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DRAFT DAMAGE ASSESSMENT SUMMARY FOR COASTAL HABITATS AND AIR AND WATER RESOURCES - EXXON VALDEZ OIL SPILL

July 1990

Introduction

This document is intended to serve as a template to guide the discussions on 23-24 July among principal investigators, key management team members, selected principal reviewers and legal team representatives with interests in damages to coastal habitats and to air and water resources. The goal of that meeting will be to review and improve the structure of this draft document and then to provide information and interpretation necessary to complete an up-to-date revision of it.

The completed document is needed for two purposes. The primary goal of preparing such a summary is to provide technical liasson between the principal investigators and the legal team. The legal team requires technical overviews and encapsulated summaries of the damage assessment studies periodically to evaluate the strength of various lines of argument in support of the efforts to secure full and appropriate damages. The second purpose of preparing this document is to help the principal investigators develop and appreciate the broader context into which their damage assessment studies will fit, fostering recognition of the importance of gathering certain bits of information critical to the overall case.

This document is best understood by first reading the overview prepared on 17 May 1990 by Malins, Spies, and Simenstadt. That overview ("The Exxon Valdez Oil Spill: A Legal-technical Approach to Ecological Damage Assessment") provides the context and philosophy which guide the preparation of this document. The intent is to group results of damage assessment studies of coastal habitats and air and water resources into a single integrated overview as support for one of the main lines of argument in the legal case for recovery of damages. For sake of clarity, the intertidal and supratidal systems are separated from the subtidal in this presentation. Each summary includes a review of what is known about damages now and an indication of the timetables on which subsequent results will become available. Furthermore, the level of uncertainty associated with each main impact is noted.

Structure of each overview

For each system (the intertidal/supratidal, including air, and the subtidal,including water), the overview follows the same sequence of presentation of results:

1. **Nature of the resource system**
   * Description of the resources
   * Intrinsic value of component resources to human society

* Importance of component resources as human food
* Importance of component resources in key food chains

2. **Hazard to the resource system**
    * Nature of contaminants
    * Mass loading into the system
    * Toxicity of contaminants
    * Fate of contaminants-deposition, transport, transformation
    * Spatial and temporal distribution of contaminants

3. **Exposure of the resources**
    * Uptake and accumulation of contaminants
    * Metabolism and fate of contaminants

4. **Ecological damage assessment**
    * Observed changes in abundance
        a. Direct impacts
        b. Rate of recovery
    * Observed sublethal effects
        a. Growth and production
        b. Reproductive output
        c. Physiological abnormalities
    * Inferred damages
        a. Based on exposure, body burdens, and literature
    * Integrated impacts of mortality, sublethal effects, and inferred damages
        a. Evaluation of significance of total damages
        b. Uncertainties
    * Issues not well covered in present damage assessments

5. **Evaluation of restoration options**
    * Feasibility of alternative options
    * Benefits of alternative options
    * Costs of alternative options

<u>Present status of damage assessment</u>

Intertidal/supratidal habitats-including air resources

1. Nature of the resource system

<u>Description of the resources</u>

The intertidal habitat varies physically from steep rock cliffs to boulder and cobble fields to sand beaches and mud flats. Each of these physically different intertidal habitats contains a different community of resident organisms. Even within physical habitat type there is substantial variation in species abundance, diversity, and composition as a function of the influence of icemelt (salinity regime), wave intensity, exposure to storms, and other factors.

Physically stable rocky shores typically possess rich biological communities of attached microalgae, seaweeds, and a diverse suite of invertebrates. Along the relevant coastline of

Alaska, the most prominent members of this rocky shore community include the seaweed Fucus, blue mussels, barnacles, and a variety of snails, seastars, and crabs. Cobble fields are extremely rigorous and intensely disturbed environments characterized by impoverished biological communities composed of a subset of the species abundant on stable hard substrate. Sand beaches and mud flats are inhabited by marine invertebrates that live buried within the sediments, especially clams, polychaete worms, and amphipods. Within the relevant coastline of Alaska, three species of clams are especially prominent, Protothaca, Saxidomus, and Siliqua. In some physically protected areas, salt marshes occur on intertidal mud sediments. Because of the intensely energetic water movements over the intertidal habitat, caused by tides, waves, and other physical driving forces, these intertidal habitats are dominated by sessile invertebrates that make a living by filtering suspended algae from the water column. This is true both for the hard rocky shores (mussels and barnacles) and for sedimentary environments (clams).

The supratidal habitat varies also as a function of the physical environment. On steep rocky shores, the virtual absence of soils precludes development of abundant plant cover. In contrast, the plant communities behind cobble beach berms and landward of intertidal sand beaches and mud flats are quite well developed. Communities of grasses, herbs, and shrubs grade into forests in many loclities.

<u>Intrinsic value of the resource system to human society</u>

The intertidal habitats and supratidal habitats represent an important part of the majestic scenary that is Alaska. Even apart from the biota of these environments, these habitats have intrinsic value as natural unspoiled landscape. Some of the most valuable of Alaska's landscapes are in fact the intertidal habitats because these seashores, where the land and sea come together, are traditionally viewed by human society as some of the most inspiring and photogenic scenes of natural beauty on the face of the earth. Furthermore, in Alaska where road travel is limited, much of the sight-seeing is done by boat, exposing the shorelines to even more intense scrutiny. To invade this grandeur by smearing the shores with visually offensive blemishes as well as by violating the pristine biotic systems is to degrade and devalue the habitats of Alaska. This is a particularly serious violation in the National Parks, where the federal government holds responsibility for preserving the public trust rights to enjoy the unspoiled, unaltered natural ecosystems into perpetuity.

<u>Importance of component resources as human food</u>

Within the affected area, harvest of all three main species of clams (Protothaca, Saxidomus, Siliqua) occurs for human consumption. Such harvest includes both subsistence consumption by native peoples and sport shellfishing in many communities. Some limited consumption of mussels also occurs.

Importance of component resources in key food chains

Numerous species of the intertidal and supratidal habitats contribute in extremely important fashions to food chains leading to valuable consumer resources. The supratidal plant Elmius is important forage for white-tailed deer. The razor clam (Siliqua) is heavily harvested by brown bears on certain beaches. All three species of clams, but especially Saxidomus, represent a dominant fraction of the diets of sea otters. Blue mussels are also consumed intensively by sea otters, but their importance in both the food chains and in community consequences is even more far-reaching. Blue mussels are known to marine ecologists as "keystone species", species whose presence and abundance affects the structure of the entire rocky intertidal ecosystem. Blue mussels are the competitive dominants in this community and have the potential to monopolize all the surface space on the mid and low intertidal rocks by overgrowing, suffocating, and displacing all the other occupiers of primary rock surface. At the same time, these mussels form beds of interconnected individuals that provide stable interstitial habitat for a diverse suite of other smaller invertebrates such as amphipods, small crabs, and polychaetes that are absent in the absence of a well developed mussel bed. Consequently, alteration of blue mussel abundance has wide-ranging and fundamental effects on the entire rocky shore ecosystem. Finally, the intertidal algae have an important food chain role in that they provide the structural habitat necessary to promote growth of populations of many small crustaceans that are important forage food for numerous juvenile fishes. These shallow coastal habitats are nursery systems for the young of many fishes, promoted in large measure by the presence of abundant food nourished in algal beds like those created by Fucus.

2. Hazard to the resource system

Nature of contaminants

A technical description is needed here.

Mass loading into the system

Results are needed here.

Toxicity of contaminants

A technical description is needed here, focussing on known and inferred toxicity to marine invertebrates and algae not only via metabolic uptake but also via external deposition.

Fate of contaminants-deposition, transport, transformation

Results are needed here.

Spatial and temporal distribution of contaminants

Results are needed here. Maps of the distribution of oiling categories along the entire affected shoreline (lightly oiled, moderately oiled, heavily oiled) will be especially valuable, and need to be superimposed upon the most up-to-date map of habitat type distributions. For this summary document some calculations of the linear extent of coverage of each habitat type by each category of oiling within specific geographic areas (Prince William Sound, Kodiak area, Kenai area) should suffice.

No documented effect of the oil spill on air resources has been found in the study of air quality.

3. Exposure of the resources

<u>Uptake and accumulation of contaminants</u>

Results are needed here from analyses of mussel tissues and of clam tissues.

<u>Metabolism and fate of contaminants</u>

Information is needed here on the persistence of contamination in the tissues of blue mussels and clams. In addition, this is probably one place to summarize results of the temporal series of samplings of the shoreline, including sampling within interstices among rocks to describe the persistence of the oil in the intertidal and supratidal environments.

4. Ecological damage assessment

<u>Observed changes in abundance</u>

Direct impacts

To my knowledge, the damage assessment studies to date have no results showing negative impacts of oiling on abundance of any biological resource of the intertidal or supratidal habitats. In the case of the studies of intertidal environments, results of the first year of study are not immediately applicable to answer the questions of impact on abundance because of problems in locating suitable control sites. This should be solved by adding appropriate control sites in the current year's studies, hopefully in a fashion that also allows use and interpretation of the first year's efforts as well. In addition, some backlog of unfinished laboratory work needs to be processed. Results from tests of impacts of oiling on intertidal populations and communities are expected to be available on ????

Results to date in the supratidal demonstrate a likely enhancement of the standing stock biomass of Elmius, consistent with the literature. This may alternatively be viewed as favorable because of provision of added forage for deer or as unfavorable if the increased standing crop were a consequence not of higher primary productivity of the plant system in response to added nutrient inputs from either oil or bioremediation activities but instead of reduced deer grazing in response to avoidance of humans doing cleanup work. In either case, the alteration of the natural plant system may violate the policy of the National Parks Department to maintain pristine ecosystems. Will more information be provided on these issues in the present year's study and when????

To my knowledge, no result of the first year's clam study demonstrates negative effects of oiling on clam abundamce. This question was not tested with a powerful statistical design, so the absence of evidence does not imply absence of even large effects. Will any more results from the clam study bear on this question and if so when will results be available?????

Rate of recovery

Clearly, no data are available from the first year's studies on rate of recovery of abundances of intertidal populations when insufficient time had elapsed to initiate mutiple year sampling necessary to estimate recovery rates. When will such information become available??? for mussels and rocky intertidal biota in general??? for supratidal plant resources and possibly also plant communities???

This is the section into which results of the new iniative to address the consequences of cleanup activities should be placed. Cleanup of oil from intertidal rocks may have greater, additional, or different impacts from that of the oil deposition itself. A component of the present year's intertidal habitat study is intended to address some of these questions. These different effects of oiling and various cleanup alternatives on the abundances of intertidal biotic resources and on their rates of recovery need to be known both to evaluate the cumulative consequences of the Exxon Valdez oil spill and also to provide information that might aid in responsible decision-making about what cleanup responses should be initiated after future spills.

<u>Observed sublethal effects</u>

Growth and reproduction

Results on growth and reproduction of intertidal resources are unavailable at this time, to the best of my knowledge. Data on how oiling affected growth of Protothaca and perhaps other clams (?) are due when??? Will similar data be available for mussels??? on what time schedule???

Reproductive output

The only currently available result with which I am familiar on how oiling affected reproductive output of an intertidal or supratidal organism is a data set suggesting reduced reproductive output of mussels in oiled areas. What is the magnitude of this effect and what are its implications????

Physiological abnormalities

Are there any results for this category??? The only results that I am aware of are some as yet unsubstantiated reports that Fucus in the vicinity of heavily oiled shores possessed a poor appearance and may have been exfoliating.

Inferred changes

Data should become available on the petroleum concentrations in mussel tissues and in clam tissues. These data may be useful in building an argument concerning the likely physiological and population level effects. In addition, this contamination of tissues is passed up the food chains and may be harmful to both human and wild animal consumers. When will these body burden data be available??? for mussels??? for clams???

Integrated impacts of mortality, sublethal effects, and inferred damages

Evaluation of significance of total damages

The data presently available do not support a desired effort to integrate all component effects into a depiction of cumulative damages. The only strong argument presently supportable is the case for widespread damages to the physical habitat itself by degrading the pristine natural environment of the intertidal and supratidal shoreline of Alaska. In addition, the tissue contamination of clams utilized by subsistence peoples and by recreational shellfishermen represents a definable harm that should form the basis for a modest penalty.

Uncertainties

There is relatively little uncertainty associated with the data on the extent of oiling of the intertidal and supratidal habitat itself. Beach walk information provides relatively unassailable evidence of the presence of oil along vast stretches of the affected coastline. These on-site observations are complemented by airplane observations for inaccessible areas. Are there data available to compare these two types of observation to control for possible biases in methodology??? There is a problem of changing levels of oiling over time as new accumulations are deposited from the sea and as previously deposited accumulations are transformed and transported. Nevertheless, there is no doubt that the maximum extent of oiling is at least as high as that observed at any given site.

Statistical uncertainty associated with data on body burdens of chemicals is typically low. Is this also true for the mussels and clams of these studies???

Issues not well covered in present damage assessments

Ecosystem level responses

It is conceivable that the major impact of the oil spill is to fundamentally alter the broader ecosystem. The damage assessment studies funded by Exxon and under CERCLA address relatively simplistic direct effects usually on individual species. Ecology as an academic and scientific discipline has advanced to the point where it is quite clear that indirect effects often operating through food chain interactions make tremendous contributions to the response of ecological systems to perturbation. Some of these system-level responses can even involve displacement of the system into an alternative stable or quasi-stable state from which return to pre-perturbation status is difficult. None of these more complex and realistic processes is being evaluated by present studies.

Biodiversity and rare species

Present damage assessment studies focus upon the common species in the ecosystems. It is quite clear that society places value on biodiversity, as evidenced by the substantial efforts now in place to arrest the extinctions occurring in the Amazon and other tropical rainforests. It is quite possible that the Exxon Valdez oil spill altered the biodiversity of component ecosystems of the Alask coast, but no study is evaluating this possible scenario.

Effects implying need for habitat acquisition

For rare species or species under severe exploitation pressure, it is conceivable that acquisition of natural habitat would be an appropriate means of promoting recovery of those resources over a broader area. This possibility of creating broodstock sanctuaries has not been fully explored.

5. Evaluation of restoration options

Feasibiity of alternative options

The most feasible restoration option for damages to the intertidal and supratidal resources is the scattering of spores of Fucus in those areas where it has been affected by the spill. Fucus is a species whose propagules are not widely dispersed by natural processes so that damage to Fucus over any extended area carries with it the possibility that recovery to pre-damage levels may require a long time in the absence of restoration. An alternative to the scattering of spores would be to import clumps of whole, fertile plants into each affected area for the same purpose of promoting more rapid spread into the area. No other restoration option has been identified at this time to mitigate for harm to intertidal or supratidal biological resources.

The physical intertidal habitat has already experienced one form of restoration in that various cleanup activities have been applied already. This cleanup of the physical habitat may have enhanced biological impacts of the spill and may require added biological restoration efforts as a consequence, but no evidence is yet available to assess this possibility. Oil is still present in the intertidal zone especially in pockets and interstices between boulders and cobbles. This may require further action to restore the physical habitat to its pre-spill condition.

<u>Benefits of alternative options</u>

Promotion of more rapid return of Fucus is beneficial because of the limited natural dispersal of its spores. In addition, Fucus plays an important role in the provision of habitat for many associated species of small crustaceans and other invertebrates that find shelter, substrate for attachment, and food in the Fucus plants. These species of smaller invertebrates are responding largely to the structural complexity that Fucus adds to the otherwise two-dimensional rock surface. These smaller invertebrates are critical forage resources for the many species of fishes that utilize the shallow vegetated environments as a nursery. Consequently, restoration of Fucus promotes restoration of an entire food web of importance to Alaskan fishery resources.

<u>Costs of alternative options</u>

Information is needed here but probably cannot be fully provided until the extent of damage to the Fucus is documented.

Subtidal habitats - including water resources

1. Nature of the resource system

<u>Description of the resources</u>

The subtidal habitats are comprised of a complex of diffferent seafloor environments. The biological resources and even entire communities of biota change dramatically with changing subtidal environment. The key physical variables that control the type of biological resources present in subtidal seafloor habitats are water depth and substrate character, which itself is largely dictated by the physical flow environment at the seafloor.

In shallow subtidal areas, seafloor communities range from those on rocks to those on sediments. Shallow subtidal rocks contain benthic communities similar to those present in the intertidal zones of those same shores, differing in that seaweeds, clonal animals, and predators are usually much more prominant in the subtidal zone. Shallow subtidal sediments harbor a biota that varies as a function of energy regime and sediment size. In physically quiescent substrates, characterized by fine muddy sediments, eelgrass beds can flourish. Such seagrass beds contain high abundances of infaunal invertebrates (those buried in the sediments, such as polychaete worms and clams and snails) as well as epibiotic microalgae and invertebrate animals (those attached to the grass surface or moving around above the seafloor, such as many amphipods, small shrimps, crabs, and some snails). Sedimentary communities in more physically energetic shallow environments are characterized by coarser sediments, sands with varying contributions from cobbles and small rocks. These physically rigorous, shallow subtidal environments provide habitat for suspension-feeding invertebrates such as some species of clams.

In deeper subtidal environments, the bottom type still continues to exert a controlling influence on the biotic community present. In relatively quiescent areas of the deeper seafloor, finer sediments are deposited and not eroded away. Such environments are typified by high levels of organic content in the sediments and benthic invertebrate communities dominated by deposit-feeding animals that make a living by injesting the sediments themselves. In more physically energetic habitats, the deeper subtidal seafloor is composed of sandy sediments, which are characterized by invertebrate animals that make a living by extracting organic particles from the water flows moving over the bottom. Under even more energetic environments, the deeper seafloor can be composed of cobbles or even stable rock surfaces, which are likewise occupied by suspension-feeding invertebrates, although by attached epibiotic forms rather than by the mobile, usually infaunal species of sandy seafloors.

Little needs be said about the nature of the water resource itself. Water quality is the life blood of a healthy marine ecosystem. It bathes and nourishes all marine organisms, serving as the vehicle that transports food to and wastes from marine organisms. Within the marine aqueous environment, there is no closed system because diffusion locally and advection broadly interconnect all localities and transport materials among them. Water quality standards for salt waters containing shellfish are even more stringent than those for human drinking water sources, in recognition of how suspension-feeding shellfish concentrate materials in their tissues during a feeding process that passes immense volumes of seawater through the filtering apparatus of the animals. The pristine clarity of Alaskan waters can be viewed as a part of the public trust to be protected indefinitely.

<u>Intrinsic value of component resources to human society</u>

Because of the prevailing clarity of Alaskan coastal waters, some elements of the subtidal habitat and biota are visible and contribute directly to the scenic value of Alaska. The clear, clean water itself represents a resource of societal value directly in that its pristine clarity is an important component of the Alaska experience that attracts millions to tour the state. Most of the subtidal biota, however, lies out of sight and has value to human society through its contributions as food or to food chains of significance.

Importance of component resources as human food

At extremely low tides, some of the subtidal clam resources become accessible to human harvest. These resources (Protothaca, Saxidomus, Siliqua) are exploited predominantly by native Alaskans in the shallow subtidal sediments. Some limited consumption of shallow subtidal mussels from rocky shores may also occur. The most important food resources for humans that are part of this subtidal benthic ecosystem are almost certainly the exploited crustaceans: crabs (Tanner, Dungenness, Red, King) and shrimp (Spot, etc).

Importance of component resources in key food chains

As in the intertidal habitat, there is tremendous importance of biological components of this subtidal habitat in important food chains. The subtidal clam resources are preferred prey for sea otters to such an extent that availability of abundant clams untainted by toxins from noxious dinoflagelate blooms has been shown to dictate the spatial distribution of sea otters in Alaskan coastal waters. To some limited degree, the mussel assemblage described for the intertidal habitat extends into the subtidal zone on rocky shores, so the same comments made earlier apply here. The shallow subtidal zone includes large beds of submerged macrophytic vegetation that serves a key role of providing the physical structure and habitat that promote development of high productivity of small grazers. These grazers, such as amphipods, crabs, gastropods, small shrimps, and fishes, serve as prey for juveniles and adults of commercially and recreationally important finfishes. Shallow vegetated habitats are widely acknowledged for their importance as nursery habitats for the broader coastal marine ecosystem. In the spill area, these include some limited areas of eelgrass (Zostera) in protected sedimentary embayments and large expanses of the macroalga Ascophylum on rocky shores. Finally, the vast areas of subtidal seafloor habitat in coastal Alaska represent the feeding grounds for demersal bottom-feeding fishes and for benthic crustacean stocks. The small polychaete worms, the molluscs, and probably especially the amphipods of this vast seafloor habitat are the food link between the primary producers and the predators high in the food chain upon which human harvest is focussed. Elimination, reduced growth and productivity, or contamination of these benthic invertebrate resources of the seafloor has wide-reaching implication for the coastal food chains of Alaska.

2. Hazard to the resource system

Nature of contaminants

A technical description is needed here, presumably the same as that needed in the section for the intertidal habitat.

Mass loading into the system

Results are needed here.

Toxicity of contaminants

A technical description is needed here, including the toxicity of various weathering products of crude oil to reflect our assumption that over time petroleum components and derivitives will be transported seaward and deposited with particles on the subtidal seafloor, where they then enter the subtidal food chains through consumption by benthic invertebrates.

Fate of contaminants-deposition, transport, transformation

Results are needed here. This section should include the results of the extensive evaluations of the uptake of petroleum by suspension-feeding invertebrates in this habitat. These data from mussel tissues and to a lesser degree from clam and scallop tissues contribute in an important way to our knowledge and understanding of the extent of pollution of the water because these suspension-feeding bivalves are extremely efficient biofilters that integrate their water sampling over extensive intervals of time.
When will these tissue contamination data become available???

Spatial and temporal distribution of contaminants

Results are needed here. These should include information on the extent and time course of transport of the oil when visible as a surface comamination. This is one obvious minimal estimate of the extent and scope of surface water pollution. This section should also include some estimates or measures of the extent of transport of petroleum and its derivatives into the subtidal seafloor habitat and its likely residence time.

3. Exposure of the resources

Uptake and accumulation of contaminants

Results are needed here from analyses of mussel tissues especially, but also from analyses of clam, scallop, spot shrimp, crab, and all other demersal and benthic species sampled for analysis of tissue contamination. Some preliminary results demonstrate presence of petroleum contamination in the body tissues of spot shrimp, clams, and several demersal fishes. When will additional results be available???

Metabolism and fate of contaminants

Information is needed here on the persistence of contamination in the tissues of mussels, clams, spot shrimp, and all other species in which contamination has been detected. A complete analysis would involve an understanding of the degree to which continued contamination is a consequence of re-exposure to persistent contamination in the environment versus slow depuration or metabolism of already incorporated contaminants. This section might also include a time series data set with accompanying analysis and interpretation of tissue contamination of mussels as a means of assessing how long the oil contamination is persisting in the water resource itself at concentrations that are biologically meaningful.

4. Ecological damage assessment

Observed changes in abundance

Direct impacts

The subtidal studies were slow to start in the first year, so little indication existed prior to the current field season of whether impacts would be detected on abundance of subtidal biotic resources. The only documented effect on subtidal biotic resources with which I am familiar is a set of observations of widespread mortality of mobile epibenthic invertebrates within a heavily oiled embayment. This embayment was characterized physically by the presence of a sill that would restrict circulation and may serve to concentrate the petroleum in some fashion. The subtidal studies of the second year were to have included examination of additional silled embayments to evaluate how widespread the phenomenon may be. A major concern with the subtidal studies of direct impacts on abundance involves the issue of whether effects will still be detectable so long after the spill. When will results be available???

Rate of recovery

In the absence of information on initial effects of the spill, there is clearly no information on how long effects persist. A component of this second year's study of subtidal habitats is designed to address how the subtidal benthic community responds to and recovers from both the oil apllication and also the cleanup activities. Evaluation of such cumulative consequences of the Exxon Valdez oil spill is important for developing informed management responss to future spills.

Observed sublethal effects

Growth and reproduction

Results on studies of growth and reproduction of subtidal biotic resources are lacking at this time, to the best of my knowledge. Will any study provide such information??? on what schedule???

Reproductive output

The only currently available result with which I am familiar on how oiling affected reproductive output of a subtidal organism is a data set suggesting reduced egg production of spot shrimp. Has this suggested effect been substantiated??? Are any other tests of reproductive impact in progress??? with what expected date of completion???

Physiological abnormalities

Are there any results in this category??? any tests in progress???

<u>Inferred changes</u>

Data should become available on the petroleum concentrations in tissues of clams, mussels, scallops, spot shrimp, various crabs, and several demersal fishes. Such data may be useful in building an argument concerning the likely physiological and population-level effects. In addition, human consumers and predators higher up in the food chains are exposed to these levels of contamination of food resources. When will these body burden data be available???

<u>Integrated impacts of mortality, sublethal effects, and inferred damages</u>

Evaluation of significance of total damages

The data presently available could support a contention that the oil spill has been widely injected into the food chains of marine systems over substantial areas of coastal Alaska, including places quite separated from the coastline itself. The presence of contamination in the tissues of spot shrimp and demersal fishes from relatively deep water demonstrates the rapid spread of contamination of biotic systems. Furthermore, the presence of contamination in tissues of mussels, clams, and scallops provides a measure of the degree to which the water itself was polluted in a fashion with a biological context. This contamination includes tissues of species taken for human consumption, so that complete evaluation of costs should include estimates of any human health effects of such contamination as well as economic impacts of markets depressed by rumor of Alaskan seafood contamination. The more wide-reaching ecosystem impacts and impacts on population processes cannot be addressed without additional information. On what timtable will such information be forthcoming???

Uncertainties

The limited amount of data presently available renders a complete examination of the statistical uncertainties premature, except to the extent that proper statistical designs must be decided a priori to insure adequate power of tests. Variability in the body burden data could be examined now. For mobile animals there will of course be some uncertainty associated with where contamination was picked up. This will cloud somewhat the arguments made about the geographical extent of the spread of the oil, but the sediment sampling programs will be important in this context. These sediment sampling programs are likely to be quite conservative because the use of grabs to collect sediment samples has the consequence of not completely sampling the floculent surface layer most likely to become contaminated in subtidal habitats. This too injects some uncertainty in the estimate of the extent of contamination of sediments.

Issues not well covered in present damage assessments

Ecosystem level responses

It is conceivable that the major impact of the oil spill is to fundamentally alter the broader ecosystem. The damage assessment studies funded by Exxon and under CERCLA address relatively simplistic direct effects usually on individual species. Ecology as an academic and scientific discipline has advanced to the point where it is quite clear that indirect effects often operating through food chain interactions make tremendous contributions to the responses of ecological systems to perturbation. Some of these system-level responses can even involve displacement of the system into an alternative stable or quasi-stable state from which return to pre-perturbation status is difficult. None of these more complex and realistic processess is being evaluated by present studies.

Biodiversity and rare species

Present damage assessment studies focus upon the common species in the ecosystems. It is quite clear that society places value on biodiversity, as evidenced by the substantial efforts now in place to arrest the extinctions occurring in the Amazon and other tropical rainforests. It is quite possible that the Exxon Valdez oil spill altered the biodiversity of the Alaska coast, but no study is evaluating this possible scenario.

Effects implying need for habitat acquisition

For rare species or species under severe exploitation pressure, it is conceivable that acquisition of natural habitat would be an appropriate means of promoting recovery of those resources over a broader area. This possibility of creating broodstock sanctuaries has not yet been fully explored.

5. Evaluation of restoration options

Feasibility of alternative options

If eelgrass beds are shown to have suffered damage from the Exxon Valdez oil spill, then restoration could include artificial reestablishment of eelgrass beds in the sites where damage occurred. Much research has been conducted on restoration of eelgrass beds, and while some major questions still exist concerning the longevity and function of transplanted seagrass beds a substantial body of knowledge and past experience is available to guide such restoration efforts in coastal Alaska. Another feasible restoration option for subtidal habitats is the establishment of artificial reefs to promote the population growth of various fishes. This alternative would seem to make most sense where natural hard bottom habitat is limited. In Alaska, the addition of more hard substrate would seem to offer an almost negligible incremental addition of such a resource.

If sediment contamination appears to be quite persistent, then one might ask the question of whether any restoration possibilities exist. If the contamination is widespread covering large areas of the subtidal seafloor, then it is difficult to envision any feasible means of providing restoration. If, on the other hand, there are certain hot spots of persistent intense contamination, then it may be possible to restore the sedimentary environment by burying the contaminated sediments and thus rendering them unavailable to the biota. This might be feasible on a small scale.

Benefits of alternative options

The motivation for establishing new seagrass beds by employing transplants is that seagrass spread by seed can be slow, whereas spread vegetatively by lateral extension of the root and rhyzome system is relatively rapid. Promoting rapid recovery of functioning seagrass beds is beneficial because of the extremely important role that they play as nursery habitat for so many marine animals.

The benefits of burial of contaminated sediments are created by removal of those sediments from the sea surface, where they are available to marine animals. Sediments buried deeply enough will not invade food chains. Furthermore, if the contamination is rendered less toxic during the period of burial, then ultimate exposure of the contamination to organisms will be less harmful than immediate exposure.

Costs of alternative options

Further information is needed here.

Charles H. Peterson
Principle Reviewer