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.

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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.

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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.

EVALUATION OF EVOS HARLEQUIN WORK

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.

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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 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.

In areas that will be 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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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

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