Proceedings, 8th Symposium on Coastal & Ocean Management, Coastal Zone '93, Vol. 2: 1278-1287, ASCE

Injury Determination and Quantification

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Abstract

Several different approaches for injury determination and quantification are discussed within the framework of the natural resource damage assessment process. The basic concepts and terminology of the regulations are defined and examples of natural resources and injuries are given. The importance of demonstrating a pathway from the oil or hazardous substance release as well as showing that the resource has been exposed to the contaminant of concern is explained. The limitations of science in demonstrating cause-and-effect due to such extraneous factors as temporal and spatial variability of natural-occurring events and deviations from normal patterns is explained. The importance of recoverability, i.e., the time needed for natural recovery is discussed within this context. To synthesize, we have attempted to structure the scientific basis of injury determination and quantification within the legal framework concerning standards of proof.

Introduction

According to the Natural Resource Damage Assessment Regulations promulgated by the Department of Interior, (43 CFR Part II), it is the responsibility of the natural resource trustees to establish that an injury to natural resources has occurred and that the injury resulted from the discharge of oil or release of hazardous substances. Usually a discharge of oil comes from accidental spills over finite periods of time that are clearly defined. Because the time scale is so compressed and the exposure so ephemeral, it is often difficult to quantify where the oil has been and the resulting effects. Effects of catastrophic spills like the *EXXON VALDEZ* are easily visualized, but it is often difficult to measure specific injuries and quantify them (Spies, 1993). In contrast, releases from contaminants in sediments are generally low-level, long-term, and difficult to quantify, but with the same potential

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for catastrophic injury to trust resources as accidental spills. Since many hazardous substances are so persistent and widespread, their effects can be more widespread and more long-term than single event spills.

Statutory and regulatory language often differ from conventional usage. Likewise, many of the concepts used in the NRDA process differ from conventional paradigms. It is therefore essential that these concepts and terms be clearly defined before explaining the process of injury determination.

According to the regulations (CFR 43 Part II, §11.14), natural resources can be divided into five broad resource categories; surface water, ground water, geological, air, and biological resources. Surface water resources include both sediments and the entire water column. Ground water resources cover water in a saturated zone or stratum beneath the surface of the land and the rocks or sediments through which ground water moves. Geological resources include elements of the earth's crust such as soils, sediments, rocks, and minerals including petroleum and natural gas. Air resources refer to those naturally-occurring constituents of the atmosphere, including those gases essential for human, plant, and animal life. Biological resources can be viewed as any living organism.

According to the law and regulations (43 CFR Part II §11.14), *injury* refers to a reduction in viability of natural resources demonstrated by a measurable adverse change. The terms destruction and loss are interchangeable with the term injury. *Destruction* means the total and irreversible loss of a natural resource. *Loss* means a measurable adverse reduction of a chemical or physical quality or viability of a natural resource. In the regulatory context then, natural resource injuries are associated with an adverse change caused by the discharge of oil or release of a hazardous substance. Specific injuries are discussed later. The public and many scientists are more familiar with the common use of the term *injury* to mean damage to a person or property such as a natural resource (Merriam-Webster, 1990).

Similarly, in common usage, the noun *damage* (Merriam-Webster, 1990) refers to a reduction in usefulness or value of a person or property such as natural resources. The verb *damage* means to cause injury or harm. In the law and in the regulations however, the term *damages* refers to money claimed or paid as compensation for injury or loss of natural resources. Monetary damages are sought by the trustees to restore the injured resources and to compensate the public for lost services that would have been provided by the injured resource.

Injury Determination

There are several key elements necessary for proving injury and determining that the injury was caused by the release of oil or a hazardous substance. First, it must be established that an injury has occurred. According to the definition in the regulations (CFR 43 §11.14) the measurable change must be adverse. Since its trust responsibilities center around marine organisms and their habitats, (i.e., surface waters), NOAA is primarily concerned with biological injuries and surface water injuries. These categories of injury are discussed below. A complete discussion of injury criteria for every resource category is beyond the scope of this paper.

DOI Regulations. The DOI regulations set forth strict criteria providing guidance on determining injury. By establishing criteria, the regulations offer clear concepts of measurable adverse change. Specific biological responses must be correlated to the effects from oil or the hazardous substance. Biological responses are the end point of either studies or observations which confirm exposure and injury. For example, eggshell thinning is a well-known adverse biological response to populations of birds exposed to the pesticide DDT and its metabolites. To demonstrate injury attributable to DDT, trustees must show that eggshells are 15% thinner than a control sample or a museum specimen collected in the same geographic area prior to 1946. This is but one example of the criteria provided for biological injuries. Each of the natural resource categories have similar criteria.

Surface Waters Resources. Water is considered injured if it cannot be used in the usual way to support normal populations of aquatic life, as a drinking water supply, or for recreational or other public purposes. Sediments are considered injured if they cannot be used in the usual way to support normal populations of aquatic life. In terms of biological resources, the surface water is considered injured if it cannot serve as a normal functioning habitat. The other two uses apply to human use value.

To demonstrate a surface water injury, it is necessary to compare the injured water quality characteristics to water quality criteria established by State or Federal regulations under the Clean Water Act (CWA). These regulations require that the surface water meet physical, chemical and biological characteristics to achieve specific designated uses (e.g., swimming, drinking water, fishing, etc.). If the criteria are not met, the water is considered injured.

Sediments do not currently have Federal quality criteria for oil or hazardous substances. The EPA however, does have five proposed sediment quality criteria (i.e., acenaphthene, dieldrin, endrin, fluoranthene, and phenanthrene, (EPA a-e, 1991)) for the protection of benthic organisms . The first sediment management standards to be adopted by a state (Washington, 1991) are based in part on the approach used by EPA Headquarters. The State of Washington uses empirical chemical and biological guidelines to define a "no effects" goal for long-term sediment quality. The lack of standards and uncertainties associated with any particular evaluation approach has led many scientists to advocate a sediment quality triad approach to the assessment of sediment quality (Long & Chapman, 1985). This would include synoptic measurements of bulk sediment chemistry, laboratory bioassays and benthic community effects. It has recently been suggested that field bioassays also be included in assessments of sediment and water quality (Salazar et. al., 1995).

It is important to note that when collecting water quality data to demonstrate injury or any other type of data, trustees must strive for litigation quality. There are commonly accepted procedures to achieve these high standards that are referred to as quality assurance and quality control. Protocols for collection and analysis of water samples are normally referenced in water quality regulations and should be followed. Poor quality data can jeopardize an otherwise sound NRDA investigation.

***Biological Resources**.* Biological resources are considered injured according to the regulations, if the discharge of oil or release of hazardous substances is sufficient to cause the biological resource or its offspring to have undergone at least one of the following changes in viability: death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction) or physical deformations; or exceed Federal action or tolerance levels or exceed levels for which an appropriate State health agency has issued directives to limit or ban consumption of such organism.

Biological resources are described in the regulations as any living organism. In many cases, injuries to biological resources are more complex than surface water, ground water or geological resource injuries. Death is the most obvious biological injury. To demonstrate injury, five different methods that use death as the critical biological response are specified in the regulations (43 CFR Part II). These are: a 50% reduction in brain enzyme activity, fish kills, wildlife kills, *in-situ* bioassays, and toxicity testing. However, death is not a sensitive measure of effects. Other more sensitive categories of biological injury categories are disease, behavioral abnormalities, cancer, genetic mutations, physiological mutations (including malfunctions in reproduction) or physical deformations.

As with drinking water, there are regulations which govern the quality of the fish we consume that can be applied to NRDA injury investigations. Concentrations in the edible tissues of organisms which exceed Federal action or tolerance levels are injuries. Similarly, if a State health agency has issued directives to limit or ban consumption of such organisms based on sound data, this too constitutes an injury.

***Exposure and Pathway**.* Two components of the injury included in the injury determination process are exposure and pathway. The regulations require trustees to demonstrate both. The route or transport medium the oil or hazardous substance traveled from the source to the injured resource establishes the pathway. To demonstrate exposure, the trustees must show that the oil or hazardous substance, or its transport medium, came into direct contact with the natural resource.

Empirical observations and documentation are often sufficient to demonstrate both of these requirements. One example might be oiling of birds during a spill. At a minimum, collection of oil samples from both the source and impacted areas are needed to establish that the oil spilled is the same type of oil found in association with the injured resource. The technique used to confirm this is referred to as oil fingerprinting (Overton, et al., 1981). It should be noted that collection and storage of oiled wildlife may be needed for physical evidence.

If the assessment area is large and the ecosystem complex, a more detailed pathway must be established from the release of oil or hazardous substance to the injured resource. This is commonly accomplished by documenting the presence and concentrations of oil and/or hazardous substances in surface water resources and the presence and concentrations of similar substances in the injured biological resources.

In the *EXXON VALDEZ* oil spill assessment several methodologies were used including collecting samples of oiled birds and mammals as well as measuring bioaccumulation of oil in the tissues of several different species from the assessment area (Shigenaka & Henry, 1993; Short & Rounds, 1993; Babcock et al., 1993). These studies were able to demonstrate that transplanted mussels accumulated petroleum hydrocarbons rapidly and were bioavailable below the surface as particulate oil. This approach demonstrated a potential pathway for other resources at risk, estimated the exposure concentration in seawater, and defined horizontal and vertical concentration gradients. More controlled laboratory experiments with mussels were used to predict exposure concentrations of the oil more accurately (Mehl & Kocan, 1993). Similarly, transplanted mussels have been used to show a pathway associated with contaminated sediments at a Superfund Site (Salazar et al., 1995). Chronic discharges of contaminants at low concentrations pose unique challenges in demonstrating pathway and exposure that require innovative manipulation and experimental control in the field such as may be afforded by mussel transplants (Salazar and Salazar, 1995). The trustees must also recognize and address issues such as bioaccumulation, bioconcentration, and biomagnification in pathway and exposure investigations.

Injury Quantification

The trustees are also responsible for quantifying the effects of the discharge or release. This is usually calculated in terms of the reduction from the baseline condition in the services with special attention to the quantity and quality of services. These calculations must be made for each resource determined to be injured. Historical data is traditionally used to establish a baseline of services. In combination with biological resources, spatial and temporal data for surface water resources can be used to construct scenarios of areal extent of injury to habitats and populations for specific time periods. The potential for natural recovery must also be assessed.

Historical Data. Injury quantification begins with historical data. Biological populations which have been well-studied and documented, or other resources that are regularly monitored, provide valuable baseline data. Conversely, establishing baselines for resources located in remote locations that have not been documented or have been infrequently monitored is more difficult.

Historical data must be scrutinized by the trustees as quantification proceeds. In most cases, trustees will need additional information to fill information gaps. The experimental design for collecting these additional data must be scientifically valid, have gone through a peer review process and include a plan that assures strict adherence to quality assurance and quality control so the data will be admissible in court. Often, techniques for sample collection, chemical analysis and statistical analysis have changed or improved since the original data was collected. In these cases, the trustees must strive for comparability between old and new data and additional work may be needed to evaluate the differences in the data. Local and regional entities, (i.e., universities, nature preserves and reserves, parks and museums) often have considerable information that should not be overlooked by the trustees.

Spatial and Temporal Variability. Spatial and temporal data covering the assessment area are important in injury quantification. Large assessment areas involving multiple contaminants and multiple species typically vary in both categories. Several factors contribute to the spatial variability of data in large assessment areas. Sampling data in sediments or other resources is patchy. Further, a homogeneous mixture of contaminants is the exception rather than the rule. Hot spots and "no detects" are present throughout the assessment area. Multiple inputs of hazardous substances, whether point or non-point sources must be considered as well. Natural and human transport mechanisms contribute to contaminant mobility. Dredging, leaching, runoff, current patterns, and erosion are just a few transport mechanisms that result in patchy data.

Temporal variability of quantification data results from just as many factors as spatial variability. Concentrations of a hazardous substance may be low at a particular site for a period of time and then increase significantly several weeks later. Seasonal weather changes, wet and dry seasons and even normal variability, are easily attributable to a situation as this. Biological sensitivity to hazardous materials can also be affected by temporal variability. Similarly, sensitivity can also vary depending on the time of the year. Under the stress of reproduction, for example, adults may become much more sensitive to the stress of contamination. Adult and juvenile populations often differ in sensitivity to the same contaminant. Although it is generally assumed that juveniles are more sensitive than adults, this is an oversimplification. Adults may be more susceptible to a contaminant than juveniles or vice versa. Migration is also an important consideration Entire populations move into and out of ecosystems every year and add another level of complexity.

***Recoverability**.* The time needed for natural recovery must also be addressed as part of the quantification process. Recoverability is defined as the ability of a resource to return to pre-spill or release baseline conditions expressed as time (43 CFR Part II). A small injury to a population, one less than natural variability, that is expected to recover in one reproductive cycle is considered to have a high recoverability. Devastating injuries that affect a significant percent of the population, that will take many of generations to recover, may result in no recoverability.

Any unusual climatic anomalies, such as unusually wet or dry seasons, influence the amount of runoff into environments. These data are often not readily available for quantification. Varying sensitivities among biological resources can make a minor problem appear large and vice versa. These data are not usually available to trustees either. Effects of particularly warm water currents like the El Niño can have significant bearing on the health and abundance of marine animals in the vicinity. The effects of natural factors are an important component of establishing injury. The effects of man-induced factors such as dredging, filling, and diking are also important to assess when attempting to discriminate between the effects of natural factors, man-induced factors, and the effects of hazardous substances or oil.

Causation

We have previously identified that the basic goal of injury determination is to determine whether injury to natural resources has occurred. However, the standards of evidence differ between science and the law because the underlying objectives differ (Cranor & Nutting, 1990). Similarly, the level of proof is different among scientists and litigators. By tradition, scientists commonly use the standard of 95% confidence which is based on the statistical criterion of rejecting the hypothesis being tested if there is only one chance in twenty that the observed outcome occurred by chance alone. The overall legal standard of proof is the *preponderance of evidence* standard which is usually considered to be 51%. To prove injury to natural resources in court, it must be demonstrated more likely than not that the injury occurred and that the oil or hazardous substance was a substantial contributing factor to the injury. This means that it should be adequate to show that the injury was observed in the assessment area, it was elicited in laboratory studies by the introduction of the contaminant in question, and that the injured resource was exposed to the oil or hazardous substance in the assessment area by demonstrating presence of the contaminants of concern in the tissues of exposed biological resources that were injured. This should constitute proof of cause-and-effect in the litigation context.

For purposes of injury determination, it is not necessary to show that other contaminants or other natural factors could cause the injury but only that the oil or hazardous substance in question is more likely than not to have contributed to the causation of the injury. Furthermore, it is appropriate for the courts to decide the issue of causation based on a preponderance of the evidence and expert testimony. In lieu of statistically significant evidence or conflicting evidence that is statistically significant, it may be sufficient for expert testimony provided to the court to decide the causality issue (Brennan, 1988). Therefore, an acceptable assessment strategy would be to document that an effect has been observed in the field, confirm the pathway of exposure and demonstrate that a similar effect is caused by laboratory exposure to the substance of concern.

Synthesis

We have provided some ideas that may be of use to natural resource trustees in planning and conducting the injury determination and quantification phases of a natural resource damage assessment. The environment is complex and the capabilities of science seldom provide absolute clarity in determining injury. However, natural resource trustees must work within these constraints to make objective determinations regarding the effects of releases of oil or hazardous substance on natural resources held in trust for the public. The key to effective injury assessment is to focus on three basic requirements:

1) Apply a clear definition of injury that is consistent with the DOI regulations and is based upon an adverse change relative to baseline conditions;

2) Demonstrate the pathway of exposure from the discharge to the injured resource;

3) Confirm that the release in question contributed to the causation of injury.

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