Exxon Valdez Oil Spill
Restoration Project Final Report

Lessons Learned: Evaluating Scientific Sampling of Effects from the Exxon Valdez Oil Spill

Restoration Project 00530
Final Report

Marianne G. See, Project Manager

Alaska Department of Environmental Conservation
Anchorage, Alaska

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LESSONS LEARNED:
EVALUATING SCIENTIFIC SAMPLING OF EFFECTS FROM THE *EXXON VALDEZ* OIL SPILL

Based on the White Papers
Associated with the April 2000 Workshops

Restoration Project 00530
Final Report

<u>Study History:</u> This project was a cooperative effort of scientists and resource managers to review existing information about the *Exxon Valdez* oil spill and determine the effectiveness of those sampling methods and studies for assessing impacts to selected natural resources and services. Resource specialists prepared white papers as the basis of a workshop to review results, assess methods, and recommend useful approaches to evaluate oil spill impacts.

<u>Abstract:</u> This pilot project reviewed scientific research conducted on the impacts of the *Exxon Valdez* oil spill, and developed recommendations regarding research effectiveness. Topics included herring, pink salmon, blue mussels, harlequin ducks, murres, sea otters, as well as recreation and archeology. Recommendations were also prepared for issues related to damage assessment including interagency coordination, ecosystem approach, post-spill studies, baseline data, and relationship to restoration. A workshop for resource scientists, managers, and authors of white papers provided the forum for examining results and developing recommendations. Participants evaluated the effectiveness of the project for assessing resource impacts associated with the spill.

<u>Key Words:</u> archeology, blue mussels, *Exxon Valdez* oil spill, harlequin ducks, herring, murres, natural resource damage assessment, oil spill impacts, pink salmon, recreation, sea otter

<u>Project Data:</u> *Description of data:* White papers provided references to original field studies and data for each of the eight resources studied. Workshop notes were taken by hand and using flipcharts.
Format: Notes were transcribed into Microsoft Word 2000. Audiotapes were also recorded.
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EXECUTIVE SUMMARY

Scientific research following the *Exxon Valdez* Oil Spill in 1989 documented a variety of effects associated with oil in the marine environment. This has been especially challenging because there was relatively little baseline information before the spill. The public at large as well as local residents, resource managers, scientists and others look to the overall spill research program to show which methods most effectively described impacts. However, there has been no comprehensive view of how the well the studies worked to assess spill effects. To better understand which methods and sampling efforts effectively provided information about impacts, this project was developed as a test or pilot to evaluate a subset of resources and services. This approach was also evaluated for potential future use.

OBJECTIVES
The overall goal of this project was to find out what was learned from studying the effects of the spill, assess how well approaches worked or not, identify data gaps, and develop recommendations. Researchers, scientists and trustee agencies needed to be meaningfully involved and stakeholders needed access to the findings. The project was implemented as a pilot to test and evaluate whether this approach achieved thorough evaluations and useful recommendations.

METHODS
A project management team, the EVOS Chief Scientist, and the Science Coordinator compiled a list of experts and a core list of proposed participants for the workshop, chose species and resources to focus on, and developed questions for the experts to address in white papers. The workshop, held on April 24 & 25, 2000, was a cooperative project that relied upon the active participation of all the attendees. Appendix A provides a list of workshop participants, plus some additional authors listed for the white papers.

The participating experts prepared the white papers relying on post-spill studies. The papers, presented in Appendix B, address eight key resources and species: recreation, archeology, pink salmon, pacific herring, blue mussels, harlequin duck, common murre and sea otter. These categories were chosen based on known vulnerability to marine spills, and available post-spill data. The resulting white papers were the basis of a small three-day workshop of specialists, resource managers, and EVOS scientists to review and discuss the information presented by authors. The recommendations developed in the workshop were compiled for this report. Participants evaluated project effectiveness and also offered suggestions on ways to improve this approach.

RESULTS
Consensus recommendations were prepared for each of the eight topics. A very abbreviated summary follows. The main results section and white papers should be consulted for context and full description of these recommendations.

Recreation
Prespill: Ensure that data collection needed to support economic studies is routinely and consistently collected by agencies and by service providers. Catalog sources of data. Evaluate recreation use data in remote sensing monitoring. Characterize regional recreation within each of Alaska's sub-areas, using designations from state land managers.

Postspill: Carry out a combined contingent valuation travel costs if spill is large. Evaluate relevant damage assessment methodologies; use appropriate methods of quantifying interim lost use and scaling compensatory restoration. Engage service providers to collect data. On-site surveying is generally not useful.

Archeology

Lessons learned: Efforts after a spill to project number of sites in the spill zone contribute nothing useful to damage assessment or corrective measures. Instead, survey and monitor during cleanup. Petroleum hydrocarbons have no known tendency to migrate from a marine spill into adjacent high ground.

Prespill: ensure that inventory and site evaluation is in the state's database. Use remote sensing surveys to find likely sites, and projections of site locations for managing resources in threats such as spills. Clarify whether archeological and other cultural resources fall within "natural resources" under damage assessment law.

Immediately after a spill: Identify potentially affected sites through records and surveys to prepare for site protection. Respond immediately as required by the National Historical Preservation Act. Discourage vandalism.

Postspill: Use the Spill Cleanup Assessment Team model from the spill, which includes an archeologist. Ensure that trained personnel are present during cleanup. In first 2-3 years monitor sites and test to verify oil. Use a third party assessment of damages. Eroded intertidal sites may need case by case mitigation. Use public interpretive programs, site stewardship and public-friendly documents.

Herring

Lessons learned: Need specific categories of information to determine life stages at risk and estimate exposure; e.g., population, spatial stock modes, oil exposure. Genetic damage was most useful indicator of sublethal injury.

Prespill: Use ecosystem models to identify pathways and processes at risk to oil injury, sample to increase model cost-effectiveness. Use categories of baseline data, e.g. unoiled embryos and larvae, parasite loads, others.

Postspill: Consistently collect data within 48 hours of spill and then monthly; collect exposure data where herring are near beach cleaning. Use larval trawls for multi-purpose data collection. Use remote sensing to track organisms and oil in real time. Assess ecologically key species, e.g. copepods. During spawning season, manage fishing fleet anchor sites. If significant impacts are found, study 3 generations in the lab to document reproductive effects. Genetic studies prove quite useful.

Pink Salmon

Lessons learned: Oil has short-term acute effects; also weathered 3- and 4-ring compounds are persistent and damaging. Egg stages are very sensitive; low doses cause delayed effects

Prespill: Ensure that studies can separate oil effects from interactions between wild and hatchery fish; design lab studies to support field studies on early life history stages. Engage agencies on oiling effects, damage assessment, and response activities.

Postspill: Document persistence of oil in streams and alevin exposure. Evaluate weiring; may be best for some spills only. Use ecological approach to determine oiling effects for juveniles. If significant oil impacts are found, study 3 generations in the lab. Document exposure in zooplankton. Monitor egg mortality for two years past no oil effect, or one generation post-exposure.

Blue Mussels
Lessons learned: In Prince William Sound, mussels helped estimate exposure levels in food chains and for subsistence, so should be included in damage assessment studies.

Prespill: Establish baseline hydrocarbons, population estimates and other parameters to document source of contamination. Collect tissue before and after spill. Recommended that studies assess how important mussel beds are to key mussel consumers as a function of shoreline type (low-energy mixed soft-sediment vs. low-energy rocky shore vs. high-energy rocky shore) to provide baseline information [R.B. Spies]

Postspill: Map mussel beds, especially on soft sediment; include in assessment team surveys. Design study to correlate to nearshore vertebrate studies. Emphasize sampling within beds. Clean reservoirs of oil underlying mussel beds on soft sediment. Determine bioavailability of oil via water column. Coordinate with seafood safety investigations.

Harlequin Ducks
Lessons learned: Lack of baseline information in spill areas precluded accurate damage and recovery assessment. Monitor populations during periods of relative stability. This species is surrogate for benthic-feeding birds.

Prespill: Monitor population change and habitat conditions, integrate with other nearshore studies to assess changes. Improve indicators of health effects. Improve information for life history, habitat characteristics; test new technologies for assessing exposure to contaminants.

Postspill: Measure acute injury, monitor populations, effects of clean ups, health parameters, changes nearshore ecosystem affecting food, over-winter survival.

Murres
Lessons learned: Mixed results with roving boat based teams. Drift studies not needed.

Prespill: Develop regional response teams for damage assessment on murres. Rank the colonies for study, other information, collect baseline data. Develop methods to identify wintering areas. Use dedicated land based teams instead of roving boats; video.

Postspill: conduct aerial surveys in and near spill; may use video recording. Focus on one colony with land-based teams, video. Consider possible restoration e.g. to enforce restrictions on disturbing wildlife. Use fishing/charter fleets to collect sea data. In special circumstances, may need to consider recolonization efforts.

Sea Otters
Lessons learned: Data prior to the spill determine predicting effects and subsequent recovery. No amount of post-spill study can replace the lack of accurate and precise pre-spill data.

Prespill: Need accurate estimates of populations, markers of individual health, diet and prey populations; fecundity, survival, home ranges.

Postspill (pre-oiling): Capture and mark animals to estimate survival and carcass recovery. Survey and mark carcasses (post-oiling). Mark and release carcasses; monitor health. Install instruments and release oiled otters.

OVERARCHING ISSUES

- Interagency Coordination: Preplan; coordinate data collection. Develop and maintain a scientific sampling or biological response plan. Coordinate key to effective resource protection and damage assessment. Consider immediate versus long-term effects for clean up strategies. Need central data clearinghouse.
- Ecosystem Approach: For large spills, damage assessment must examine food chains. Use ecosystem models to estimate risks to oil injury.
- Baseline data: Commit to baseline studies. For damage assessment purposes, collect data on highly sensitive species in specific high risk areas.
- Restoration: Need broader understanding of natural resource damage assessment process, and separate discussion (e.g. workshop) on restoration and endpoints.

DISCUSSION

Project participants broadly endorsed the use of white papers and subsequent workshop as a means to collaboratively develop recommendations and necessary documentation. A future project for additional resources was recommended, as well as a separate workshop on restoration. Native interests need to be represented in future projects of this type.

CONCLUSIONS

Resource managers and scientists can use and adapt these recommendations to better understand what worked in the past and what may be useful in the future. Additional effort, modeled on this project, was recommended for other resources and services affected by the spill. A workshop on restoration was also recommended.

INTRODUCTION

A substantial amount of information about the effects on natural resources from the Exxon Valdez Oil spill has been generated since 1989. This has been a daunting task, because the spill occurred in an area with a very limited history of "baseline data." Although more than a decade of work has been amassed, there was no comprehensive view of how well the studies worked to assess spill effects, as well as what did not work. Resource managers, scientists and the public at large wanted to know what kind of information and methods provided the foundation for understanding damage, and for helping accomplish restoration. Thus there was a compelling need to review the "lessons learned" to not only further our knowledge of ecosystem response, but also to help heal damaged resources.

Depending on the nature of the effect, some impacts after the 1989 spill were clearly evident and were quantifiable; for example, oiled beaches, and dead or injured wildlife. Other oil spill impacts were more difficult to quantify because they were subtle or not yet evident in short-term assessments. For many resources there was no consensus-based approach on the most effective methods of assessing impacts. With more than ten years of study results to evaluate, it was time to assess the effectiveness of sampling methods and studies.

This project was developed as a cooperative effort to review existing oil spill information and determine the effectiveness of sampling methods and studies for assessing impacts to natural resources and services. The review findings interpreted "lessons learned" from scientific research conducted since the *Exxon Valdez* oil spill. The resulting evaluation is intended to contribute to an understanding of quantifiable effects of spills on sensitive resources and services.

In addition, the assessment from the project can help provide support for restoration decisions. To ensure useful results, this project was conducted as a pilot to test this approach with a limited number of topics. The methodology, modified as needed, potentially could be used to conduct additional evaluations.

The results of this project are part of the EVOS Trustee Council's increased emphasis to "transfer study results to resource managers and stakeholders so that they can take full advantage of what has been learned through the EVOS program (Exxon Valdez Oil Spill Trustee Council 1999). The Council also notes that "results of these studies and the approaches underlying them can provide valuable guidance for the ongoing restoration program as well as for natural resource managers and other stakeholders who may make decisions or take actions that bear on the long-term recovery of injured resources or lost or reduced services."

As a longer-term benefit of this project, it may be appropriate to use the findings to guide impact evaluations in the future. This may be especially valuable if another spill occurs in an area where resources are not yet fully restored. The tanker corridor in Prince William sound is a unique industrial usage area associated with potential risks from accidental discharge of oil or other hazardous substances. Although industry has made significant progress after 1989 in preventing and limiting the extent of such problems, oil spills continue to be documented.

Future assessments of oil spills will be significantly influenced by changes in laws that came about after the *Exxon Valdez* oil spill. One key legislative change, the federal Oil Pollution Act of 1990 (OPA90), outlines the rationale for natural resource damage assessment or NRDA. As a further step, several states have enacted their own NRDA laws. Key to these requirements is the concept that injury or loss must be made whole through restoration and related actions, with compensation owed during the process of repairing or mitigating the damage.

Under these laws, there must be a baseline condition against which damage is evaluated. The strategy to accomplish restoration is then based on a plan to achieve a specific endpoint and the injury should be measured against a standard of where the resource would have been in the absence of the spill event. Scientific and practical criteria enter into the choice of techniques to use, such as rehabilitation, replacement, acquisition of comparable resources or services. The values associated with loss or damage, and the time it takes to accomplish restoration then is calculated into the formula for damage claims. The white paper by Mead, Bockstael and McConnell (Appendix B) provides more background and further explores how this concept can be applied to the service of recreation, but neither does that paper nor this report attempt to address the many other changes to injury assessment brought about by OPA 90.

The post-spill requirements influence much of the current thinking about how to effectively describe impacts. The recommendations in this project report thus form a bridge between the lessons from the past and the needs of the future. The ultimate success of this project and others that may follow is to ensure that there is a roadmap for evaluation of damage that provides the basis for scientifically credible plans to reach an achievable endpoint.

OBJECTIVES

Project objectives were as follows:

1. To develop the scope and questions addressing what was learned from studying effects of the oil spill; how well approaches worked or not, data gaps, and recommendations.

2. To meaningfully involve researchers, scientists, and trustee agencies to answer these questions.

3. To help ensure stakeholder access to this information by distributing the final report.

4. To implement this project as a pilot to test and evaluate whether this approach helps elucidate “lessons learned.”

White paper objectives included: gain expert evaluations of what worked, determine what didn’t work, and evaluate what should be done based on what proved useful.

Specific workshop objectives were as follows:

1. To assess effectiveness of sampling and research regarding effects of the Exxon Valdez oil spill on eight key resources and species: recreation, archeology, pink salmon, herring blue mussels, harlequin ducks, common herring, and sea otter.

2. To consider “lessons learned” and develop recommendations regarding methods for assessing and monitoring oil spill effects.

3. To evaluate whether the process of writing white papers and evaluating them in a workshop would be useful for developing sampling recommendations for other species and resources damaged by the spill.

METHODS

This project was phased to ensure technically rigorous focus and full involvement of trustee agencies with resource management responsibilities.

Trustee agency representatives, the EVOS Chief Scientist and Science Coordinator developed a list of experts, questions for experts to address in white papers, and a core list of proposed participants for the workshop.

Experienced, respected scientists considered to be expert on studies conducted after the oil spill occurred in 1989 prepared white papers. Contractual support was provided as necessary. These papers, included in this report in Appendix B, evaluated the effectiveness of sampling and other research and studies that were conducted after the oil spill. Authors reviewed relevant information and addressed specific questions. Each specific resource or service was selected based on known vulnerability to marine spills, and available data from the initial post-spill phase.

Questions that white paper authors were asked to answer were based on one model, included here for herring:

- What herring data, if any, would need to be collected immediately following the spill in areas that will be oiled, but have not yet been oiled? Please describe, in detail, what would be included in this effort and explain why it is important.
- What herring data collection/studies would need to be initiated immediately following the spill (i.e., during the first 24 to 48 hours)? Please describe, in detail, what would be included in these efforts and explain why they are important.
- What additional herring studies/data collection, if any, would need to be initiated following the first 24 to 48 hours? Please describe, in detail, what would be included in these efforts and explain why they are important.
- Were there any herring studies/data collection activities initiated/completed following the 1989 EVOS that you <u>would not</u> recommend initiating in a future spill? If so, please explain.
- Would you recommend taking an ecosystem-based approach to injury assessment and restoration? If so, please describe whether the data collection/studies identified above would need to be modified and why the modifications would be required.
- The new NOAA NRDA regulations emphasize restoration endpoints rather than a determination of damages. With restoration in mind, would you suggest any modifications to the herring data collection/studies identified above? If so, please explain what would need to be modified and why.
- What restoration activities could be successfully implemented for injured herring?
- Briefly describe the herring data collection/studies that were done for EVOS.
- How were EVOS injury assessment data collection/studies selected for herring?
- What herring data collection/studies, if any, were dropped after the first year or two following EVOS. Please explain why these activities were dropped.
- Please describe what role, if any, the EVOS legal team(s) played in determining which herring data collection/studies were conducted?
- Describe which of the EVOS herring injury assessment data collection/studies proved useful and which ones, if any, did not.
- In hind sight, were there herring data collection/studies that should have been conducted?

- If yes, please describe them and discuss why they should have been conducted.
- Please explain under what circumstances, if any, you think an ecosystem approach would not be appropriate.
- Were any of the herring data collection/studies too costly based on the end results (determination of damages or opportunity for restoration)?

The resulting white papers (Appendix B) served as the basis of a small workshop to collaboratively review and discuss the information contained in each white paper.
A selected group of resource specialists and scientists with expertise in oil spill impacts from the *Exxon Valdez* were invited to participate in the workshop to review and discuss the papers, the related issues, and help craft specific recommendations. The names of these participants are listed in Appendix A.

The three-day workshop provided time for each author or team to present findings of the white paper, followed by substantial time for discussion and development of recommendations. The third day also included time to address overarching themes.

Results of the workshop were compiled into an overall summary to capture the areas of consensus as well as alternative approaches that were proposed. Authors assisted in revising recommendations or white papers, as they deemed appropriate. Authors were not required to use a specific style or to revise their papers after the workshop but were strongly encouraged to further develop the content of these papers for subsequent publication.

Participants evaluated the pilot project to help identify whether this was a useful approach for developing recommendations and to offer suggestions on ways to improve further efforts.

RESULTS

This section presents the consensus recommendations reached by workshop participants for the six resources and two services evaluated. They are presented here in the same order as in the workshop.

White papers (Appendix B) were used as the basis for recommendations, which in most cases were modified by the interactions in the workshop. These papers address more details and explanations for the recommendations and thus serve as a useful companion to the recommendations.

RECREATION

Recommendations

Prespill:

1. Ask resource managers, including DNR/Division of Parks and National Park Service and the U.S. Forest Service, to evaluate data collection to ensure that visitation data and other relevant statistics needed to support economic studies are collected consistently, systematically, and in a coordinated fashion across agency and geographic boundaries.

2. Evaluate the use of, and incorporate as appropriate, recreational use data in all remote sensing monitoring activities.

3. Catalogue sources of recreational use data, e.g., EIS studies in PWS and other locations, studies conducted by Alaska Sea Life Center, and then cross-reference and coordinate to get entities gathering data on the same variables.

4. Coordinate with recreation service providers to engage them in oil spill-related data collection, e.g., tracking cancellations.

5. Identify regional recreation characteristics for Alaska's 10 sub-areas with area committees. Consult with DNR State Parks for these geographic boundaries.

Postspill:

1. For large spills, carry out a combined contingent valuation (CV)/travel costs study. If the resources affected are of national importance, a national study would be needed.

2. At the time of any oil spill, regardless of its size, location, etc., evaluate all relevant damage assessment methodologies and implement the most appropriate method(s) for quantifying interim lost use and scaling compensatory restoration.

3. Distribute a brochure/data sheet to recreation service providers to engage them in oil spill-related data collection, e.g., tracking cancellations.

4. On-site surveying is generally not appropriate or valuable. There may be instances where it is warranted.

ARCHAEOLOGY

Lessons Learned

1. Extensive efforts after a spill to project an expected total number of sites lying in the spill zone contribute nothing important to usable damage assessment or corrective measures. Similarly, after a spill occurs it is too late to gain from developing predictive models of site location from scratch. What is needed at that point is people on the ground to both survey and monitor while cleanup progresses.

2. There is no acceptable evidence that petroleum hydrocarbons have any tendency to migrate from a coastal spill on water into adjacent high ground.

Recommendations

Prespill:

1. Every agency should submit relevant site location information to the state to ensure that it is entered into the AHRS database. Pre-spill inventory and site evaluation contribute greatly to effective damage assessment.

2. Pre-spill site location projections are useful for managing resources in the face of threats such as oil spills. The use of GIS, satellite, and aerial surveys to identify old shorelines as well as present shoreline conformations where sites are likely are of aid in this connection.

3. Archaeological and other cultural sites are agreed to be multi-valued resources. The consensus of the group is that clarification is needed as to whether such archaeological and other cultural resources fall within "natural resources" for NRDA purposes under OPA.

Postspill (immediate):

1. Identify potentially affected sites through search of records such as those held by AHRS or land-managing agencies, and by on-ground surveys with trained personnel to determine the presence of additional recognizable but unregistered sites in the region. This sets the stage for proactive efforts – possibly to prevent oil spread to important but eroded (i.e., intertidal) sites that may be worthy of having further damage mitigated through data collection, and to prepare for protecting all recognized sites as cleanup begins.

2. Immediate and adequate response as required by Section 106 of the National Historical Preservation Act is essential to protecting cultural and archaeological resources following an oil spill. This can best be accomplished by following the provisions of the Nationwide Programmatic Agreement on Protection of Historic Properties during Emergency Response under the National Oil and Hazardous Substances Pollution Contingency Plan (1988), the parties to which include the Department of Justice, the Coast Guard, the Environmental Protection Agency, the Department of the Interior, the Department of Commerce, the Department of Agriculture, the Department of Defense, the Advisory Council on Historic Preservation, and the National Conference of State Historic Preservation Officers. (Specific guidelines for application within Alaska are currently under development, and will be included on the web page of the Alaska Regional Response Team.)

3. Discourage vandalism through education, monitoring, and law enforcement.

Post-spill:

1. The Spill Cleanup Assessment Team (SCAT) model used during EVOS, in which an archaeologist was a member of each three-man assessment crew, should be used.

2. Trained personnel should be present during all cleanup in crucial regions in order to prevent physical damage through equipment staging, etc., as well as through vandalism. As in EVOS, such persons would record hitherto undiscovered sites, as well as educate cleanup personnel and monitor their activities.

3. As was the case with certain especially important sites during EVOS, cleanup activity may well be delayed in some sensitive locations until additional and appropriate personnel can be enlisted.

4. In addition to the organization of SCAT teams, certain post-spill activities are desirable:
    a. Early efforts should be made to collate reports from field (SCAT) archaeologists on a regular basis.
    b. The use of field or laboratory tests for hydrocarbons to verify suspected contamination of sites on the immediate shoreline should be applied during the first 2 to 3 years following a spill, but should be unnecessary for longer periods.
    c. A third-party assessment of damages to provide verification of injury and the scale of restoration to be required is especially useful if litigation is pending, and is desirable in any case to support restoration proposals.
    d. Some eroded intertidal sites inundated with oil may be worthy of having the combined damages mitigated through at least limited data collection, for once completely destroyed there is no information to be gained. Any such decision to mitigate should be site-specific and made at the time.
    e. A limited program (2-3 years at least) of heightened monitoring of sites receiving physical damage either through oil spill cleanup or attendant vandalism should be conducted. If a program of site stewardship can be worked into these efforts, they should provide a helpful adjunct.

5. A judicious use of public interpretive programs should assist in the lessening of vandalism and preservation of archaeological values both over the short and long terms.

6. A site stewardship program can also provide a way to lessen vandalism and raise respect for cultural resources. Such programs should be considered as ameliorative if there is an increase in vandalism due to oil spill cleanup activities.

7. As perishable and non-renewable resources, archaeological sites cannot be restored. The only mitigations of destruction include (a) protection again continued erosion and vandalism by modifications of terrain and surveillance, and (b) – when destruction is essentially unavoidable – the introduction of controlled destruction, i.e., archaeological excavation, in order to salvage information before it is lost. In addition to technical reports, efforts should be made to share such information with the general public through documents, signage, etc.

Non-consensus recommendation:

- Focus on paleobiological information from excavation of archaeological sites a san important addition to long-term baseline information against which to interpret oil spill damage to resources such as birds, fish, and mammals.

HERRING

Lessons Learned

1. Ecological population/life history and spatial stock models are needed to provide information about life stages at risk and estimate percentage of population exposed (assuming trajectory information is available).

2. Agencies must be committed to prespill response protocols and plans.

3. Lack of cooperation between response, NRDA, and agencies caused major problems during EVOS, e.g., overlapping control and study sites.

4. It is essential to have oil exposure data, i.e., WSF, particulate oil distribution, slick and mussel tissue. Researchers need to know detection limits for hydrocarbon samples and collect enough tissue to obtain valid results.

5. During EVOS, too much time was spent in response mode looking for dead fish. Studies were not built on existing knowledge. Appropriate response to future spills depends on the toxin spilled.

6. During EVOS, researchers could not link disease events and reproductive impairment to population level because they did not follow one or more age cohorts from egg to juvenile. It is important to do this to obtain a complete picture.

7. Chromosome/genetic damage endpoints were the most valuable in estimating sublethal injury, especially the anaphase aberration rate. *(Added by author, Evelyn Brown, subsequent to group discussion.)*

Recommendations

Prespill:

1. Need response plan, training, and "precontracted" resource experts, with <u>all</u> agencies on board.

2. When a spill hits, extra staff will be needed. Use trained existing staff, programs and equipment whenever possible. Existing agency staff needs to be prepared to supervise and lead oil spill response.

3. Use ecosystem models to pinpoint pathways and processes at risk to oil injury. This also helps to identify food chain transfer of toxins. If an ecological assessment model is in place, sample where model input is required to increase cost-effectiveness.

4. Important baseline data for herring include: prespill tissue and bile samples, parasite loads, disease assessment at specific times, AWL in key index locations where abundance in concentrated, and energetic content for juveniles and adults; unoiled embryos and larvae (baseline abnormalities); baseline mussel tissue from sits adjacent to spawning grounds; zooplankton, approximate predator abundance and ocean conditions at nursery sites.

Postspill:

1. Collect the same suite of data as above within 48 hours after the spill and sample monthly thereafter. Collect exposure data (tissues samples and particulates) where herring are near beach cleaning. Sample temporally and spatially to match duration and location of

exposure.

2. Agencies should agree on control sites for post-spill studies.

3. Use larval trawl for multi-purpose data collection to assess larval damage and exposure for all species, invertebrates and zooplankton. Use this data to validate and correct the larval trajectory model.

4. Use remote sensing technologies (laser, spectral imaging, radiometers, SAR, infrared, aerial and satellite surveys) to track distribution of forage fish, predators, zooplankton, and oil in real time.

5. Assess ecologically key species, e.g., copepods, sand lance, euphasids, and pollock, not just commercially valuable and charismatic species.

6. If spill occurs during spawning season, keep fish fleet and other vessels anchored well away and downstream or down current of spawning grounds.

7. If significant oil impacts are found, study three generations in lab to document spill effects on reproductive impairment.

PINK SALMON

Lessons Learned

1. Oil persists. BTEX chemicals (Benzene, Toluene, Ethylbenzene, and Xylenes) are important because they have short-term acute effects. However, from a long-term damage assessment point of view, BTEX chemicals are less important. Weathered, 3- and 4-ring compounds can be especially persistent and damaging.

2. Egg stages are very sensitive. Low doses cause various delays effects.

Recommendations

The following recommendations apply to other species where biology is appropriate.

Prespill:

1. Study to separate oil effects from effects of interaction between hatchery and wild salmon.

2. Customize lab studies so they can support and allow better interpretation of field studies to establish effects on early life history stages.

3. Initiate interagency discussions to consider immediate and long-term oiling effects of NRDA and response activities (e.g., dispersant policy).

Postspill:

1. Implement surface microlayer sampling for PAH's.

2. Document persistence of oil in streams and alevin exposure. Conduct stream-side and stream-mouth sampling during the first year following a spill using SPMD's and P450's and continue next 3-4 years following. Consider less intrusive methods than egg digs.

3. Weiring should not be done unless financial resources are sufficient to "do it right" and generate statistically valid results. Weiring may not be practical or appropriate for large spills, because of the number of weirs required. However, for small spills and/or populations that are geographically confined, weiring may be appropriate.

4. Take an ecological approach to determine oiling effects during the juvenile stage, i.e., prey, predators, and growing rates. Study oil effects on abundance and species composition of zooplankton.

5. If significant oil impacts are found, study three generations in lab to document spill effects on reproductive impairments.

6. To document exposure, immediately after a spill or near beach cleaning, test for oil particulate matter (e.g., zooplankton) either by testing guts or P450. Over time, only P450 test can be used.

7. Field monitoring of egg mortality should continue two years beyond the point when there appears to be no oil effect, or one generation post-exposure.

BLUE MUSSELS

Lessons Learned

- In Prince William Sound, mussels were important in estimating exposure levels, in food chain, trapping oil, and for subsistence. Depending on the spill location and whether these functions are present, NRDA studies should probably include mussels.

Recommendations

Prespill:

1. Establish baseline hydrocarbon concentrations, population estimates, and bed parameters to document source of contamination.

2. In order to establish exposure levels, mussel tissue should be collected before and after spill for hydrocarbon testing.

3. To facilitate good decision-making on where to clean aggressively and where not to, assess how important mussel beds are to key mussel consumers as a function of shoreline type (low-energy mixed soft-sediment vs. low-energy rocky shore vs. high-energy rocky shore) to provide baseline information

Postspill:

1. Soon after the spill, map mussel beds with special attention to those beds on soft sediments by including on SCAT surveys. Determine how many soft sediment beds of mussels there are in spill area and how many are oiled. To correlate exposure to nearshore vertebrate studies use randomized block design. (bed surveys and chemical sampling)

2. Because of intrabed variability, less emphasis should be placed on getting replicate pooled samples and more emphasis on sampling from different spots in beds. Survey design is an important consideration.

3. Reservoirs of oil underlying mussel beds on soft sediment need to be cleaned as part of

response, taking into consideration timing and impact on adjacent species.

4. Caged mussels or semi-permeable membrane devices (SPMD's) should also be deployed throughout spill area to determine the bioavailability of the oil via the water column.

5. If there are health and human concerns, then coordinate with seafood safety investigations.

HARLEQUIN DUCKS

Lessons Learned

1. The effectiveness of post-spill monitoring to determine injury and recovery is directly related to the quality and quantity of prespill baseline information on life history, habitat, contaminant exposure, health parameters, and population size and annual variability. The lack of baseline information within the spill and reference areas precluded accurate damage and recovery assessment.

2. Population monitoring should be sex and age based on focus on winter surveys and molting surveys because these are periods of relative stability.

3. A Biological Response Plan that says who will do what, and how, is essential for an efficient and effective immediate post-spill response.

4. Harlequins are a good surrogate species for nearshore benthic-feeding birds.

Recommendations

Prespill:

1. Continue to consistently monitor population change (i.e., abundance, age structure, and sex ratios) and habitat conditions (i.e., food abundance, feeding habits, and contaminant levels) and integrate with other nearshore studies to illuminate mechanism of change.

2. Improve methods of assessing health (e.g., blood assay, biomarkers) and response to various levels of contaminant exposure. Improve understanding of link between oil-contaminated diet and measures of health. Demonstration of cause and effect can be strengthened by linkage of exposure markers and physiological responses on an individual-by-individual basis.

3. Identify "missing links" in life history (e.g., nesting areas, productivity, and dispersal immigration/emigration).

4. Improve knowledge of regional habitat differences in order to help select reference areas. Improve knowledge of the effects of microclimates, food abundance, and human activity (e.g., logging, roads, and tourism) on population size and variability.

5. Develop and maintain a regularly updated Biological Response Plan that says who will do what and when.

6. Test new technologies for counting the ducks and assessing exposure to contaminants.

Postspill:

1. Measure accurate injury to ducks (i.e., carcass count and predation rate on carcasses) using

park-recovery and telemetry.

2. Continue to monitor population structure, distribution, and abundance.

3. Monitor the effects of cleanup activities on distribution and abundance.

4. Monitor post-spill health parameters (body condition, biomarkers, blood assays) to compare with prespill values and help assess injury and recovery.

5. Monitor changes in nearshore ecosystem, primarily food toxicity and availability (including size class distribution and abundance).

6. Measure over-winter survival rates between affected and reference populations.

MURRES

Lessons Learned

1. There were pros and cons in regard to using roving, boat-based study teams. These mobile teams covered a wide area and were able to gather data at several different study sites. However, they were not able to collect data on some variables during the correct time periods at some colonies, and they were also not able to collect adequate amounts of data on some variables at some study sites.

2. Shooting birds and dipping them in oil for drift studies is not necessary or advisable (the technology is available to allow drift studies to be conducted with simulated carcasses – this type of research and additional research on sinking and carcass retention rates should be conducted in the field and lab prior to spills).

Recommendations

Prespill:

1. Develop trained/knowledgeable regional response teams for designing studies and conducting NRDA on murres. *(Refer to white paper for details.)*

2. In advance of spill, prioritize study colonies and the types of work that can be done at them. Measure population size, reproductive success, and timing of nesting using appropriate protocols.

3. For each colony, summarize historical information and methods used to collect these data, and determine if monitoring plot maps/photographs are available (if so, list sources). Also, list and describe any previously established monitoring plots and observation posts and how they can be accessed.

4. For each colony, develop a basic study plan based on standardized, accepted, state-of-the-art methods that takes into account historical data and methods used to collect them (the plan should also address use of time lapse and remote video cameras, if appropriate).

5. Collect colony baseline data, including information on population size, productivity, timing of nesting events, diets, and feeding areas used during the breeding season.

6. Develop methods to access/identify wintering areas.

7. Instead of roving boat-based research teams, use dedicated land-based field teams equipped with small boats whenever possible. Teams should focus on one colony, gathering repeated measures according to specified protocols, and collect data throughout the nesting season or during the correct time periods to provide statistically valid results and an understanding of natural variation. Consider using supplemental video technology to record data.

Post-spill:

1. Immediately follow a spill, conduct aerial surveys to identify distribution of murres in and near oil spill area. Consider using supplemental video technology to record data.

2. Begin salvaging carcasses, as per previously established sampling protocols.

3. Instead of roving boat-based research teams, use dedicated land-based field teams equipped with small boats whenever possible. Teams should focus on one colony, gather repeated measures according to specified protocols, and collect data throughout the nesting season or during the correct time periods to provide statistically valid results and an understanding of natural variation. Consider using supplemental video technology to record data.

4. Consider possible restoration activities, such as enforcing any existing regulations or restrictions that may apply to disturbance of wildlife, including those restricting aircraft to certain altitudes in some areas (e.g., published restrictions on FAA charts regarding nesting peregine falcons); controlling predators and introduced species; establishing marine sanctuaries to no-boating/no-fly zones; and protecting critical breeding and feeding grounds. *(refer to white paper for additional details)*

5. Use fishing/charter fleets to assist with data collection at sea.

6. Under special or extreme circumstances, recolonization methods may be appropriate.

SEA OTTERS

Lessons Learned

1. Our ability to accurately and defensibly determine the effects of any perturbation on sea otter (or other) populations and subsequent recovery processes will be determined largely on the quantity and quality of data available to describe the affected, as well as an unaffected or reference population, immediately prior to the perturbation.

2. Studies that are implemented to determine spill effects in the absence of baseline data must lead to uncertainty in the conclusions that can be drawn.

3. Many and diverse tools are available to evaluating the acute and long-term effects of oil spills on sea otters, but their ability is diminished if they are not put to use before an anticipated event, such as an oil spill. Although our tools have improved in the past decade, they have not been widely used outside Prince William Sound.

4. If a single lesson should be learned from the 1989 oil spill in Prince William Sound, it is that no amount of post-spill study can replace the lack of accurate and precise prespill data.

Studies That Were Most Valuable
1. Carcass recovery
2. Carcass marking and release
3. Mortality surveys
4. Sea otter necropsies
5. Physiological and toxicological measures of oil exposure

Studies That Were Valuable
1. Skiff surveys of sea otter abundance
2. Hydrocarbon assays
3. Estimates of age/sex specific survival

Studies That Were Least Valuable (only in the context of EVOS damage assessment)
1. Intersection model of mortality
2. Foraging behavior and hydrocarbon levels of prey
3. Bioindicators of genotoxicity
4. Design and testing of an aerial survey method for sea otters; although valuable as a monitoring tool, was not helpful for damage assessment
5. Carcass drift study
6. Helicopter surveys of abundance

Recommendations

Prespill data requirements (in declining priority):
1. Accurate estimates of distribution, population size and status (unbiased estimates of abundance, an index won't do)

2. Age and sex specific measures of individual health (capture, marking, blood, serum, biomarkers, etc.)

3. Age specific survival (carcass collections)

4. Sea otter diet and prey populations (visual observations of foraging and direct measures of prey populations)

5. Age/sex specific fecundity, survival and home range sizes (telemetry study of individuals)

At spill data requirements (prior to oiling) to augment acute loss and estimate sub-acute/chronic effects:
1. Capture and marking of individuals to estimate survival and carcass recovery rates (capture before and during spill)

2. Surveys and marking of beach cast carcasses (carcass recovery and retention rates)

Post-spill data requirements (post-oiling):
1. Carcass collections and marking and release of carcasses (carcass recovery and retention rates)

2. Monitoring of age and sex specific measures of individual health (capture, marking and sampling)

3. Instrumenting and releasing captured oiled otters (oiling/survival function)

OVERARCHING ISSUES
AND RECOMMENDATIONS FOR
NATURAL RESOURCE DAMAGE ASSESSMENT

Interagency Coordination

Preparation

1. Preplanning, including coordinated data collection, leads to more effective response.

2. Develop and maintain a regularly updated scientific sampling or biological response plan that says who will do what and when; and identifies specific training.
    a. Need to fund prespill plans and develop assessment approaches that do not require extensive baseline data.
    b. Biological response plan would include science coordination group to prioritize exposure sample processing; should take into account risk, time of year, type and size of spill.
    c. Designate trained staff, programs and equipment whenever possible. Existing agency staff needs to be prepared to supervise and lead biological sampling as part of an oil spill response. See Appendix B (Roseneau) for response team example.
    d. Planning should address the most probable events, not just worst-case scenarios.

Response and Damage Assessment

1. Interdisciplinary response and coordination is key to effective oil spill resource protection and damage assessment.

2. Agencies need to communicate, cooperate, and coordinate for successful response and damage assessment, e.g., control and study sites for post-spill studies.

3. Where appropriate, reconcile species/resource specific recommendations about damage assessments, with response guidelines, e.g., leave the carcass or pick it up.

4. Consider both immediate and long-term effects. Difficult decisions will include: protecting habitat vs. protecting individual animals, cleaning vs. natural recovery, and using vs. not-using dispersants.

5. Central data clearinghouse is needed for shared data. "Critical" types of data include:
    - oil trajectory – geo referenced oil concentration;
    - ocean and meteorological conditions, nearshore and offshore;
    - food base information – zooplankton, forage fish, etc.; and cleanup activity.

Ecosystem Approach

1. In Prince William Sound, spill-related ecosystem perturbation questions are mostly pointed to changes in food availability, quantity and quality. For large spills, NRDA must examine food chain, specifically, monitoring and measuring effects on zooplankton, forage fish, and

critical nearshore prey (benthic fish, mussels). Also, the contamination of prey by oil has the implication of sublethal effects extending to population levels through added energy costs for depuration. [R.B. Spies]

2. Use ecosystem models to pinpoint pathways and processes at risk to oil injury. This also helps to identify food chain transfer of toxins (e.g., effects on zooplankton). If an ecological assessment model is in place, sample where model input is required to increase cost-effectiveness. Ecological population/life history and spatial stock models can provide information about life stages at risk and estimate percentage and population exposed (assuming trajectory information is available).

Postspill Study Considerations

1. Need data on oil exposure – duration and concentrations of oil by location.
    a. Overarching need for all biological/toxicological NRDA studies.
    b. Need to define exposure and exposure units (depths and real locations).

2. For response and NRDA, launch multi-purpose remote sensing package (tracking surface and subsurface biota, surface features, e.g., ocean, fronts, and oil) shortly after spill to provide near real-time tracking of oil, biota and overlap.

3. Ongoing hydrocarbon monitoring, short-term and long-term, at all sites, not just "oiled" and "unoiled," with faster turn-around times.

4. Better integration between biological and statistical teams to measure oil particulate matter (e.g., zooplankton).

5. For planktivores, e.g., pink salmon and herring, the best way to gauge exposure is to check for hydrocarbons in guts of prey or with P450 immediately after spill.

6. Surface microlayer sampling for PAH's.

7. Multiple control sites needed to reduce risk of study failure.

8. Review industry science response papers and use information relevant to Alaska.

9. Need to prioritize documentation of acute impacts in a valid manner. The body counts of birds and mammals will serve as a minimum injury level. Better estimates of animals "not found" would be useful.

10. Response actions are often the most easily identified injuries.

11. Need to have funding sources to support NRDA activities and to fund relevant projects that would not be funded with injury assessment or restoration dollars. Especially critical in light of OPA 90, which requires trustees and the responsible parties to agree before studies can be initiated.

Baseline Data

Definition: Pre-existing survey or life history (e.g., abundance, distribution, population structure, seasonal movements, normal variation, threshold toxic levels) data (quantifiable and repeatable) that can be compared pre- and post-spill.

1. Baseline data needs to be collected in a manner consistent with the way it will be used. Collect the data that is needed.

2. For oil spill damage assessment purposes, collect selected baseline data on highly sensitive species (e.g., sea otters, pink salmon) in specific high risk areas. Selection criteria need to be developed.

3. Need to look realistically at agency budgets and priorities in determining how much baseline work to do.

4. Need to commit to baseline studies based on species and locality considerations that will maintain temporal value.

5. For biological species, there is a critical minimum of baseline data needed to establish oil spill damages.

6. Rather than investing in extensive baseline data collection that may or may not be useful, consider investing that money in developing protocols and techniques (e.g., remote sensing tools) that may have a longer and stable "shelf life" and have more broad applicability to spills statewide.

7. See the discussion of baseline data under "Otters: Lessons Learned."

Restoration

1. Need broader understanding of NRDA process and separate discussion on restoration endpoints.

2. Trustee agencies need to discuss restoration issues.

3. An equivalent amount of workshop time (3 days) could be spent on restoration.

4. Under new OPA endpoint construction, we need better, more credible restoration endpoints.

5. When developing restoration plans, think broadly, particularly in regard to compensatory restoration. When baseline restoration is not feasible or necessary, compensatory restoration should still be considered for the interim loss. If compensatory restoration of the same resources/services as those that were injured is not feasible, consider comparable alternatives.

6. Think broadly and undertake planning studies necessary to accomplish compensatory restoration.

DISCUSSION: Evaluation of Pilot Project

Many participants in the April 2000 workshop evaluated the effectiveness of the white papers and the workshop in developing useful recommendations. Participants broadly endorsed the development and use of the eight white papers to capture specific analysis and recommendations. The group further agreed that the sea otter paper proved to be the best model for focusing on specific lessons and recommendations. This paper was recommended as an example for further assessments of research on other species and resources.

The workshop was also endorsed as an effective way to get an interactive, interdisciplinary forum to develop useful recommendations. Participants agreed that keeping one large group was more productive and a better choice than using small break out sessions as originally envisioned. Dissent was generally considered helpful and productive. Some felt that covering two instead of three resources per day would have allowed a more suitable amount of time to develop recommendations.

The facilitators were considered highly successful in keeping the meeting focused and productive, and in enforcing fair ground rules. Even so, some speakers still dominated somewhat and others were less engaged in the discussion than was desired.

Having the authors as the presenters was considered essential to help guide the discussion and answer questions. Presentations needed to focus on the primary questions and minimize extra research details. The sea otter presentation was considered exemplary. Had it occurred as the first species instead of last, it might have helped provide a more consistent approach for the other species presentations and subsequent discussions to craft recommendations.

Some participants noted that the analysis and recommendations should more strongly emphasize restoration, and that spill response should be de-emphasized. A further recommendation was to spend an entire 3-day workshop on restoration.

Others noted that more focus was needed on natural resource damage assessment (NRDA), including an introductory session "NRDA 101" as part of the first day to provide participants with a common foundation and understanding. An introductory session on OPA 90 was also recommended.

The lack of baseline data, a complaint of the workshop participants, needed to lead more consistently to recommendations for alternative approaches that do not depend on baseline data. This could be designed into a future project.

A shortcoming of this project proved to be that the native tribal and corporate representatives were not directly included in the workshop, and thus did not have an opportunity to raise their issues and concerns about the "lessons learned" and future implications. These should be a concerted effort to engage native leaders in any future session to assess past efforts and particularly to look at assessing environmental damages in the future.

One of the participants noted that acute injuries need scrutiny as well as long-term studies of exposure and sublethal effects. A closer look at what was done well and what should have been done would be beneficial.

Three related recommendations were noted by various attendees regarding participants and reviewers. The first was to engage participation by those who were not dependent upon EVOS research funding, to ensure objectivity and a commitment to critical, fair review. The second was that participants wanted to have more participation from researchers and managers from the Trustee Council agencies. Those specialists might not be funded by EVOS, thus meeting the first recommendation.

Third, a commitment to stay for the whole workshop was desired. Although, as one participant noted, archeologists don't necessarily want to sit in on herring discussions, hearing the other topics was a key way to build better recommendations, especially for cross-cutting issues. A plenary summary session at the end might help achieve constructive interactions.

Two recommendations about workshop process and timing should be adopted for future use. All the white papers or review comments and the workshop should be scheduled well outside spring and summer field seasons to ensure full participation. Instead of flip charts, use a computer projection system and a printer to speed up the recording and note production process.

CONCLUSIONS

The recommendations resulting from this project can be used and adapted by resource managers and scientists to better understand what worked in the past and may be useful in the future.

Participants recommended additional effort for other resources and services to develop multi-agency "lessons learned" from studies following the oil spill. The rationale was that a truly collaborative approach to these questions is becoming increasingly necessary to understand and manage ecosystems.

ACKNOWLEDGMENTS

This was a highly cooperative project that relied heavily upon all the participants. A full list is in Appendix A, which also includes additional authors listed for the white papers.

Guidance for the project was provided by EVOS scientists Robert Spies and Philip Mundy, Jeep Rice, and the workshop planning group, also known as the Interagancy Natural Resource Damage Assessment Group: Pamela Bergmann, Mark Fink, Carol Fries, Doug Mutter, Bud Rice, Alex Swiderski, Doug Helton, Betsy Walatka, Robert Hanson, and Deborah Vo. The facilitation and recording team of Lisa O'Brien and Heidi Chay kept the workshop on track and compiled recommendations for use in this report.

LITERATURE CITED

Exxon Valdez Oil Spill Trustee Council. 1999. Invitation to Submit Restoration Proposals for Federal Fiscal Year 2000. Exxon Valdez Oil Spill Trustee Council Office, Anchorage, Alaska.

APPENDIX A -LIST OF PARTICIPANTS

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APPENDIX B – WHITE PAPERS

WHITE PAPER ON RECREATION STUDIES

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APRIL 24-26, 2000
Anchorage, Alaska

Introduction

In 1989, following the Exxon Valdez oil spill (EVOS), federal and State (Alaska) natural Resource Trustees undertook a broad program of economic studies in support of resource damage (NDR) litigation. When the Federal Trustees' economic damage studies were suspended in October 1991, because of the settlement of all Trustee NRD claims against Exxon, economic assessments were being conducted in six areas: total value (contingent valuation); recreation; commercial fishing; species unit valuation; archaeology; and petroleum price impacts. The purpose of this paper is to discuss the recreation damage studies undertaken by the federal Trustees in support of the natural resource damage assessment (NRDA) and to address questions about them posed to the authors by the organizers of this Workshop.

To the best of our knowledge the State of Alaska Trustees did not undertake any recreation damage studies for the NRDA. They did conduct a separate contingent valuation (CV) study that was intended to estimate the total value of natural resource damages for litigation, however. Given the representative random nationwide sample that was drawn for the CV survey and the very low incidence of recreationists who take Alaska trips among the general population, it is unlikely that the estimate of total damages captured any recreational losses.

We begin by briefly reviewing the concept of economic value and then discuss factors that affect natural resource values as estimated in natural resource damage assessments. We then summarize the goals of NRDA, largely from the perspective of the Oil Pollution Act of 1990. Following that, the paper describes the goals of each of the recreation studies undertaken for the EVOS NRDA and the results that were achieved at the time the studies were suspended. Next, the studies are evaluated in terms of the questions posed by the workshop organizers and in light of the present state of the art of NRDA. Finally, prescriptions are made for conducting recreation studies for natural resource damage assessments that may be required for future oil spills in Prince William Sound (PWS). We also address briefly the assessment of natural resource damages to recreational activities from oil spills that may occur elsewhere in Alaska.

Economic Value and Natural Resources Damages

Economic values are anthropomorphic by definition. The economic value of a good or service reflects some measure of the level of satisfaction an individual or group of individuals receives from the enjoyment of the particular good or service. The total economic value of a natural resource is the sum of the direct use values and passive use values of the goods and services it provides to the population of interest, however defined, e.g., all individuals or households in the United States, or households in a particular state or region.

Natural resources have value if the services they provide, both directly and indirectly, e.g., through an ecosystem, provide utility to people. The concept of consumer surplus can be used to measure both the economic value of lost services, such as interrupted service flows from an oil spill, and the economic value of restoration actions, such as increased or enhanced services natural resources. Consumer surplus is an approximate measure of the maximum amount an individual would be willing to give up (willingness-to-pay) to obtain a good or service or maximum amount he would be willing to accept (willingness-to-accept) to forgo it. For goods sold in a marketplace, surplus is the willingness to pay above and beyond what the individual must pay (i.e., the market price) to obtain his desired quantity of the good. In such cases consumer surplus measures can be deduced from information about how much of a good individuals purchase at different prices. For goods not sold in a market-place (non-market goods), such as recreational trips to a particular site, the cost of access, in terms of money and time, represents the effective price to the consumer and provides key information for estimating the consumer surplus associated with the existence of the site.

The economic value of the service flows from a natural resource is affected by both the frequency with which it is used (e.g., the number of recreational trips taken to the site) and the quality of the natural resource, which affects the value, associated with each use. For example, a beach can provide recreational services of varying quality, depending upon the users' preferences for various site characteristics like cleanliness of the water, type and quantity of wildlife present, crowding, etc. Similarly, a beach can provide varying quantities of services depending, for example, on how many individuals visit it, or how long they stay, etc. The decision to use such a natural resource is, of course, affected by the quality of the resource, but also by the cost of accessing it. Differences in the quality and accessibility of natural resources and services may result in differences in the economic value per unit of lost or restored natural resources and services.

The timing of the provision of services also affects how much they are valued from today's perspective. In general, individuals are willing to pay less today for the right to consume a good 10 years from now than for the right to consume that same good today. Thus, providing a given quantity of goods and services in the future is worth less than providing that same quantity today, all else equal. Therefore, the future loss of goods and services that occur over time as a result natural resource injuries are discounted to the present to provide comparability. Conversely, past losses are compounded to the present. Selection of the appropriate interest rate to use for discounting/compounding can be controversial, however, although several agencies have recommended discount rates to be used in assessing benefits and costs over time.

Goals of Natural Resources Damage Assessment

Following the EVOS, the United States passed the Oil Pollution Act of 1990 (OPA). This law has strongly influenced how subsequent NRDAs for oil spills have been carried out. Many states, including Alaska, have their own NRDA statutes. For all but the smallest oil spills, though, damage assessments have generally been carried out in accordance with the OPA NRDA regulations in recent years. A major goal of OPA and most state NRDA statutes is to make the public and environment whole for injury to or loss of natural resources and services as a result of an oil spill. This goal is achieved through returning injured natural resources and services to the condition they would have been in if the incident had not occurred (baseline condition) and compensating for interim losses from the date of the incident until recovery through the restoration, rehabilitation, replacement, or acquisition of equivalent natural resources and/or service.

According to the OPA NRDA regulations, the costs of implementing a restoration plan form the basis of a damage claim. A restoration plan consists of a set of restoration actions designed to meet the statutory goals of restoring natural resources to baseline (primary restoration) and compensating the public for the interim losses from the time natural resources are injured until they return to baseline (compensatory restoration). Primary and compensatory restoration actions are linked. The faster that the injured resources are returned to baseline, all else equal, the smaller the interim lost use and required compensatory restoration.

Under OPA regulations, the injury assessment, restoration project selection, and scaling processes proceed in parallel. NRDA for recreational losses is concerned primarily with determining the appropriate scale of the restoration action necessary to compensate for the interim loss of natural resources/services from the time of injury until recovery to baseline. The process of scaling a project involves adjusting the size of a restoration action to ensure that the present discounted value of gains from the action equals the present discounted value of interim losses from the injury.

The two major categories of scaling approaches are: 1) the resource-to resource/service-to service approach; and 2) the valuation approach. Both approaches frame the scaling question in terms of the trade-off between services lost due to the injury and services to be provided by potential compensatory restoration actions. The valuation approach is typically based on a quantitative estimation of the tradeoffs people make between the injured and restored services. The metric is usually dollars, but could involve the use of units of physical quantities of natural resources or services, as well.

The “resource-to-resource”/”service-to-service” approach is based on simplifying assumptions about these tradeoffs and uses physical quantities of goods and services as the metric, rather than dollars. In the OPA regulations, it is the preferred approach when in the judgment of the trustees the proposed restoration action provides services of the same type and quality and comparable value as those lost due to the injury.

The valuation approach relies on the use of economic methods to determine the discounted monetary value of the interim losses. In the preferred version of the valuation approach, referred to in the OPA regulations as the "value-to-value" approach, scaling a project involves adjusting the size and type of a restoration action to ensure that the present discounted value of the increased services equals the present discounted value of the interim losses, i.e., interim lost use value (ILUV). When valuation of the replacement natural resources and/or services is not practicable at reasonable cost or within a reasonable time period, the value-to-cost approach may be used. The value-to-cost approach scales the compensatory restoration action by the present discounted value (in dollars) of the interim loss. In other words, the amount spent on the restoration action equals the ILUV (or at least the amount of ILUV that is recovered by the Trustees).

Exxon Valdez Oil Spill Recreational Damage Studies

The federal EVOS recreational damage assessment consisted of exploration of five different pathways through which recreationists might be affected by the spill: 1) recreational boating; 2) cruiseship tourism; 3) recreational fishing; 4) charterboat trips; and *5)* general tourism. The exploratory research and research designs for proposed studies were developed by the economic experts retained by the federal Trustees. These studies were designed using the traditional pre-OPA monetary valuation approach. Data were to be collected to identify factors affecting the quality of the recreational experiences potentially affected by the spill and any shifts in the supply and/or demand for them. Damage estimates for each of the study categories were to be made additive (no double-counting), i.e., they were not to contain overlapping estimates of damages. While exploratory research had been conducted, none of the five studies had entered the formal execution stage, which begins with sampling, prior to cessation of all federal Trustee economic damage assessment activities in October 1991.

The essential task for each of the recreational damage studies was to determine the economic loss induced by the reduction in demand from the EVOS. This task is quite similar across most natural resource damage cases. The similarities and differences between the EVOS and damages from other contaminated sites warrant some discussion, however. Typically, recreational activity is non-market. Usually only participation and trip data for fisheries are available in time-series, because of the need to monitor harvest. Activities like boating, swimming and camping typically go unrecorded. This is true for wilderness areas like AK and for densely populated areas outside of AK. Hence, almost all natural resource damage cases must overcome the absence of good historical data on activity levels. The chief difference between AK and many other natural resource recreational damage cases is the dispersed nature of the user population for AK. Because PWS is a potential destination for recreationists from very distant areas, sampling of the user population is more difficult. A further difficulty came from the many different activities that were injured. In many NRDA cases, there are only one or two activities, such as beach use or recreational fishing. These difficulties were reflected in the various recreational studies that were being planned.

Recreational Boating

The recreational boating category included seakayaking, sailing and canoeing. Initial investigations into changes in the demand for these activities revealed that only seakayaking likely suffered any significant interim lost use in PWS as a result of the spill. To provide the most definitive estimate possible of the damages for this category, it would have been desirable to conduct a nationwide random sample of seakayakers. However, the fact that there are a large number of substitute sites for this type of activity emerged from early focus groups. This, together with the low absolute numbers of seakayakers in the general population of the U.S., made it impracticable to undertake a sample survey for this category of lost use. Some other approach, such as the benefits transfer method, would be necessary to address this category of loss. No such approach had been undertaken by October 1991, however.

Even armed with an estimate of the value of a seakayaking trip, estimation of losses would still have required an additional step. The number of affected seakayakers would need to be determined. Affected seakayakers included: those who took fewer trips to PWS to avoid the risk of experiencing a reduction in consumer surplus due to the injuries to the resources; and, those who did go to PWS and experienced a reduction in the quality of their trip, from what it would have been absent the spill. Both reflect lost consumer surplus, or ILUV. At the time that the recreational studies were suspended, no decision had been reached on how best to estimate the affected population of users at a reasonable cost.

Cruiseship Tourism
The Alaska Division of Tourism regularly collects data from cruiseship companies and reports the actual number of cruiseship passengers arriving in Alaska each month. These data show a significant decline in cruiseship passengers in 1989. It was difficult, however, to identify the extent to which the decline was due only to the spill, as opposed to other factors, such as general economic conditions and non-spill related trends in consumer preferences. Any decline due to the spill would have resulted in a loss of consumer surplus (ILUV) for those passengers who would have taken a cruise to AK that year but for the EVOS. It proved difficult to obtain data from the cruiseship companies about their clients and about the numbers of cancellations due to the spill. Efforts to obtain those data were underway in the fall of 1991. Finally, there appeared to be no way to obtain information that would lead to the estimation of lost consumer surplus of passengers that did take cruises to Alaska in 1989 and suffered a reduction in the quality or quantity of their natural resource experience because of EVOS. It was anticipated that a benefits transfer approach would have been undertaken for this category of loss, as well.

Recreational Fishing
This study's original intent was to estimate reductions in consumer surplus for any losses in the numbers of trips from averting behavior by anglers and any reductions in quality for anglers who fished in the PWS area despite the spill. The assessment team examined Alaska Department of Fish and Game (ADF&G) 1989 recreational fishing data for PWS looking for evidence of losses in recreational fishing catch and user days. If losses could be estimated and tied solely to the EVOS, then an existing travel cost model for estimating recreational fishing values in AK, a model developed by Carson and Hanemann, could have been used to estimate damages for lost and/or diminished quality trips.

The ADF&G report on recreational fishing in AK showed no clear changes in pattern for recreational angling days or catch rates in PWS that year. The total number of days fished by all anglers in PWS actually increased in 1989, while the total number of fishing trips (not equivalent to days of fishing because of multiple day trips) was down -- as they were across all of AK that year. The total number of anglers visiting PWS in 1989 declined, as well. Because clean-up workers pursued incidental fishing activities and because catch rates appeared higher (probably due to many commercial fishing closures), the aggregate data did not support a clear negative effect on recreational fishing.

Because no consistent pattern emerged from the data, the researchers were not confident they could demonstrate losses to recreational fishing from the oil spill. Considerable variation from year to year in the reported data and the confounding effects of clean-up workers and commercial closures contributed to this conclusion. Thus, work on this particular study had been stopped prior to the time that the entire economic assessment was suspended in October 1991.

Charterboat Trips
The intent of this study was to estimate consumer surplus losses resulting from a decline in number of recreational charter boat trips taken in PWS following the spill. Charterboats were defined broadly to include most types of motorized boats available for hire by recreationists, such as tour boats and vessels providing wildlife and scenic viewing trips. Had recreational fishing losses been pursued in a separate study, recreational charter boat *fishing* trip losses would not have been included here to avoid double-counting. The number of charterboat trips could have been reduced as a result of two different effects. First, demand for trips may have shifted back, i.e., individuals may have engaged in averting behavior because they believed that the quality of their anticipated recreational experience had been diminished. Second, the supply

of trips may have shifted backwards because the availability of boats and/or related services (such as accommodations) in the PWS area were reduced due to crowding out from clean-up related demand.

The study of charterboat consumer surplus losses would have required a survey of charterboat operators from the affected area. They would have been surveyed for information related to their recreational and clean-up related activities in 1989, including the number of recreationists served, the extent of cancellations (total and spill-related) and the amount of elapsed time of spill cleanup activities. The names and addresses of recreationists using the sampled charterboats in 1988, 1989 and 1990 would have been obtained, where possible. The study of charterboat operators would have made it possible to estimate the total number of trips lost as a consequence of the spill.

By the fall of 1991, the names and addresses of over 3,000 charterboat operators in the PWS area had been assembled for sampling. Informal interviews with charterboat operators in the PWS had laid the groundwork for the development of a questionnaire that was on-going at the time of the cessation of damage assessment. It had not been decided how a change in charterboat trips would be valued, however. The two options being considered at the time were: a benefits-transfer approach to estimate a per trip value from the existing economics literature; or a separate contingent valuation study of charterboat users.

General Tourism
This study component was not directed towards the estimation of lost consumer surplus associated with any specific recreational activity, *per se.* Rather, it was a study of the possible overall change in tourism activity in the area of the spill at an aggregate level, either for the PWS region or for the state as a whole. Tourists, other than those covered in the above studies, e.g., sightseers, campers, hikers, etc., could have suffered losses from reduced trips to the region. These lost trips may have come about because of fears that the trips would be of lower quality as a result of the spill. Trips may also have been lost because of capacity constraints in the tourist service industries (especially accommodations) caused by the large demand from spill response personnel. At a minimum, this would have served as a check on whether large numbers of lost recreational trips had not been accounted for through the other activity-specific studies, i.e., of fishermen, charterboat users and cruiseship passengers. Additional recreational damages studies could have been designed to capture these other losses.

By the fall of 1991, some data on visitation to AK prior to and following the EVOS had been collected from the Alaska Visitors Association and from the State Division of Tourism by the study team. However, it had not been analyzed by the fall of 1991.

Evaluation of Recreational Studies

All of the recreation studies described above would have potentially been useful for the natural resource damage litigation. At the time that these studies were being implemented, a federal contingent valuation study was also being conducted. In principle, the contingent valuation study would have estimated both direct recreational use value losses and passive use losses from the spill event. To the extent that direct use recreational values would have been captured in the EVOS contingent valuation study, there would have been double-counting if the recreational damage studies and the CV study results were added together. It is doubtful, however, that a probability sample of the United States and a few thousand respondents for the CV study would have captured any recreational users of the AK resources affected by the EVOS. And any direct users that were included in the CV sample could have been dropped from the total value estimate, thus rendering its results purely an estimate of passive use value. In t his way, the CV interim lost use value estimates would have been additive to the recreational interim lost use value estimates obtained through the studies described above.

Furthermore, because it is quite likely that few if any recreational users of the injured resources from the EVOS would have been included in the CV study sample, the only way to have included interim recreational losses in the total damage estimate would have been to undertake recreational studies similar to the ones described above. An alternative approach would have been to increase the sample size for the CV study and oversample those segments of the population that would be more likely to take recreational trips. Given the very low incidence in the general population of recreationists who take trips to Alaska in a given year, the sample would have had to have been very large, indeed.

It is not likely that any of the five recreational studies would have been excessively costly, from the “not grossly disproportionate” perspective. Had they turned out to be, adjustments to the study designs could have been made. Since none of the studies had been completed, no final decisions had been reached in that regard. There are always tradeoffs that must be considered between the magnitude of expected damage estimates and the funds available for conducting assessments. However, now that the Oil Spill Liability Trust Fund is available to Trustees for the up-front financing of natural resource damage studies that meet the necessary legal requirements, the limitations on available funds for the NRDA studies that Trustees’ wish to conduct is not nearly as restrictive as it was at the time of the EVOS analysis.

Recreation Data Collection

It is difficult to draw general conclusions about the optimum amount and type of data collection that should take place immediately following another spill in PWS. The decision would have to be based largely on the size, location and season of the occurrence. It is hard to think of situations where a PWS spill would have immediate impacts on many direct users (beach, fishing, viewing, boating etc.), such that it would be necessary to take aerial photographs of impacted, soon to be impacted and control sites, for example. These are the types of recreational data that are typically sought within the first hours to days following a spill in most coastal areas of the U.S. That model does not particularly fit the reality of the very low density recreational experiences that take place in PWS.

More generally, revealed preference methods for obtaining estimates of losses to users of a resource require the existence of data on the behavior of individuals faced with varying resource situations. Because of this, revealed preference studies may not be possible if data collection does not begin until the time of the spill event. Or it may be feasible to undertake a combined revealed preference-stated preference, e.g., a travel cost-contingent valuation survey, approach to the estimation of ILUV.

The Alaska Department of Fish and Game maintains a good time series of baseline data on recreational fishing – both trips and catch rates – by time period, location, fishing mode, and target species. However, similarly high quality baseline data are not available for other recreational activities, although there are some data on park use. Acquisition of baseline data for other recreation experiences may pose particular problems in Alaska where the density of use is low and the areas to be covered are vast. On the other hand, non-Alaskan recreationists are surprisingly easy to intercept, because the entry points into the state are limited. Also, recreation in Alaska often requires the services of private firms in conjunction with the use of the resource. Examples include fishing guides, charterboats, tour companies, etc. By establishing good relations with these industries, a regular data collection system that produced baseline data might be possible at relatively low costs.

In addition, systematic collection of user day data at federal, state and municipal parks and recreation areas may be feasible. Any significant use of resources that can be adversely affected by oil spills should be considered a candidate, budgetary resources permitting, for the collection of user day data to serve as a baseline against which changes caused by a spill could be compared. All other things equal, longer time series are inherently better from the point of view of "statistical standard-of-proof." Once a time series of baseline data has been started, there can be great benefits associated with maintaining it at regular intervals over a long period of time.

In addition to collecting data on baseline use levels, studies that produced baseline user day values would be useful for those recreational activities most vulnerable to oil spills. Baseline use value studies are particularly important in the Alaskan setting where recreational experiences may differ in character from those enjoyed elsewhere. The prior existence of such estimates would prevent future researchers from having to rely solely on benefit transfer from substantively different sites.

OPA Regulations and Recreation Damage Studies

So far, the emphasis placed on restoration endpoints in the NOAA NRDA regulations appears to have had only a limited direct impact on the design of recreation damage assessment studies. This is largely due to the difficulty of designing and scaling restoration projects that provide a) the same type of recreational services, b) the same quality of those services, and c) comparable economic value to the lost services. Unless a restoration project for lost recreational use meets all three criteria, it would not be considered suitable as compensation for the ILUV.

Without carefully measuring the value of recreational trips lost and those replaced, it can be quite difficult to design a restoration project for lost recreational services that meet all three criteria. For example, replacing lost fishing days with new opportunities to fish elsewhere may appear to fit the similar type criterion, but it might be difficult to compare the quality and to determine whether total value might be equivalent, given that visitation rates will affect this estimate. Comparability is largely an empirical question requiring considerable study. Such studies are difficult and costly to conduct, and few have been undertaken to date. Furthermore, they tend to be quite site-specific, making generalization quite challenging.

Random utility models of recreationists' decisions provide a logical means of learning about the relative values of different characteristics of redreational opportunities. However, such studies are very data intensive. It may also be possible to compensate for loss beach days with new beach days elsewhere of comparable type and quality and value in limited circumstances. There are few other resource types that involve significant human uses that are fungible enough to permit the sealing of compensatory restoration projects via the service-to-service/resource-to-resource approach, however, given the present states of economic knowledge and restoration technology.

In the absence of such studies, the types of interim losses most suitable for direct resource-to-Resource/service-to-service restoration projects may be ecological service losses without significant direct uses. One of the most common types of injuries fitting this definition is wetland service losses. Loss of services from plants and wildlife, including fish and birds that are not directly used by humans, could potentially be compensated for with like resources, as well.

Oil Spills Elsewhere in Alaska

In contrast to the PWS oil spill, an inland incident such as one along the Trans-Alaska Pipeline (TAPS) could generate quite different types of ILUV. These damages might include interim lost hunting values. Although the population of affected recreationists would be different, the losses might be estimated in a similar way to recreational fishing losses. An estimate of affected hunting days would be multiplied by an estimate of the value of hunting days (by type) lost or diminished in quality. The quantity and quality of the baseline data that exists on hunting use and values in AK, although some hunting is licensed, and there is a well organized industry in guiding and related services that would aid in determining baseline levels of use.

While freshwater recreational fishing could also be adversely affected by an inland/TAPS oil spill, it likely would affect few recreational fishermen, given the low density of use in most locations. The quantity and quality of the baseline data that exists on AK fresh water fishing use and values is unknown to the authors, however. General tourism, hiking, camping, and wildlife viewing could also be affected by such a spill, particularly if it was very large.

In the vent of a small inland/TAPS spill that affected few direct users and included little passive use loss, it might be possible to compensate the public by direct resource-to-resource/service-to-service restoration. Of course, an ex-ante judgment about the size of the potential passive use losses (and potential recreational losses, for that matter) can be difficult and controversial to make and ultimately can only be answered empirically, if challenged.

Conclusions

One of the most important lessons that emerged from the recreation studies undertaken for the EVOS incident is that analysts must be willing to adapt their analytical methods to the particular situation at hand. This lesson holds as true today as it did in 1989. Good recreation study designs require more thought than simply forcing an application of a standard off-the-shelf valuation model. In the EVOS case, the charterboat study serves as an example of this improvisation. Perhaps the largest category of damages to potential charterboat users occurred, not because of reduced quality of trips, but because clean-up activities bid away services that would normally be purchased by the recreationists. Both charter boats and accommodations were unavailable to recreationists because they had been hired at higher than normal prices by clean-up personnel. This required designing a study of the suppliers of related services and not just the recreationists themselves.

Perhaps the major problem facing damage assessment analysts after an incident is the determination of the affected population – the "extent of the market" for the services of the injured resource. This difficulty is particularly great in Alaska. Its own population is small, and a large share of recreationists come from the rest of the world. This means that costs of visitation will be high and substitutes will include a broad range of alternatives. As a result, recreational experiences may be valuable but are of low frequency, and the population of potential recreationists may be difficult to locate and interview. In the absence of changes in baseline data collection, future studies will be plagued with the same sorts of challenges that this one was – the difficulty of identifying the "extent of the market" and the difficulty of determining the change in behavior.

EVOS INJURY ASSESSMENT AND RESTORATION: ARCHAEOLOGICAL RESOURCES

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OUTLINE

A SUMMARY OF MEASURES TAKEN FOR EVOS

In the spring and summer following the *Exxon Valdez* oil spill of March 1989 (EVOS), Alaska state and federal agencies as well as the EXXON company were driven to attend to archaeological resources with several dangers in mind: physical damage to low-lying coastal sites incidental to shoreline activities of the oil cleanup; vandalism by cleanup crews or other persons among the large numbers of people attracted to the coast in the period; and the possibility that oil contamination would invade coastal sites to the extent that laboratory analyses of materials, particularly dating of organic materials by the radiocarbon method, would be seriously compromised.

Early Damage Mitigation

Exxon contracted with archaeologists to monitor such oil spill cleanup activities which might involve archaeological resources, placing an archaeologist on each three-man Spill Cleanup Assessment (SCAT) team, in order to educate cleanup crews to the problems, to monitor their activities near recognized sites, and to place on record hitherto unrecorded sites in the spill area. Twenty-six archaeologists were so employed in 1989 and 14 in 1990, a period in which 326 new sites were recorded and information on 335 others was updated.[1] In 1989, 16 sites were found to have been vandalized, two known to be by individuals associated with the cleanup program. No new cases were reported in 1990 after the monitoring system was fully worked out.[2] Overall, some 255 sites or immediate site vicinities were reported to have been oiled to some extent.

In 1990 EXXON cooperated with agency personnel to conduct especially careful cleanup and partial mitigation (through data collection) of one site in Prince William Sound, with the effort continued under Trustee sponsorship the following year.[3] Similar Trustee sponsorship continued in later years, permitting a few other damaged but apparently critical sites to be studied at length, with data collection and analysis by way of mitigation.[4]

During the same period, Alaska agencies funded additional work. The State evidently sponsored a study on the effects of oiling on the radiocarbon dating process; the National Park Service began test work on certain of their properties and later was involved with a Stranded Oil Persistence Study; and there may well have been others.[5]

In 1991, as hearings with EXXON approached, agency work continued. The Office of History and Archaeology examined and, where warranted, tested 13 sites in the spill area, all but one in the intertidal zone; this demonstrated that peat mats even in the intertidal zone may retain enough stratigraphic integrity to make mitigation data collection worthwhile, and added to an indication that with proper (although possibly expensive) cleaning, radiocarbon determinations from contaminated samples were less affected than originally feared.[6]

Damage Assessment

In April 1991 the USDA Forest Service issues an RFP for third-party assessment, shortly awarding the contract to the State University of New York at Binghamton through the SUNY Foundation. One important condition was that the contractor produce a rigorously achieved projection of total sites in the various sections of the spill area, as an estimate of total sites possibly damaged. Later that year, as it became clear that the SUNY projections could not be available in time for scheduled EXXON restitution hearings, a two-stage plan for an interim assessment of damage was drawn up by a committee for the Interagency Oil Spill Management Team.[7] Despite an earlier than anticipated settlement with EXXON, the interim assessment was continued.

Stage One of this “interim assessment” involved a distillation by Jesperson and Griffin of reports previously submitted by EXXON contract archaeologists and agency personnel, intended to arrive at a total number of sites known to have been injured. Their result enumerated 35 sites injured to some extent by cleanup activities or recent vandalized, presumably as a byproduct of attention focused during cleanup. Of these, 13 were known to have also been oiled.[8] Stage Two was to include a projection of total sites believed to be injured, including not yet discovered. Meanwhile, the draft SUNY report of early 1992 provided results of the SUNY projection, which would be drawn on for some further projections by the Interagency Team.

The SUNY report, finalized in 1993, in addition to reporting numerous on-site evaluations and sediment analyses, built for its projections on the baseline of sites reported by EXXON and agency personnel as damaged or oiled to some extent; SUNY projected a total of 531 sites as oiled, and 338 damaged by cleanup.[9] For their own projections in Stage Two, the Interagency Team first reduced the Stage One totals to 24 sites (rather than 35) deemed to be damaged, not yet repaired, but still worthy of repair; of these, five were relatively little damaged but suffered substantial oiling, five were more heavily damaged and also oiled, and 14 suffered physical damage only . From this sample, cost estimates were produced for physical repair of cleanup-caused scars, and for systematic testing by means of three separate sediment samples each year from each site for a period of ten years, to determine the extent of any permanent oil contamination, if any (the McAllister report). The cost estimates were then applied to various projections of total sites in the spill area, sites both known and still unknown. The most modest of the results enumerated 46 sites needing physical repair of some sort, and 24 requiring oil monitoring, for a total cost over ten years of somewhat more than two million dollars.[10]

Follow-Up Measures

Post-Spill Site Monitoring. Not surprisingly, with restitution hearings no longer pending, the Trustee Council failed to accept even this most modest of the cost estimates. Proposals submitted before the 1993 season had two aspects: a) damaged sites would be physically repaired as much as possible in that year; b) in ensuing years a series of "index" sites selected from the First Stage list of damaged sites – especially those damaged by vandalism – would be examined on an approximate bi-yearly basis to monitor vandal damage, with some non-index sites visited from time to time as an additional control, and with sediments from known oiled sites tested on more or less the same schedule to identify possible continuing contamination in sites adjacent to the intertidal zone.[11]

In 1993, 23 sites were visited in the monitoring program. Although these were apparently to be drawn from the list of 24 damaged sites developed by Jesperson and Griffin, and modified by the Interagency Team, only 13 of them were among the 24 identified damaged sites, with 10 others not so identified. In 1994, two more of the 24 were visited, and in later years three more, but as of 1998, six had not been reportedly ever visited. All in all, 37 sites received visits in the six years, four of them visited yearly, four others visited four times during the period (although one of them had been eliminated as a site of interest in the McAllister report), seven sites were visited three times, and an additional 22 sites were visited either once or twice.

Although the specific rationale for eliminating certain sites from those to be visited is unclear, the final result seems to have sufficiently met the original intention. During the first years of the period some sites showed evidence of recent and continuing vandalism, which apparently lessened with the passage of time. Testing of sediments for hydrocarbons during the period by means of the Hanby field test kit has indicated no significant tendency for oil to migrate upslope from the intertidal zone, where traces of oil are evidently still to be found.[12]

A Stewardship Program. Interests of local people in their heritage, as well as the apparent fact that cleanup activities served to increase the level of vandalism of sites, brought certain measures not directly related to the effect of oil but rather focused toward increasing public awareness of the value of cultural resources. Using a model developed in other states, in 1992 the Trustee Council supported design of a program through which local individuals would be recruited to serve as unpaid site "stewards," each of whom would have certain sites under observation and would report to land managers any changes in site status – particularly vandalism, but also processes such as increased erosion.[13] Field implementation of a trial program was funded for 1996 through 1998, during which time attempts were made to recruit stewards, with variable results. Problems were encountered in practical matters such as the provision of transportation for stewards, as well as in the disinclination of some stewards to communicate by means of written reports. The greatest degree of success was reported in the few instances in which stewards had some prior training as archaeologists, and in locations where there are on-going training courses in post-secondary-level schools (as in Kenai) or functioning museums (as in Homer and Kodiak) around which stewardship programs can be centered. Finally, a promising result is that at least certain of the land-managing agencies agreed to work toward continuation of the program in their areas.[14]

Cultural Centers. This brings reference to the final element to be mentioned here, the funding of museums or cultural centers. In 1993 the Trustee Council awarded a substantial sum to partly defray the cost of establishing the Alutiiq Museum in Kodiak, the rationale being apparently a combination of a need for a repository for collections resulting from the archaeological measures attendant on the spill cleanup, and a desire to heighten local cultural awareness. Such measures, as well as the stewardship program, were urged in an evaluation of collection plans for the area made in 1994.[15] In 1996 Chenega Bay applied for similar support. Although without definite knowledge, I have indirectly been led to believe that some funding was made available for that purpose.[16]

In any event, the case of such expenditures must be made on bases that are not directly related to oil spill repairs. Although local cultural centers or museums have multiple values in addition to their importance in heightened local awareness of the public heritage, of which the site stewardship program is one facet, problems with them lie especially in the need for ongoing financial support. Like libraries, museums are not self-supporting. And whereas many local people appear to feel that the major need is a building, in fact the major need in any such program is operation funding in perpetuity.

ASSESSMENT OF THE EXPERIENCE

The Selection of Studies

The first selection of subjects for study was simply based on the need to discover what sites were in the way of the spill and the cleanup activities. Although many sites were listed at the outset in AHRS files, it has always been clear that the listings are incomplete. The result was on-ground study, combined with attempts to lessen the impact on the sites of coastline cleaning measures. Thus, physical damage was the first consideration.

The second area of selection dealt with effects of oil contamination in a chemical, rather than physical sense, and the very crucial question of whether hydrocarbons would migrate into upland sites adjacent to the spill. This might have an effect on a number of laboratory analyses, but especially through the introduction of ancient carbon could seriously skew the results of radiocarbon dating, a process in which ages are estimated by means of the ratio of radioactive to dead carbon, as the proportions of the latter increases through time.

Both of these situations led to the attempts to project the total number of sites expected to lie within the spill area. First of all, these attempts were initiated before a restitution agreement was reached, and a major interest was in assessing damages. Of the two, however, the second – contamination by migrating oil – was especially important, for such damage could occur as seriously to undiscovered as to discovered sites in the area.

It is safe to say that all measures of injury assessment and mitigation described above derive from these two considerations. An ulterior aim in the heightening of awareness, for instance, is to further the protection of cultural resources.

In terms of selecting specific sites for attention, after the first widespread survey and protection efforts of actual cleanup in 1989-1990, sites for further examination were those known to have received physical damage, some of them also oiled and with the possibility of oil spreading, as in the list developed by the Interagency Team with its 24 sites worthy of follow-up work.

The Useful Studies

It is entirely safe to say that all of the studies involved with physical examination of sites were useful, although it is not to say that all would need to be repeated. The initial efforts (1989-90) located sites that were in danger from oil and protected those during cleanup. The third-party assessment (by SUNY) served to confirm many of the results reported by EXXON-funded archaeologists, and to verify the overall impact of the EVOS. The later, follow-up efforts, even when providing negative results, were useful in documenting the decline of vandalism following 1989 and the absence of evidence for spill-oil contamination in any but sites already eroded into the intertidal zone. All of these were related directly to assessment both of damage and of rejuvenation. The site stewardship program was less directly related to these concerns, but was obviously related to attempts to lessen vandalism, some of which was heightened by cleanup activities and the attendant notice given to archaeological resources. Still less directly related to site repair was financial sponsorship of cultural centers, although as noted earlier, they also can be shown to have heightened local awareness of the values inherent in undisturbed cultural resources.

Less Useful Studies

The only studies that cannot now be shown to have had utility to the protection of archaeological sites in the spill area are those that were directed to projecting the total number of sites expected to lie in the EVOS area. These include a substantial part of the laboratory work of the SUNY assessment project, as well as much of the effort of the Interagency Team involved with cost assessment. These projections were evidently made part of third-party contracts in the expectation that they would contribute to the final assessment of damages, and with possible litigation in mind. The damage would include that to undiscovered sites – damage which would lie not so much in physical harm, which should have contributed to making the sites observable and discovered, but rather to damage from oil seepage that would render certain archaeological analyses potentially unless.

In hindsight, there are two fallacies here. On one hand, the demonstration through the index monitoring program, through measures taken as a part of the SUNY ground-assessment work, and through work in 1991 by the Office of History and Archaeology, has been that there is no significant danger from migrating hydrocarbons, this cancels out the major problem of hidden damage. On the other hand, the notion that monetary damages could ever be collected in a court of law through asserting hidden damages to undiscovered sites is almost certainly erroneous.

Should Other Studies Have Been Conducted?

My own feeling is that the studies conducted did as much as could reasonably be expected. It is possible that there were additional sites that were found in the intertidal zone in the process of becoming oiled that were worthy of having the combined damage to them mitigated through data collection that was not performed, but these would have to have been identified specifically in the field, and I, from the distance at which I stand from the situation, am unaware of any such information.

Costly Studies

A major cost element was the assessment study by SUNY. As noted above, the only portion of the study without utility was the attempt to project the numbers of sites, damaged and undamaged, lying in the EVOS area. To judge from the length of the projection section in the final report, this part of the contract must have cost a considerable sum. Other parts of the report contributed positively to the body of spill studies. This is not to say that all of the other parts of the SUNY study, such as all of the laboratory analyses, would need to be repeated in the future, however. Such measures are touched on in the following section.

THE COLLECTION OF SPILL DATA IN THE FUTURE

Before Oil Spreads and Immediately After

The first question to be answered, rather obviously is "What sites are in the way?" The answer involves (a) search of any available site location records, such as those in AHRS or held by land managing agencies, and (b) an on-ground survey to determine the presence of additional recognizable but unregistered sites in the region. This sets the stage for proactive efforts – possibly in some cases to prevent oil spread to important but eroded (i.e., intertidal) sites that may be worthy of having further damage mitigated through data collection, but certainly to prepare for protecting all recognized sites as the inevitable physical cleanup begins. These require both record searches and physical surveys on the ground by personnel with some training.

As the Oil Spreads

These same efforts (records review and on-ground survey) would be on-going as oil spreads, but should also the provision of trained personnel to be present during cleanup in crucial regions, as a control to physical damage through equipment staging, etc., as well as through vandalism. As with the EXXON contract archaeologists, such persons would record indications of hitherto undiscovered sites, as well as attempt to educate cleanup personnel and to monitor their activities. The model here should be the Spill Cleanup Assessment Teams made use of by EXXON, in which an archaeologist was the member of each three-man assessment crew. And as in the case with certain especially important sites in the EVOS area, early activity might well include delays of cleanup in some sensitive locations until additional and appropriate personnel could be enlisted.

Later Endeavors

Following spill and the initiation of cleanup, certain activities in addition to the organization of Cleanup Assessment crews are desirable.

a. Early attempts to collate reports from field archaeologists. This is to lead to a timely assessment of damages and necessary restoration.

b. The use of field or laboratory tests for hydrocarbons to verify suspected contamination of sites on the immediate shoreline, applied during the first year or two after cleanup.

c. A third-party assessment of damages to provide verification of injury and the scale of restoration to be required. This would be especially needful if litigation is pending, but would be desirable in any case as a justification for restoration proposals.

d. Despite the fact that sites eroded into the intertidal zone are already partially damaged, their inundation with oil would in the long run render them hopelessly so. Some of these may be worthy of having the combined damage mitigated through at least limited data collection efforts, for once completely destroyed there is no information to be gained. Any such decision to mitigate would be site-specific and made at the time.

e. A limited period (203 years, at least) of heightened monitoring of sites receiving visible damage either through oil spill cleanup or through any attendant vandalism. The major thrust would be the discouragement of vandalism. If a program of site stewardship can be worked into these efforts, they could provide a helpful adjunct.

Studies Not Needed

1. From what I have said above, it should be clear that I recommend strongly against undertaking extensive efforts to project an expected total number of sites lying in a spill zone. Although such studies may certainly have scientific or academic value, and be of considerable utility to lane managers, they contribute nothing essential to usable oil spill damage assessment or corrective measures. The same is true of predictive models of site locations: if such models area available before the spill occurs, they might well be helpful in guiding especially intensive survey activities as oil spreads. But after the spill occurs it is too late to gain from attempting to develop models from scratch: what is needed is people on the ground to both survey and monitor as cleanup progresses.

2. Although the long-term monitoring of oil contamination in the EVOS studies were highly important in demonstrating with reasonable certainty that oil contamination would not encroach on adjacent upland sites, there is no apparent need for them to be repeated, although it is not unlikely that some analyses for hydrocarbons will be advisable immediately following a

spill.

3. Although a site stewardship program may promise results in the long run, such programs should actually be a regular part of the program of land-managing agencies. In my own opinion such programs, if successful, provide one of the distinctly better ways to lessen vandalism and raise respect for cultural resources, but they should be ongoing, not considered as simply remedial in the short term.

4. The funding of cultural centers, while desirable overall, rests basically on decisions of a political nature, rather than on the immediate needs of oil spill mitigation. Nevertheless, it should be recognized that both a stewardship program and the enhancement of cultural centers should tend to have a long-term effect in lessening vandalism.

Tactical Modifications

Modifications would consist only of elimination of attempts to project total sites potentially damageable but still unrecognized, and elimination of long-term testing for the presence of residual hydrocarbons.

"Restoration" of Injured Archaeological Resources

As perishable and non-renewable resources, archaeological sites cannot be restored. The only mitigations of destruction include (a) protection against continued erosion and vandalism by modifications of terrain and surveillance, and (b) – when destruction is essentially unavoidable – the introduction of controlled destruction, i.e., archaeological excavation, in order to salvage information before it is lost.

Having said this, one must add that it is seldom expected or desirable that archaeological sites should ever be excavated in their entirety, so that in many cases the loss of relatively minor portions of sites through erosion or oil contamination may not be absolutely injurious to their ultimate value, despite the fact that the destroyed parts are irreplaceable. Thus when important sites are seriously threatened, in whole or in part, with destruction from natural or man-made causes, important decisions are necessary as to when mitigation through archaeological salvage is indicated and when it is not. Such mitigation should always be a potential part of response to disasters such as oil spills, however.

NOTES

[1] Mobely et al. 1990; Haggarty et al. 1991.
[2] Mobely et al. 1990: 133-145; Haggarty et al. 1991: 155. More specific accounts of site protection measures developed in those years are in Bittner 1996 and Wooley and Haggarty 1995.
[3] Betts et al. 1991.
[4] Yarborough 1997.
[5] For the first, Mifflin and Associate 1991, as cited by Reger et al. 1992: 1 and Bittner 1996; for the second, Schaaf and Johnson 1990, as cited by Reger at al. 1996: 19; for the third, see reference by Reger at al. 1996: 18. Inasmuch as the present authori was peer reviewer only for work under the auspices of the Trustee Council, in-house reports by the agencies have not been routinely made available to him.
[6] Reger et al. 1992; see also Bittner 1996.
[7] Berkedal 1992, in Jesperson and Griffin 1992:9.
[8] Jesperson and Griffin 1992.
[9] Dekin et al. 1993.
[10] McAllister n.d.
[11] Birkendal et al. 1993. Evidence in Mifflin and Associates 1991 and Dekin et al. 1993 had suggested that spill-oil mitigation to upland sites was unlikely.

[12] Bland et al. 1998; Reger et al. 1996a, 1996b; Reger et al. 1997, 1998; Reger et al. 1999.
[13] Corbett and Reger 1993.
[14] Reger and Corbett 1997, 1998, 1999.
[15] Bittner and Reger 1995.
[16] One difficulty for a peer reviewer in developing an overview such as this one is the inconsistent reporting of funding decisions. Although I have regularly seen and commented on proposals, Trustee work plans have come to me intermittently, so that I am very often unaware of the response to applications unless later I see final reports – or, of course, finally never see one at all.

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White Paper on Scientific Response Plan to the Studies on Injury to Pacific Herring Following the *Exxon Valdez* Oil Spill

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Summary of Herring Studies

The investigation of injury to Pacific herring by oil was implemented rapidly due to the timing of the spill. The spill occurred March 24, coinciding with the migration of prespawning adult herring to spawning beaches and natal habitats in Prince William Sound (PWS). The first response was to monitor potential fish kills as herring intersected patches of oil. This response was to include collections of adult tissues for histopathlogical examination including potential egg absorption by females due to exposure to oil. The second response was to investigate the effect of oil exposure on the incubating eggs, pre- and post-hatch larvae at the natal habitats. The third response was to examine the effects of oil on the growth and survival of the free-swimming larval herring. No studies of juvenile herring were conducted. The first three responses were initiated in 1989 and several components were continued through 1991. [A small study in 1989 sampled herring for hydrocarbon analysis and the samples from oiled sites contained hydrocarbons consistent with weathered crude oil. Details can be found in this publication: Marty, G.D., M.Okihiro, E.Brown, D.Hanes, & D.Hinton. 1999. Histopathology fo adult Pacific herring in PWS, Alaska after the ExxonValdez Oil Spill. Can.J.Fish.Aquat.Sci.56(3):419-426.]

Then in 1992, when the 1988 year class (exposed to oil as 1 yr. olds) recruited to spawn, an investigation was initiated to examine the effects of previous oil exposure to reproductive impairment (genetic damage); this study was not continued in 1993. In 1993, the herring population in PWS crashed due to a massive disease event. In response to this an investigation of the disease event and potential links to oil exposure was initiated. The disease study continues to the present. The reproductive impairment study was reinitiated in 1994 with field collections from PWS starting in 1995; that study was completed in 1996. In 1999, a synthesis project summarizing the oil injury and disease event was completed. All of these studies resulted in over a dozen scientific papers. Even though injury to specific life stages of herring was proven and documented, the impact of oil on the population as a whole was still poorly understood; the role of oil in the disease event remains unclear. As with many of the other damage assessment studies, inconclusive results were largely the result of lack of prespill baseline data along with a poor understanding of how the marine ecosystem functions and affects long-term trends in production.

A related study examining the ecology of Pacific herring in PWS was initiated in 1994 as part of the Sound Ecosystem Assessment (SEA) project. This motivation behind this massive effort was three prong: 1) EVOS TC wanted to move toward ecosystem research, 2) fishermen and other user groups were frustrated by the lack of answers about just what happened to herring and salmon in PWS and protested to add more studies, 3) herring were recognized as a key species in the PWS food chain and the lack of herring recruitment was thought to have effected reproductive success of various seabirds and marine mammals. The SEA investigation continued for 5 years and is currently in closeout with focus on the production of publications.

Two other studies have herring components. Related to the SEA program, but independent of it is a retrospective study on spawning and recruitment and ecological factors affecting both; this project is closing out in 2000. In addition, the Alaska Predator Ecosystem Experiment (APEX) project, another large ecosystem study initiated in 1994 and closing out this year, has components examining the effects of juvenile herring distribution and abundance (in addition to other forage fish) on foraging and reproductive success of seabirds.

Damage Assessment Studies

The selection of studies to examine the effects of oil on Pacific herring occurred rapidly and without much background information. The Alaska Department of Fish and Game was assigned the damage assessment studies concerning commercially and sport caught fish and invertebrates. Since there were no pre-established guidelines established for investigating damage assessment from exposure to toxic substances, each Principal Investigator (PI) operated relatively independently with assistance from varying sources. The approaches for damage assessment varied tremendously by species and the one for herring was semi-haphazard as a result of the lack of plans and the speed in which the study was formulated. For herring, the ADFG statewide fish pathologist was brought in to oversee potential fish kills and sample tissues from adult herring collected in PWS. The field team monitored the spawning aggregations at the spawning beaches and guided sampling efforts. Experts from NOAA, Auke Bay lab were on hand to advise the ADFG PIs how to collect hydrocarbon samples from tissues and sediments; they provided protocols and chain-of-command forms. The Minerals Management Service (MMS) of the Department of the Interior had a contractor working on larval herring out in the Aleutian Chain and brought him into PWS as an emergency response to assist with herring studies. This expert assisted the herring PI in designing egg mortality and larval impact studies. Other experts were found by word of mouth during conversations between the PI and other investigators. Specifically, experts in toxicology were contracted to assist in examining sublethal injury to embryo, larval and adult tissues, but not until 1990. The response to the disease event in 1993 was a reaction to an emergency situation as well using the ADFG statewide pathology laboratory. Systematic disease studies were on line by 1994 due to the recognized need for a dedicated disease PI. Without guidelines about how long studies should continue, studies were eliminated as soon as oil injury could not be significantly detected.

The most useful data came from the investigations on sublethal injury, especially when site-specific oil exposure data was available. At the natal habitats, establishing oil exposure was easily established via the collection of mussel tissue at each collection site for embryos. Live embryos were collected after incubating for over a week and the rearing to hatch was completed in the laboratory so that newly hatched larvae could be collected. Although oil affected egg mortality, the occurrence was only at the moderate to heavily oiled sites. In contrast, a full range of sublethal effects was found including morphological and genetic abnormalities, low birth weights and shortened larvae at hatch, and premature hatch occurring at all oil levels. The severity of sublethal injury was highly correlated with the level of oil indexed by the mussel tissue. It was surmised that none of the larvae with sublethal injury would survive to the free-swimming stage. This was confirmed by the significantly higher egg-larval mortality rate estimated in areas offshore from the oiled sights (by the MMS researcher). If we had been looking strictly for mortality at the embryo stage, we would have vastly underestimated the damage to the 1989 cohort.

Established exposure rates for adult herring was more problematic since the fish are moving, exact migration routes are unknown, and the subpopulation structure in PWS is poorly understood. However, the collection of adult herring tissue indicated sublethal injury from oil exposure that, from the literature, could result in impacts on growth, feeding, reproduction, and disease resistance. Serendipitously, a NOAA researcher working on his graduate studies, sampled adult herring on his own recognizance (not part of the study plan) and found that gut parasites in oiled herring had migrated into the muscle tissue. The health of the oiled herring was in question due to that finding. The downside was that not nearly enough tissues were collected for pathological examination and no bile fluids were sampled for oil content. Looking for oil metabolites in the bile of fish is one way to establish oil exposure, but protocols for collection are difficult and require rapid storage in liquid nitrogen to preserve the highly reactive compounds. Because we did not plan for this type of collection, it never took place.

The search for fish kills was not useful. Because large numbers of dead fish were not found, ADFG's pathology involvement ended during the middle of the study and adult tissues were not collected by ADFG. In retrospect, large numbers of dead fish have rarely been found following oil spills and I feel we wasted time and money looking. This left no one, except the NOAA graduate student, to oversee adult tissue collection. This was a huge mistake since the sublethal injury in adults in 1989 was poorly understood, yet held enormous consequences for sorting out injury at the population level.

In hindsight, we should have dramatically increased the numbers of adult tissues taken and sampled juvenile herring at the nursery sites. This increase in effort would have provided some continuity of information through the life stages and helped us to understand impacts we observed years after the spill included reproductive impairment in 1992 and the disease event in 1993. We should have collected bile samples from many of these same fish, especially when clean-up activities overlapped nursery areas and adult feeding zones. For both juveniles and adults, we should have monitored growth during the summer since stunting is a common effect from oiling. We should have established protocols for when effects were no longer significant, observable and studies could be ended. Finally, during tissue sampling, we should have been monitoring for disease in both juveniles and adults since immunocompentancy is another known oil effect. In fact, the herring study group submitted a memo to the Trustee Council in 1992 summarizing the potential damage at all life stages and what studies were needed to continue to track injury. However, the injury to herring project was in closeout in 1993 just as the population crashed. The herring group was not able to respond to the event in a systematic fashion, despite the fact that the event was on the list of predicted effects in the 1992 memo. This last item was probably one of the single most frustrating occurrences of the whole process.

Ecosystem Approach

I would recommend taking an ecosystem approach to oil spill injury. This approach entails tracking how energy flows in the system, via the food chain, are impeded or changed by injury from oil exposure. In order to take this approach, baseline information is needed as well as a good understanding of the structure of the system and how it functions. In addition, a functional mathematical model of the system is needed in order to simulate or predict areas of blocked flow or injury and then samples to test whether or not the model was correct. The model is used as a tool to generate hypothesis driven science. Prior to EVOS, we did not have sufficient baseline information about many of the key components in the PWS ecosystem (in this case juvenile herring) nor did we have a preconceived functional model. However, I believe we could take that kind of approach in the future. An ecosystem approach has a greater chance of documenting interrupted processes that result in long-term damage or changes to the system (probably like what we are seeing now in PWS). In addition, a modeled approach would enable researchers to separate changes expected due to natural variability and separate those changes caused by oil exposure. In order to enable an ecosystem approach, a scientific response plan is essential. The response plan details key components in the ecosystem and guides research objectives. The response plan must include a definition of agency roles and cooperative working agreements in order to be cost-effective. In addition, collecting basic, long-term annual population estimates of a adult and juvenile herring is needed to implement an ecosystem approach. Without a conceptual model and implementation plan, I do not think an ecosystem approach would work nor do I think it would be feasible.

Recommendations for Oil Spill Response for the Study of Herring

In terms of cost, none of the components of the herring study were excessive. We used research platforms for multiple types of data collection, worked with existing agency programs (an important feature for cost savings), and used existing staff wherever possible. One factor that resulted in inefficiencies was that while oil spill research programs were ramping up (in funding), the regular agency budget was being slashed undermining cooperative efforts and causing an increased burden on oil spill funds to bolster regular programs in order to maintain the data base. In addition, the agency was tempted to use oil spill funds, especially on personnel, to assist other regions experiencing shortfalls (i.e., shifting the pork). Finally, agency missions or objectives may not be aligned with damage assessment objectives; an implementation plan would prevent this from happening and restrict funding to activities aligned with assessment goals.

Baseline data collected prior to the spill is very important and plays a critical role in sorting out damage. For herring, the types of information that would be useful depend on the timing of the spill since distribution of herring changes seasonally. In general, tissue samples (key organs and muscle), disease assessments, bile samples, parasite counts, and age-weight-length data should be collected from both juvenile and adult herring in a few key locations (where abundance is concentrated). If the spill occurs post spawning, the collection of unoiled embryos and free-swimming larvae should be done at a number of pre-established index sites. These collections will help establish the baseline state of the herring since disease and abnormalities can occur naturally. Baseline mussel tissue data from adjacent sites would be important in establishing exposure history. For ecological evaluation, the physics of the system, amount of food available (zooplankton), and the relative abundance of predators should be assessed at the same index sites.

Immediately following the spill, the same information as above should be collected from the same sites (if possible) for comparison. The immediate collections would establish the proportion of the population exposed, the level of oiling, and the acute injury sustained. For ecological assessments, immediate post-spill assessments of zooplankton availability and predator abundance would provide advance warnings for potential problems with growth and changes in predation.

Beyond 48 hours from the spill, monthly sampling of the same index sites and indices would be sufficient to monitor changes in growth, mortality, food availability, disease and sustained exposure from beaches leaching oil or clean-up activities. After the first year, monitoring can be limited to key periods when bottlenecks in survival occur or when we expect (from the initial assessment) to observe sustained injury. Monitoring should be conducted at the baseline index sites as well as in areas where exposure is expected to continue via clean-up procedures. Oil could be re-suspended as particulate matter during hot water spraying or from heavily beaches during tides. Examples of key periods in survival may be disease and pathological assessment of adults in the spring and winter along with investigations of reproductive impairment (only if it was shown a portion of the population was exposed to oil). A larval survey, similar to the baseline surveys, should be continued at index sites following hatch to track relative densities and levels of sustained abnormality rates. Age-1 herring can be indexed for abundance and distribution in the summer and sampled during summer and spring (following overwintering) for disease and pathology along with monitoring of growth and food availability at the index nursery sites. The survey of age-1 herring will provide a measure of first year survival (during which mortality rates are highest) and enable researchers to track the injury from egg to larvae to juveniles. Continuing the monitoring into the adult stage would allow researchers to track an injured cohort all the way to recruitment increasing the chances of estimating damage at the population level. The summer survey of juveniles will also provide seabird researchers with an index of prey availability since data on the occurrence of herring and other forage fish can be collected synoptically.

Studies that I would not recommend conducting are those which strictly measure mortality. For juveniles and adults, dead fish are generally eaten, sink and difficult if not impossible to estimate. In 1993, very few dead herring were observed following the disease event even though it was estimated that *75%* of the population disappeared! A second example is the egg mortality study conducted following the spill. The increase in direct egg mortality due to oiling was only *5%* while the level of abnormalities in live hatch larvae (certain to die) was an order of magnitude higher. Our time was better spent collecting live eggs to be hatched in laboratory or field experiments.

Restoration activities that I feel are most worthwhile are protective measures. Fisheries management should be conservative and based on a clear understanding of population structure in order to mitigate oil damage to all or a part of the population. Natal habitats and key nursery bays should be protected from development and pollution. In this and other oil spill studies, we know that fish embryos including herring are very sensitive to oil pollution. Heavy boat traffic, light fuel spills, and human traffic can do serious damage to spawning areas because a large proportion of the eggs are exposed to air and the water surface (containing the toxic micro-layer of floating pollutants) via tidal action.

Another restoration activity that might be worthwhile is in the case that a spill occurs after spawning. If there is a potential for exposure of a large amount of eggs to oil, the kelp with roe can be harvested and moved to pristine, unaffected areas and allowed to hatch there. This could be costly, but may be an alternative job for clean-up workers rather than spraying hot-water on beaches (an activity that may have been as damaging for nearshore nursery fish as the original spill). Again, this is a preventative, rather than restorative measure.

The only truly restorative measure I can think of is to reduce predation. This entails closing commercial fisheries, which was done in PWS, or redirecting humpback whales (an unrealistic goal). The population in PWS may be in a "predator pit" where the number of predators has not changed drastically, while availability of herring has. If this is the case, recovery will be delayed until predation rates are reduced or exceptional survival (optimal conditions during the first year) occurs. In this case, the wisest use of restoration funds is simply monitoring and letting Mother Nature do the rest for free.

White Paper on Pink Salmon

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21 March 2002

Pink Salmon were the most studied species before and after the spill. The damage assessment studies were driven by a combination of the value of pink salmon stocks, the dependence on the impacted near-shore habitat, and the quality of prespill information. Pink salmon were likely the most ideal species for these studies due to the combination of a short life history (2 years) and the isolation of the brood lines from each other, which allowed for more observation to be made in a shorter time period while allowing for a cleaner experimental design, easier sampling and subsequent analysis [ADFG]. Consequently, we know more about the short and long term damages to this species. These studies have generated criticism from Exxon, who contest some of the findings, and continue to point out that damages were negligible because of the high adult returns to the fishery in the years immediately following the spill.

What did we know prior to the spill?

The most sensitive life stage of pink salmon was believed to be emergent fry in seawater, and the most toxic components of oil to be the single ringed aromatic compounds like benzene, toluene, ethylbenzene, and xylene (BTEX). Emergent fry, with their estuarine lifestyle would be vulnerable to oil exposure either through contaminated food, or to hydrocarbons in the water from the stranded oil on the shore. Laboratory research suggested that growth and other sublethal effects could be expected to cause damage. The shoreline habitat for feeding was thought to be the critical habitat most likely to be affected by the spill, since freshwater spawning habitat was unlikely to be contaminated, even in the intertidal zone. Eggs and alevins were also believed to be highly tolerant of oil exposure. Consequently, the damage assessment studies in the first year focused on the potential damage to emergent fry in seawater, their migration patterns and growth, feeding behavior, basic ecology, and evidence of exposure (contamination loads and P450 measurements). Nearly all the attention focused on fry, the life stage present during the initial days of the spill. Little attention was paid to eggs and spawning habitat, except to assess their numbers in order to track population level effects, presumably from impacts at later life stages. An initial design to evaluate the effect of oil contamination on pink salmon egg to fry survival by sampling egg densities in the fall and comparing them to fry densities in the spring was not successful, most likely due to problems with sample design, but did indicate problems with embryo survival in oiled streams. Stream habitat contamination data were not collected in an appropriate manner for a quantitative analysis until 1995, although contamination in the water column and shoreline habitat of fry was assessed.

What did we learn in the first years following the spill?

The ADFG and NMFS studies were successful in documenting exposure and growth effects in fry in the marine environment. These conclusions were contested by Exxon researchers, but the studies were statistically powerful and the results were consistent with all of the prior knowledge of toxic effects. However, contamination loads in the water column were surprisingly low, and diminished rapidly in the first few weeks of the spill. These measurements were not consistent with the previous toxicity paradigm, which assumed that the BTEX compounds were the primary agents responsible for any and all toxicity. Weathered oil was not perceived as a problem since it was believed that the lighter BTEX compounds were largely lost during weathering. Ingestion of whole oil directly, or via contaminated food, was observed and was a more likely exposure pathway. Modeling of the returns estimated 1.9 million adult fish did not return because of the cumulative oil impacts. Exxon contested those results citing that the overall returns were very good. (Such an interpretation by Exxon fails to consider the issue of natural temporal variability and the issue of how much higher the returns might have been in the absence of spill effects. [R.B. Spies]) .

Elevated egg mortalities were measured in 1989 and 1990 in oiled streams by ADFG; while surprising to some extent, the egg mortalities in oiled streams were in zones adjacent to where oil had been the heaviest. No effort was made to document the concentration of oil in the streams at that time. ADFG investigated hydrocarbon exposure of eggs and alevins in oiled streams; Cytochrome P4501A analysis indicated exposure in alevins up to two years after the spill.

Evidence for long term effects mounts:

By 1991, the continued elevated mortalities in oiled streams elicited concern, and explanations were sought. Were the mortalities due to poor sampling technique, or was it due to oil? This stimulated both field and laboratory studies to find explanations. The egg sampling continued to find elevated egg mortalities through 1993, an unprecedented finding of long term damage. Controlled laboratory tests determined that the sensitivity of eggs to long term exposures was dramatically different than the short term acute toxicity measured in tests of the 1970's. In 1995, oil along the stream banks of oiled streams was re-surveyed and compared to levels of oil found by ADFG in 1989 and 1990 by "oil spill response" staff (as opposed to "damage assessment staff"). Oil was found, and the quantities were sufficient to implicate this contamination as the likely cause of egg mortalities up to 1993. However, confirmation of direct exposure in the salmon spawning redds was still never attempted, and continued to be a hole in the studies. Exxon continues to contest the possibility of exposure to salmon eggs, and argues that the elevated egg mortalities were a sampling problem.

Lack of documentation of oil exposure in the early years, particularly in the streams themselves (no oil measurements, no contamination measurements in eggs or collection devices) was seen as a shortcoming in these damage assessment studies. Also, it was becoming increasingly evident that the weathering state of the oil was an important variable: weathered oil was diminished in volume compared to less weathered oil, but the toxic components remained. The source of the long-term toxicity was ascribed to the multi-ringed aromatic hydrocarbons and not to the single-ringed BTEX aromatics.

What have we learned?:

Oil persists longer than we would have predicted in certain environments, particularly contaminated stream deltas. Persistence in mussel beds and armored beaches also confirms the potential for persistence. The composition of the oil matters a lot- long term toxicity is associated with the multi-ringed aromatics, not the BTEX aromatics. Eggs are more sensitive than the acute toxicity data of the 1970's would have indicated. The oil toxicity paradigm model had changed significantly – shifting from an acute toxicity/BTEX model to a chronic toxicity /weathered oil model.

If another spill were to occur, what should we do different relative to pink salmon?

Most of the 25 funded studies proved useful, although much more data could and should have been collected in the first year. The genome project was the one possible exception. Documenting exposure to eggs would be the high priority difference between the past and the future. Measurement of oil along side of streams, measurement of oil in spawning beds, and measurement of oil in eggs would be the major upgrades needed. Weiring oiled and unoiled streams to track hydrocarbon loads and marine survival coupled with sediment characterization of the streams would have given important information in the first year, and in the future should be done to as many streams as practicable. The limited number of streams (3 contaminated, 3 reference) weired for the EVOS proved too limiting for providing the best study results. Egg mortality measurements should be taken weekly rather than just once, at least in some benchmark streams, though controlled laboratory studies using eggs from a hatchery could prove a preferred method in order to lessen any impacts to wild eggs.[ADFG]

Ecological vs. species damage assessment studies – should the research plan have been different?

No, and yes. It is important to lead with a species damage assessment plan, particularly for a high profile fish and fisheries, such as pink salmon. The initial plan in 1989 was appropriate for pink salmon damage assessment, based on our knowledge base at the time. That knowledge base is different now, so there would be modifications. As for ecological studies, they would be needed to dissect out the indirect influences of oil and natural factors, such as those that resulted in the surprising crash in 1993. Herring also crashed in 1993, indicating a failure in the system, rather than a species specific problem. It is unknown whether the ecosystem was perturbed by oil, or other unknown natural factors, but crashes in pink salmon or herring did not occur anywhere else in the state. The crashes in herring and pink salmon in 1993 were related to some sort of ecological perturbation, which can not be identified retroactively. The ecological studies initiated after 1993 would have to have been initiated prior to that date to understand the role of oil in ecosystem perturbations. The damage assessment process was driven by a legal process, hence the initial emphasis on species damages, particularly for those species that could result in monetary damages (pink salmon, otters) rather than species that will help you diagnose energy flow and the state of an ecosystem (like forage fish, energy mass balance). For restoration rather than damage assessment endpoints, the importance of measuring hydrocarbon levels in the streams over time becomes more important. The fact that the run returns to some historic levels is no indication that long term effects cannot happen over a longer time scale. As with an "r" type reproductive mode, the important criterion for restoration is the absence of additional oiling in the streams.

Relevance to other spills?

Pink salmon may not exist in other spill environments, but these studies have demonstrated that the reproductive process is a sensitive measure of oil impacts and that eggs are a vulnerable life stage. Species depend on recruitment to survive, and if the reproductive process is damaged, even if only incrementally, recruitment is diminished. The ability of the species to survive natural hard times is thereby diminished, and the threat to extinction is increased. Other spill environments will have different species, but if spawning or egg rearing habitats are oiled, reproductive success may be compromised. Furthermore, oil spills and their impacts on stressed reproductive and recruitment are added to other anthropogenic stresses.

Significance of long term pink salmon impacts to future decisions?

Long-term damage of pink salmon from the Exxon Valdez oil spill is unprecedented- and is a product of a combination of early life stage sensitivity and long-term persistence of weathered oil. Long-term damage has been observed in other species, but the suite of pink salmon studies are the strongest evidence of cause and effect. Decisions on how to cope with future spills should be based on long term damage potential and an understanding of critical habitat rather than acute toxicity information. Decisions should not be based on the potential for initial mortalities, but based on the cumulative mortalities over a 10 year period. For example, does one use dispersants to minimize the amount of oil coming on shore, risking increased acute mortalities but causing less habitat contamination and less long term impacts? In the past, decisions about these questions have been driven by the risk of acute toxicities and immediate species impacts and less by long-term impacts and habitat protection. Our priorities should be reversed, judging by the present body of evidence for long-term impacts.

White Paper on Mussel Bed

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NOAA Auke Bay Laboratory

22 MARCH 2000

Research on oiled mussel beds was passed over in the early years of the spill. Damage assessment studies were the focus, and damages to mussel beds were either perceived not to be a significant issue or not a resource that could net returns if there was a damage settlement. During the response effort, the decision was made not to clean mussel beds on soft sediment. Based on the knowledge of the time, nature would take care of the oil, and more harm was probable if the beds were cleaned. The persistence of the oil in the beds was not foreseen at the time, and the significance of mussel beds to several vertebrate predators was not known. In the future, during a spill response, any decision to address the "cleaning" pf mussel beds must be given careful conssideration.

What did we know prior to the spill?

Rigorous baseline studies of the mussels and sediments of Prince William Sound demonstrated the general absence of hydrocarbon contamination prior to the *Exxon Valdez* spill. Sampling was repeated immediately prior to the oiling in 1989, and these samples provided the best legal proof of non-contamination prior to the spill. As a consequence, it was possible to compare pre- and post-spill oil concentrations in mussel tissue and verify the general cleanliness of the ecosystem as a whole.

What did we learn in the first years following the spill?

Because many of these mussel beds were not cleaned, particularly those on soft sediments, these mussel beds had high concentrations of hydrocarbons. Because species orientated damage assessment studies dominated the research in '89-'91, mussel beds were not followed. It was hoped that they would cleanse themselves through natural processes. By 1991, long-term damage was noted with some species, and a pilot study demonstrated remarkably high tissue loads in oiled mussel beds and relatively unweathered oil beneath these beds. The first mussel bed studies looked at distribution of the oil beneath the beds, variability within the beds, and possible ways to restore the beds. The persistence of these contaminants was followed periodically over the next few years. This was the only study for which sufficient prespill data existed and for which it was possible to assess continuing contamination.

Mussel bed studies were evolving as an important study. Oil in the beds or in the mussels was probably a major vector for any long-term effects to predators that depended on the mussel beds for part of their forage base. The mussels were indicating the bioavailability of hydrocarbons that were previously assumed to be buried and not available. Further, clean-caged mussels allowed researchers to document the presence of oil in the water column, which was below the detection limits of water-based sampling.

Evidence for long term effects mounts:

Mussel beds remain one of the few habitats in which oil still persists after 11 years, and with oil that is bioavailable. Both within the bed and in the sediments underlying the beds, oil often persists, sheltered from the cleansing effects of wind and waves. These beds, which provide food to birds and mammals and act as stabilizing influences in the intertidal zone, provide a source of residual oil longer after other habitats have no measurable amount of bioavailable oil. Some of the species have indications of long-term exposure (elevated P450, for example) and poor recruitment, but these are difficult species to track and measure impacts. Consequently, the direct connection of oiled mussel bed exposure to the higher vertebrate predator impacts remains weak. These predators remain mobile and have a larger foraging base than mussel beds in general, let alone a specific oiled mussel bed. For some of the species, such as Harlequin duck reproduction, one or two feedings in an oiled mussel bed may be sufficient to interrupt their reproductive staging and success. The primary evidence is the presence of oil in the mussel beds, the use of the beds as foraging habitat for some portion of the year, some subtle exposure indications, and poor recruitment.

What have we learned about natural restoration?

Tracking of the oil in mussel beds has demonstrated a wide varying pattern of general decline, with some beds showing very little diminishment of the underlying oil. Basically, oil that was readily exposed to the natural elements has mostly disappeared from the local ecosystems through tidal movement, wave action or permeable underlying sediments. But oil that has been hidden or protected from theses natural cleansing actions persist, and this is generally the case with the oil in mussel beds where there is less access to wave energy and which tend to contain finer grained and tighter sediments. The expectation now is that oil will be found after three decades in some of the oiled mussel beds. These beds are indicators that the original decision to not clean mussel beds may not have been the best decision due to the long-term exposure to a variety of species.

What have we learned about restoring mussel beds with cleaning activities?

Later attempts were made to clean some of these beds through a variety of methods, mostly relying on manual labor, but the results were mixed. Basically, restoration may be possible, but manual techniques are physically limiting. How many 75 pound buckets of sand and mud can a person carry in a day? In a week? These pilot study efforts were costly because of the labor, but they were successful in reducing hydrocarbon loads, to a point. Workers were not able to dig deep enough to remove all of the oiled underlying sediments. Some low level contamination persists in the cleaned beds, and in fact, there is evidence that the hydrocarbon loads are slowly rising in the overlying clean sediments as the deep residual oil re-equilibrates in the sediments immediately under the mussels. Some mussels did not survive removal during the cleaning process, and but mortality was not high enough to indicate that the cleaning concept has no merit.

In the future, mussels can be manually removed from soft sediment beds and moved to a nearby floating pen set up for culturing shellfish in massive numbers where they can depurate for a few weeks. In the meantime, the appropriate cleaning techniques can be applied to the soft sediments, though these techniques need to be developed. Reliance on manual labor is not as effective as it needs to be, particularly during a large-scale response.

Cost is always a concern. But the value of a mussel bed over a 10-30 year period can be priceless. This is primarily due to the value of mussels as a supporting species during critical life stage events for higher vertebrate species. Time has demonstrated that long-term exposure to the natural elements will not necessarily remove hydrocarbons from the mussel bed environment. The cleaning of these habitats has to be given a much high priority than in the past.

If another spill were to occur, what should we do different relative to mussels?

Mussels appear in countless tidal environments, so it is easy to dismiss the significance of mussels. However, this specific habitat retains oil for very long periods of time and is a major vector into higher vertebrates for possibly decades. Doing nothing about these beds is not an option in future spills. We have to do more to recognize these specific habitats, sample them, and clean them up.

Sampling: Less emphasis on getting replicate POOLED samples, and more emphasis on sampling from different spots in the beds. Are we interested in what is a representative number for a bed, or interested in how bad the bed is? How much oil can we find in a bed? – that will determine, along with other factors, the priority for the bed to be cleaned and tracked.

Cleaning: Oiled mussel beds on soft sediment with reservoirs of oil underlying need to be cleaned. Manual efforts are not sufficient, and more intrusive technology needs to be used. Manual efforts can remove mussels for culture and depuration and for the replanting of the beds when the cleaning is completed.

Ecological vs. species damage assessment should the research plan have been different?

The research plan was slow to evolve and deficient. The initial efforts failed to recognize the probability of long-term retention of oil and the significance the retention may have on vertebrates. Efforts to look at these issues began long after the spill, when contamination loads were declining in intensity within a bed and in number of beds contaminated. Even today, we do not know if we have examined all of the probable mussel beds on soft sediment that could have been contaminated. The SCAT surveys were looking for oil, but at that time did not know the significance that mussel beds on soft sediment might have, and therefore did not give them the scrutiny they deserved.

Future research plans would need to follow the oil loads from the beginning, presumably in concert with a higher level of cleaning activity and with a higher commitment to understand the linkage of mussel beds to vertebrate predators. This linkage issue has received some attention in recent years (NVP), but the initial focus was on the forage base in numbers, not from an oil load perspective. Hence, the linkages between oiled mussel beds and predators were not the focus. This issue may be even more critical in the winter, when food sources are restricted, and mussels and fauna in mussel beds may increase in forage base importance. Even now, the role of mussel beds as a forage base in non-summer months is poorly understood, and the links in the food chain are poorly documented and poorly quantified.

Recent studies examined whether the availability of prey such as mussels was limiting the recovery of vertebrate predators in the oiled areas of Prince William Sound. These mussel studies were a component of an ecosystem study integrating studies on prey with their higher trophic level predators such as otters and birds. This study was selected through an ecosystem level approach to restoration that assembled researchers on habitat, prey, and predators. It is still too early to judge whether the mussel portion of this Nearshore Vertebrate Predator study was useful, but an ecosystems approach has a high probability of finding linkages to help assess damage – even if some single component was not a factor.

Relevance to other spills?

The mussel bed niche in the upper intertidal zone is present in many parts of the world, even if the species differs. The issues of oil retention underlying mussel beds and the issue of bioavailability of oil to other fauna and predators will be of concern in other spills.

Tracking oil exposure must be done immediately following the spill-and ahead of the leading edge. If at all practical, tissue and sediment hydrocarbons from mussel beds should be collected. This should probably be the first order of business in any injury/restoration response team if these habitats are present. Caged mussels should also be deployed throughout the spill area to determine the bioavailability of the oil via the water column. Early orders of business should include mapping mussel beds, with special attention to those beds on soft sediments. For restoration, it is important to establish baseline hydrocarbon concentrations, population estimates, and bed parameters. Shortly after the spill has coated the beaches, it is important to identify affected areas and the degree of oiling with both bed surveys and chemical sampling. These are likely to be the highest levels of contamination and can give the degree of restoration when compared with baseline and subsequent samples.

Studies of linkages to other predators may be initiated depending on the significance of these habitats in the spill area. Again, it is the long-term impacts of a spill that is a concern if these habitats are contaminated, and the following questions must be investigated: what species are foraging in this habitat, when and how much?

Significance of long term mussel impacts to future decisions?

AFTER the first year of the spill, the highest oil concentrations in sediments and in fauna came from oiled mussel beds. The most important vector of oil into higher vertebrates is probably the oiled mussel beds if they are not cleaned. Evidence shows that this could project out to 30 years or more. We do not fully understand the ecological significance of these habitats, particularly in winter, but the persistence of oil in these habitats dictates that we should not be as casual in the next spill with the decision not to clean mussel beds and that we should not underestimate their ecological significance.

White Paper on Lessons Learned: Evaluating *Exxon Valdez* Oil Spill Science Programs for Harlequin Ducks

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Hindsight is always twenty-twenty.
--Billy Wilder

INTRODUCTION

The purpose of this white paper is to review and evaluate the scientific data collections used to assess damages to sea ducks from the *Exxon Valdez* Oil Spill (EVOS) and make recommendations for future damage assessment and restoration work. Specifically this paper focuses on the series of projects that were conducted to study injury to harlequin ducks *(Histrionicus histrionicus),* monitor their status in relation to restoration goals, and develop restoration strategies.

Although this paper is not intended to address factors that broadly affected most EVOS science projects, it is important to recognize that data collection programs for any major oil spill are products of: (1) the size, nature, and dynamics of the particular spill; (2) the environment and conditions in the spill area; (3) the extent of available baseline on affected species, habitats and ecological processes; (4) the nature and effectiveness of the spill management regime; and (5) the legal, political and social influences on scientific planning and performance (see Piper 1993). Consequently, we primarily address specific aspects of sea duck science projects, but also include illustrations of external factors that sometimes had major effects on the objectives, direction and products of these efforts. We have tried to include all projects that assessed damage or recovery of harlequin ducks whether specifically or as part of a broader suite of marine birds.

SUMMARY OF HARLEQUIN DUCK DATA COLLECTION PROJECTS

Briefly describe the harlequin duck data collection/studies that were done for EVOS.

Harlequin duck studies are divided into damage assessment and restoration projects. Natural Resource Damage Assessment (NRDA) studies began soon after the grounding of the *Exxon Valdez* in 1989 and some damage assessment studies continued through 1993. Restoration projects began in 1992. Harlequin duck damage assessment and restoration studies were conducted primarily by the Alaska Department of Fish and Game and agencies within the U.S. Department of the Interior.

Natural Resource Damage Assessment Studies:

ADF&G

Bird Study No. 11 - Sea duck damage assessment. (Patten et al. 2000a)

NRDA Bird Study 11 was one of the initial resource projects approved after the oil spill. The goal of this project was to determine whether the *Exxon Valdez* Oil Spill had measurable sublethal effects on six species of sea ducks breeding and wintering in Prince William Sound (PWS) and the Kodiak Archipelago, Alaska. To investigate and quantify sublethal effects to sea ducks in the spill area, the study was composed of several components: (1) investigate sea duck food habits; (2) document exposure of sea ducks to oil; (3) determine the sublethal effects of oil exposure; and (4) monitor reproduction of harlequin ducks.

Start-up funding was not made available until September of 1989, six months after the spill. This delayed the beginning of fieldwork and prevented the collection of specimens exposed to oil immediately after the spill. A total of 231 sea ducks of six species were collected for food habits and contaminant samples in 1989-1990. The collection of sea ducks was suspended by USFWS in fall 1990. In 1991, this study became progressively more focused on harlequin duck distribution, abundance, and productivity. Shoreline surveys to assess population trends and productivity, mist-netting on streams to assess breeding potential and compilation of records on oiled habitats intensified. During 1991 and 1992, Bird Study 11 activities in western Prince William Sound (PWS) were conducted in tandem with Restoration Study 71 (see below) in eastern PWS to compare sea duck status in the oiled and unoiled areas of PWS.

This study suggested that harlequins suffered population-level effects through 1992 as indicated by reduced densities in early summer and declining molting populations in late-summer. The study also reported poor production of young and higher concentrations of hydrocarbon metabolites in bile samples. Oil spill effects and regional ecologies could not be separated to explain differences in abundance and productivity between oiled and unoiled areas.

Department of the Interior

Bird Study 1. Beached bird collections. (Wohl and Denlinger 1990).

Other studies and reviews of the dead bird collection and mortality estimates have been conducted (Piatt et al. 1990, Ecological Consulting 1991, Piatt and Ford 1996). A further review is outside the scope of this paper.

Bird Study 2. Marine bird surveys. (Klosiewski and Laing 1994).

The original purpose of this study was to determine population abundance of marine birds (including harlequin ducks) and sea otters, compare this information with prespill surveys (1972-1973 and 1984-1985), and assess damage to marine bird and sea otter populations from the oil spill. These NRDA surveys were conducted from 1989-1991. Injury to harlequin ducks was documented for summer populations in PWS through 1991. In 1993 this became Restoration Study 159 (see below).

Bird Study 2A. Aerial surveys. (Hotchkiss 1991).

The purpose of this survey was to document the relative abundance and seasonal distribution of marine birds (including harlequin ducks) and marine mammals along the shoreline of PWS and the Kenai Peninsula. Data were collected for comparison with PWS aerial survey data from 1971 and to monitor changes in the distribution and relative abundance of waterbirds between oiled and unoiled areas of PWS and the Kenai Peninsula. Aerial surveys were flown in March, April, May, July, and October 1989, and March, May, and October 1990. In 1989, attempts were made to correlate aerial surveys with boat surveys in the same area to develop visibility correction factors (corrections for species visibility bias). Because this was never completed data could not be analyzed for comparison with data from boat surveys.

Restoration Studies:

ADF&G

Project 93033 -Restoration monitoring. (Patten et al. 2000b)

This project, conducted during 1993, continued the research and monitoring begun in NRDA Bird Study 11. The 1993 monitoring program was composed of four tasks: (1) Collections - Harlequin ducks were collected in eastern and western PWS during spring to document evidence of oil exposure and impacts on reproductive physiology. (2) Trend surveys - As a result of indicated declines in molting birds in the oil spill area during 1991-1992, trend surveys focused on the numbers of post-breeding harlequin ducks in PWS. (3) Brood surveys - Because low production was observed in 1990-1992, this study conducted a harlequin duck brood survey in western PWS, and (4) Habitat assessment - An assessment of harlequin duck use and habitat conditions on Afognak Island was included in this study to support potential land acquisitions by the EVOS Trustee Council. This work is reported as two subprojects: 93033-1 includes survey tasks (items 2-4 above); 93033-2 includes duck collection and oil exposure tasks.

This study reported a decline in molting populations in oiled areas from 1991-1993 while populations in unoiled areas of PWS remained stable. Differences in survey timing and coverage among years may have biased the density index. The study concluded that molting harlequins were still being exposed to hydrocarbons by using oiled habitats. This study also reported a decline in productivity in oiled areas from 1991 to 1993 while numbers and densities of broods in unoiled areas remained relatively stable. The authors suggested that direct mortality of females, combined with sublethal effects of oil toxicity on reproductive physiology and survival might have caused low productivity and a decline of molting harlequin ducks in WPWS. However, the lack of prespill baseline data, and habitat differences between WPWS and EPWS, precluded differentiation among the effects of these variables versus exposure to oil.

Results of 1993 harlequin duck collections, food habits, and physiological studies (histopathology and blood chemistry) (Project 93033-2), were included in a contract report by Dr. D. Michael Fry, University of California-Davis. This was prepared under separate cover. The purpose of this study was to determine whether there were detectable physiological effects of continued direct exposure to residual petroleum in the intertidal habitats of Western Prince William Sound in 1993. Dr. Fry collected 41 harlequin ducks from oiled and unoiled areas of Prince William Sound. The author investigated the gross morphology and microanatomy of the reproductive systems of both males and females, measured levels of mixed function oxygenase enzyme in the livers, compared blood chemistry levels, and measured cytokine levels and acute phase proteins in birds from both areas. No conclusive evidence of physiological effects from oil exposure was detected.

As an adjunct task, analysis of tissues for P450 activity was performed by Dr. John Stegeman of Woods Hole Oceanographic Institute. His results indicated significantly more positive samples for oil exposure in harlequins from western PWS than in those from eastern PWS. However, no conclusions could be drawn about the source of oil, period of exposure or magnitude of physiological effects. Diet of harlequin ducks was similar to that described in other studies. Blue mussels were a substantial component of their diverse diet in spring, 1993.

Project R71. Breeding ecology. (Crowley and Patten 1996).

During the planning of oil spill restoration activities in 1990 it was apparent that basic information on the ecology of harlequin ducks was needed in order to design good restoration studies. Restoration Study 71 was initiated in 1991 (1991-1993) to describe breeding habitat and productivity of harlequin ducks in EPWS.

Harlequin ducks usually selected the largest anadromous salmon streams available for nesting. Volume discharge of breeding streams was the strongest variable distinguishing between streams used and not used by breeding harlequins. Ten nests of harlequins were located on southwest-facing, steeply sloped banks of first order tributaries near timberline elevations. Productivity of harlequin ducks in EPWS was low compared to results of limited studies in the western U.S. Results were reported for nest density, breeding propensity of adult females, average clutch size, duckling mortality, average brood size, recruitment and coastline densities of broods during 1991-1993.

Project/427. Recovery monitoring. (Rosenberg and Petrula 1998).
Restoration Project (RP) 94427 (Experimental Harlequin Duck Breeding Survey) was initiated in 1994 in response to declines in numbers and productivity reported in Bird Study 11. The objective of Restoration Study 427 was to determine whether harlequin duck population in WPWS was recovering from the effects of the oil spill. The study developed a survey design to evaluate population trends and differentiate harlequin ducks by age and sex to compare demographic characteristics of populations inhabiting oiled and unoiled areas in PWS.

Population structure, molt chronology, and number of broods were used to determine whether harlequin ducks in EPWS and WPWS exhibited similar demographic characteristics. Variation in population structure, trends, and productivity between locations would indicate dissimilar extrinsic influences affecting harlequin populations. Changes in demography can affect population growth rates and recovery. Restoration Projects 95427, 96427, and 97427 utilized methods derived from RP 94427.

Preferably, comparisons would be made between pre-and postspill populations of harlequin ducks in WPWS to determine recovery. However, few data on the population status of harlequin ducks existed prior to the spill. Consequently, accurate comparisons with post-spill populations could not be made so demographic characteristics of harlequin ducks utilizing areas not affected by the oil spill in eastern Prince William Sound (EPWS) were compared with harlequin ducks in WPWS.

No major differences in population structure between EPWS and WPWS were detected. This suggested similar breeding propensity, recruitment, breeding success, and survival rates. However, a significant decrease in the number of harlequin ducks occurred in WPWS, while no significant change was observed for EPWS. Therefore, the study concluded that harlequin duck populations in oiled areas of WPWS have the potential to recover from the effects of the EVOS, but numbers are still declining and recovery has not occurred. Suitable breeding habitat limits breeding activity in PWS, and breeding habitat in EPWS is more favorable than that in WPWS.

Department of the Interior
Project/159. Marine bird surveys (Formerly Bird Study 2). (Agler et al. 1994, Agler et al. 1995, Agler and Kendall 1997, Lance et al. 1999).
The purpose of this study was to monitor marine birds (including harlequin ducks) and sea otter populations of PWS following the oil spill to determine whether species affected by the oil spill were recovering. Primary objectives included estimating abundance of marine bird and sea otter populations during March and July and combining these with previous estimates to ascertain population trends. Boat surveys were conducted along shoreline and offshore transects in oiled and unoiled areas of PWS. Conclusions, regarding the recovery of harlequin ducks are equivocal. In general it appeared that harlequin ducks have not recovered although some evidence indicates that recovery may be underway. This survey was most recently conducted in

1998.

Project/025. Nearshore Vertebrate Predator project. (Holland-Bartels et al. 1999)
The objective of the Nearshore Vertebrate Predator project (NVP) was to determine the recovery status of nearshore vertebrate predators by:

1. Determining if there are differences between oiled and unoiled areas in abundance, demographic characteristics, measures of health, and abundance or size distribution of prey,
2. Determine if recovery is constrained by demographic factors unrelated to oil toxicity or food,
3. Determine if recovery is constrained by oil toxicity, and,
4. Determine if recovery is constrained by food availability.

The Nearshore Vertebrate Predator Study (NVP) focused on the status of system recovery using a suite of apex predators - sea otter, harlequin duck, pigeon guillemot, and river otter. The NVP project assessed each of the most likely parameters limiting recovery (intrinsic demography, continued hydrocarbon exposure, and lack of food). A variety of measurements were used to assess health and continued oil exposure. This provided an assessment of the recovery of injured resources that was independent of measures of recovery based on population abundance or demographic data. It also allowed for an assessment of the factors limiting recovery and therefore could predict the potential for recovery.

Each parameter was assessed for each nearshore predator to form a matrix that could be used to assess ecosystem health. Population density and demographics were measured at oiled and unoiled sites. Health of animals, biomarkers of oil exposure, and prey availability were also examined to try and determine if oil or food was limiting recovery. Only river otters were classified as recovered. For harlequin ducks adult female survival during winter was significantly lower in oiled areas, site fidelity to molting and wintering areas was very high, and birds in oiled areas had significantly higher levels of Cytochrome P450, an indicator of recent exposure to hydrocarbons.

Project/161. Population genetics. (Goatcher et al. 1998).
This two-year study was initiated in 1996 to study harlequin duck demography in the spill area and help understand movements and genetic interchange among harlequin duck populations. If genetically distinct populations occur within the spill area then recovery may be prolonged due to low or no immigration. Genetic markers, which differed in mode of inheritance, were used to evaluate the degree of genetic differentiation among wintering areas within PWS, Katmai National Park, and Kodiak National Wildlife Refuge. Birds were also marked with colored leg bands as a means to detect population interchange. Genetic samples also were collected throughout the species range in North America to provide a broader picture of population structuring.

Results suggested no population structuring among wintering locations within the spill area or much of the Pacific Coast. This suggests that male and female movement and gene flow occurs (or has occurred historically) at a sufficient level among populations and regions to homogenize allele and haplotype frequencies. As life history characteristics suggest reproductively isolated populations, then either insufficient time has elapsed for genetic differences to evolve, episodic dispersal may occur as a result of cataclysmic events, or a low level of adult or juvenile movement may occur. The latter appears the most likely explanation for this panmictic population. However, it is unknown if sufficient movement occurs to facilitate recovery assuming no continuing effects from oil exposure.

DEVELOPMENT OF EVOS HARLEQUIN DUCK PROJECTS 1989-1999

How were EVOS injury assessment data collection/studies selected for harlequin ducks?

Initial Response

Immediately upon news of the *Exxon Valdez* spill, waterbirds and marine mammals were recognized as resources at high risk. When the Alaska Department of Fish and Game (ADF&G) put the first wildlife crew into the field on March 25, 1989, the primary task was to assess the number of species and animals directly threatened by spreading crude oil. Skiff and helicopter reconnaissance surveys documented the presence of numerous sea ducks (scoters, harlequins, and goldeneyes) near Bligh Reef, as well as areas "downstream" of the spill, and recovered the first dead ducks. A system was established to compile numbers, locations, and oiling condition of wildlife observed opportunistically by all field staff. These records provided the first on-scene assessments of species at risk and their relative abundance.

Two factors largely influenced the direction of scientific data collection on sea ducks immediately after the spill: (1) lack of interagency science coordination and (2) directives to meet legal requirements for proving damages. Although interagency coordination was accomplished sporadically during the first week of the spill, comprehensive planning was preempted by poor access to the spill site, organizational chaos and unilaterally reactive actions by a multitude of agencies. These conditions resulted in long delays in deployment of personnel to the field and lack of unified plans to objectively measure mortalities. Ultimately, the opportunity to estimate the total number of dead sea ducks was lost.

Ironically, the state Attorney General's office and the U.S. Department of Justice immediately directed the wildlife agencies to secure carcasses as evidence and focus on estimates of wildlife deaths for the inevitable lawsuits over damages. Their legal strategies largely were derived from CERCLA, the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (42 USC 9601) and its regulations (43 CFR Part 11) in place at the time of the spill. In layman's terms, CERCLA rules specified that damages for wildlife losses would be determined largely on the basis of the number of dead animals, proof of damage had to follow specific protocols, and damage compensation was calculated on predetermined monetary values of resources. Thus, state and federal legal objectives focused initial science efforts on body counts (see Future Response for science needs under new rules for damage assessment). For a long time, this emphasis on proving losses took precedence over investigations of ecological relationships and life histories needed to assess long-term impacts and restoration.

Damage Assessment Planning

During April of 1989, a series of meetings was convened among government agencies to plan comprehensive damage assessments and coordination functions. These early meetings can be fairly characterized as exclusive among only state and federal agencies, and following traditional divisions of responsibilities along lines of statutory authorities. In the case of migratory bird studies, where U.S. Fish and Wildlife Service (USFWS) and shared interests, the Service was acknowledged as the lead agency, with authority to direct and approve projects, as well as control funding for bird work. The primary outcome of these meetings was to establish that ADF&G would conduct studies on sea ducks, while USFWS initiated studies on seabirds, shorebirds, raptors, and passerines. The involvement of the University of Alaska-Fairbanks and other academic institutions with expertise in marine birds was conspicuously absent.

Continuing the tone of anticipated litigation needs, the program of damage assessment studies that emerged was focused heavily on documenting bird mortalities, proving exposure to EVOS crude oil, and estimating indirect and sublethal impacts on bird populations. Bird Study 11 was designed to quantify oil exposure and potential lethality to a suite of sea duck species, as well as document numbers of harlequin ducks in the spill region. Collection of sea ducks for hydrocarbon exposure did not begin until September 1989 when USFWS released funding for the study, and was terminated by USFWS in fall of 1990 over concerns about public opinion. The delay in start-up and withdrawal of authorization to collect ducks severely compromised the prospects of documenting oil exposure in sea ducks.

The search for the "smoking gun" (evidence of exposure to EVOS crude) in harlequin ducks was resumed in 1993 when it appeared that harlequin duck production remained very low in western PWS. A study employing analyses of blood chemistry, histology of reproductive tissues, and P450 induction was conducted in spring of 1993, but no compelling evidence of oil damage was produced.

Monitoring and Restoration Planning.
During 1990, it became apparent that determining abundance of harlequin ducks throughout Prince William Sound (PWS) would be difficult, as would obtaining population indices rigorous enough to accurately detect trends in decline or recovery. Survey data indicated that numbers and densities of harlequin ducks were lower in the spill region of PWS than in eastern PWS, but there were no reliable prespill for comparison. Furthermore, there was no evidence that these disparities were caused by the spill rather than regional ecological differences. In addition, the number, sex and age, and distribution of harlequin ducks in PWS varied significantly by season.

The EVOS Restoration Program decided to support a multi-year monitoring effort to improve understanding of seasonal population dynamics, put this in context with the estimated oil spill mortality in spring 1989, and aid in establishment of population restoration objectives. Monitoring surveys during 1990 -1993 were needed to confirm further declines in harlequin ducks using western PWS and to document an apparent continued lack of production in western PWS. Survey projects from 1994 through 1998 were designed to correct inadequacies in prior survey techniques and more effectively monitor the status of breeding and molting harlequin ducks.

The lack of basic information on life history, habitat requirements, and productivity of harlequin ducks in PWS significantly hampered efforts to interpret population data in terms of spill effects and to develop effective restoration strategies. This led to the implementation of Restoration Study 71. For harlequin ducks as an injured resource, no viable means has been found to directly enhance the population or to significantly reduce mortality rates whether the result of natural or oil-induced causes. Consequently, restoration efforts have focused on monitoring recovery and acquisition and protection of breeding streams and coastal post-breeding habitats.

With restoration efforts becoming more focused on an ecosystem approach, the Nearshore Vertebrate Predator Project was implemented in 1995. Although not directly part of this project, Project/427 played an integral role because it assessed population trends in harlequin ducks throughout a much broader area of oiled and unoiled habitats in PWS.

<u>EVALUATION OF EVOS HARLEQUIN WORK</u>

Please describe which EVOS harlequin duck injury data collection/studies were useful and why. Describe which EVOS harlequin duck injury data collection/studies, if any, did <u>not</u> prove to be useful and why.

Prior to the oil spill we had little specific information on harlequin duck biology and population status in Prince William Sound. This lack of information made it extremely difficult to design a research and monitoring program that could determine the damage and recovery status of harlequin duck populations. It clearly pointed out the need to have good baseline information on numbers, distribution, seasonal movements, and a variety of life history events. Lessons were learned as much from our failures as our successes.

To characterize the work as useful or not useful is to ignore the utility of "learning from experience" especially in light of the lack of knowledge on harlequin duck life history and ecology at the time of the spill. While much of the work may not have provided useful information to directly assess damage or recovery, it often provided the basis for the next set of studies. Thus, the most useful EVOS studies were the latter ones.

Natural Resource Damage Assessment:
ADF&G
Bird Study 11. Sea duck damage assessment.
Bird Study 11, as the principal damage assessment study for sea ducks, produced a mixture of success and failure in meeting scientific objectives in three main areas: (1) documenting exposure of sea ducks to EVOS oil and pathways of impact; (2) evaluating potential adverse effects on physiology and body condition; and (3) assessing the post-spill population status and production of harlequin ducks in PWS.

This study produced very little conclusive evidence of widespread oil ingestion by six species of sea ducks, including harlequins.

- ↓ Start-up was not authorized by USFWS until 5-1/2 months after the spill. By mid-September 1989, only low densities of ducks remained in the spill region for sampling and the probability of collecting ducks with ingested oil was low. The opportunity to document indirect and sublethal effects was effectively lost. Of 231 ducks collected, only 5 ducks were found with ingested Exxon Valdez crude oil (EVO).

- ↓ Authorization to collect sea ducks was withdrawn by USFWS in fall of 1990. This limited sample sizes of sea ducks and precluded more detailed analyses of foods and tissues.

- ↓ Joint NRDA projects for hydrocarbon analysis did not process many samples from Bird Study 11.

- ↓ Analysis of liver tissue samples from 50 ducks did not document exposure to EVO; very few samples contained hydrocarbons, and levels were predominately below detection limits. Elevated concentrations of polyaromatic hydrocarbons (PAH) were found in a majority of bile samples from harlequin ducks (74%) and goldeneyes (88%) collected in the spill region. Neither liver nor bile samples served as proof of exposure to EVO because concentrations were too low, did not match expected signatures of EVO, and there was no previous scientific information on transformation of crude oil into metabolites in sea ducks. Under these circumstances, widespread detection of PAH in bile samples was considered only circumstantial.
- ↑ Collections of sea ducks confirmed and strengthened information on food habits of sea duck species and their foods in PWS during winter.

This study produced no conclusive evidence of histological or physiological impacts of EVOS oil on sea ducks.

- ↓ Histological examination of any array of tissues from 202 ducks did not produce any signs of tissue damage that could be linked to EVOS (birds collected 5-20 months after the spill).

- ↓ An attempt to index body condition by rating fat deposits was negated by a fatally flawed design. Fat index scoring was not standardized among observers, and there was no way to control for substantial regional differences between oiled and unoiled study areas.

During 1989-1992, Bird Study 11 produced a substantial amount of information on the abundance and distribution of harlequin ducks in eastern and western PWS, including the prevalence of broods. However, several factors limited the utility of this information in demonstrating that declines in harlequins and low production in western PWS were direct results of EVOS.

- ↓ There were no reliable prespill estimates of the number of harlequin ducks in PWS during any season.
- ↓ Although there were apparently lower numbers of breeding ducks and very few broods in the oiled region of PWS compared to eastern PWS, it was not possible to determine whether these differences are attributable to EVOS mortality, displacement from EVOS or regional ecological differences.
- ↓ Spring and fall surveys of the very large study areas were so protracted that final population estimates may have been biased by immigration, emigration or "roll-up" movements within survey areas.
- ↓ There is reason to believe that historical records of broods and some brood observations made during EVOS studies may have been groups of post-breeding birds rather than young of the year. By late August and September juveniles are very difficult to distinguish from subadults.
- ↑ Bird Study 11 skill surveys, despite their flaws, provided the first extensive record of harlequin duck numbers and distribution in PWS. These surveys documented seasonal changes in composition, distribution, and habitat associations, and the chronology of brood rearing and fledging. The surveys documented a seasonal aggregation of molting harlequin ducks from July through early September.
- ↑ Innovative methods were developed for monitoring use of streams by harlequin breeding pairs, capturing birds by mist nets, and following breeding adults with radio telemetry. This is the first project anywhere to mark and track breeding females to nest sites to determine habitat needs, breeding success and brood movements.

Department of the Interior

Bird Study 2. Population monitoring.

- ↑ Bird Study 2 pointed out the need for more long-term monitoring and the difficulties of applying a multi-species survey of PWS to assess the damage and recovery for a single species such as harlequin ducks.

- ↓ Although Bird Study 2 detected a difference in harlequin duck trends in oiled and unoiled areas, it lacked statistical power.

In 1998, ADF&G compared the harlequin duck survey techniques utilized in Bird Study 2 with those from Restoration Project/427 in order to determine the best method to assess recovery, and clarify some of the uncertainty surrounding the status of harlequin ducks in PWS (Rosenberg and Petrula 1998).

We believe the disparity in results between ADF&G and the USFWS survey data are related to the following: (1) Differences in the allocation of survey effort among oiled and unoiled areas and (2) The failure of randomly selected transects, used by multi-species surveys, to incorporate high-density areas for species that exhibit a patchy (rather than uniform) distribution. This was especially true in oiled areas.

Thus, the number of harlequin ducks sampled by the USFWS in oiled areas of WPWS was insufficient to predict population trends. A species-specific survey conducted in higher density areas over consecutive years is more likely to generate meaningful trend data for this species. Bird Study 2 has sufficient transects to detect changes in harlequin duck in PWS. However, once divided between two regions, the oiled area lacked enough transects to adequately sample harlequin ducks. Therefore, Bird Study 2 lacked sufficient power to detect population changes in the oiled area.

Bird Study 2A. Aerial surveys.

- ↓ Information from Bird Study 2A was not utilized in damage assessment studies because it lacked visibility correction factors.

No comparable boat surveys (Air/ground comparison segments), designed for the purpose of developing Visibility Correction Factors for the aerial survey were conducted. Therefore, the data could not be corrected, species by species, to develop population indices that could be compared with 1972-73 surveys or 1984-85 boat surveys.

Restoration Projects:
ADF&G

Restoration Project 71. Breeding ecology.
Restoration Study 71 encompassed two general groups of objectives in eastern PWS: (1) to locate and describe streams used by coastal breeding harlequin ducks to document habitat requirements and evaluate habitat restoration concepts; and (2) to study population biology to determine factors in breeding effort and production.

- ↑ Productive breeding streams in eastern PWS were thoroughly described, and their characteristics were modeled for evaluation of streams in other regions.
- ↑ Habitat parameters determined in R71 provided a basis for protection of harlequin duck habitat within PWS through land acquisition, conservation easements, and forestry practices that promoted conservation. Habitat protection was the primary avenue of restoration for harlequin ducks.
- ↓ R71 did not include extensive studies of streams in western PWS, but led to realization that there were substantial differences in stream morophology between oiled and unoiled regions. Regional ecological differences reduced the fit of eastern stream models to western streams and reduced confidence in the value of habitat restoration projects in western PWS.
- ↑ Capture and radiotracking techniques developed during R71 provided the first study of seasonal breeding pair activity and nest site selection for this species. This set the stage for further studies and consideration of nesting habitat in restoration planning.
- ↑ Nesting and post-nesting studies provided the first integrated documentation of clutch sizes, brood sizes, and brood survival to fledging. Such data gave the first impressions of natural factors affecting annual productivity of harlequin ducks.

- ↓ Regional differences in harlequin breeding habitat and population structures were sufficiently different between eastern and western PWS that assumptions could not be made about “normal” productivity in the EVOS region.
- ↓ R71 was limited to study harlequin duck breeding parameters within PWS where only a small percentage of the population nests.

Project M93. Restoration monitoring.
The 1993 monitoring project had three very different components: (1) search for evidence of continued exposure of harlequin ducks to EVOS oil and impairment of reproductive physiology; (2) extension of post-breeding surveys of harlequin ducks to evaluate an apparent decline in molting ducks and continued low production in western PWS; and (3) evaluation of breeding streams and habitat use patterns on northern Afognak Island.

- ↓ Collection and comparative analysis of harlequins from eastern and western PWS, four years after the spill, found no conclusive evidence of exposure to EVOS or impairment of reproductive functions, based on histology of reproductive tracts and other organs, blood chemistry, or other physiological indicators. P450 induction suggested that more harlequins in western PWS had been exposed to oil than in eastern PWS, but without a direct link to EVOS. In 1993, the lack of laboratory studies on the fate and effects of oil in sea ducks hindered interpretation of results, and analytical techniques were simpler than those now available.
- → The 1993 boat surveys in PWS helped document a multi-year decline in the number of harlequins that molted in western PWS. However, design problems with these protracted surveys affected confidence in the results. It was difficult to relate changes in molting aggregations to impacts on a specific population, and by 1993 these data were not applied to damage assessment. The boat surveys extended documentation of continued use of oiled habitats by harlequin ducks.
- ↓ Low brood production in western PWS in 1993 remained unattributable to EVOS. A hypothesis that breeding habitats in western PWS were naturally poorer than those in eastern PWS became an increasingly viable alternative explanation.
- ↑ Surveys of stream use by breeding harlequin pairs and use of coastal habitats on northern Afognak Island successfully characterized the value of this region to harlequin ducks. These surveys provided information to evaluate potential land acquisitions for the restoration program. Assessments of habitat on Afognak effectively applied survey techniques developed since 1989 and information from Restoration Study 71 on the characteristics of good breeding streams.

Project/427. Recovery monitoring.

- ↑ This project examined population structure and trends adding a critical dimension lacking in previous studies and successfully addressed the question of the recovery status of harlequin ducks. Sampling was stratified spatially and temporally, which reduced the variation inherent in previous surveys (Bird Study 11) and used replicate sampling to detect seasonal changes and increase the power to detect trends.
- ↑ This project was the first to use sex and age criteria to compare population structure between oiled and unoiled areas and quantify seasonal changes in population structure.
- ↑ Project/427 developed sex and age criteria for identifying harlequin ducks in field studies.
- ↑ The feasibility of conducting a winter survey was tested and confirmed.

↑ A new hypothesis was developed for explaining low productivity in western PWS by reexamining historical data and life history aspects of harlequin ducks.

↓ Regional habitat differences in oiled and unoiled areas that may account for independent variation in population status and mechanisms of impact/recovery were not assessed.

↑ Data from this and the NVP project, when presented in concert, supported and augmented separate evidence of a lack of recovery in harlequin ducks.

Department of the Interior
Project/159. Marine bird surveys.
(See Bird Study No. 2 above).

Project/025. Nearshore Vertebrate Predator project.

↑ This project addressed the status of recovery and mechanisms that impeded recovery. The NVP project took a multi-species systems based approach to try and understand the mechanisms that impeded the recovery process and correlated similar conditions among several species.

↑ This project took a "top down" approach, focusing on the higher trophic level predators.

↑ Valuable information was gathered on the biology and life history of harlequin ducks including molt and winter site-fidelity, female survival rates, body condition, and CYP1A exposure rates.

↑ Field techniques were improved or developed for capturing ducks, bioassays of oil exposure, and radio telemetry implants.

↑ The project addressed the hypothesis that a lack of food may be limiting recovery of harlequin ducks, as well as oil, or demographics.

→ A lack of food hypothesis was addressed, understandably so, by examining the abundance of a few prey items and comparing results between oiled and unoiled areas. The abundance of prey in various size classes, and the presence of co-predators also affects food availability and because harlequin ducks exhibit eclectric food habits that may vary with season and location, the abundance of a few prey species may not accurately assess food availability or nutritional requirements. Some of the difficulty in interpreting this work results from a lack of knowledge on food needs by species and size class, seasonal changes, the effects of co-predators. Prey studies were done in oiled areas with low densities of harlequin ducks and may not have reflected preferred habitats.

→ CYP1A expression may be induced by very low levels of hydrocarbons and may not be indicative of behavioral or physiological problems. Dosing studies are planned that will generate a dose-response curve to translate. CYP1A values to oil ingestion and behavioral differences.

→ Blood panels – Blood panels did not indicate health differences in harlequin ducks between oiled and unoiled areas, although there were clear differences in overwinter survival between areas. Body condition influences survival and reproduction and in turn is influenced by contaminant exposure. Collecting blood samples and assessing body condition during the molt may not be indicative of health problems in winter. Animals that migrate from an area for periods of one to four months may not immediately exhibit health problems associated with the wintering area soon after they return.

➔ Blood panels that reflected acute health problems immediately after the spill may not reflect low-level chronic health problems several years after the spill or acute responses of short duration. Implement to develop a blood assay for oil exposure and chronic health effects.

Project/161. Population genetics.

🡅 This study provided good information on harlequin duck genetics that will help interpret other findings. Options for restoring a population of birds, especially sea ducks, are limited. Therefore, the restoration program focused on assessing the status of this species and protecting habitat. Recovery could theoretically occur through two avenues, immigration and local production. The rate of recovery would be most rapid if both occurred.

🡅 This study suggested that male and female movement and gene flow occurs (or has occurred historically) at a sufficient level among populations and regions to homogenize allele and haplotype frequencies. Thus, we would expect some immigration to contribute to recovery.

➔ We do not know the relative rate or avenue (by sex and age) of immigration. If the majority of the influx was composed of sub-adult males, we may detect an increase in total numbers without a corresponding increase in production, as the numbers of females ultimately limit population growth.

➔ It also tells us that if we wanted to artificially increase the rate of recovery by capturing birds in an area of greater abundance and moving them to an area of lesser abundance we would not be introducing different genotypes. However, we would first have to identify and eliminate the original cause of the population decline. We also don't know if the forced immigrants would remain in their new environment or return to the point of capture as harlequin ducks exhibit strong fidelity to nesting and molting areas.

Were there any harlequin duck studies/data collection activities initiated/completed following the 1989 EVOS that you would <u>not</u> recommend initiating in a future spill? If so, please explain.

In hindsight, were there harlequin duck data collection/studies that should have been conducted? If yes, please describe them and discuss why they should have been conducted.

All of the EVOS harlequin duck projects were appropriate to the information needs at the time they were planned. Goals and objects, by necessity, were adapted to the extensive science needs of the Trustees for both damage assessment and restoration, the lack of baseline population data and life history information on the species, and the legal, fiscal and logistic constraints of the EVOS program. An adaptive approach ensured that subsequent projects were refocused on priority questions as new information emerged.

The greatest biological problem in identifying the effects of the EVOS was our lack of basic knowledge on harlequin duck life history, ecology, distribution, and abundance. Poor knowledge of harlequin duck life history at the time of the spill made it difficult to design effective damage assessment and monitoring programs. Scant baseline data on population size made assigning injury and recovery, based on pre- and postspill comparisons, tenuous because of a low sample size, high annual variability, and data that were collected many years before the spill. Poor understanding of regional differences within PWS confounded interpretations of differences between oiled and unoiled areas. A lack of knowledge on the fate of oiled carcasses compromised damage assessment studies. This lack of information led in part, to faulty survey designs and poor interpretation of results during the early damage assessment and recovery studies.

Establishing the occurrence of injury and recovery depends on knowledge of the status of the resource immediately prior to the spill and the ability to accurately measure changes. It also requires an understanding of inter-annual variability – the normal variation between years during periods of little perturbations in the larger physical system. Our ability to detect departures from natural variation is necessary if we are to accurately evaluate the effects of major environmental perturbations, natural or man-caused.

While detecting departures from normal variation will allow us to determine damage and assess recovery, it will not explain the mechanisms for these processes. Long-term data sets on demographics, food, and habitat preference, prey abundance, changes in physical and chemical parameters, and zones of human influence are all important in understanding the mechanisms of population change. Without time-series data on harlequin duck abundance and abiotic and biotic ecosystem changes, we lack the ability to interpret the affects of natural processes. Initial monitoring efforts will depend on our knowledge of a species in a given area prior to a spill.

Detecting population change requires numerous samples, distributed through time, preferably focusing on long-lived species that tend to show less natural variability. We need to design species-specific methodologies to account for unique life histories and evaluate whether these studies can be effectively coordinated with those of other species in the ecosystem. The physical and chemical parameters being measured need to be standardized and be pertinent to the life history of the species in question. In many cases, additional research will be required to determine the most appropriate variables to measure.

In addition we also lacked baseline data and methodologies to assess the health of wild animals. Baseline data on the levels and variation in CYPIA harlequin ducks will allow better assessment of exposure and help identify links between oil exposure, productivity and survival. Prespill baseline data on levels of PAHs in the water column, sediments, and food of nearshore predators will help evaluate the health of the ecosystem and the status of recovery.

Greater emphasis is needed on the identification of breeding origins and nesting habitat of harlequins that use PWS. Many variables affect successful recruitment and ultimately population growth rates. With migratory species, this may be related to conditions at breeding sites rather than wintering or molting sites. In order to understand the extent of injury and the ability to recover, we need to know affiliations between wintering, molting, and breeding areas. Perpetuation of breeding habitat, wherever it may be, is critical to maintaining wintering populations in PWS. Much effort was focused on identifying productivity in PWS and using this information to determine injury and recovery. However, it appears that PWS contributes little to harlequin duck productivity. More effort needed to be expended to identify where PWS harlequin ducks breed in order to quantify the effects of an oil spill on productivity and help guide restoration (land acquisition and protection programs). Telemetry studies are a first step towards identifying breeding areas.

Collecting live birds for food habits and contaminant analysis may be unnecessary or should be minimized in future spills. Collecting birds is additive to existing injury and further impedes recovery especially if females are killed. Liver biopsies and blood assays can be employed on live birds to determine hydrocarbon exposure and subsequent health effects.

For aerial surveys to be effective in the nearshore environment, species visibility correction factors need to be established. If large sections of coastline are to be surveyed in front of an advancing spill, aerial surveys may be the only practical method to quickly assess the prespill status of populations. Harlequin ducks are particularly difficult to detect from the air, and tested visibility correction factors are needed to provide accurate estimates of abundance.

Pre- and postnesting movements of harlequin ducks within and through PWS will provide useful information for damage assessment should a spill occur in spring or fall.

Food habits may vary seasonally and inter-annually depending upon availability of food (size and type). To fully understand if recovery is limited by food availability, more information needs to be obtained on seasonal diets and foraging habits of harlequin ducks.

Internal radio transmitters were placed in almost 300 female harlequin ducks. More information on the long-term effects of internal transmitters on reproductive success and survival would help guide future research and assessment of recovery.

The role of immigration and emigration and its effects on population change is unknown. Immigration may be a factor in the rate of recovery but we have little information to support or refute this hypothesis. Telemetry and mark-recapture studies focusing on subadults will help address this question.

Development of methods to promptly and accurately determine the fate and recovery rate of oiled corpses will improve mortality estimates.

Were any of the harlequin duck data collection/study too costly based on the results (determination of damage or opportunity for restoration)?

In hindsight, it is easy to identify ways that work could have been done at lower costs. However, EVOS projects, like those for the next great spill, must be justified on the basis of (1) level of need for critical information; (2) level of information to start from; (3) adversities to be overcome in field operations; and (4) opportunities for cost-savings. In addition, it is important to recognize that most surveys and research are designed to study the unknown. The pay-off in evaluating damages, determining resource status or discovering means of restoration is unpredictable until considerable investment is made.

In the case of EVOS sea duck projects, harlequin ducks were a very vulnerable species that became a highly visible element of damage assessment surveys. There was little question that these birds needed to be counted, and that proof of oiling was an important element of the legal case for the NRDA process. The lack of baseline population data for PWS meant that surveys had to be more extensive, including eastern PWS. An absence of literature and previous work on oil ingestion in sea ducks required more in-depth field and laboratory work to determine appropriate evidence of contamination. Similarly, basic harlequin duck life history information needed to be investigated before interpretation could begin on observed productivity and importance of specific habitats.

In most projects, a large proportion of total costs were composed of salaries and basic transportation – costs that would be incurred regardless of scientific objectives. The PWS environment was, by nature, expensive to work in and to maintain science crews. The largest area of potential cost savings was the prospect of coordinated and shared field logistics – camps and lodging, fuel and supplies, boat and aircraft support. Although the concept was often and widely discussed, joint support functions were not developed and generally were not available to projects. Therefore, most budget requests contained separate expenses for each project and total costs were high.

VALUE OF AN ECOSYSTEM APPROACH TO EVOS HARLEQUIN DUCK WORK

Would you recommend taking an ecosystem-based approach to injury assessment and restoration? If so, please describe whether the data collection/studies identified above would need to be modified and why the modifications would be required.

The complexity of nearshore ecosystems prevents a pure systems approach as a practical matter. However, coordinating and integrating the study of several key species within the nearshore ecosystem is beneficial and pragmatic. Damage assessment and restoration need to be designed around the specific life history and habitat requirements of key indicator species, then integrated where appropriate. This was the approach of the NVP project and it, along with the ADF&G monitoring surveys, would be a good starting point for discussions of future work. Monitoring for changes in distribution and abundance is an important component of this type of investigation.

Please explain under what circumstances, if any, you think an ecosystem approach would not be appropriate.

An ecosystem approach may not be necessary for the initial damage assessment of individual high-profile resources or indicator species. Of course, this depends on the extent of our knowledge at the time of a spill.

FUTURE RESPONSIVENESS FOR HARLEQUIN DUCK WORK

Natural resource damage assessment methodologies for oil spills (under CERCLA for the EVOS spill) have been superceded by provisions of the Oil Pollution Act of 1990 (33 USC 2701) and regulations promulgated by NOAA in 1996 (15 CFR 990). Scientific data to meet litigation and damage assessment needs for future spills will be guided by these new rules.

The burden of proof of wildlife damages from oil under OPA 90 procedures has not changed much from the old CERCLA rules. Determinations of injury will require: (1) proof of exposure to the specific oil of the incident; (2) specification of an oil pathway from the incident to the injured resource; (3) demonstration that observed direct or indirect impacts on the resource are adverse; and (4) quantification of the scope and magnitude of effects. However, the new regulations permit greater latitude in methods used to quantify damages to resources and services. For example, modeling may be used to estimate exposure of animals to oil, and health effects can be documented from scientific literature and previously collected data. These provisions are intended to avoid redundant data collection programs for each spill, when appropriate.

Perhaps the most important science implications of the new NRDA rules under OPA 90 come from a more rapid approach to restoration. Injury assessment is designed to quantify the magnitude and scope of affected resources to facilitate planning of restoration alternatives. Appropriate restoration projects are developed earlier in the process, and monetary settlements are aimed at the total cost of restoration (including contingent valuation of resources and services). In order to respond to this new process, scientific data collection will need to be focused more rapidly on aspects of population dynamics, ecology, and species habitat requirements to provide effective restoration concepts. It will be important to have quick access to both available data on oil impacts to species and potentially feasible restoration techniques.

Modifications of previous studies will be based on the extent of our knowledge on these species and their habitats at the time of a spill and the latest techniques to monitor population change, assess oil exposure and health parameters. Good baseline data, preparedness, flexibility and "adaptive management" will be the key to success.

What harlequin duck data collection/studies would need to be initiated immediately following a spill (i.e., during the first 24 to 48 hours)? Please describe, in detail, what would be included in these efforts and explain why they are important.

The most glaring need is the development of an initial biological response plan that is reviewed and updated regularly. The plan must clearly identify the roles of each agency and, at a minimum, include objective methods for mortality assessment, tissue sampling protocols, and population monitoring of key indicator species.

What harlequin duck data, if any, would need to be collected immediately following a spill in areas that <u>will be</u> oiled, but have not yet been oiled? Please describe, in detail, what would be included in this effort and explain why it is important.

In areas that <u>will be</u> oiled, efforts should focus on the following in key core areas:

1. Record distribution, abundance, and age and sex data preferably by skiff surveys;

2. Capture birds to test for evidence of oil exposure (CYPIA) and collect blood samples prior to contact with the spill;

3. Mark birds with radio transmitters and metal leg bands in order to determine their movements, turnover rates, and fate;

4. Collect data on body weights in order to assess body condition immediately prior to a spill;

5. Employ remove video cameras at high-density areas to monitor the reaction of birds to oil;

6. Collect data on prespill hydrocarbon concentrations in the water column, intertidal sediments, invertebrates, and mussel beds and conduct intertidal surveys in key areas to document invertebrate abundance, species richness, and distribution;

7. Monitor the amount of additional human activity in these areas as a result of the spill and the effects it may have on numbers and distribution; and

8. Using objective and repeatable methods, record the number of carcasses on beaches prior to oiling for prespill conditions.

The above should be coordinated and integrated with other nearshore projects and be repeated at various time intervals after oil has reached these same sites.

What additional harlequin duck studies/data collection, if any, would need to be initiated following the first 24 to 48 hours after a spill? Please describe, in detail, what would be included in these efforts and explain why they are important.

Initially we need to focus on the approach of projects/425 Recovery monitoring and /025 Nearshore Vertebrate Predators. How we proceed will depend on the extent of baseline data available on life history, ecology, and population status at the time of the spill and the characteristics of the spill, and the time of year it occurs. The above mentioned prespill tasks should be repeated throughout the course of the spill.

Effective damage assessment will require prompt application of the best available sampling techniques (blood, biopsies) to demonstrate oil ingestion and contamination from the incident during the first 6 months. Otherwise, the course of sublethal and chronic expose cannot be determined.

POSSIBLE RESTORATION EFFORTS

As you know, the new NOAA NRDA regulations emphasize restoration endpoints rather than a determination of damages. With restoration in mind, would you suggest any modifications to the harlequin duck data collection/studies identified above? If so, please explain what would need to be modified and why.

What restoration activities could be successfully implemented for injured harlequin ducks?

Habitat protection appears to be the most important activity for protecting harlequin duck populations. This includes protecting habitat used in all phases of the life cycle - wintering, breeding, post-breeding, and molting. Unfortunately, we know very little about the affiliations between wintering and breeding areas. While EVOS land acquisitions protected molting and wintering areas, breeding habitat was protected for only a small proportion of locally breeding harlequins; most PWS ducks migrate to more distant river systems to nest, probably in interior Alaska and the Yukon. Disruption of normal nesting activities on these rivers and streams from disturbance or environmental damage could have a profound effect on wintering numbers in PWS.

The effectiveness of hazing operations in critical habitat areas could be further investigated, but the propensity of harlequin ducks to remain in specific areas is strong. If a spill occurred during the molt, plans could be developed to capture as many birds as possible and move them to safe molting areas in the hope they would not exceed the carrying capacity of those areas or attempt to return to the original site. No specific research has been done on this aspect of harlequin duck biology.

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White Paper on Lessons Learned: Evaluating Scientific Sampling of Oil Spill Effects on Murres

Draft White Paper

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Question 1: What murre data, if any, would need to be collected immediately following the spill in areas that will be oiled, but have not yet been oiled?

Data on presence or absence of concentrations of murres: Areas downstream of spills that are likely to be oiled should be surveyed immediately after the event for the presence or absence of concentrations of murres. How and where these surveys should be conducted will depend on the location, timing, and size of the spills, and the locations of nesting colonies and wintering areas in relation to them. For example, if spills occur during late September - early April in the Prince William Sound or Cook Inlet areas when murres are not attending colonies, aerial surveys should be flown ahead of the oil-fronts to determine if concentrations of birds are in their projected paths and at risk, and if so, the approximate numbers of individuals that are in the at-risk concentrations (e.g., 100's, 1,000's, 10,000's). These types of surveys are particularly relevant, if oil heads offshore toward the Gulf of Alaska and Cook Inlet shelf-breaks, or toward Shelikof Strait and the bays and inlets of the Kodiak archipelago (all known or suspected wintering areas). If events occur during late April - late May when murres are beginning to aggregate in large numbers on waters in the general vicinities of breeding colonies, or during late May -late June when large flocks of birds frequent waters adjacent to them, surveys should be flown around any colonies thought to be at risk to document the sizes and locations of at-risk prebreeding concentrations. If spills occur during June - early September when large numbers of murres, including breeders and younger prospecting subadults (birds that are about 3-6 years old), are attending colonies, most efforts should be directed toward collecting initial numbers, productivity, and nesting chronology data at colonies downstream of the spill (see below). If oil is expected to reach breeding colonies during mid-August - mid-September when large groups of flightless chicks and attending adult males are still at or near them, surveys should be flown around the colonies to document the sizes and locations of at-risk post-breeding concentrations.

To be effective, the survey should be made from aircraft, because large areas will need to be searched quickly (vessel-based surveys are too slow). The surveys should be conducted systematically by experienced aerial observers familiar with seabirds, and all methods should be well-documented. Also, to help ensure the effectiveness of the surveys, protocols for conducting them should be developed and included in spill-response plans before spills occur. Protocols should contain directions on how to use video cameras and Global Positioning Systems (GPS) linked to lap-top computers to document bird concentrations and locate them accurately.

Surveys to find at-sea concentrations of murres in the direct paths of spills soon after they occur will provide valuable information on the numbers of birds that are likely to be lost during the events. They will also provide information on where these losses are most likely to occur in relation to nesting locations and wintering areas. In certain cases, they will also help document whether losses are likely to be higher among some breeding populations and population segments than others (e.g., heavy losses of adult males and chicks in post-seagoing groups from specific colonies). In summary, collecting these data will provide better estimates of total murre mortality from spills, and better estimates of mortality in specific breeding populations in spill areas. These data will also help put information collected at nesting colonies after spills in perspective. For example, if surveys found large at-sea prebreeding aggregations or groups of adult males and chicks at or near a colony in the direct path of floating oil, this information would help researchers refine estimates of total impacts to the colony. It would also help researchers evaluate and analyze patterns in colony attendance that might become apparent during later restoration monitoring studies. For example, losses of chick cohorts at colonies may be reflected in population counts several years later, and the knowledge that large aggregations of sea-going chicks were in the direct path of the spill and probably lost, will help researchers interpret patterns that may become apparent in data sets collected during postspill restoration monitoring studies.

Data on population numbers, productivity, and nesting chronology of murres: If spills occur during June -early September, when murres are attending breeding colonies, and it has been determined that colonies are in danger of being oiled, response teams should be sent to the at-risk nesting locations to begin collecting data before the oil arrives. Several factors, including the size and anticipated extent of the spill, the speed at which the oil is spreading and its potential direction, colony sizes and their importance to regional populations, presence or absence of monitoring plots and historical data sets, quality and quantity of prespill information, and topographical features that may hinder data collection, should be used to prioritize the at-risk colonies and determine which ones should be visited first and receive the most attention. Several of these factors, including size, topography, and data histories, should be used to develop preliminary lists of high priority study sites for inclusion in regional response plans in anticipation of future spills (a task that could be assigned to regional murre response teams-see Question 2).

The most important types of data that should be collected at nesting colonies before oiling occurs are population numbers, productivity, and nesting chronology information (data types may vary from site-to-site, depending on topography and other factors – see below). These parameters provide the best chances for detecting and describing direct and indirect effects of spills. They are also the primary variables for measuring population recovery. The data should be collected by experienced personnel using standardized methods and protocols. If at-risk colonies already contain well-documented monitoring plots for collecting this information, data should be collected from these sampling units. If previously established monitoring plots are not present at study sites, these sampling units should be set as soon as possible after arrival using appropriate procedures and protocols. Researchers should also be prepared to set up additional plots at any at-risk colony where increasing sample sizes will improve chances of detecting significant changes during follow-up restoration monitoring work. *Note: Standardized methods and procedures for collecting murre population numbers, productivity, and nesting chronology data have been developed by the Alaska Maritime National Wildlife Refuge [e.g., see Roseneau, D.G., A.B. Kettle, and G.V. Byrd. 1998. Common murre population monitoring at the Barren Islands, Alaska, 1997. Unpubl. Annual Rept. By the Alaska Maritime National Wildlife Refuge for the Exxon Valdez Oil Spill Trustee Council, Anchorage (Restoration Proj. 97144); and D.G., A.B. Kettle, and G.V. Byrd. 1998. Barren Islands seabird studies. 1997. Appendix J in Apex: Alaska Predator Ecosystem Experiment (D.C. Duffy, Compiler), Exxon Valdez Oil Spill Restoration Proj. Annual Rept. (Restoration Proj. 97163), Alaska Natural Heritage Program, Univ. of Alaska, Anchorage]. These AMNWR protocols are too lengthy to describe here;*

however, they are available for inclusion in regional murre oil spill response plans.
If time permits, several other types of information should also be collected at nesting colonies before oiling occurs. These data include information on prey species brought to chicks, adult foraging trip duration and time spent at nest sites by adults, and water temperatures (see comments in response to Question 5).

Data collected at the unoiled colonies and the methods used for obtaining them may vary from site-to-site, depending on the timing of spill in relation to the murre breeding cycle, the time it may take for the oil to reach them, and their individual topographical features and prespill data histories. For example, the topography of the Chiswell Islands colonies makes it difficult to collect high quality productivity and nesting chronology data at them. However, these colonies can be censused easily, and the number of population counts already available from them allow the data to be tested for differences between and among years (e.g., t-tests, linear regressions). Therefore, if these colonies were in danger of being oiled during the height of the breeding season, censusing them before oil arrives should take precedence over attempting to collect productivity and nesting chronology information at them (even if only one or two population counts could be made before oiling occurs, these data would be valuable). Also, in some cases, certain types of data may need to be collected in specific ways to be directly comparable with historical information. When these situations are encountered, data should <u>also</u> be collected using current methods and protocols (i.e., information should be obtained in ways that satisfy both approaches). Although employing two different methods to collect the same type of data may require more time and effort, this strategy is important, because it allows the information to be analyzed in two different ways: it can be compared directly with historical data (which often provides the longest time series), and it can be directly compared with information obtained by the more up-to-date methods and procedures in subsequent years (e.g., during postspill restoration monitoring studies).

Question 2: What murre data collection/studies would need to be initiated immediately following the spill (i.e., during the first 24-48 hours)?

<u>Identification of at-risk breeding colonies and known or suspected wintering areas</u>: Immediately after a spill, a pre-designated response team of seabird biologists familiar with the spill region, its murre populations, and historical data bases should be contacted and given the best information available on the spill's size, location, type of product involved, and its probable trajectory so that they can quickly identify all breeding colony locations and known or suspected wintering areas that may be at risk. Rapid identification of at-risk breeding colonies and known or suspected wintering areas will be needed immediately after the spill to allow effective implementation of activities recommended under Question 1 (see above).

Regional murre oil spill response teams should be formed to help ensure that important murre habitats are identified quickly and accurately during spill events (also see comments in response to Question 3). Team members should be familiar with the species and current monitoring techniques and protocols. Team membership should not depend on agency affiliation, and teams should be kept relatively small to increase effectiveness (i.e., 3-4 people; using small experienced groups of people will keep communications from becoming too complex and speed up the decision making process). Once formed, these regional teams could design and direct both initial response and more detailed damage assessment efforts (see Questions 1 and 3), and plan and direct long-term restoration monitoring studies (see Question 7). They could also provide experienced personnel for first-response efforts immediately after spills (using experienced team members during initial responses would be beneficial, because they can more accurately evaluate situations and provide information on what may be needed in terms of additional response efforts).

Salvaging murre carcasses for postspill analysis: After at-risk breeding colonies and known or suspected wintering areas are identified, a program should be implemented to immediately collect and preserve samples of murre carcasses for later analyses (other tasks may also need to be initiated at the same time as this work, or immediately after it – see Question 1). To help ensure the program's effectiveness, protocols for implementing and conducting it should be developed before spills occur, and after they have been developed, they should be incorporated in spill-response plans. Protocols should include methods for systematically collecting and properly preserving specimens. They should also describe sampling designs and appropriate sample sizes.

Collecting and preserving samples of murres killed by spills will allow researchers to obtain potentially valuable information on the age and sex of the birds that will be useful when analyzing and interpreting data collected during later postspill restoration monitoring studies. Murre carcasses can be easily sexed, and they can also be divided into at least 3 age classes: chicks, 1-year-olds, and birds that are more than 1-year old. It may also be possible to identify a fourth age category: subadults that are more than 1 year old that have not bred for the first time. Knowing that losses consisted of a large percentage of males or females, or one of the above age groups, may help explain patterns that may become apparent during later restoration monitoring studies and help clarify the recovery process.

Salvaging and preserving samples of murres killed by spills will also provide material for postspill genetic studies. Techniques for genetically identifying populations of birds are evolving rapidly, and analyzing tissue samples may provide information useful to postspill restoration monitoring projects. If carcasses are not picked up and preserved properly during spill events, the option to eventually conduct potentially valuable postspill genetic studies will be lost.

Initiating collection of population numbers, productivity, and nesting chronology data: If spills occur during the breeding season and nesting colonies are in immediate danger of being oiled, response teams should be sent to them as soon as possible to collect whatever information can be obtained on population numbers, productivity, and nesting chronology before the oil arrives (see in response to Questions 1 and 3). Even if time is short and only small amounts of data can be obtained by the response teams (e.g., single counts of birds on population monitoring plots, single counts of adults in incubation/brooding postures on productivity plots), this information would help place data obtained during later damage assessment and restoration monitoring studies in perspective.

Question 3: What additional murre studies/collection, if any, would need to be initiated following the first 24-48 hours?

The types of studies and data collection activities that should be initiated after the initial response period has passed (i.e., the first 24-48 hrs), will depend on the timing of the spill in relation to the annual murre breeding cycle, and its size, location, and movement in relation to areas where large concentrations of birds may be at risk (e.g., known or suspected wintering areas and nesting colonies – also see comments in response to Questions 1 and 2). In some cases, activities may consist of continuing and expanding one or more of the initial response phase activities (e.g., flying aerial surveys to locate concentrations of birds; salvaging samples of carcasses; collecting population numbers, productivity, and nesting chronology data).

If nesting colonies are at risk, efforts to obtain information on population numbers, productivity, and timing of nesting events should be intensified. Field crews should be organized and sent to specific locations to initiate larger scale studies designed to collect these data. To increase the overall effectiveness these efforts, it would be beneficial to preplan basic studies for the most important nesting colonies in each potential spill region (a task that could be assigned to regional murre response teams – see Question 2). For example, in the northern Gulf of Alaska, it would be relatively easy to predesign basic damage assessment and restoration monitoring studies for the Barren and Chiswell islands colonies. The study plans should contain information on the kinds of data to be collected and what is needed to collect it (e.g., numbers of personnel and types of equipment needed to safely collect it; copies of maps and/or photographs showing population census and productivity plot boundaries; locations of observation posts and methods for reaching them; descriptions of any anticipated problems associated with collecting the information, such as the presence of strong prevailing currents and rip-tides). The study plans should rely on standardized methods and procedures for collecting data, and they should contain complete descriptions of them (e.g., as attached data collection protocols). *Note: Standardized methods of procedures for collecting murre population numbers, productivity, and nesting chronology data have been developed by the Alaska Maritime National Wildlife Refuge [e.g., see Roseneau, D.G., A.B. Kettle, and G.V. Byrd. 1998. Common murre population monitoring at the Barren Islands, Alaska. 1997. Unpubl. Annual Rept. By the Alaska Maritime National Wildlife Refuge for the Exxon Valdez Oil Spill Trustee Council, Anchorage (Restoration Proj. 97144); and D.G., A.B. Kettle, and G.V. Byrd. 1998. Barren Islands seabird studies. 1997. Appendix J in Apex: Alaska Predator Ecosystem Experiment (D.C. Duffy,k Compiler), Exxon Valdez Oil Spill Restoration Proj. Annual Rept. (Resotration Proj. 97163), Alaska Natural Heritage Program, Univ. of Alaska, Anchorage]. These AMNWR protocols are too lengthy to describe here; however, they are available for inclusion in regional murre oil spill response plans. Information relevant to murre monitoring study designs can also be found in Warheit K.I., C.S. Harrison, and G.J. Divody (eds.). 1997. Exxon Valdez Oil Spill Seabird Restoration Workshop. Exxon Valdez Oil Spill Restoration Project 95038 Final Rept. Pacific Seabird Group Tech. Publ. No. 1. Pacific Seabird Group, Seattle.*

Implementing well designed damage assessment studies shortly after spills occur will improve the effectiveness of restoration monitoring work by providing high quality, well-documented data sets that can be directly compared with information collected during these follow-up efforts – something that was often impossible to do during some of the early EVOS restoration monitoring projects (see comments in response to Question 4).

In summary, reviews of the EVOS murre damage assessment studies, and papers and publications from Exxon-sponsored murre investigations, clearly indicate that it would be beneficial to create knowledgeable regional murre oil spill response teams before spills occur (see comments in response to Question 2). The reviews also indicate that it would be beneficial to have these teams preplan basic damage assessment and restoration monitoring studies for these vulnerable seabirds. The predesigned study plans should rely on up-to-date standardized method and protocols for collecting data, and they should address winter, spring, summer, and fall events that may affect wintering, prebreeding, breeding, and post-breeding concentrations of murres. The response teams should consist of seabird biologists, and most of the members should have extensive practical experience working with murres at both large and small Alaskan nesting colonies. Some members should also be familiar with current methods and protocols for making population counts and collecting data on the breeding and foraging parameters of these seabirds. Team membership should not be dependent on agency affiliations, and teams should limited to 3-4 personnel to keep the communications and decision making processes from becoming too complex. The response teams should work closely together, and several of the most experienced members of the teams should be given key leadership roles in designing and planning the damage assessment and restoration monitoring studies for all potential spill regions.

Question 4: Were there any murre studies/data collection activities initiated/completed following the 1989 EVOS that you would not recommend initiating in a future spill?

No specific murre studies or murre data collection activities come to mind. However, several murre restoration projects were considered or proposed during the damage assessment phase of the *T/V Exxon Valdez* oil spill that should only be considered in very special and/or extreme cases. One proposed study was based on social attraction techniques: use of decoys and recorded calls to attract murres to injured colonies to increase breeding populations. Another proposed project was based on captive management techniques: the rearing and releasing chicks at injured colonies to supplement reproduction and stimulate population growth. A third potential study, based on translocation techniques, was similar to the proposed captive management program. It centered around capturing chicks at healthy, uninjured colonies and releasing them at injured sites to supplement reproduction and boost population growth. In all but special cases, these types of restoration projects are not only costly, but also impractical and biologically ineffective impractical and [see Warheit, K. I., C.S. Harrison, and G.J. Divoky (eds.). 1997. *Exxon Valdez* Oil Spill Seabird Restoration Workshop. *Exxon Valdez* Oil Spill Restoration Project 95038 Final Rept. Pacific Seabird Group Tech. Publ. No. 1. Pacific Seabird Group, Seattle]. Also, large amounts of and effort were spent trying to rehabilitate oiled murres and other seabirds during the 1989 EVOS event. Rehabilitation of murres (and most other seabirds) is generally not successful. Furthermore, it is costly, and also tends to mislead to the by creating false impressions about spill impacts and subsequent chances for quick recovery.

Efforts to rehabilitate murres should only be implemented in special cases involving small discreet populations that are known or likely to be dependent on the survival of individual birds to maintain the viability of the populations [again, see Warheit, K. I., C.S. Harrison, and G.J. Divoky (eds.). 1997. *Exxon Valdez* Oil Spill Seabird Restoration Workshop. *Exxon Valdez* Oil Spill Restoration Project 95038 Final Rept. Pacific Seabird Group Tech. Publ. No. 1. Pacific Seabird Group, Seattle]. In most Alaskan oil spill scenarios, even large-scale efforts to clean and rehabilitate murres (and most other seabirds) are not likely to be biologically significant to the injured populations. They also use up funds that could be better spent on spill prevention projects, assessing impacts more thoroughly during and after spills, and designing and conducting restoration monitoring studies to more accurately assess the recovery status of injured populations.

Also, the EVOS murre damage assessment studies at the northern Gulf of Alaska nesting colonies were not as well designed as they should have been in tenns of numbers and locations of study sites in relationship to the number of field crews and the logistics needed to accomplish the work efficiently and effectively. In spite of the fact that murre mortality was high and most birds were lost outside of Prince William Sound in the vicinities of colonies, only 2 field teams were allocated to these studies in 1989, and only one of these teams was assigned to a specific study site (Puale Bay). The second team used a vessel to visit several widely scattered study sites ranging from the Chiswell Islands near Resurrection Bay and the Barren Islands near the entrance to Cook Inlet, to the Triplet islands near Kodiak and the Semidi Islands southwest of the Kodiak archipelago (a linear distance of about 360 miles and sailing distance of about 450-500 miles). The same strategy was used in 1990-1991, with the exception that personnel were stationed at the Semidi Islands colony to collect data (i.e., 3 field teams were deployed, 1 to

Puale Bay, 1 to the Semidi's, and 1 on a vessel that traveled between the Chiswell and Barren islands, and Ugaiushak Island colonies). Having a single team attempt to obtain information at several widely separated study sites from a slow-moving vessel affected data quality and quantity. Because of the time needed to travel between study sites, the mobile field crew was not present at some of them during the best time periods for collecting certain types of data (e.g., population counts need to be made during the most stable part of nesting cycle and time of day – between the peak of egg-laying and first sea-going of chicks, and about 1100 hrs and 3000 hrs). Also, less time was available to make population counts, and in some cass, numbers of counts were too low to measure daily variation in attendance (census protocols call for a minimum of *5* counts to be made on separate days during the census period to measure variability). Because they were traveling from colony-to-colony, the roving team also was able to spend the time necessary to obtain good information on timing of murre nesting events and productivity at the Barren Islands colonies, the most important study sites on their itinerary because of population size, exposure to drifting oil, and topographical features that allow monitoring plots to be set up for collecting these data. For example, in one of the damage assessment years at the Barren Islands, first egg-laying dates were based on a single observation of a raven taking an egg from 1 of the 2 colonies.

The 1989-1991 EVOS murre damage assessment studies were also not as well focused as they could have been. Field teams collecting data on murres spent time surveying and recording a variety of seabirds and marine mammals on the water in the general vicinities of some of the injured colonies (e.g., Barren Islands). These data proved to be of little value because of the highly variable nature of day-to-day at-sea bird and marine mammal distribution, and the lack of comparable historical information. The time taken to collect and record these data would have been better spent collecting more detailed information on murres at the respective study sites.

Furthermore, methods used to collect data on murres during the 1989-1991 EVOS damage assessment studies were poorly described and documented in field notes and reports. During a 1993-1994 in-house review of this information, attempts to reconstruct how, when, and where some of the data were obtained, and how numerical results were calculated often proved to be difficult and sometimes impossible chores. Also, some of the data were not summarized in a fashion that allowed results to be easily recalculated and checked for accuracy, or data to be reanalyzed by different methods at later dates for comparative purposes.

Based on the 1993-1994 in-hourse review of the 1989-1991 damage assessment work, several general recommendations can be made with regard to collecting data at murre colonies during and after spill events.

- Colonies should be ranked and prioritized according to their location in relation to the spill, how important they are to the regional breeding population in terms of size, productivity, and possible roles as sources of birds. During the ranking process, the types of data that can be effectively collected at the colonies and the presence or absence of historical data sets should also be taken into account (e.g., can only population counts be made at the study site, or can productivity, nesting chronology, and other types of data also be collected there?; are monitoring plots already set up at the study site, and if so, are they well-documented on maps or photographs?; are historical data available from the study site, and if so, what are they, and will they actually be useful to damage assessment and restoration work?; if historical data are available and relevant to the work, how and when were they acquired, and how extensive are they?).

- Data collection activities should be base don sound, well-designed study plans and standardized data collection methods and protocols. Basic study lans and data collection protocols should be prepared before spills occur and included in regional reponse plans for murres.

- One field team should be assigned to collect data at each study site, unless special circumstances make it possible for a team to effectively collect high quality information at more than one study location.

- Data should be summarized and entered into spread sheets designed and formatted for this purpose, and all methods used to collect the data should be fully described and documented in spread sheets and reports.

Question 5: Would you recommend taking an ecosystem-based approach to injury assessment and restoration?

Yes. Murre damage assessment and restoration studies should take regional populations into account (e.g., losses at individual colonies should be placed in perspective with information on the region's total population numbers and overall population status/health). Also, in addition to collecting data on murre numbers, productivity, and nesting chronology at injured or likely to be injured nesting colonies, information should be obtained on important forage fish species (e.g., capelin, *Mallotus villosus;* sand lance, *Ammodytes hexapterus)* and environmental parameters (e.g., local water temperatures and salinity, broader scale sea-surface temperature patterns) that influence their distribution and availability to foraging seabirds. Collecting some of these data may be difficult during initial phases of a spill; however, broad-scale sea-surface temperature information can be obtained from satellite imagery after the event, and it may be possible to obtain some information on types of prey brought to chicks, if response efforts include collecting data on productivity monitoring plots. Collecting information on forage (e.g., prey species brought to chicks), adult foraging trip duration and time spent at nest sites by adults, and water temperatures would be particularly valuable during restoration studies, because natural changes in food webs and prey availability may positively or negatively influence the recovery of murre populations injured by spill events (e.g., see the EVOS APEX Project).

Question 6: As you know, the new NOAA NRDA regulations emphasize restoration endpoints rather than a determination of damages. With restoration in mind, would you suggest any modifications to the murre data identified above?

Regardless of the new NOAA NRDA regulations that emphasize restoration endpoints and de-emphasize determining damages, studies should still be made to measure impacts/injuries to murre populations that may result from spills (e.g., direct mortality). This information is needed to help understand the recovery process, including patterns that may become apparent in population monitoring data sets during postspill restoration monitoring studies.

Question 7: What restoration activities could be successfully implemented for injured murres?

If murre nesting colonies are injured by spills, the primary restoration activities that can be successfully implemented after the events consist of postspill population monitoring studies designed to carefully document and track recovery of the injured populations. These studies can provide important information on the recovery process and identify population recovery endpoints.

Other restoration techniques could also be implemented to help murre populations recover after a spill, depending on the circumstances [see Warheit, K.K., C.S. Harrison, and G.J. Divoky (eds.). 1997. *Exxon Valdez* Oil Spill Seabird Restoration Workshop. *Exxon Valdez* Oil Spill Restoration Project 95038 Final Rept. Pacific Seabird Group Tech. Publ. No. 1. Pacific Seabird Group, Seattle]. These techniques fall into three general categories: reducing or preventing mortality, reducing human disturbance, and evaluating and modifying fisheries management practices that may affect important forage fish populations. Examples of these techniques include removing introduced predators from nesting habitats both in and outside of spill areas (e.g., foxes, rats), preventing introduction of predators to nesting habitats both in and outside of spill areas (e.g., foxes, rats), reducing chances of birds being caught and drowned in gillnets, reducing effects of hatchery-raised salmon (particularly pink salmon, *Onchorhynchus gorbuscha)* on forage fish food webs, limiting commercial catches of some species of fish (e.g., walleye Pollock, *Theragra chalcogramma),* and protecting sand lance and capelin populations, and their spawning grounds.

Question 8. Briefly describe the murre data collections/studies that were done for EVOS.

Murre damage assessment studies were conducted studies were conducted at the Chiswell Islands (1989-1991), Barren Islands (1989-1991), Triplets (1989), Puale Bay (1989-1991), and Ugaiushak Island (1990-1991). Data were also obtained from two control/reference sites, Chowiet Island in the Semidi Islands (1989-1991) and Middleton Island (1989-1991; the Middleton Island murre studies were part of a separate long-term research project that did not depend on EVOS funds). During the damage assessment work, efforts were directed toward collecting data on population numbers, productivity, and timing of nesting events. This information was collected by a roving vessel-based field crew at some of the study sites (Chiswell and Barren islands, 1989-1991; Triplets, 1989; Ugaiushak Island. 1990-1991; Semidi Islands, 1989), and by land-based teams that were specifically assigned to others (Puale Bay, 1989-1991; Semidi Islands, 1990-1991; Middleton Islands, 1989-1991). Birds were counted on a variety of different population monitoring plot sets at all of the study sites (e.g., six complete islands representing six separate plots in the Chiswell Islands; Light Rock and one additional set of two plots at the East Amatuli Island – Light Rock colony, and all of Nord Island, including a separate set of 11 plots, at the Nord Island – Northwest Islet colony in the Barren Islands). Count quality varied among study sites and years; in some cases, counts on some plot sets were incomplete (e.g., Chiswell Islands 1989-1990), or insufficient to obtain good measures daily variation in attendance (e.g., Chiswell Islands 1989, Barren Islands 1989-1991), or made in a manner that did not follow count protocols (Light Rock, Barren Islands, 1991). Some information on productivity and timing of nesting events was obtained at the Barren Islands, and better data on these variables were collected at Puale Bay. Puale Bay data were collected by regularly observing birds on plots, which allowed fledglings per egg and mean/median laying dates to be calculated. Barren Islands information was less useful because it was collected less rigorously – it consisted of estimates of first laying dates and chicks per adult (both highly variable parameters) based on random spot-checks of a few nesting ledges and general observations of adult behavior. *Note: Using one vessel-based team to cover several study sites affected data quality and quantity – see comments in response to Question 4.*

Restoration monitoring studies of were conducted during 1992-1994. During the 1992 studies, data were collected at the Chiswell Islands (population counts) and Barren islands (population counts, productivity, timing of nesting) by a roving vessel-based field crew, and at Puale Bay (population counts, productivity, timing of nesting) by a land-based team. As in 1989-1991, population count quality varied, and in some cases, numbers of counts were insufficient to measure daily variability (e.g., Chiswell Islands). Also, some population plot sets were counted before 1100 hrs. when attendance at nesting cliffs tends to be low (e.g., Barren Islands). Collection of productivity and nesting chronology data improved at the Barren Islands in 1992 (e.g., eight plots were established at Nord Island to collect these data). However, productivity information only consisted of chicks per adult ratios (a highly variable parameter), not fledglings per egg, and first laying dates (also a highly variable parameter) derived from spot checks of nesting ledges and observations of eggs taken at predators (e.g., gulls, ravens) were used to describe timing of nesting events. *Note: Weather was exceptionally poor in the northern Gulf of Alaska in 1992, and rough sea conditions made it difficult for the boat-based crew to collect information at the Chiswell and Barren islands study sites.*

In 1993-1994, murre restoration monitoring studies were only conducted at the Barren Islands colonies because of funding constraints. These colonies were selected for the work because of their importance to the regional breeding population. Concentrating efforts at 1 location provided opportunities to markedly improve data quality and quantity at these important study sites. Data were collected by 2 land-based field crews using standardized methods and protocols. The research teams were equipped with small boats and supported by a larger vessel during some phases of the work (e.g., population counts at the Nord Island – Northwest Islet colony). Eight new census plots were set up at the East Island – Light Rock colony in increase sample size, and numerous counts were made on a variety of plot sets to provide a solid basis for tracking long-term population trends (e.g., whole colony counts at both colonies; several counts of major subsections of colonies; several series of replicate counts on smaller sets of plots to measure daily variation in attendance and allow better statistical comparisons to be made between and among years). Also, 10 productivity plots and an observation post were set up at the East Amatuli Island – Light Rock colony, and access to the 1992 Nord Island productivity plots was improved. Both plot sets were visited every 3-4 days, weather permitting, throughout the nesting season, and the data collected on them allowed productivity to be calculated as fledglings per egg. These data sets also provided high quality information on timing of nesting events, including mean/median laying, hatching, and chick sea-going dates.

During 1995-1999, similar high quality murre productivity and nesting chronology data were collected at the Barren Islands East Amatuli Island – Light Rock colony as part of the 5-year-long EVOS Alaska Predator Experiment (APEX) project. This information allowed a variety of statistical comparisons to be made between and among 1993-1999 results. In 1995, replicate counts of birds were also made on the primary 8-plot East Amatuli Island – Light Rock population monitoring plot set. Other data types obtained on murres during the APEX work included information on prey species fed to chicks, time spent at nest sites by adults, and adult foraging trip duration. All data collected during the APEX studies were obtained using standardized methods and protocols, and they provide a foundation for future work.

Murre restoration monitoring studies also conducted at the Barren Islands in 1996-1997 and 1999. During these projects, large amounts of high quality census data were obtained from population monitoring plots at both colonies by vessel- and land-based teams using the same standardized methods and protocols employed during the 1993-1994 studies. Data collected during these projects allowed a variety of statistical comparisons to be made between and among 1989-1995 Fish and Wildlife Service, 1990-1992 University of Washington, and 1991 Dames & Moore counts. They also provide the type of baseline information needed to accurately assess impacts to murre populations during future spills.

Murre restoration monitoring work was also conducted at the Chiswell Islands in 1998. During this study, murres were censused at the six islands where population counts were made during the 1989-1991 damage assessment and 1992 restoration studies. The study was conducted from a support vessel using small boats, and information was collected by the same standardized methods and protocols used during the 1993-1994 and 1996-1997 Barren Islands population monitoring projects (e.g., birds were counted six times on separate days to provide a measure of daily variation in attendance). Data collected during this work allowed statistical comparisons to be made between and among the 1989-1992 and 1998 counts.

Question 9: How were injury assessment data collection/studies selected for murres?

Shortly after the 1989 *T/V Exxon Valdez* oil spill, a large-scale program was initiated to pick up birds and mammals killed or injured by the event. After initial information on mortality was obtained from these efforts, it became clear that murres were an important group of seabirds to evaluate, because they comprised most of the birds killed by the oil (the high mortality rate for murres also confirmed their vulnerability to spills, as indicated by literature reviews).

Consultations among Fish and Wildlife Service biologists familiar with murres and literature reviews were used to identify breeding colonies in the path of the oil (the Alaskan seabird colony catalog was the primary source for this information – see Sowls, A.L., S.A. Hatch, and C.J. Lensink. 1978. Catalog of Alaskan seabird colonies. U.S. Fish and Wildl. Serv., Biol. Serv. Prog. FWS/OBS 78/78, Anchorage). These biologists also identified population numbers (making counts of birds at colonies), nesting chronology (determining timing of nesting events), and productivity (determining reproductive success) as primary parameters for assessing damages, because these variables were likely to detect direct and indirect effects of the spill, including disruptions to social structures of breeding populations from high mortality rates. Five nesting locations in the spill area were chosen as study sites (Chiswell and Barren islands, Puale Bay, Ugaiushak Island, and the Triplets). Study site selection was apparently based on the presence of prespill information and land ownership patterns (see comments on the Cape Resurrection and Barwell Island colonies in response to Question 12). Two additional nesting locations were chosen as control/reference sites (Chowiet Island in the Semidi Islands and Middleton Island – also see comments in response to Question 10). Based on the prespill information that was available from the five damage assessment study locations and two control/reference sites, first egg-laying dates and chick/adult ratios were selected as the measurements of nesting chronology and productivity, respectively (these parameters are highly variable from day-to-day and year-to-year, and as a result, they are not well-suited for detecting and describing meaningful differences between and among years and colonies).

Methods used to collect murre data during damage assessment studies were generally based on methods and procedures developed for monitoring these birds at other study sites (e.g., see Birdhead, T.R. and N.D. Nettleship. 1980. Census methods for murres, *Uria* species: a unified approach. Occ. Paper No. 43. Can. Wildl. Serv., Ottawa). In some cases, methods were selected on the basis of how data were collected during prespill studies to facilitate direct comparison of pre- and postspill information (e.g., productivity and nesting chronology data – see above; also population counts at the Chiswell Islands colonies). In other cases, information was obtained by more up-to-date methods that were not directly comparable with those used during prespill investigations (e.g., population counts at the Barren Islands colonies). Some procedures were modified and refined after Trustee Council contract statisticians reviewed preliminary study plans and peer reviewers evaluated preliminary reports.

Question 10: What murre data collection/studies, if any, were dropped after the first year or two following EVOS?

In 1989, murre damage assessment work was conducted at the Chiswell, Barren, and Semidi

Islands; Puale Bay; and the Triplets, a small group of islands near Kodiak (Chowiet Island in the Semidi Islands was one of two control/reference sites; Middleton Island, where a long-term research project was already being conducted, was the second control/reference site). Work was also conducted at the Chiswell, Barren, and Semidi Islands, and Puale Bay in 1990-1991; however, the Triplets, which support about 1,000 murres, were not visited after 1989, probably because of small numbers of birds, funding and manpower constraints, and the decision to census murres at Ugaiushak Island in 1990 and 1991 (Ugaiushak Island supports about 8,000 murres; it is located along the Alaska Peninsula coast southwest of Kodiak Island).

Question 11: Describe which of the EVOS murre injury assessment data collection/studies proved useful and which, ones, if any, did not.

Initial efforts to assess damage to murres were poorly focused, in part because these efforts were heavily entwined with and influenced by larger scale efforts to assess damages to many different bird and mammal species and a variety of other resources (i.e., some murre damage assessment teams spent time collecting data that were not relevant to these birds – see comments in response to Question 4). Also, during the first few years following the EVOS event, most efforts to assess damages to wildlife populations were centered in Prince William Sound, and considerably less emphasis was placed on determining what may or may not have happened to species and populations outside of this relatively small portion of the spill area (an interesting situation, given that murres, clearly among the hardest hit species, do not nest in Prince William Sound, and most of the impacts to these birds occurred outside of this area in the vicinities of important northern Gulf of Alaska breeding colonies). In general, northern Gulf of Alaska murre received less support than many projects in Prince William Sound, and this difference in support probably contributed to one murre damage assessment team attempting to visit more study sites than could be effectively handled without affecting data quality and quantity (see comments in response to Question 4).

In retrospect, it should have been clear that murres were likely to be among the hardest hit species because of their flocking and diving behavior, and their tendency to stage in large rafts near their nesting colonies prior to the breeding season. Because murres were highly vulnerable to floating oil and the Barren Islands were directly in the path of the spill, greater emphasis should have been placed on conducting more intensive studies at this important nesting location (the Barren Islands supported the largest concentration of nesting in the path of the spill).

Studies that obtained information on the population numbers, productivity, and nesting chronology of murres were the most useful. However, greater emphasis should have been placed on collecting high quality productivity and nesting chronology data at the Barren Islands colonies. Also, the Barren Islands and Puale Bay colonies should have been given the highest priority, because it was possible to collect productivity and nesting chronology information at them, and they contained the largest concentrations of nesting in the path of the spill.

Censusing murres at the Chiswell and Barren islands and Puale Bay was more useful than counting birds at the Triplets and Ugaiushak Island because of their location relative to the spill and their respective data histories. The time, effort, and funds required to visit the Triplets and Ugaiushak Island colonies would have been better spent at the Barren and Chiswell islands and Puale Bay.

Question 12: In hindsight, were there murre data collection/studies that should have been conducted?

Not specifically, however, the 1989-1991 damage assessment studies should have been conducted in a manner that ensured that enough population counts were obtained at the colonies to measure daily variation in attendance (e.g., the Barren Islands). These studies should have also been designed to collect better productivity and nesting chronology data at the Barren Islands (e.g., by setting up monitoring plots and visiting them on a regular schedule, weather permitting, during the incubation and chick-rearing periods). Again, the fact that well-supported field teams were not assigned to work at 1 study location apiece to collect specific types of data limited the amounts and kinds of information collected during the damage assessment work (also see comments on damage assessment teams in response to Question 4). *Note: These issues were addressed during the 1993-1999 restoration work.*

Also, damage assessment studies were apparently not conducted at the Barwell Island and Cape Resurrection murre colonies at the eastern entrance to Resurrection Bay because they were located on State owned or selected lands, and were not part of the National Wildlife Refuge system (all damage assessment studies were conducted on federal refuge lands). Indeed, even though these colonies were closer to the source of the EVOS spill than any of the 5 study sites chosen for damage assessment work, and were in the direct path of the oil, they were never surveyed or mentioned in any of the EVOS reports. The Barwell Island and Cape Resurrection colonies were estimated to support about 8,800 and 2,025 murres in 1975, respectively [see Bailey, E.P. Distribution and abundance of marine birds and mammals on the south side of the Kenai Peninsula, Alaska. Unpubl. U.S. Fish and Wildlife rpt., Anchorage. Also Erikson, D.E. 1995. Surveys of murre colony attendance in the northern Gulf of Alaska following the *Exxon Valdez* oil spill. Pp. 780-819 in *Exxon Valdez* oil spill: Fate and effects in Alaskan waters, ASTM STP 1219, P.G. Wells, J.N. Butler, and J.S. Hughes (eds.), Amer. Soc. for Testing and Materials, Philadelphia]. However, at the time of the EVOS event, these colonies were listed in the USFWS Alaskan seabird colony catalog as containing 17,600 and 4,300 birds, respectively (see Sowls, A.L., S.A. Hatch, and C.J. Lensink. 1978. Catalog of Alaskan seabird colonies. U.S. Fish Wildl. Serv., Biol. Serv. Prog. FWS/OBS 78/78, Anchorage). These latter numbers were not correct (Bailey's estimates were inadvertently doubled in the colony catalog). However, given both the real and apparent sizes of these colonies, they should have been included in the assessment studies regardless of land ownership. The topography of the Barwell Island and Cape Resurrection colonies make collecting productivity and nesting chronology data difficult; however, if these nesting locations had been censused during the EVOS damage assessment phase, the counts would have provided valuable information on initial impacts to murres that could have been used to help evaluate the recovery status of these birds in the spill area.

Question 13: Please explain under what circumstances, if any, you think an ecosystem approach would not be appropriate.

No specific circumstances come to mind at this time (also see comments in response to Question 5).

Question 14: Were any of the murre data collection/studies too costly based on the end results (determination of damages or opportunity for restoration)?

Specific examples are difficult to pinpoint. However, the data/dollar ratio was almost certainly poor during the 1989-1991 murre damage assessment studies because of the attempt to use a single vessel-based research team to collect data at several widely separated study sites. Also, the costs of collecting, cataloging, and storing all of the murre carcasses were high and probably excessive, based on the final results of this exercise.

A Retrospective Evaluation Of *Exxon Valdez* Oil Spill Trustee Council Sponsored Sea Otter Studies

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An extensive and diverse array of studies were implemented concurrent with and for several years following the *Exxon Valdez* oil spill to determine the acute and chronic effects to sea otters. Additional studies were implemented 1996 to determine the status of sea otter populations relative to recovery and to determine what factors could be constraining recovery. The purpose of this paper is to 1) identify studies of sea otters that are required to effectively evaluate the acute, sub-acute and potential chronic effects of another spill of similar magnitude, 2) identify studies that will be useful in evaluating recovery from damages in the context of a restoration endpoint, and 3) provide a retrospective analysis of the utility of sea otter studies that were implemented after the 1989 spill. The first part of this paper will describe what activities relative to sea otters should take place prior to, during and following another spill similar to the *Exxon Valdez.* The second part will focus on what was done in 1989 and the years following related sea otters.

Our ability to accurately and defensibly determine the effects of any perturbation on sea otter (or other) and subsequent recovery processes will be determined largely on the quantity and quality of data available to describe the affected, as well as an unaffected, or reference population immediately prior to the perturbation. Post spill data collection for the most part will consist of repeating prespill data collection protocols. Attempts to describe spill effects in the absence of this baseline data for the affected (treatment) and unaffected (reference) populations can, and will be subjected to the valid criticism of an inadequate experimental design to assign cause to effect. Studies that are implemented to determine spill effects in the absence of baseline data will lead to uncertainty in the conclusions that will ultimately be drawn. Moreover, a lack of accurate and defensible baseline data on populations will preclude assigning meaningful restoration endpoints. Estimating the magnitude of acute mortality should be directly assessed by two independent methods; 1) subtracting post spill abundance estimates from prespill estimates, and 2) summing the number of carcasses recovered and those not recovered. Estimating effects of sub-acute or chronic exposure or constraints to recovery are more difficult and require additional data collected under the experimental design described above. The primary objectives of some studies will be acute, or immediate mortality estimates (e.g., carcass marking and recovery), others will be used to estimate potential longer term effects (e.g., bioindicators, health measures), and some will be useful in determining both acute and chronic effects (e.g., surveys of abundance, survival estimates).

Despite the extensive resources that were allocated to describing the effects of the *Exxon Valdez* spill, we were unable to defensibly quantify the magnitude of the spill effect, or unequivocally describe the status of affected sea otter populations relative to recovery. If a single lesson should be learned from the 1989 spill in Prince William Sound (PWS), it is that no amount of post spill study can replace the lack of accurate and precise prespill data.

A. Prespill data requirements

Sea otters provide a good case study of what can be done in preparation for a large scale perturbation such as an oil spill, largely because of the methods available to acquire accurate data on a variety of population and individual parameters. Sea otters, a coastal marine species, dive for relatively short periods, consume their benthic prey on the surface and are easily observed from shore. Capture, visual and remote sensing techniques are well developed and the relations of sea otters to the structure and function of coastal marine communities are reasonably well described. Additionally, life history variables contributing to population dynamics such as age specific fecundity and survival are measurable.

Data needs in the following list are provided in a declining order of priority. For each data need, techniques are suggested to acquire the data. Priorities are based primarily on the value of the data, but secondarily include cost considerations. In conjunction with each of these specific recommendations, sampling protocols as well as plans for sample and data acquisition and management and quality control are critical and should be part of the spill preparation/response plan.

1) Accurate estimates of geographic distribution, population size and status (rate of change).
Aerial surveys that estimate sea otter abundance and distribution were developed following the *Exxon Valdez* spill. The methodology should be implemented in and adjacent to areas of oil storage and transport at intervals to determine prespill population abundance and trends in abundance. These surveys should be repeated as soon as possible following a spill, and at appropriate intervals through recovery. Without any additional prc spill data collection, these surveys could provide defensible mortality estimates, rates of recovery and restoration endpoints. However, these surveys alone would not provide information on causes of mortality or sub-acute effects, factors contributing to or limiting recovery, or ecosystem level effects of the spill.

2) Age and sex specific measures of individual health.
Systematic capture and marking of sea otters prior to a spill will provide baseline data on blood and serum chemistries, bioindicators of health and exposure to naturally occurring contaminants, morphometrics and sex and age composition in the population. Effective and efficient techniques to capture and permanently mark individual sea otters are available. *Exxon Valdez* studies of individual health are suggestive of spill induced changes as many as 10 years post spill. Interpretation of post spill data is compromised because we lack prespill data for comparison. We are forced to compare these measures with values from one or more unoiled areas, which we assume to be comparable (but which we know vary in potentially important ways, e.g., habitat and sea otter density).

3) Age specific survival.
Collections of sea otter carcasses that died prespill can be used to estimate prespill age specific survival rates. This technique requires relatively large sample sizes that can be acquired efficiently prior to a spill. Combined with similar post spill collections, time varying population models can describe if, and the most likely ways how, survival changes following a spill.

4) Sea otter diet and prey populations.
Visual observations of foraging sea otters with high resolution telescopes provide data on foraging success rates, prey number, species and size, dive times and surface intervals. These data are useful for two purposes. First, they can be used to estimate the time an individual (and by inference, a population) allocates to foraging. This parameter has been used to determine

population status relative to prey resources and was of value in defining injured population status and identifying potential constraints to recovery during the *Exxon* Valdez event. Secondly, this parameter can be used to assess if and how prey populations may have been affected by a spill.

Because sea otter prey can be easily determined by visual observations and most prey are sessile or of limited mobility, evaluations of the species composition, density and size distribution of many prey populations are practical. Declines in some sea otter prey (e.g., mussels and clams) were documented and attributed to the *Exxon Valdez* spill. Additionally, we have observed differences in the species, abundance and sizes of some sea otter prey between oiled and unoiled areas that have led to speculation regarding the status and potential constraints to recovery of affected sea otter populations. Without knowing how, or if prey populations differed among or within sites prior to the spill, or because of the spill, uncertainty prevails in interpretation of observed differences in prey populations between oiled and unoiled sites. Additionally, measures of benthic invertebrates would also fill a data need to evaluate community or "ecosystem" effects of the spill and endpoints for recovery of invertebrate populations.

5. <u>Age/sex specific fecundity, survival and home range sizes</u>.
Survival of juvenile sea otters was significantly lower in oiled compared to unoiled areas in PWS. Because of the potential confounding area effect we could not unequivocally conclude this resulted from the oil spill. Prespill data on this parameter, which appears to be a sensitive indicator of population status, would allow determination of a likely spill effect as well as provide an important variable for modeling population recovery and defining restoration endpoints.

Despite increases in the western PWS sea otter population of about 800 animals between 1993 and 1998, we have failed to detect any increase in abundance in areas where oiling was heaviest and mortality greatest. Reproduction and food appears adequate to support growth, therefore mortality (or emigration) may be elevated. Direct measures of survival are obtained through telemetry and would also provide estimates of home range size. If the carrying capacity of the habitat was diminished due to the spill, home range sizes may be predicated to increase (as observed in river otters) and reflected in lower population density.

Standard telemetry tools are available and tested and can provide accurate and precise estimates of fecundity, survival, and home range sizes; however, such studies are relatively expensive.

B. At spill data requirements (prior to oiling)

Regardless of the extent, if any, of studies prior to the time of the spill, the additional studies identified below should be implemented with the following objectives; 1) augment acute loss estimate, and 2) provide description and estimates of sub-acute and chronic effects of oiling and aid in determining restoration endpoints. In addition, if prespill studies were conducted they should be repeated at appropriate times and places to provide the necessary experimental rigor to defensibly ascribe effects to the spill (see post spill data requirements). Additionally, it may be possible to implement some aspects of the studies identified above in A. 1-3, after oil has spilled but prior to contact with sea otter populations. However, this would be a poor general strategy as it may be impossible to acquire any prespill data after a spill occurs.

1. <u>Capture and marking of individuals to estimate survival and carcass recovery rates</u>.
Marking of individuals potentially exposed to oil can provide estimates of survival and carcass recovery rates useful in determining overall effects and defining restoration endpoints. Marking

should include both a permanent visual (or electronic) aspect, a telemetry component, as well as biological sample collections.

2. Surveys and marking of beach cast carcasses.
Surveys and collection of sea otters that died and were deposited on beaches prior to the spill will allow accurate determination of the proportion of carcasses eventually recovered during and after the spill that should be classified as spill related. The ages of these dead, prespill animals can also be used in estimating spill survival rates (see A.2 above).

Other potential at spill activities may include the emergency pre-emptive capture of sea otters. It may be possible to actively capture and remove sea otters from the path of an encroaching spill. Although not a study to assess impacts or restoration, this activity may potentially reduce immediate spill effects. The potential for capture, holding and relocation effects should be considered. This activity has not been tested and may be applicable only under limited circumstances. However, given the relatively lower proportion of animals that survived following rehabilitation and release and the high cost of rehabilitating oiled otters, this strategy should be considered, and may benefit from development and testing prior to implementation.

C. Post spill data requirements (post oiling)

1. Carcass collections and marking and release of carcasses.
The collection of carcasses post oiling can provide a reasonable estimate of total mortality. However, data to address several assumptions in this procedure require the marking and release of carcasses. A systematic process for selecting carcasses for marking, marking methods, and release should be designed a priori. Carcasses not selected for marking and release should be collected for necropsy and tissue sampling to evaluate causes of death and a potential dose/response curve. Some common sampling of all carcasses, bth those marked and released and those selected for necropsy should occur.

2. Monitoring of age and sex specific measures of individual health.
Capture, marking, biological sampling and subsequent release of live sea otters during and following sub-acute exposure will provide a dose/response curve that will be valuable in assessing potential effects of exposure to oil

3. Instrumenting and releasing captured oiled otters.
A study designed to estimate survival of sea otters with varying degrees of external oiling would improve our understanding of the degree of oiling an animal can endure without immediate mortality. Additional similar study of surviving sea otters, following acute mortality, would also allow us to look at the long term survival of sea otters subjected to sub-lethal or residual oiling, as there are data suggestive of long term pathologies in sea otters that survived *Exxon Valdez* rehabilitation that are similar to those that died of acute exposure. In addition, these surviving otters appear to have reduced long term survival compared to non oiled animals. Evidence from the *Exxon Valdez* spill indicate survival may be the demographic factor limiting recovery of PWS sea otter populations.

Although not designed to determine oiling effects or restoration, the rehabilitation of oiled otters is a response that can compromise studies of spill effects by eliminating access to potential study animals. A thorough discussion of the pros and cons of this response activity is outside the scope of this paper. However, from a strictly biological perspective, the success of the past rehabilitation in terms of the relatively low proportion of animals that survived following release and the potential for introduction of disease into the wild population require serious review before this option is undertaken. Effects of this activity should consider relations to other assessment and restoration objectives.

D. The ecosystem approach

While temperate coastal marine communities are complex, the complexities may be better understood in this system than many others. This relatively good understanding, plus the spatial constraints, and limited mobility of many member species could facilitate a level of "ecosystem" study of damage assessment and restoration that might not be possible for other communities. Nonetheless, an "ecosystem" approach will likely still depend on estimates of composition, densities, productivity and status of selected species that comprise the system. In addition this approach will require understanding how those species are influenced by environmental conditions, biological productivity, and ecological interactions. The "ecosystem approach" should not be viewed as an easier path to damage assessment and restoration. The data required to satisfy this approach will still need to be collected prior to the treatment. The data identified under prespill data requirements (A. 1-4) above should meet many of the basic requirements of an "ecosystem approach" at least from the perspective of the sea otters as an important component of the community.

In 1996 sea otters were included in the Nearshore Vertebrate Predator ecosystem study to assess the status of recovery of the nearshore community in PWS. That work is in progress, nearing completion and incorporates many of the study components identified in this review that would be useful in assessing sub acute oil exposure effects and identifying restoration endpoints.

E. Restoration endpoints and activities

From the information collected under sections A-C above, we would likely have a reasonable definition of a “restoration endpoint” for sea otters. That endpoint could consist of a return to prespill density, distribution, and age/sex composition, projected from prespill population data. Additional endpoints could include age/sex specific survival, home ranges, individual health measures, bio-indicators, and energy budgets equivalent to prespill values (or adjusted for prespill trends).

Direct restoration of sea otter populations may be affected by several direct actions. Nearshore habitats were altered by oiling and response activities that resulted in reduced nearshore clam habitats and clam populations. If the prespill status of the habitat and were known (or could be inferred from known effects), it may be possible to actively restore habitat and some prey populations. In addition, human related mortality through the subsistence harvest can contribute to delayed recovery, particularly where mortality is limiting the recovery rate. Restoration may be enhanced by redirecting that portion of the mortality caused by hunting to unaffected areas.

A retrospective analysis

A diverse array of studies were initiated in the 10 years following the *Exxon Valdez* spill, most of which are encompassed in some way in the studies identified in A-C above. These studies include surveys of abundance, productivity, mortality, estimates of age/sex specific fecundity and survival, age and sex composition, carcass movement and recovery rates, oil exposure and measures of individual health (including blood and serum chemistries, bioindicators, sperm viability and body condition), foraging success, descriptions of prey populations and contaminant levels, assigning causes of death and development of an aerial survey method. The fundamental problems arose not necessarily with the data, or how they were collected, but with the comparisons we were able to make and thereby the inferences we could draw. Prespill data were available in only limited instances (mortality surveys, based on beach cast carcasses, shoreline skiff surveys). Thus imposing a study design requiring comparisons between affected and unaffected sites (without prespill data) and the assumption that the sites varied in no ways other than the oiling (a recognized invalid assumption).

During the damage assessment phase sea otter studies were apparently selected based on two criteria; 1) a probability of contributing to documented damages, or 2) in response to potential public perceptions. Initial planning efforts at the time of the spill included the capture and marking of sea otters to estimate survival and carcass recovery rates (see B.1 and C.3 above). Although initially approved by the agency, this project was soon suspended, and never implemented, due to potential negative public perceptions. Most studies that were approved and implemented, were completed at least to some reasonable endpoint. The Nearshore Vertebrate Predator study is nearing completion in 2000.

Despite the shortcomings imposed by an inadequate study design, the results of several sea otter studies were instrumental in damage assessment and eventually defining restoration endpoints. Those include the following; listed by category as most useful, useful, and least valuable relative to describing spill effects or restoration endpoints. The categorizations are not meant to assign values outside the context of the *Exxon Valdez* spill. Several of the "less valuable" studies are now valuable contributions to the primary scientific literature and would not most valuable contributions to improved responses and restoration in future spills assuming that prespill data are available. No ranking of value within category is intended.

Most Valuable

1. Carcass recovery. These studies provided an absolute minimum mortality estimate that was the foundation of at least 2 published total mortality estimates. The total mortality estimates provided a range of potential restoration endpoints and a second method independent of abundance surveys to estimate total mortality.

2. Carcass marking and release. This study provided our only estimate of the proportion of carcasses that were recovered, an essential component of a total loss estimate derived from the number of carcasses recovered. The recovery rate estimates could have been improved by increasing the sample size of marked and released carcasses and the geographic extent of the sampling.

3. Mortality surveys. This study provides good evidence of the value of pretreatment data, although data from a reference site may have increased the utility of the data. Beach cast sea otters were counted and aged for 10 years prior to 1989, providing a distribution of the ages of dying animals before the spill. Similar work after the spill provides a distribution of ages of animals dying after the spill. These two data sets have been used to estimate post spill age specific survival rates and describe how they differ from prespill rates. Direct measures of survival are possible through telemetry and avoid some assumptions required in t his modeling method.

4. Sea otter necropsies. These studies proved valuable in assigning cause and time of death to recovered carcasses, an important aspect in estimating total mortality. Moreover, these studies contributed new information of the pathologies suffered by sea otters exposed to oil. The data acquired may have been improved by processing carcasses prior to freezing (e.g., lung and bile for hydrocarbon analysis). In the event of a very large number of carcasses to necropsy, it may

be appropriate to sub sample.

5. Physiological and toxicological measures of oil exposure. These studies have allowed us to monitor the duration of injury, variation among individuals within a population, and return of affected populations to normal baseline conditions, based on comparisons to unaffected populations. These studies were compromised by the ability to measure exposure accurately but should be improved in future spills by improved techniques to quantify oiling.

Valuable

1. Skiff surveys of sea otter abundance. Sea otter surveys by skiff provide an index to abundance rather than an estimate of abundance. The index cannot be used to estimate the magnitude of change, but can detect trends in numbers over time. The use of the PWS skiff survey data to evaluate spill effects provides a good example of the effects of using data for a purpose it was not designed, in this case estimating spill mortality from trend data. Depending on the analysis, sea otter populations between 1984/85 and after the spill either declined by up to nearly 3,000 otters or increased by a small number. Nonetheless, these survey data do allow for evaluating trends in sea otter abundance in both oiled and unoiled areas, that can be used in defining restoration endpoints.

2. Hydrocarbon assays. Elevated concentrations of hydrocarbons were measured in sea otter tissues, but returned to within 1 year. Because vertebrates metabolize hydrocarbons, a bioindicator such as Cytochrome P4501A would have been valuable to look at in conjunction with tissue hydrocarbon values over time. Cytochrome P4501A assays were not implemented until 1996, and were observed to be elevated as recently as 1998.

3. Estimates of age/sex specific survival. Employee radio telemetry, these studies estimated survival and reproduction in sea otters from the spill area and from eastern PWS as well as reproduction and survival of rehabilitated and released sea otters. Although statistically significant differences were found in juvenile survival between areas, we could not exclude potential area differences, independent of the spill, from contributing to the observed differential survival rates. Overall the telemetry studies were extremely costly and were compromised by limits of study design. Some of the telemetry data were utilized in the development of population recovery models.

Least Valuable *(But only in the context of EVOS)*

1. Intersection model of mortality. This study provided an estimate of exposure and mortality along the Kenai Peninsula. This work contributed little to provide defensible mortality estimates but did provide a tool that should be valuable to future oil spill risk assessments.

2. Foraging behavior and hydrocarbon levels of prey. This study described foraging attributes of sea otters in an oiled and unoiled area of PWS. It provided suggested mechanisms of transport of residual oil to sea otters through prey, particularly among juveniles, but did not contribute significantly to damage assessment.

3. Bioindicator of genotoxicity. Early studies on bioindicators examined sperm cells for evidence of genotoxic effects. Similar methods had been used successfully on other mammalian species but applicability to sea otters under field conditions was limited by our ability to collect high-quality semen samples from the otters, and by the number of adult males

captured and samples.

4. Design and testing of an aerial survey method for sea otters. Prespill skiff surveys of sea otter abundance are biased to the extent they do not account for detection of diving animals or avoidance behavior, and only sampled a 200m shoreline strip. A new method was designed and tested that reduced these biases. Because comparable prespill data are not available, this work did not aid in damage assessment directly, but implementation and repeated surveys during recovery have aided in evaluating recovery.

5. Carcass drift study. Using radio telemetry and surrogate sea otter carcasses, this study attempted to describe patterns of sea otter carcass drift in PWS. Inferences to the spill were limited by study design, primarily uncontrolled space and time effects. A similar study implemented during a spill may be more useful.

6. Helicopter surveys of abundance. These surveys, initiated after the spill and conducted prior to, or concurrent with the spill, took place along the Kenai and Alaska Peninsulas and Kodiak Island. Post spill surveys were conducted in the fall of 1989. The results of the surveys provide our only recent estimates of abundance in some of these remote areas. These surveys identified non significant spill related declines in abundance; however, the precision of the estimates was low. Further, the survey method did not receive adequate research and development prior to implementation.

Conclusion

A diverse array of tools are available for evaluating effects of oil spills on sea otters, evidenced in work supported by the *Exxon Valdez* Trustee Council. Advances in population estimation, health assessments and bioindicators of oil exposure that resulted from the 1989 spill have increased the tools at our disposal. However, these tools cannot be skillfully or efficiently used if they are brought to bear only after the next tanker goes aground. Estimating acute mortality from oiling can be readily estimated by rigorous surveys of abundance and carcass mark recapture experiments. Estimation of population abundance, not an index, is required in advance of the event. Carcass mark recapture can be initiated at the spill, but requires advance planning.

Determining effects of sub-acute initial oiling or continued exposure to residual oil is more difficult, but ample evidence demonstrates that effects extend beyond the acute mortality phase. Those effects include, but may not be limited to; delayed recovery rates, organ damage, higher rates of mortality, and increased levels of exposure to residual oil. Accurately estimating chronic damage or restoration endpoints will be made possible only if the appropriate prespill studies have been completed.

Due to a lack of funds, throughout most of the spill area, as well as in most of the sea otter habitat in the north Pacific, we are little better prepared today for another *Exxon Valdez* than we were a decade ago. Because of the demonstrated susceptibility of this species to spilled oil it is important that we do not repeat past mistakes.

Following is a list of papers published after the Exxon Valdez that review or recommend sea otter study relative to oil spill planning and response.

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