adulthood (< 10%, Nettleship), high cost of captive rearing, and potential negative impact on colonies that serve as sources for eggs (Nettleship) led some experts to recommend against this restoration option (Nettleship, Swennen).

Conclusion: The captive-rearing and release is, in my opinion, not justified as a technique to enhance recruitment at active murre colonies. However, if a breeding colony has been completely extirpated, this technique may be the sole option for reestablishing a colony. To date no murre breeding colonies are known to have been abandoned as a result of the Exxon Valdez spill. Even in cases of complete abandonment, this technique is experimental, risky, and expensive. It would be valuable to develop the technology for successful reestablishment of extirpated colonies or enhancement of decimated colonies, but Gulf of Alaska colonies seem to be a poor choice for feasibility assessment. This restoration option is not recommended for implementation or feasibility study during the 1992 breeding season.

II. Indirect On-site Restoration

A. Avian Predator Control

1. Control populations of gulls and ravens using lethal means (Nysewander)
   - DRC-1339 poison bread baits
   - shooting
   - oiling eggs

1. Live-trap and remove juvenile Bald Eagles
   - transport problem eagles to sites in the lower 48 where eagle restoration programs are underway (Nysewander)

Notes: Glaucous-winged Gulls and Common Ravens are the most frequent predators on murre eggs and young at spill-affected colonies (Nysewander). Gulls can be a major source of egg mortality, accounting for 40% of egg losses at some colonies (Gaston). Gulls also take chicks from nesting ledges or as they attempt to fledge. Gull colonies are associated with most of the murre colonies in the northern GOA. Gulls have a much higher reproductive potential than murres and populations in the Gulf of Alaska are generally increasing. Temporary gull control measures could enhance murre productivity without threatening gull populations. Gulls and ravens nest earlier than murres, so control activities could be timed so as not to disrupt murre nesting (Nysewander, Kress). Gull control has been used successfully to enhance nesting success at some seabird colonies and has been an integral part of attempts to reestablish extirpated seabird colonies in the Gulf of Maine (Kress). Bread baits treated with the avicide DRC-1339 are an effective means of controlling gulls and pose no risk to other piscivorous seabirds (Kress). However, poisoned gulls might be a source of secondary poisoning for Bald Eagles. Shooting is another effective means of gull control with little chance of affecting non-target species. Another method of controlling gull populations is to oil gull eggs so that they fail to hatch, but the parents continue to attend the eggs until it is too late in the season to renest. However, this control technique may have little affect on the size of the gull population for some years. Destructive gull control is the only proven effective technique for mitigating the impact of gulls on seabird reproductive success (Kress) (but see I-D above).

Bald Eagles, unlike gulls and ravens, are known to take adult murres (Nysewander). Eagles elicit a strong panic response from adult murres on nesting ledges and indirectly result in losses of eggs and young to other avian predators. Some juvenile Bald Eagles are resident at murre colonies during the breeding season and cause significant disruption of breeding activities (Nysewander). Bald Eagles have apparently increased significantly in the northwestern GOA during the last few decades and are causing considerably more losses at murre colonies than in the past (Nysewander). Destructive control of problem Bald Eagles is certainly not feasible, but removing them to remote locations from which they are unlikely to return is an option.

Conclusions: Where decimated murre colonies are experiencing consistently poor reproductive success, it may be advisable to control gulls, eagles, and/or ravens on a temporary basis as a means to enhance natural recovery. However, this restoration option creates public relations problems. Before any avian predator control is instituted, it is crucial that intensive field studies be conducted to document prevalence and intensity of mortality and reproductive failure associated with avian predators. A clear justification for predator control needs to be obtained prior to initiation of control measures. I recommend that the effects of avian predators on murre survival and reproductive success at spill-affected colonies be investigated in 1992, as a prelude to potential predator control measures.

B. Mammalian Predator Control

1. Eliminate introduced foxes from islands that support murre colonies

2. Eliminate or control other introduced mammals (e.g., ground squirrels on the Barren Islands) on breeding islands

3. Control native mammalian predators on islands and headlands where murre colonies exist

Notes: Elimination of arctic foxes that were intentionally introduced to the Aleutian Islands has been shown to be a very effective seabird restoration activity. Although murres generally nest on inaccessible cliff ledges, foxes are adept at reaching these ledges and preying on large numbers of eggs, chicks, and even adults (pers. obs.). However, there are apparently no colonies in the spill-affected area that are subject to fox predation (Nysewander, Piatt). Arctic ground squirrels have been introduced to the Barren Islands, but apparently pose no threat to murres, their eggs, or their young, mostly affecting burrow-nesting seabirds (Nysewander). In cases where native mammalian predators (e.g., otter, mink) are contributing to egg and chick losses, temporary predator control may be warranted. However, I know of no murre colonies in the spill-affected area that suffer significant losses to mammalian predators.

Conclusions: Current knowledge indicates that this is not a restoration option for murre colonies in the oil spill area. However, mammalian predation on murre eggs, chicks, or adults may not be apparent without fairly intensive on-site investigations, so it is possible that this is a viable restoration option for some spill-affected colonies. As with restoration option II-A, it is critical to acquire more site-specific information on the effects of predators on murre nesting success prior to initiation of any predator control measures.

C. Reduction of Human Disturbance at Breeding Colonies

1. Prohibit discharge of firearms near murre colonies during the breeding season
   - use of firearms to kill halibut has been noted near colonies in the spill-affected area, resulting in disturbance of breeding murres (Nysewander)

2. Prohibit use of explosive devices near murre colonies during the breeding season
   - use of firecrackers to drive salmon into gill nets has been noted near colonies in the spill-affected area and resulted in disturbance of breeding murres (Nysewander)

3. Prohibit over-flights of colonies by helicopters and fixed-wing aircraft during the breeding season
   - breeding murres respond to aircraft with panic flights that are at least as disruptive as those elicited by avian predators

4. Prohibit close approach to colonies by tour boats and other watercraft during the breeding season
   - on occasion tour boats and other pleasure craft approach murre colonies so closely that breeding adults may leave nest ledges

Notes: This restoration option seeks to minimize disturbance that may cause adult murres to leave the breeding ledges in panic flights, thus causing eggs to roll off ledges or expose eggs and chicks to avian predation. Breeding murres are more sensitive to loud noises and aircraft than the close approach of vessels. The evidence that any of the above factors result in significant nesting failure in the spill-affected area is anecdotal at best, and needs better documentation. Regulations limiting any or all of the potentially injurious activities listed above may be feasible, but enforcement will be difficult. Enforcement and compliance may also be limited in the absence of documentation of damages related to these activities.

Conclusions: Another advantage of the kind of intensive colony-based investigations required to document murre losses to predators is to document losses resulting from human disturbance. Without Nysewander's observations on the effects of firearms and firecrackers on murre colonies, these activities would not be suspected as factors contributing to reproductive failure. Regulations restricting disruptive human activities near murre colonies during the breeding season (particularly C-1, C-2, and C-3 above) should receive careful consideration as restoration options for 1992.

D. Monitor Recovery, Including from Restoration Actions

1. Regular population monitoring at several selected colonies
   - use standardized census techniques to monitor population size at colonies affected by the oil spill
   - determine recovery rates of damaged colonies
   - compare population trends with colonies outside the spill-affected area (i.e., Semidi Islands, Middleton Island)

2. Colony-based monitoring of reproductive output
   - investigate factors responsible for persistent reproductive failure at some murre colonies
   - determine proportion of attending adults that produce eggs
   - determine timing of hatching, hatching success, and hatching synchrony
   - determine chick survival and fledging success

3. Monitor results from on-site restoration activities
   - determine cost-effectiveness of restoration options

Notes: Monitoring recovery is an important information need. The extent and persistence of damages to particular murre colonies should determine the type and intensity of murre restoration activities. A major information need is for data to improve our understanding of the underlying causes of continued colony decline, reproductive failure, or failure of some colonies to recover in the aftermath of the spill. We still do not know what factors (e.g., social disruption, food supply, food contamination) are responsible for the unexpected persistence of reproductive failure at some spill-affected colonies. Most experts expressed serious concern that the underlying causes of continued reproductive impairment at some murre colonies are not understood. Restoration activities designed to provide social facilitation for reproduction will fail if reproduction is limited by food supply (Nettleship).

Murres are long-lived and it would require reproductive failure over an extended period to lose the tradition of nesting at a particular breeding colony, providing the surviving adults did not abandon the colony first. This underlines the importance of monitoring all affected colonies, not just the largest or most accessible. A major information need is to known if and when colonies that have experienced reproductive failure resume laying, hatching young, and successfully fledging young. Colony attendance should be monitored to determine if certain colonies are eventually lost due to attrition of breeding adults. If a trend toward declining colony attendance and little or no reproductive success is documented over a period of several years, then restoration activities should be directed at the threatened colony.

Conclusions: Monitoring recovery, determining factors affecting recovery, and monitoring effects of restoration activities are critical components of restoration. Current monitoring activities for murres should be expanded to include more intensive investigations at colonies that experienced severe losses of breeding adults and that have shown no indication of natural recovery.

III. Off-site Restoration

A. Mitigate Incidental Take

1. Restrict use of salmon gill nets near murre breeding colonies in the spill area

2. Restrict fishing practices that result in a significant by-catch of Common Murres in the northern GOA

Notes: Incidental take of murres by commercial fisheries in the Gulf of Alaska portion of the EEZ is unknown but probably small (Piatt). Salmon gill net fisheries in West Greenland were responsible for huge losses of Thick-billed Murres, but there is no indication of a comparable by-catch in Alaska. For a long-lived species with low fecundity, such as the Common Murre, an increase in adult mortality would have a greater population-level effect than a decline in productivity. Mitigating losses of adults may be one of the most effective means of enhancing natural recovery.

Conclusions: This potential restoration option identifies an important information need: the extent of incidental take of murres by commercial fisheries in the northern Gulf of Alaska. Restoration options designed to mitigate incidental take are not recommended in the absence of evidence that significant mortality occurs.

B. Enhance Forage Fish Availability

1. Restrict commercial harvest of forage fish, i.e., capelin and sandlance

2. Mitigate by-catch of forage fish by commercial fisheries

3. Restrict production of hatchery salmon
   - hatchery salmon may compete directly with murres and other seabirds for forage fish stocks

Notes: The continued reproductive failure at some murre colonies affected by the spill is probably caused by the loss of most of the experienced adult breeders in those colonies and the resultant social disruption (Nisbet, Nysewander, Gaston). However, delayed onset of laying, lack of laying synchrony, and poor reproductive success are also indicators of inadequate food supply within foraging distance of the breeding colony (Nettleship). Several experts considered forage fish availability to be a reasonable alternative explanation for persistent reproductive failure (Mead, Nettleship, O'Connor). This explanation was given more credence by experts from the U.K. and Maritime Canada, where there is a well-documented history of commercial over-harvest of forage fish coupled with poor seabird reproductive success. The forage fish explanation is less favored by Alaska and West Coast experts.

Waiting until four or five years of reproductive failure have elapsed before investigating alternative explanations for reproductive failure is ill-advised (O'Connor). Food supply can be investigated by monitoring the type, size, and frequency of prey delivered by parents to their chicks, as well as the growth rates of chicks. Although murre breeding success has remained normal at the Semidi Islands and Middleton Island (Nysewander), colonies to the west and east of the oil spill area, respectively, these colonies are also influenced by different currents (Piatt). The concensus among Alaska seabird experts seems to be that commercial harvest or incidental take of forage fish (i.e., capelin and sandlance) in the northern GOA is not sufficient to warrant concern (Nysewander, Piatt). However, the large production of hatchery salmon may be responsible for reductions in forage fish stocks, possibly resulting in poor reproduction and population declines in a variety of seabirds and marine mammals. Murres are relatively tolerant of reductions of forage fish compared to surface-feeding seabirds, such as kittiwakes (Gaston). Kittiwakes have been suffering mediocre-poor reproductive success in much of the northern GOA for the last decade.

Persistent contamination of the food supply is a third potential explanation for continued reproductive failure at some murre colonies. Sandlance in particular may be a dietary source of petroleum hydrocarbons for murres (Nisbet). Effects of petroleum ingestion on reproduction have persisted for two years in some seabirds (Fry). However, the concensus among seabird experts seems to be that persistent contamination of the food supply is an unlikely explanation for three years of reproductive failure following the spill (Fry, Gaston, Nysewander, Piatt).

Conclusions: Forage fish availability may be limiting reproductive success at spill-affected murre colonies. Information is badly needed to address food supply and food contamination as potential causes of persistent reproductive failure in murres. Food supply problems may offer few options for murre restoration. But if food is limiting, otherwise effective restoration options may fail to expedite natural recovery. Shortages of forage fish appear to be affecting a variety of piscivorous marine birds and mammals in the PWS/GOA ecosystem. Murres are but one of the species that would benefit from a better understanding of the factors limiting forage fish. Without better information, it will be impossible to take effective measures to restore forage fish stocks.

C. Predator Control

1. Eradication of introduced arctic foxes on seabird breeding islands

2. Gull control at murre colonies

Notes: Eradication of introduced arctic foxes from some islands in the Aleutian Chain has resulted in dramatic increases of breeding seabirds. Some Aleutian islands still support fox populations, but none of the islands in question were affected by the oil spill. Nevertheless, restoration of large numbers of murres (and other seabirds) could be realized at a relatively low cost from fox eradication programs. Eradication could be achieved by a combination of shooting, poisoning, and gasing dens, followed by dropping of poisoned baits from aircraft during late winter when food is limiting for foxes and they spend most of their time foraging for food along the beach.

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Another potential means of enhancing recovery is to mitigate factors that impair fledging success at murre colonies within the oil spill area, but not severely affected by the spill. For example, the Chisik Island colony of about 24,000 murres in Cook Inlet was not affected by the oil spill, but murres raised on Chisik may be recruited to nearby colonies decimated by the spill. Gull control at Chisik Island may be a means of helping restore the murre population on the Barrens.

Conclusions: Fox eradication projects on the Aleutian Islands are extremely worthwhile and should receive consideration, despite the absence of benefits to the spill area.

D. Protect/Acquire Breeding Colonies

1. Purchase murre breeding colonies that are currently in private ownership

Notes: Gull Rock in Kachemak Bay, The Triplets off Kodiak Island, and Ugaiushak Island off the Alaska Peninsula are examples of murre breeding colonies in the oil spill area that are currently or may soon be in private ownership. Most murre colonies are in federal ownership as part of the Alaska Maritime National Wildlife Refuge. Those not in federal ownership do not appear to be in imminent danger, but inclusion in the Refuge would assure that future developments would not threaten the resource. Gull Rock in particular is in a high visibility location with considerable tourist visitation and nonconsumptive use. It is also close to the Refuge office in Homer.

The Triplets are located near Kodiak Island and are currently in private ownership (Nysewander). Pre-spill murre population estimates were about 1,300 and the population is apparently down 35% in the aftermath of the spill (Nysewander). Ugaiushak, off the Alaska Peninsula, supported about 9,200 breeding murres prior to the spill. Losses due to the oil spill are thought to be minor (Nysewander). The island has been selected by a native corporation and future ownership is uncertain.

Conclusions: I recommend that attempts be made to acquire Gull Rock for inclusion in the Alaska Maritime N.W.R. Because this murre colony was apparently not significantly affected by the spill, it can potentially provide new recruits for the decimated colonies in the Barren Islands. Because of its location it could provide to the public an accessible example of the kinds of wildlife resources and habitats protected by the Refuge. Prospects for acquiring The Triplets and Ugaiushak Island should be investigated.

SUMMARY OF CONCLUSIONS

The most feasible options for direct restoration are enhancement of social stimuli (I-A), with its various permutations, and nest site improvement (I-B). These two approaches could be tested in concert. The most promising potential method of indirect restoration is control of avian predators, but no control program should be initiated without prior studies to assess the severity of the problem. Such research could also provide information on the impact of mammalian predation and human disturbance, two other options for indirect restoration.

The best off-site restoration options appear to be eradication of introduced arctic foxes from islands in the Aleutians and acquisition/protection of seabird breeding colonies that are currently in private ownership. Enhancement of forage fish stocks and mitigation of incidental take of murres by commercial fisheries are both potentially effective restoration techniques, but current knowledge of these factors as they affect murre survival and reproduction are inadequate to judge potential efficacy. The efficacy of any and all restoration options is dependent on continued monitoring of spill-affected and control murre populations and the factors limiting those populations.

MEMORANDUM

State of Alaska

DEPARTMENT OF FISH AND GAME

Privileged & Confidential**Attorney Work Product

To: Daniel D. Roby, Ph.D.
Southern Illinois Univ.

COPY

Date: 20 September 1991

File No: REST 1.3.11

Telephone No: 907-271-2461

Stan Senner

From: Stanley E. Senner
Restoration Program Mgr.

Subject: Murre restoration

This memorandum is to follow up our telephone conversation about summarizing ideas for murre restoration.

The need of the Restoration Planning Work Group is simple: There are many suggestions for murre restoration projects, mostly to increase social facilitation and reduce predation. Augmenting productivity through captive breeding and fostering also has been mentioned. Because there are a number of ways to approach these endpoints, we need help in sifting the options.

Our request is for you to prepare a short memorandum (perhaps a few pages) which groups and explains the options to facilitate evaluation. Please explain each option or permutation briefly, and perhaps indicate those that in your judgement are most promising for implementation and/or testing (e.g., in 1992).

I suggest that you first consult with Dave Nysewander to get the latest in damage assessment results. You may want to call Tony Gaston, Canadian Wildlife Service, and others to identify restoration options. Gaston has signed a confidentiality agreement, but if you consult others (e.g., Kress or Croxall), you will need to speak carefully about the damage assessment on murres. The 18-page summary on injuries (April 1991) can be your guide for what information can be disclosed.

I will provide a copy of the current list of restoration endpoints under consideration by RPWG. When you have prepared a draft memorandum, which should be marked "confidential," provide copies to Mike Fry, Tony Gaston (if he is willing), Dave Nysewander, and me for review and comment before finalizing. In terms of level of effort, I envision about 3 days. If this is acceptable, let this signed memorandum serve as our agreement to proceed.

cc: B. Freedman, A. Swiderski, R. Spies, M. Fry, D. Nysewander, T. Gaston, S. Rabinowitch, files--RPWG & OSIAR

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Executive Summary - Common Murre Life History

Uria aalga inornata is the only subspecies of the common murre, a species with a holarctic distribution, found along the coast of Alaska. Concentration sites within the affected area include breeding colonies in the Barren Islands, Chiswell Islands and Paule Bay. Wintering concentrations occur around Kodiak Island and to a lesser degree in Prince William Sound.

Most murres breed in their fifth year. They lay a single egg which is incubated for 28-34 days by both adults. Hatching occurs between July 10 and early August. When the chicks are approximately 20 days old, when they 'fledge' to the ocean. Subadults, about which very little is known, usually return to visit the colony when they are 3 years old.

Common murres breed in dense colonies, usually on cliffs or flat barren islands. Success varies considerably between colonies and years. The highest breeding success occurs when common murres nest in large, dense (greater than 10 birds/meter2) groups which usually occur on broad ledges. High density helps against predation and helps in synchronizing laying. Common murres have an extremely high site tenacity with over 95 percent of the adults returning to the same square foot of ledge in successive years. They show a nest site selection preference for narrow ledges with a medium density of nesting birds.

Predation is an important influence on breeding success. Gulls (Larus spp.) are the primary predators and will take eggs, chicks and fledgings. High densities of nesting murres can effectively defend their eggs and chicks from avian predators.

Common murres eat a wide variety of small fishes and invertebrates. Three species: capelin, Pacific sand lance, and walleye pollock are identified as important components of murre diets in several studies. Geographic and seasonal variability in prey abundance will influence the which species are most important to the murres.

Entanglement in commercial fishery nets, and competition for food, is probably not a major influence on murre populations in the affected area due to the type and location of the fisheries in the area. Although the establishment of a capelin fishery could cause significant impacts.

Differences between common and thick-billed murres are most noticeable in nest site selection, and breeding dates.

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COMMON MURRES

I. TAXONOMIC DESCRIPTION

A. Common Names: Common murre, common guillemot (U.K)

B. Scientific Name: Uria aalge

C. Subspecies: There are seven subspecies of common murre. Two of these, Uria aalge inornata and U. aalge californica, are found in the North Pacific Ocean, with the distribution of U. a. californica restricted to the coast of California and Oregon.

II. RANGE

A. Worldwide:

Common murres have a holarctic distribution, predominately south of the Arctic Circle in the low-arctic and boreal marine zones (Tuck 1960). Tuck (1960) describes the breeding range of the subspecies U. a. inornata from Point Hope, Alaska, south to Washington and Oregon; including the islands of the Bering Sea, the Aleutians, and Komandorskie Islands and extends as far south in Japan as Tsugaru Strait. U. a. inornata integrates with U. a. californica in Washington and Oregon. U. a. californica is the only other subspecies found in the Pacific Ocean. Its range extends from Washington to Hurricane Point, California.

The other subspecies are found in the N. Atlantic Ocean ranging from Nova Scotia, north to the arctic circle in Greenland and east to Novaya Zemlya in the Barents Sea; south to the northern coast of Spain (Tuck 1960).

B. Alaska:

The distribution of common murres in Alaska includes coastal areas south of the Arctic Circle.

C. Population Status within Exxon Valdez Oil Spill Area:

The 1990 NRDA report (**Nysewander and Dippel 1990**) stated that there are approximately 320 seabird colonies within the affected area. The colonies contain approximately 319,130 breeding murres of both species. The ratio of common murres to thick-billed murres (Uria lomvia) has been estimated at 30:1 for Kodiak area wintering populations (Forsell and Gould 1981).

Prince William Sound. Population data on murres in Prince William Sound is available from aerial surveys flown in 1971 (Hogan and Murk 1982). Because murres have the tendency to dive when disturbed, aerial surveys are believed to underestimate the population numbers. However, this survey provided good information on concentration areas within the sound. The winter distribution of murres were concentrated in protected bays in the western part of the sound, with the largest flocks observed in Unakwik Inlet (Hogan and Murk 1982). Spring and summer concentrations were found at Port Etches, Sheep Point and Gravina Point. Porpoise Rocks, at the entrance to Port Etches, is the only breeding colony in Prince William Sound, and has a population of approximately 750 breeding pairs (ibid). Fall concentrations were found in the northern fjords and bays (ibid).

Kodiak Archipelago:
A combination of aerial and water surveys were used to census marine bird populations in the Kodiak area of Alaska. Both species of murres were combined in this census; however, a 30:1 ratio of common to thick-billed murres was calculated for the Kodiak Archipelago during winter (Forsell and Gould 1981). Forsell and Gould documented changes in murre abundance in nearshore and continental shelf surveys between summer and winter. Summer surveys indicated an abundance of 2 bird/km^2 which increased to 22 B/km^2 in November and peaked at 70 B/km^2 in February. These data, along with the observation of especially large numbers of young birds, led the authors to describe the Kodiak Archipelago as a major nursery and wintering area for murres. Large concentrations of young murres were found in Uyak Bay and huge rafts (125,000 - 130,000) of murres were found in Sitkalidak Strait where they are believed to seek shelter from winter storms.

1990 NRDA Study:
Table I provides a rough summary from population status information provided in the 1990 NRDA Bird Study Number 3 report (Nyswander and Dippel 1990). These data contain averages and some speculation; therefore, it is important to consult the original report for specific information. These data are combined for common and thick-billed murres; 5-10 percent of the birds at the breeding colonies are believed to be thick-billed murres (D.Nysewander[1] pers. comm.).

III. BREEDING CHRONOLOGY

Common murres begin arriving at their colony site in mid-April (Hatch and Hatch 1989). Between mid-April and late

[1] David Nysewander. Alaska Maritime NWR; 202 Pioneer Avenue; Homer Alaska 99603. (907) 235-6546

Table I. Summary of pre and post-spill population status on some colonies within, and near, the EXXON VALDEZ spill area.

LOCATION	PRE-SPILL BREEDING POPULATION	POST-SPILL BREEDING POPULATION	BREEDING BEHAVIOR
Middleton Island (control)	X = 5,994 (n=13)		Probably normal
Semidi Islands (control)	1,133,300	no sig. difference	Normal
Chiswell Islands	28,850	slight increase?	Never bred in 1989, late & asynchronous in 1990
Barren Islands	130,000	48,750	30 days late/ asynchronous
Paule Bay	92,800 (1976) 74,500 (1981)	37,032	30-45 days late & asynchronous

May, the murres make erratic visits to the colony, sometime staying for hours or days (Tuck 1960, Hatch and Hatch 1989). Courtship flights are common during this time, with large groups of birds flying or swimming in synchronized flocks (Tuck 1960).

There is a strong correlation between age and reproductive success in murres. Most common murres do not begin breeding until they are 5 years old (Birkhead 1977). Some individuals may nest as 4 year olds, but they are generally not successful (ibid.). Juvenile murres may not return to the colony until their third year, although a small proportion do return in their second year. These young birds spend varying lengths of time congregated on the fringes of the breeding colony, but are mostly found in "clubs" on intertidal boulders at the base of the cliffs (Birkhead and Hudson 1977).

Adult murres lay a single egg on a bare rock ledge. The eggs are laid throughout June and are incubated for 28-34 days by both parents (Hatch and Hatch 1989). Hatching occurs between July 10 and early August (Hatch and Hatch 1989). Late hatching chicks are often from immature birds (generally 4 year olds), or are the results of second nesting attempts by pairs that lost their first egg early in the incubation process. At least one parent is always present until the chick fledges, unless the adult is disturbed by predators or humans.

Fledging, the departure of chicks from the cliff to the ocean, occurs between July 30th and August 30th when the chicks are approximately 20 days old (Murphy et al. 1985, Hatch and Hatch 1989). The chick is attended by one of the parents, usually the male, as it is led away from the colony. Very little information is known about this stage of the murres' life cycle. The distribution and behavior of subadults when they are away from the colony site has not been studied. Chicks may be extremely vulnerable to predation during the fledging process, especially if they must travel over land to access the water (Tuck 1960, Williams 1975).

IV. FACTORS AFFECTING BREEDING SUCCESS:

Common murres breed in dense colonies on cliffs, flat barren islands, and sometimes in caves and under boulders (Tuck 1960, Birkhead 1977). High fluctuations in the reproductive success of a colony are common. Murphy et. al. (1985) documented poor reproductive success in 1975 and 1976 (0.18 and 0.04 chicks/pair respectively), in the Bluff murre colony in Norton Sound. In 1979 the reproductive success at the same colony was 0.54 chicks/pair. The population studied by Birkhead and Hudson (1977) had a breeding success of 0.7 chicks/pair. There are a variety of factors that influence breeding success that can be attributed to social and physical characteristics of the birds and their breeding habitat.

A. Social characteristics:

Birkhead (1977) found that the nesting density (i.e. the number of birds/meter^2) was the main factor influencing breeding success. Murres have their highest breeding success when they nest in high densities (greater than 10 birds/meter^2). The dense congregation of birds allows for protection from avian predators and helps synchronize egg laying so that fledging occurs simultaneously. Synchronization is important because it allows for predator swamping and group defense of eggs and chicks. Birkhead showed that chicks left alone on a ledge with their parents were 100 times more likely to be depredated than chicks fledging together.

Common murres have extremely high site tenacity with over 95 percent of the adults returning to the same square foot of ledge in successive years (Birkhead 1977). However, murre colonies have been known to shift sites early in the breeding season due to disturbance or after several consecutive years of low productivity (Johnson 1938 as cited in Birkhead 1977).

B. Physical characteristics:
There are three areas of physical characteristics at the colony site that can influence breeding success. These areas include the structure of the nesting area as it relates to the nesting density and vulnerability to predators. The availability of suitable nesting habitat for murre predators, and the distance from the nesting sites to open water.

Birkhead (1977) studied a murre colony in South Wales and discovered important information on nesting preferences and behavior. He found that common murres preferred to nest on narrow ledges (mean = 0.29 meters) at medium densities, even though breeding success was highest on broad ledges at high densities. He hypothesized that this was due to the greater stability of medium density groups and that the narrow ledges made the birds less vulnerable to predation. Because murres do not make nests, the slope of the ledge is important to prevent eggs from rolling off of the ledge (Birkhead et al. 1985).

During the fledging process, murre chicks are coaxed to the ocean by one of the parents (generally the male). One parent calls to the chick from the water and then meets the chick when it reaches the water. There is conflicting information on the vulnerability of the fledging chick to predation. Williams (1975) found that the chicks are extremely vulnerable to predation until they are met by their parent. Birkhead (1977) found insignificant losses during fledging. This vulnerability appears to be related to the physical placement of the nesting colony to water. The vulnerability is increased when the chick must cross over land to reach the water (Williams 1975).

The availability of nesting areas for murre predators has obvious impacts on the breeding success of murres. This is seldom discussed in the literature.

C. Weather:
Reproductive success is also believed to be linked to spring temperatures with cold springs, or exceptionally warm springs, causing a decline in reproductive success (Murphy et al. 1985). Large die-offs, called "wrecks", are associated with severe storms and can kill thousands of birds; however, these incidents occur infrequently and have not been document to cause more than a one or two year population effect (Bailey and Davenport 1972).

V. FOOD WEB INTER-RELATIONSHIPS:

A. Predation

Predation is an important factor in the breeding success of a murre colony. The primary avian predators are glaucous-winged and mew gulls (<u>Larus glaucescens</u> and <u>L. canus</u> respectively), and ravens (<u>Corvus corax</u>). Foxes (<u>Alopex lagopus</u>) can be significant predators if fledging chicks have to cross land to reach the ocean (Williams 1975). Birkhead (1977) documented the importance of the murre density in decreasing predation. He found that murres nesting at medium or high densities were able to defend an unattended egg or chick for several days, while birds nesting at low densities were unable to protect the egg and had a higher loss of attended eggs and chicks. This same phenomena was recorded for murres whose chick hatched late and was not able to fledge with the other chicks in its subcolony (ibid.).

B. Feeding Behavior and Diets:
The Outer Continental Shelf Environmental Assessment Program (OCSEAP) sponsored a study of seabird diets and food web relationships in the Gulf of Alaska. Stomach contents were analyzed from 166 common murres collected throughout the seasons and between years (Sanger 1978). These data were used to develop an index of relative importance (IRI) for each prey species. This analysis identified capelin (<u>Mallotus villosus</u>) as the most important prey species, followed by Pacific sand lance (<u>Ammodytes hexapterus</u>), walleye pollock (<u>Theragra chalcogramma</u>) and Mysids. Other shrimp, Euphausiids and Pandalids, were also utilized. Appendix A includes a food web diagram from Sanger's (1978) report which illustrates the relationship and relative importance of the different prey species.

Sanger (1978) also compared stomach contents between regions and seasons. Although these divisions greatly reduced the samples sizes, it illustrated the need for caution in generalizing the importance of prey species. During summer, common murres in the NE Gulf of Alaska (collected near Hinchinbrook Island) ate mostly Pacific sand lance; while Kodiak murres consumed more capelin during the same season. Pacific sand lance did not comprise a significant portion of the Kodiak murres' diet until the Fall season. Appendix A includes a copy of the table from Sanger's report which shows the breakdown of food use between areas and seasons.

Other studies which have looked at stomach contents of common murres in the Pacific Northwest have found similar components of prey species, with different emphases between areas. A comparative study of seabird diets around the Pribilof Islands during the summer found that walleye pollock were the most common prey found in the stomachs of 85 birds (Schneider and Hunt, Jr. 1984). Shrimp (Euphausiids), capelin, miscellaneous crustaceans and squid were also found present in the diets. Four birds collected off of St. George Island had fed predominately on shrimp, with very small amounts of pollock (ibid.). Although these data are inconclusive due to small sample sizes, it does imply that geographical variation in diets may be significant.

VI. HUMAN INTERACTIONS:

A. Commercial Fisheries

The impact of commercial fisheries on murre populations varies with the type of fishery, the distance from shoreline, and the time of year. Significant numbers of breeding murres have been lost in commercial fisheries in the Atlantic Ocean (Piatt et. al. 1984, Furness and Ainley 1984). Twice as many murres were killed in cod gillnets versus salmon gillnets (ibid.). No comparable impact to murre populations has been documented for the Gulf of Alaska populations. During 1990 the marine mammal observer program recorded the number of seabirds killed in the salmon gillnet fisheries in Prince William Sound (PWS) and South Unimak Island. No murres were recorded drowned in the PWS fishery; 8 of 16 seabirds drowned in South Unimak were common murres (Wynne et.al. 1991). The salmon fishery in Cook Inlet and around Kodiak may take a small number of murres, but these fisheries have not been studied (A. DeGange[2] pers. comm.). The incidental catch of murres around the Aleutian Islands has the greatest likelihood of impacting a population of murres in Alaska (Ogi 1984); however, these fisheries have not been studied so their actual impact is unknown.

Competition between seabirds and commercial fisheries is probably not significant for Gulf of Alaska murres. Sanger (1978) showed that juvenile salmon were uncommon in the diets of murres, even though the majority of collections occured during smolt migrations. The establishment of a capelin fishery in the Gulf of Alaska could have a significant impact on the murre population (ibid.)

B. Subsistence and Disturbance

Although subsistence harvest of murres and their eggs occur elsewhere in Alaska, murres in the affected area

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are seldom harvested. Other forms of disturbance from humans include any activity which causes breeding murres to flush from their nesting ledges leaving their eggs or chicks exposed to predation. **D. Nysewander** (pers. comm.) commented that shots fired by halibut fishermen disturbed the colonies. He also said that the fishermen were willing to use other means for killing large halibut near the colonies once they were made aware of the problem.

VII. COMPARISONS BETWEEN COMMON AND THICK-BILLED MURRES:

Five to 10 percent of the breeding population of murres in the affected area are thick-billed murres. The two species are quite similar and are often found nesting in mixed colonies where their ranges overlap. The thick-billed murre has a more northern distribution and overlap with common murres in the southern half of their range (Tuck 1960). Differences in nest site preference and feeding behavior occur between the species.

Birkhead (1977) showed that the breeding success of common murres was influenced most strongly by the density of conspecifics on the nesting ledge. In contrast, the greatest influence on thick-billed murres were the nest site characteristics which varied between colonies (Birkhead et al. 1985). In general, thick-billed murres select nesting ledges which are narrower than those selected by common murres (Williams 1974, Birkhead et al. 1985). During incubation, thick-billed murres rest their breasts against the cliff wall, therefore, the proximity to the cliff face or other walls is important (ibid.).

The diets of the two species of murres differ considerably. Fishes comprised the most important prey species for common murres while cephalopods, fish and crustaceans were important for thick-billed murres (Sanger 1986). Appendix A provides food web charts for both species and a table which compares the prey species. Capelin, Pacific sandlance and walley pollock were the only species which were important to both species of murres (Sanger 1986).

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APPENDIX A

These figures and tables are copied directly from G.A. Sanger's 1978 report to OCSEAP. They have not been modified in any way.

[Note: The acronym "IRI" in Tables 6, 15 and 16, refers to the Index of Relative Importance. Higher values indicate greater importance.]

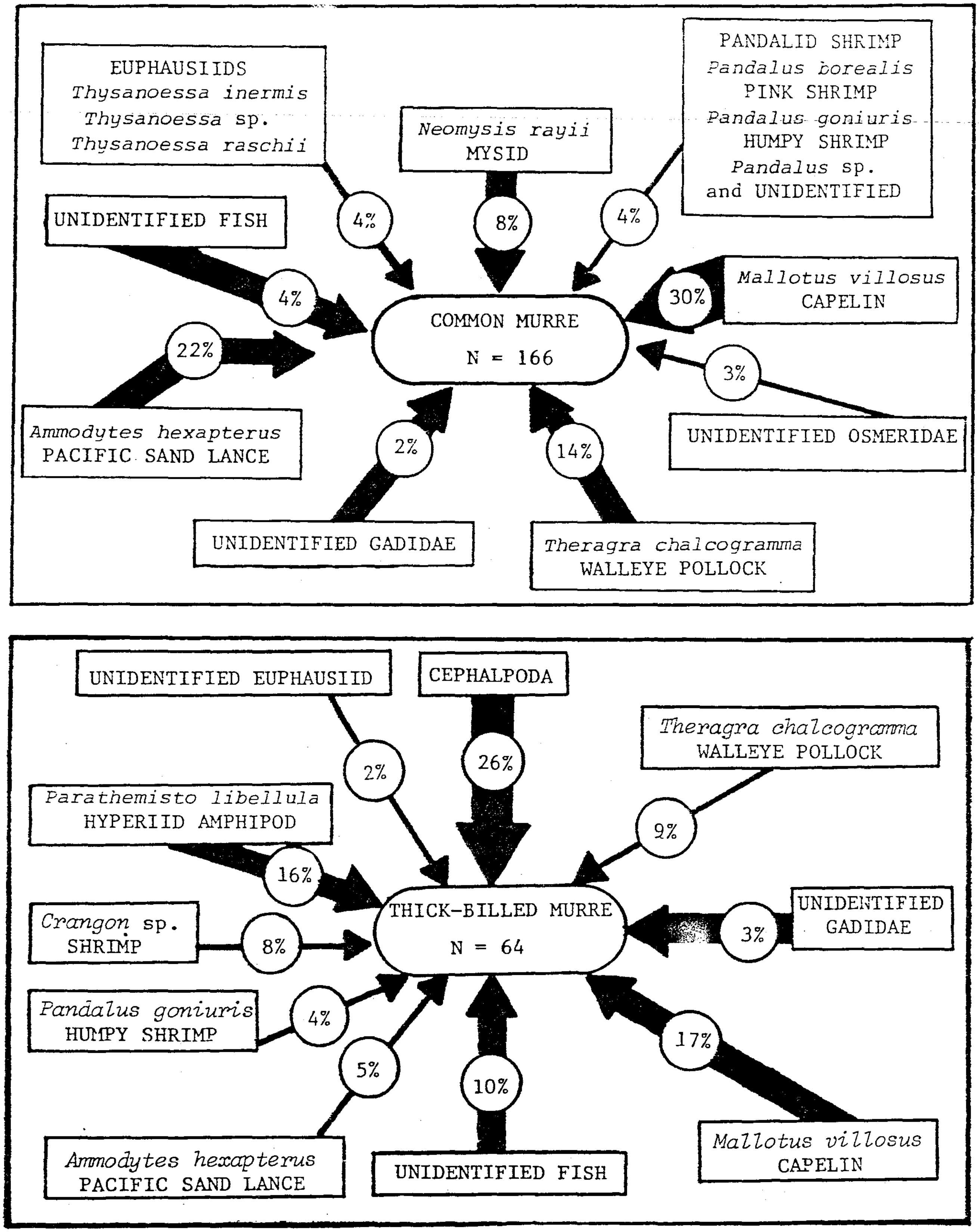

Figure 24. Food webs for common (top) and thick-billed murres (bottom), showing main prey items as indicated by data pooled from all years, seasons and regions; see Fig. 2 caption.

Table 6. Comparative importance of prey to murres, based on data pooled from stomach samples collected in Alaskan waters. Importance levels based on IRI values, as follows: trace (tr) = 0 - 9; 1 = 10 - 99; 2 = 100 - 999; 3 = 1,000+

PREY NAME	Importance of Prey to Bird Species: Common Murre N = 166	Thick-billed Murre N = 38
POLYCHAETE, Nereidae	tr	tr
GASTROPOD, Unidentified	-	tr
CEPHALOPODA,		
Unidentified/Unidentified Squid/ Unidentified Gonatid Squid	tr	3
CRUSTACEA		
Calanoid Copepod	-	tr
Leucon sp. (Cumacean)	tr	-
Neomysis rayii (Mysid)	2	
Gammarid Amphipods		
Protomedeia sp.	tr	-
Anonyx sp.	tr	-
Unidentified	tr	tr
Hyperiid Amphipods		
Parathemisto libellula	-	2
P. pacifica	-	tr
Euphausiids		
Thysanoessa inermis	1	tr
T. raschii	tr	-
T. sp./Unidentified	1	1
Decapods		
Eualus stimpsoni (Shrimp)	tr	-
Pandalus borealis (Pink Shrimp)	1	-
P. goniuris (Humpy Shrimp)	tr	1
Crangon franciscorum (Bay Crangon Shrimp)	tr	-
C. sp. (Crangon Shrimp)	-	1
INSECT, Unidentified	tr	-
ECHINODERM		
Amphipodia sp. (Brittle Star)	tr	-
FISH		
Clupea harengus (Pacific Herring)	tr	-
Mallotus villosus (Capelin)	3	2
Gadus macrocephalus (Pacific Cod)	tr	-
Boreogadus saida (Arctic Cod)	-	tr
Microgadus proximus (Pacific Tomcod)	tr	-
Theragra chalcogramma (Walleye Pollock)	2	1
Trichodon trichodon (Pacific Sandfish)	tr	-
Lumpenus maculatus (Daubed Shanny)	tr	-
L. saggita (Snake Prickleback)	tr	-
Ammodytes hexapterus (Pacific Sand Lance)	2	1

Table 15. Comparison of the importance of the main prey species of common murres in Alaskan waters, by major geographic region and season. Prey Importance levels based on their IRI values, as follows: 0 - 9 = trace (tr); 10 - 99 = 1; 100 - 999 = 2; 1,000 - 9,999 = 3; 10,000 and up = 4; x = present. Seasons: W = winter; Sp = spring; Su = summer; F = fall.

	Bering Sea			Kodiak				Lower Cook Inlet			NE Gulf of AK	
	W	Su	F	W	Sp	Su	F	W	Sp	F	W	Su
Sample Size =	1	6	1	11	11	81	8	23	9	5	2	9
PREY NAME												
Nereid Polychaete.....	-	-	-	tr	-	-	-	tr	-	-	-	-
Unidentified Squid....	-	-	-	-	-	tr	-	-	-	-	-	-
Acanthomysis sp.......	-	-	-	2	-	-	-	-	-	-	-	-
Neomysis rayii........	-	-	-	-	-	-	-	3	-	-	-	-
Anonyx sp.(gamm. amph)	-	-	-	-	-	-	-	-	-	-	x	-
Gammarid Amphipod.....	-	-	-	1	-	-	-	-	-	-	-	-
Euphausiids												
Thysanoessa inermis...	-	-	-	tr	-	2	-	-	-	-	-	-
T. raschii............	-	2	-	-	-	tr	-	-	-	-	-	-
T. sp./Un. Euphausiid.	-	-	-	-	-	2	-	-	-	-	-	-
Shrimp												
Eualus sp.............	-	-	-	-	-	-	-	tr	-	-	-	-
Pink Shrimp...........	-	-	-	tr	-	-	-	2	3	-	-	-
Humpy Shrimp..........	-	-	-	-	-	-	-	tr	-	-	-	-
Unidentified Pandalid.	-	-	-	2	-	-	-	1	-	-	-	-
Crangon franciscorum..	-	-	-	-	-	-	-	1	2	-	-	-
Unidentified Shrimp...	-	-	-	-	-	-	-	1	2	-	-	-
Unidentified Insect...	-	-	-	-	-	-	-	-	-	-	x	-
Fish												
Pacific Herring.......	-	-	-	-	-	-	-	1	-	-	-	-
Capelin...............	-	3	-	2	2	3	3	1	2	3	-	1
Pacific Cod...........	-	-	-	-	-	tr	-	-	-	-	-	-
Pacific Tom Cod.......	-	-	-	-	-	tr	-	-	1	-	-	-
Walleye Pollock.......	-	-	x	3	3	1	1	1	2	-	-	-
Unidentified Gadid....	x	2	-	2	3	1	-	tr	2	-	-	-
Pacific Sandfish......	-	-	-	tr	-	1	-	-	-	-	-	-
Daubed Shanny.........	-	-	-	1	-	-	-	-	2	-	-	-
Snake Prickleback.....	-	-	-	-	-	-	-	-	-	-	-	2
Pacific Sand Lance....	-	2	-	1	2	2	3	tr	-	-	-	3
Pleuronectid flounder.	-	-	-	-	-	tr	-	-	-	-	-	-
Unidentified Fish.....	-	3	-	-	1	2	1	1	2	3	-	2

Table 16. Comparison of the importance of the main prey species of thick-billed murres in Alaskan waters, by major geographic region and season. Prey Importance levels based on their IRI values, as follows: 0 - 9 = trace (tr); 10 - 99 = 1; 100 - 999 = 2; 1,000 - 9,999 = 3; 10,000 and up = 4; x = present
Seasons: W = winter; Sp = spring; Su = summer; F = fall.

	Bering Sea			Aleutians			W Gulf of AK	Kodiak
	Sp	Su	F	W	Sp	Su	W	Su
Sample Size =	1	5	3	4	2	4	4	9
PREY NAME								
Nereid Polychaete.....	-	-	2	-	-	-	-	-
Unident. Gastropod....	-	-	-	-	-	-	-	1
Unident. Cephalopod...	-	-	-	4	x	3	4	1
Calanoid Copepod......	-	-	-	-	-	1	-	-
Gammarid Amphipod.....	-	-	-	-	-	1	-	-
Parathemisto libellula	-	3	3	-	-	-	-	-
P. pacifica..........	-	-	-	-	x	-	-	-
Thysanoessa inermis...	-	-	-	-	-	-	-	1
Unident. Euphausiid...	-	-	-	-	-	3	-	-
Unident. Decapod......	-	-	-	-	-	-	-	1
Crangon sp. (shrimp)..	-	2	-	-	-	-	-	-
Unidentified Crustacea	-	-	2	-	-	-	-	-
Capelin..............	-	-	-	-	-	-	-	3
Arctic Cod...........	-	2	-	-	-	-	-	-
Walleye Pollock.......	-	1	-	-	-	-	-	2
Unidentified Gadid....	x	1	3	-	-	-	-	2
Pacific Sand Lance....	-	2	-	-	-	-	-	2
Unidentified Fish.....	-	2	3	-	-	3	-	2

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EXECUTIVE SUMMARY - Harlequin Duck Life History

The harlequin duck (Histrionicus histrionicus) has a disjunct holarctic distribution. The western population is more numerous with the greatest concentration of birds found in the Aleutian Islands of Alaska. Harlequin ducks breed and winter in relatively inaccessible areas and are therefore one of the least studied ducks in the northern hemisphere. Population estimates are limited and inexact; however, pre-spill wintering populations were estimated at 9,600 birds for the Kodiak Archipelago and 10,000 birds for Prince William Sound.

Harlequin ducks do not breed until their second year. Egg laying is believed to begin between May 10 and May 30; 3-7 eggs are laid and incubated for 28-30 days. Broods hatch in early to mid-July. Breeding birds conduct nesting and brood rearing inland next to turbulent mountain streams. Stream characteristics vary and preliminary information on nest sites found in Prince William Sound imply a considerable difference in preferred streams characteristics than published information from Iceland. Sam Patten found several nests at approximately 1000 feet elevation, next to cascading streams as narrow as 1 meter wide. Further information will be available in the 1991 NRDA report. Most harlequins nest on the ground beneath dense vegetation, however, harlequins have been known to nest in tree cavities and rock crevices. Aquatic invertebrates are the primary prey for breeding birds and broods.

Immature birds remain in coastal habitats throughout the summer. Breeding males join the non-breeding birds in early July to form large flocks for the pre-basic molt. Protected bays with anadromous fish streams are preferred congregating areas. Marine invertebrates, especially mussels, are the primary food source in winter and spring. Once freshwater invertebrates become available within the intertidal zone, feeding behavior shifts to the mouths of the stream. Salmon roe is believed to be the principal food source when it becomes available. Hens with broods will return to coastal habitats in late August and will utilize many of the same molting areas used by the males.

Harlequin populations are potentially impacted by disturbance and habitat loss. Harvest levels are believed to be low for both subsistence and recreational hunting.

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HARLEQUIN DUCK

I. TAXONOMIC DESCRIPTION
   A. Common Name: Harlequin Duck
   B. Scientific Name: Histrionicus histrionicus
   C. Races: Currently, there are no races described.

II. RANGE
   A. Worldwide (Figure 1):
   Harlequin ducks have a disjunct distribution with at least two geographically isolated populations. The western population of harlequins breeds in eastern Siberia, north to the arctic circle, east to the Chukchi and Kamchatka Peninsulas. In North America, breeding populations range from the Seward Peninsula, south to the Aleutian Islands, east to the Mackenzie River then south to central California and the northern Rocky Mountains. Wintering populations concentrate along the coast of California to the end of the Aleutian Islands, then south to Korea and central Japan (Delacour 1959, Bellrose 1980).

   The eastern population of harlequins breed in Iceland, the southern half of Greenland, southeastern Baffin Island, and parts of Labrador. Wintering birds concentrate on the southern end of Greenland, near coastal areas around Iceland and extend down the coast of N. America to New Jersey (Delacour 1959, Bellrose 1980). The eastern harlequin duck is a casual visitor to the Great Lakes and accidental in Europe (Delacour 1959).

   B. Alaska
   The Aleutian Islands, Alaska Peninsula and the Alexander Archipelago contain the greatest numbers of breeding Harlequin ducks in their North American distribution (Bellrose 1980). The greatest wintering concentration of birds occurs in the Aleutian Islands, but wintering harlequins are also abundant in Prince William Sound and the Alexander Archipelago (Bellrose 1980). Bellrose (ibid.) estimated the wintering population in the Aleutian Islands to be between 600,000 and 1 million birds; however, **Patten**[1] cautions

[1] Patten, S.M. Jr., Alaska Department of Fish and Game. 333 Raspberry Road; Anchorage, Alaska 99559. Anchorage: (907) 267 - 2179. Fairbanks: 455-6101

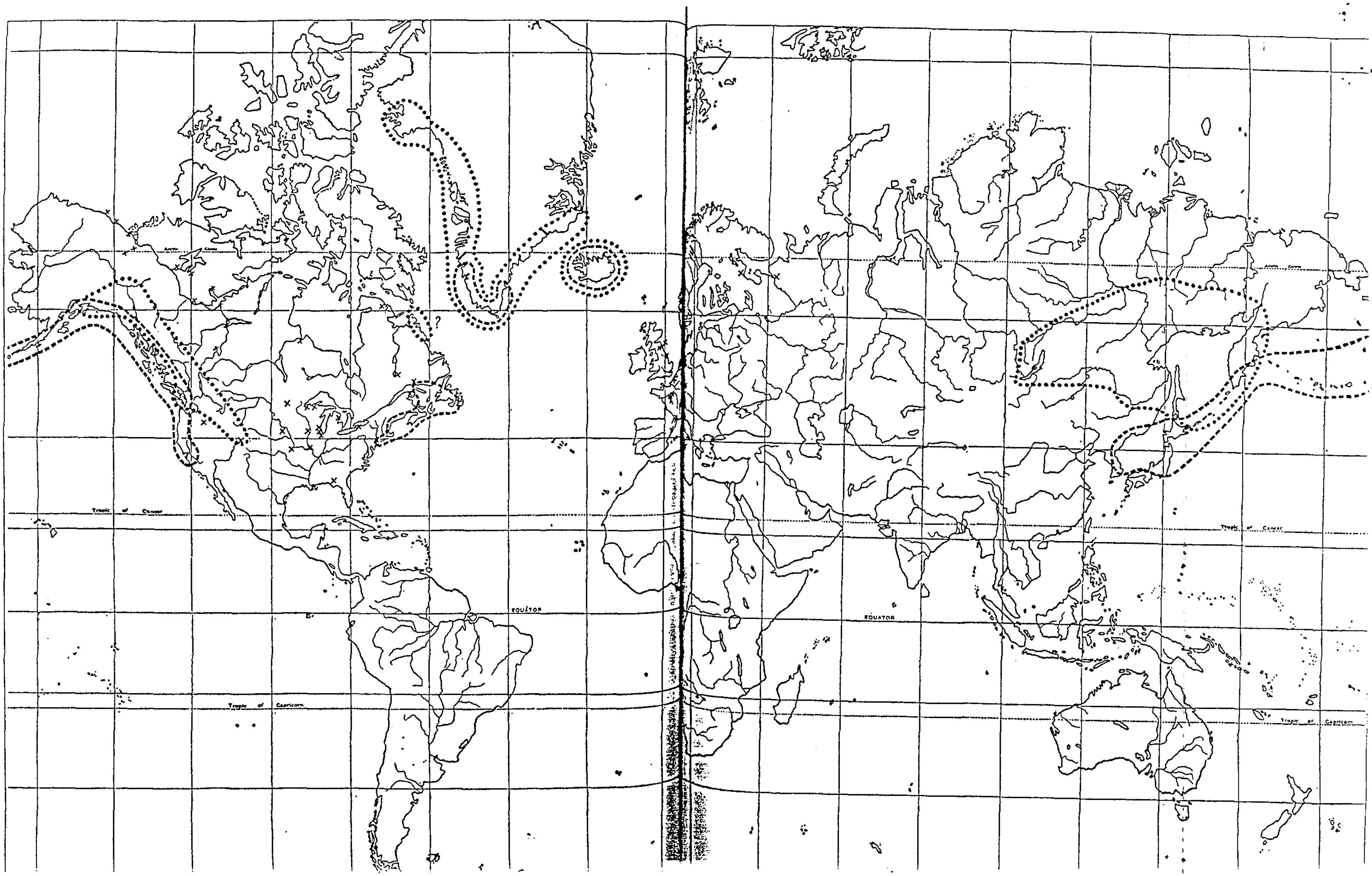

Figure 1. Breeding (...) and wintering (---) distribution of Harlequin ducks (copied from Phillips 1925).

that this estimate is considered to be too high (pers. comm.). He also estimated the wintering population of harlequins in Prince William Sound at 10,000 birds. An estimate of 9600 wintering harlequins in the Kodiak Archipelago were extrapolated from winter surveys in 1979 and 1980 (Forsell and Gould 1981). The highest concentrations were found in Sitkaladik Narrows and between Narrow Cape and Ugak Island. There are no estimates for other areas impacted by the oil spill.

C. Population Status

Harlequin ducks are the least studied duck species in North America. There are no good data on population trends before the spill.

III. MIGRATION CHRONOLOGY

Harlequin ducks begin arriving on their wintering grounds in the Aleutian Islands in mid-September and remain there until May (Bellrose 1980). In interior Alaska, the birds begin to arrive on breeding grounds from mid-May, to late May in the Brooks range (Bellrose 1980). Birds which winter and breed in south-central Alaska may begin congregating near the mouths of suitable breeding streams in late April or early May (**Patten pers. comm.**). In July, males congregate in protected bays, with good feeding areas, for the prebasic molt. They congregate in extremely large flocks (Patten found a flock of 350 males in 1991) during the flightless portion of the molt. Non-breeding and failed-nesting females begin their molts in August and utilize many of the same molting sites as the males. Females with broods migrate to marine habitats in late August (**Patten pers. comm.**).

IV. BREEDING CHRONOLOGY

Very little is known about breeding behavior and chronology of Harlequins. Most of the information published in the literature are based on studies in Iceland.

Harlequin ducks do not reach maturity until their second year (Delacour 1959, Bengtson 1972, Bellrose 1980). In Alaska, laying is believed to begin between May 10 and May 30 (Bellrose 1980). Harlequins lay a total of 3-7 eggs with a 2 day laying interval, and incubate the eggs for 28-30 days (Bengtson 1966, Bellrose 1980). Males desert the females early in the incubation period.

There is very little information available on the brood rearing period. Given the incubation period, broods would be expected to hatch in early to mid-July. Bengtson (1972) describes a 30-40 percent mortality for ducklings during the first 2 weeks. Patten (**NRDA REPORT - 1990**) reports seeing 3.1 ducklings per hen in late summer. This is comparable to the mean of 2.8 fully grown ducklings/breeding female found in Iceland over a 4 year period (Bengtson 1972).

V. HABITAT REQUIREMENTS

Harlequin ducks have unique habitat requirements because they use both marine and inland habitats. In coastal ecosystems, paired birds will be found in the intertidal reaches of mountain rivers and streams before moving inland to nesting habitats. Coastal areas are used throughout the summer by non-breeding birds, breeding males after the pair bonds are broken, and by failed nesting females (Bellrose 1980, Dzinbal and Jarvis 1982). Coastal habitats are used throughout the winter by all sex and age classes of harlequins.

A. Nesting and Brood Rearing Habitats

Harlequin ducks nest along rapidly flowing mountain streams. The width, turbidity and current velocity vary considerably, but most nests are located along shallow rivers and streams (0.5 - 1.0 meters deep) with gravel or rocky substrates (Bengtson 1972). Selection of streams is also related to nest site availability and the abundance of macroinvertebrates (Bengtson 1972). Early results from **NRDA Bird Study 11** (Patten 1990) identified 9 streams in Prince William Sound that are used by nesting Harlequins. A list of stream characteristics were developed (see Appendix I for a copy of these characteristics) which varied slightly Bengtson's (1972) findings. The results from the 1991 NRDA study are expected to provide substantially different information from published data. **Patten** (pers. comm.) found more streams used for nesting (approximately 20 in PWS) than documented in 1990. Many of these streams were considerably different than previously identified streams, a complete description of these streams will be provided in the November report.

Published literature describes preferred nesting sites located on islands and islets (Bengtson 1972). Ground nests are usually located beneath shrubs and other dense vegetation. Harlequins will also nest in tree cavities and in rock crevices (Delacour 1959), but these nests have been documented less frequently than ground nests. Bengtson (1972) located 98 nests in Iceland, of these only 7 were more than 5 meters from water. The mean nesting density was 1.3 pairs/km. Although harlequins cannot be considered colonial nesting birds, Delacour (1959) states that several nests may be located close together on islands in high velocity streams. Harlequins appear to have high site tenacity, often returning to within 100 meters of previous years nesting sites, females may use the same nest site for more than one season (Bengtson 1972).

In Prince William Sound, several of the nests located in 1991 were at approximately 1000 feet elevation, in timbered areas next to small, turbulent streams (Patten pers. comm.). Patten described these streams as "pocket cascades", sometimes only 1 meter wide.

Slow stretches in oxbows, or lee sides of curves, are used by broods for feeding and resting. Outlets from lakes, beneath waterfalls and turbulent stretches of streams no more than 0.8 meters deep are favorite feeding locations for adults (Bengtson 1972). Young broods (Age classes Ia - IIb) feed mostly on surface insects and on insects from over hanging vegetation; older broods feed in the same areas and manners as the adults (Bengtson 1972).

B. Summer Habitats: Non-breeders and Males

Fjords and bays are used extensively by males and non-breeding females throughout the summer. In spring, harlequins congregate at the mouths of mountain streams, feeding in the bays and intertidal areas. Paired birds feed extensively in the intertidal areas before moving inland to nesting areas.

Dzinbal and Jarvis (1982) studied the summer habitat use and feeding ecology of harlequins at Sawmill Bay in Prince William Sound. They found that intertidal areas within the rivers were used for feeding until the second week of July. At that time, the ducks moved inland and fed in the lower 1 km of the creeks (upstream from the intertidal zone). This shift in feeding areas corresponded with an increase in macroinvertebrates and an increase in salmon (Oncorhynchus spp.) spawning. In Sawmill Bay, males and nonbreeders rarely fed upstream from the lower 1.5 km of the streams.

Dzinbal and Jarvis (ibid.) compared the relative amount of time harlequin ducks spent in a given habitat type, to the amount of time spent feeding within each habitat type. From these data they determined that the creek habitats were utilized more for feeding. Harlequins spent most of their time near small rock islands in the bays, but spent proportionately less of their time feeding in these areas. The unstated implication from these data are that harlequins use the rock areas for loafing and resting and the creek areas for feeding. Inglis et. al. (1989) found that harlequins preferred to rest on the banks of islands within the rivers, but also used rocks protruding from the water for loafing.

C. Wintering Habitats

Harlequins winter in small flocks (up to 10 birds) along exposed, rocky coasts. Foraging ducks use intertidal and subtidal areas throughout the coast line. They are more evenly distributed throughout the coastal areas during the winter, which shows a wider range of habitat use than during the summer (**Patten** pers. comm.). During severe storms, the flocks will move to sheltered bays which offer protection from rough seas and strong winds.

VI. FOOD WEB INTER-RELATIONSHIPS

A. Predation

Predation is not believed to be a major source of mortality for adult harlequin ducks. Of the 98 nests observed by Bengtson (1972) 9 were depredated by raven (Corvus corax), mink (Mustela spp.), arctic skua (Stercorarius parasiticus), and arctic fox (Alopex lagopus). Ravens were believed to have destroyed 5 of the nests. Very little information is available about brood rearing and mortality. Bengtson (1972) estimated a 30-40 percent mortality for ducklings in the first two weeks after hatch, adverse weather during this time period may be a significant cause of mortality.

B. Feeding Behavior and Diets - Summer

Harlequin ducks feed almost exclusively on animal matter. Breeding birds and broods in Iceland, fed mostly on abundant Simuliidae (Diptera), but also fed on Chironomidae larvae and Trichoptera (n=31) (Bengtson 1972). Once salmon begin spawning, harlequins begin eating roe (Delacour 1959, Dzinbal and Jarvis 1982). It is unclear in the literature if brood movement downstream is linked to spawning. It is believed that breeding birds in Coastal ecosystems with short mountain streams, may fly from nesting areas to the mouths of the rivers for feeding (Bengtson 1972, Dzinbal and Jarvis 1982). This is apparently linked to shorter streams having lower nutrient quality and therefore less productive invertebrate populations (Bengtson 1972).

It is important to recognize that the information on feeding habits and preferences of harlequins in Alaska is extremely limited. Much of the information that follows is based on small sample sizes and observations.

The summer diets (n=5) of coastal harlequins in Prince William Sound consisted of a variety of crustacea and invertebrates (Dzinbal and Jarvis 1982). Feeding patterns suggest that the birds ate marine invertebrates until freshwater invertebrates became abundant. Once salmon began spawning, the diets may shift predominantly to salmon roe.

C. Prey Species - winter

Wintering harlequins forage mostly along exposed coasts and in bays (Delacour 1959, Bellrose 1980). They are generally found in small groups, usually less than 10 birds and are seen foraging closer to shore than other sea-ducks (Bellrose 1980). Crustaceans and mollusks (Crustacea and Mollusca respectively) comprise the bulk of the winter diet for harlequins (Delacour 1959, Bellrose 1980, Dzinbal and Jarvis 1982). Other animals which supplement this diet include insects, starfish (Echinodermata), and fishes (Bellrose 1980, Dzinbal and Jarvis 1982).

VII. HUMAN INTERACTIONS

The holarctic distribution and migration patterns of harlequin ducks limits the hunting impacts on the species. The annual take of harlequins in Prince William Sound is unknown, but believed to be small since most harvesting is associated with using males as decorative mounts (**Patten pers. comm.**). There does not seem to be any significant Native use of harlequins; although, Nelson (1887 cited in Phillips 1925) mentioned that some Native populations killed male harlequins and stuffed them as toys for children.

Patten believes that disturbance to the molting flocks would be one of the greatest human-related impacts, aside from toxic spills, on the harlequin population. He expects to provide a detailed accounting of locations of molting flocks and potential impacts of disturbance in the NRDA report.

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DRAFT

Copied from: Patten, S.M. 1990. Prince William Sound Harlequin Duck Breeding Habitat Analysis Feasibility Study. Appendix I. NRDA BIRD STUDY No. 11.

Table 2

Characteristics of Harlequin Nesting Streams in Prince William Sound

Characteristics
30 - 50 ft wide at mouth to estuary
extensive intertidal areas in estuary
moderate gradient
discharge rates of 1.5 - 7.0 cu. m/sec.
.3 -.5 m deep
elevation at onset of stream approx. 750 ft.
clear, not glacial or turbid
substrate of large stones, rocks, boulders
5 - 8 km length (relatively short)
bordered by mature spruce-hemlock forest
salmon spawning stream (chum, humpback)
Harlequin nest areas begin approx. .5 km from mouth (Dzinbal, 1982)
nests found from 2 to 20 m from water (Bengston, 1966)
mean clutch size approx. 5.5 eggs (Bengston, 1966)
mean brood size summer 1990 observed outside oil spill area: 3.1 ducklings per brood

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Dr. Stan Senner
CACI, Inc. - Commercial
645 G Street
Anchorage, Alaska 99501

Dear Dr. Senner,

Thank you for the opportunity to review the memorandum of Dr. Roby of December 17, 1991 on restoration options for the murres. It appears that Dan did a very thorough job, surveying most of the North American experts on this subject. The following is more-or-less my preliminary reaction to the available options that might be explored for 1992. I'm not an expert on this subject, so feel free to ignore these if they do not make sense to you.

1. **Preliminary nest site improvement in the early spring before nesting or aggregations of birds appear on the Barren Islands.** It may be possible to document (by photo) this spring the detailed physical characteristics of the most commonly used nest sites in the decimated colony. A climber or helicopter fitted with a large-format high-resolution camera could obtain enough overlapping large photos to build a large (wall-sized), detailed montage. Stereophotography might also be useful to be able to understand the detailed topography of the cliff face(s). After the birds return later in the spring, their use of the habitat could provide further clues to microhabitat preferences. Understanding topography and usage in 1992, one could plan how to best modify the habitat by ***subtle*** alterations of the cliff face.in the spring of 1993 (before

the birds arrive at the colony). The success of the alterations could be documented later in 1993 or later, when breeding takes place in 1993. It seems that wholesale alterations run too many risks of negative aesthetic and biological consequences.

2. **Limited use of vocalization, decoys and predator barriers.** The potential for negative biological effects resulting in alteration of behavior necessitate a cautious approach in using these tools. In my opinion we would want to try this on a small scale first, away from the largest congregations of birds, so that we do not disrupt or alter any incipient natural recovery in breeding colonies.

3. **Continued monitoring is essential.**

I hope that this is useful. It all depends on the local conditions on the Barren Islands. Can you get on a local area network so that I could use Art's compuserve connection to transmit these messages?

Sincerely yours,

Robert Spies
Chief Scientist

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9 December 1991

Stanley E. Senner
Oil Spill Restoration Planning Office
Alaska Department of Fish and Game

From: George Hunt FAX (714) 725-2181 -2284
Department of Ecology & Evolutionary Biology
University of California, Irvine

RE: Review of Roby report on murre restoration

This is a wide-ranging and provocative report. It presents many ideas worthy of consideration, and provides a useful analysis of the potential benefits of these options. In several instances the report seems to downplay potential problems with various options. Although these potential drawbacks may not be reason enough to abandon exploring some options, the drawbacks need to be considered and planned for in experimental design.

In examining Roby's memo, it seems clear that there are potentially two completely separate problems; one is the availability of recruits and the second is the social integration of those few birds that are attempting to breed. Before we invest greatly in one or more solutions, it would seem imperative to identify the problem we need to solve.

The lack of birds on the colonies is very likely due to the loss to oil of the majority of the breeding adults and the 1989 pre-breeding recruits. If this is the case, then we would expect one or two years of modest increases for two to three years after the spill due to recruitment of the last of the cohorts produced by the colonies prior to the spill. This should be followed by many years (? 30 or more) of very slow colony growth generated by newly produced cohorts from the greatly diminished colonies. In this situation, there is little we can do to speed colony growth other than protecting the breeding stock and their reproductive efforts. The colonies may also grow due to recruitment of individuals from other, unaffected colonies, particularly if these colonies are "crowded".

There are several actions we can take to determine whether a lack of recruits in constraining colony growth.

1. Monitor colony growth to determine the rate of increase in the number of birds

a) visiting the colony and b) breeding. Compare the ratio of visitors to breeders with control colonies that are healthy.

2. Survey the waters around the colonies that have been severely reduced in size to determine if there are larger numbers of murres in the vicinity available for recruitment. Numbers on the water in relation to colony size (breeding birds on the colony) can be compared with numbers at "healthy" colonies to see if there is an excess or deficit of birds offshore of the damaged colonies.

3. Examine the age-class distribution of birds on the reduced colonies (this will necessitate killing 100 or so birds) to determine if the ratio of young to old birds differs from that in healthy colonies.

4. Compare observed colony growth rates with those generated by models of recruitment and age class structure to access whether colony growth is dependent on internally generated recruits or if immigration is aiding recruitment.

If recruitment is found to be limited by the availability of recruits, then there will be little that we can do that will enhance colony growth via decoying new individuals to the colony. If the birds now breeding on the colonies (and those likely to be recruited) are mostly young birds, social stimulation is unlikely to hasten greatly the improvement of synchrony and timing of breeding. Even in large, well established colonies, these birds are incompetent and frequently fail. Time and practice is needed for them to learn how to raise young. The results from 1991 suggest that this process is beginning to take place as the fragmented colonies and pairs begin to reorganize.

If studies show that there are potential recruits offshore and that a major bottleneck is attraction of birds onto the colony, then it will be worthwhile investigating methods of attraction, as outlined by Roby. In addition elimination of disruption of breeding efforts due to human disturbance is likely to be of benefit, as is reduction of predation. The number of predators around the colonies may well be "appropriate" for the much larger colonies present before the spill. The birds in the reduced colonies are more vulnerable due to a larger amount of edge in relation to center of colony and a lesser dilution of the impact of predators. Preparations for predator control would seem of likely high value, if predation is a major factor as is suggested by the 1991 data.

I would also like to provide some specific responses to Dr. Roby's proposals for various restoration options. I do not disagree with any of the possible benefits of the proposed actions, but I wish to offer some cautions.

1-A-1 Playbook of calls - probably of benefit, possibly not too expensive, and little chance for harm unless the wrong calls (alarm, aggressive) are recorded.

1-A-2 Painted decoys - possibly beneficial - but some chance for harm. They may cause gaps between birds that predators will use for access to the colony center. Possibly more appropriate for burrow nesters such as puffins.

Decoys on the water - these may initially attract birds, but they then may hold birds on the water and decrease movement to the nest sites. An unknown.

1-A-3 Mirrors - large mirrors may cause birds to fly into them; mirrors may elicit endless aggressive behavior as birds "fight" with their own reflection; how would you keep them clean? The effect of mirrors might vary with the scale of deployment. They will also interfere with already present site fidelity.

1-A-4 Dummy eggs - are murres attracted to eggs? Are recruits attracted to the colony after eggs are laid, but when the ledges are without adults? I suspect that dummy eggs would attract predators, although they might also cause predators to lose interest in "eggs". This experiment would probably have to be done on a large scale if it were to work, but on a large scale, dummy eggs might occupy useful nest sites.

1-B-1 Sills on ledges - this could be useful for the narrow ledges occupied by thick-billed murres, but is unlikely to help on the wide ledges preferred by common murres. Will eggs piled up against a sill be retrieved by the parents?

1-B-2 Partitions and roofs - this could be useful, but these structures could also provide perches for crows, ravens, eagles and even gulls. These birds will use horizontal surfaces not occupied by the murres as places to sit and wait for openings.

1-B-3 Covering parts of the colonies - this seems a poor idea as we don't know where the murres will choose to settle and we may cover the most favored sites.

1-B-4 Bigger ledges may be better, but only when covered with birds. When unused ledge is present, it provides a perch from which predators can attack.

1-C-1,2,3 These are all measures of desperation. If you modify cliffs in any but permanent ways, birds that take advantage of the modified habitat will be done in when the modification fails due to aging. With declines in murre numbers, it seems unlikely that nest sites will be limiting for some time to come.

I-D-1,2,3 Release of murre chicks seems extremely chancy, given possible damage to donor colonies, costs and problems of chick survival when not accompanied by the male parent. The results at Texel are encouraging, but it is in an area with few (?no) nearby murre colonies. I wonder if, with other large active colonies providing wintering companions, the young murres might be recruited to healthy colonies?

II-A-1,2 If avian predation is a problem, then some gull and raven control seems appropriate. Oiling eggs is too slow to be useful. Trapping "pest" eagles also seems useful.

II-B-1,2,3 The need for control of mammalian predators does not seem great at this time.

II-C-1,2,3,4 Control of human disturbance would seem of great value and relatively easily accomplished, particularly if those on the islands had marine radios and enforcement power. If support vessels and those engaged on pelagic work carry an occasional enforcement officer, human disturbances should be controllable.

II-D-1,2,3 I strongly agree with this section.

III-A-1,2 This is a potentially important option.

III-B-1,2,3 Forage fish availability is a potentially important issue. There is considerable circumstantial evidence that a lack of available forage fish has had a negative impact on both marine birds and mammals. If declines and breeding failures during the last 15 years have been due to a shortage of fish, then recovery of murre, other seabird, and marine mammal populations may be constrained regardless of what we do to improve conditions in the breeding colonies. Birds on the wintering grounds or at the colonies apparently cannot get enough energy to support egg laying. However, showing that foraging fish are in short supply will not be easy. We will need to use carefully designed comparisons of the distribution and abundance of forage fishes in the vicinity of successful and unsuccessful colonies during critical periods, and possibly on the wintering grounds. These will have to be multi-year studies and will be expensive. They are important, but they will have to be very carefully planned if they are to yield useful results. I suggest that a year or so of planning will be appropriate before any move is made in this direction. In the meanwhile, information on diets should be obtained at as many successful and unsuccessful colonies as can be sampled.

III-C,D These are attractive possibilities, but may do little to help restore populations in the affected areas. They should be pursued for their own merits, but separately from the restoration program.

FAX COVER SHEET

TO: Dan Roby, Coop. Wildl. Res. Lab

FAX NUMBER: (618) 453-6944

LOCATION: Carbondale, IL

DATE: 11 December 1991

NUMBER OF COPIES (INCLUDING COVER SHEET): 5

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FROM: Stan Senner, ADF+G

COMMENTS: Here are George Hunt's comments, which I've not had time to read.

FAX COMPLETE

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1-A-3 Mirrors - large mirrors may cause birds to fly into them; mirrors may elicit endless aggressive behavior as birds "fight" with their own reflection; how would you keep them clean? The effect of mirrors might vary with the scale of deployment. They will also interfere with already present site fidelity.

1-A-4 Dummy eggs - are murres attracted to eggs? Are recruits attracted to the colony after eggs are laid, but when the ledges are without adults? I suspect that dummy eggs would attract predators, although they might also cause predators to lose interest in "eggs". This experiment would probably have to be done on a large scale if it were to work, but on a large scale, dummy eggs might occupy useful nest sites.

1-B-1 Sills on ledges - this could be useful for the narrow ledges occupied by thick-billed murres, but is unlikely to help on the wide ledges preferred by common murres. Will eggs piled up against a sill be retrieved by the parents?

1-B-2 Partitions and roofs - this could be useful, but these structures could also provide perches for crows, ravens, eagles and even gulls. These birds will use horizontal surfaces not occupied by the murres as places to sit and wait for openings.

1-B-3 Covering parts of the colonies - this seems a poor idea as we don't know where the murres will choose to settle and we may cover the most favored sites.

1-B-4 Bigger ledges may be better, but only when covered with birds. When unused ledge is present, it provides a perch from which predators can attack.

1-C-1,2,3 These are all measures of desperation. If you modify cliffs in any but permanent ways, birds that take advantage of the modified habitat will be done in when the modification fails due to aging. With declines in murre numbers, it seems unlikely that nest sites will be limiting for some time to come.

I-D-1,2,3 Release of murre chicks seems extremely chancy, given possible damage to donor colonies, costs and problems of chick survival when not accompanied by the male parent. The results at Texel are encouraging, but it is in an area with few (?no) nearby murre colonies. I wonder if, with other large active colonies providing wintering companions, the young murres might be recruited to healthy colonies?

II-A-1,2 If avian predation is a problem, then some gull and raven control seems appropriate. Oiling eggs is too slow to be useful. Trapping "pest" eagles also seems useful.

II-B-1,2,3 The need for control of mammalian predators does not seem great at this time.

II-C-1,2,3,4 Control of human disturbance would seem of great value and relatively easily accomplished, particularly if those on the islands had marine radios and enforcement power. If support vessels and those engaged on pelagic work carry an occasional enforcement officer, human disturbances should be controllable.

II-D-1,2,3 I strongly agree with this section.

III-A-1,2 This is a potentially important option.

III-B-1,2,3 Forage fish availability is a potentially important issue. There is considerable circumstantial evidence that a lack of available forage fish has had a negative impact on both marine birds and mammals. If declines and breeding failures during the last 15 years have been due to a shortage of fish, then recovery of murre, other seabird, and marine mammal populations may be constrained regardless of what we do to improve conditions in the breeding colonies. Birds on the wintering grounds or at the colonies apparently cannot get enough energy to support egg laying. However, showing that foraging fish are in short supply will not be easy. We will need to use carefully designed comparisons of the distribution and abundance of forage fishes in the vicinity of successful and unsuccessful colonies during critical periods, and possibly on the wintering grounds. These will have to be multi-year studies and will be expensive. They are important, but they will have to be very carefully planned if they are to yield useful results. I suggest that a year or so of planning will be appropriate before any move is made in this direction. In the meanwhile, information on diets should be obtained at as many successful and unsuccessful colonies as can be sampled.

III-C,D These are attractive possibilities, but may do little to help restore populations in the affected areas. They should be pursued for their own merits, but separately from the restoration program.

Stan's copy

Southern Illinois University at Carbondale
Carbondale, Illinois 62901-6504

Cooperative Wildlife Research Laboratory
618-536-7766

MEMORANDUM DATE: 29 November 1991

CONFIDENTIAL

TO: Stanley E. Senner
Oil Spill Restoration Planning Office
Alaska Department of Fish and Game

FROM: Daniel D. Roby FAX: 618-453-6944
Cooperative Wildlife Research Laboratory
Southern Illinois University

Daniel D. Roby

RE: Review of Murre Restoration Options

In response to your memo of 20 September, I have reviewed potential murre restoration options, paying particular attention to those options that may be feasible for implementation or study in 1992. Common Murres (Uria aalge) suffered the greatest direct mortality from the Exxon Valdez spill of any species of higher vertebrate. Murre populations are characterized by low intrinsic rate of increase. Some spill-affected colonies have apparently experienced near total reproductive failure during the three breeding seasons since the spill. These considerations indicate the need for restoration activities to encourage, enhance, and/or supplement natural recovery processes. It is not clear at the time of writing whether all damaged colonies have begun the recovery process, and results from continued monitoring may indicate that extirpation of some colonies can only be avoided by direct restoration efforts. The loss of a few small breeding colonies of Common Murres is not significant for the statewide population, but some of the colonies decimated by the spill are also some of the most accessible to nonconsumptive users (Chiswell Islands, Barren Islands).

I have divided the restoration options listed below into three groups: (1) direct on-site restoration, (2) indirect on-site restoration, and (3) off-site restoration, both direct and indirect. By direct restoration, I mean activities that are directed specifically at murres, as opposed to their food supply or predators. By on-site, I mean restoration activities conducted at breeding colonies that were damaged by the spill. Off-site restoration is either regional or directed at murre populations outside the spill area.

I have spoken by phone with the following experts regarding potential restoration techniques for murres: Michael Fry (U.C. Davis), Anthony Gaston (CWS), Stephen Kress (Cornell Lab. of Ornithology), Christopher Mead (BTO), David Nettleship (CWS), Ian Nisbet, David Nysewander (USF&WS), Raymond O'Connor (U. of Maine), John Piatt (USF&WS). In addition, I have corresponded with C. Swennen (Netherlands Institute for Sea Research), William Montevecchi (Memorial U.), and John Croxall (British Antarctic Survey). I am grateful to these individuals for freely sharing their ideas and expertise with me. In the discussion that follows, I have tried to credit them for their input on particular restoration options.

Direct restoration of murres is a novel and somewhat controversial endeavor. Although murre populations have been previously damaged by oil spills and other human-related perturbations, I have found no evidence of previous direct restoration activities that targeted murres. Proponents of direct restoration of murres cite (1) the slow pace of murre colony recovery in the absence of human intervention, (2) the need to prevent extirpation of decimated murre colonies should natural recovery fail, (3) long-term benefits that may derive from development of murre restoration technology, (4) the opportunity afforded by the spill to test the feasibility of various direct restoration options using controlled experimentation, and (5) an obligation to expend restoration resources on species most damaged by the spill. Detractors of direct restoration for murres voice all or some of the following concerns: (1) technology for direct restoration of murres is in its infancy and there is a high risk of failure; (2) there is risk of unanticipated negative side effects from direct restoration; (3) direct restoration will not provide significant benefits to damaged murre colonies at a reasonable cost; (4) limited restoration funds should be spent on habitat restoration or protection that will benefit more than a single species.

The success of murre restoration, whether direct or indirect, will depend on the availability of data on the factors influencing murre survival and productivity. Indirect restoration techniques, such as predator control, protection of breeding colonies from human disturbance, and reduction of forage fish harvest, have been used in attempts to restore or expedite natural recovery of seabird populations. But the success of these efforts has varied, depending on the extent to which these factors are limiting for any particular seabird population. Murre restoration poses a three-pronged challenge: (1) determine the factors currently limiting murre survival and productivity, (2) devise techniques to mitigate those factors, and (3) evaluate the effectiveness of restoration techniques.

I will fax a copy of the Annotated List directly to Tony Gaston for his comments. Please provide copies to Mike Fry and Dave Nysewander when you see them. Based on their responses and yours, I will finalize the memorandum and fax it to you before I depart for the south.

CONFIDENTIAL

DRAFT ANNOTATED LIST OF RESTORATION OPTIONS FOR COMMON MURRES IN THE AFTERMATH OF THE EXXON VALDEZ SPILL

I. DIRECT ON-SITE RESTORATION

DRAFT

A. Social Stimulus Enhancement

1. Playback of recorded murre calls
   - use solar-powered tape players to continuously play recordings of murre calls at breeding colonies (Kress)

2. Painted murre decoys
   - place wood decoys on breeding ledges in an attempt to attract more adults to nest sites (Kress)
   - place styrofoam decoys on water beneath breeding cliffs (Montevecchi)

3. Mirrors
   - create the illusion of larger numbers of murres in attendance on breeding ledges (Gaston)

4. Dummy murre eggs
   - place painted wooden or plaster eggs on breeding ledges to provide a visual stimulus for laying (Gaston)

Notes: Productivity at colonies affected by the spill is suffering from delayed phenology, lack of reproductive synchrony, low hatching success, and low survival of pre-fledging chicks (Nysewander). The late timing of fledging probably also results in poor post-fledging survival. Surprisingly, these problems have persisted at some spill-affected colonies for three breeding seasons after the spill. Social factors are the most likely cause of these effects (Fry, Nisbet, O'Connor, Piatt, Swennen), but other factors may be involved (see below). There are probably few experienced breeders at those colonies where extensive adult mortality occurred following the spill. Also, breeding adults that did survive probably lost their mate and were forced to pair with inexperienced individuals (Nisbet). Those subadults that survived the spill and replaced breeding adults that died would be expected to breed later and be less synchronized (Nettleship, Gaston). Even for experienced breeders, there may be a critical number or density of other breeding adults necessary to stimulate ovulation. The persistence of reproductive impairment following the spill suggests that the vast majority of experienced breeders at certain colonies were killed (Gaston).

An increase in social stimuli may increase colony attendance, stimulate earlier onset of egg-laying, and increase egg-laying synchrony. All of these changes would be expected to result in improved production of young. Social stimulation of reproduction (using playbacks of murre calls and painted wooden decoys in the colony) has proved effective in attracting Atlantic Puffins to nest on islands off the coast of Maine where they have been absent for over a century (Kress). Providing an auditory "super stimulus" (high volume playbacks of murre calls recorded at a large colony) may serve as a strong attractant for prospecting murres that periodically visit colonies other than their natal colony (Mead).

Use of decoys, recordings, mirrors, and dummy eggs may be effective in the case of murre colonies that were severely affected by the spill and where breeding synchrony and reproductive success are chronically impaired. If a colony is declining with little prospect of recruiting additional breeders, then this restoration option may be effective in maintaining the colony as an active breeding site (Kress). This restoration activity is experimental, and the feasibility of stimulating breeding using decoys, recordings, dummy eggs, and mirrors should be tested prior to implementation on a large scale. The oil spill offers an excellent opportunity to test restoration techniques for enhancing productivity following decimation of a murre colony (Gaston). However, in order to evaluate the effectiveness of any novel and direct restoration technique, it is vital to carefully establish and monitor control sites.

Conclusions: This restoration option should receive careful consideration for feasibility studies during the 1992 breeding season. The techniques are amenable to tests of effectiveness by designating portions of decimated colonies as control and experimental sites. Experimental and control sites must be carefully selected so that differences in site characteristics do not confound interpretation of results. If nest site occupancy, onset of laying, egg production, laying synchrony, and fledging success are significantly enhanced in experimental sites compared to controls, then efforts to employ these techniques could be expanded.

B. Nest Site Improvement

1. Provide breeding ledges with sills
   - sills would mitigate egg loss due to eggs rolling off the breeding ledge (Gaston)

2. Construct partitions and/or roofs on nesting ledges
   - enhance security of nest sites from avian predators (i.e., bald eagles, gulls, ravens) (Gaston, Nysewander)

3. Blanket-off or cover portions of breeding cliffs
   - exluding murres from portions of cliffs that offer few large ledges may induce aggregations on a few broad ledges that provide the best opportunity for successful breeding (Mead)

4. Enlarge nesting ledges on cliff faces
   - dense aggregations of breeding murres on broad ledges are conducive of high production (Gaston)

Notes: All of the above restoration techniques are experimental. But experiences of biologists in the field suggest that these techniques may be effective in enhancing murre nesting success. All modifications to cliff nesting sites should, of course, be accomplished during the non-breeding season. The simple technique of providing nesting ledges with a sill to prevent murre eggs from rolling off the ledge could considerably improve hatching success. At some murre colonies egg breakage accounts for 60% of egg losses (Gaston). Protection of nest sites from avian predators would be enhanced by construction of partitions and/or roofs on nesting ledges (Gaston). Avian predators on murre adults, chicks, or eggs normally approach nesting ledges from above (eagles) or from the side (gulls), whereas adult murres approach their nest sites from below. Partitions and roofs would inhibit predators without detering use of nest sites by murres. Partitions spaced at 2'- 3' intervals may provide the greatest benefits without impairing murre reproduction (Gaston). Partions, roofs, and sills in conjunction with decoys, mirrors, dummy eggs, and playbacks could attract murres to safe nest sites that would otherwise go unused due to a lack of social stimuli.

Excluding murres from suboptimal nest sites may improve occupancy on better ledges and enhance reproductive success (Mead), but it is difficult in practice because of the strong nest site tenacity of murres (Gaston). Forcing breeding murres to occupy new nest sites may also disrupt breeding pairs and contribute to delayed and unsynchronized laying. By providing larger nesting ledges, larger aggregations of breeding murres may form and thereby increase social stimulation for breeding.

These restoration techniques may enhance reproductive success and colony occupancy at sites where reproduction is chronically impaired. But the practical aspects of effectively modifying cliff nesting habitat to achieve the desired results have not been worked out. Also, modification of breeding ledges runs the risk of displacing breeding pairs that are attempting to nest (Nettleship). Murres display strong nest site fidelity and displacement from nest sites may seriously disrupt breeding.

Conclusions: This restoration option carries some risk of negative side effects and may not produce a detectable increase in colony numbers. However, modifications of particular breeding cliff may provide significant enhancement of productivity. The cost-effectiveness of this restoration approach can not be ascertained based on current knowledge. While some experts question whether this restoration option will provide appreciable and cost-effective enhancement of breeding populations affected by the spill, I believe that it warrants consideration for a feasibility study. Murre restoration technology that could be developed in this area would be valuable. It will be critical to the success of any feasibility studies that all experiments be controlled.

C. Construction of Artificial Nesting Habitat

1. Modify cliff faces
   - relatively minor alterations of cliffs otherwise suitable for murre nest sites to render them inaccessible to mammalian predators
   - use scaffolding to provide nesting ledges on sheer cliffs

2. Construct artificial cliffs
   - masonry cliff faces to provide nest sites at locales where steep slopes or cliffs do not exist

3. Create cliff nest sites using explosives
   - blast out cliffs from slopes over-looking the sea

Notes: This restoration option seeks to enhance local productivity by increasing the availability of nest sites (cliff ledges) where they are limiting or lacking. This technique can vary from inobtrusive and minor modifications of cliff faces so as to eliminate access points by mammalian predators to use of explosives to produce cliff faces suitable for murre nesting. In some instances, fairly minor modifications to a site may render it inaccessible to foxes and other potential egg and chick predators.

However, none of the spill-affected colonies are apparently subject to significant mammalian predation. At sites where sheer cliffs rise from cobble beaches, scaffolding might be used to provide broad nesting ledges where they are otherwise absent. Use of explosives or construction of artificial ledges may be necessary to provide suitable nesting habitat where none currently exist, but there is no assurance that new nesting habitat would be occupied. These restoration options are unlikely to be effective if suitable nesting habitat is not limiting (Nettleship).

Conclusions: It is unlikely that this restoration option will provide appreciable and cost-effective enhancement of breeding populations affected by the spill. Also, there is no indication that suitable nest sites are limiting, particularly for populations decimated by the spill. Finally, some of these options may result in permanent alteration of coastal landscapes to benefit murres, but detract from the pristine character of the landscape. I do not recommend this murre restoration option for consideration in 1992.

D. Release of Captive-reared Murres

1. Captive propagation of murres
   - use captive adult murres to obtain murre fledglings for release at target colonies (Swennen)

2. Captive rearing of murre eggs/chicks
   - collect fresh eggs from healthy murre colonies, hatch and raise chicks in captivity, transfer chicks to target colony for imprinting and release

3. Transfer of chicks between colonies
   - transfer young chicks caught at healthy murre colonies to colonies where reproduction is impaired, hold in pens until imprinted, and release (Kress)

Notes: This option makes use of the natural tendency of many colonial seabirds to return to their natal colony to breed. Transfer of chicks between colonies has been successfully employed to reestablish extirpated Atlantic Puffin colonies in the Gulf of Maine, and has been suggested as a potential method to enhance murre recruitment at colonies where reproduction is chronically impaired (Kress). Successful propagation of Common Murres in captivity has been accomplished by the Netherlands Institute for Sea Research, Texel, where captive adult murres produced fertile eggs that were then successfully raised by hand (Swennen). Captive-reared murres were released at Texel and later returned to the site where they had been raised and released, apparently prospecting for nest sites. This demonstrated for the first time that captive-reared murres could survive in the wild and would return to their natal area.

Annual egg production of captive adult murres is low, and using captive adults as a source of young for release is not cost-effective (Swennen). Alternatively, young murre chicks could be captured at healthy murre colonies and transferred to damaged ones. However, collecting chicks at murre colonies would impair recruitment at the donor colony due to: (1) removal of chicks, (2) egg loss resulting from breakage and predation when parents were not guarding their eggs, and (3) chick mortality resulting from premature fledging (Nettleship). The best option for obtaining chicks to release at a target colony is to collect fresh eggs from healthy donor breeding colonies. Wild murres will frequently (usually?) relay if their egg is removed or destroyed shortly after laying (pers. obs.), so collection of eggs in the wild may have little affect on donor colony productivity. Eggs would be placed in incubators for hatching and hatchlings would be fed by hand until 4-5 weeks old. The young do well in captivity on a diet of frozen fish (Swennen). Beginning at 4-5 weeks, murre fledglings will feed themselves if provided with fish in a tank or swimming area (Swennen). At three weeks post-hatching, murre chicks would be transported to the release site and held in outdoor pens with access to seawater. Murre feathers are easily fouled with excrement and waste food, causing lose of water repellancy, so providing fresh seawater is critical (Swennen). At approximately 8 weeks of age, fledgling murres would be released in groups of several dozen individuals. Murre fledglings normally go to sea with their male parent at about three weeks of age and receive considerable post-fledging parental care. Captive-reared fledglings released in groups when nearly full-grown may survive at nearly the rate of natural fledglings.

Common Murres normally breed for the first time at 4 years, so it would be several years before the survival of released murres could be determined through resightings of color-banded individuals at the release colony. If the release site had been completely abandoned by breeding adults, captive-reared birds would presumably search out other active colonies in which to breed. Artificial social stimuli (decoys, playbacks, dummy eggs, mirrors) would be necessary to attract captive-reared subadults to an abandoned colony.

Captive-rearing and release is a highly experimental restoration method. Development of the technology for reestablishing extirpated murre colonies would be valuable, regardless of whether it is used to restore colonies affected by the spill. Plans are underway to use captive-rearing and release techniques to reestablish decimated murre colonies in California (Kress). But conducting such a feasibility study at spill-affected colonies in the Gulf of Alaska would be expensive and logistically difficult (Swennen).

If one or more murre colonies are eventually completely abandoned, releasing captive-reared young should be given consideration as a restoration option (Kress). However, the captive propagation and release option would only produce relatively small numbers of potential recruits (100's). The low predicted survival of released young to adulthood (< 10%, Nettleship), high cost of captive rearing, and potential negative impact on colonies that serve as sources for eggs (Nettleship) led some experts to recommend against this restoration option (Nettleship, Swennen).

Conclusion: The captive-rearing and release is, in my opinion, not justified as a technique to enhance recruitment at active murre colonies. However, if a breeding colony has been completely extirpated, this technique may be the sole option for reestablishing a colony. To date no murre breeding colonies are known to have been abandoned as a result of the Exxon Valdez spill. Even in cases of complete abandonment, this technique is experimental, risky, and expensive. It would be valuable to develop the technology for successful reestablishment of extirpated colonies or enhancement of decimated colonies, but Gulf of Alaska colonies seem to be a poor choice for feasibility assessment. This restoration option is not recommended for implementation or feasibility study during the 1992 breeding season.

II. Indirect On-site Restoration

A. Avian Predator Control

1. Control populations of gulls and ravens using lethal means (Nysewander)
   - DRC-1339 poison bread baits
   - shooting
   - oiling eggs

1. Live-trap and remove juvenile Bald Eagles
   - transport problem eagles to sites in the lower 48 where eagle restoration programs are underway (Nysewander)

Notes: Glaucous-winged Gulls and Common Ravens are the most frequent predators on murre eggs and young at spill-affected colonies (Nysewander). Gulls can be a major source of egg mortality, accounting for 40% of egg losses at some colonies (Gaston). Gulls also take chicks from nesting ledges or as they attempt to fledge. Gull colonies are associated with most of the murre colonies in the northern GOA. Gulls have a much higher reproductive potential than murres and populations in the Gulf of Alaska are generally increasing. Temporary gull control measures could enhance murre productivity without threatening gull populations. Gulls and ravens nest earlier than murres, so control activities could be timed so as not to disrupt murre nesting (Nysewander, Kress). Gull control has been used successfully to enhance nesting success at some seabird colonies and has been an integral part of attempts to reestablish extirpated seabird colonies in the Gulf of Maine (Kress). Bread baits treated with the avicide DRC-1339 are an effective means of controlling gulls and pose no risk to other piscivorous seabirds (Kress). However, poisoned gulls might be a source of secondary poisoning for Bald Eagles. Shooting is another effective means of gull control with little chance of affecting non-target species. Another method of controlling gull populations is to oil gull eggs so that they fail to hatch, but the parents continue to attend the eggs until it is too late in the season to renest. However, this control technique may have little affect on the size of the gull population for some years. Destructive gull control is the only proven effective technique for mitigating the impact of gulls on seabird reproductive success (Kress) (but see I-D above).

Bald Eagles, unlike gulls and ravens, are known to take adult murres (Nysewander). Eagles elicit a strong panic response from adult murres on nesting ledges and indirectly result in losses of eggs and young to other avian predators. Some juvenile Bald Eagles are resident at murre colonies during the breeding season and cause significant disruption of breeding activities (Nysewander). Bald Eagles have apparently increased significantly in the northwestern GOA during the last few decades and are causing considerably more losses at murre colonies than in the past (Nysewander). Destructive control of problem Bald Eagles is certainly not feasible, but removing them to remote locations from which they are unlikely to return is an option.

Conclusions: Where decimated murre colonies are experiencing consistently poor reproductive success, it may be advisable to control gulls, eagles, and/or ravens on a temporary basis as a means to enhance natural recovery. However, this restoration option creates public relations problems. Before any avian predator control is instituted, it is crucial that intensive field studies be conducted to document prevalence and intensity of mortality and reproductive failure associated with avian predators. A clear justification for predator control needs to be obtained prior to initiation of control measures. I recommend that the effects of avian predators on murre survival and reproductive success at spill-affected colonies be investigated in 1992, as a prelude to potential predator control measures.

B. Mammalian Predator Control

1. Eliminate introduced foxes from islands that support murre colonies

2. Eliminate or control other introduced mammals (e.g., ground squirrels on the Barren Islands) on breeding islands

3. Control native mammalian predators on islands and headlands where murre colonies exist

Notes: Elimination of arctic foxes that were intentionally introduced to the Aleutian Islands has been shown to be a very effective seabird restoration activity. Although murres generally nest on inaccessible cliff ledges, foxes are adept at reaching these ledges and preying on large numbers of eggs, chicks, and even adults (pers. obs.). However, there are apparently no colonies in the spill-affected area that are subject to fox predation (Nysewander, Piatt). Arctic ground squirrels have been introduced to the Barren Islands, but apparently pose no threat to murres, their eggs, or their young, mostly affecting burrow-nesting seabirds (Nysewander). In cases where native mammalian predators (e.g., otter, mink) are contributing to egg and chick losses, temporary predator control may be warranted. However, I know of no murre colonies in the spill-affected area that suffer significant losses to mammalian predators.

Conclusions: Current knowledge indicates that this is not a restoration option for murre colonies in the oil spill area. However, mammalian predation on murre eggs, chicks, or adults may not be apparent without fairly intensive on-site investigations, so it is possible that this is a viable restoration option for some spill-affected colonies. As with restoration option II-A, it is critical to acquire more site-specific information on the effects of predators on murre nesting success prior to initiation of any predator control measures.

C. Reduction of Human Disturbance at Breeding Colonies

1. Prohibit discharge of firearms near murre colonies during the breeding season
   - use of firearms to kill halibut has been noted near colonies in the spill-affected area, resulting in disturbance of breeding murres (Nysewander)

2. Prohibit use of explosive devices near murre colonies during the breeding season
   - use of firecrackers to drive salmon into gill nets has been noted near colonies in the spill-affected area and resulted in disturbance of breeding murres (Nysewander)

3. Prohibit over-flights of colonies by helicopters and fixed-wing aircraft during the breeding season
   - breeding murres respond to aircraft with panic flights that are at least as disruptive as those elicited by avian predators

4. Prohibit close approach to colonies by tour boats and other watercraft during the breeding season
   - on occasion tour boats and other pleasure craft approach murre colonies so closely that breeding adults may leave nest ledges

Notes: This restoration option seeks to minimize disturbance that may cause adult murres to leave the breeding ledges in panic flights, thus causing eggs to roll off ledges or expose eggs and chicks to avian predation. Breeding murres are more sensitive to loud noises and aircraft than the close approach of vessels. The evidence that any of the above factors result in significant nesting failure in the spill-affected area is anecdotal at best, and needs better documentation. Regulations limiting any or all of the potentially injurious activities listed above may be feasible, but enforcement will be difficult. Enforcement and compliance may also be limited in the absence of documentation of damages related to these activities.

Conclusions: Another advantage of the kind of intensive colony-based investigations required to document murre losses to predators is to document losses resulting from human disturbance. Without Nysewander's observations on the effects of firearms and firecrackers on murre colonies, these activities would not be suspected as factors contributing to reproductive failure. Regulations restricting disruptive human activities near murre colonies during the breeding season (particularly C-1, C-2, and C-3 above) should receive careful consideration as restoration options for 1992.

D. Monitor Recovery, Including from Restoration Actions

1. Regular population monitoring at several selected colonies
   - use standardized census techniques to monitor population size at colonies affected by the oil spill
   - determine recovery rates of damaged colonies
   - compare population trends with colonies outside the spill-affected area (i.e., Semidi Islands, Middleton Island)

2. Colony-based monitoring of reproductive output
   - investigate factors responsible for persistent reproductive failure at some murre colonies
   - determine proportion of attending adults that produce eggs
   - determine timing of hatching, hatching success, and hatching synchrony
   - determine chick survival and fledging success

3. Monitor results from on-site restoration activities
   - determine cost-effectiveness of restoration options

Notes: Monitoring recovery is an important information need. The extent and persistence of damages to particular murre colonies should determine the type and intensity of murre restoration activities. A major information need is for data to improve our understanding of the underlying causes of continued colony decline, reproductive failure, or failure of some colonies to recover in the aftermath of the spill. We still do not know what factors (e.g., social disruption, food supply, food contamination) are responsible for the unexpected persistence of reproductive failure at some spill-affected colonies. Most experts expressed serious concern that the underlying causes of continued reproductive impairment at some murre colonies are not understood. Restoration activities designed to provide social facilitation for reproduction will fail if reproduction is limited by food supply (Nettleship).

Murres are long-lived and it would require reproductive failure over an extended period to lose the tradition of nesting at a particular breeding colony, providing the surviving adults did not abandon the colony first. This underlines the importance of monitoring all affected colonies, not just the largest or most accessible. A major information need is to known if and when colonies that have experienced reproductive failure resume laying, hatching young, and successfully fledging young. Colony attendance should be monitored to determine if certain colonies are eventually lost due to attrition of breeding adults. If a trend toward declining colony attendance and little or no reproductive success is documented over a period of several years, then restoration activities should be directed at the threatened colony.

Conclusions: Monitoring recovery, determining factors affecting recovery, and monitoring effects of restoration activities are critical components of restoration. Current monitoring activities for murres should be expanded to include more intensive investigations at colonies that experienced severe losses of breeding adults and that have shown no indication of natural recovery.

III. Off-site Restoration

A. Mitigate Incidental Take

1. Restrict use of salmon gill nets near murre breeding colonies in the spill area

2. Restrict fishing practices that result in a significant by-catch of Common Murres in the northern GOA

Notes: Incidental take of murres by commercial fisheries in the Gulf of Alaska portion of the EEZ is unknown but probably small (Piatt). Salmon gill net fisheries in West Greenland were responsible for huge losses of Thick-billed Murres, but there is no indication of a comparable by-catch in Alaska. For a long-lived species with low fecundity, such as the Common Murre, an increase in adult mortality would have a greater population-level effect than a decline in productivity. Mitigating losses of adults may be one of the most effective means of enhancing natural recovery.

Conclusions: This potential restoration option identifies an important information need: the extent of incidental take of murres by commercial fisheries in the northern Gulf of Alaska. Restoration options designed to mitigate incidental take are not recommended in the absence of evidence that significant mortality occurs.

B. Enhance Forage Fish Availability

1. Restrict commercial harvest of forage fish, i.e., capelin and sandlance

2. Mitigate by-catch of forage fish by commercial fisheries

3. Restrict production of hatchery salmon
   - hatchery salmon may compete directly with murres and other seabirds for forage fish stocks

Notes: The continued reproductive failure at some murre colonies affected by the spill is probably caused by the loss of most of the experienced adult breeders in those colonies and the resultant social disruption (Nisbet, Nysewander, Gaston). However, delayed onset of laying, lack of laying synchrony, and poor reproductive success are also indicators of inadequate food supply within foraging distance of the breeding colony (Nettleship). Several experts considered forage fish availability to be a reasonable alternative explanation for persistent reproductive failure (Mead, Nettleship, O'Connor). This explanation was given more credence by experts from the U.K. and Maritime Canada, where there is a well-documented history of commercial over-harvest of forage fish coupled with poor seabird reproductive success. The forage fish explanation is less favored by Alaska and West Coast experts.

Waiting until four or five years of reproductive failure have elapsed before investigating alternative explanations for reproductive failure is ill-advised (O'Connor). Food supply can be investigated by monitoring the type, size, and frequency of prey delivered by parents to their chicks, as well as the growth rates of chicks. Although murre breeding success has remained normal at the Semidi Islands and Middleton Island (Nysewander), colonies to the west and east of the oil spill area, respectively, these colonies are also influenced by different currents (Piatt). The concensus among Alaska seabird experts seems to be that commercial harvest or incidental take of forage fish (i.e., capelin and sandlance) in the northern GOA is not sufficient to warrant concern (Nysewander, Piatt). However, the large production of hatchery salmon may be responsible for reductions in forage fish stocks, possibly resulting in poor reproduction and population declines in a variety of seabirds and marine mammals. Murres are relatively tolerant of reductions of forage fish compared to surface-feeding seabirds, such as kittiwakes (Gaston). Kittiwakes have been suffering mediocre-poor reproductive success in much of the northern GOA for the last decade.

Persistent contamination of the food supply is a third potential explanation for continued reproductive failure at some murre colonies. Sandlance in particular may be a dietary source of petroleum hydrocarbons for murres (Nisbet). Effects of petroleum ingestion on reproduction have persisted for two years in some seabirds (Fry). However, the concensus among seabird experts seems to be that persistent contamination of the food supply is an unlikely explanation for three years of reproductive failure following the spill (Fry, Gaston, Nysewander, Piatt).

Conclusions: Forage fish availability may be limiting reproductive success at spill-affected murre colonies. Information is badly needed to address food supply and food contamination as potential causes of persistent reproductive failure in murres. Food supply problems may offer few options for murre restoration. But if food is limiting, otherwise effective restoration options may fail to expedite natural recovery. Shortages of forage fish appear to be affecting a variety of piscivorous marine birds and mammals in the PWS/GOA ecosystem. Murres are but one of the species that would benefit from a better understanding of the factors limiting forage fish. Without better information, it will be impossible to take effective measures to restore forage fish stocks.

C. Predator Control

1. Eradication of introduced arctic foxes on seabird breeding islands

2. Gull control at murre colonies

Notes: Eradication of introduced arctic foxes from some islands in the Aleutian Chain has resulted in dramatic increases of breeding seabirds. Some Aleutian Islands still support fox populations, but none of the islands in question were affected by the oil spill. Nevertheless, restoration of large numbers of murres (and other seabirds) could be realized at a relatively low cost from fox eradication programs. Eradication could be achieved by a combination of shooting, poisoning, and gasing dens, followed by dropping of poisoned baits from aircraft during late winter when food is limiting for foxes and they spend most of their time foraging for food along the beach.

Another potential means of enhancing recovery is to mitigate factors that impair fledging success at murre colonies within the oil spill area, but not severely affected by the spill. For example, the Chisik Island colony of about 24,000 murres in Cook Inlet was not affected by the oil spill, but murres raised on Chisik may be recruited to nearby colonies decimated by the spill. Gull control at Chisik Island may be a means of helping restore the murre population on the Barrens.

Conclusions: Fox eradication projects on the Aleutian Islands are extremely worthwhile and should receive consideration, despite the absence of benefits to the spill area.

D. Protect/Acquire Breeding Colonies

1. Purchase murre breeding colonies that are currently in private ownership

Notes: Gull Rock in Kachemak Bay, The Triplets off Kodiak Island, and Ugaiushak Island off the Alaska Peninsula are examples of murre breeding colonies in the oil spill area that are currently or may soon be in private ownership. Most murre colonies are in federal ownership as part of the Alaska Maritime National Wildlife Refuge. Those not in federal ownership do not appear to be in imminent danger, but inclusion in the Refuge would assure that future developments would not threaten the resource. Gull Rock in particular is in a high visibility location with considerable tourist visitation and nonconsumptive use. It is also close to the Refuge office in Homer.

The Triplets are located near Kodiak Island and are currently in private ownership (Nysewander). Pre-spill murre population estimates were about 1,300 and the population is apparently down 35% in the aftermath of the spill (Nysewander). Ugaiushak, off the Alaska Peninsula, supported about 9,200 breeding murres prior to the spill. Losses due to the oil spill are thought to be minor (Nysewander). The island has been selected by a native corporation and future ownership is uncertain.

Conclusions: I recommend that attempts be made to acquire Gull Rock for inclusion in the Alaska Maritime N.W.R. Because this murre colony was apparently not significantly affected by the spill, it can potentially provide new recruits for the decimated colonies in the Barren Islands. Because of its location it could provide to the public an accessible example of the kinds of wildlife resources and habitats protected by the Refuge. Prospects for acquiring The Triplets and Ugaiushak Island should be investigated.

SUMMARY OF CONCLUSIONS

The most feasible options for direct restoration are enhancement of social stimuli (I-A), with its various permutations, and nest site improvement (I-B). These two approaches could be tested in concert. The most promising potential method of indirect restoration is control of avian predators, but no control program should be initiated without prior studies to assess the severity of the problem. Such research could also provide information on the impact of mammalian predation and human disturbance, two other options for indirect restoration.

The best off-site restoration options appear to be eradication of introduced arctic foxes from islands in the Aleutians and acquisition/protection of seabird breeding colonies that are currently in private ownership. Enhancement of forage fish stocks and mitigation of incidental take of murres by commercial fisheries are both potentially effective restoration techniques, but current knowledge of these factors as they affect murre survival and reproduction are inadequate to judge potential efficacy. The efficacy of any and all restoration options is dependent on continued monitoring of spill-affected and control murre populations and the factors limiting those populations.

FAX COVER SHEET

TO: Dan Roby, Wildl. Research Unit

FAX NUMBER: 618-453-6944

LOCATION: Carbondale, IL

DATE: 07 December 1991

NUMBER OF COPIES (INCLUDING COVER SHEET): 3

CACI, INC. - COMMERCIAL
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(907) 278-8012
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FROM: Stan Senner

COMMENTS: Here are Dave Nysewander's comments on your memo (draft). I also gave the memo to M. Fry, G. Hunt, R. Spies, and P. Gertler. If I get anything from them, I'll pass on the comments. If not, you can finalize. Will call you during the week next week.

attachment: 2 pp

U. S. Fish and Wildlife Service
Alaska Maritime National Wildlife Refuge
202 West Pioneer Avenue
Homer, Alaska 99603

December 6, 1991

Memorandum:

To: Stan Senner, Oil Spill Restoration Planning Office, Alaska Department of Fish and Game

From: David Nysewander, Supervisory Wildlife Biologist, Alaska Maritime National Wildlife Refuge

Subject: Review of Dan Roby's Murre Restoration Options in His November 29 Memorandum

I have reviewed the document you gave me on December 3 and I basically agreed with most everything I read. I do have three suggestions for change or modification:

1) On page 10, line 19 he suggests "prohibiting close approach to colonies by tour boats and other watercraft during the breeding season". I would suggest educating tour boats as to proper etiquette upon close approach to birds colonies during certain critical times. I say this because I see murre colonies adjust to frequent visits with no troubles provided no sudden loud noises or phenomena occur. I think it is important to keep and create a public constituency for marine resources. This is more likely to happen when the public has some proper way of seeing or experiencing the bird colonies such as those out of Seward. If the education effort does not work, then the prohibition ruling may be necessary.

2) The various enhancement options discussed on pages 1-4 are interesting experiments and are more likely to be practical for feasibility studies than widespread application, at least on the Alaskan murre colonies affected during this oil spill. However, even the feasibility studies may be hard put to find a way to implement both controls and experiments on sites like the Barrens given that these particular murre colonies have so few portions that are logistically feasible to work. It may still be feasible to conduct one of these feasibility studies in the Barrens given creative thought, plenty of rope work, and plenty of time and salaries to set something up, but it will not be easy. The one site (East Amatuli Light) where it would be easiest already has demonstrated the most recovery in terms of earlier egg laying and density. An experiment here would be confused with a recovery process already much ahead of the rest of the colony in the Barrens.

3) The monitoring of recovery in the murre colonies in the oil spill areas is discussed on page 11 and I read in different portions of the document how everything else seems to hinge on this monitoring. The last sentence on page 16 emphasizes this. It seems that this needs to be emphasized more in some fashion by having it on page 1 or in some other fashion. Otherwise, I can visualize a restoration group picking an enhancement technique and leave out the monitoring aspect upon which it relies.