

SCOMM

78:26

*to fig
out
better*
Discussion with Bruce Sutherland - Oregon
DEQ.
Ch. 1000 2/2/81

I spent several hours on Wednesday, September 11, with Bruce Sutherland who is the professional staff dealing with oil spill issues for the State of Oregon's Department of Environmental Quality. We talked about the approach Oregon is likely to take on planning for oil spill damage assessment, about the timing of work on this issue by the States/British Columbia Oil Spill Task Force, and about the possibility of inter-state cooperation to develop common scientific protocols among western states which would be used in oil spill response and damage assessment research.

Environmental Vulnerability Index and Compensation Formula

Mr. Sutherland reported that the State of Oregon has used a Geographic Information System (GIS)-based approach to identification of critical natural and manmade resources which might be affected by an oil spill. (See his draft attached.) Resources are mapped on a 1 square kilometer grid and these "cells" are rated on 1-5 scales for each resources sensitivity to the spilled material (their Environmental Vulnerability Index). This data on each resource becomes a "data layer" in the GIS system. These resource ratings can then be combined in any way one wishes to serve three principle management purposes:

- 1) informing spill prevention planning,
- 2) setting priorities during cleanup of an actual spill, and
- 3) determining the amount of damages to be claimed from a spiller -

When the relative resource values determined for a set of cells is plugged into a compensation formula (as proposed in draft regulations now being worked on in the state of Washington) and multiplied by the number of gallons spilled and other factors, a dollar amount of damages to be assessed can be derived.

Oregon is slowly assembling the information which would be input into the GIS program and is still evaluating the proposed ranking system. I don't believe the state has yet used this information for either prevention or response planning.

Oregon's use of a compensation formula for determining damage claims is even further in the future. Oregon seems to be willing to let Washington state work out all the problems with this approach and then modify the Washington approach to suit Oregon's needs. Mr. Sutherland reported that he thought the Washington approach would have trouble both with industry because for the first time it could be cost effective to assess damages for small spills, and also with the public. However, he said that the originator of the Washington regs, Dick Logan, was optimistic that these regs would be finalized soon. Development of the Washington regs had been put on hold when I talked three weeks ago with a senior staff at the Washington Department of Ecology.

Mr. Sutherland thought that the States/British Columbia Task Force would wait for a conclusion on Washington's proposed damage assessment regs before it seriously dealt with the question of interstate coordination of damage assessment approaches. At the Task Force's next meeting in October, they plan to begin addressing rules coordination for oil spill topics other than damage assessment. Mr. Sutherland agreed with me that there are still problems with the Washington approach and that it may be found to be totally inappropriate in Alaska, given the large and constantly changing coastal area and the huge task of identifying existing resources. He feels that an especially weak point in compensation formulas is that numbers of gallons of oil spilled may be difficult to estimate and this number is critical in determining the final damage claim.

Research Protocols

A final area we talked about was the possibility of the western states establishing common protocols for scientific research (sometimes referred to as "standard operating procedures" in oil spill contingency planning) which could be used for oil spill response and damage assessment. Common West Coast agreements about how research would be done is relevant for damage assessment in that pre-approved procedures could reduce the confusion of setting up a damage assessment program, could save money and time by pre-planning and pre-contracting for lab work or research staff, may be less "attackable" in court, may be able to attract federal money under OPA 90, and could make oil spill research data from different states more comparable.

Mr. Sutherland was unaware that there are existing models for marine scientific research protocols for the Puget Sound Area and the Channel Island sanctuary off the California coast. He is interested in exploring this idea and suggested that if the Department of Fish and Game wanted to make a proposal to the States/British Columbia Task Force that West Coast cooperation on protocols be studied, the proposal could be made through the Alaska DEC representative who chairs the relevant subcommittee.

It should be noted that this idea could be explored whether or not the states decided to take the same approaches to carrying out damage assessments, e.g. either tending to plan for use of only a compensation formula or tending to rely on planning for a full-blown CERCLA Type-B in case of a large spill. Cooperation between states might also be accomplished in increments, starting with resources or habitats where agreement on approaches was easiest.

It should also be noted that Claudia Slater of the Habitat Division-RII, who has been the ADF&G representative for most of the contingency planning work, in May of this year recommended to the DEC that the Emergency Response Committee (ERC) assign the task of defining standard operating procedures to the State Emergency Response Committee (SERC) and that the SERC fund agencies to do such planning. (See attached memo.)

GINNY

Please excuse handwritten notes but for speed here it is:

- I have appended yellow sticky notes to highlight what pieces are for.
- They are organized in sequential order to:
 1. history of how it started.
 2. General approach
 3. Specific comp table model approach
 4. draft regs to support
 5. how comp is calculated

Please keep in mind all of this is out for public review and not formalized in regulatory language yet.

Chris -

Dick

Dick Logan
Dept. of Ecology
State of Washington

Feb 22, 1991

Spring ~~Season~~ Season (higher value)

In summary what happens for a single bay is

Spill occurs 20,000 gal PB crude

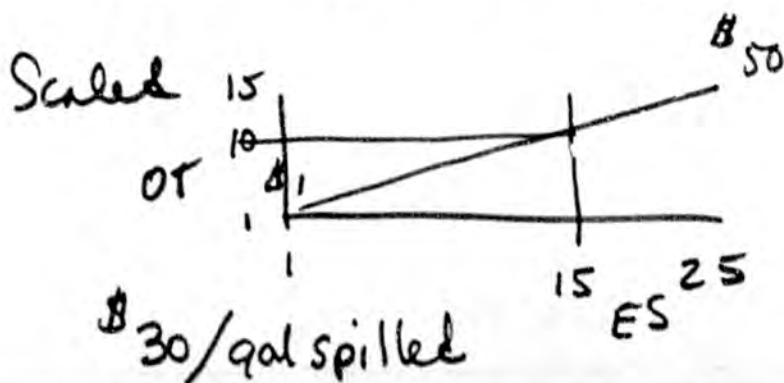
bay was ranked as follows

Habitat	5	extensive eel grass & salt marsh
Fish	4	extensive Herring & smelt spawning
Marine Mam	2	50 harbor seals 2 oiled
Birds	2	Some black brant 300 birds total 120 reported dead
Ree	2	some shellfish recreation harvest

==

15

Oil toxicity Prudhoe Bay Crude 10



2

Total Assessment \$ 600,000 settlement

Actions to reduce assessment.

RP - replaced all lost surf-smelt blocks
cost \$ 200,000 with new gravel

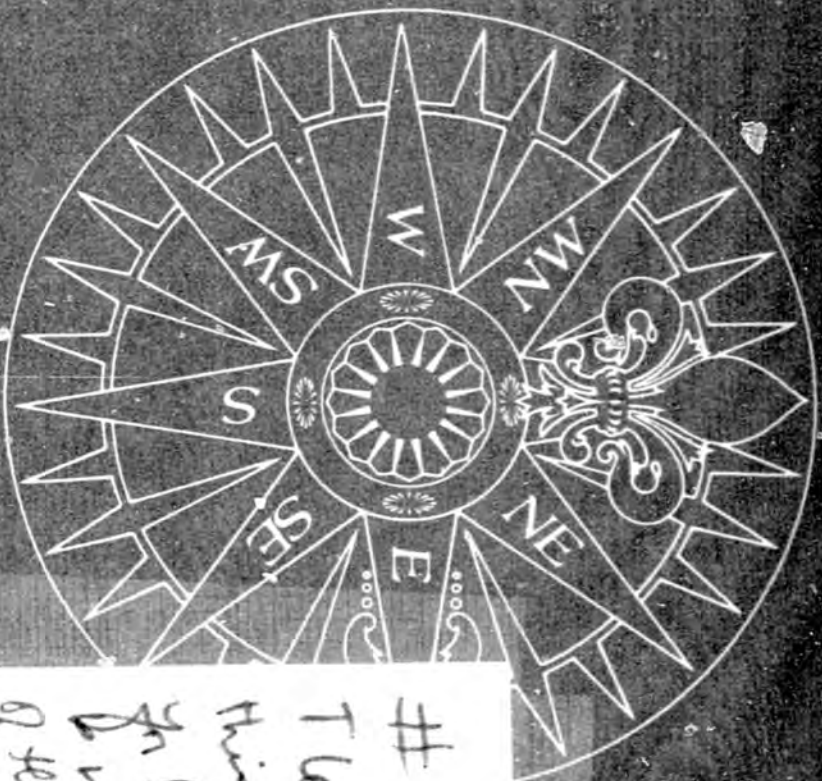
-	600,000	total
-	200,000	surf-smelt
-	100,000	replaced eelgrass beds destroyed by skimmers during cleanup

\$ 300,000 settlement

Had Type B Cercla Resource Damage assess.

been conducted cost would have been

\$ 400,000 with chance of no definitive answers
better than what we had.



1 History
Teschner submitted
this to leg as basis
for legislation which
is included in appendix
of this paper.

Institute for Marine Studies • University of Washington

Prepared for

**The Oil Spill Damage Assessment Study
Institute for Marine Studies
University of Washington
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**A Proposed Compensation
Schedule for Unquantifiable
Oil Spill Damages**

**by Thomas M. Leschine
and Jonathan Rubin**

May 1989

To the Reader:

This report is one of several products of the Oil Spill Damage Assessment Study conducted by the University of Washington's Institute for Marine Studies. Both the study and the publication of this report were supported by an appropriation from the Washington State Legislature, under SSSB 5986, Laws of 1987.

The study's purpose was to examine:

the state's method of assessing damages as a result of spills of oil,...[including]...an evaluation of Alaska's method of assessing oil spill damages, a survey of other states' damage assessment methods, and development of a recommended damage assessment methodology.

The study resulted in a package of legislative proposals for the 1989 Legislature (HB 1853, HB 1854), directed at reforming the methods by which Washington state agencies conduct natural resource damage assessments. The complete set of project reports is listed at the end of this document.

We are grateful to the legislature for providing us with the opportunity to work on what has proved to be a fascinating topic. Our thanks go out to individuals too numerous to mention who assisted us along the way. We are especially thankful for the assistance of the members of our technical advisory committee, who gave us a new appreciation for the administrative and technical difficulties of running a natural resources damage assessment program. Any opinions expressed herein are nevertheless solely those of the authors.

Thomas M. Leschine

Project Director and
Associate Professor of Marine Studies

March 1989

Contents

Acknowledgements.....	iii
I. Introduction.....	1
II. Structure of the Compensation Schedule.....	14
1. Potential for Injury (Preliminary Hazard Identification).....	14
2. Physical-Chemical Characteristics of Spilled Oil.....	15
3. Potential Vulnerability of Resources.....	17
4. Extent of Harm Likely to Occur and Value of Resources Affected.....	19
5. Aggregate Potential for Harm.....	22
6. Unadjusted Dollar-Per-Gallon Charge Rate.....	23
7. Consideration of Actions Undertaken by the Responsible Party and Actual Charge for Unquantifiable Damages.....	24
References.....	25
List of Study Reports.....	57

Appendices

1. Proposed Oil Classifications and Assessment of Environmental Influences and Oil-Environment Interactions.....	26
2. Alaska's Civil Penalty System for Oil Spills.....	32
3. Texas Guidelines for the Determination of Values for Fish and Wildlife.....	37
4. Washington's Oil Spill Compensation Schedule Authorizing Legislation (EHB 1853 and EHB 1854).....	40

Figures

1. Steps to Assess Damages Following an Oil Spill.....	2
2. Resource Damage Assessment Methodology Created by EHB 1853.....	4
3. Hazard Assessment for an Oil Spill.....	6
4. Schematic Diagram of Compensation Schedule.....	10

Acknowledgements

We offer special thanks to Dr. Roy Carpenter of the University of Washington's School of Oceanography for assistance in developing portions of this approach.

I. Introduction

Oil Spill damage assessment has traditionally relied upon extensive field investigation to establish the extent of biological or physical resource injury following a spill. It is generally necessary to verify not only that the resources in question have been exposed to the oil, but also that exposure has lead to injury. The actual extent of injury must then be quantified and translated into monetary value (Fig. 1).

Actually carrying a damage assessment investigation through to completion can present numerous difficulties however. As the "shunts" in Figure 1 suggest, it may not be possible to verify that threatened resources have actually come in contact with the oil, or that when contact has occurred, injury has resulted. Even when the extent of injury is clear, translation of injury into monetary terms may offer both theoretical and practical difficulties (Rubin 1989a). Moreover, though the technical means to complete successfully each step of damage assessment may exist, the cost of actually doing so may prove unreasonable in relation to the monetary damages likely to be identified. In Washington State, agency efforts to quantify damages fell victim to runaway costs in two instances (the 1984 Mobiloil spill and the 1985 Arco Anchorage spill). In the 1988 MCN#5 spill neither injury nor the extent of exposure of resources to the spilled oil proved possible to observe (See Geselbracht (1989) for a detailed analysis of these three spills).

Such difficulties, by no means unique to Washington State, have inspired a search for alternatives to the standard damage assessment paradigm. Under CERCLA (the Comprehensive Environmental Response, Compensation, and Liability Act of 1980) natural resources damage "type B" assessments are guided by "reasonable cost" rules designed to limit claims for damages to areas where injury determination and

DAMAGE ASSESSMENT

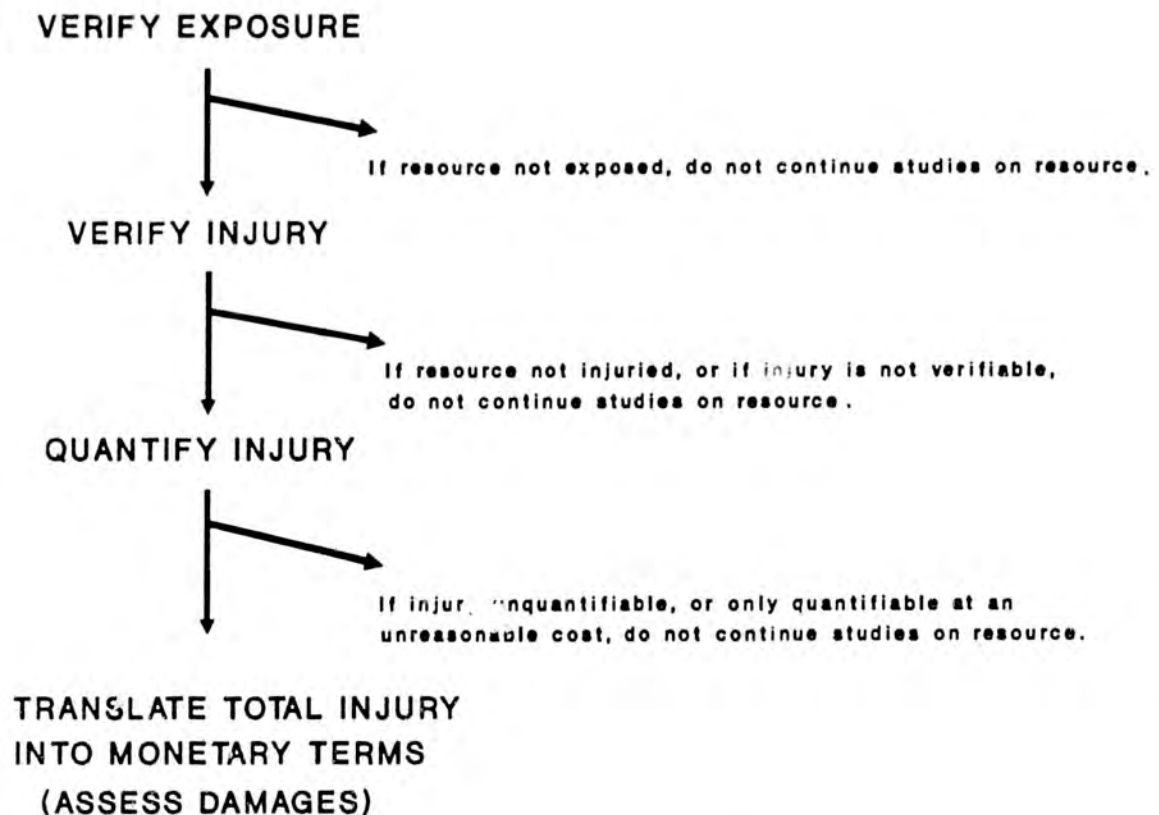


Figure 1

Steps to assess damages following an oil spill

quantification costs can be minimized (43 CFR 11.14(ee)).¹ CERCLA "type A" assessments eliminate field investigation entirely, replacing them with computer simulations of spill trajectories and resultant damages (43 CFR 11 Subpart D). In Alaska, state law encourages use of a formula which assigns a cost per gallon of oil-spilled-and-not-recovered on the basis of predetermined classifications of oil toxicity, dispersibility, and degradability and environmental sensitivity (see Appendix 2).

The purpose of this report is to describe a framework for an alternative approach to damage assessments for Washington State. Legislation recently approved by the Washington State Legislature (EHB 1853; see Appendix 4) directs that such an alternative be developed. The damage assessment program created by the law can be seen as a combination of features of both the Alaska and the CERCLA "type B" assessment systems. A CERCLA-like "preassessment screening" procedure would be used to determine whether to quantify the damages caused by a spill by means of the traditional field investigation approach or by means of the new "compensation schedule" (EHB 1853 Sec. 2; Figure 2 gives an overview of the damage assessment methodology created by EHB 1853). A possible framework for the compensation schedule, which is an extension of the Alaska civil penalty scheme, is developed in the sections which follow.

A Conceptual Framework for Oil Spill Damage Assessment

In thinking about approaches to oil spill damage assessment it is useful to have a conceptual model against which alternatives can be compared. A hazard assessment model can be used to characterize conceptually the risks posed by oil spills to the aquatic environment. A "causal anatomy" for technological hazards results from developing, in

¹Strictly speaking, the reasonable cost criterion specifies three conditions: "that the Injury, Quantification, and Damage Determination phases of the Assessment Plan have a well-defined relationship to each other; that the anticipated increment of extra benefits in terms of the precision or accuracy of estimates obtained by using a more costly methodology for injury, quantification, or damage determination outweigh the anticipated increment of extra costs of the more expensive procedure; and that the anticipated costs of performing the assessment are expected to be less than the anticipated damage amount. (43 CFR 11; 51 Federal Register 27728).

Resource Damage Assessment Methodology Created by ESHB 1853

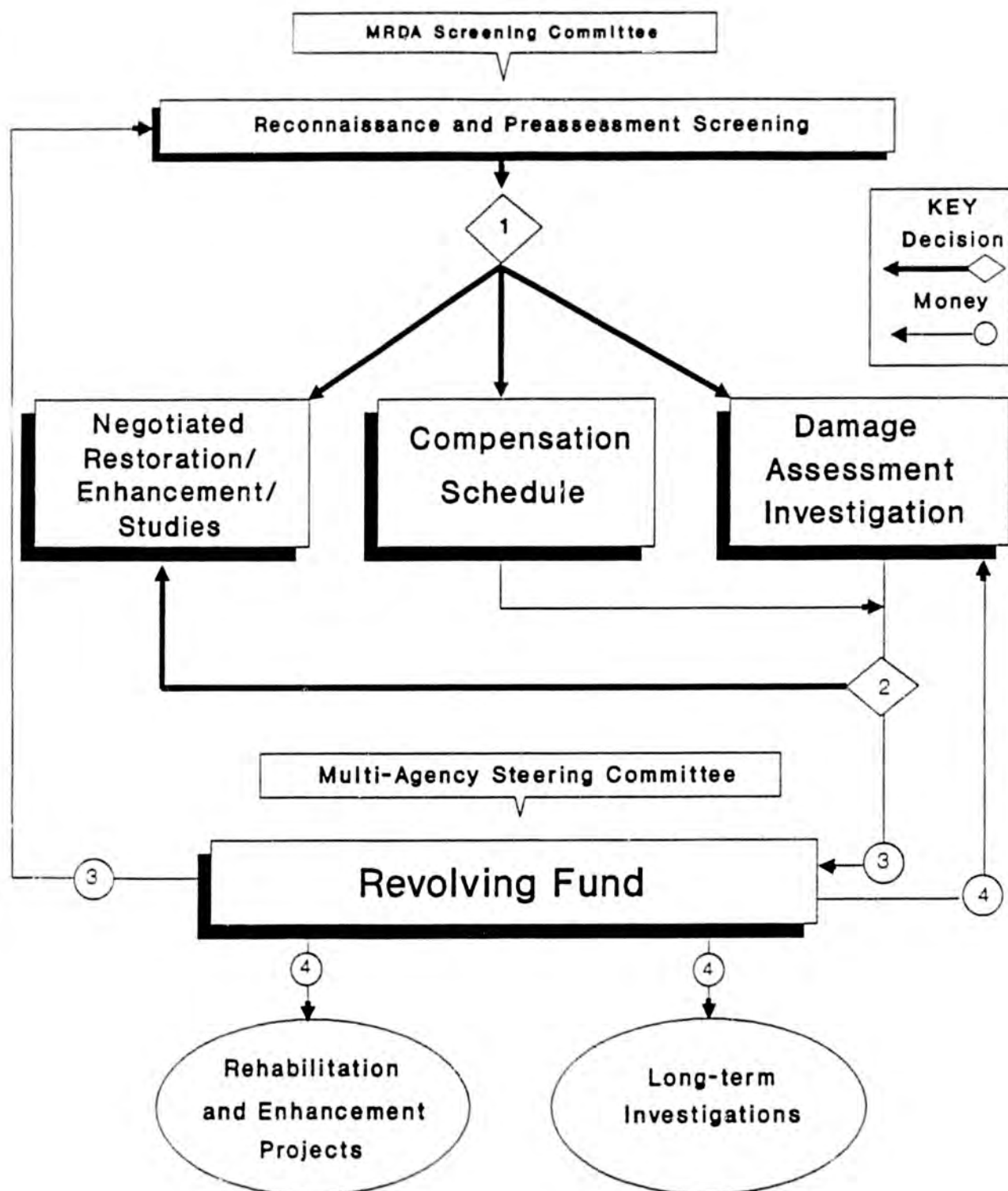


Figure 2

branching tree format, the causal linkages connecting initiating events (typically accidents) to their consequences in terms of resource injury or other types of harm (Hohenemser et al. 1985). In diagnosing ways to reduce the risk posed by such hazards, it has been found useful to segment the pathways which lead from initiating events to ultimate consequences. The standard approach is to develop the intermediate pathways connecting "events" to "outcomes," "outcomes" to "exposure," and "exposure" to "consequences."

Such a sequencing of linkages for a typical oil spill is shown in Figure 3. The illustration highlights ways in which actions aimed at preventing or reducing resource injury following an accident can be targeted on each of the linkages in the causal chain. In the short term, actions may be distributed simultaneously over efforts to minimize the release of oil, efforts to prevent or reduce oil already in the environment from coming into contact with resources, and efforts to reduce injury after contact with oil has occurred. In the longer term, actions tend to concentrate on environmental restoration and repair, or other mitigation-oriented responses.

When resource injury does occur, it is the particular set of pathways leading from the release of oil to the exposure of sensitive resources, and from resource exposure to actual consequences in terms of resource harm, which determines the nature and extent of the damages. Key questions include: How much oil has gotten into areas where important resources are, how is the oil carried in the water column, and how sensitive are the resources to the oil in the form and amount in which it affects them? As is now widely recognized, marine resources vary widely in their sensitivity to injury from contact with oil, and the ability of a particular oil or oil product to cause a particular harm is highly dependent on the oil's physical and chemical characteristics. Nature plays a major role in determining how much damage occurs, as winds, temperature, time of year, and currents affect the extent of mixing, spreading, dissolution, or evaporation of spilled oil and thus the particular pathways by which it contacts or harms resources in the vicinity of a spill (see Rubin 1989b for a review).

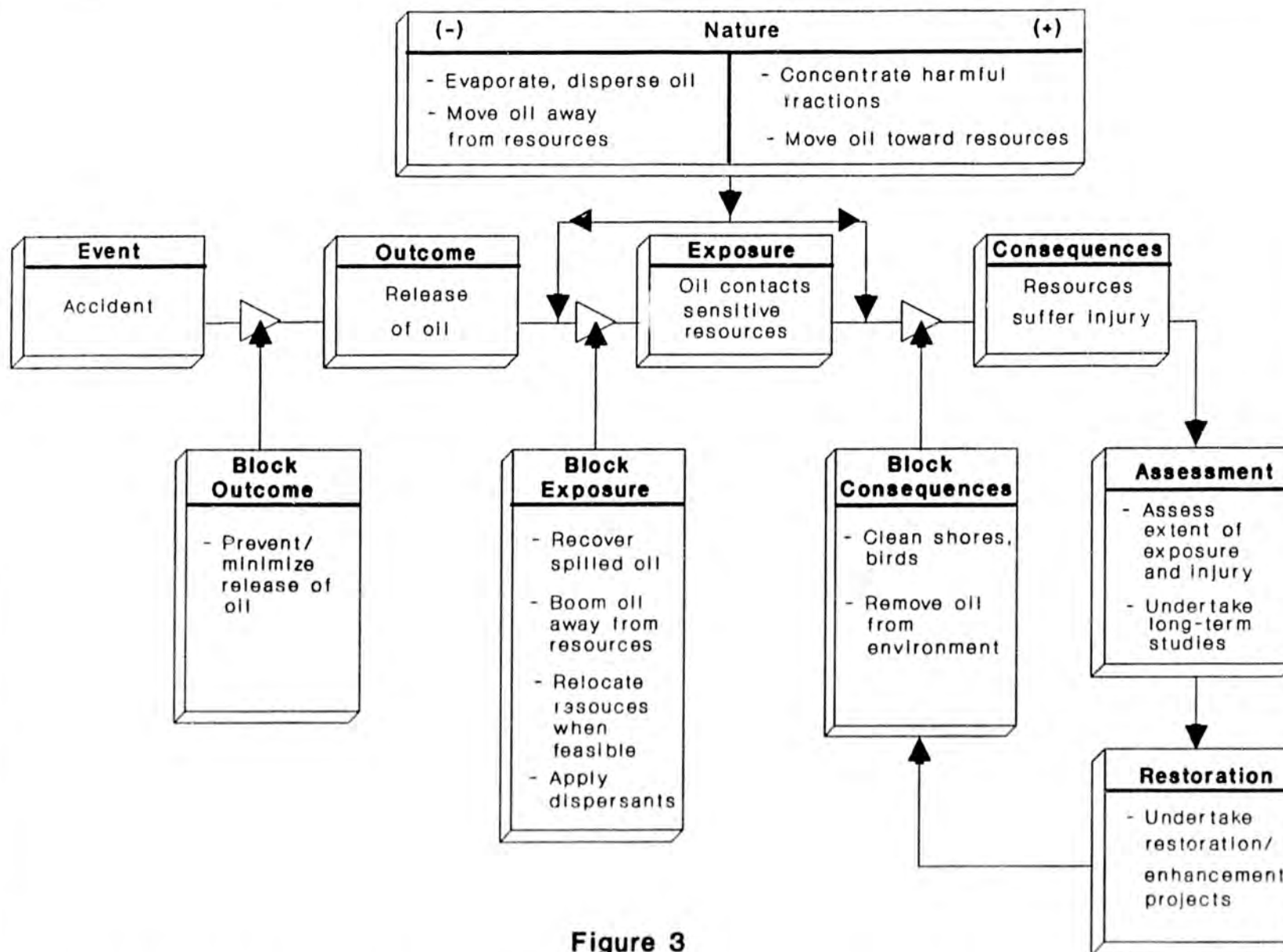


Figure 3

Hazard assessment for an oil spill, illustrating how actions by a spiller or others can reduce or mitigate harmful effects. Nature can act either to diminish (-) or intensify (+) the extent of exposure or effects (after Hohenemuer et al. 1985).

The causal anatomy of oil spill hazard provided in Figure 3 can be used as a template for comparing various approaches to oil spill damage assessment. A comparison of Figures 1 and 3 suggests that damage assessment is primarily concerned with the pathways connecting "outcome" to "consequences" (and the translation of the deleterious consequences identified into monetary value). The traditional field investigation-based approach aims basically to quantify the result (in terms of resource injury) of the interactions displayed in the center of Figure 3. As can be seen from Geselbracht's (1989) reconstruction of the Arco Anchorage and Mobiloil spills, the bulk of the field work is likely to be aimed at verification of exposure and injury and determination of the extent to which each has occurred. Additional effort may focus on characterizing the effects of natural processes in distributing spilled oil (e.g. studies of oil fate) or actions of man (e.g., how much oil was actually spilled or subsequently recovered).

The CERCLA "type B" regulations, while not offering specific guidelines on how much emphasis to place on each of these potential areas of investigation, nevertheless attempt to contain the overall scope of the assessment activities. Because there must be a well-defined relationship among injury, quantification and damage determination, investigations aimed simply at determining the fate of spilled oil are less likely to be supported as part of a damage assessment investigation. Because the anticipated costs are expected to be less than the anticipated damages, ecosystem components of low intrinsic value, (e.g., plankton) are likewise less likely to be investigated as part of damage assessment studies. With CERCLA "type B", there is a conscious effort to separate research and damage assessment investigations on the basis of cost-benefit criteria.

By contrast, CERCLA "type A" assessments largely eliminate the need for field investigations aimed at verifying exposure and injury. The resources likely to be injured in a spill in a particular geographic province are pre-programmed into the computer model. Once the user specifies the amount and type of oil spilled, the propensity for the oil in question to harm the region's resources is likewise model determined. The principal

judgmental tasks left to the model user concern the state of nature in relation to the spill. The user must specify initial conditions defining the zone (subtidal or intertidal) and depth of water where the spill occurred, its relation to coastal topography, and the windfield affecting the spill's subsequent trajectory. The computer program then computes effects of the type noted in the "nature" box of Figure 3.

While the CERCLA model does not ignore the complications posed by the real-world interaction among effects of nature, physical and chemical characteristics of oil, and resource sensitivity, the "black box" deterministic modelling approach employed is unlikely to reproduce reliably the range of actual consequences observed in actual spills. In many situations the model user will know the model is basing its damage estimate on resource injury which bears little relation to the injury actually incurred. But because the range of user-controllable inputs is so limited, there is little ability to adjust the model toward more realistic results. The complexity of these interactions is perhaps the most significant barrier to replacing field investigation-based damage assessment with "short-cut" methods like CERCLA "type A."

The Alaska penalty formula treats resource sensitivity to injury from contact with oil as independent of both the nature of the oil spilled and the effects of nature during the spill event. Resources are pre-classified as to their sensitivity to oil spill damage. Also, while the importance of degradation and dispersion of oil after its release into the environment in affecting the nature and extent of contact with resources is acknowledged, these factors are treated as properties of the oil itself, independent of such effects of nature as wind and currents. (see Appendix 2).

A method used by the U.S.S.R. to estimate damages to marine resources following a 1979 spill involving the vessel Antonio Gramsci, is worthy of mention. The volume of sea water necessary to dilute the oil to its (theoretical) ultimate steady state concentration in the ocean was calculated. This volume of impacted water was then multiplied by the estimated cost to restore it to an acceptable condition. Tables specify unit restoration costs

for waters in different regions of the coast. Thus, damages were assessed on a charge per unit-volume-of-water-affected basis.²

The compensation schedule proposal developed in subsequent sections differs from the Alaska and other simplified approaches principally in the way it attempts to account explicitly for effects of nature (top box in Figure 3) and actions by man (bottom row of boxes in Figure 3). Judgment is relied upon to account for these factors. In the case of effects of nature, the judgments are those of experts, on-the-scene, aided by pre-determined checklists and scoring procedures. These are intended to help them weigh the relative importance of an array of phenomena of nature in affecting the extent of exposure and adverse effects to resources. Otherwise, several specific types of resource injury are considered, again with the aid of pre-specified determinations of the propensity of selected resources to suffer each type of injury (independent of characteristics of the oil spilled). The differential effects of oils of differing chemical and physical characteristics are accounted for through pre-classification of oils on the basis of their propensity to cause each type of injury considered (see Appendix 1). These last two elements are similar to elements of the Alaska approach, except that they are developed here in somewhat more detail. The overall scheme is illustrated in Figure 4 below and explained in subsequent sections.

General Approach

The discussion above suggests that existing schemes for extracting compensation following spills can be classified in terms of how they infer information about the pathways linking a release into the environment to the exposure and subsequent injury of resources. Characteristics of the product spilled, influences of nature on spill behavior, and specifics

²The International Oil Pollution Compensation Fund Assembly would not recognize Soviet claims for damages under the Civil Liability Convention (CLC) because the conventions did not allow compensation for damages without regard to incident-specific factors such as the location of the incident, the sensitive resources at the incident site, the composition and toxicity of the spilled oil and the fate of the spilled oil (RPI, 1983).

SCHEMATIC DIAGRAM OF COMPENSATION SCHEDULE

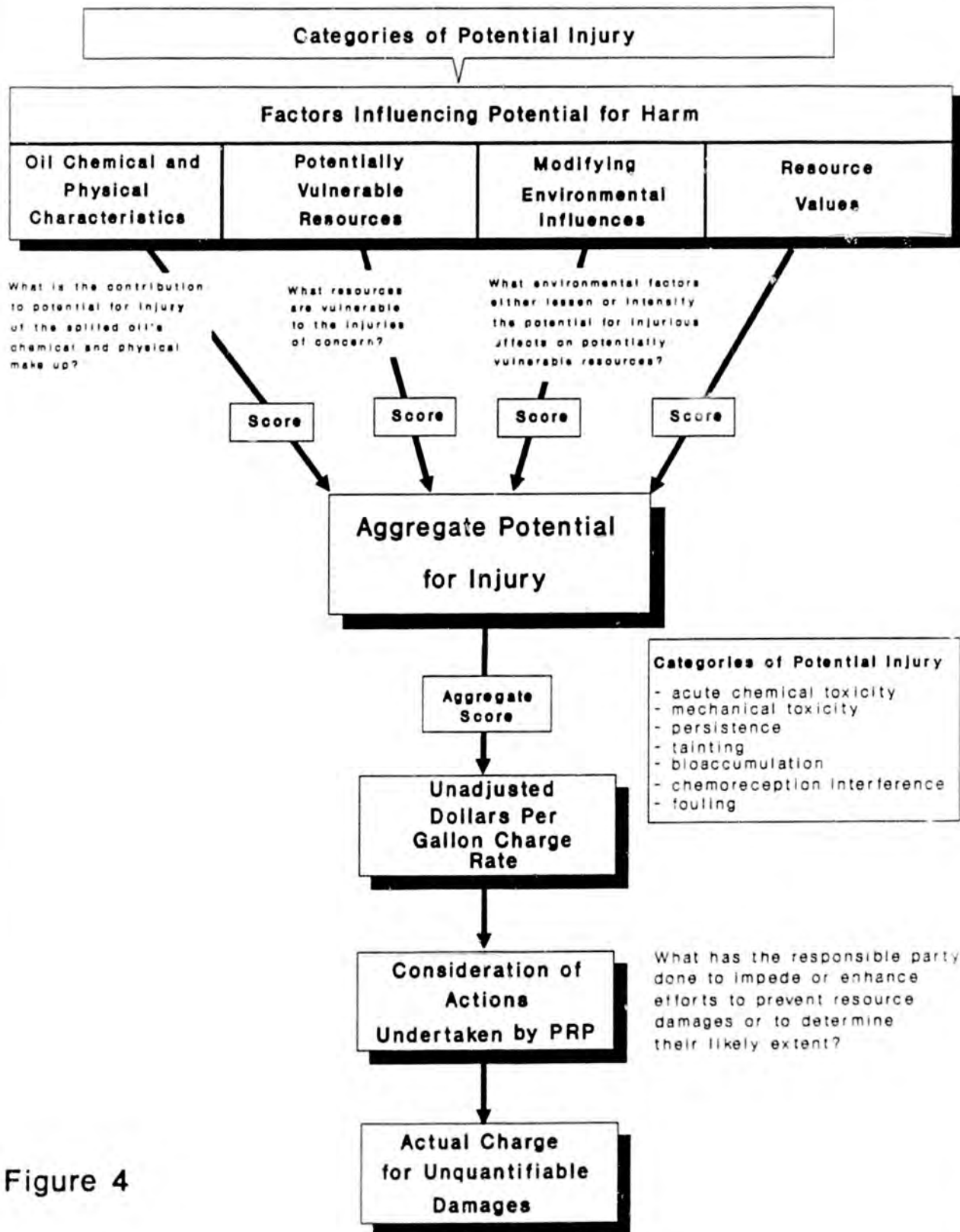


Figure 4

about the sensitivity and location of resources in relation to the spill may or may not be considered explicitly or realistically.

The detailed proposal which follows is motivated by the following general assumptions and philosophy: 1) each of the major elements noted in the discussion above should be given some explicit consideration; 2) pre-classification can be relied upon for primary generic information about a) the relative sensitivity of particular resources to specific types of injury, and b) the relative propensity of different oils to cause these types of injury; and 3) expert judgment can be reliably applied to the development of site-specific information about a) the presence or absence of resources likely to be injured by a spill, and b) the effects of nature in lessening or intensifying the injurious effects of concern. Other approaches could clearly be taken, which could be either more or less information intensive than the proposed approach. Moreover, even within the scheme outlined considerable latitude exists concerning the level of detail, the exact aggregation rules to be used in "scoring" spills in terms of their propensity for causing harm, and in a number of other areas.

A cost per gallon charge on a sliding scale is imposed on oil spilled into the state's aquatic environment (or entering state waters when spilled elsewhere) as compensation for resource damages. This charge is imposed only when preassessment screening procedures suggest that field investigation based damage assessment is infeasible at a reasonable cost (see EHB 1853, Sec. 3, included as Appendix 4). The charge ranges from a low of \$1 per gallon to a high of \$50 per gallon (EHB 1853, Sec. 2). The actual level of the per gallon charge for a particular spill is determined by the "potential for injury to biological or physical resources" posed by the presence of the spill on the state's waters, shorelines or submerged lands. The compensation claim ultimately made, however, may be modified in consideration of actions taken by the responsible party. This adjustment could be either upwards or downwards, depending on how these actions affect the potential of the spill to cause resource damage or affect the ability of state agents to determine how much damage

for waters in different regions of the coast. Thus, damages were assessed on a charge per unit-volume-of-water-affected basis.²

The compensation schedule proposal developed in subsequent sections differs from the Alaska and other simplified approaches principally in the way it attempts to account explicitly for effects of nature (top box in Figure 3) and actions by man (bottom row of boxes in Figure 3). Judgment is relied upon to account for these factors. In the case of effects of nature, the judgments are those of experts, on-the-scene, aided by pre-determined checklists and scoring procedures. These are intended to help them weigh the relative importance of an array of phenomena of nature in affecting the extent of exposure and adverse effects to resources. Otherwise, several specific types of resource injury are considered, again with the aid of pre-specified determinations of the propensity of selected resources to suffer each type of injury (independent of characteristics of the oil spilled). The differential effects of oils of differing chemical and physical characteristics are accounted for through pre-classification of oils on the basis of their propensity to cause each type of injury considered (see Appendix 1). These last two elements are similar to elements of the Alaska approach, except that they are developed here in somewhat more detail. The overall scheme is illustrated in Figure 4 below and explained in subsequent sections.

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to which vulnerable resources are present in the area affected by the spill and b) estimating the influence of environmental factors on the severity of the effects which do occur.

Points are assigned separately under each category of injury. Because different resources will have different sensitivities and potentials for exposure to particular types of injury, resource types are also considered separately in the scoring. The separation of resources and injuries, and the disaggregation of the pathways leading from the release of oil to resource harm, allow for offsetting or amplifying factors to be taken into account. For example, dispersion of oil through the water column due to wind-induced mixing may lessen the chances for some types of harm to occur while increasing the chances for others (e.g., less potential for harm to birds but more potential for harm to fish).

The "unadjusted dollars per gallon charge rate" (Figure 4) is not intended to lead to an estimate of the actual value of the injury caused by a spill. Rather, it represents a civil penalty. The primary aim of the thought process outlined here is to assure that the resulting charge has the characteristics of fairness generally expected of penalty systems in law: The penalty should be proportionate to the actual injury caused by the spill, and similar spill events should receive similar penalties.³

The actual amount billed to the responsible party may, however, be increased up to the maximum \$50 per gallon rate or decreased down to the minimum \$1 per gallon rate, depending on how the responsible party's post-spill behavior affects efforts to limit resource damages or to estimate their likely extent (bottom of Figure 4). This feature is again analogous to features of other penalty systems, where an individual's behavior following an incident may well affect how he or she is treated by the legal system.

³For a discussion on the use of monetary penalties to induce socially desirable behavior and issues such as fairness and proportionality in fines, see United States Sentencing Commission, 1988.

II. Structure of the Compensation Schedule

1. Potential for Injury (Preliminary Hazard Identification)

What are the potential harmful effects of the spill?

The focal point of this hazard assessment approach to assigning a dollars-per-gallon charge rate to a spill is the estimation of the potential for injury to biological or physical resources it poses. Potential for injury is divided into six categories of potential harms to biological resources and one category of potential harm to non-living resources.

Categories of potential injury

Potential biological harms (in rough order of perceived importance) are:

- mechanical toxicity (smothering, coating)
- acute chemical toxicity
- persistence (proxy for chronic toxicity)
- tainting of marine food organisms
- bioaccumulation and biomagnification
- chemoreception interference

Potential non-living resource harm:

- fouling (shorelines, fixed structures, boat hulls, etc.)

For purposes of scoring, these categories of potential injury could appear in the schedule pre-sorted into groupings reflective of experts' beliefs about the relative severity of the effects each category represents. For example, chemoreception interference might not be considered as important a harm as the oiling of wildlife (mechanical toxicity). If

there were two such levels, Level I harms might receive twice as much weight as Level II harms in the scoring formula.

In a particular spill situation, the preliminary hazard identification involves field and other personnel reviewing the categories above with respect to whether significant potential exists for harm of each type to occur. The categories considered to be significant are carried forward into subsequent stages of the analysis.

2. Physical-Chemical Characteristics of Spilled Oil

What characteristics of the oil or oil product spilled tend to either lessen or intensify its harmful effects on valued resources?

Research suggests that a complex array of chemical and physical properties act to influence the actual fate and effects of oil in the marine environment (See Rubin, 1989b for a review). These include such characteristics as viscosity, density, or percentage of aromatic or aliphatic compounds. Crude oils will have different actions than refined products, and even quite similar refined products can differ significantly from one another in their potential toxicities. By focusing on the fairly specific types of harms described above it appears feasible to pre-classify the oils and oil derivatives most commonly hauled in Washington's waters according to their propensity (all other things being equal) for causing each type of harm. This is similar to the approach taken under the Alaska civil penalty system (see Appendix 2) although the Alaska classification scheme does not explicitly distinguish among different types of harms.

Usage in the compensation schedule: Commonly hauled oils and oil products would be pre-sorted into "high", "medium" and "low" propensity-for-harm groupings under each category of potential harm identified above (see Appendix 1 for a preliminary classification). Each group would have associated with it a predetermined set of points. Under each category of harm, aa points would be assigned to oils with a "high" propensity

for causing the associated type of the harm, bb points would be assigned when the propensity for harm is "medium", and cc points would be assigned when the propensity for harm is "low", where $aa > bb > cc$. For example, Alaska North Slope Crude would likely be classified as "medium" on its potential for acute toxicity (bb points) and "high" on its potential for mechanical toxicity (aa points; see also Appendix 1).

Note that in some cases the actual propensity for a particular type of harm from some oil products may still vary within a product category. For example, different gasolines might have much different acute toxicities, depending on their aromatics content. In these cases, a sliding scale of points would be developed, based on the relevant parameters. This is how refined products are treated under the Alaska penalty system (see Appendix 2).

In an actual spill situation, at least one of the categories of injury listed in Sec. 1 above would likely be identified as potentially significant. In any event, the oil spilled would be scored with respect to its propensity for causing each type of harm by reference to the tables. On-scene investigators would identify a separate score under each category, seven scores in all. The table they would refer to would be of the following type:

Oils and Oil Products	Categories of Injury						
	1	2	3	4	5	6	7
Alaska N.S. Crude							

The table entries would represent propensities for causing harm, numerically scaled. If $aa = 10$, $bb = 5$ and $cc = 1$, all entries would be values between 1 and 10.

3. Potential Vulnerability of Resources

What resources are potentially vulnerable to the harmful effects in each category?

In some cases the possibility of occurrence for some of the types of harm noted in the preliminary hazard identification can be eliminated by simply noting the absence of resources which could suffer the kind of effect described. For example, the vulnerability of chemoreceptive abilities in salmonids to hydrocarbon "jamming" would only be of concern when large numbers of salmonids are likely to be in the area affected by a spill at the time it occurs. Similarly, shorelines are unlikely to be affected by oil which spills and remains far from the shore.

The purpose of this step is two-fold: a) to highlight resources of particular vulnerability (or effects of particular concern) with respect to one or more of the above categories of potential injury, and b) to eliminate categories of potential injury when resources sensitive to the type of harm encompassed are unlikely to be present in the area affected by the spill.

Usage in the compensation schedule: Habitat and/or resource types of Washington waters and shorelines vulnerable to oil spill damage would be pre-classified with respect to their sensitivity to harm under each category of potential harm identified above. Three classifications would be developed under each such category: "low" (or no) sensitivity, "medium" sensitivity, and "high" sensitivity. The scheme is similar to Alaska's habitat classification (see Appendix 2), except that biological assemblages would be considered in addition to physical habitats. Under each category of potential harm identified in Sec. 1 above, assign xx points to each potentially vulnerable resource type on the list when the resource type is of "low" sensitivity. Assign yy points for each resource type of "medium" sensitivity, and zz points for each resource type of "high" sensitivity, where $zz > yy > xx$.

In some cases habitats might be more finely classified than they are in the Alaska system. As an example, the 10-point index of shoreline sensitivity recently applied to a

mapping of the Washington Coast by Research Planning Institute for NOAA (RPI; 1980, 1986) could be incorporated under the "fouling" category as follows:

Classes 1-3: "low" sensitivity to fouling damage

Classes 4-7: "medium" sensitivity to fouling damage

Classes 8-10: "high" sensitivity to fouling damage

In many cases biological resources will exhibit greatly different sensitivities to harm at different stages in their life cycles. Adult salmonids appear to be less sensitive to acute toxicity than fry and larval stages, for example. In these situations different life stages would be listed and scored separately.

Agency personnel using the system in the field would be provided with a detailed checklist of resources, with the listed resources pre-classified as "high", "medium" or "low" in sensitivity under each category of harm identified in Sec. 1 above. If a particular resource is highly sensitive to one type of harm (e.g. marine mammals to mechanical toxicity) but relatively insensitive to another type (e.g. marine mammals to chemoreceptor interference), then the resource would be classified differently under the two categories.

The task for the individuals using the lists in the field is simply to note the presence or absence of the resources in the area affected by the spill at the time it occurs. Each "present" check mark counts for the number of points associated with the pre-classification on the checklist. The entries would represent sensitivities to harm, numerically scaled. If $zz = 10$, $yy = 5$, and $xx = 1$, then all entries would be values between 1 and 10. The checklist would have a matrix format similar to that described in Sec. 2 above:

Resource Types	Categories of Injury						
	1	2	3	4	5	6	7
Dungeness Crab							

4. Extent of Harm Likely to Occur and Value of Resources Affected

The elements of the compensation schedule developed so far lead to an ability to characterize, in a qualitative way, the (relative) vulnerability of particular resource types to particular types of injury. The associated numerical values could be calculated simply as the product of the values described in Sections 2 and 3 above.⁴ If, for example, the "high", "medium", and "low" scores used to classify both the spilled oil's propensity to cause a particular injury and the sensitivity of the resource type in questions to it are scored as 10, 5, and 1 point, respectively, then the product of these two scores generates values on a 100 point scale. One hundred points corresponds to a resource highly sensitive to a particular effect which the spilled oil has a high propensity to cause, while one point would correspond to a resource with low sensitivity to a harm which the oil in question has low propensity to cause.

Turning the focus to the resources which field personnel would identify as being in the area of impact when a spill occurs, each of these could then be associated with a vector of seven values -- one value for each of the types of injury identified in Sec. 1.

⁴It should be noted however that, strictly speaking, scoring formulas that rely on either addition or multiplication require that certain conditions of independence among variables be satisfied.

Ultimately one might want to be guided in assigning a score to the spill's overall potential for causing harm by its maximum potential for causing injury of any kind to each resource of concern identified through reconnaissance studies. Two additional factors could be taken into account, however:

- A. The likely extent of effects to the resource relative to its extent or abundance in the area affected by the spill;
- B. The intrinsic value or worth of the resources vulnerable to harm.

A. Extent of effects (and modification for environmental influences)

What environmental influences are at work to either lessen or intensify harmful effects on vulnerable resources?

Whether winds and tides carry spilled oil toward or away from valued resources, or act to disperse or evaporate spilled oil, could be crucial determinants of how much damage is done, regardless of whether the damages are being quantified or not. Experienced MRDA (Marine Resource Damage Assessment) team members involved with spill response in Washington will be in a unique position to observe how these factors are influencing the course of events as a spill event unfolds.

MRDA team members would be provided with a list of questions about such factors, which they would answer on numerical scales. The questions would be specific to particular types of harm and particular resources. The same general question might apply to several different types of resources under a particular category of harm, or to several different categories of potential harm to a particular resource. A typical question might be:

"How are winds acting to affect the ability of this spill to oil shorelines?"

Significantly
lessening harm

Not a
factor

Significantly
adding to harm

-mm
points

0 points

+mm
points

A number of such questions would likely be associated with each category of potential harm: If winds, air temperature and currents are all determinants of the extent or intensity of a particular effect, then questions related to each category would be included. Designing this portion of the compensation schedule is very much akin to designing a so-called "expert system".

Usage in the compensation schedule: Using a "preponderance of evidence" approach, the individuals using the compensation schedule would decide, for each identified resource of concern and each category of potential harm to it, whether the predominant effect of environmental conditions is to magnify or diminish the impacts of concern. This would result in additional multipliers ($\times 5$, $\times 10$, $\times 100$) to be applied to the relevant categories of harm (in the case of a tendency for environmental conditions to magnify impacts in these categories) or, in the case of a tendency for environmental conditions to diminish impacts, in the use of fractional multipliers ($\times 1/5$, $\times 1/10$, $\times 1/100$). If such factors were judged to be relatively insignificant, the appropriate multiplier would be one (no change in the score).

B. Resource Values

What relative significance do we attach to the possibility of harm to various types of resources?

Although judgments about the relative values of resources are often exceedingly difficult to make, they are nevertheless important to any scoring scheme of the type embodied in this proposed compensation schedule. Moreover, resource values are implicit in elements already included -- notably in the resource sensitivities considered in Sec. 3.

The approach to incorporating resource values could be similar to that used to estimate the effects of environment in subsection A above. A series of questions with answers to be scored on a scale of significance could be employed to assure that relevant considerations are addressed. These would include the commercial, recreational, or

aesthetic significance of species affected (or the significance of habitats affected to species of commercial, recreational or aesthetic importance), and whether species affected were threatened or endangered or otherwise accorded special protection in the area of the spill. The relative abundance or special ecological significance of species affected would also be considered. Whether geographic areas affected were of special recreational or aesthetic importance would also be considered. The natural resource damage assessment system employed by the State of Texas (included as Appendix 3) approaches this problem of value by scoring each resource against eight criteria chosen to reflect the major definable elements of social, economic, and ecological value.

While resource values, like other elements of this proposal, could be provided through predetermined valuation, some resources might have value or significance in the area of a spill different from their significant elsewhere in the state. For example, a species relatively rare on the outer coast might be relatively abundant in Puget Sound, or vice versa.

In any case, multipliers for resource values would be generated through considerations described above, possibly by means of the question and scaled answer approach used in A above. Such multipliers (x 5, x 10, x 100) would be applied to all categories of harm affecting the resources in question.

5. Aggregate Potential for Harm

Each resource of concern in a particular spill event has now been characterized, through a series of multiplications, with respect to the propensity for each of the seven types of injury identified in Sec. 1 to occur to it. Roughly speaking, the numerical values which have been arrived at can be likened to conditional probabilities: Each represents the propensity for the specific injury in question to occur to the resource, given that a spill of a particular size and or oil product has occurred in an area occupied by the resource. Depending on how the multipliers have been applied, the values in the column vector

associated with the resource could range from fractional points less than one to values of perhaps 1,000 or 10,000. The higher values in the array would represent harms which first, are highly associated with the type of oil spilled and second, are harms to which the resource in question is particularly sensitive. Moreover, the resource affected is of high economic, social, or ecological value, and environmental conditions are such that oil is highly likely to come in contact with a significant portion of the total resource stock in the vicinity of the spill.

To assign an aggregate value to the spill's total potential for harm, one could now pick the maximum score associated with any harm to each resource of concern, and then sum these scores over all such resources. For spills of any significance in terms of the threat they represent to valued resources, this value would likely be several thousands of points.

6. Unadjusted Dollars-Per-Gallon Charge Rate

By working through the system described in the preceding sections hypothetically, the reasonable maximum and minimum number of points which could represent potential harms can be determined. This range of points would then be rescaled from 1 to 50, representing the dollars-per-gallon charge rates.

Usage in the compensation schedule: The total number of points assigned to the spill is matched against the resulting conversion scale to determine the appropriate dollars-per-gallon charge rate.

7. Consideration of Actions Undertaken by the Responsible Party and Actual Charge for Unquantifiable Damages

What has the responsible party done to enhance or impede efforts to prevent resource damages or to determine their likely extent?

The charge rate determined in step 6 above will lie somewhere between \$1 and \$50 per gallon. The Department of Ecology, acting in conjunction with the MRDA team, may now choose to adjust the charge rate upwards or downwards within those limits, as a way of acknowledging the degree to which the responsible party has aided or impeded remediation of the damages caused, or determination of the level of compensation appropriate to the event which has occurred. Figure 3 above provides an indication of the types of considerations which would likely count for a reduction in the charge rate.

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Appendix 1 - Proposed Oil Classifications

The characterization of crude oil and products transported through Washington's waters is simplified by recognizing that over 90 percent of all crude imports come from Alaska's North slope.⁵ This means that it is reasonable to expect transported crude and products to have fairly well defined ranges for some of the parameters of interest.

Acute Toxicity to water column organisms, birds, and mammals

1. High
 - a) Kerosene
 - b) Jet fuels
 - c) Gasoline
2. Medium
 - a) Crude oils
 - b) Middle distillates
3. Low
 - a) Bunker and Residuals
 - b) Asphalt
 - c) Other

Acute toxicity categories are to be modified by the percent of 2 or 3 ring or total aromatic hydrocarbons in the spilled oil.

Mechanical Toxicity to diving birds, mammals, intertidal organisms, and benthic organisms in shallow water.

1. High
 - a) Crude oils of API gravity __ and viscosity __
 - b) Middle distillates
 - c) Bunker and Residuals
2. Medium
 - a) Crude oils of API gravity __ and viscosity __
 - b) Middle distillates

⁵*Pacific Northwest Executive*, January 1988, p. 14.

3. Low

- a) Kerosene
- b) Jet fuels
- c) Gasoline
- d) Crude oils of API gravity __ and viscosity __

Mechanical toxicity will be modified by API gravity and pour point.

Persistence in the environment (chemical and physical)

1. High

- a) Bunker and Residuals
- b) Tar
- c) Asphalt

2. Medium

- a) Crude oils with __ % aromatics and __ API gravity
- b) Middle distillates

3. Low

- a) Kerosene
- b) Jet fuels
- c) Gasoline
- d) Crude oils with __ % aromatics and __ API gravity

Tainting to commercially and recreationally valuable and subsistence species

1. High

- a) Middle distillates
- b) Crudes of __ API gravity

2. Medium

- a) Gasoline
- b) Kerosene
- c) Jet fuel
- d) Crudes of __ API gravity

3. Low

- a) Bunker and Residuals
- b) Tars and asphalt

Exposure Assessment

Acute Chemical and Mechanical Toxicity

For assessment of the potential for acute chemical or mechanical toxicity due to exposure to oil, an indicator species approach could be taken. Depending on area or season of the spill, appropriate species could be selected from the following categories:

- fed/state threatened/endangered species;
- birds;
- salmon;
- smelt;
- herring;
- shrimp;
- clams;
- oysters;
- marine mammals;
- kelp and eelgrass.

Persistence

For persistence, both physical and chemical, habitat rather than the actual organisms may be the more important parameter. Perhaps indicator habitats could be selected following the classification system of NOAA's emergency response maps.

For example:

- habitat for fed/state threatened/endangered species;
- bird rookeries and some buffer zone;
- marine mammal haulout areas and buffer zone;
- bays/sheltered waters;
- coastal estuaries.

Tainting

For tainting effects the presence of food species is the most appropriate criterion.

For example:

- salmon;
- other food fish which could get oiled;
- subsistence food organisms (Native Americans and others);
- clams;
- oysters;

Physical harm

The effects from physical harm will vary with the type of oil spilled. The ranking used for mechanical affects would probably be most appropriate.

Significant non-biological resources include:

- shorelines;
- boat launches;
- underwater parks;
- seaside parks;
- other physical attributes and man-made structures.

Assessment of Environmental Influences and Oil-Environment Interactions

Factors Affecting the Impact of a spill:

Meteorological conditions;

- Do high winds drive oil into sensitive regions?
- Do high (offshore) winds aid evaporation and keep oil away from sensitive areas?

Oceanographic conditions;

- Do extreme tides or winds deposit oil above normal high tide lines?
- Does strong wave action help remove oil from affected areas?
- Does strong wave action promote mixing and dispersion?
- Do currents direct the oil towards or away from important resources?
- Do extreme tides, wave action, and wind act synergistically to increase the range of affected areas?

Oil dosage and impact area;

- Did the oil enter a confined area where it was unable to escape and thereby cause greater harm per unit volume of the spill?

- Did the oil enter a confined (biologically unimportant) area where it was able to be removed without affecting many other resources?

Season;

- The season will determine whether or not specific organisms are present to be harmed. In some cases, it will determine whether they are particularly vulnerable to harm.

Temperature;

- Affects the transport of oil into water. If ambient water temperature is below the pour point of oil then it could significantly retard the dispersion of the oil.
- Warmer temperatures increase evaporation and microbial action. This is a second order effect for Washington's waters.

Relevant Crudes and Products

Crudes

Alaska North Slope
Canadian crudes
Indonesian and other

Products

Kerosene
Jet fuels
 Naphtha-type
 Kerosene-type
Gasoline
 Leaded
 Unleaded
 Blending components
Middle distillates
 # 1 fuel oil
 # 2 fuel oil
 # 4 fuel oil
Bunker and Residual oils
Lubricating oils
Asphalt and road oils
Tars
Petroleum coke
Petroleum wax
Propane/propylene
Butane/Butylene
Other

Appendix 2 - Alaska's Civil Penalty System for Oil Spills

18 AAC 75.570 Schedule of Civil Penalties

The civil penalty which a person may be held liable under AS 46.03.758(e) is established as follows:

(1) Base penalty for discharges into various receiving environments is:⁶

	<u>Freshwater</u>	<u>Marine</u>
Critical environmental resources	\$10.00	\$2.50
Sensitive environmental resources	\$5.00	\$2.00
Without significant environmental resources	\$1.00	\$1.00

(2) Toxicity, degradability and dispersibility factors are as follows:

Toxicity	Factor	Degradability	Factor
High	1.00	Low	1.00
Moderate	0.75	Moderate	0.50
Less	0.50	High	0.25
Relatively nontoxic	0.25		

Dispersibility	Factor
High	0.15
Moderate	0.50
Low	1.00

(3) The net per gallon penalty is calculated by multiplying the base penalty (Number 1) by the arithmetic mean of the toxicity, degradability and dispersibility factors (Number 2). If a portion of the oil enters more than one receiving environment, the penalty is based on the most sensitive receiving environment which that portion of the oil enters.

⁶For a description of each type of environment, see below.

Alaska's Formula for Crude Oil

$$\frac{(\text{toxicity} \cdot (\text{API}/30) + \text{degradability} \cdot (30/\text{API}) + \text{dispersibility}) \cdot \text{penalty} \cdot \text{volume}}{3} \quad ^7$$

Alaska's Formula for Refined Products

$$\frac{(\text{toxicity} \cdot (\% \text{ aromatics}/45) + \text{degradability} + \text{dispersibility}) \cdot \text{penalty} \cdot \text{volume}}{3}$$

18 ACC 75.540 Toxicity of Petroleum Products/By-products⁸

Highly Toxic	Moderately Toxic	Less Toxic	Relatively Nontoxic
#1,2 & Arctic diesel fuel & heating oil	waste oil & waste oil mixtures	bunker & residual fuel oils	asphalts
jet aviation fuels A and B	lubricating oil	hydraulic fluids;	tars
motor gasoline including aviation gasoline	all other jet fuels		all other petroleum products & by-products
kerosene	crude oil		
stationary turbine fuels			

⁷Where API represents the gravity of oil obtained using a hydrometer graduated to the American Petroleum Institute scale. The relationship between the API scale and specific gravity of petroleum is expressed by the formula: Degrees API = 141.5/(sp. gr. 60/60 °F) - 131.5.

⁸To determine the toxicity factor for a refined product, the factor from the table (previous page) is multiplied by a fraction whose numerator is the percent concentration of aromatics in the oil and whose denominator is 45. The toxicity factor shall never exceed 1.0. For crude oil, the toxicity factor is multiplied by a fraction whose numerator is the API gravity of the crude and whose denominator is 30.

18 AAC 75.550 Degradability of Petroleum Products/By-products⁹

Low	Moderate	High
asphalt	hydraulic fluids	motor gasoline including aviation gasoline
tar	lubricating oil	#1,2 & Arctic diesel fuel & heating oil
bunker & residual fuel oils	waste oils, waste oil mixtures	jet & stationary turbine fuels
all other petroleum products/by-products	crude oil	kerosene

18 AAC 75.560 Dispersibility of Petroleum Products/By-products

High	Moderate	Low
motor gasoline including aviation gasoline	emulsified oil mixes	bunker & residual fuel oils
all jet fuels	lubricating oils	asphalts
kerosene	waste oils & waste oil mixtures	tars
#1,2 & Arctic diesel fuel & heating oil	crude oils	all other petroleum products/by-products
hydraulic fluid		
stationary turbine fuels		

⁹For crude oil, the degradability factor is multiplied by a fraction whose numerator is 30 and whose denominator is the API gravity of the crude.

18 AAC 75.510 Freshwater Environments

(a) Freshwater environments with significant aquatic resources are classified as follows:

Critical

- surface and subsurface waters supplies for which the commissioner of natural resources has issued a permit;
- rivers, lakes and streams important for the spawning, rearing or migration of anadromous fish, and the water of lakes, streams, and rivers which flow or empty into designated waters;
- lakes, streams, rivers and freshwater wetlands within the boundaries of lands administered under the National Wildlife Refuge System, and the waters of lakes, streams and rivers which flow or empty into those waters;
- lakes, streams, rivers and freshwater wetlands within the boundaries of game reserve areas, refuges, critical habitat areas, and sanctuaries and the water of lakes, streams, and rivers which flow or empty into these waters;
- Lakes, streams, rivers and freshwater wetlands within the boundaries of fish reserve areas, refuges, critical habitat areas and sanctuaries, and the water of lakes, streams and rivers which flow or empty into those waters.

Sensitive

- lakes other than those classified in (A) of this subsection;
- freshwater wetlands other than classified in (A) of this subsection; and
- subsurface freshwater other than those classified in (A)(1) of this subsection.

(b) All freshwater not classified above are classified as "without significant aquatic resources."

18 AAC 75.520 Marine Environments

(a) Estuarine, intertidal and saltwater environments;

Critical

- marine water within the boundaries of state game refuges;
- marine water within the boundaries of fish and game critical habitats;
- marine water within the boundaries of marine sanctuaries;
- marine water within the boundaries of areas administered under the National Wildlife Refuge System;
- marine water within one statute mile of the mouth of waters designated as important for the spawning, rearing or migration of anadromous fish;
- marine water within one statute mile of a seabird colony or marine mammal rookery or hauling ground;
- high density sea otter habitat;
- marine water within the barrier island-lagoon ecosystems extending from the Colville River to Canning River, and seaward of the Copper River delta.

Sensitive

- the inside water of SE Alaska not otherwise classified in (A) of this subsection;
- saltwater wetlands and other intertidal and estuarine areas not otherwise classified in (A) of this subsection; and
- Prince William Sound, and the bays, arms fjords, ports and other inside marine waters of Prince William Sound; and
- all marine water within 10 statute miles of any point of those waters designated in (A) of this subsection.

(b) All marine water not classified in (A) or (B) of this subsection, is classified as without significant aquatic resources.

Appendix 3 - Texas Guidelines for the Determination of Values for Fish and Wildlife

The Texas Parks and Wildlife Code (sections 12.301-12.303) directs the Texas Wildlife Commission to adopt rules that establish guidelines for valuing fish and wildlife, thus quantifying the damages recoverable in suits for unlawful injury or destruction of fish and wildlife.

The value determined through use of these guidelines for each species is arrived at through a rating of factors that contribute to the relative significance of that species, followed by application of a monetary scale to the overall rating.

A species is rated on a scale of 0-3 for each of eight criteria "...selected to reflect the major definable elements of social and economic values attributable to wildlife, while at the same time avoiding overlaps or duplications in accounting for those elements" (11 Texas Register 1561). These eight scores are summed, then adjusted through multiplication by a factor "that reflects the extent to which public demand for the species exceeds what might be expected purely on the basis of the objective elements of value attributable to that species" (11 Texas Register 1561-62).

31 TAC 69.22

(a) Each species of bird, mammal, reptile, amphibian, threatened or endangered aquatic life is assigned a score of 0-3 for each of eight criteria. Scores are then summed, multiplied by a weighting factor and compared to a monetary scale to obtain a monetary value. A partial list of wildlife values obtained by applying these guidelines is included at Table 1 of Section 69.31 of this title.

(b) The scoring criteria are as follows:

1) Recreation. This criterion takes account of the traditional extent to which a species is actively sought by sportsmen, photographers, bird watchers, nature enthusiasts, park visitors, and others with wildlife interests. Scoring considers both harvest and non-harvest use of a species. A species that is not sought at all would be scored as 0; a highly sought-after species would be scored as 3.

2) Aesthetic. This criterion takes account of high (score:3) to low (score:0) intangible social values of wildlife species that arise from their beauty or interesting qualities (behavior, coloration, movement, or other attributes), and that exist merely because of the species' known presence in an area, whether or not a given person ever would encounter one in the wild.

3) Educational. This criterion takes account of high (score:3) to low (score:0) perceived educational value of a species arising from, for example, published materials and other audio-visual media about the species, displays in zoos, or the relative frequency with which the species is used to exemplify important curricula principles.

4) Scarcity. This criterion takes account of relative population of a species within the range of its habitat, from very abundant (score:0) to scarce (score:3).

5) Environmental tolerance. This criterion takes account of whether a species is tolerant of a wide range of environmental conditions and the normally considered limiting factors (score:0) or is sensitive to climate, topography, water regimes, or other ecological factors (score:3), and is thus limited in range and population.

6) Economics. This criterion takes account of high (score:3) to low (score:0) direct or indirect cash flow attributable to the species as a result of recreational

transactions (such as hunting leases), sightseeing tours, park visits, pelt value, or other similar legal financial transactions.

7) Recruitment. This criterion takes account of high (score:0) to low (score:3) reproductive and survival potential of a species as it relates to the capability for replacement of its population following decrease or loss.

8) Ecological role. This criterion takes account of a species' relationships with other lifeforms - contributing to a healthful and stable balance of nature. For example, widely-consumed forage species score high (score:3), as do important predators (score:3) which keep prey species populations under control. Forage species that are not widely consumed score low (score:0), as do rare predators (score:0) which contribute little to regulation of prey populations.

(c) Weighting factors are applied to the basic score achieved by applying the eight criteria listed in subsection (b) of this section, in order to account for any existing variance in public demand and/or perception of value for a species. These weighting factors relate to overall demand for the species relative to existing supply and to future opportunity as management programs evolve. The total basic criteria score is multiplied by the relevant weighting factor to obtain the adjusted criteria score. These multipliers are assigned as follows:

(1) 1.0 - no additional public demand or perception of value exists beyond that reflected by the eight criteria above.

(2) 1.1 - minor disparity exists between resource availability and public interest and the public demand fluctuates periodically around an equilibrium point;

(3) 1.3 - substantial disparity exists between available supply and identified public interest in wildlife resources (species) that are subject to ongoing management programs;

(4) 1.5 - the wildlife resource (species) supply is never expected to meet identified demands and needs, or management programs for a limited species are not fully developed with respect to planned recreational opportunity and economic contribution.

(d) Once a species has been scored using the guidelines established in subsections (a) - (c) of this section, the following table is used to determine the monetary value for each species.

<u>Adjusted Criteria Score Range</u>	<u>Monetary Range</u>
1-5	\$1-\$5
6-8	\$6-10
9-10	\$11-20
11-12	\$21-50
13-14	\$51-75
15-16	\$76-250
17-18	\$251-800
19-20	\$801-1,500
21-23	\$1,501-4,200
24-36	\$4,210-10,000

A \$1000 and \$500 premium is added for each individual member of an endangered and threatened species, respectively.

All recovery values are updated on August 31 of each year to reflect changes in the CPI.

(e) For each individual member of a species categorized as endangered or threatened, a premium is added to the monetary value derived by application of this section. The premium is \$1,000 for each individual member of an endangered species and \$500 for each individual member of a threatened species.

§69.28. Updating Existing Recovery Values. All recovery values obtained by the application of this chapter shall be updated by the department on August 31 of each year to reflect an increase or decrease (percent of change) in the consumer price index of retail sales as prepared by the Bureau of Labor Statistics, United States Department of

Labor (using the National Consumer Price Index, all urban consumers, 1967-100) to reflect current estimated values as adjusted for inflationary factors.

(or a proclamation or regulation adopted under that Code) or in violation of the Texas Water Code, §26.121.

§69.30. Savings Clause. If any word, phrase, sentence, paragraph, section, subsection, or any other part of this chapter is invalidated or held inapplicable for any reason, the balance of the chapter shall not be affected thereby, but shall remain in full force and effect to the greatest extent permitted by law.

§69.31. Computed Values for Selected Species. The values contained in the tables within this section were computed as of March 1, 1986, by the Texas Parks and Wildlife Department personnel, using the valuation methodologies established by this chapter:

SAMPLE PAGE

TABLE 1. PARTIAL LIST WILDLIFE VALUES:

SPECIES	CATEGORY	REC	AES	EDU	SCA	ENV	ECO	RET	ECOL	SUM	MUL	SCORE	VALUE RANGE
Whooping Crane	ENDANGERED	2	3	3	3	3	1	3	2	20	1.5	30	\$4,201 - \$10,000**
Bighorn-H	ENDANGERED	0	3	3	3	3	0	3	1	16	1.5	24	\$4,201 - \$10,000**
Bald Eagle	ENDANGERED	1	3	3	2	3	0	3	2	17	1.3	22	\$1,501 - \$4,200**
Bighorn-F	ENDANGERED	0	2	2	3	3	0	3	1	14	1.5	21	\$1,501 - \$4,200**
Atlantic Ridley Turtle	ENDANGERED	0	1	1	3	3	1	3	1	13	1.5	20	\$801 - \$1,500**
Peregrine Falcon	ENDANGERED	1	2	2	2	3	0	3	2	15	1.3	20	\$801 - \$1,500**
Ocelot	ENDANGERED	0	3	0	3	3	0	2	2	13	1.5	20	\$801 - \$1,500**
Mule deer-H	GAME MAMMAL	1	2	2	1	2	1	2	1	12	1.5	18	\$251 - \$800
Brown Pelican	ENDANGERED	0	2	2	3	3	0	3	1	14	1.3	18	\$251 - \$800**
Red-Cockaded Woodpecker	ENDANGERED	1	1	2	3	3	0	2	2	14	1.3	18	\$251 - \$800**
Eastern Turkey	GAME BIRD	1	3	1	3	2	1	1	2	14	1.3	18	\$251 - \$800
Golden-cheeked Warbler	THREATENED	1	1	1	3	3	1	2	2	14	1.3	18	\$251 - \$800*
Attwater's P. Chick	ENDANGERED	1	1	1	3	3	0	1	2	12	1.5	18	\$251 - \$800**
Black-footed Ferner	ENDANGERED	0	1	1	3	3	0	3	1	12	1.5	18	\$251 - \$800**
Elk-H	GAME MAMMAL	0	3	1	3	2	0	2	1	12	1.5	18	\$251 - \$800
White-tail-H	GAME MAMMAL	3	3	3	0	1	3	2	1	16	1.1	18	\$251 - \$800
Black Bear	GAME MAMMAL	0	2	1	3	2	0	2	2	12	1.5	18	\$251 - \$800
Alligator	STATUTORY	1	2	2	1	2	1	1	3	13	1.3	17	\$251 - \$800
Pronghorn-H	GAME MAMMAL	1	3	1	2	2	1	2	1	13	1.3	17	\$251 - \$800
Elk-F	GAME MAMMAL	0	3	1	3	2	0	2	1	12	1.3	16	\$76 - \$250
Mule deer-F	GAME MAMMAL	1	3	2	1	1	1	2	1	12	1.3	16	\$76 - \$250

Appendix 4 - EHB 1853 and EHB 1854



CERTIFICATION OF ENROLLED ENACTMENT

SUBSTITUTE HOUSE BILL NO. 1853.....

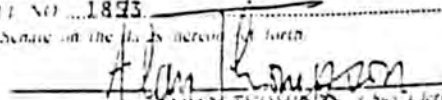
Passed the House... March 9, 1989
as amended
Yeas 95 Nays 0

Passed the Senate... April 5, 1989
as amended
Yeas 17 Nays 10

April 15, 1989: The House concurred in the Senate
amendments and passed the bill as
amended by the Senate.
Yeas: 92 Nays: 0

CERTIFICATE

I, Alan Thompson, Chief Clerk of the House of Representatives of the State of Washington, do hereby certify that
the attached is enrolled SUBSTITUTE HOUSE BILL NO. 1853
as passed by the House of Representatives and the Senate on the 15th day of April 1989.


ALAN THOMPSON, Chief Clerk

ENGROSSED SUBSTITUTE HOUSE BILL NO. 1853
AS AMENDED BY THE SENATE

State of Washington 51st Legislature 1989 Regular Session
by Committee on Environmental Affairs (originally sponsored by
Representatives Jones, Hargrove, Rust, Winsley, Haugen, Spanel,
Basich, R. King, Belcher, Cole, Jacobsen, Pruitt, P. King, Valle
and Nelson)

Read first time 2/27/89 and referred to Committee on Appropriations.

1 AN ACT Relating to oil spill damage assessment, compensation, and
2 penalties under the state water pollution control act; amending RCW
3 90.48.315, 90.48.390, 90.48.400, and 90.48.350; adding new sections
4 to chapter 90.48 RCW; creating new sections; prescribing penalties;
5 making an appropriation; and declaring an emergency.

6 BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF WASHINGTON:

7 NEW SECTION. Sec. 1. INTENT. The legislature finds that oil
8 spills can cause significant damage to the environment and natural
9 resources held in trust by and for the people of this state. Some of
10 these damages are unquantifiable, and others cannot be quantified at
11 a reasonable cost. Both quantifiable and unquantifiable damages
12 often occur despite prompt containment and cleanup measures. Due to
13 the inability to measure the exact nature and extent of certain types
14 of damages, current damage assessment methodologies used by the state
15 inadequately assess the damage caused by oil spills.

16 In light of the magnitude of environmental and natural resource
17 damage which may be caused by oil spills, and the importance of
18 fishing, tourism, recreation, and Washington's natural abundance and
19 beauty to the quality of life and economic future of the people of
20 this state, the legislature declares that compensation should be
21 sought for those damages that cannot be quantified at a reasonable
22 cost and for those unquantifiable damages that result from oil
23 spills. This compensation is intended to ensure that the public does
24 not bear substantial losses caused by oil pollution for which
25 compensation may not otherwise be received.

26 NEW SECTION. Sec. 2. COMPENSATION SCHEDULE. By July 1, 1991,
27 the department, in consultation with the departments of fisheries,
28 wildlife, and natural resources, and the parks and recreation

Sec. 2

1 commission, shall adopt rules establishing a compensation schedule
2 for the discharge of oil in violation of RCW 90.48.320, by persons
3 liable under RCW 90.48.336. The department shall establish a
4 scientific advisory board to assist in establishing the compensation
5 schedule. The amount of compensation assessed under this schedule
6 shall be no less than one dollar per gallon of oil spilled and no
7 greater than fifty dollars per gallon of oil spilled. The
8 compensation schedule shall reflect adequate compensation for
9 unquantifiable damages or for damages not quantifiable at reasonable
10 cost for any adverse environmental, recreational, aesthetic, or other
11 effects caused by the oil spill and shall take into account:

12 (1) Characteristics of the oil spilled, such as toxicity,
13 dispersibility, solubility, and persistence, that may affect the
14 severity of the effects on the receiving environment, living
15 organisms, and recreational and aesthetic resources;

16 (2) The sensitivity of the affected area as determined by such
17 factors as: (a) The location of the spill; (b) habitat and living
18 resource sensitivity; (c) seasonal distribution or sensitivity of
19 living resources; (d) areas of recreational use or aesthetic
20 importance; (e) the proximity of the spill to important habitats for
21 birds, aquatic mammals, fish, or to species listed as threatened or
22 endangered under state or federal law; and (f) other areas of special
23 ecological or recreational importance, as determined by the
24 department; and

25 (3) Actions taken by the party who spilled the oil or any party
26 liable for the spill that: (a) Demonstrate a recognition and
27 affirmative acceptance of responsibility for the spill, such as the
28 immediate removal of oil and the amount of oil removed from the
29 environment; or (b) enhance or impede the detection of the spill, the
30 determination of the number of gallons spilled, or the extent of
31 damage, including the unauthorized removal of evidence such as oiled
32 fish or wildlife.

33 NEW SECTION. Sec. 3. ASSESSMENT OF COMPENSATION. (1) Prior to
34 assessing compensation under section 2 of this act, the department
35 shall conduct a formal preassessment screening as provided in section
36 4 of this act. The department shall use the compensation schedule

1 established under section 2 of this act if the preassessment
2 screening committee determines that: (a) Restoration or enhancement
3 of the injured resources is not technically feasible; (b) damages are
4 not quantifiable at a reasonable cost; and (c) the restoration and
5 enhancement projects or studies proposed by the liable parties are
6 insufficient to adequately compensate the people of the state for
7 damages sustained as a result of the oil spill.

8 (2) Compensation shall not be assessed under this section for oil
9 spills for which damages have been or will be assessed under RCW
10 90.48.142.

11 (3) Compensation assessed under this section shall be recoverable
12 in an action brought by the attorney general on behalf of the people
13 of the state of Washington in the superior court of Thurston county
14 or any county in which damages occurred. Moneys recovered by the
15 attorney general under this section shall be deposited in the coastal
16 protection fund established under RCW 90.48.390, and shall only be
17 used for the purposes stated in RCW 90.48.400.

18 (4) Compensation assessed under this section for a particular oil
19 spill shall preclude claims under this chapter by local governments
20 for compensation for damages to publicly owned resources resulting
21 from the same spill.

22 NEW SECTION. Sec. 4. PREASSESSMENT SCREENING. (1) The
23 department shall adopt rules establishing a formal process for
24 preassessment screening of damages resulting from oil spills. The
25 rules shall specify the conditions under which the department shall
26 convene a preassessment screening committee. The preassessment
27 screening process shall occur concurrently with reconnaissance
28 activities. The committee shall use information obtained from oil
29 spill reconnaissance activities as well as any other relevant
30 resource and resource use information. For each oil spill, the
31 committee shall determine whether a damage assessment investigation
32 should be conducted under RCW 90.48.142, or alternatively, whether
33 the compensation schedule authorized under sections 2 and 3 of this
34 act should be used to assess damages. The committee may accept
35 restoration or enhancement projects or studies proposed by the liable
36 parties in lieu of some or all of: (a) The compensation schedule

Sec. 4

1 authorized under this chapter; or (b) the claims from damage
2 assessment studies authorized under RCW 90.48.142.

3 (2) A preassessment screening committee may consist of
4 representatives of the departments of ecology, fisheries, wildlife,
5 natural resources, social and health services, and emergency
6 management, the parks and recreation commission, as well as other
7 federal, state, and local agencies, and tribal and local governments
8 whose presence would enhance the reconnaissance or damage assessment
9 aspects of oil spill response. The department shall chair the
10 committee and determine which representatives will be needed on a
11 spill-by-spill basis.

12 (3) The committee shall consider the following factors when
13 determining whether a damage assessment study authorized under RCW
14 90.48.142 should be conducted: (a) Whether evidence from
15 reconnaissance investigations suggests that injury has occurred or is
16 likely to occur to publicly owned resources; (b) the potential loss
17 in services provided by resources injured or likely to be injured and
18 the expected value of the potential loss; (c) whether a restoration
19 project to return lost services is technically feasible; (d) the
20 accuracy of damage quantification methods that could be used and the
21 anticipated cost-effectiveness of applying each method; (e) the
22 extent to which likely injury to resources can be verified with
23 available quantification methods; and (f) whether the injury, once
24 quantified, can be translated into monetary values with sufficient
25 precision or accuracy.

26 (4) Oil spill damage assessment studies authorized under RCW
27 90.48.142 may only be conducted if the committee, after considering
28 the factors enumerated in subsection (3) of this section, determines
29 that the damages to be investigated are quantifiable at a reasonable
30 cost and that proposed assessment studies are clearly linked to
31 quantification of the damages incurred.

32 (5) As new information becomes available, the committee may
33 reevaluate the scope of damage assessment using the factors listed in
34 subsection (3) of this section and may reduce or expand the scope of
35 damage assessment as appropriate.

36 (6) The preassessment screening process shall provide for the

1 ongoing assessment of persons who may be liable for damages
2 resulting from an oil spill. The department may negotiate with a
3 potentially liable party to perform restoration and enhancement
4 projects or studies which may substitute for all or part of the
5 compensation authorized under sections 2 and 3 of this act or the
6 damage assessment studies authorized under RCW 90.48.142.

7 (7) For the purposes of this section and section 3 of this act,
8 the cost of a damage assessment shall be considered "reasonable" when
9 the anticipated cost of the damage assessment is expected to be less
10 than the anticipated damage that may have occurred or may occur.

11 NEW SECTION. Sec. 5. ANNUAL REPORT. The department shall
12 submit an annual report to the appropriate standing committees of the
13 legislature for the next five years beginning January 1, 1990. The
14 annual report shall cover the implementation of this act and shall
15 include information on each oil spill for which a preassessment
16 screening committee was convened, the outcome of each process, any
17 compensation claims imposed or damage assessment studies conducted,
18 and the revenues to and expenditures from the coastal protection
19 fund.

20 Sec. 6. Section 10, chapter 133, Laws of 1969 ex. sess. as last
21 amended by section 5, chapter 316, Laws of 1985 and RCW 90.48.315 are
22 each amended to read as follows:

23 For purposes of RCW 90.48.315 through 90.48.365 ~~((and RCW))~~,
24 78.52.020, 78.52.125, 82.36.330, 90.48.315, 90.48.370 through
25 90.48.410, 90.48.903, 90.48.906 and 90.48.907, and sections 2 through
26 5 of this act, the following definitions shall apply unless the
27 context indicates otherwise:

28 (1) "Board" shall mean the pollution control hearings board.

29 (2) "Committee" shall mean the preassessment screening committee
30 established under section 4 of this act.

31 (3) "Department" shall mean the department of ecology.

32 ~~((3))~~ (4) "Director" shall mean the director of the department
33 of ecology.

34 ~~((4))~~ (5) "Discharge" shall mean any spilling, leaking,
35 pumping, pouring, emitting, emptying, or dumping.

Sec. 6

1 (((5))) (6) "Fund" shall mean the state coastal protection fund
2 as provided in RCW 90.48.390 and 90.48.400.

3 (((6))) (7) "Having control over oil" shall include but not be
4 limited to any person using, storing, or transporting oil immediately
5 prior to entry of such oil into the waters of the state, and shall
6 specifically include carriers and bailees of such oil.

7 (((7))) (8) "Necessary expenses" means the expenses incurred by
8 the department and assisting state agencies for (a) investigating the
9 source of the discharge; (b) investigating the extent of the
10 environmental damage caused by the discharge; and (c) conducting
11 actions necessary to clean up the discharge.

12 (((8))) (9) "Oil" or "oil" shall mean oil, including gasoline,
13 crude oil, fuel oil, diesel oil, lubricating oil, sludge, oil refuse,
14 liquid natural gas, propane, butane, gas distilled from coal, and
15 other liquid hydrocarbons regardless of specific gravity, or any
16 other petroleum-related product.

17 (((9))) (10) "Person" shall mean any political subdivision,
18 government agency, municipality, industry, public or private
19 corporation, copartnership, association, firm, individual, or any
20 other entity whatsoever and its owner, operator, master, officer, or
21 employee of a ship.

22 (((10))) (11) "Ship" shall mean any boat, ship, vessel, barge, or
23 other floating craft of any kind.

24 (((11))) (12) "Technical feasibility" or "technically feasible"
25 shall mean that given available technology a restoration or
26 enhancement project can be successfully completed at a cost that is
27 not disproportionate to the value of the resource prior to the
28 injury.

29 (13) "Waters of the state" shall include lakes, rivers, ponds,
30 streams, inland waters, underground water, salt waters, estuaries,
31 tidal flats, beaches and lands adjoining the seacoast of the state,
32 sewers, and all other surface waters and watercourses within the
33 jurisdiction of the state of Washington.

34 Sec. 7. Section 4, chapter 180, Laws of 1971 ex. sess. and RCW
35 90.48.390 are each amended to read as follows:

36 The coastal protection fund is established to be used by the

1 department as a revolving fund for carrying out the purposes of RCW
2 90.48.315 through 90.48.365 ((and--RCW)), 78.52.020, 78.52.125,
3 82.36.330, 90.48.315, 90.48.370 through 90.48.410, 90.48.903,
4 90.48.906 and 90.48.907, and sections 2 through 4 of this act. To
5 this fund there shall be credited penalties, fees, and charges
6 received pursuant to the provisions of RCW 90.48.315 through
7 90.48.365, compensation for damages received under sections 2 through
8 4 of this act, and an amount equivalent to one cent per gallon from
9 each marine use refund claim under RCW 82.36.330.

10 Moneys in the fund not needed currently to meet the obligations
11 of the department in the exercise of its powers, duties, and
12 functions under RCW 90.48.315 through 90.48.365 and RCW 78.52.020,
13 78.52.125, 82.36.330, 90.48.315, 90.48.370 through 90.48.410,
14 90.48.903, 90.48.906 and 90.48.907 shall be deposited with the state
15 treasurer to the credit of the fund and may be invested in such
16 manner as is provided for by law. Interest received on such
17 investment shall be credited to the fund.

18 Sec. 8. Section 5, chapter 180, Laws of 1971 ex. sess. and RCW
19 90.48.400 are each amended to read as follows:

20 (1) Moneys in the coastal protection fund shall be disbursed for
21 the following purposes and no others:

22 (a) All costs of the department related to the enforcement of RCW
23 90.48.315 through 90.48.365 ((and--RCW)), 78.52.020, 78.52.125,
24 82.36.330, 90.48.315, 90.48.370 through 90.48.410, 90.48.903,
25 90.48.906 and 90.48.907, and sections 2 through 4 of this act
26 including but not limited to equipment rental and contracting costs.

27 (b) All costs involved in the abatement of pollution related to
28 the discharge of oil.

29 (c) The director may allocate a portion of the fund to be devoted
30 to research and development in the causes, effects, and removal of
31 pollution caused by the discharge of oil.

32 (2) Moneys disbursed from the coastal protection fund for the
33 abatement of pollution caused by the discharge of oil shall be
34 reimbursed to the fund whenever:

35 (a) Moneys are available under any federal program; or

36 (b) Moneys are available from a recovery made by the department

1 from the person liable for the discharge of oil.

2 (3) A steering committee consisting of representatives of the
3 department of ecology, fisheries, wildlife, and natural resources,
4 and the parks and recreation commission shall authorize the
5 expenditure of the moneys collected under sections 2 through 4 of
6 this act, after consulting impacted local agencies and local and
7 tribal governments. The moneys collected under sections 2 through 4
8 of this act shall only be used for the following purposes: (a)
9 Environmental restoration and enhancement projects intended to
10 restore or enhance environmental, recreational, or aesthetic
11 resources for the benefit of Washington's citizens: (b)
12 investigations of the long-term effects of oil spills on state
13 resources: and (c) reimbursement of agencies for reasonable
14 reconnaissance and damage assessment costs. Agencies may not be
15 reimbursed under this section for the salaries and benefits of
16 permanent employees for routine operational support. Agencies may
17 only be reimbursed under this section if money for reconnaissance and
18 damage assessment activities is unavailable from other sources.

19 Sec. 9. Section 7, chapter 133, Laws of 1969 ex. sess. as last
20 amended by section 20, chapter 109, Laws of 1987 and RCW 90.48.350
21 are each amended to read as follows:

22 Any person who ~~((intentionally or))~~ negligently discharges oil,
23 or causes or permits the entry of the same, shall incur, in addition
24 to any other penalty as provided by law, a penalty in an amount of up
25 to twenty thousand dollars for every such violation, and for each day
26 ~~((of a continuing violation of said amount to))~~ the spill poses risks
27 to the environment as determined by the director. Any person who
28 intentionally or recklessly discharges or causes or permits the entry
29 of oil into the waters of the state shall incur, in addition to any
30 other penalty authorized by law, a penalty of up to one hundred
31 thousand dollars for every such violation and for each day the spill
32 poses risks to the environment as determined by the director. The
33 amount of the penalty shall be determined by the director after
34 taking into consideration the gravity of the violation, the previous
35 record of the violator in complying, or failing to comply, with the
36 provisions of chapter 90.48 RCW, the speed and thoroughness of the

1 collection and removal of the oil, and such other considerations as
2 the director deems appropriate. Every act of commission or omission
3 which procures, aids or abets in the violation shall be considered a
4 violation under the provisions of this section and subject to the
5 penalty herein provided for. The penalty herein provided for shall
6 be imposed pursuant to RCW 43.21B.300.

7 NEW SECTION. Sec. 10. The sum of seventy-five thousand dollars,
8 or as much thereof as may be necessary, is appropriated from the
9 state toxics control account to the department of ecology for the
10 biennium ending June 30, 1991, for the purpose of preparing the
11 compensation schedule required under section 2 of this act.

12 NEW SECTION. Sec. 11. Sections 2 through 5 of this act are each
13 added to chapter 90.48 RCW.

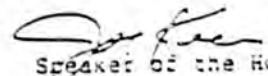
14 NEW SECTION. Sec. 12. This act applies prospectively only, and
15 not retroactively. It applies only to causes of action which arise
16 after the effective date of this act.

17 NEW SECTION. Sec. 13. Section headings as used in this act do
18 not constitute any part of the law.

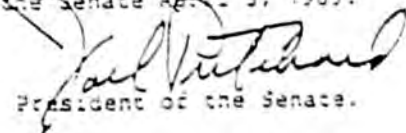
19 NEW SECTION. Sec. 14. If any provision of this act or its
20 application to any person or circumstance is held invalid, the
21 remainder of the act or the application of the provision to other
22 persons or circumstances is not affected.

23 NEW SECTION. Sec. 15. This act is necessary for the immediate
24 preservation of the public peace, health, or safety, or support of
25 the state government and its existing public institutions, and shall
26 take effect immediately.

Passed the House April 15, 1989.


Speaker of the House.

Passed the Senate April 5, 1989.


President of the Senate.

IN THE LEGISLATURE
of the
STATE OF WASHINGTON



CERTIFICATION OF ENROLLED ENACTMENT

SUBSTITUTE HOUSE BILL NO. 1854

Passed the House March 7 1989.

Yeas 25 Nays 0

Passed the Senate April 6 1989
as amended

Yeas 41 Nays 3

April 15, 1989: The House concurred in the Senate
amendment and passed the bill as
amended by the Senate.

Yeas: 92 Nays: 0

CERTIFICATE

I, Alan Thompson, Chief Clerk of the House of Representatives of the State of Washington, do hereby certify that
the attached is enrolled SUBSTITUTE HOUSE BILL, NO. 1854
as passed by the House of Representatives and the Senate on the dates herein set forth.

Alan Thompson
ALAN THOMPSON, Chief Clerk

SUBSTITUTE HOUSE BILL NO. 1854
AS AMENDED BY THE SENATE

State of Washington 51st Legislature 1989 Regular Session
by Committee on Environmental Affairs (originally sponsored by
Representatives Jones, Hargrove, Rust, Winsley, Basich, R. King,
Belcher, Cole, Spanel, P. King and Nelson)

Read first time 2/22/89.

1 AN ACT Relating to resource damage assessment under the state
2 water pollution control act; amending RCW 90.48.142, 90.48.390, and
3 90.48.400; creating new sections; and declaring an emergency.

4 BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF WASHINGTON:

5 NEW SECTION. Sec. 1. The legislature finds that there is
6 confusion regarding the measure of damages authorized under RCW
7 90.48.142. The intent of this act is to clarify existing law on the
8 measure of damages authorized under RCW 90.48.142, not to change the
9 law.

10 Sec. 2. Section 13, chapter 139, Laws of 1967 ex. sess. as last
11 amended by section 69, chapter 36, Laws of 1988 and RCW 90.48.142 are
12 each amended to read as follows:

13 (1) Any person who violates any of the provisions of this
14 chapter, or fails to perform any duty imposed by this chapter, or
15 violates an order or other determination of the department or the
16 director made pursuant to the provisions of this chapter, including
17 the conditions of a waste discharge permit issued pursuant to RCW
18 90.48.160, and in the course thereof causes the death of, or injury
19 to, fish, animals, vegetation or other resources of the state, or
20 otherwise causes a reduction in the quality of the state's waters
21 below the standards set by the department or, if no standards have
22 been set, causes significant degradation of water quality, thereby
23 damaging the same, shall be liable to pay the state damages in an
24 amount equal to the sum of money necessary to: (a) Restore any
25 damaged resource to its condition prior to the injury, to the extent
26 technically feasible, and compensate for the lost value incurred
27 during the period between injury and restoration; or (b) compensate
28 for the lost value throughout the duration of the injury that the

Sec. 2

1 resource previously provided if restoration is not technically
2 feasible and, when only partial restoration is technically feasible,
3 compensate for the remaining lost value. "Technical feasibility" or
4 "technically feasible" shall mean for the purposes of this
5 subsection, that given available technology, a restoration or
6 enhancement project can be successfully completed at a cost that is
7 not disproportionate to the value of the resource prior to the
8 injury.

9 (2) Restoration shall include the cost to restock such waters,
10 replenish or replace such resources, and otherwise restore the
11 stream, lake or other ((water-seuree)) waters of the state, including
12 any estuary, ocean area, submerged lands, shoreline, bank, or other
13 lands adjoining such waters to its condition prior to the injury, as
14 such condition is determined by the department. The lost value of a
15 damaged resource shall be equal to the sum of consumptive,
16 nonconsumptive, and indirect use values, as well as lost taxation,
17 leasing, and licensing revenues. Indirect use values may include
18 existence, bequest, option, and aesthetic values. Damages shall be
19 determined by generally accepted and cost-effective procedures.

20 (3) Such damages shall be recoverable in an action brought by the
21 attorney general on behalf of the people of the state of Washington
22 in the superior court of Thurston county or the county in which such
23 damages occurred: PROVIDED, That if damages occurred in more than
24 one county the attorney general may bring action in any of the
25 counties where the damages occurred. Any money so recovered by the
26 attorney general shall be transferred to ((either-the-state-wildlife
27 fund-of-the-department-of-fisheries-to-use-for-feed-fish-or-shellfish
28 management-purposes-and-propagation,-or-to-any-other--agency--of--the
29 state--having--jurisdiction--over--the-resource-damaged-and-for-which
30 said-moneys-were--recovered;--as--appropriate;--PROVIDED;--That--the
31 agency--receiving--such-money-shall-utilize-not-less-than-one-half-of
32 said-money-on-activities-of)) the coastal protection fund established
33 under RCW 90.48.390. A steering committee consisting of
34 representatives of the departments of ecology, fisheries, wildlife,
35 natural resources, and the parks and recreation commission shall
36 authorize the expenditure of the moneys collected under this section

1 after consulting impacted local agencies and local and tribal
 2 governments. The department shall chair the steering committee. The
 3 moneys collected under this section shall only be used for the
 4 following purposes: (a) Environmental restoration and enhancement
 5 projects intended to restore or enhance environmental, recreational,
 6 or aesthetic resources for the benefit of Washington's citizens: (b)
 7 investigations of the long-term effects of discharges, including
 8 sewer sludge, on state resources: and (c) reimbursement of agencies
 9 for reasonable reconnaissance and damage assessment costs under this
 10 chapter. Agencies may not be reimbursed under this section for the
 11 salaries and benefits of permanent employees for routine operational
 12 support. Agencies may only be reimbursed under this section if money
 13 for reconnaissance and damage assessment activities is unavailable
 14 from other sources. In authorizing restoration or enhancement
 15 projects, preference shall be given to projects within ((the-county))
 16 counties where ((the-action-was-brought-by-the-attorney-general)) the
 17 injury occurred. No action shall be authorized under this section
 18 against any person operating in compliance with the conditions of a
 19 waste discharge permit issued pursuant to RCW 90.48.160.

20 Sec. 3. Section 4, chapter 180, Laws of 1971 ex. sess. and RCW
 21 90.48.390 are each amended to read as follows:

22 The coastal protection fund is established to be used by the
 23 department as a revolving fund for carrying out the purposes of RCW
 24 90.48.315 through 90.48.365 and RCW 78.52.020, 78.52.125, 82.36.330,
 25 90.48.142, 90.48.315, 90.48.370 through 90.48.410, 90.48.903,
 26 90.48.906 and 90.48.907. To this fund there shall be credited
 27 penalties, fees, damages, and charges received pursuant to the
 28 provisions of RCW 90.48.142 and 90.48.315 through 90.48.365 and an
 29 amount equivalent to one cent per gallon from each marine use refund
 30 claim under RCW 82.36.330.

31 Moneys in the fund not needed currently to meet the obligations
 32 of the department in the exercise of its powers, duties, and
 33 functions under RCW 90.48.315 through 90.48.365 and RCW 78.52.020,
 34 78.52.125, 82.36.330, 90.48.142, 90.48.315, 90.48.370 through
 35 90.48.410, 90.48.903, 90.48.906 and 90.48.907 shall be deposited with
 36 the state treasurer to the credit of the fund and may be invested in

Sec. 3

1 such manner as is provided for by law. Interest received on such
2 investment shall be credited to the fund.

3 Sec. 4. Section 5, chapter 180, Laws of 1971 ex. sess. and RCW
4 90.48.400 are each amended to read as follows:

5 (1) Moneys in the coastal protection fund shall be disbursed for
6 the following purposes and no others:

7 (a) All costs of the department related to the enforcement of RCW
8 90.48.315 through 90.48.365 and RCW 78.52.020, 78.52.125, 82.36.330,
9 90.48.142, 90.48.315, 90.48.370 through 90.48.410, 90.48.903,
10 90.48.906 and 90.48.907 including but not limited to equipment rental
11 and contracting costs.

12 (b) All costs involved in the abatement of pollution related to
13 the discharge of oil.

14 (c) The director may allocate a portion of the fund to be devoted
15 to research and development in the causes, effects, and removal of
16 pollution caused by the discharge of oil.

17 (2) Moneys disbursed from the coastal protection fund for the
18 abatement of pollution caused by the discharge of oil shall be
19 reimbursed to the fund whenever:

20 (a) Moneys are available under any federal program; or

21 (b) Moneys are available from a recovery made by the department
22 from the person liable for the discharge of oil.

23 (3) Moneys collected under section 2 of this act shall only be
24 used for the purposes enumerated in that section, subject to the
25 approval of the steering committee.

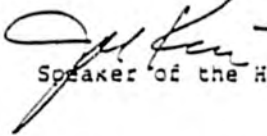
26 NEW SECTION. Sec. 5. This act applies prospectively only and
27 not retroactively. It applies only to causes of action which arise
28 after the effective date of this act.

29 NEW SECTION. Sec. 6. If any provision of this act or its
30 application to any person or circumstance is held invalid, the
31 remainder of the act or the application of the provision to other
32 persons or circumstances is not affected.

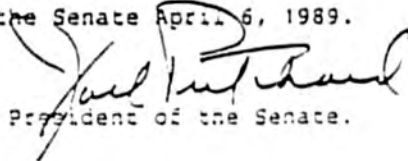
33 NEW SECTION. Sec. 7. This act is necessary for the immediate
34 preservation of the public peace, health, or safety, or support of

- 1 the state government and its existing public institutions, and shall
- 2 take effect immediately.

Passed the House April 15, 1989.


Speaker of the House.

Passed the Senate April 6, 1989.


President of the Senate.

OIL SPILL DAMAGE ASSESSMENT STUDY

LIST OF STUDY REPORTS

May 1989

Economic Issues and Valuation Concepts for Natural Resource Damages and an Analysis of Washington's Assessment Procedures. Jonathan Rubin. Final Report, April 1989, 37pp.

Description and Analysis of Alaska's Formula to Assess Civil Penalties and Applications of this Formula to the Port Angeles and Anacortes Oil Spills. Jonathan Rubin. Final Report, March 1989, 28pp.

Oil Spill Liability and Compensation: A Review and Evaluation of Alaska's Civil Penalty Scheme. Wendy Graham. Final Report, January 1989, 87pp.

Petroleum Toxicity and Fate in the Marine Environment with Implications for the Development of a Compensation Schedule for Spilled Oil. Jonathan Rubin. Final Report, March 1989, 29pp.

Policy Recommendations and Summary of Findings. Thomas M. Leschine. Preliminary Draft, October 1, 1988, 60pp.

A Proposed Compensation Schedule for Unquantifiable Oil Spill Damages. Thomas M. Leschine and Jonathan Rubin. May 1989 57pp.

Washington's Compensation Recovery Mechanisms for Aquatic Resource Damages from Pollutant Spills: A Review and Appraisal. Laura Geselbracht. Final Report, March 1989, 64pp.

RESOURCE DAMAGE ASSESSMENT

RESOURCE DAMAGE COMPENSATION TABLE

A SHORT CUT TO EXPENSIVE RESOURCE DAMAGE STUDIES

#2 General Approach
This is the slide
show I use to
describe the table
approach

#2

PENALITY VS RESOURCE DAMAGE ASSESSMENT

2 Separate and distinct actions may be taken by Ecology as the result of an oil spill

1. Penalty - Violation 90.48.320

Discharge of oil into the waters of the state

2. Resource Damage Assessment Claim - 90.48.142

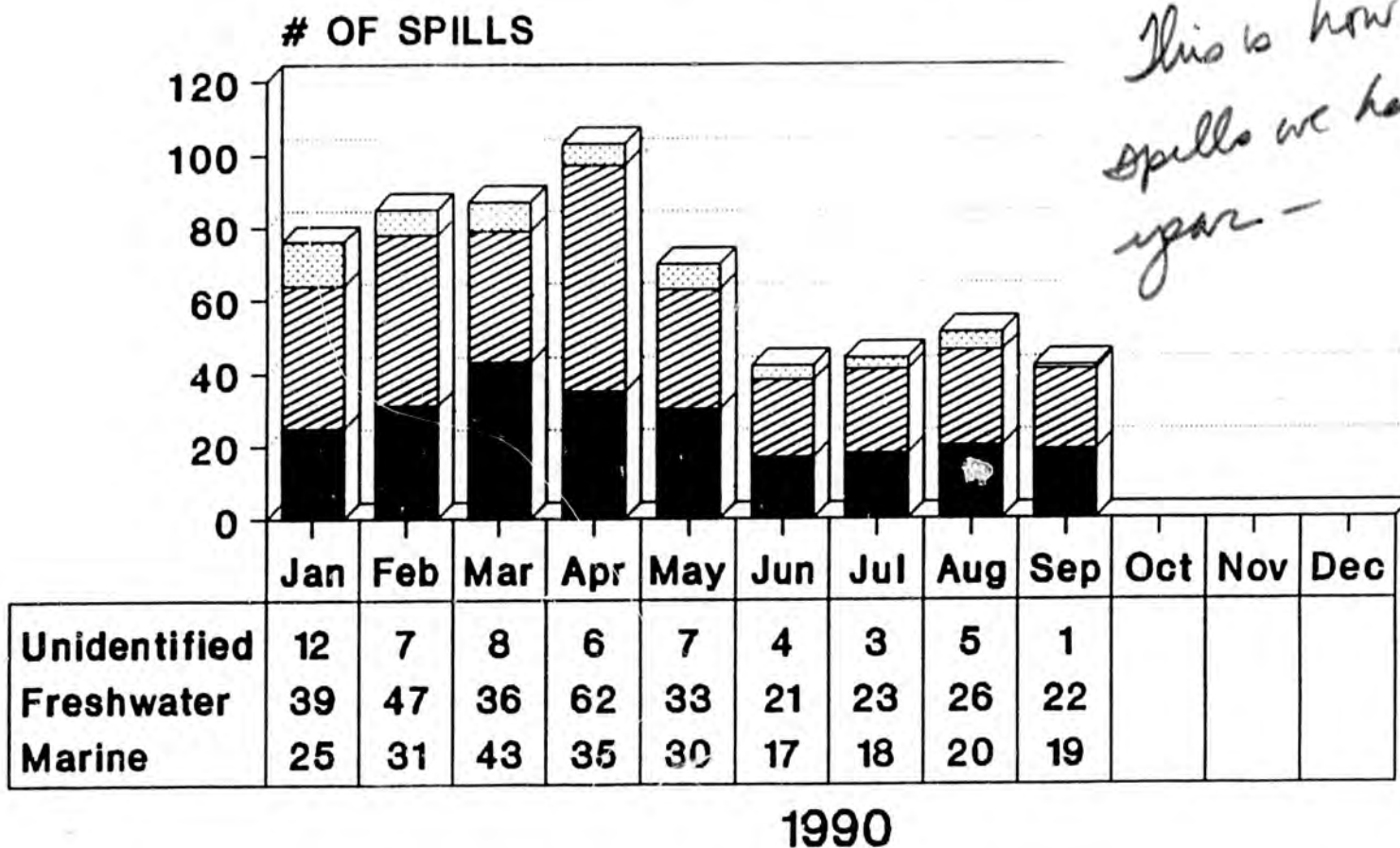
Compensation for loss of natural resources

*Table 15 for
resource damage
assessment rules*



1990 Oil/Petroleum Spills

Western Washington



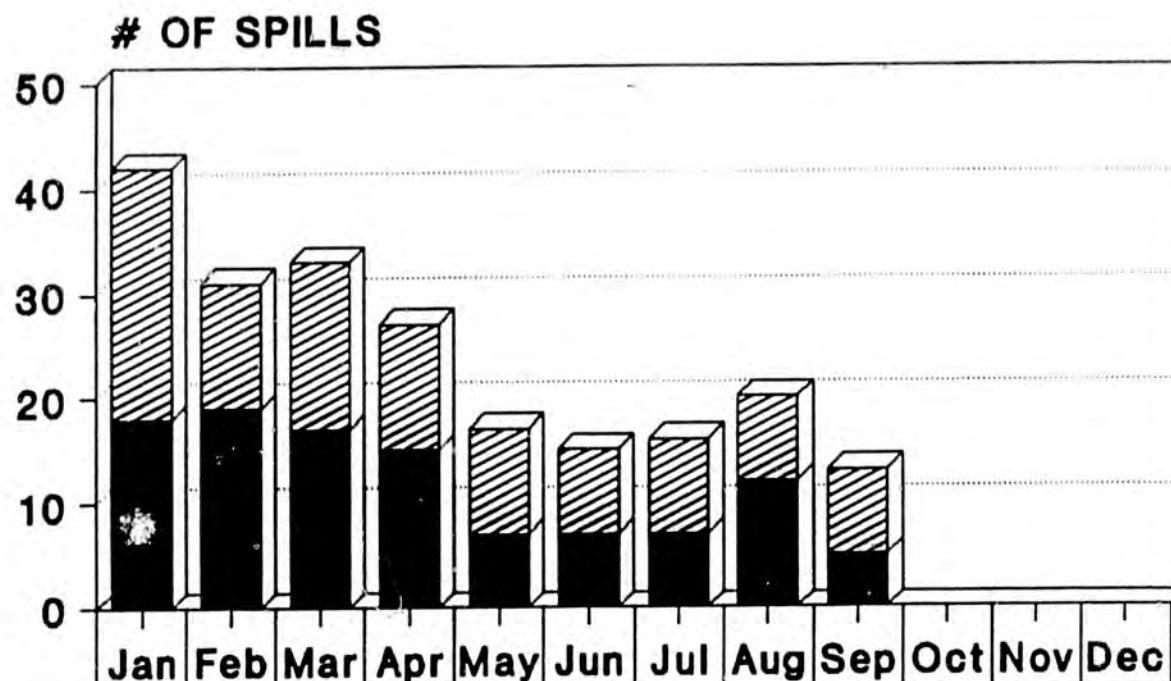
Marine
 Freshwater
 Unidentified

Source: Ecology

1990 SWRO Oil/Petroleum Spills

Identification of Responsible Party

This shows we only catch 50% of responsible parties



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Unidentified RP	24	12	16	12	10	8	9	8	8			
Responsible Party	18	19	17	15	7	7	7	12	5			

1990

Responsible Party
 Unidentified RP

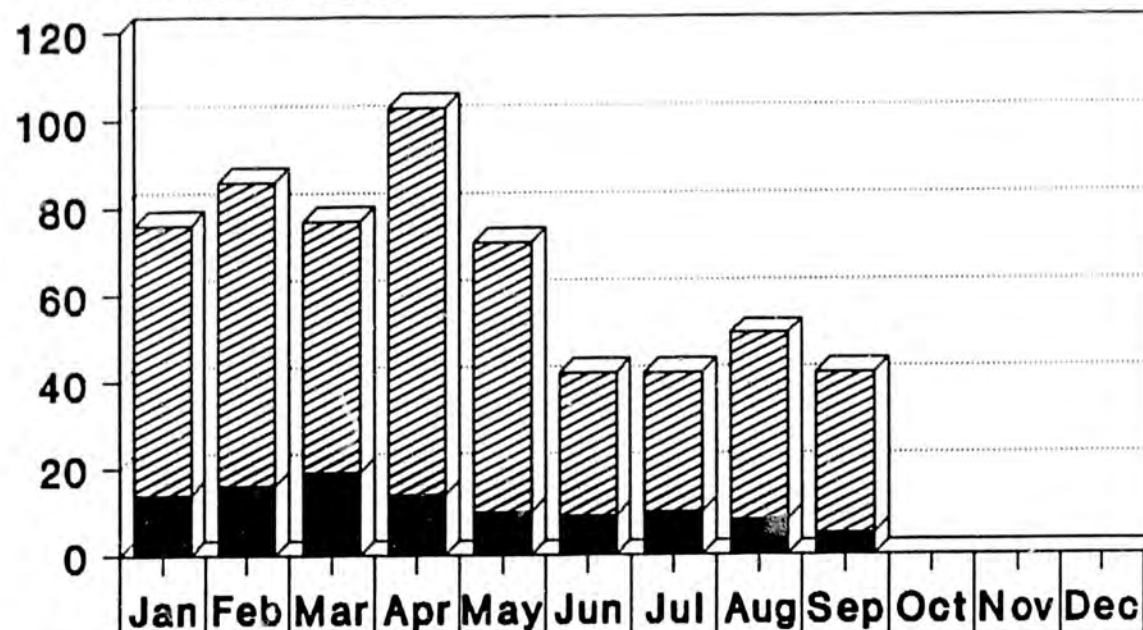
Source: Ecology

1990 Oil/Petroleum Spills

Western Washington

We do even worse when it comes to determining # of gallons spilled which is crucial to success of table.

OF SPILLS



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
No Gallons Reported	62	70	58	89	62	33	32	43	37			
Gallons Reported	14	16	19	14	10	9	10	8	5			

1990

Gallons Reported
 No Gallons Reported

Source: Ecology

House Bill 1853

RDA Compensation Schedule Guidance

- Compensation assessed shall be no less than \$1 per gallon to no greater than \$50 per gallon spilled
- Schedule shall reflect adequate compensation for unquantifiable damages or damages not quantifiable at a reasonable rate
- Schedule shall take into account
 1. Characteristics of oil spilled and its toxicity
 2. Sensitivity of the affected areas
 3. Actions taken by party responsible for the spill

*This is all it
started with*

OIL SPILL COMPENSATION TABLE

CT SCORE • RHVS • PROPENSITY OF OIL TO CAUSE HARM

THE PROPENSITY OF OIL TO CAUSE HARM is measured by:

1. Acute Toxicity
2. Mechanical Toxicity
3. Persistence

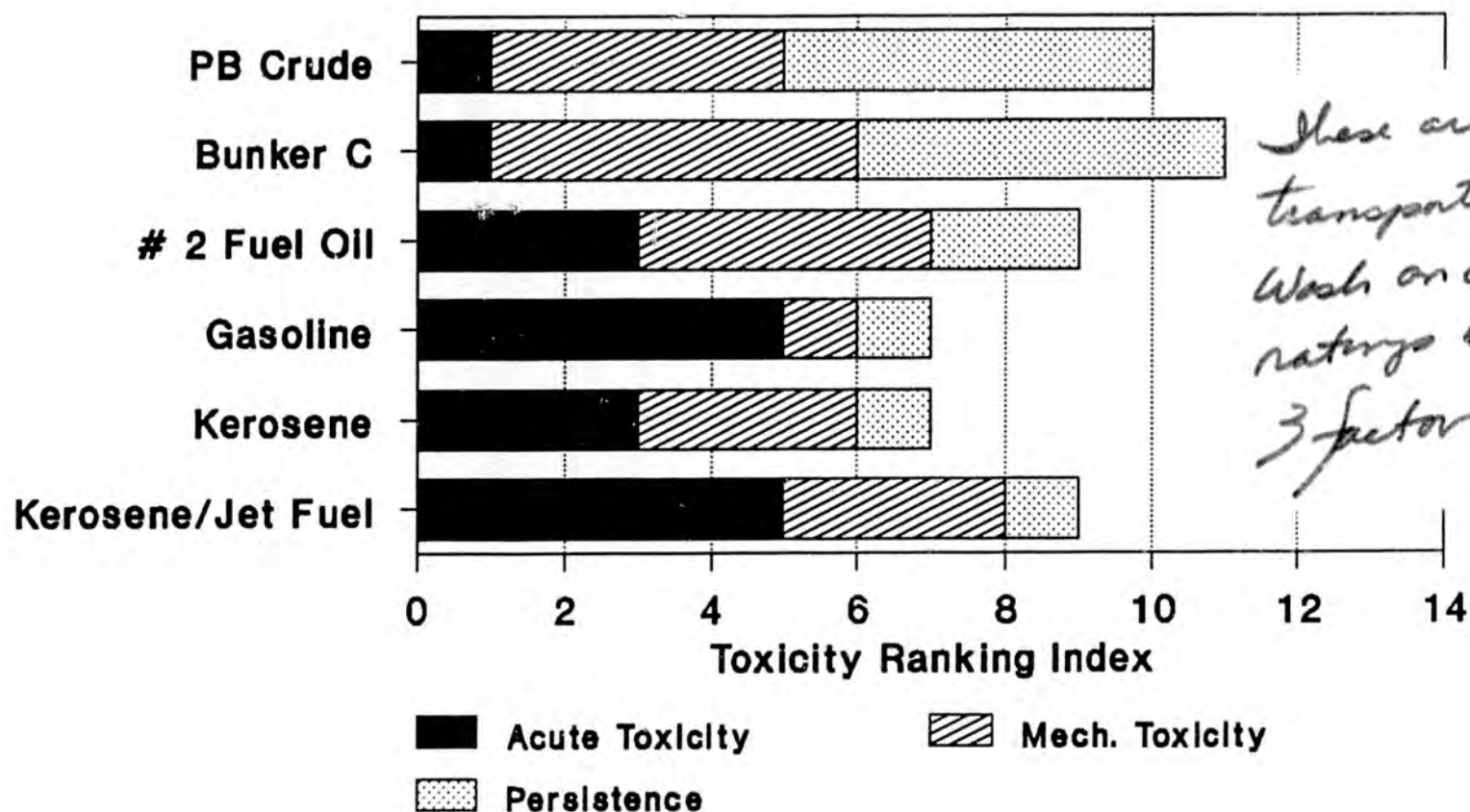
*This is analysis approach
for # 1 prior page
re: oil toxicity*

*Also see attached
Leskine paper
1991*

SCORE: 1-5

Relative Ranking of Acute Toxicity

Mechanical Injury & Oil Persistence



Source: T. Leschine, 1991

OIL SPILL COMPENSATION TABLE

COMP TABLE SCORE (CT)

CT SCORE = RVS * PROPENSITY OF OIL TO DO HARM

where CT SCORE is the numerical score that will be scaled to dollars per gallon spilled

RVS is a relative vulnerability score which measures productivity, diversity and sensitivity

Propensity of oil to do harm measures the affect of the oil on the affected resource

*errors to look
at effect on animals
and habitat this
model. determine
species/habitat importance
and how vulnerable to
oil those are*

ENVIRONMENTAL SENSITIVITY

Parameters That Were Ranked

- Habitats
- Fisheries - Marine & Freshwater Fish and Shellfish
- Birds
- Marine Mammals
- Recreational use

5 categories were selected for ranking

Source: Logan

OIL SPILL COMPENSATION TABLE

CT SCORE = RHVS * PROPENSITY OF OIL TO DO HARM

RHVS = Habitat Productivity * Habitat Sensitivity

The Relative Habitat Vulnerability Score (RHVS) measure

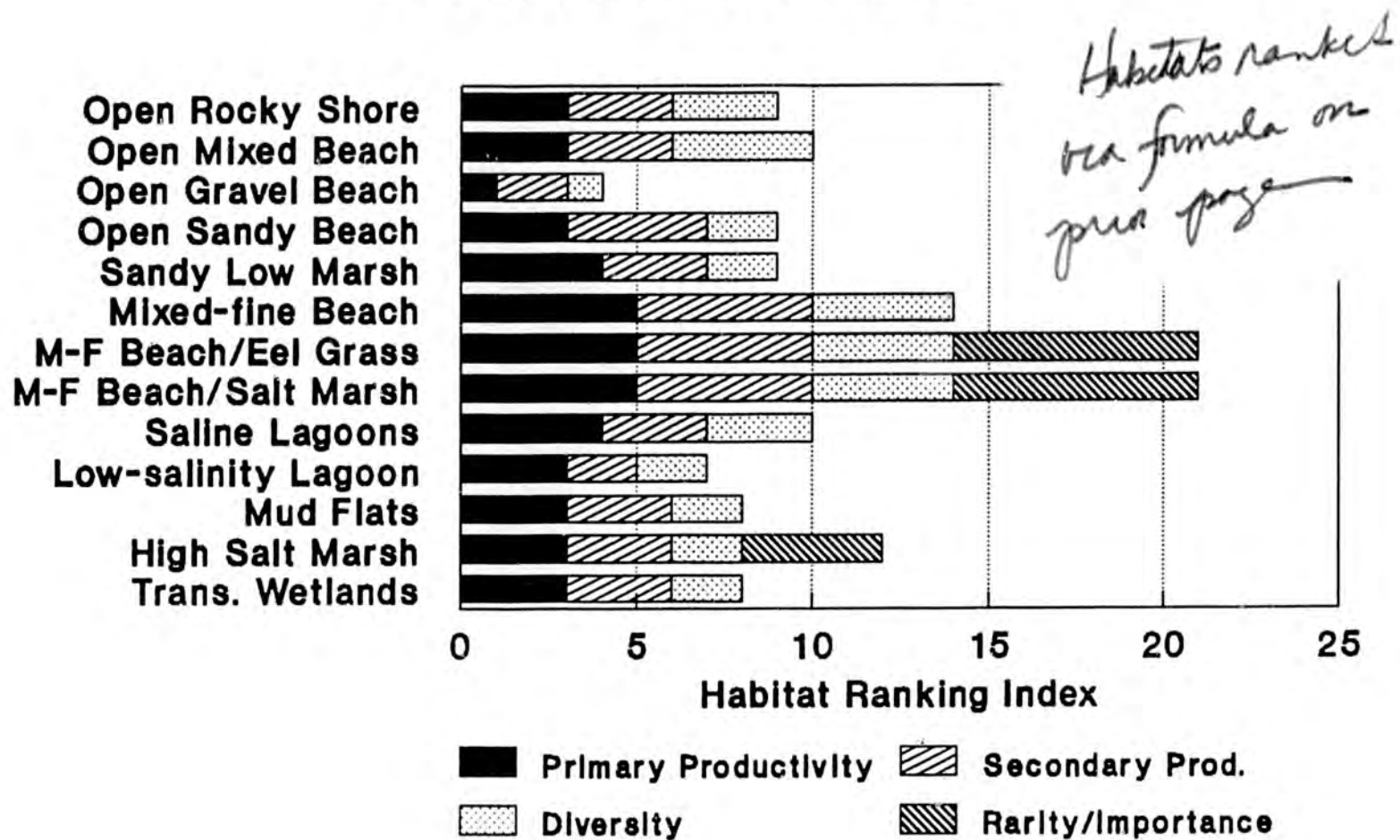
1. The amount of food production
2. The different number of species, and
3. How sensitive that habitat and those species are to oil spills

Which is converted into an index (RHVS) that numerically describes how biologically sensitive the zone is

Scale: 1-5

*This is habitat
sub model approach*

Relative Ranking of Marine & Estuarine Habitats



Source: M. Dethler, 1991

OIL SPILL COMPENSATION TABLE

Relative Habitat Vulnerability Score (RHVS)

<u>RESOURCE</u>	<u>PADILLA BAY</u>	<u>ELLIOTT BAY</u>
HABITAT	5	1
BIRDS	5	2
FISHERIES	5	2
MARINE MAMMALS	2	1
RECREATION	3	1

*We got lots of
you will score everything
5 - This table looks
at best of worst bay
in Wa - dramatic
difference in scores*

ENVIRONMENTAL SENSITIVITY

Parameters That Were Ranked

- Habitats
- Fisheries - Marine & Freshwater Fish and Shellfish
- Birds
- Marine Mammals
- Recreational use

*I included more
detail of fisheries
used since fish
are a big deal up
here FYI*

FISHERY RANKING

Fish Oil Index (FOI)

There are 8 components to the FOI:

$$\text{FOI} = [P * (CC * ((AS + PD) + (SR * (F + LS + ES))))]$$

where P = Presence/abundance in zone

AS = Adult sensitivity

PD = Normal distributional range of species

CC = Commercial catch in pounds harvested

SR = Seasonal risk of developmental stages

F = Fecundity

LS = Larval sensitivity

ES = Egg sensitivity

Source: Logan

FISHERY RANKING

Relative Abundance

<u>Ranking Charateristic</u>	<u>Score</u>
No Known Records	0
Uncommon	1
Common	3
Abundant	4
Very Abundant	5

Source: Mills et al, 1984; Miller & Borton, 1980

FISHERY RANKING

Larval/Adult Habitat

<u>Ranking Charateristic</u>	<u>Score</u>
Always deeper than 20 meters	0
Primarily deeper than 20 m	1
Primarily less than 20 meters	3
Pelagic	5

Source: Logan; Garrison & Miller, 1982; Hart, 1973

FISHERY RANKING

Population Distribution

<u>Ranking Characteristic</u>	<u>Score</u>
Widespread along West Coast	1
At North or South end of Distribution Range	3
Rare Throughout Range	4
Endemic Species	5

Source: Logan; Miller & Borton, 1980; Hart, 1973

FISHERY RANKING

Commercial Harvest in Pounds

<u>Ranking Charateristic</u>	<u>Score</u>
0-50,000 ##	1
50,001-100,000 ##	2
100,001-150,000 ##	3
150,001-200,000 ##	4
Over 200,000 ##	5

Source: Logan; WDF

FISHERY RANKING

Fecundity

<u>Ranking Charateristic</u>	<u>Score</u>
500,000+ eggs/female	1
100,001 - 500,000 eggs/female	3
1-100,000 eggs/female	5

Source: Logan; Garrison & Miller, 1982; Hart, 1973

FISHERY RANKING

Seasonal Larval/Egg Risk

<u>Ranking Charateristic</u>	<u>Score</u>
No Risk	0
Minor Risk	1
1-2 month risk - Usually either beginning or end of period	3
Major risk due to long term surface water concentrations	5

Source: Logan; Garrison & Miller, 1982; Hart, 1973

#3 Specific model
approach

Here is a little
more detail of how
individual scoring
is done

April 1991

#3

Oil Spill Compensation Schedule

Procedures for Determining Compensation for Resource Damages that are Unquantifiable or Not Quantifiable at a Reasonable Cost Using the Oil Spill Compensation Schedule

Introduction

In 1989, the state legislature passed HB 1853 which allows compensation for resource damages that are unquantifiable or not quantifiable for a reasonable cost to be recovered using an oil spill compensation schedule. Under the bill, compensation is to range between \$1 and \$50 per gallon of oil spilled and is to be based on the oil's propensity to caused environmental harm, sensitivity of the environment impacted and actions taken by the responsible party.

In general, the approach presented here calculates compensation by multiplying a resource vulnerability score by a score reflecting the spilled oil's propensity to cause environmental harm, as follows:

Compensation Score = RVS * Spilled Oil's Propensity to Cause Harm

where RVS = Resource Vulnerability Score.

RVS is a composite of marine bird, marine mammal, fishery species, recreation and habitat vulnerability scores. An oil's propensity to cause environmental harm is based on three characteristics of the oil, its propensity to cause acute toxicity, mechanical injury and its propensity to persist in a particular type of habitat. Amount of compensation calculated may be further modified depending on actions taken by the responsible party. Specifics on how compensation will be calculated using the compensation schedule are provided in the following sections.

Acute Toxicity, Mechanical Injury and Persistence Scoring for Oils

For purposes of the compensation schedule, the crude oils, oil products and byproducts comprising 90% of the total oil shipped around Washington coastal waters have been relatively ranked for acute toxicity, mechanical injury and persistence on a 1 to 5 scale (Leschine et al., 1990). The relative ranking of these oils is presented below in Table 1.

Table 1. Relative Ranking Scores of Selected Oils for Acute Toxicity, Mechanical Injury and Persistence.

<u>Oil</u>	<u>Acute Toxicity</u>	<u>Mechanical Injury</u>	<u>Persistence</u>
Prudhoe Bay Crude	1	4	5
Bunker C	1	5	5
No. 2 Fuel Oil	3	4	2
Gasoline	5	1	1
Kerosene	2	3	1
Kerosene-type Jet Fuel	5	3	1

In cases where the oil spilled does not fit into one of the above classification of oil, the score for the category of oil best describing the spilled oil will be used.

Marine and Estuarine Regions and Subregions of the State

The marine and estuarine waters of the state have been subdivided into the regions and subregions designated on the maps attached as Appendix 1.

Marine and Estuarine Habitat Vulnerability Scoring

Dethier (1990) has classified the marine and estuarine habitats of Washington State into 35 habitat classes for purposes of the compensation schedule. Vulnerability of each habitat type to oil spill effects, is rated using a two-part approach. In the first part of the approach habitat vulnerability is ranked as a function of biota productivity and diversity. The second portion of the approach ranks habitat vulnerability as a function of the habitat's sensitivity to the acutely toxic, mechanical and persistence effects of oil. Table 2 presents Dethier's (1990) relative ranking of habitats for primary productivity, secondary productivity and diversity on a 1 to 5 scale. Table 3 presents Dethier's (1990) relative ranking of habitat sensitivity to oil effects.

Table 2. Relative Ranking of Marine and Estuarine Habitats for Primary Productivity, Secondary Productivity and Diversity

<u>Habitat Class</u>	<u>Primary Productivity</u>	<u>Secondary Productivity</u>	<u>Diversity</u>
ESTUARINE INTERTIDAL			
(a) open rocky shores	3	3	3
(b) open mixed-coarse beaches & low marsh	3	3	4
(c) open gravel beaches	1	2	1
(d) open sandy beaches	3	4	2
(e) sandy low marshes	4	3	2
(f) mixed-fine beaches and low marshes	5	5	4
(g) saline lagoons	4	3	3
(h) low-salinity lagoons	3	2	2
(i) mud flats	3	3	2
(j) high salt marshes	3	3	2
(k) transition zone wetlands	3	3	2
ESTUARINE SUBTIDAL			
(l) shallow subtidal rock & boulders	4	3	3
(m) deep subtidal rock and boulders	2	4	4
(n) shallow subtidal cobble and mixed-coarse areas	3	3	3
(o) deep subtidal cobble and mixed coarse areas	1	3	2
(p) shallow subtidal sandy or mixed-fine areas	3	4	3
(q) deep subtidal sandy or mixed fine areas	1	3	2
(r) shallow subtidal muddy bays	3	3	2
(s) deep subtidal muddy bays	0	3	2
MARINE INTERTIDAL			
(a) exposed and semi-exposed rocky shores	4	5	5
(b) sand-scoured rocky shores	3	4	4
(c) protected rocky shores	3	3	3
(d) semi-exposed cobble and mixed coarse beaches	2	4	4

(e) semi-exposed gravel beaches	1	2	1
(f) exposed sandy beaches	1	3	1
(g) semi-protected mixed-fine beaches	3	4	3
(h) protected mud flats	4	4	2

MARINE SUBTIDAL

(i) shallow subtidal rock and boulders	5	4	5
(j) deep subtidal rock and boulders	2	4	5
(k) deep subtidal cobble and mixed-coarse areas	1	3	2
(l) shallow subtidal mixed-coarse to mixed fine	5	4	4
(m) shallow subtidal gravel or mixed-fine areas	2	3	3
(n) deep subtidal sand	0	2	1
(o) deep subtidal mixed-fine areas	1	3	2
(p) deep subtidal muddy areas	0	2	2

Table 4. Acute Toxicity, Mechanical Injury and Persistence Ranking Scores for Marine and Estuarine Habitats of Washington

<u>Habitat Class</u>	<u>Acute Toxicity Score</u>	<u>Mechanical Toxicity Score</u>	<u>Persistence Score</u>
ESTUARINE INTERTIDAL			
(a) open rocky shores	3	4	3
(b) open mixed-coarse beaches & low marsh	3	3	3
(c) open gravel beaches	5	1	2
(d) open sandy beaches	4	3	2
(e) sandy low marshes	4	3	3
(f) mixed-fine beaches and low marshes	4	4	4
(g) saline lagoons	4	4	5
(h) low-salinity lagoons	3	4	5
(i) mud flats	4	2	5
(j) high salt marshes	2	4	5
(k) transition zone wetlands	2	4	5

ESTUARINE SUBTIDAL

(l) shallow subtidal rock & boulders	3	3	2
(m) deep subtidal rock and boulders	2	2	3
(n) shallow subtidal cobble and mixed-coarse areas	2	3	3
(o) deep subtidal cobble and mixed coarse areas	1	2	3
(p) shallow subtidal sandy or mixed-fine areas	3	3	3
(q) deep subtidal sandy or mixed fine areas	2	3	4
(r) shallow subtidal muddy bays	3	2	5
(s) deep subtidal muddy bays	2	2	5

MARINE INTERTIDAL

(a) exposed and semi-exposed rocky shores	4	3	2
(b) sand-scoured rocky shores	4	3	2
(c) protected rocky shores	4	3	3
(d) semi-exposed cobble and mixed coarse beaches	3	3	3
(e) semi-exposed gravel beaches	1	5	2
(f) exposed sandy beaches	1	5	1
(g) semi-protected mixed-fine beaches	2	3	4
(h) protected mud flats	2	4	5

MARINE SUBTIDAL

(i) shallow subtidal rock and boulders	3	3	2
(j) deep subtidal rock and boulders	2	2	3
(k) deep subtidal cobble and mixed-coarse areas	2	1	2
(l) shallow subtidal mixed-coarse to mixed fine	3	3	3
(m) shallow subtidal gravel or mixed-fine areas	1	3	2
(n) deep subtidal sand	3	2	2
(o) deep subtidal mixed-fine areas	3	1	4
(p) deep subtidal muddy areas	2	2	5

The relative vulnerability of each habitat type to each of the three oil effects (acute toxicity, mechanical injury and persistence) is determined by taking the square root of the average of the productivity and diversity values multiplied by the appropriate oil effect as follows:

Formula 1:

Relative Habitat Vulnerability Score_j =

$$\{[(PPS_i + SPS_i + DS_i)/3] * HVS_j\}^{-2}$$

where: PPS = primary productivity score
SPS = secondary productivity score
DS = diversity score
i = habitat type

HVS = habitat vulnerability score
j = acute toxicity, mechanical injury or persistence

Relative Habitat Vulnerability scores may be increased either through a multiplier or through addition of points to account for special cases where the ranking methodology may not be able to adequately represent resource vulnerability. Potential special cases for consideration include the presence of eelgrass, kelp, or rare habitats in a subregion.

Marine and Estuarine Habitat Vulnerability Scores By Subregion.

Until the time when computerized marine and estuarine habitat mapping on a state-wide basis is completed as anticipated, habitat vulnerability scoring for each of the subregions impacted by spilled oil will be determined at the time of the spill. Subregional habitat vulnerability scores for acute toxicity, mechanical injury and persistence are determined by summing the weighted habitat vulnerability scores for each of the habitats present in the zone prior to determining the square root in formula 1 above. Weighting is defined by percent coverage of each habitat in a zone at the time of the spill.

Example:

Assume that an oil spill occurred in a subregion with two habitat types. Habitat type 1 covers 80% of the subregion. Habitat type 2 covers 20% of the subregion. The subregional habitat vulnerability score would then be calculated as follows:

Formula 2:

$$\{[(PPS_1+SPS_1+DS_1)/3*HVS_j*PC_1]+[(PPS_2+SPS_2+DS_2)/3*HVS_j*PC_2]\}^{-2}$$

where PC_1 = Percent-coverage of habitat-type i

all other variables are those listed under formula 1 above.

Marine Bird Oil Spill Vulnerability Scores

Each of the marine and estuarine subregions of the state will be relatively ranked for marine bird vulnerability to oil spills on a 1 to 5 scale for each season. Marine bird vulnerability rankings for each subregion will be based on a method described in Wahl et al. (1981). Marine bird vulnerability rankings take into consideration seasonal presence of species, population status of present species, abundance of present species and species vulnerability to oil spills. Species vulnerability is based on the following: roosting habits, escape behavior, flocking behavior, feeding specialization, population size, reproductive capacity, breeding dispersion, winter dispersion, seasonal exposure to waters where oil spills could occur, and significance of Washington population to total population in each season. Marine Bird Vulnerability rankings are currently in the process of being determined by the Marine Bird Subcommittee of the Scientific Advisory Board.

Relative Marine Bird Vulnerability scores for a subregion may be increased either through a multiplier or through addition of points to account for special cases where the ranking methodology may not be able to adequately represent resource vulnerability. Potential special cases for consideration include the presence of rare or endangered species in a subregion.

Marine Mammal Oil Spill Vulnerability Scores

Each of the marine and estuarine subregions of the state will be scored for marine mammal vulnerability to oil spills on a scale from 1 to 5 for each season. A marine mammal oil vulnerability ranking methodology is under development by the Marine Mammal Subcommittee of the Scientific Advisory Board. The marine mammal vulnerability ranking methodology will take into consideration the following: species presence, population status of species present, breeding vulnerability, presence of young, physiological vulnerability, abundance, and other factors influencing species vulnerability.

Relative Marine Mammal Vulnerability scores for a subregion may be increased either through a multiplier or through addition of points to account for special cases where the ranking methodology may not be able to adequately represent resource vulnerability. Potential special cases for consideration include the presence of congregating animals in a subregion.

Marine Fishery Species Vulnerability Scores

Each of the marine and estuarine subregions of the state will be relatively ranked for fishery species vulnerability to oil spills on a 1 to 5 scale for each season. A marine fishery species ranking methodology is under development by the Marine Fish, Shellfish and Salmonids Subcommittees of the Scientific Advisory Board. The marine fishery species ranking methodology will take into consideration the following: species present, population status of species present, abundance and vulnerability of life stages among other factors influencing vulnerability.

Relative Marine Fishery Species Vulnerability scores for a subregion may be increased either through a multiplier or through addition of points to account for special cases where the ranking methodology may not be able to adequately represent resource vulnerability. Potential special cases for consideration include the presence of salmon fry or returning adults in river estuaries or other areas.

Marine- and estuarine-related recreation vulnerability scoring

Each of the marine and estuarine subregions of the state waters will be relatively ranked for marine- and estuarine-related recreation vulnerability to oil spills on a 1 to 5 scale for each season. A marine- and estuarine-related vulnerability ranking methodology is under development by the Recreation Subcommittee of the Scientific Advisory Board. The ranking methodology will take into consideration seasonal level of participation in recreational activities, sensitivity of recreational activities to oil spills, number of recreation sites in a subregion, and level of use, among other factors influencing vulnerability.

Relative Recreation Vulnerability scores for a subregion may be increased either through a multiplier or through addition of points to account for special cases where the ranking methodology may not be able to adequately represent resource vulnerability. Potential special cases for consideration may include the presence of national parks, state parks, or other preserves or protected areas.

Determination of Compensation Score

A compensation score for each spill incident will be determined by multiplying oil vulnerability factors by the appropriate oil effects factors as illustrated by Formula 3.

Formula 3:

Compensation Score =

$$OIL_{mech} * (MB_{mech} + MM_{mech} + FS_{mech} + REC_{mech} + HAB_{mech}) +$$

$$OIL_{tox} * (MB_{tox} + MM_{tox} + FS_{tox} + REC_{tox} + HAB_{tox}) +$$

$$OIL_{pers} * (MB_{pers} + MM_{pers} + FS_{pers} + REC_{pers} + HAB_{pers})$$

where OIL_i = oil effects score
 MB_j = marine bird vulnerability score
 MM_j = marine mammal vulnerability score
 FS_j = fisheries species vulnerability score
 REC_j = recreation vulnerability score
 HAB_j = habitat vulnerability score

i = tox, mech and pers
tox = propensity to cause acute toxicity
mech = propensity to cause mechanical injury
pers = propensity to persist

j = VT, VM, and VP
VT = vulnerability to acute toxicity
VM = vulnerability to mechanical injury
VP = vulnerability to persisting oil

In cases where more than one subregion is exposed to spilled oil, compensation shall be calculated using resource vulnerability scores from the most sensitive subregion exposed.

Dollar amount of compensation will be calculated by multiplying the number of gallons spilled by the compensation score and a yet to be determined factor or factors. The yet to be determined factor or factors will be necessary to scale compensation to \$1 to \$50 per gallon value.

Formula 4:

Compensation (\$) = No. of gallons spilled * CS * scaling factor

where CS = Compensation Score.

Modification to calculated compensation for actions taken by the spiller or other potentially liable party

The dollar amount of compensation will be reduced for spillers or other potentially liable parties that recover spilled oil within a specified time period following the spill, or that enhance detection of the spill, determination of the number of gallons spilled, or extent of resource injuries. Such a reduction in compensation shall not be reduced below \$1 per gallon of oil spilled.

Potential Ways in Which the Dollar Amount of Compensation Might be Reduced:

1. Subtract the number of gallons recovered from the number of gallons spilled, and use this value instead as the multiplier of the compensation score.
2. Reduce persistence and/or mechanical injury scores for the oil by a fraction equal to the fraction of the total spill recovered.
3. Where the spiller or other potentially responsible party enhances spill response and reconnaissance efforts as above, reduce the dollar amount of compensation calculated by 0.75.

The dollar amount of compensation will be increased for spillers or other potentially liable parties that impede detection of the spill, determination of the number of gallons spilled, or extent of resource injuries. Such an increase in compensation shall not exceed \$50 per gallon of oil spilled.

Potential Ways in Which the Dollar Amount of Compensation Might be Increased:

- 1) Increase the dollar amount of compensation by multiplying whatever savings the responsible party or other potentially liable party may have realized by their actions by 1.25 and add this to the base level of compensation calculated.
- 2) Increase the dollar amount of the compensation calculated by 1.25.

REFERENCES

- Detheir, M. 1990. Rankings of Productivity, Diversity and Oil Sensitivity for Marine and Estuarine Habitat Types in Washington. Draft Final Report, Friday Harbor Laboratories, University of Washington.
- Leschine, T., R. Carpenter, and E. Gideon. 1991. Petroleum Toxicity Relationships for the Washington Compensation Schedule. Draft Final Report, College of Ocean and Fishery Sciences, University of Washington, Seattle.
- Wahl, T.R., S.M. Speich, D.A. Manuwal, K.V. Hirsch, and C. Miller. 1981. Marine Bird Populations of the Strait of Juan de Fuca, Strait of Georgia, and Adjacent Waters in 1978 and 1979. U.S. Environmental protection Agency, EPA-600/7-81-156.

APPENDIX 1

REGIONS AND SUBREGIONS OF MARINE AND ESTUARINE AREAS OF THE STATE

Designated For Purposes of the Oil Spill Compensation Schedule

Zones we used
for proving

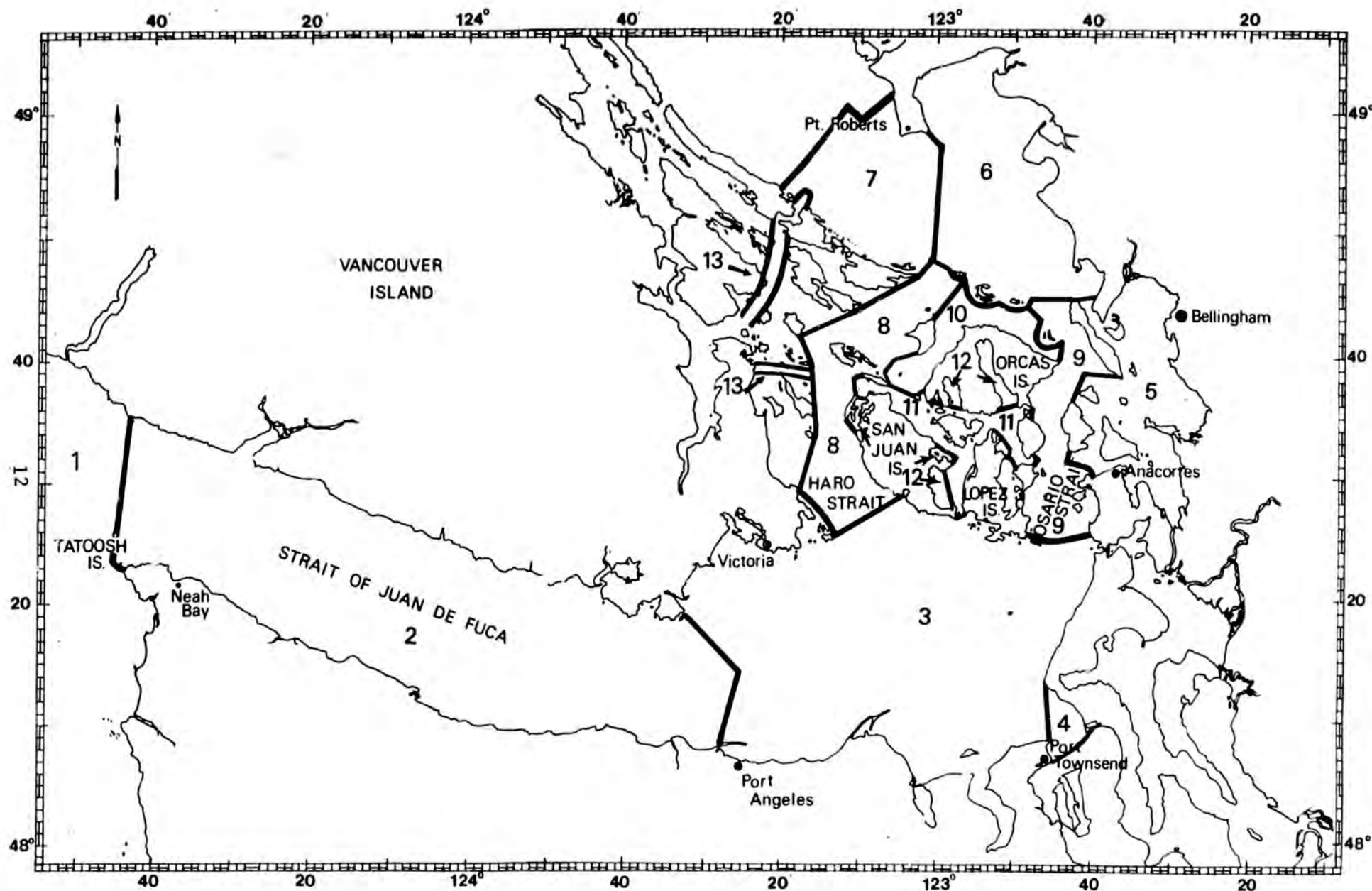


FIGURE 1. MAP OF STUDY AREA SHOWING THE 13 REGIONS.

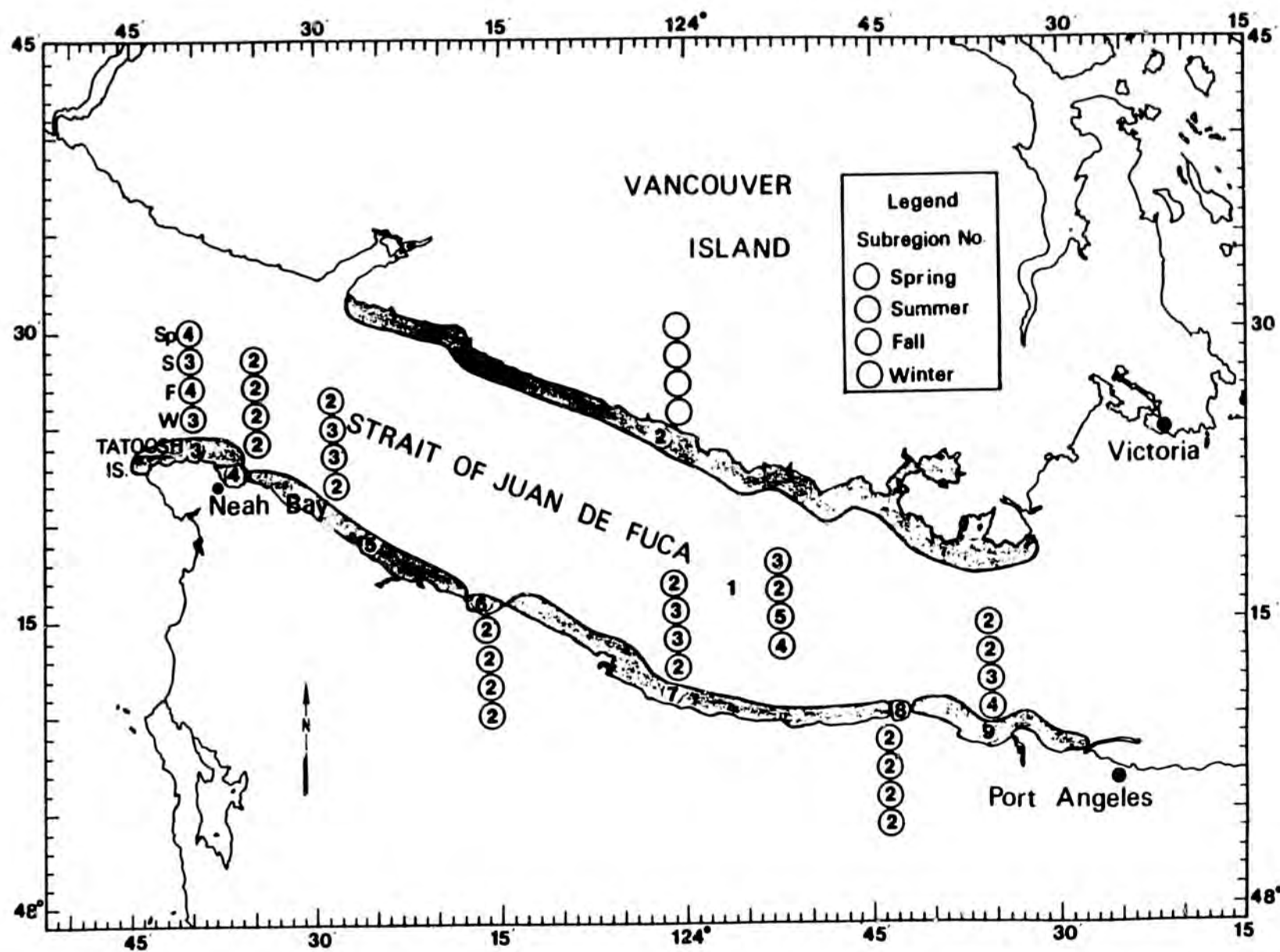


Figure 29. Seasonal subregional BOI rankings, 1978 and 1979 combined, for the Strait of Juan de Fuca, Outer region, region no. 2.

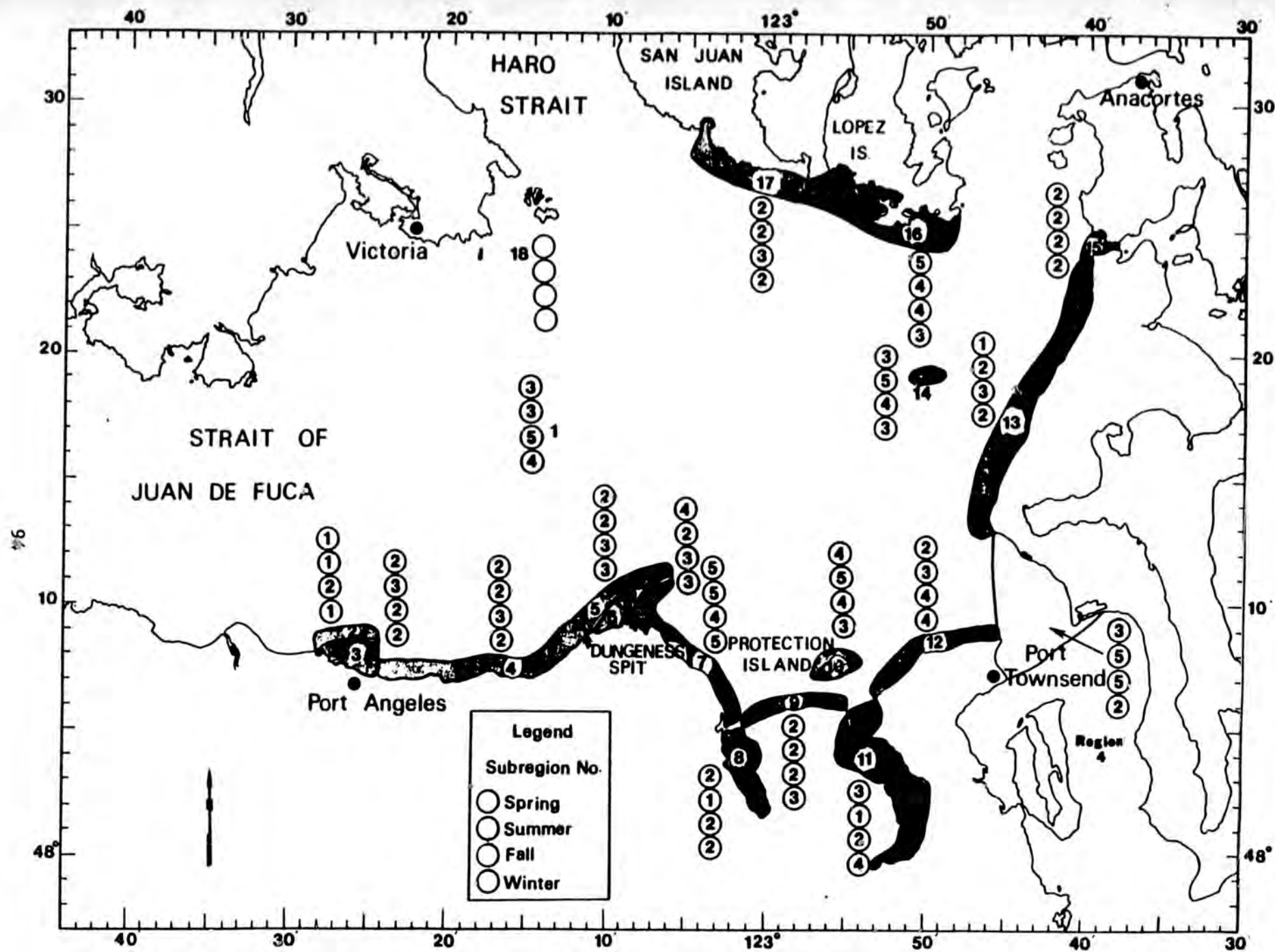


Figure 30. Seasonal subregional BOI rankings, 1978 and 1979 combined, for the Strait of Juan de Fuca, Inner region, region no. 3, and Admiralty Inlet region, region no. 4.

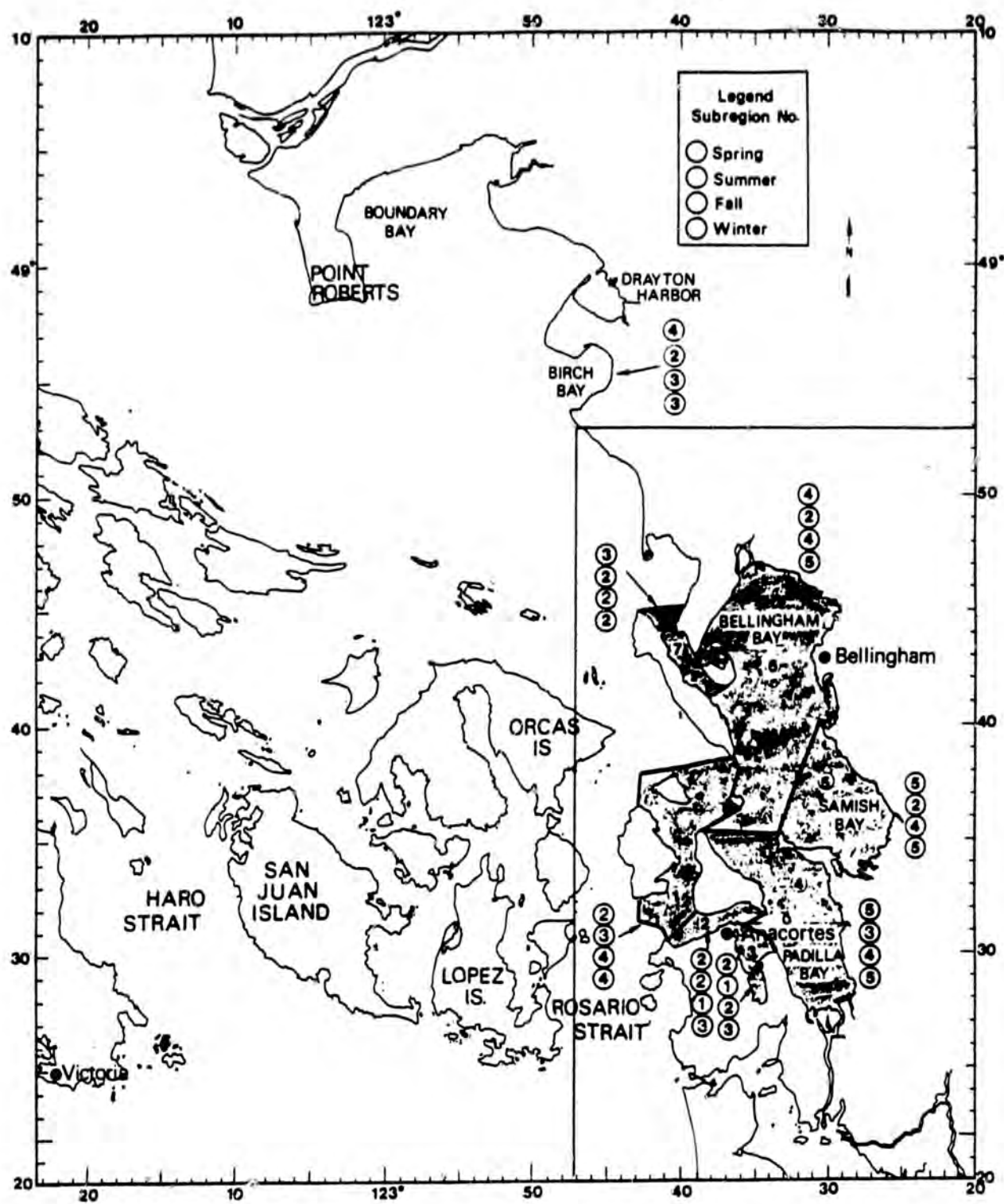


Figure 31. Seasonal subregional BOI rankings, 1978 and 1979 combined, for the Anacortes to Hale Passage region, region no. 5.

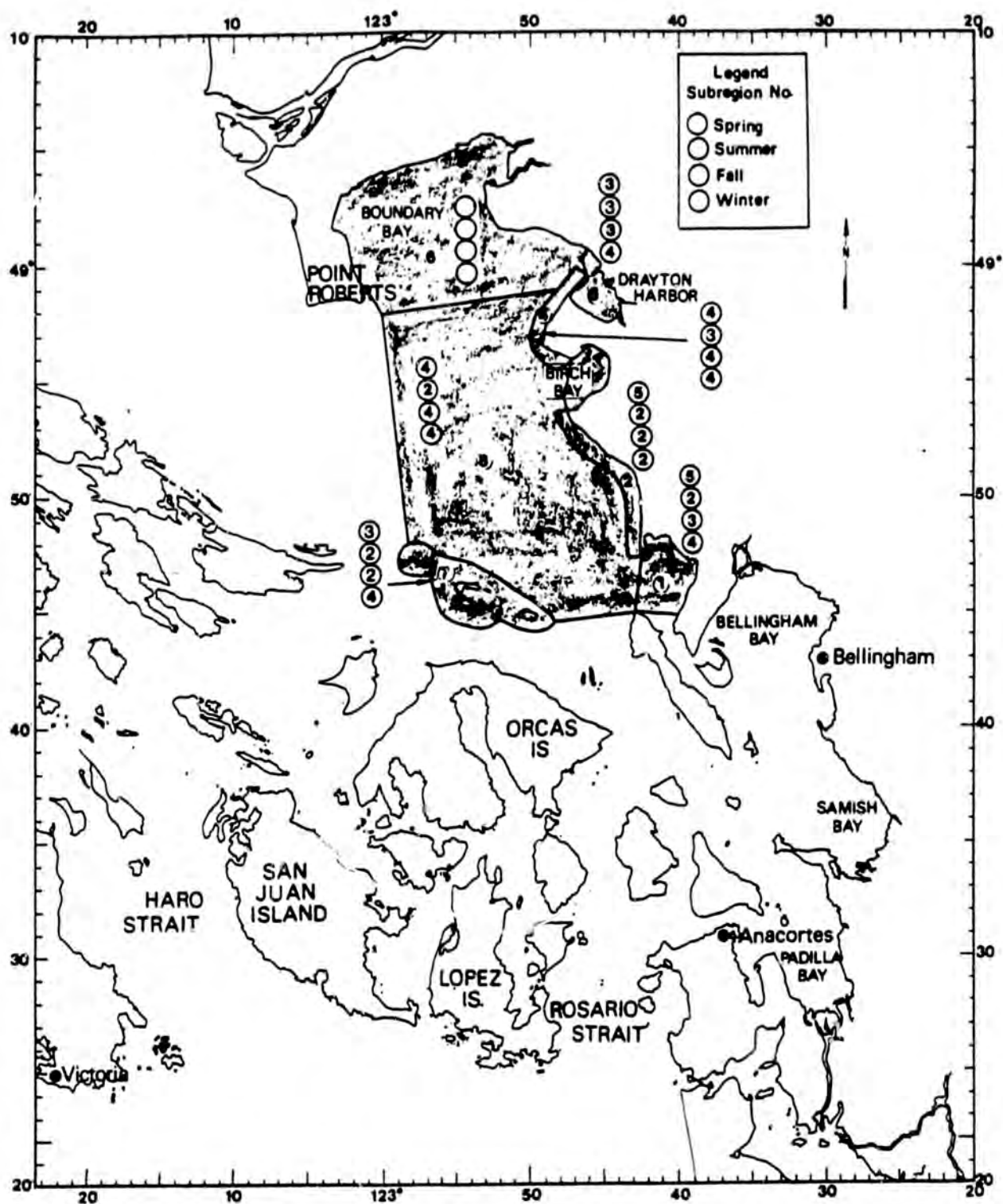


Figure 32. Seasonal subregional BOI rankings, 1978 and 1979 combined, for the Georgia Strait, Eastern region, region no. 6.

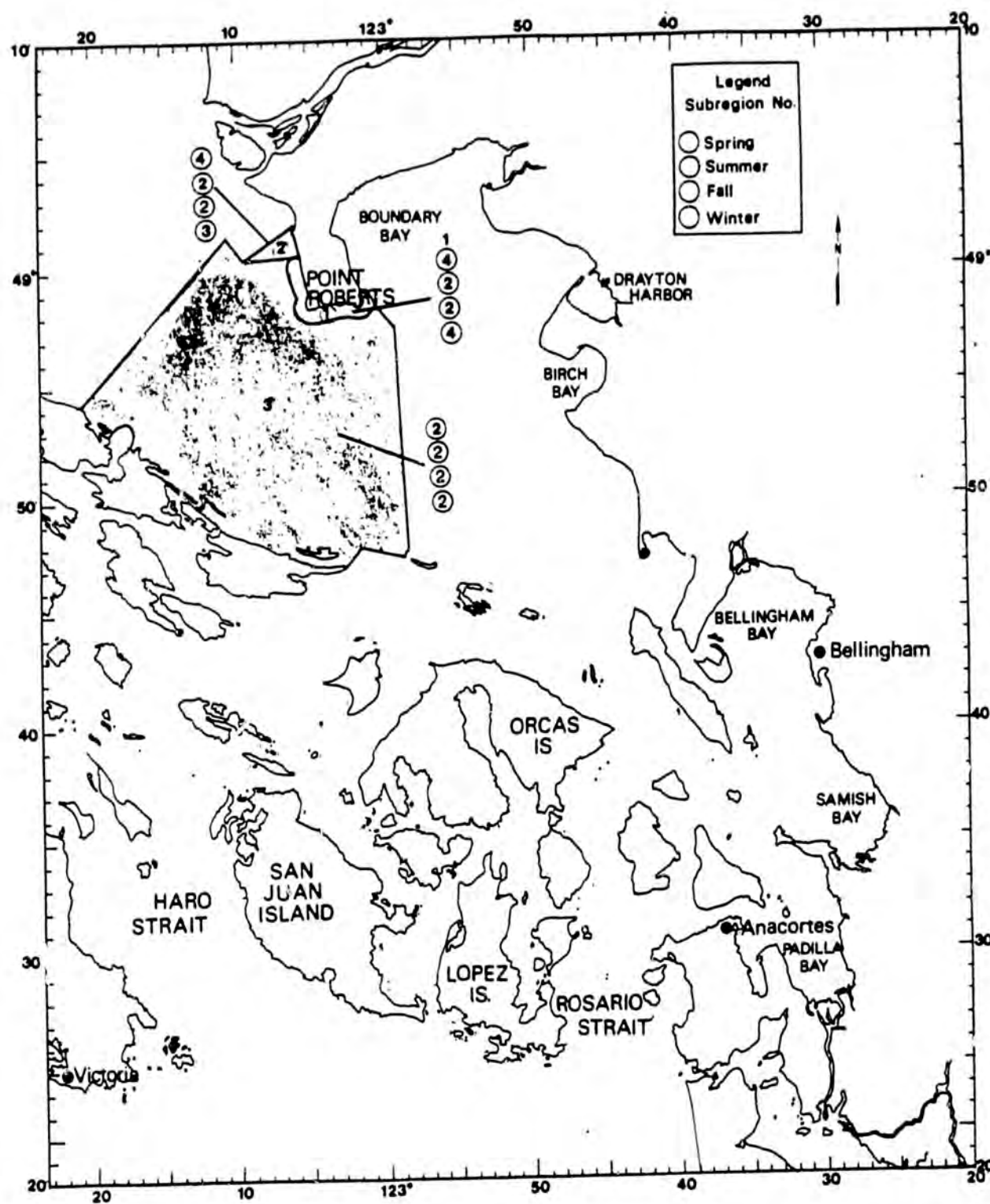


Figure 33. Seasonal subregional BOI rankings, 1978 and 1979 combined, for the Georgia Strait, Western region, region no. 7.

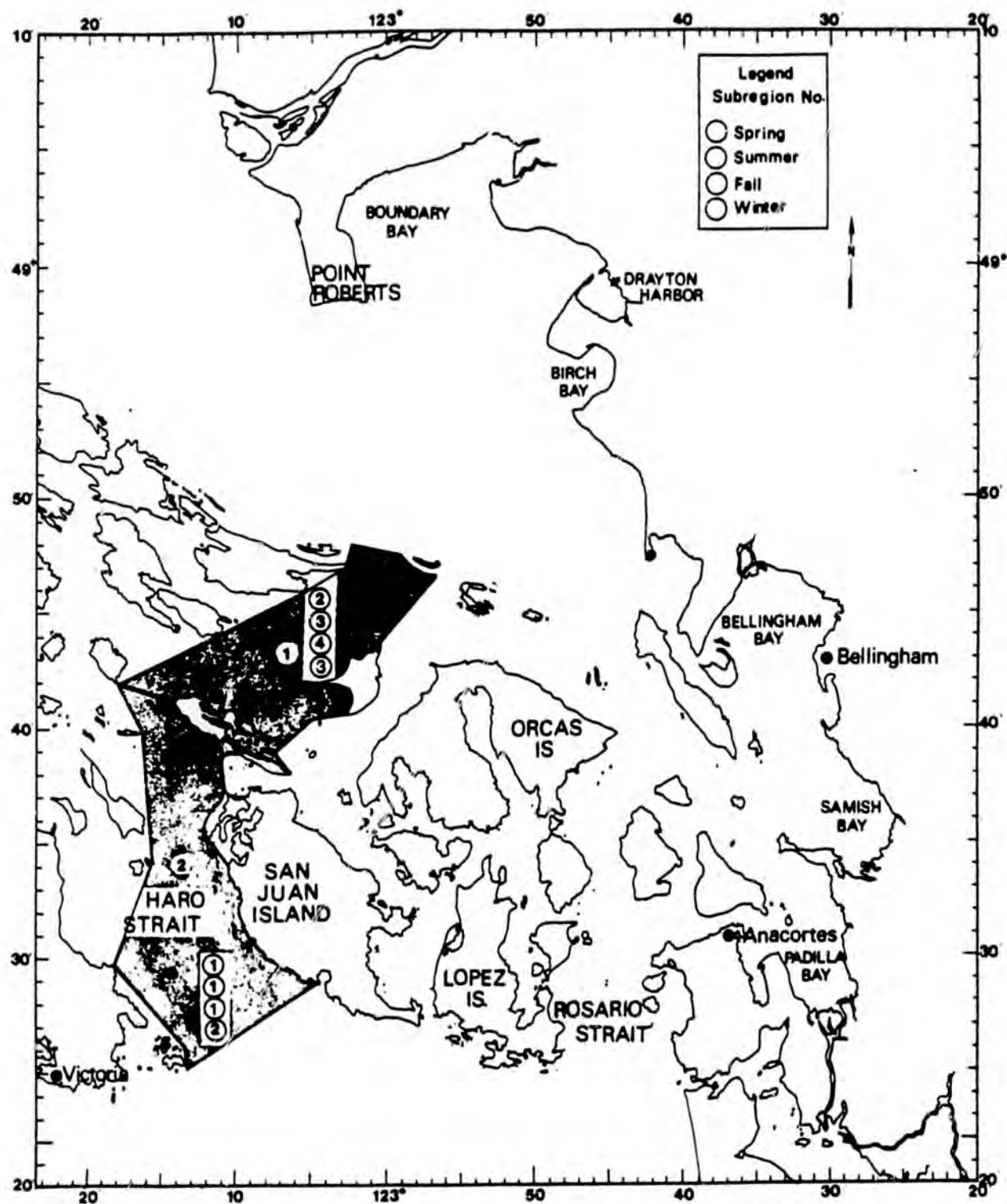


Figure 34. Seasonal subregional BOI rankings, 1978 and 1979 combined, for the Haro Strait region, region no. 8.

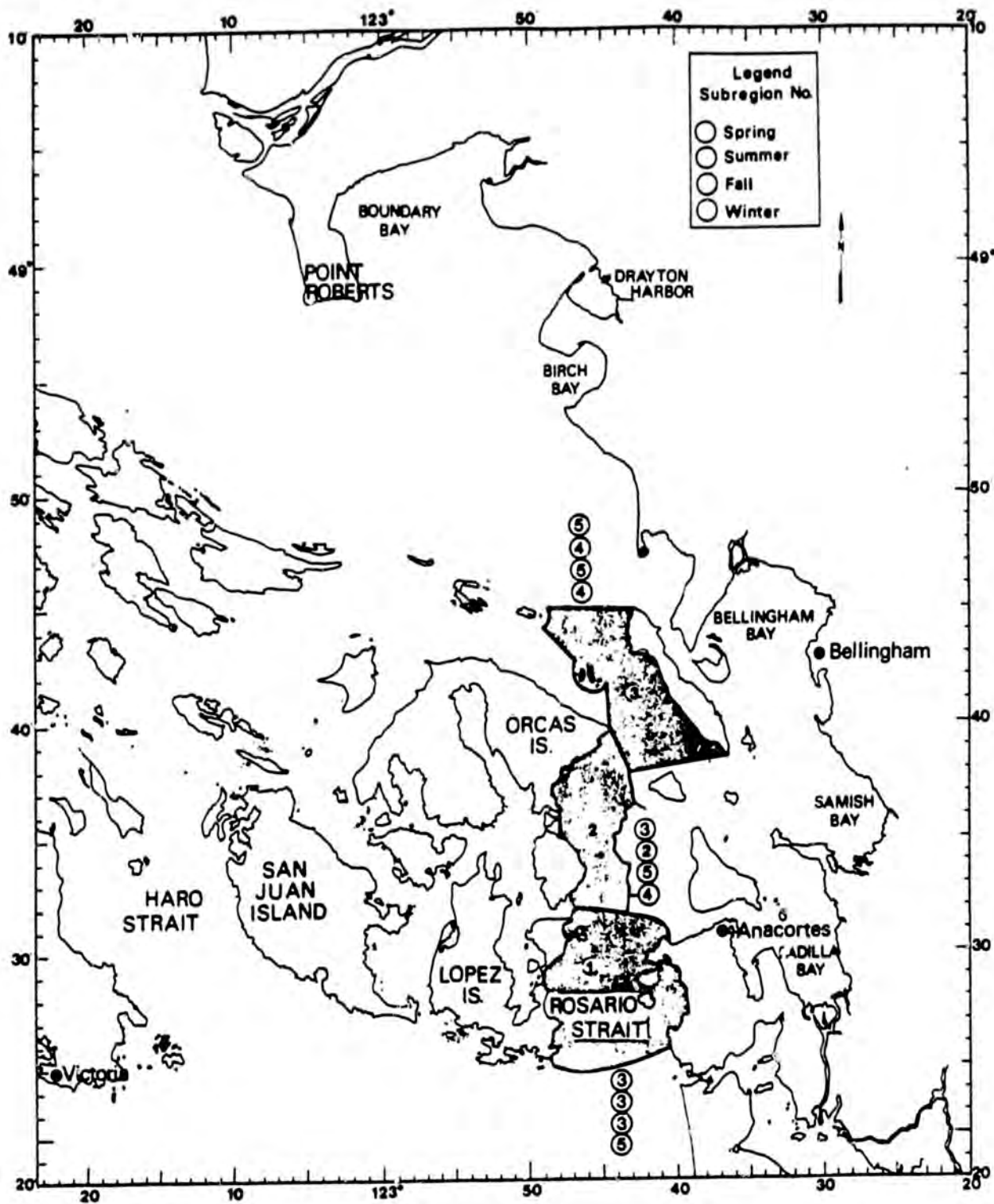


Figure 35. Seasonal subregional BOI rankings, 1978 and 1979 combined, for the Rosario Strait region, region no. 9.

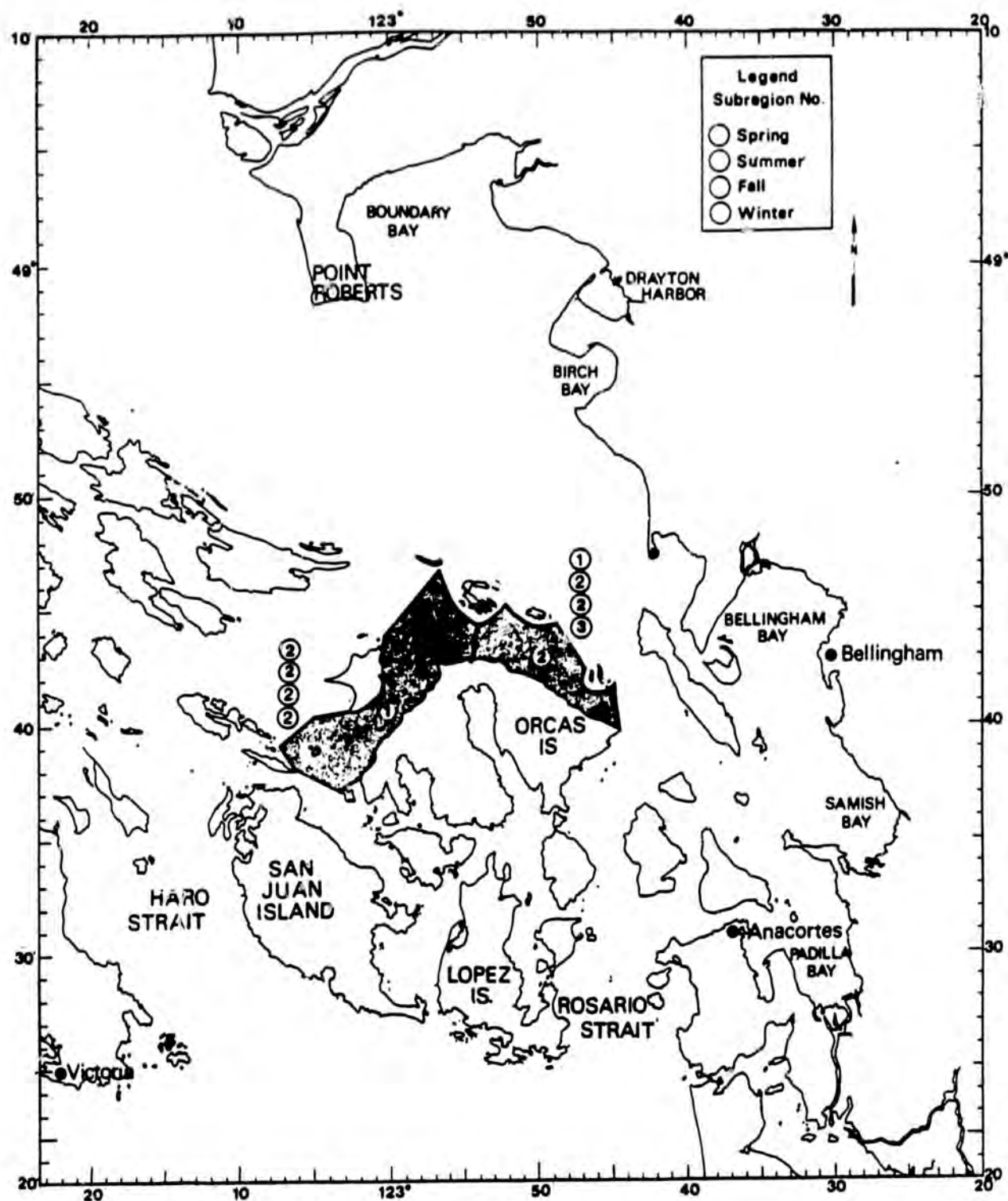


Figure 36. Seasonal subregional BOI rankings, 1978 and 1979 combined, for the San Juan Islands, Northern Waters region, region no. 10.

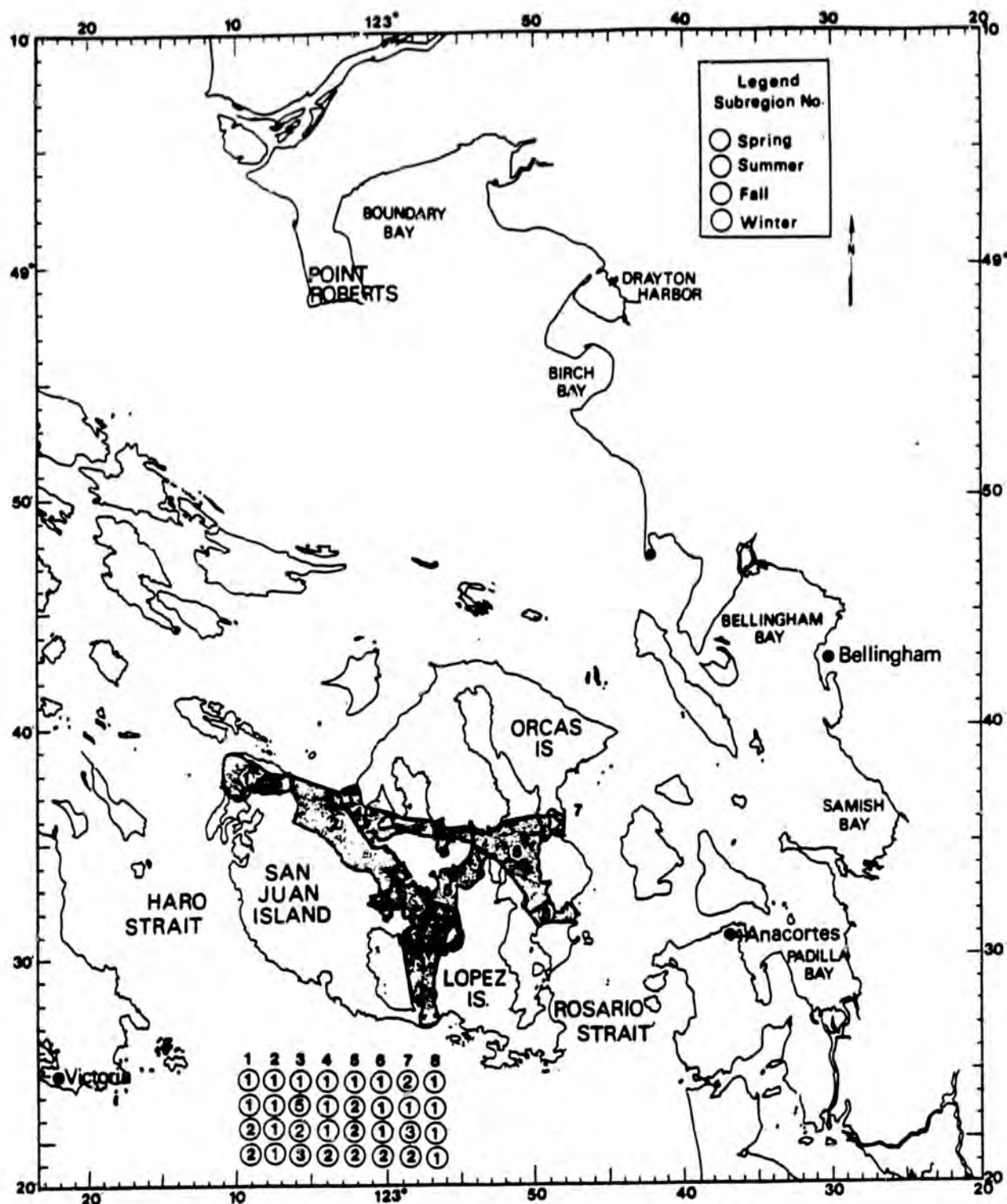


Figure 37. Seasonal subregional BOI rankings, 1978 and 1979 combined, for the San Juan Islands, Interior Channels and Passages region, region no. 11.

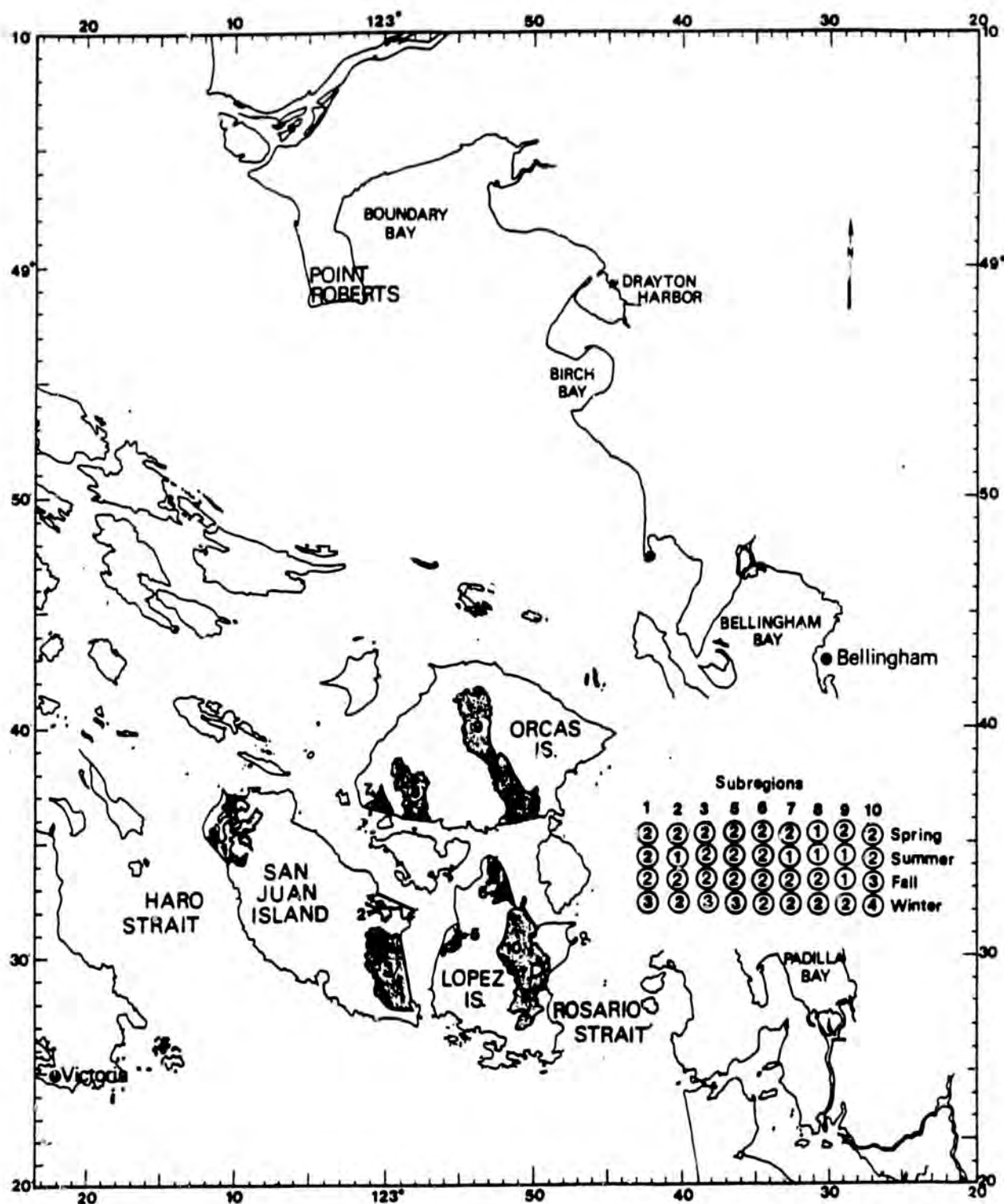
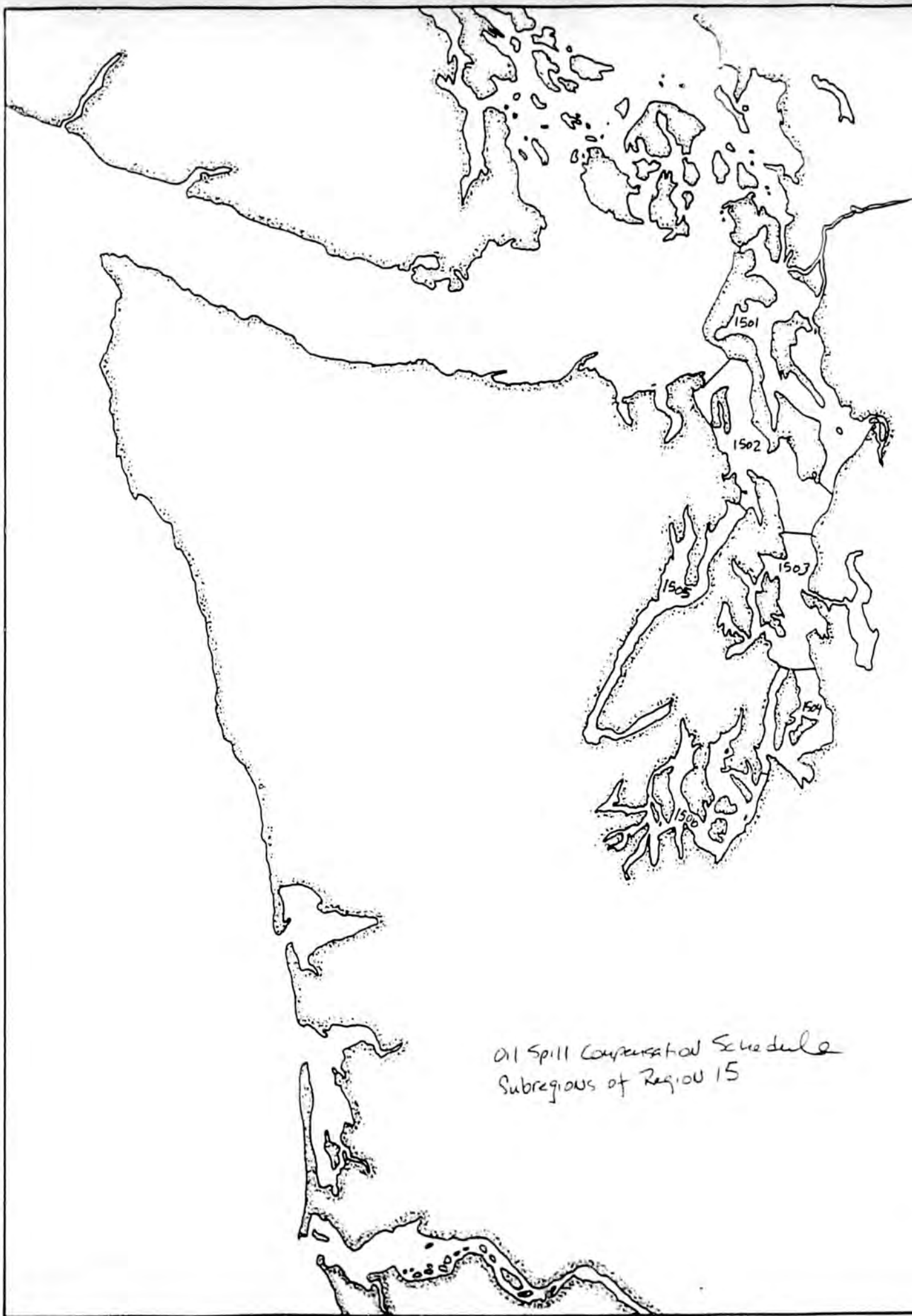
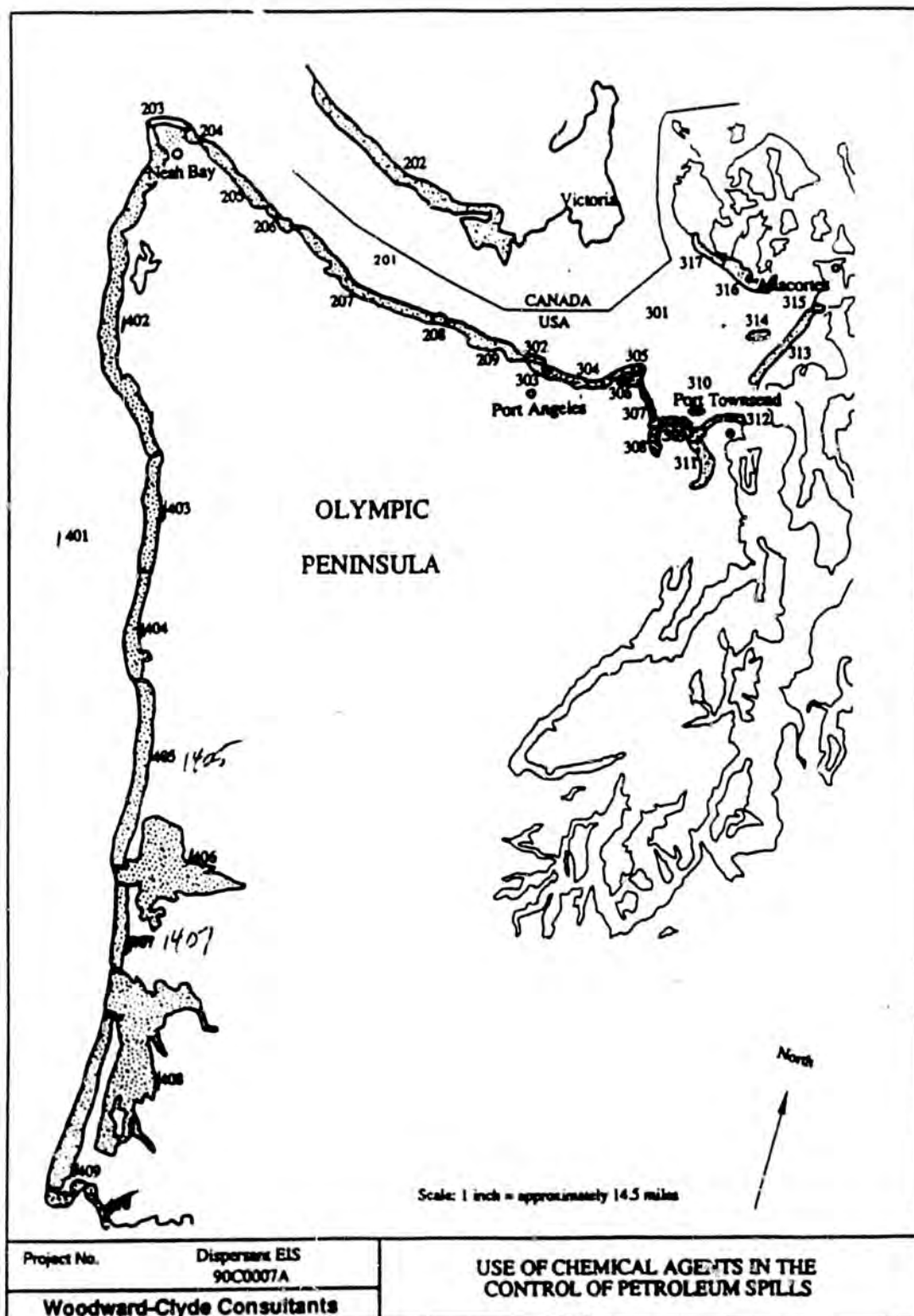


Figure 38. Seasonal subregional BOI rankings, 1978 and 1979 combined, for the San Juan Islands, Interior Bays and Harbors region, region no. 12.



Oil Spill Compensation Schedule
Subregions of Region 15

Oil Spill Compensation Schedule Subregions of Region 14, outer coast



Areas 1405, 1407, and 1409 are considered
to be the southern limit
Figure 1. Coast

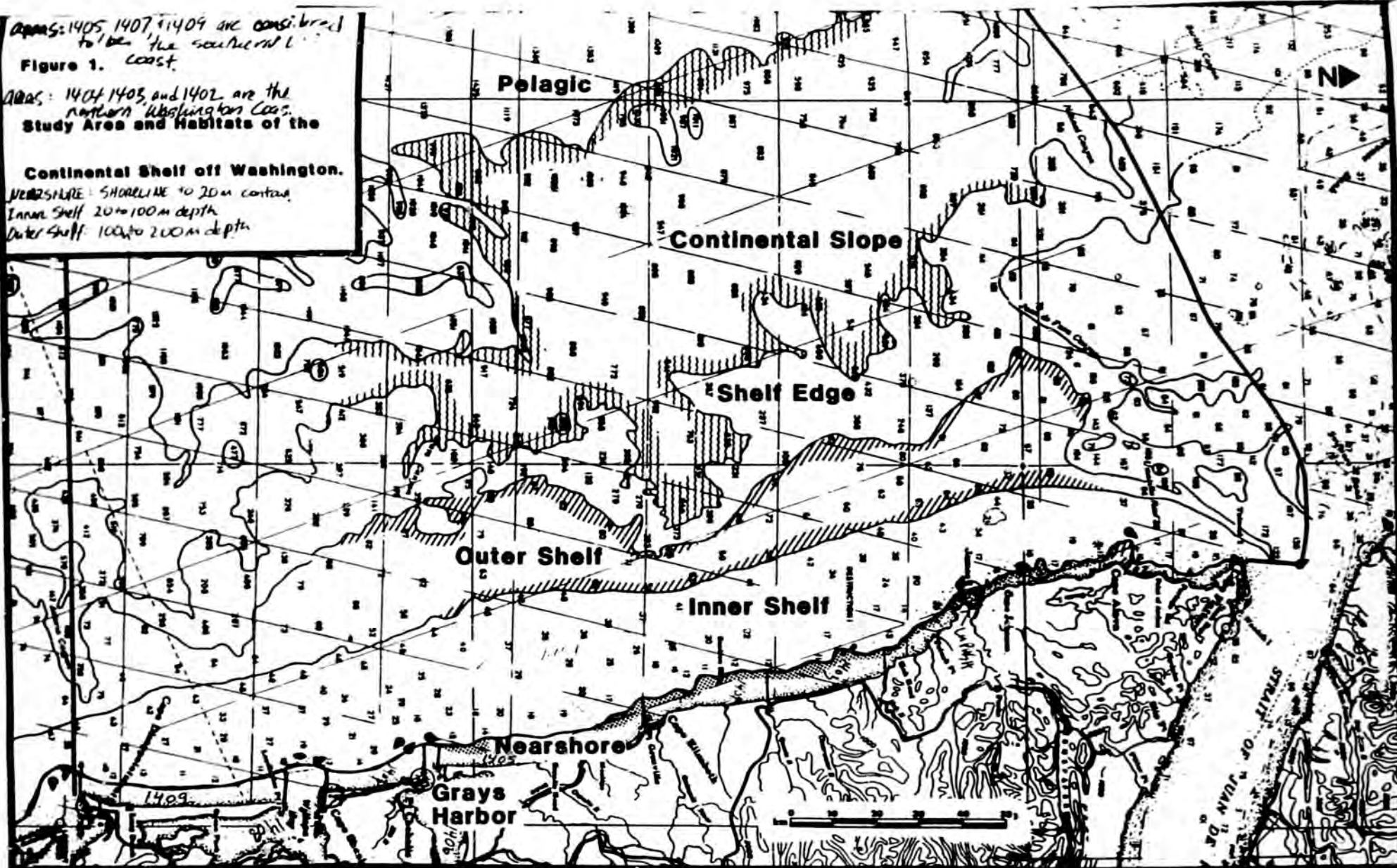
Areas 1401, 1403, and 1402 are the
northern Washington Coast.
Study Area and Habitats of the

Continental Shelf off Washington.

Nearshore: Shoreline to 20 m contour

Inner Shelf: 20 to 100 m depth

Outer Shelf: 100 to 200 m depth



Subregions
of Region 14
Outer
Coast

Habitat stuff to
support model

RANKINGS OF PRODUCTIVITY, DIVERSITY, AND OIL SENSITIVITY
FOR MARINE AND ESTUARINE HABITAT TYPES IN WASHINGTON

"The first consideration in the analysis of the sensitivity of biological systems to oil spills is to establish and identify the analytical units to be ranked. To be useful in oil spill response planning, these units should be ecologically sound, geographically delineable, and capable of being classified as to the relative importance of the damage to them caused by oiling. The "habitat" was selected as the best available unit for this purpose. The term "habitat" refers to the place occupied by an entire community of organisms; it has geographic boundaries that can be measured and mapped" (p. 2, Adams et al. 1984).

The habitats ranked below are described in Appendix 1; this is a shortened and simplified list derived from the habitat classification system of Dethier (1990). Rankings for productivity, diversity, and oil sensitivity are based on the best or most pristine examples of each habitat type, and range from 0 (lowest, e.g. where there is no primary productivity) to 5 (highest). Two rankings are given for productivity: 1) Primary productivity, i.e. from benthic algae, seagrass, or marsh plants living in a habitat type, and 2) Secondary productivity of invertebrates living in a habitat type, either 'fed' by local primary production or by plankton and detritus brought to that habitat by waves or currents.

Primary productivity rankings have the following definitions:

5. Algae or vascular plants abundant and fast growing year round.
4. Plants less abundant but still productive, or with only small seasonal reduction.
3. Productivity somewhat reduced due to lower abundance, somewhat seasonal environment, or some physiological stress.
2. Plants rather sparse, quite seasonal, or quite stressed by physical conditions such that productivity is reduced.
1. Plants rare or with a very short growing/productive season.
0. No living plants of any kind.

Secondary productivity rankings vary from 0 (no consumers supported in the habitat) to 5 (high biomass and growth rates of consumers present).

Diversity rankings are based on an approximation of the number of species commonly found in a pristine example of the habitat type. They are as follows:

5. >80 species
4. 60 - 80 species
3. 40 - 60 species

2. 20 - 40 species
1. 1 - 20 species
0. No living organisms

Oil Sensitivity rankings assume that mixed-cargo oil is spilled and gets into each habitat type (via waves, sinking, etc.) in measurable amounts. That is, the rankings assume that every habitat is vulnerable (has some likelihood of contact by oil), but habitats vary in their sensitivity (response of the biotic resource to oil). Each rating is based on a worst-case scenario, i.e. oil hitting a pristine example of each habitat type. Four rankings are given: a) Mechanical damage, i.e. from smothering, weighting, or tearing off of organisms, smothering of substrate, or asphaltting of substrate; b) Toxicity, i.e. susceptibility to short-term acute mortality or sublethal damage due to chemical constituents in oil; c) Persistence, i.e. the retention of oil in different habitat types, and d) Recovery, i.e. the time taken for organisms to return to their pre-spill abundances and sizes, or for the community as a whole to recover its functional attributes (productivity and diversity).

For both potential Mechanical and Toxicity sensitivity, the rankings are as follows:

5. Destruction of most or all of organisms in a habitat possible
4. Death or significant population decline of a large proportion of the organisms
3. Death or loss of a moderate proportion of organisms, or broad sublethal effects
2. Moderate, mostly sublethal effects
1. Little damage

For Oil Persistence the rankings are as follows:

5. Oil present for >10 years
4. Oil present for 5-10 years
3. Oil present for 1-5 years
2. Oil gone in < 1 year
1. Oil gone in days to weeks

For Recovery from Oil the rankings are as follows:

5. Community requires > 10 years to recover
4. Community requires 5-10 years to recover
3. Community requires 1-5 years to recover
2. Community recovers in < 1 year

	<u>PRIM. PROD.</u>	<u>SECOND. PROD.</u>	<u>DIVERSITY</u>
MARINE INTERTIDAL			
Exposed and semi-exposed rocky shores	4	5	5
Sand-scoured rocky shores	3	4	4
Protected rocky shores	3	3	3
Semi-exposed cobble and mixed coarse beaches	2	4	4
Semi-exposed gravel beaches	1	2	1
Exposed sandy beaches	1	3	1
Semi-protected mixed-fine beaches	3	4	3
Protected mud flats	4	4	2
MARINE SUBTIDAL			
Shallow subtidal rock and boulders	5	4	5
Deep subtidal rock and boulders	2	4	5
Deep subtidal cobble and mixed-coarse areas (mod-high energy)	1	3	2
Shallow subtidal mixed-coarse to mixed-fine areas (mod-low energy)	5	4	4
Shallow subtidal gravel or mixed- fine areas (mod-high energy)	2	3	3
Deep subtidal sand (high energy)	0	2	1
Deep subtidal mixed-fine areas (mod-low energy)	1	3	2
Deep subtidal muddy areas	0	2	2

SENSITIVITY TO OIL

	<u>MECHANICAL</u>	<u>TOXICITY</u>	<u>PERSISTENCE</u>	<u>RECOVERY</u>
MARINE INTERTIDAL				
Exposed and semi-exposed rocky shores	4 (M,O,S,V,Y) *	3 (B,I,S,T)	2 (L,P)	4 (T,X,AB)
Sand-scoured rocky shores	4	3	2	3
Protected rocky shores	4 (D,H,O,U,AA)	3 (T)	3 (L,P,X)	3 (H,AA)
Semi-exposed cobble and mixed-coarse beaches	3	3 (B,J)	3 (B)	4 (Q)
Semi-exposed gravel beaches	1	5 (H)	2 (L,AD)	2 (H)
Exposed sandy beaches	1	5 (B,J,L,R)	1	3
			(E,L,P,AD)	(J,L,R,X,AB)
Semi-protected mixed-fine beaches	2 (N)	3 (H,J,L,Z)	4 (AD)	4 (H,X)
Protected mud flats	2 (N)	4 (B,H,Z)	5 (B,Q,V)	5 (H)
MARINE SUBTIDAL				
Shallow subtidal rock and boulders	3 (H,T)	3 (H,T)	2	4 (H,T,X)
Deep subtidal rock and boulders	2	2	3	3
Deep subtidal cobble and mixed-coarse areas (mod-high energy)	2	1	2	3
Shallow subtidal mixed-coarse to mixed-fine areas (mod-low energy)	3 (N)	3 (J)	3	3 (J)
Shallow subtidal gravel or mixed-fine areas (mod-high energy)	1	3	2	3 (X)
Deep subtidal sand (high energy)	3	2	2	3
Deep subtidal mixed-fine areas (mod-low energy)	3	1	4	4
Deep subtidal muddy areas	2	2	5	5

*Letters refer to literature cited in Bibliography

	<u>PRIM. PROD.</u>	<u>SECOND. PROD.</u>	<u>DIVERSITY</u>
ESTUARINE INTERTIDAL			
Open rocky shores	3	3	3
Open mixed-coarse beaches and low marsh	3	3	4
Open gravel beaches	1	2	1
Open sandy beaches	3	4	2
Sandy low marshes	4	3	2
Mixed-fine beaches and low marshes	5	5	4
Saline lagoons	4	3	3
Low-salinity lagoons	3	2	2
Mud flats	3	3	2
High salt marshes	3	3	2
Transition zone wetlands	3	3	2
ESTUARINE SUBTIDAL			
Shallow subtidal rock and boulders	4	3	3
Deep subtidal rock and boulders	2	4	4
Shallow subtidal cobble and mixed-coarse areas	3	3	3
Deep subtidal cobble and mixed-coarse areas	1	3	2
Shallow subtidal sandy or mixed-fine areas	3	4	3
Deep subtidal sandy or mixed-fine areas	1	3	2
Shallow subtidal muddy bays	3	3	2
Deep subtidal muddy bays	0	3	2

SENSITIVITY TO OIL

	<u>MECHANICAL</u>	<u>TOXICITY</u>	<u>PERSISTENCE</u>	<u>RECOVERY</u>
ESTUARINE INTERTIDAL				
Open rocky shores	4(AA)	3(AA)	3	3(AA)
Open mixed-coarse beaches and low marsh	3	3	3	3
Open gravel beaches	1	5	2	2
Open sandy beaches	3(N)	4	2	3
Sandy low marshes	3(Y)	4(S)	3(L)	3
Mixed-fine beaches and low marshes	4(F,H,AA)	4(F,L,S,W)	4(P)	4(F,H,W,AA)
Saline lagoons	4(AA)	4(S,AA)	5	5(AA)
Low-salinity lagoons	4	3	5	4
Mud flats	2	4(W,Z)	5(Q)	5(H,W)
High salt marshes	4(F)	2(F,S)	5	4(F)
Transition zone wetlands	4	2	5	4
ESTUARINE SUBTIDAL				
Shallow subtidal rock and boulders	3	3	2	3
Deep subtidal rock and boulders	2	2	3	3
Shallow subtidal cobble and mixed-coarse areas	3	2	3	3
Deep subtidal cobble and mixed-coarse areas	2	1	3	3
Shallow subtidal sandy or mixed-fine areas	3	3(W)	3	3(W)
Deep subtidal sandy or mixed-fine areas	3	2	4	4
Shallow subtidal muddy bays	2(N)	3(W)	5	5(W)
Deep subtidal muddy bays	2	2	5	5

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APPENDIX I. CONDENSED AND SIMPLIFIED MARINE AND ESTUARINE
HABITAT DESCRIPTIONS FOR OIL SPILL COMPENSATION DETERMINATIONS

MARINE: Intertidal

Exposed and semi-exposed rocky shores

Bedrock and boulder habitats exposed to the full range of wave energies of the Pacific (i.e., on the outer coast), or to extensive wave fetch along the Strait of Juan de Fuca. Rocky areas on the coast partly protected behind sea stacks or islands also fall into this category.

Sand-scoured rocky shores

Rocky headlands or sea stacks directly adjacent to high energy sandy beaches such that there is much suspended sand in the water, which scours the rock. Unique plants and animals are found here.

Protected rocky shores

Bedrock and boulder habitats lacking oceanic swell and extensive wave fetch; e.g., inside waters of the San Juan Islands, headlands in bays off the Strait of Juan de Fuca or well protected behind islands on the outer coast.

Semi-exposed cobble and mixed-coarse beaches

Beaches exposed to moderate wave action composed of cobble overlying sand, or to somewhat less wave action, with a mix of cobble, gravel, and sand where no one component occupies more than 70% of the surface. Algae may grow on larger cobbles, and animals live both on the surface and in the sediment. Species vary dramatically with degree of wave exposure and composition of the sediment. Found inside the San Juan Islands, outside of Whidbey Island, at semi-protected sites along the Strait, and behind island and sea stacks on the coast.

Semi-exposed gravel beaches

Unstable beaches, containing some sand in more protected areas. Many sites along the Strait of Juan de Fuca.

Exposed sandy beaches

Pure marine sands found in moderate to high-energy areas, e.g. on the outer coast and along the Strait of Juan de Fuca. Mouths of bays with some wave action also fall into this category.

Semi-protected mixed-fine beaches

Mixed sand and silt habitats, found in bays and inlets with some wave action so they are not dominated by the finer sediments (muds). Patches of gravel may be present high on the shore.

Protected mud flats

Areas of little to no wave energy, where fine sediments settle and accumulate organic matter. Found in calm bays and inlets with little freshwater influx (i.e. not estuaries).

MARINE: Subtidal

Shallow subtidal rock and boulders

Areas less than 15 m depth with some currents so that sediments do not totally cover bedrock. Kelp beds are found in these habitats, which are widespread in the state.

Deep subtidal rock and boulders

Areas deeper than 15 m and thus lacking in significant algal cover, but still with enough currents to keep the substrate exposed. Common in the San Juans and the Strait.

Deep subtidal cobble and mixed-coarse areas

"Scoured" areas in channels or passes with high currents, composed entirely of cobbles or with gravel and sand mixed in.

Shallow subtidal mixed-coarse to mixed-fine areas (Low energy)

Areas ranging from cobbles lying over a matrix of sand and gravel to mixed sand and silt, in waters less than 15 m. Bays and inlets commonly have this range of substrate types. Plants and animals exist both on the cobbles and in the sediment.

Shallow subtidal gravel or mixed-fine areas (High energy)

Areas just offshore of sand or gravel beaches, where swells or wave action keep fine sediments from accumulating. Substrates range from pure gravel to gravel mixed with sand and shells. Common in the Strait.

Deep subtidal sand

Areas deeper than 15 m in the Strait or on the coast where swells keep the substratum fairly coarse.

Deep subtidal mixed-fine areas

Areas of sand, shells, and pebbles with some currents removing finer particles.

Deep subtidal muddy areas

Areas with no swell and few currents, where fine silts settle out and accumulate organic matter.

ESTUARINE: Intertidal

Open rocky shores

Rocky intertidal areas (including hardpan and riprap) in areas exposed to moderate waves or currents, e.g. on headlands in Puget Sound.

Open mixed-coarse beaches

One of the most common beach types in Puget Sound, composed of a mix of cobble, gravel, and sand in areas with some wave action that keeps finer silts suspended. Sparse salt marsh vegetation may occur at the tops of these beaches, especially in quieter areas.

Open gravel beaches

Areas of gravel or pebbles, often overlying sand, in areas of moderate wave action.

Open sandy beaches

Common habitats of gently sloping beaches but moderate wave action. May have gravel on the upper shore. Found in Puget Sound and in some areas of other estuaries, including Grays Harbor.

Sandy low marshes

Found on spits, berms, and deltas where sand collects. Areas of different salinities are dominated by different marsh plant communities. Widespread (although disturbed) throughout the Puget Trough.

Mixed-fine beaches and low marshes

Found in backwaters or deltas away from large channels, where the substrate is mixed sand and mud, sometimes with patches of gravel or peat. Substrate is stable and organic-rich. Marsh communities vary with salinity.

Saline lagoons

Areas where water-borne sediments are deposited into a spit closing off an embayment, which is flushed regularly or irregularly. Salinities vary with evaporation and runoff but are generally high.

Low-salinity lagoons

Lagoons that are nearly separated from tidal/salt influence by a berm, and where there is a source of freshwater. Substrate is usually soft silt. This habitat is rare in the state.

Mud flats

Areas lacking in gravel or significant amounts of sand due to limited wave action, usually found in the heads of bays and inlets. Includes undisturbed channels and sloughs which drain slowly through a tidal cycle, and which may contain some sand.

High salt marshes

Areas above normal high water but salt influenced, with organic/peat substrata. Salinities vary, and plant communities with them.

Transition zone wetland

Areas transitional between salt marshes and uplands, where salt water only rarely inundates. Substrata are peat or fine silts.

ESTUARINE: Subtidal

Shallow subtidal rock and boulders

Areas less than 15 m deep with moderate currents or wave action that remove silt. Kelp beds develop here.

Deep subtidal rock and boulders

Areas in narrow channels or around headlands where currents remove sediment that otherwise would settle in these deeper areas. These habitats are essentially marine, since freshwater tends to stay layered in shallow water.

Shallow subtidal cobble and mixed-coarse areas

Mixed cobble, gravel, and sand remain in shallow areas fairly open to wave action or currents.

Deep subtidal cobble and mixed-coarse areas

Tidal currents running through deep channels in Puget Sound keep fine silts from settling and create areas of mixed cobbles, sand, and gravel.

Shallow subtidal sandy or mixed-fine areas

High-current areas with little debris and some gravel, or less current-swept with more debris. Both are common outside of enclosed bays in Puget Sound.

Deep subtidal sandy or mixed-fine areas

Current-swept areas below 15 m. Organic debris and gravel tend to accumulate deeper (below 30 m), leading to different assemblages there.

Shallow subtidal muddy bays

Common habitats in open to partly enclosed bays in Puget Sound, where limited water movement allows fine sediments to accumulate. Organic enrichment is high, especially in more enclosed bays.

Deep subtidal muddy bays

Habitats in the heads and centers of inlets in Puget Sound where there is little motion and the substrate is soft mud and sand. Assemblages vary with depth and amount of organic debris accumulated.

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SHELLFISH VULNERABILITY TO OIL SPILLS
A RANKING SYSTEM FOR THE
OIL SPILL COMPENSATION SCHEDULE

DRAFT

prepared by

Laura Geselbracht

2/21/91

*example
model detail
of shellfish stuff*

Key 1 to zone

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Definition

For purposes of the oil spill compensation schedule, shellfish are defined as all marine invertebrates with important commercial or recreational value occurring within marine waters of Washington State including species without obvious shells or exoskeletons such as octopuses and squid.

Method for Ranking Shellfish Vulnerability to Oil Spills

The Shellfish Oil Index (SOI)

The Shellfish Oil Index (SOI) provides a methodology to relatively rank both shellfish species and Washington State marine environments for their vulnerability to oil spills. Shellfish depend on the marine environment for their survival. Species biology determines the relative vulnerability of shellfish species to spills, and includes factors such as depth of occurrence for the various life stages, range, concentration, population size, and reproductive characteristics. Nine factors were selected to rank species vulnerability to oil spills. Each factor was scored for each species. A description of the ranking factors and their scoring parameters are listed below.

Adult/Juvenile Habitat (AJH)

- 5 - primarily occurs intertidally or on the surface
- 3 - primarily occurs in shallow waters (at depths of less than 20 meters)
- 1 - occurs both shallow and deep (at depths greater than 20 meters)
- 0 - primarily occurs only in deep waters (at depths greater than 20 meters)

Larval Habitat (LH)

same scoring scheme as for Adult/Juvenile Habitat

Location of Eggs (LE)

same scoring scheme as for Adult/Juvenile Habitat

Relative Significance of Washington Population (i.e. distribution). (SD)

- 5 - species found only in Washington waters
- 3 - Washington waters account for a moderate proportion of species range (i.e., species found in Pacific NW only, or from B.C. to OR)
- 1 - wide population distribution (i.e., found from AK to So. CA and further south, or with temperate water distribution)
- 0 - introduced species

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Concentration of Washington Population (PC)

- 5 - species WA population concentrated in very few locations
- 3 - known to occur in moderate number of areas statewide
- 1 - ubiquitous in WA marine waters, not known to concentrate

Size of Washington Population (PS)

- 5 - rare or uncommon; small population, limited numbers
- 3 - common; population of moderate size
- 1 - abundant; large population

Length of Spawning Period (SP)

- 5 - annual spawning period limited to a few days
- 3 - spawning takes place primarily during one season
- 1 - spawning occurs during more than one season with a peak in one season, or has bimodal spawning
- 0 - spawns throughout the year

Reproductive Potential (number of eggs spawned per female annually), (RP)

- 5 - relatively low, less than 100,000 eggs per female
- 3 - moderate, 100,00 to 1 million eggs per female
- 1 - relatively high, more than 1 million eggs per female

Age at Sexual Maturity (SM)

- 5 - more than 3 years
- 3 - one to three years
- 1 - less than one year

To account for the seasonality of vulnerability, each of the factors is scored in each season. For example, for species with larvae present during only one season of each year, only the season in which larvae are present receives a score. Appendix A lists factor scores in each season for each species. Factor scores for each species were then combined using the following formula to derive a composite for each species in each season:

$$SOI = [AJH + SP(LH + LE + RP)](PC + SD + PS + SM)$$

Composite scores for each species are also listed in Appendix A.

To determine area vulnerability to oil spills (for shellfish only), the

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SOI of each shellfish species present in a subregion were summed for each season. SOIs for each compensation schedule subregion are listed in Tables 1 - 9. Subregional SOIs are graphically represented in Figures 1 - 9.

Table 1

SHELLFISH AND OTHER INVERTEBRATES OF COMMERCIAL OR RECREATIONAL IMPORTANCE
SOI FOR REGION 2

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date: 2/15/91

P/A - presence/absence in a zone

1 - present

0 - absent

SPRING

Group	Species Common Name	SOI SP	201 P/A	203 SOI P/A	204 P/A	205 SOI P/A	206 P/A	207 SOI P/A	208 P/A	209 SOI P/A	210 P/A	211 SOI P/A	212 P/A	213 SOI P/A	214 P/A	215 SOI P/A	216 P/A	217 SOI P/A	218 P/A	219 SOI P/A	220 P/A	

Bivalves	Pacific Oyster	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Olympia Oyster	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		0																				
	Pacific Razor Clam	480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Geoduck	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Butter Clam	18	0	0	0	0	1	18	1	18	1	18	1	18	1	18	0	0	0	0	0	
	Native Little Neck	144	0	0	0	0	1	144	1	144	1	144	1	144	1	144	0	0	0	0	0	
	Manila Clam	15	0	0	0	0	1	15	1	15	1	15	1	15	1	15	0	0	0	0	0	
	Horse Clam	18	0	0	0	0	1	18	1	18	1	18	1	18	1	18	0	0	0	0	0	
	Horse Clam	18	0	0	0	0	1	18	1	18	1	18	1	18	1	18	0	0	0	0	0	
	Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Cockles	24	0	0	0	0	1	24	1	24	1	24	1	24	1	24	0	0	0	0	0	
		0																				
		Pink Scallop	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Rock Scallop	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Weathervane Scallop	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0																			
	Bay Mussel	30	0	0	1	30	1	30	1	30	1	30	1	30	1	30	0	0	0	0	0	
	California Mussel	30	0	0	1	30	1	30	1	30	1	30	1	30	1	30	0	0	0	0	0	
		0																				
Cephalopods	Squid	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Octopus	24	0	0	1	24	1	24	1	24	1	24	1	24	1	24	1	24	1	24	1	
		0																				
Sea Snails	Northern Abalone	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		0																				
Echinoderms	Sea Cucumber	80	0	0	0	0	1	80	1	80	1	80	1	80	1	80	1	80	1	80	1	
	Red Sea Urchin	168	0	0	1	168	0	0	1	168	1	168	1	168	1	168	1	168	1	168	1	
	Green Sea Urchin	60	0	0	0	0	1	60	1	60	1	60	1	60	1	60	1	60	1	60	1	
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Crustaceans		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Dungeness Crab	42	1	42	0	0	1	42	0	0	1	42	1	42	1	42	1	42	1	42	1	
	Red (Rock) Crab	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Spot Shrimp	220	0	0	0	0	1	220	1	220	1	220	1	220	1	220	1	220	1	220	1	
	Coon Stripe Shrimp	220	0	0	0	0	1	220	1	220	1	220	1	220	1	220	1	220	1	220	1	
	Side Shrimp	308	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Pink Shrimp	126	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
			1	42	4	252	10	363	14	1069	13	1051	13	1051	7	814	7	814	7	814	7	

SUMMER

Group	Species	Summer	201		203		204		205		206		207		208		209	
			P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI
Mollusks	Pacific Oyster	96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Olympia Oyster	456		0		0		0		0		0		0		0		0
		0																
	Pacific Razor Clam	420	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Geoduck	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Butter Clam	144	0	0	0	0	1	144	1	144	1	144	1	144	0	0	0	0
	Native Little Neck	144	0	0	0	0	1	144	1	144	1	144	1	144	0	0	0	0
	Manila Clam	120	0	0	0	0	1	120	1	120	1	120	1	120	0	0	0	0
	Horse Clam	60	0	0	0	0	1	60	1	60	1	60	1	60	0	0	0	0
	Horse Clam	18	0	0	0	0	1	18	1	18	1	18	1	18	0	0	0	0
Mollusks	Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cockles	192	0	0	0	0	1	192	1	192	1	192	1	192	0	0	0	0
		0																
	Pink Scallop	0		0		0		0		0		0		0		0		0
	Rock Scallop	48		0		0		0		0		0		0		0		0
	Weathervane Scallop	24		0		0		0		0		0		0		0		0
		0																
	Bay Mussel	30	0	0	1	30	1	30	1	30		0	0	0		0	0	0
	California Mussel	30	0	0	1	30	1	30	1	30		0	0	0	0	0	0	0
		0																
Cephalopods	Squid	6		0		0		0		0		0		0		0		0
	Octopus	8	0	0	1	8	1	8	1	8	1	8	1	8	1	8	1	8
Sea Snails	Northern Abalone	384	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0																
Echinoderms	Sea Cucumber	96	0	0	0	0	0	0	1	96	1	96	1	96	1	96	1	96
	Red Sea Urchin	6	0	0	1	6	0	0	1	6	1	6	1	6	1	6	1	6
	Green Sea Urchin	6	0	0	0	0	0	0	1	6	1	6	1	6	1	6	1	6
Crustaceans		0		0		0		0		0		0		0		0		0
	Dungeness Crab	6	1	6	0	0	1	6	0	0	1	6	1	6	1	6	1	6
	Red (Rock) Crab	66		0		0		0		0		0		0		0		0
		0		0		0		0		0		0		0		0		0
	Spot Shrimp	220	0	0		0		0	1	220	1	220	1	220	1	220	1	220
	Coon Stripe Shrimp	220	0	0		0		0	1	220	1	220	1	220	1	220	1	220
	Side Shrimp	308	0	0		0		0		0		0		0		0		0
	Pink Shrimp	126		0		0		0		0		0		0		0		0
			1	6	4	74	10	752	14	1294	13	1240	13	1240	7	562	7	562

FALL

	Species	SOI	201	203	204	205	206	207	208	209
Group	Common Name	Fall	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI

Bivalves										
	Pacific Oyster	15	0	0	0	0	0	0	0	0
	Olympia Oyster	60	0	0	0	0	0	0	0	0
		0								
	Pacific Razor Clam	480	0	0	0	0	0	0	0	0
	Geoduck	6	0	0	0	0	0	0	0	0
	Butter Clam	18	0	0	0	18	18	18	18	0
	Native Little Neck	18	0	0	0	18	18	18	18	0
	Manila Clam	15	0	0	0	15	15	15	15	0
	Horse Clam	18	0	0	0	18	18	18	18	0
	Horse Clam	18	0	0	0	18	18	18	18	0
	Eastern Soft Shell	156	0	0	0	0	0	0	0	0
	Cockles	24	0	0	0	24	1	24	1	24
		0								
	Pink Scallop	12	0	0	0	0	0	0	0	0
	Rock Scallop	48	0	0	0	0	0	0	0	0
	Weathervane Scallop	0	0	0	0	0	0	0	0	0
		0								
	Bay Mussel	156	0	0	156	1	156	0	0	0
	California Mussel	30	0	0	30	1	30	0	0	0
		0								
Cephalopods/Squid		0	0	0	0	0	0	0	0	0
	Octopus	8	0	0	1	8	1	8	1	8
		0								
Sea Snails	Northern Abalone	48	0	0	0	0	0	0	0	0
		0								
Echinoderms	Sea Cucumber	8	0	0	0	0	1	8	1	8
	Red Sea Urchin	6	0	0	1	6	0	6	1	6
	Green Sea Urchin	6	0	0	0	0	1	6	1	6
		0	0	0	0	0	0	0	0	0
Crustaceans		0	0	0	0	0	0	0	0	0
	Rock Crab	6	1	6	0	0	1	6	1	6
	Red (Rock) Crab	66	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0
	Spot Shrimp	10	0	0	0	1	10	1	10	1
	Coon Stripe Shrimp	10	0	0	0	1	10	1	10	1
	Side Shrimp	14	0	0	0	0	0	0	0	0
	Pink Shrimp	0	0	0	0	0	0	0	0	0
			1	6	4	200	10	311	14	345
									13	165
									13	165
									7	54
									7	54

Group	Species Common Name	SOI	201		203		204		205		206		207		208		209 *	
			P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI

Bivalves																		
	Pacific Oyster	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Olympia Oyster	60	0		0		0		0		0		0		0		0	
		0																
	Pacific Razor Clam	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Geoduck	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Butter Clam	18	0	0	0	0	1	18	1	18	1	18	1	18	0	0	0	0
	Native Little Neck	18	0	0	0	0	1	18	1	18	1	18	1	18	0	0	0	0
	Manila Clam	15	0	0	0	0	1	15	1	15	1	15	1	15	0	0	0	0
	Horse Clam	18	0	0	0	0	1	18	1	18	1	18	1	18	0	0	0	0
	Horse Clam	60	0	0	0	0	1	60	1	60	1	60		60	0	0	0	0
	Eastern Soft Shell	65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cockles	24	0	0	0	0	1	24	1	24	1	24	1	24	0	0	0	0
		0																
	Pink Scallop	0	0		0		0		0		0		0		0		0	
	Rock Scallop	48	0		0		0		0		0		0		0		0	
	Weathervane Scallop	12	0		0		0		0		0		0		0		0	
		0																
	Bay Mussel	156	0	0	1	156	1	156	1	156		0	0	0		0	0	0
	California Mussel	30	0	0	1	30	1	30	1	30		0	0	0	0	0	0	0
		0																
Cephalopods	Squid	114	0		0		0		0		0		0		0		0	
	Octopus	8	0	0	1	8	1	8	1	8	1	8	1	8	1	8	1	8
		0																
Sea Snails	Northern Abalone	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0																
Echinoderms	Sea Cucumber	8	0	0	0	0	0	0	1	8	1	8	1	8	1	8	1	8
	Red Sea Urchin	6	0	0	1	6	0	0	1	6	1	6	1	6	1	6	1	6
	Green Sea Urchin	60	0		0		0		1	60	1	60	1	60	1	60	1	60
		0	0		0		0		0		0		0		0		0	
Crustaceans		0	0		0		0		0		0		0		0		0	
	Dungeness Crab	48	1	48	0	0	1	48	0	0	1	48	1	48	1	48	1	48
	Red (Rock) Crab	18	0		0		0		0		0		0		0		0	
		0	0		0		0		0		0		0		0		0	
	Spot Shrimp	10	0	0		0		0	1	10	1							

Table 2

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Date: 2/20/91

SPRING

[illegible]

SUNN EA

	Species	SOI	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318
Group	Common Name	Summer	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI
Bivalves																				
	Pacific Oyster	96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chum Oyster	456	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pacific Razor Clam	480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Geoduck	6	1	6	0	0	0	0	1	6	1	6	0	0	1	6	1	6	0	0
	Butter Clam	144	1	144	0	0	0	0	1	144	0	0	1	144	1	144	1	144	0	0
	Native Little Neck	144	0	0	0	0	0	0	1	144	0	0	1	144	1	144	1	144	0	0
	Manila Clam	120	1	120	0	0	0	0	1	120	1	120	1	120	1	120	1	120	0	0
	Horse Clam	60	0	0	0	0	0	0	1	60	0	0	1	60	1	60	1	60	0	0
	Horse Clam	18	0	0	0	0	0	0	1	18	0	0	1	18	1	18	1	18	0	0
	Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cockles	192	0	0	0	0	0	0	1	192	0	0	1	192	1	192	1	192	0	0
	Pink Scallop	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rock Scallop	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Wentherve Scallop	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bay Mussel	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	California Mussel	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cephalopods																				
	Squid	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Octopus	8	1	8	0	0	0	0	0	0	0	0	0	1	8	0	0	0	0	0
Sea Snails																				
	Northern Abalone	384	1	384	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Echinoderms																				
	Sea Cucumber	96	1	96	0	0	0	0	1	96	1	96	1	96	1	96	1	96	0	0
	Red Sea Urchin	6	1	6	0	0	0	0	1	6	1	6	0	0	0	0	0	0	0	0
	Green Sea Urchin	6	1	6	0	0	0	0	1	6	1	6	0	0	0	0	0	0	0	0
Crustaceans																				
	Dungeness Crab	6	1	6	0	0	0	0	1	6	1	6	0	0	0	0	0	0	0	0
	Red (Rock) Crab	66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Spot Shrimp	220	1	220	0	0	0	0	1	220	1	220	0	0	0	0	0	0	0	0
	Coon Stripe Shrimp	220	0	0	0	0	0	0	1	220	0	0	0	0	0	0	0	0	0	0
	Side Shrimp	308	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pink Shrimp	126	0	0	0	0	0	0	1	126	0	0	0	0	0	0	0	0	0	0
Subregional Total:			10	996	0	0	2	226	14	1364	9	806	9	876	15	1590	12	1228	12	1182

FALL

10	131	0	0	2	16	14	163	9	67	9	140	15	233	12	158	12	161	7	117	8	123	3	20	11	139	7	159	0	0	8	103	7	88
----	-----	---	---	---	----	----	-----	---	----	---	-----	----	-----	----	-----	----	-----	---	-----	---	-----	---	----	----	-----	---	-----	---	---	---	-----	---	----

VINTER

Group	Species Common Name	:SOI	:301	:302	:303	:304	:305	:306	:307	:308	:309	:310	:311	:312	:313	:314	:315	:316	:317
		P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI
Bivalves:																			
	Pacific Oyster	15	0	0	0	0	0	0	0	0	0	1	15	0	0	1	15	0	0
	Olympia Oyster	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pacific Razor Clam	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Geoduck	132	1	132	0	0	0	0	1	132	1	132	0	0	1	132	1	132	0
	Butter Clam	18	1	18	0	0	0	0	1	18	0	0	1	18	1	18	0	0	0
	Native Little Neck	18	0	0	0	0	0	0	1	18	0	0	1	18	1	18	0	0	0
	Manila Clam	15	1	15	0	0	0	0	1	15	1	15	1	15	1	15	1	15	1
	Horse Clam	18	0	0	0	0	0	0	1	18	0	0	1	18	1	18	0	0	0
	Horse Clam	60	0	0	0	0	0	0	1	60	0	0	1	60	1	60	0	0	0
	Eastern Soft Shell	65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cockles	24	0	0	0	0	0	0	1	24	0	0	1	24	1	24	0	0	0
	Pink Scallop	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rock Scallop	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Weathervane Scallop	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bay Mussel	156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	California Mussel	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cephalopod:	Squid	114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Octopus	8	1	8	0	0	0	0	0	0	0	0	0	1	8	0	0	0	0
Sea Snails:	Northern Abalone	48	1	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Echinoderm:	Sea Cucumber	8	1	8	0	0	0	0	1	8	1	8	1	8	1	8	1	8	1
	Red Sea Urchin	6	1	6	0	0	0	0	1	6	1	6	0	0	0	0	0	0	0
	Green Sea Urchin	60	1	60	0	0	0	1	60	1	60	0	0	0	0	0	0	0	0
Crustacean:	Dungeness Crab	48	1	48	0	0	1	48	1	48	1	48	1	48	1	48	1	48	1
	Red (Rock) Crab	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Spot Shrimp	10	1	10	0	0	1	10	1	10	0	0	1	10	1	10	1	10	1
	Coon Stripe Shrimp	10	0	0	0	0	1	10	1	10	0	0	1	10	0	0	1	10	1
	Side Shrimp	14	0	0	0	0	0	0	0	0	0	0	1	14	0	0	1	14	0
	Pink Shrimp	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0	1

Table 3

SHELLFISH AND OTHER INVERTEBRATES OF COMMERCIAL OR RECREATIONAL IMPORTANCE
SOI FOR REGIONS 4 and 5

file: inver4 5.ws

date: 2/15/91

SPRING

	Species	SOI	401		501		502		503		504		505		506		507	
Group	Common Name	SP	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI

Bivalves	Pacific Oyster	15	0	0	0	0	0	0	1	15	1	15	1	15	1	15	1	15
	Olympia Oyster	60		0		0		0		0		0		0		0		0
		0																
	Pacific Razor Clam	480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Geoduck	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Butter Clam	18	1	18	1	18	0	0	1	18	1	18	1	18	1	18	1	18
	Native Little Neck	144	1	144	1	144	0	0	1	144	1	144	1	144	1	144	1	144
	Manila Clam	15	1	15	1	15	0	0	1	15	1	15	1	15	1	15	1	15
	Horse Clam	18	1	18	1	18	0	0	1	18	1	18	1	18	1	18	1	18
	Horse Clam	18	1	18	1	18	0	0	1	18	1	18	1	18	1	18	1	18
Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Cockles	24	1	24	1	24	0	0	1	24	1	24	1	24	1	24	1	24	
		0																
	Pink Scallop	12	1	12	1	12		0		0		0		0		0		0
	Rock Scallop	48	1	48	1	48		0		0		0	0	0	1	48		0
	Weathervane Scallop	12	1	12	1	12		0		0		0	0	0	1	12		0
		0																
	Bay Mussel	30	0	0	0	0	0	0	0	0		0		0	0	0		0
	California Mussel	30	0	0	0	0	0	0	0	0		0		0	0	0	0	0
		0																
Cephalopods	Squid	132	1	132		0		0		0		0		0		0	1	132
	Octopus	24	1	24	0	0	0	0	0	0	0	0	0	0	1	24	1	24
		0																
Sea Snails	Northern Abalone	48	0	0	1	48	0	0	0	0	0	0		0	0	0	0	0
		0																
Echinoderms	Sea Cucumber	80	1	80	1	80	0	0	0	0	0	0	1	80	0	0	1	80
	Red Sea Urchin	168	1	168	1	168	0	0	0	0	0	0		0	0	0	0	0
	Green Sea Urchin	60	1	60	1	60	1	60	1	60	1	60		0	0	0	1	60
		0		0		0		0		0		0			0		0	0
Crustaceans		0		0		0		0		0		0		0		0		0
	Dungeness Crab	42	1	42	1	42	1	42	1	42	1	42	1	42	1	42	1	42
	Red (Rock) Crab	18		0		0		0		0		0		0		0		0
		0		0		0		0		0		0			0		0	0
	Spot Shrimp	220	1	220	1	220	0	0	0	0	0	0		0	0	0	0	0
	Coon Stripe Shrimp	220	1	220	1	220	1	220	1	220	1	220	1	220	0	0	0	0
	Side Shrimp	308	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
	Pink Shrimp	126		0	1	126		0	0	0	0	0		0	0	0	0	0
			17	1255	17	1273	3	322	10	574	10	574	10	594	11	378	12	590

SUMMER

Group	Species Common Name	SOI Summer	401 P/A	SOI	501 P/A	SOI	502 P/A	SOI	503 P/A	SOI	504 P/A	SOI	505 P/A	SOI	506 P/A	SOI	507 P/A	SOI
Bivalves																		
	Pacific Oyster	96	0	0	0	0	0	0	1	96	1	96	1	96	1	96	1	96
	Olympia Oyster	456		0		0		0		0		0		0		0		0
		0																
	Pacific Razor Clam	480	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
	Geoduck	6	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
	Butter Clam	144	1	144	1	144	0	0	1	144	1	144	1	144	1	144	1	144
	Native Little Neck	144	1	144	1	144	0	0	1	144	1	144	1	144	1	144	1	144
	Manila Clam	120	1	120	1	120	0	0	1	120	1	120	1	120	1	120	1	120
	Horse Clam	60	1	60	1	60	0	0	1	60	1	60	1	60	1	60	1	60
	Horse Clam	18	1	18	1	18	0	0	1	18	1	18	1	18	1	18	1	18
	Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cockles	192	1	192	1	192	0	0	1	192	1	192	1	192	1	192	1	192
		0																
	Pink Scallop	0	1	0	1	0		0		0		0		0		0		0
	Rock Scallop	48	1	48	1	48		0		0		0	0	0	1	48		0
	Weathervane Scallop	24	1	24	1	24		0		0		0	0	0	1	24		0
		0																
	Bay Mussel	30	0	0	0	0	0	0	0	0		0		0	0	0		0
	California Mussel	30	0	0	0	0	0	0	0	0		0		0	0	0	0	0
		0																
Cephalopods	Squid	6	1	6		0		0		0		0		0		0	1	6
	Octopus	8	1	8	0	0	0	0	0	0	0	0	0	0	1	8	1	8
		0																
Sea Snails	Northern Abalone	384	0	0	1	384	0	0	0	0	0	0		0	0	0	0	0
		0																
Echinoderms	Sea Cucumber	96	1	96	1	96	0	0	0	0	0	0	1	96	0	0	1	96
	Red Sea Urchin	6	1	6	1	6	0	0	0	0	0	0		0	0	0	0	0
	Green Sea Urchin	6	1	6	1	6	1	6	1	6	1	6		0	0	0	1	6
		0		0		0		0		0		0			0		0	
Crustaceans		0		0		0		0		0		0		0		0		0
	Dungeness Crab	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6
	Red (Rock) Crab	66		0		0		0		0		0		0		0		0
		0		0		0		0		0		0			0		0	
	Spot Shrimp	220	1	220	1	220	0	0	0	0	0	0		0	0	0	0	0
	Coon Stripe Shrimp	220	1	220	1	220	1	220	1	220	1	220	1	220	0	0	0	0
	Side Shrimp	308	0	0	0	0		0	0	0	0	0		0	0	0	0	0
	Pink Shrimp	126		0	1	126		0	0	0	0	0		0	0	0	0	0

17 1318 17 1814 3 232 10 1006 10 1006 10 1096 11 860 12 896

FALL

	Species	SOI	401		501		502		503		504		505		506		507		
Group	Common Name	Fall	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	

Bivalves	Pacific Oyster	15	0	0	0	0	0	0	1	15	1	15	1	15	1	15	1	15	
	Olympia Oyster	60		0		0		0		0		0		0		0		0	
		0	-----												-----		-----		
	Pacific Razor Clam	480	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	
	Geoduck	6	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	
	Butter Clam	18	1	18	1	18	0	0	1	18	1	18	1	18	1	18	1	18	
	Native Little Neck	18	1	18	1	18	0	0	1	18	1	18	1	18	1	18	1	18	
	Manila Clam	15	1	15	1	15	0	0	1	15	1	15	1	15	1	15	1	15	
	Horse Clam	18	1	18	1	18	0	0	1	18	1	18	1	18	1	18	1	18	
	Horse Clam	18	1	18	1	18	0	0	1	18	1	18	1	18	1	18	1	18	
	Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Cockles	24	1	24	1	24	0	0	1	24	1	24	1	24	1	24	1	24	
		0	-----												-----		-----		
		Pink Scallop	12	1	12	1	12		0		0		0		0		0		0
		Rock Scallop	48	1	48	1	48		0		0		0	0	0	1	48		0
		Weathervane Scallop	0	1	0	1	0		0		0		0	0	0	1	0		0
		0	-----												-----		-----		
		Bay Mussel	156	0	0	0	0	0	0	0	0		0		0	0	0		0
		California Mussel	30	0	0	0	0	0	0	0	0		0		0	0	0	0	0
	0	-----												-----		-----			
Cephalopods	Squid	6	1	6		0		0		0		0		0		0	1	6	
	Octopus	8	1	8	0	0	0	0	0	0	0	0	0	0	1	8	1	8	
		0	-----												-----		-----		
Sea Snails	Northern Abalone	48	0	0	1	48	0	0	0	0	0	0		0	0	0	0	0	
	0	-----												-----		-----			
Echinoderms	Sea Cucumber	8	1	8	1	8	0	0	0	0	0	0	1	8	0	0	1	8	
	Red Sea Urchin	6	1	6	1	6	0	0	0	0	0	0		0	0	0	0	0	
	Green Sea Urchin	6	1	6	1	6	1	6	1	6	1	6	5	0	0	0	1	6	
		0	-----												-----		-----		
Crustaceans		0	-----												-----		-----		
	Dungeness Crab	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6	
	Red (Rock) Crab	66		0		0		0		0		0		0		0		0	
		0	-----												-----		-----		
	Spot Shrimp	10	1	10	1	10	0	0	0	0	0	0		0	0	0	0	0	
	Coon Stripe Shrimp	10	1	10	1	10	1	10	1	10	1	10	1	10	0	0	0	0	
	Side Shrimp	14	0	0	0	0		0	0	0	0	0		0	0	0	0	0	
	Pink Shrimp	0		0	1	0		0	0	0	0	0		0	0	0	0	0	

17 231 17 265 3 22 10 148 10 148 10 150 11 188 12 160

WINTER

Group	Species Common Name	SOI Wint	401 P/A	SOI	501 P/A	SOI	502 P/A	SOI	503 P/A	SOI	504 P/A	SOI	505 P/A	SOI	506 P/A	SOI	507 P/A	SOI
Bivalves																		
	Pacific Oyster	15	0	0	0	0	0	0	1	15	1	15	1	15	1	15	1	15
	Olympia Oyster	60		0		0		0		0		0		0		0		0
		0																
	Pacific Razor Clam	30	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
	Geoduck	132	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
	Butter Clam	18	1	18	1	18	0	0	1	18	1	18	1	18	1	18	1	18
	Native Little Neck	18	1	18	1	18	0	0	1	18	1	18	1	18	1	18	1	18
	Manila Clam	15	1	15	1	15	0	0	1	15	1	15	1	15	1	15	1	15
	Horse Clam	18	1	18	1	18	0	0	1	18	1	18	1	18	1	18	1	18
	Horse Clam	60	1	60	1	60	0	0	1	60	1	60	1	60	1	60	1	60
	Eastern Soft Shell	65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cockles	24	1	24	1	24	0	0	1	24	1	24	1	24	1	24	1	24
		0																
	Pink Scallop	0	1	0	1	0		0		0		0		0		0		0
	Rock Scallop	48	1	48	1	48		0		0		0	0	0	1	48		0
	Weathervane Scallop	12	1	12	1	12		0		0		0	0	0	1	12		0
		0																
	Bay Mussel	156	0	0	0	0	0	0	0	0		0		0	0	0		0
	California Mussel	30	0	0	0	0	0	0	0	0		0		0	0	0	0	0
		0																
Cephalopods	Squid	114	1	114		0		0		0		0		0		0	1	114
	Octopus	8	1	8	0	0	0	0	0	0	0	0	0	0	1	8	1	8
		0																
Sea Snails	Northern Abalone	48	0	0	1	48	0	0	0	0	0	0		0	0	0	0	0
		0																
Echinoderms	Sea Cucumber	8	1	8	1	8	0	0	0	0	0	0	1	8	0	0	1	8
	Red Sea Urchin	6	1	6	1	6	0	0	0	0	0	0		0	0	0	0	0
	Green Sea Urchin	60	1	60	1	60	1	60	1	60	1	60		0	0	0	1	60
		0		0		0		0		0		0			0		0	0
Crustaceans		0		0		0		0		0		0		0		0		0
	Dungeness Crab	48	1	48	1	48	1	48	1	48	1	48	1	48	1	48	1	48
	Red (Rock) Crab	18		0		0		0		0		0		0		0		0
		0		0		0		0		0		0			0		0	0
	Spot Shrimp	10	1	10	1	10	0	0	0	0	0	0		0	0	0	0	0
	Coon Stripe Shrimp	10	1	10	1	10	1	10	1	10	1	10	1	10	0	0	0	0
	Side Shrimp	14	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
	Pink Shrimp	0		0	1	0		0	0	0	0	0		0	0	0	0	0

17 477 17 403 3 118 10 286 10 286 10 234 11 284 12 406

Table 4

SHELLFISH AND OTHER INVERTEBRATES OF COMMERCIAL OR RECREATIONAL IMPORTANCE
SOI FOR REGION 6

file: invert6.ws

date: 2/13/91

SPRING

Group	Species Common Name	SOI SP	601 P/A	602 SOI	603 P/A	604 SOI	605 P/A	606 SOI	607 P/A	608 SOI
Bivalves										
	Pacific Oyster	15	1	15	0	0	0	0	1	15
	Olympia Oyster	60		0		0		0		0
		0								
	Pacific Razor Clam	480	0	0	0	0	0	0	0	0
	Geoduck	132	0	0	0	0	0	0	0	0
	Butter Clam	18	1	18	1	18	1	18	1	18
	Native Little Neck	144	1	144	1	144	1	144	1	144
	Manila Clam	15	1	15	1	15	1	15	1	15
	Horse Clam	18	1	18	1	18	1	18	1	18
	Horse Clam	18	1	18	1	18	1	18	1	18
	Eastern Soft Shell	156	0	0	0	0	0	0	0	0
	Cockles	24	1	24	1	24	1	24	1	24
		0								
	Pink Scallop	12	0	0	0	0	0	0	0	0
	Rock Scallop	48	0	0	0	0	0	0	1	48
	Weathervane Scallop	12	0	0	0	0	0	0	1	12
		0								
	Bay Mussel	30	0	0	0	0	0	0	0	0
	California Mussel	30	0	0	0	0	0	0	0	0
		0								
Cephalopods	Squid	132	0	0	0	0	0	0	1	132
	Octopus	24	1	24	1	24	1	24	1	24
		0								
Sea Snails	Northern Abalone	48	0	0	0	0	0	0	0	0
		0								
Echinoderms	Sea Cucumber	80	1	80	1	80	1	80	1	80
	Red Sea Urchin	168		0		0		0		0
	Green Sea Urchin	60	1	60	1	60	1	60	1	60
		0		0		0		0		0
Crustaceans		0		0		0		0		0
	Dungeness Crab	42	1	42	1	42	1	42	1	42
	Red (Rock) Crab	18		0		0		0		0
		0		0		0		0		0
	Spot Shrimp	220	0	0	0	0	0	0	0	0
	Coon Stripe Shrimp	220	0	0	0	0	0	0	0	0
	Side Shrimp	308	0	0	0	0	0	0	0	0
	Pink Shrimp	128	0	0	0	0	0	0	0	0

11 458 10 443 10 443 10 443 11 458 13 635 7 402 5 338

SUMMER

Subregions

Group	Species Common Name	SOI Summer	Subregions															
			601		602		603		604		605		606		607		608	
			P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI

Bivalves																		
	Pacific Oyster	96	1	96	0	0	0	0	0	0	1	96	0	0	0	0	0	0
	Olympia Oyster	456	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0																
	Pacific Razor Clam	480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Geoduck	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Butter Clam	144	1	144	1	144	1	144	1	144	1	144	1	144	0	0	0	0
	Native Little Neck	144	1	144	1	144	1	144	1	144	1	144	1	144	0	0	0	0
	Manila Clam	120	1	120	1	120	1	120	1	120	1	120	1	120	0	0	0	0
	Horse Clam	60	1	60	1	60	1	60	1	60	1	60	1	60	0	0	0	0
	Horse Clam	18	1	18	1	18	1	18	1	18	1	18	1	18	0	0	0	0
	Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cockles	192	1	192	1	192	1	192	1	192	1	192	1	192	0	0	0	0
		0																
	Pink Scallop	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rock Scallop	48	0	0	0	0	0	0	0	0	0	0	1	48	1	48	0	0
	Veathervane Scallop	24	0	0	0	0	0	0	0	0	0	0	1	24	1	24	0	0
		0																
	Bay Mussel	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	California Mussel	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0																
Cephalopods	Squid	6	0	0	0	0	0	0	0	0	0	0	1	6	0	0	1	6
	Octopus	8	1	8	1	8	1	8	1	8	1	8	1	8	1	8	1	8
		0																
Sea Snails	Northern Abalone	384	0	0	0	0	0	0	0	0	0	0	0	0	1	384	0	0
		0																
Echinoderms	Sea Cucumber	96	1	96	1	96	1	96	1	96	1	96	1	96	0	0	1	96
	Red Sea Urchin	6	0	0	0	0	0	0	0	0	0	0	0	0	1	6	0	0
	Green Sea Urchin	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crustaceans		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dungeness Crab	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6
	Red (Rock) Crab	66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Spot Shrimp	220	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Coon Stripe Shrimp	220	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Side Shrimp	308	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pink Shrimp	126	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subregional Totals:			11	890	10	794	10	794	10	794	11	890	13	872	7	482	5	122

FALL

Group	Species Common Name	SOI Fall	601 P/A	SOI	602 P/A	SOI	603 P/A	SOI	604 P/A	SOI	605 P/A	SOI	606 P/A	SOI	607 P/A	SOI	608 P/A	SOI
Bivalves																		
	Pacific Oyster	15	1	15	0	0	0	0	0	0	1	15	0	0	0	0	0	0
	Olympia Oyster	60		0		0		0		0		0		0		0		0
		0																
	Pacific Razor Clam	480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Geoduck	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Butter Clam	18	1	18	1	18	1	18	1	18	1	18	1	18	0	0	0	0
	Native Little Neck	18	1	18	1	18	1	18	1	18	1	18	1	18	0	0	0	0
	Manila Clam	15	1	15	1	15	1	15	1	15	1	15	1	15	0	0	0	0
	Horse Clam	18	1	18	1	18	1	18	1	18	1	18	1	18	0	0	0	0
	Horse Clam	18	1	18	1	18	1	18	1	18	1	18	1	18	0	0	0	0
	Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cockles	24	1	24	1	24	1	24	1	24	1	24	1	24	0	0	0	0
		0																
	Pink Scallop	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rock Scallop	48	0	0	0	0	0	0	0	0	0	0	48	1	48	0	0	0
	Weathered Scallop	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
		0																
	Bay Mussel	156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	California Mussel	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0																
Cephalopods	Squid	6	0	0	0	0	0	0	0	0	0	0	6	0	0	1	6	0
	Octopus	8	1	8	1	8	1	8	1	8	1	8	1	8	1	8	1	8
		0																
Sea Snails	Northern Abalone	48	0	0	0	0	0	0	0	0	0	0	0	1	48	0	0	0
		0																
Echinoderms	Sea Cucumber	8	1	8	1	8	1	8	1	8	1	8	1	8	0	0	1	8
	Red Sea Urchin	6		0	0	0	0	0	0	0	0	0	0	1	6	0	0	0
	Green Sea Urchin	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6
		0		0		0		0		0		0		0		0		0
Crustaceans		0		0		0		0		0		0		0		0		0
	Dungeness Crab	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6
	Red (Rock) Crab	66		0		0		0		0		0		0		0		0
		0		0		0		0		0		0		0		0		0
	Spot Shrimp	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Coon Stripe Shrimp	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Side Shrimp	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pink Shrimp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

11 154 10 139 10 139 10 139 11 154 13 193 7 122 5 34

WINTER

	Species	SOI	601		602		603		604		605		606		607		608	
Group	Common Name	Wint	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI

Bivalves																		
	Pacific Oyster	15	1	15	0	0	0	0	0	0	1	15	0	0	0	0	0	0
	Olympia Oyster	60		0		0		0		0		0		0		0		0
		0																
	Pacific Razor Clam	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Geoduck	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Butter Clam	18	1	18	1	18	1	18	1	18	1	18	1	18	0	0	0	0
	Native Little Neck	18	1	18	1	18	1	18	1	18	1	18	1	18	0	0	0	0
	Manila Clam	15	1	15	1	15	1	15	1	15	1	15	1	15	0	0	0	0
	Horse Clam	18	1	18	1	18	1	18	1	18	1	18	1	18	0	0	0	0
	Horse Clam	60	1	60	1	60	1	60	1	60	1	60	1	60	0	0	0	0
	Eastern Soft Shell	65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cockles	24	1	24	1	24	1	24	1	24	1	24	1	24	0	0	0	0
		0																
	Pink Scallop	0	0	0	0	0		0		0		0		0		0		0
	Rock Scallop	48	0	0	0	0		0		0		0	1	48	1	48		0
	Weathervane Scallop	12	0	0	0	0		0		0		0	1	12	1	12		0
		0																
	Bay Mussel	156	0	0	0	0	0	0	0	0		0		0	0	0		0
	California Mussel	30	0	0	0	0	0	0	0	0		0		0	0	0	0	0
		0																
Cephalopods	Squid	114	0	0		0		0		0		0	1	114		0	1	114
	Octopus	8	1	8	1	8	1	8	1	8	1	8	1	8	1	8	1	8
		0																
Sea Snails	Northern Abalone	48	0	0	0	0	0	0	0	0	0	0		0	1	48	0	0
		0																
Echinoderms	Sea Cucumber	8	1	8	1	8	1	8	1	8	1	8	1	8	0	0	1	8
	Red Sea Urchin	6		0	0	0	0	0	0	0	0	0		0	1	6	0	0
	Green Sea Urchin	60	1	60	1	60	1	60	1	60	1	60	1	60	1	60	1	60
		0		0		0		0		0		0				0		0
Crustaceans		0		0		0		0		0		0		0		0		0
	Dungeness Crab	48	1	48	1	48	1	48	1	48	1	48	1	48	1	48	1	48
	Red (Rock) Crab	18		0		0		0		0		0		0		0		0
		0		0		0		0		0		0				0		0
	Spot Shrimp	10	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
	Coon Stripe Shrimp	10	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
	Side Shrimp	14	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
	Pink Shrimp	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0

11 292 10 277 10 277 10 277 11 292 13 451 7 230 5 238

Table 5

SHELLFISH AND OTHER INVERTEBRATES OF COMMERCIAL OR RECREATIONAL IMPORTANCE
SOI FOR REGIONS 7, 8, 9 and 10

file: inv7-10.ws

date: 2/20/91

SPRING

Group	Species Common Name	SOI SP	701 P/A SOI	703 P/A SOI	801 P/A SOI	802 P/A SOI	901 P/A SOI	902 P/A SOI	903 P/A SOI	100 P/A SOI	1002 P/A SOI
Bivalves											
	Pacific Oyster	15	0	0	0	0	15	0	0	0	0
	Olympia Oyster	60	0	0	0	0	0	0	0	0	0
		0									
	Pacific Razor Clam	480	0	0	0	0	0	0	0	0	0
	Geoduck	132	0	0	0	0	0	0	0	0	0
	Butter Clam	18	1	18	0	0	0	0	0	18	0
	Native Little Neck	144	1	144	0	0	0	0	0	144	0
	Manila Clam	15	1	15	0	0	0	0	0	15	0
	Horse Clam	18	1	18	0	0	0	0	0	18	0
	Horse Clam	18	1	18	0	0	0	0	0	18	0
	Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0
	Cockles	24	1	24	0	0	0	0	0	24	0
		0									
	Pink Scallop	12	0	0	0	0	12	12	12	0	0
	Rock Scallop	48	0	0	0	48	48	48	48	48	48
	Weatherlane Scallop	12	0	0	0	12	12	12	12	12	12
		0									
	Bay Mussel	30	0	0	0	0	0	0	0	0	0
	California Mussel	30	0	0	0	0	0	0	0	0	0
		0									
Cephalopods	Squid	132	0	0	132	0	0	0	0	0	0
	Octopus	24	1	24	1	24	1	24	1	24	1
		0									
Sea Snails	Northern Abalone	48	0	0	0	48	48	48	48	48	48
		0									
Echinoderms	Sea Cucumber	80	1	80	1	80	1	80	1	80	1
	Red Sea Urchin	168	1	0	0	168	1	168	1	168	1
	Green Sea Urchin	60	1	60	1	60	1	60	0	0	60
		0									
Crustaceans		0	0	0	0	0	0	0	0	0	0
	Dungeness Crab	42	1	42	1	42	0	0	1	42	1
	Red (Rock) Crab	18	0	0	0	0	0	0	0	0	0
		0									
	Spot Shrimp	220	0	0	0	0	0	220	0	0	0
	Coon Stripe Shrimp	220	0	0	0	0	0	220	0	0	0
	Side Shrimp	308	0	0	0	0	0	0	0	0	0
	Pink Shrimp	126	0	0	0	0	0	126	0	0	0
Total:			10	443	5	338	8	482	10	509	11
			1018	8	434	12	617	8	482	18	602

SUMMER

Group	Species Common Name	SOI Summer	701 P/A SOI	703 P/A SOI	801 P/A SOI	802 P/A SOI	901 P/A SOI	902 P/A SOI	903 P/A SOI	100 P/A SOI	1002 P/A SOI

Bivalves											
	Pacific Oyster	96	0	0	0	0	0	0	0	0	0
	Olympia Oyster	456	0	0	0	0	0	0	0	0	0
		0									
	Pacific Razor Clam	480	0	0	0	0	0	0	0	0	0
	Geoduck	6	0	0	0	0	0	0	0	0	0
	Butter Clam	144	1	144	0	0	0	0	0	1	144
	Native Little Neck	144	1	144	0	0	0	0	0	1	144
	Manila Clam	120	1	120	0	0	0	0	0	1	120
	Horse Clam	60	1	60	0	0	0	0	0	1	60
	Horse Clam	18	1	18	0	0	0	0	0	1	18
	Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0
	Cockles	192	1	192	0	0	0	0	0	1	192
		0									
	Pink Scallop	0	0	0	0	0	1	0	1	0	0
	Rock Scallop	48	0	0	0	0	1	48	1	48	1
	Weathervane Scallop	24	0	0	0	0	1	24	1	24	1
		0									
	Bay Mussel	30	0	0	0	0	0	0	0	0	0
	California Mussel	30	0	0	0	0	0	0	0	0	0
		0									
Cephalopods	Squid	6	0	0	1	6	0	0	0	0	0
	Octopus	8	1	8	1	8	1	8	1	8	1
		0									
Sea Snails	Northern Abalone	384	0	0	0	0	1	384	1	384	1
		0									
Echinoderms	Sea Cucumber	96	1	96	1	96	1	96	1	96	1
	Red Sea Urchin	6	0	0	0	1	6	1	6	1	6
	Green Sea Urchin	6	1	6	1	6	1	6	0	0	0
		0									
Crustaceans		0	0	0	0	0	0	0	0	0	0
	Dungeness Crab	6	1	6	1	6	1	6	0	0	1
	Red (Rock) Crab	66	0	0	0	0	0	0	0	0	0
		0									
	Spot Shrimp	220	0	0	0	0	0	0	1	220	0
	Coon Stripe Shrimp	220	0	0	0	0	0	0	1	220	0
	Side Shrimp	308	0	0	0	0	0	0	0	0	0
	Pink Shrimp	126	0	0	0	0	0	0	1	126	0
Total:			10	794	5	122	8	578	10	674	11
			8	572	12	1244	8	578	18	818	

FALL

Species	SOI	701	703	801	802	901	902	903	100	1002
Group	Common Name	Fall	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI
Bivalves										
	Pacific Oyster	15	0	0	0	0	0	0	0	0
	Olympia Oyster	60	0	0	0	0	0	0	0	0
		0								
	Pacific Razor Clam	480	0	0	0	0	0	0	0	0
	Geoduck	6	0	0	0	0	0	0	0	0
	Butter Clam	18	1	18	0	0	0	0	0	0
	Native Little Neck	18	1	18	0	0	0	0	0	0
	Manila Clam	15	1	15	0	0	0	0	0	0
	Horse Clam	18	1	18	0	0	0	0	0	0
	Horse Clam	18	1	18	0	0	0	0	0	0
	Eastern Soft Shell	156	0	0	0	0	0	0	0	0
	Cockles	24	1	24	0	0	0	0	0	0
		0								
	Pink Scallop	12	0	0	0	0	1	12	1	12
	Rock Scallop	48	0	0	0	0	1	48	1	48
	Weathervane Scallop	0	0	0	0	0	1	0	1	0
		0								
	Bay Mussel	156	0	0	0	0	0	0	0	0
	California Mussel	30	0	0	0	0	0	0	0	0
		0								
Cephalopods	Squid	6	0	0	1	6	0	0	0	0
	Octopus	8	1	8	1	8	1	8	1	8
		0								
Sea Snails	Northern Abalone	48	0	0	0	0	1	48	1	48
		0								
Echinoderms	Sea Cucumber	8	1	8	1	8	1	8	1	8
	Red Sea Urchin	6	0	0	0	1	6	1	6	1
	Green Sea Urchin	6	1	6	1	6	1	6	0	0
		0								
Crustaceans		0	0	0	0	0	0	0	0	0
	Dungeness Crab	6	1	6	1	6	1	6	0	0
	Red (Rock) Crab	66	0	0	0	0	0	0	0	0
		0								
	Spot Shrimp	10	0	0	0	0	0	0	0	0
	Coon Stripe Shrimp	10	0	0	0	0	0	0	0	0
	Side Shrimp	14	0	0	0	0	0	0	0	0
	Pink Shrimp	0	0	0	0	0	0	0	0	0
Total:			10	139	5	34	8	130	10	157

WINTER

Group	Species Common Name	SOI Winte	701 P/A SOI	703 P/A SOI	801 P/A SOI	802 P/A SOI	901 P/A SOI	902 P/A SOI	903 P/A SOI	100 P/A SOI	1002 P/A SOI
Bivalves											
	Pacific Oyster	15	0	0	0	0	0	1	15	0	0
	Olympia Oyster	60	0	0	0	0	0	0	0	0	0
		0									
	Pacific Razor Clam	30	0	0	0	0	0	0	0	0	0
	Geoduck	132	0	0	0	0	0	0	0	0	0
	Butter Clam	18	1	18	0	0	0	0	0	0	18
	Native Little Neck	18	1	18	0	0	0	0	0	0	18
	Manila Clam	15	1	15	0	0	0	0	0	0	15
	Horse Clam	18	1	18	0	0	0	0	0	0	18
	Horse Clam	60	1	60	0	0	0	0	0	0	60
	Eastern Soft Shell	65	0	0	0	0	0	0	0	0	0
	Cockles	24	1	24	0	0	0	0	0	0	24
		0									
	Pink Scallop	0	0	0	0	0	0	0	0	0	0
	Rock Scallop	48	0	0	0	0	1	48	1	48	1
	Weather-vane Scallop	12	0	0	0	0	1	12	1	12	1
		0									
	Bay Mussel	156	0	0	0	0	0	0	0	0	0
	California Mussel	30	0	0	0	0	0	0	0	0	0
		0									
Cephalopods	Squid	114	0	0	1	114	0	0	0	0	0
	Octopus	8	1	8	1	8	1	8	1	8	1
		0									
Sea Snails	Northern Abalone	48	0	0	0	0	1	48	1	48	1
		0									
Echinoderms	Sea Cucumber	8	1	8	1	8	1	8	1	8	1
	Red Sea Urchin	6	0	0	0	1	6	1	6	1	6
	Green Sea Urchin	60	1	60	1	60	1	60	1	60	1
		0									
Crustaceans		0	0	0	0	0	0	0	0	0	0
	Dungeness Crab	48	1	48	1	48	1	48	1	48	1
	Red (Rock) Crab	18	0	0	0	0	0	0	0	0	0
		0									
	Spot Shrimp	10	0	0	0	0	0	0	1	10	0
	Coon Stripe Shrimp	10	0	0	0	0	0	0	1	10	0
	Side Shrimp	14	0	0	0	0	0	0	0	0	0
	Pink Shrimp	0	0	0	0	0	0	0	0	0	0
Total:			10	277	5	238	8	238	10	253	11
			210	8	178	12	283	8	238	18	358

Table 6

SHELLFISH AND OTHER INVERTEBRATES OF COMMERCIAL OR RECREATIONAL IMPORTANCE
SOI FOR REGION II

file: inverll.ws

date: 2/20/91

SPRING

Group	Species Common Name	SOI SP	1101 P/A	SOI	1102 P/A	SOI	1103 P/A	SOI	1104 P/A	SOI	1105 P/A	SOI	1106 P/A	SOI	1107 P/A	SOI	1108 P/A	SOI

Bivalves																		
	Pacific Oyster	15	0	0	0	0	0	0	0	0	1	15	0	0	0	0	0	0
	Olympia Oyster	60		0		0		0		0		0		0		0		0
		0																
	Pacific Razor Clam	480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Geoduck	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Butter Clam	18	0	0	0	0	0	0	1	18	0	0	0	0	0	0	0	0
	Native Little Neck	144	0	0	0	0	0	0	1	144	0	0	0	0	0	0	0	0
	Manila Clam	15	0	0	0	0	0	0	1	15	0	0	0	0	0	0	0	0
	Horse Clam	18	0	0	0	0	0	0	1	18	0	0	0	0	0	0	0	0
	Horse Clam	18	0	0	0	0	0	0	1	18	0	0	0	0	0	0	0	0
	Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cockles	24	0	0	0	0	0	0	1	24	0	0	0	0	0	0	0	0
		0																
	Pink Scallop	12	1	12	1	12	1	12	1	12	1	12	1	12	1	12	1	12
	Rock Scallop	48	1	48	1	48	1	48	1	48	1	48	1	48	1	48	1	48
	Weather-vane Scallop	12	1	12	1	12	1	12	1	12	1	12	1	12	1	12	1	12
		0																
	Bay Mussel	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	California Mussel	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0																
Cephalopods:	Squid	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Octopus	24	1	24	1	24	1	24	1	24	1	24	1	24	1	24	1	24
		0																
Sea Snails	Northern Abalone	48	1	48	1	48	1	48	1	48	1	48	0	0	0	0	0	0
		0																
Echinoderms:	Sea Cucumber	80	1	80	0	0	1	80	1	80	0	0	1	80	1	80	0	0
	Red Sea Urchin	168	1	168	0	0	1	168	1	168	1	168	0	0	1	168	1	168
	Green Sea Urchin	60	1	60	0	0	1	60	0	0	0	0	0	0	0	0	1	60
		0																
Crustaceans:		0																0
	Dungeness Crab	42	0	0	0	0	0	0	1	42	0	0	1	42	0	0	1	42
	Red (Rock) Crab	18		0		0		0		0		0		0		0		0
		0																
	Spot Shrimp	220	0	0	0	0	0	0	1	220	0	0	1	220	1	220	1	220
	Coon Stripe Shrimp	220	0	0	0	0	0	0	1	220	0	0	1	220	1	220	1	220
	Side Shrimp	308	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pink Shrimp	126	0	0	0	0	0	0	1	126	0	0	1	126	1	126	1	126
			8	452	5	144	8	452	17	1237	7	327	9	784	9	910	10	932

SUMMER

Group	Species Common Name	SOI Summer	1101 P/A	SOI	1102 P/A	SOI	1103 P/A	SOI	1104 P/A	SOI	1105 P/A	SOI	1106 P/A	SOI	1107 P/A	SOI	1108 P/A	SOI
Bivalves																		
	Pacific Oyster	96	0	0	0	0	0	0	0	0	1	96	0	0	0	0	0	0
	Olympia Oyster	456	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0																
	Pacific Razor Clam	480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Geoduck	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Butter Clam	144	0	0	0	0	0	0	1	144	0	0	0	0	0	0	0	0
	Native Little Neck	144	0	0	0	0	0	0	1	144	0	0	0	0	0	0	0	0
	Manila Clam	120	0	0	0	0	0	0	1	120	0	0	0	0	0	0	0	0
	Horse Clam	60	0	0	0	0	0	0	1	60	0	0	0	0	0	0	0	0
	Horse Clam	18	0	0	0	0	0	0	1	18	0	0	0	0	0	0	0	0
	Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cockles	192	0	0	0	0	0	0	1	192	0	0	0	0	0	0	0	0
		0																
	Pink Scallop	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
	Rock Scallop	48	1	48	1	48	1	48	1	48	1	48	1	48	1	48	1	48
	Weathervane Scallop	24	1	24	1	24	1	24	1	24	1	24	1	24	1	24	1	24
		0																
	Bay Mussel	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	California Mussel	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0																
Cephalopods	Squid	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Octopus	8	1	8	1	8	1	8	1	8	1	8	1	8	1	8	1	8
		0																
Sea Snails	Northern Abalone	384	1	384	1	384	1	384	1	384	1	384	1	384	1	384	1	384
		0																
Echinoderms	Sea Cucumber	96	1	96	0	1	96	1	96	0	0	1	96	1	96	0	0	0
	Red Sea Urchin	6	1	6	0	1	6	1	6	1	6	0	1	6	1	6	1	6
	Green Sea Urchin	6	1	6	0	1	6	0	0	0	0	0	0	0	0	1	6	6
		0																
Crustaceans		0																0
	Dungeness Crab	6	0	0	0	0	0	1	6	0	0	1	6	0	0	1	6	6
	Red (Rock) Crab	66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0																
	Spot Shrimp	220	0	0	0	0	0	1	220	0	1	220	1	220	1	220	1	220
	Coon Stripe Shrimp	220	0	0	0	0	0	1	220	0	1	220	1	220	1	220	1	220
	Side Shrimp	308	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pink Shrimp	126	0	0	0	0	0	1	126	0	1	126	1	126	1	126	1	126
			8	572	5	464	8	572	17	1816	7	566	9	748	9	748	10	664

FALL

Group	Species Common Name	SOI Fall	1101 P/A	SOI P/A	1102 SOI P/A	1103 SOI P/A	1104 SOI P/A	1105 SOI P/A	1106 SOI P/A	1107 SOI P/A	1108 SOI P/A

Bivalves											
	Pacific Oyster	15	0	0	0	0	0	0	1	15	0
	Olympia Oyster	60		0		0		0		0	0
		0									
	Pacific Razor Clam	480	0	0	0	0	0	0	0	0	0
	Geoduck	6	0	0	0	0	0	0	0	0	0
	Butter Clam	18	0	0	0	0	0	1	18	0	0
	Native Little Neck	18	0	0	0	0	0	1	18	0	0
	Manila Clam	15	0	0	0	0	0	1	15	0	0
	Horse Clam	18	0	0	0	0	0	1	18	0	0
	Horse Clam	18	0	0	0	0	0	1	18	0	0
	Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0
	Cockles	24	0	0	0	0	0	1	24	0	0
		0									
	Pink Scallop	12	1	12	1	12	1	12	1	12	1
	Rock Scallop	48	1	48	1	48	1	48	1	48	1
	Weathervane Scallop	0	1	0	1	0	1	0	1	0	1
		0									
	Bay Mussel	156	0	0	0	0	0	0	0	0	0
	California Mussel	30	0	0	0	0	0	0	0	0	0
		0									
Cephalopods	Squid	6	0	0		0		0		0	0
	Octopus	8	1	8	1	8	1	8	1	8	1
		0									
Sea Snails	Northern Abalone	48	1	48	1	48	1	48	1	48	0
		0									
Echinoderms	Sea Cucumber	8	1	8		0	1	8	1	8	1
	Red Sea Urchin	6	1	6		0	1	6	1	6	1
	Green Sea Urchin	6	1	6		0	1	6	0	0	0
		0									
Crustaceans		0									0
	Dungeness Crab	6	0	0		0		0	1	6	0
	Red (Rock) Crab	66		0		0		0		0	0
		0									
	Spot Shrimp	10	0	0	0	0	0	1	10	0	1
	Coon Stripe Shrimp	10	0	0	0	0	0	1	10	0	1
	Side Shrimp	14	0	0	0	0	0	0	0	0	0
	Pink Shrimp	0	0	0	0	0	0	1	0	1	0

8 136 5 116 8 136 17 267 7 137 9 102 9 102 10 106

WINTER

Group	Species Common Name	SOI Wint	1101 P/A	SOI	1102 P/A	SOI	1103 P/A	SOI	1104 P/A	SOI	1105 P/A	SOI	1106 P/A	SOI	1107 P/A	SOI	1108 P/A	SOI

Bivalves																		
	Pacific Oyster	15	0	0	0	0	0	0	0	0	1	15		0	0	0	0	0
	Olympia Oyster	60		0		0		0		0		0		0		0		0
		0																
	Pacific Razor Clam	30	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
	Geoduck	132	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
	Butter Clam	18	0	0	0	0	0	0	1	18	0	0	0	0	0	0	0	0
	Native Little Neck	18	0	0	0	0	0	0	1	18	0	0	0	0	0	0	0	0
	Manila Clam	15	0	0	0	0	0	0	1	15	0	0	0	0	0	0	0	0
	Horse Clam	18	0	0	0	0	0	0	1	18	0	0	0	0	0	0	0	0
	Horse Clam	60	0	0	0	0	0	0	1	60	0	0	0	0	0	0	0	0
	Eastern Soft Shell	65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cockles	24	0	0	0	0	0	0	1	24	0	0	0	0	0	0	0	0
		0																
	Pink Scallop	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
	Rock Scallop	48	1	48	1	48	1	48	1	48	1	48	1	48	1	48	1	48
	Weathervane Scallop	12	1	12	1	12	1	12	1	12	1	12	1	12	1	12	1	12
		0																
	Bay Mussel	156	0	0	0	0	0	0	0	0		0		0	0	0		0
	California Mussel	30	0	0	0	0	0	0	0	0		0		0	0	0		0
		0																
Cephalopods	Squid	14	0	0		0		0		0		0		0		0		0
	Octopus	8	1	8	1	8	1	8	1	8	1	8	1	8	1	8	1	8
		0																
Sea Snails	Northern Abalone	48	1	48	1	48	1	48	1	48	1	48		0	0	0	0	0
		0																
Echinoderms	Sea Cucumber	8	1	8		0	1	8	1	8	0	0	1	8	1	8	0	0
	Red Sea Urchin	6	1	6		0	1	6	1	6	1	6		0	1	6	1	6
	Green Sea Urchin	60	1	60		0	1	60	0	0	0	0		0	0	0	1	60
		0																
Crustaceans		0																0
	Dungeness Crab	48	0	0		0		0	1	48	0	0	1	48	0	0	1	48
	Red (Rock) Crab	18		0		0		0		0		0		0		0		0
		0																
	Spot Shrimp	10	0	0	0	0	0	0	1	10		0	1	10	1	10	1	10
	Coon Stripe Shrimp	10	0	0	0	0	0	0	1	10		0	1	10	1	10	1	10
	Side Shrimp	14	0	0	0	0	0	0	0	0		0		0	0	0	0	0
	Pink Shrimp	0	0	0	0	0	0	0	1	0		0	1	0	1	0	1	0

8 190 5 116 8 190 17 351 7 137 9 144 9 102 10 202

Table 7

SHELLFISH AND OTHER INVERTEBRATES OF COMMERCIAL OR RECREATIONAL IMPORTANCE
SOI FOR REGION 12

file: inver12.ws

date: 2/20/91

SPRING

Species	SOI	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210
Common Name	SP	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI
Pacific Oyster	15	1	15	0	0	0	0	0	0	0	0
Olympia Oyster	60		0		0		0		0		0
Pacific Razor Clam	480	0	0	0	0	0	0	0	0	0	0
Geoduck	132	0	0	0	0	0	0	0	0	0	0
Butter Clam	18	0	0	0	0	0	0	0	0	0	0
Native Little Neck	144	0	0	0	0	0	0	0	0	0	0
Manila Clam	15	0	0	0	0	0	0	0	0	0	0
Horse Clam	18	0	0	0	0	0	0	0	0	0	0
Horse Clam	18	0	0	0	0	0	0	0	0	0	0
Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0	0
Cockles	24	0	0	0	0	0	0	0	0	0	0
Pink Scallop	12	1	12	1	12	1	12	1	12	1	12
Rock Scallop	48	1	48	1	48	1	48	1	48	1	48
Weathervane Scallop	12	1	12	1	12	1	12	1	12	1	12
Bay Mussel	30	0	0	0	0	0	0	0	0	0	0
California Mussel	30	0	0	0	0	0	0	0	0	0	0
Squid	132	0	0	0	0	0	0	0	0	0	0
Octopus	24	1	24	1	24	1	24	1	24	1	24
Northern Abalone	48	0	0	1	48	1	48	0	0	0	0
Sea Cucumber	80	1	80	0	0	0	0	0	0	0	0
Red Sea Urchin	168	1	168	0	0	0	0	0	0	0	0
Green Sea Urchin	60	0	0	0	0	0	0	0	0	0	0
Dungeness Crab	42	1	42	0	0	0	0	0	0	0	0
Red (Rock) Crab	18		0		0		0		0		0
Spot Shrimp	220	0	0	0	0	0	0	0	0	0	0
Coon Stripe Shrimp	220	0	0	0	0	0	0	0	0	0	0
Side Shrimp	308	0	0	0	0	0	0	0	0	0	0
Pink Shrimp	126	0	0	0	0	0	0	0	0	0	0
		8	401	5	144	5	144	5	111	15	1021
		8	401	13	899	15	1021	15	1109		

SUMMER

Species	SOI	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	
Common Name	Summer	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	
Pacific Oyster	96	1	96	0	0	0	0	0	0	1	96	0
Olympia Oyster	456		0		0		0		0		0	
Pacific Razor Clam	480	0	0	0	0	0	0	0	0	0	0	0
Geoduck	3	0	0	0	0	0	0	0	0	0	0	0
Butter Clam	144	0	0	0	0	0	0	0	0	1	144	0
Native Little Neck	144	0	0	0	0	0	0	0	0	1	144	0
Manila Clam	120	0	0	0	0	0	0	0	0	1	120	0
Horse Clam	60	0	0	0	0	0	0	0	0	1	60	0
Horse Clam	18	0	0	0	0	0	0	0	0	1	18	0
Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0	0	0
Cockles	192	0	0	0	0	0	0	0	0	1	192	0
Pink Scallop	0	1	0	1	0	1	0	1	0	1	0	1
Rock Scallop	48	1	48	1	48	1	48	1	48	1	48	1
Weathered Scallop	24	1	24	1	24	1	24	1	24	1	24	1
Bay Mussel	30	0	0	0	0	0	0	0	0	0	0	0
California Mussel	30	0	0	0	0	0	0	0	0	0	0	0
Squid	6	0	0	0	0	0	0	0	0	0	0	0
Octopus	8	1	8	1	8	1	8	1	8	1	8	1
Northern Abalone	384	0	0	1	384	1	384	1	384	0	0	0
Sea Cucumber	96	1	96	0	0	0	0	0	0	1	96	0
Red Sea Urchin	6	1	6	0	0	0	0	0	0	0	0	0
Green Sea Urchin	6	0	0	0	0	0	0	0	0	0	0	0
Dungeness Crab	6	1	6	0	0	0	0	0	0	1	6	1
Red (Rock) Crab	66	0	0	0	0	0	0	0	0	0	0	0
Spot Shrimp	220	0	0	0	0	0	0	0	0	1	220	0
Coc. Stripe Shrimp	220	0	0	0	0	0	0	0	0	1	220	0
Side Shrimp	308	0	0	0	0	0	0	0	0	0	0	0
Pink Shrimp	126	0	0	0	0	0	0	0	0	1	126	0
		8	284	5	464	5	464	5	464	5	176	15
		8	284	13	1324	15	1426	15	1426	15	1336	

FALL

Species	SOI	1201		1202		1203		1204		1205		1206		1207		1208		1209		1210	
Common Name	Fall	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI

Pacific Oyster	15	1	15	0	0	0	0	0	0	1	15	0	0	1	15	0	0	0	0	0	0
Olympia Oyster	60		0		0		0		0		0		0		0		0		0		0
-----		0																			0
Pacific Razor Clam	480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Geoduck	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Butter Clam	18	0	0	0	0	0	0	0	0	0	0	1	18	0	0	1	18	1	18	1	18
Native Little Neck	18	0	0	0	0	0	0	0	0	0	0	1	18	0	0	1	18	1	18	1	18
Manila Clam	15	0	0	0	0	0	0	0	0	0	0	1	15	0	0	1	15	1	15	1	15
Horse Clam	18	0	0	0	0	0	0	0	0	0	0	1	18	0	0	1	18	1	18	1	18
Horse Clam	18	0	0	0	0	0	0	0	0	0	0	1	18	0	0	1	18	1	18	1	18
Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cockles	24	0	0	0	0	0	0	0	0	0	0	1	24	0	0	1	24	1	24	1	24
-----		0																			0
Pink Scallop	12	1	12	1	12	1	12	1	12	1	12	1	12	1	12	1	12	1	12	1	12
Rock Scallop	48	1	48	1	48	1	48	1	48	1	48	1	48	1	48	1	48	1	48	1	48
Weathered Scallop	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
-----		0																			0
Bay Mussel	156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
California Mussel	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-----		0																			0
Squid	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Octopus	8	1	8	1	8	1	8	1	8	1	8	1	8	1	8	1	8	1	8	1	8
-----		0																			0
Northern Abalone	48	0	0	1	48	1	48	1	48	0	0	0	0	0	0	0	0	0	0	0	0
-----		0																			0
Sea Cucumber	8	1	8	0	0	0	0	0	0	0	0	1	8	1	8	0	0	1	8	0	0
Red Sea Urchin	6	1	6	0	0	0	0	0	0	0	0	0	0	1	6	0	0	0	1	6	6
Green Sea Urchin	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-----		0																			0
Dungeness Crab	6	1	6	0	0	0	0	0	0	0	0	1	6	1	6	0	0	1	6	1	6
Red (Rock) Crab	66		0		0		0		0		0		0		0		0		0		0
-----		0																			0
Spot Shrimp	10	0	0	0	0	0	0	0	0	0	0	1	10	0	0	1	10	1	10	1	10
Coon Stripe Shrimp	10	0	0	0	0	0	0	0	0	0	0	1	10	0	0	1	10	1	10	1	10
Side Shrimp	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pink Shrimp	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	1	0
		8	103	5	116	5	116	5	116	5	83	15	213	8	103	13	199	15	213	15	211

WINTER

Species	SOI	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	
Common Name	Wint	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	
Pacific Oyster	15	1	15	0	0	0	0	0	0	1	15	0
Olympia Oyster	60		0		0		0		0		0	0
Pacific Razor Clam	30	0	0	0	0	0	0	0	0	0	0	0
Geoduck	132	0	0	0	0	0	0	0	0	0	0	0
Butter Clam	18	0	0	0	0	0	0	0	0	1	18	0
Native Little Neck	18	0	0	0	0	0	0	0	0	1	18	0
Manila Clam	15	0	0	0	0	0	0	0	0	1	15	0
Horse Clam	18	0	0	0	0	0	0	0	0	1	18	0
Horse Clam	60	0	0	0	0	0	0	0	0	1	60	0
Eastern Soft Shell	65	0	0	0	0	0	0	0	0	0	0	0
Cockles	24	0	0	0	0	0	0	0	0	1	24	0
Pink Scallop	0	1	0	1	0	1	0	1	0	1	0	1
Rock Scallop	48	1	48	1	48	1	48	1	48	1	48	1
Weathered Scallop	12	1	12	1	12	1	12	1	12	1	12	1
Bay Mussel	156	0	0	0	0	0	0	0	0	0	0	0
California Mussel	30	0	0	0	0	0	0	0	0	0	0	0
Squid	114	0	0	0	0	0	0	0	0	0	0	0
Octopus	8	1	8	1	8	1	8	1	8	1	8	1
Northern Abalone	48	0	1	48	1	48	1	48	0	0	0	0
Sea Cucumber	8	1	8	0	0	0	0	0	0	1	8	1
Red Sea Urchin	6	1	6	0	0	0	0	0	0	0	0	1
Green Sea Urchin	60	0	0	0	0	0	0	0	0	0	0	0
Dungeness Crab	48	1	48	0	0	0	0	0	0	1	48	1
Red (Rock) Crab	18	0	0	0	0	0	0	0	0	0	0	0
Spot Shrimp	10	0	0	0	0	0	0	0	0	1	10	0
Coon Stripe Shrimp	10	0	0	0	0	0	0	0	0	1	10	0
Side Shrimp	14	0	0	0	0	0	0	0	0	0	0	0
Pink Shrimp	0	0	0	0	0	0	0	0	0	1	0	0
		8	145	5	116	5	116	5	116	5	83	15
		297	8	145	13	241	15	297	15	295		

Table 8

SHELLFISH AND OTHER INVERTEBRATES OF COMMERCIAL OR RECREATIONAL IMPORTANCE
SOI FOR REGION 14

file: invert14.ws P/A = Presence/Absence
 date: 2/20/91 Presence = 1
 Absence = 0

SPRING

Species Common Name	SOI SP	Subregions																	
		1401 P/A	1402 SOI P/A	1403 SOI P/A	1404 SOI P/A	1405 SOI P/A	1406 SOI P/A	1407 SOI P/A	1408 SOI P/A	1409 SOI P/A	1410 SOI P/A	1411 SOI P/A	1412 SOI P/A	1413 SOI P/A	1414 SOI P/A	1415 SOI P/A	1416 SOI P/A	1417 SOI P/A	1418 SOI P/A
Pacific Oyster	15	0	0	0	0	0	0	0	0	0	0	0	0	1	15	0	0	1	15
Olympia Oyster	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pacific Razor Clam	480	1	480	1	480	1	480	1	480	1	480	0	0	1	480	0	0	1	480
Geoduck	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Butter Clam	18	0	0	1	18	0	0	0	0	0	0	0	0	1	18	0	0	1	18
Native Little Neck	144	0	0	1	144	0	0	0	0	0	0	0	0	1	144	0	0	1	144
Manila Clam	15	0	0	1	15	0	0	0	0	0	0	0	0	1	15	0	0	1	15
Horse Clam	18	0	0	1	18	0	0	0	0	0	0	0	0	1	18	0	0	1	18
Horse Clam	18	0	0	1	18	0	0	0	0	0	0	0	0	1	18	0	0	1	18
Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0	0	0	0	1	156	0	0	0	0
Cockles	24	0	0	1	24	0	0	0	0	0	0	0	0	1	24	0	0	1	24
Pink Scallop	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Scallop	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Weathered Scallop	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bay Mussel	30	0	0	0	0	0	0	0	0	0	0	0	0	1	30	0	0	0	0
California Mussel	30	0	0	1	30	1	30	1	30	1	30	0	0	0	0	0	0	0	0
Squid	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Octopus	24	0	0	1	24	1	24	1	24	1	24	0	0	1	24	0	0	1	24
Northern Abalone	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sea Cucumber	80	0	0	1	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red Sea Urchin	168	0	0	1	168	1	168	0	0	0	0	0	0	0	0	0	0	0	0
Green Sea Urchin	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dungeness Crab	42	1	42	1	42	1	42	1	42	1	42	1	42	1	42	1	42	1	42
Red (Rock) Crab	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spot Shrimp	220	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coon Stripe Shrimp	220	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Side Shrimp	308	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pink Shrimp	126	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2	522	12	1061	5	744	4	576	4	576	10	480	3	546	8	294	4	576

SUMMER

Species	SOI	1401	1402	1403	1404	1405	1406	1407	1408	1409									
Common Name	Summer	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI
Pacific Oyster	96	0	0	0	0	0	0	0	0	0	0	1	96	0	0	1	96	0	0
Olympia Oyster	456	0		0		0		0		0		0	0	0		0		0	
Pacific Razor Clam	480	1	480	1	480	1	480	1	480	1	480	0	0	1	480	0	0	1	480
Geoduck	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Butter Clam	144	0	0	1	144	0	0	0	0	0	0	1	144	0	0	1	144	0	0
Native Little Neck	144	0	0	1	144	0	0	0	0	0	0	1	144	0	0	1	144	0	0
Manila Clam	120	0	0	1	120	0	0	0	0	0	0	1	120	0	0	1	120	0	0
Horse Clam	60	0	0	1	60	0	0	0	0	0	0	1	60	0	0	1	60	0	0
Horse Clam	18	0	0	1	18	0	0	0	0	0	0	1	18	0	0	1	18	0	0
Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0	0	1	156	0	0	0	0	0	0
Cockles	192	0	0	1	192	0	0	0	0	0	0	1	192	0	0	1	192	0	0
Pink Scallop	0		0		0		0		0		0		0		0		0		0
Rock Scallop	48		0		0		0		0		0		0		0		0		0
Weathervane Scallop	24		0		0		0		0		0		0		0		0		0
Bay Mussel	30	0	0	0	0	0	0	0	0	0	0	1	30	0	0		0	1	30
California Mussel	30	0	0	1	30	1	30	1	30	1	30	0	0	0	0	0	0	0	0
Squid	6		0		0		0		0		0		0		0		0		0
Octopus	8	0	0	1	8	1	8	1	8	1	8	0	0	1	8	0	0	1	8
Northern Abalone	384	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sea Cucumber	96	0	0	1	96	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red Sea Urchin	6	0	0	1	6	1	6	0	0	0	0	0	0	0	0	0	0	0	0
Green Sea Urchin	6		0		0		0		0		0		0		0		0		0
Dungeness Crab	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6
Red (Rock) Crab	66		0		0		0		0		0		0		0		0		0
Spot Shrimp	220	0	0		0		0		0		0		0		0		0		0
Coon Stripe Shrimp	220	0	0		0		0		0		0		0		0		0		0
Side Shrimp	308	0	0		0		0		0		0		0		0		0		0
Pink Shrimp	126		0		0		0		0		0		0		0		0		0

2 486 12 1304 5 530 4 524 4 524 10 966 3 494 8 780 4 524

FALL

Species	SOI	1401	1402	1403	1404	1405	1406	1407	1408	1409									
Common Name	Fall	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI
Pacific Oyster	15	0	0	0	0	0	0	0	0	0	0	1	15	0	0	1	15	0	0
Olympia Oyster	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pacific Razor Clam	480	1	480	1	480	1	480	1	480	1	480	0	0	1	480	0	0	1	480
Geoduck	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Butter Clam	18	0	0	1	18	0	0	0	0	0	0	1	18	0	0	1	18	0	0
Native Little Neck	18	0	0	1	18	0	0	0	0	0	0	1	18	0	0	1	18	0	0
Manila Clam	15	0	0	1	15	0	0	0	0	0	0	1	15	0	0	1	15	0	0
Horse Clam	18	0	0	1	18	0	0	0	0	0	0	1	18	0	0	1	18	0	0
Horse Clam	18	0	0	1	18	0	0	0	0	0	0	1	18	0	0	1	18	0	0
Eastern Soft Shell	156	0	0	0	0	0	0	0	0	0	0	1	156	0	0	0	0	0	0
Cockles	24	0	0	1	24	0	0	0	0	0	0	1	24	0	0	1	24	0	0
Pink Scallop	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Scallop	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Weathervane Scallop	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bay Mussel	156	0	0	0	0	0	0	0	0	0	0	1	156	0	0	0	0	1	156
California Mussel	30	0	0	1	30	1	30	1	30	1	30	0	0	0	0	0	0	0	0
Squid	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Octopus	8	0	0	1	8	1	8	1	8	1	8	0	0	1	8	0	0	1	8
Northern Abalone	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sea Cucumber	8	0	0	1	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red Sea Urchin	6	0	0	1	6	1	6	0	0	0	0	0	0	0	0	0	0	0	0
Green Sea Urchin	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dungeness Crab	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6
Red (Rock) Crab	66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spot Shrimp	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coon Stripe Shrimp	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Side Shrimp	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pink Shrimp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2	486	12	649	5	530	4	524	4	524	10	444	3	494	8	132	4	650

WINTER

Species	SOI	1401		1402		1403		1404		1405		1406		1407		1408		1409	
Common Name	Wint	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI

Pacific Oyster	15	0	0	0	0	0	0	0	0	0	0	1	15	0	0	1	15	0	0
Olympia Oyster	60		0		0		0		0		0		0		0		0		0
	0																		
Pacific Razor Clam	30	1	30	1	30	1	30	1	30	1	30	0	0	1	30	0	0	1	30
Geoduck	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Butter Clam	18	0	0	1	18	0	0	0	0	0	0	1	18	0	0	1	18	0	0
Native Little Neck	18	0	0	1	18	0	0	0	0	0	0	1	18	0	0	1	18	0	0
Manila Clam	15	0	0	1	15	0	0	0	0	0	0	1	15	0	0	1	15	0	0
Horse Clam	18	0	0	1	18	0	0	0	0	0	0	1	18	0	0	1	18	0	0
Horse Clam	60	0	0	1	60	0	0	0	0	0	0	1	60	0	0	1	60	0	0
Eastern Soft Shell	65	0	0	0	0	0	0	0	0	0	0	1	65	0	0	0	0	0	0
Cockles	24	0	0	1	24	0	0	0	0	0	0	1	24	0	0	1	24	0	0
	0																		
Pink Scallop	0		0		0		0		0		0		0		0		0		0
Rock Scallop	48		0		0		0		0		0		0		0		0		0
Weathered Scallop	12		0		0		0		0		0		0		0		0		0
	0																		
Bay Mussel	156	0	0	0	0	0	0	0	0	0	0	1	156	0	0	0	0	1	156
California Mussel	30	0	0	1	30	1	30	1	30	1	30	0	0	0	0	0	0	0	0
	0																		
Squid	114		0		0		0		0		0		0		0		0		0
Octopus	8	0	0	1	8	1	8	1	8	1	8	0	0	1	8	0	0	1	8
	0																		
Northern Abalone	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0																		
Sea Cucumber	8	0	0	1	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red Sea Urchin	6	0	0	1	6	1	6	0	0	0	0	0	0	0	0	0	0	0	0
Green Sea Urchin	60		0		0		0		0		0		0		0		0		0
	0		0		0		0		0		0		0		0		0		0
	0		0		0		0		0		0		0		0		0		0
Dungeness Crab	48	1	48	1	48	1	48	1	48	1	48	1	48	1	48	1	48	1	48
Red (Rock) Crab	18		0		0		0		0		0		0		0		0		0
	0		0		0		0		0		0		0		0		0		0
Spot Shrimp	10	0	0		0		0		0		0		0		0		0		0
Coon Stripe Shrimp	10	0	0		0		0		0		0		0		0		0		0
Side Shrimp	14	0	0		0		0		0		0		0		0		0		0
Pink Shrimp	0		0		0		0		0		0		0		0		0		0

2 78 12 283 5 122 4 116 4 116 10 437 3 86 8 216 4 242

Table 9

SHELLFISH AND OTHER INVERTEBRATES OF COMMERCIAL OR RECREATIONAL IMPORTANCE
SOI FOR REGION 15

file: inver15.ws

date: 2/20/91

SPRING

Species	SOI	1501		1502		1503		1504		1505		1506	
Common Name	SP	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI

Pacific Oyster	15	1	15	0	0	1	15	0	0	1	15	1	15
Olympia Oyster	60	0	0		0		0		0		0	1	60
	0												
Pacific Razor Clam	480	0	0	0	0	0	0	0	0	0	0	0	0
Geoduck	132	1	132	1	132	1	132	1	132	1	132	1	132
Butter Clam	18	1	18	1	18	1	18	1	18	1	18	1	18
Native Little Neck	144	1	144	1	144	1	144	1	144		144	1	144
Manila Clam	15	1	15	1	15	1	15	1	15	1	15	1	15
Horse Clam	18	1	18	1	18	1	18	1	18	1	18	1	18
Horse Clam	18	1	18	1	18	1	18	1	18	1	18	1	18
Eastern Soft Shell	156	1	156	1	156	0	0	0	0	0	0	0	0
Cockles	24	1	24	1	24	1	24	1	24	1	24	1	24
	0												
Pink Scallop	12	0	0	1	12	1	12	0	0	0	0	0	0
Rock Scallop	48	0	0	1	48	1	48	0	0	0	0	0	0
Weathervane Scallop	12	0	0	1	12	1	12	0	0	0	0	0	0
	0												
Bay Mussel	30	1	30	0	0	1	30	0	0		0	1	30
California Mussel	30	0	0	0	0	0	0	0	0		0	0	0
	0												
Squid	132	0	0	0	0		0		0		0		0
Octopus	24	1	24	1	24	1	24	1	24	1	24	1	24
	0												
Northern Abalone	48	0	0	0	0	0	0	0	0	0	0	0	0
	0												
Sea Cucumber	80	1	80	1	80	1	80	1	80	0	0	1	80
Red Sea Urchin	168	0	0	1	168	1	168	0	0	0	0	0	0
Green Sea Urchin	60	0	0	1	60	1	60	1	60	0	0	1	60
	0												
	0												0
Dungeness Crab	42	1	42	1	42	1	42	0	0	1	42	1	42
Red (Rock) Crab	18	0	0		0		0		0		0	1	18
	0												
Spot Shrimp	220	1	220	1	220	1	220	0	0	1	220	1	220
Coon Stripe Shrimp	220	1	220	1	220	0	0	0	0	1	220	0	0
Side Shrimp	308	1	308	0	0	0	0	0	0	0	0	0	0
Pink Shrimp	126	1	126	0	0	0	0	0	0	1	126	0	0

17 1590 18 1411 18 1080 10 533 13 1016 16 918

SUMMER

Species	SOI	1501		1502		1503		1504		1505		1506	
Common Name	Summer	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI

Pacific Oyster	96	1	96	0	0	1	96	0	0	1	96	1	96
Olympia Oyster	456	0	0		0		0		0		0	1	456
	0												
Pacific Razor Clam	480	0	0	0	0	0	0	0	0	0	0	0	0
Geoduck	6	1	6	1	6	1	6	1	6	1	6	1	6
Butter Clam	144	1	144	1	144	1	144	1	144	1	144	1	144
Native Little Neck	144	1	144	1	144	1	144	1	144	1	144	1	144
Manila Clam	120	1	120	1	120	1	120	1	120	1	120	1	120
Horse Clam	60	1	60	1	60	1	60	1	60	1	60	1	60
Horse Clam	18	1	18	1	18	1	18	1	18	1	18	1	18
Eastern Soft Shell	156	1	156	1	156	0	0	0	0	0	0	0	0
Cockles	192	1	192	1	192	1	192	1	192	1	192	1	192
	0												
Pink Scallop	0	0	0	1	0	1	0	0	0	0	0	0	0
Rock Scallop	48	0	0	1	48	1	48	0	0	0	0	0	0
Weathervane Scallop	24	0	0	1	24	1	24	0	0	0	0	0	0
	0												
Bay Mussel	30	1	30	0	0	1	30	0	0		0	1	30
California Mussel	30	0	0	0	0	0	0	0	0		0	0	0
	0												
Squid	6	0	0	0	0		0		0		0		0
Octopus	8	1	8	1	8	1	8	1	8	1	8	1	8
	0												
Northern Abalone	384	0	0	0	0	0	0	0	0	0	0	0	0
	0												
Sea Cucumber	96	1	96	1	96	1	96	1	96	0	0	1	96
Red Sea Urchin	6	0	0	1	6	1	6	0	0	0	0	0	0
Green Sea Urchin	6	0	0	1	6	1	6	1	6	0	0	1	6
	0												
	0												0
Dungeness Crab	6	1	6	1	6	1	6	0	0	1	6	1	6
Red (Rock) Crab	66	0	0		0		0		0		0	1	66
	0												
Spot Shrimp	220	1	220	1	220	1	220	0	0	1	220	1	220
Coon Stripe Shrimp	220	1	220	1	220	0	0	0	0	1	220	0	0
Side Shrimp	308	1	308	0	0	0	0	0	0	0	0	0	0
Pink Shrimp	126	1	126	0	0	0	0	0	0	1	126	0	0

17 1950 18 1474 18 1224 10 794 13 1360 16 1668

FALL

Species	SOI	1501		1502		1503		1504		1505		1506	
Common Name	Fall	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI
Pacific Oyster	15	1	15	0	0	1	15	0	0	1	15	1	15
Olympia Oyster	60	0	0		0		0		0		0	1	60
Pacific Razor Clam	480	0	0	0	0	0	0	0	0	0	0	0	0
Geoduck	6	1	6	1	6	1	6	1	6	1	6	1	6
Butter Clam	18	1	18	1	18	1	18	1	18	1	18	1	18
Native Little Neck	18	1	18	1	18	1	18	1	18	1	18	1	18
Manila Clam	15	1	15	1	15	1	15	1	15	1	15	1	15
Horse Clam	18	1	18	1	18	1	18	1	18	1	18	1	18
Horse Clam	18	1	18	1	18	1	18	1	18	1	18	1	18
Eastern Soft Shell	156	1	156	1	156	0	0	0	0	0	0	0	0
Cockles	24	1	24	1	24	1	24	1	24	1	24	1	24
Pink Scallop	12	0	0	1	12	1	12	0	0	0	0	0	0
Rock Scallop	48	0	0	1	48	1	48	0	0	0	0	0	0
Weathervane Scallop	0	0	0	1	0	1	0	0	0	0	0	0	0
Bay Mussel	156	1	156	0	0	1	156	0	0		0	1	156
California Mussel	30	0	0	0	0	0	0	0	0		0	0	0
Squid	6	0	0	0	0		0		0		0		0
Octopus	8	1	8	1	8	1	8	1	8	1	8	1	8
Northern Abalone	0	0	0	0	0	0	0	0	0	0	0	0	0
Sea Cucumber	8	1	8	1	8	1	8	1	8	0	0	1	8
Red Sea Urchin	6	0	0	1	6	1	6	0	0	0	0	0	0
Green Sea Urchin	6	0	0	1	6	1	6	1	6	0	0	1	6
Dungeness Crab	6	1	6	1	6	1	6	0	0	1	6	1	6
Red (Rock) Crab	66	0	0		0		0		0		0	1	66
Spot Shrimp	10	1	10	1	10	1	10	0	0	1	10	1	10
Coon Stripe Shrimp	10	1	10	1	10	0	0	0	0	1	10	0	0
Side Shrimp	14	1	14	0	0	0	0	0	0	0	0	0	0
Pink Shrimp	0	1	0	0	0	0	0	0	0	1	0	0	0

17 500 18 387 18 392 10 139 13 166 16 452

WINTER

Species	SOI	1501		1502		1503		1504		1505		1506	
Common Name	Wint	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI	P/A	SOI

Pacific Oyster	15	1	15	0	0	1	15	0	0	1	15	1	15
Olympia Oyster	60	0	0		0		0		0		0	1	60
	0												
Pacific Razor Clam	30	0	0	0	0	0	0	0	0	0	0	0	0
Geoduck	132	1	132	1	132	1	132	1	132	1	132	1	132
Butter Clam	18	1	18	1	18	1	18	1	18	1	18	1	18
Native Little Neck	18	1	18	1	18	1	18	1	18	1	18	1	18
Manila Clam	15	1	15	1	15	1	15	1	15	1	15	1	15
Horse Clam	18	1	18	1	18	1	18	1	18	1	18	1	18
Horse Clam	60	1	60	1	60	1	60	1	60	1	60	1	60
Eastern Soft Shell	65	1	65	1	65	0	0	0	0	0	0	0	0
Cockles	24	1	24	1	24	1	24	1	24	1	24	1	24
	0												
Pink Scallop	0	0	0	1	0	1	0	0	0	0	0	0	0
Rock Scallop	48	0	0	1	48	1	48	0	0	0	0	0	0
Weathered Scallop	12	0	0	1	12	1	12	0	0	0	0	0	0
	0												
Bay Mussel	156	1	156	0	0	1	156	0	0		0	1	156
California Mussel	30	0	0	0	0	0	0	0	0		0	0	0
	0												
Squid	114	0	0	0	0		0		0		0		0
Octopus	8	1	8	1	8	1	8	1	8	1	8	1	8
	0												
Northern Abalone	48	0	0	0	0	0	0	0	0	0	0	0	0
	0												
Sea Cucumber	8	1	8	1	8	1	8	1	8	0	0	1	8
Red Sea Urchin	6	0	0	1	6	1	6	0	0	0	0	0	0
Green Sea Urchin	60	0	0	1	60	1	60	1	60	0	0	1	60
	0												
	0												0
Dungeness Crab	48	1	48	1	48	1	48	0	0	1	48	1	48
Red (Rock) Crab	18	0	0		0		0		0		0	1	18
	0												
Spot Shrimp	10	1	10	1	10	1	10	0	0	1	10	1	10
Coon Stripe Shrimp	10	1	10	1	10	0	0	0	0	1	10	0	0
Side Shrimp	14	1	14	0	0	0	0	0	0	0	0	0	0
Pink Shrimp	0	1	0	0	0	0	0	0	0	1	0	0	0

17 619 18 560 18 656 10 361 13 376 16 668

Figure 1

SHELLFISH VULNERABILITY TO OIL SPILLS REGION 2

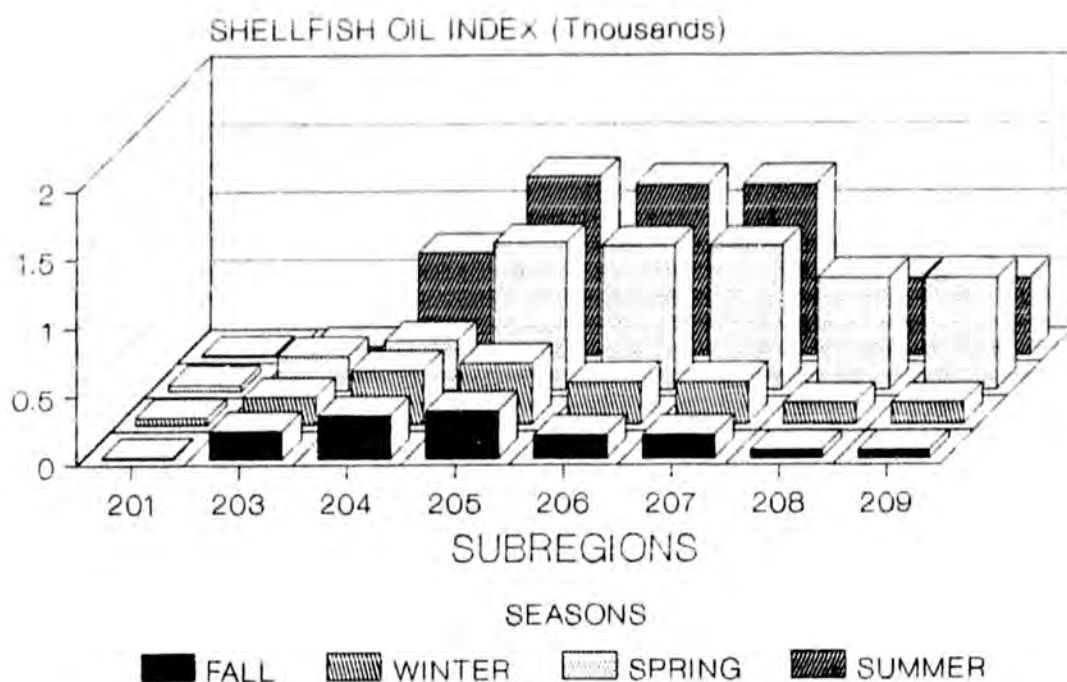


Figure 2

SHELLFISH VULNERABILITY TO OIL SPILLS REGION 3

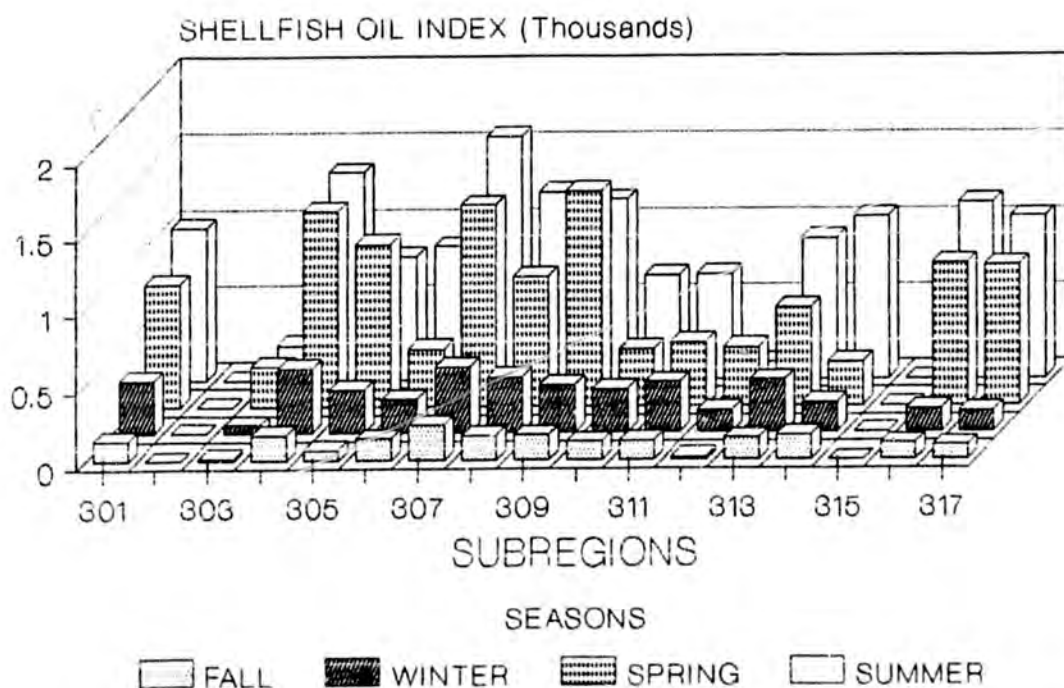


Figure 3

SHELLFISH VULNERABILITY TO OIL SPILLS REGIONS 4 AND 5

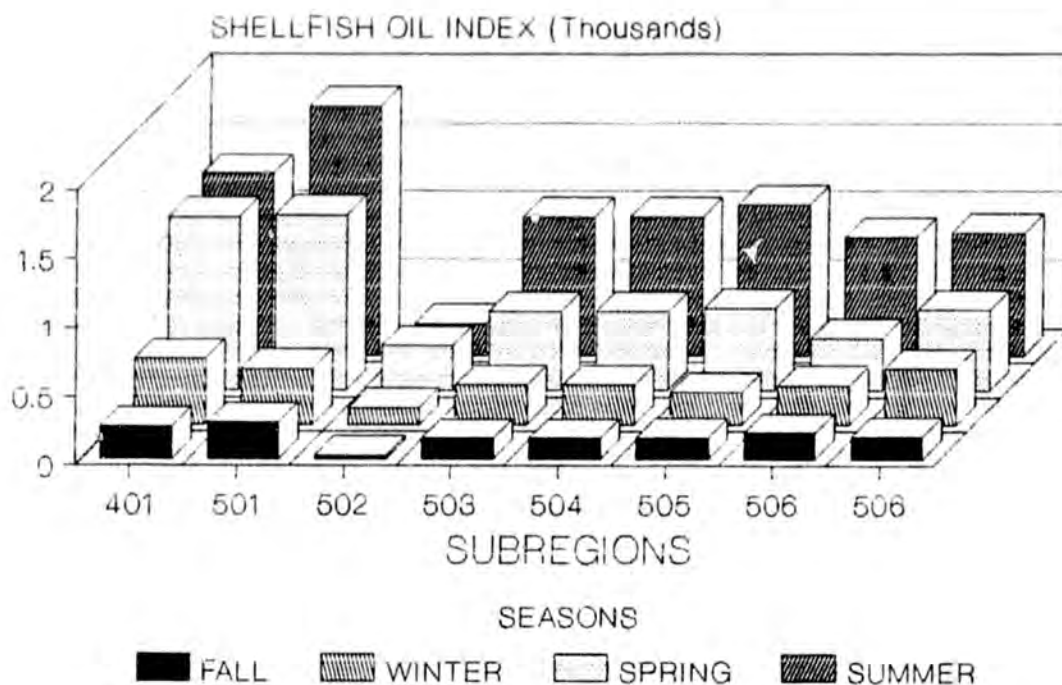


Figure 4

SHELLFISH VULNERABILITY TO OIL SPILLS REGION 6

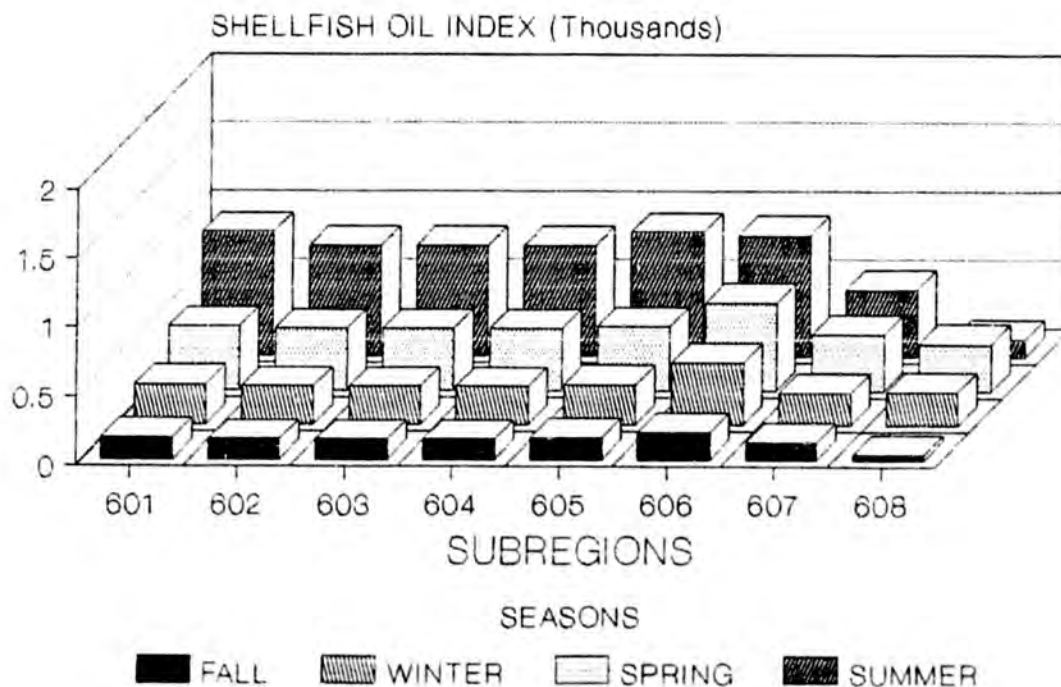


Figure 5

SHELLFISH VULNERABILITY TO OIL SPILLS REGIONS 7 THROUGH 10

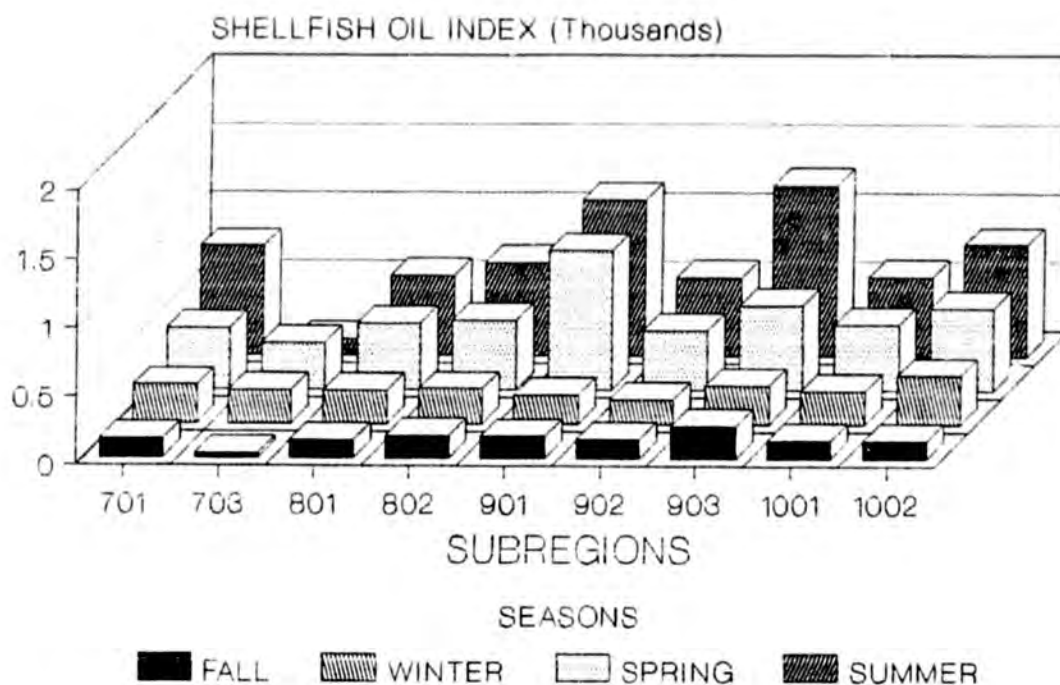


Figure 6

SHELLFISH VULNERABILITY TO OIL SPILLS REGION 11

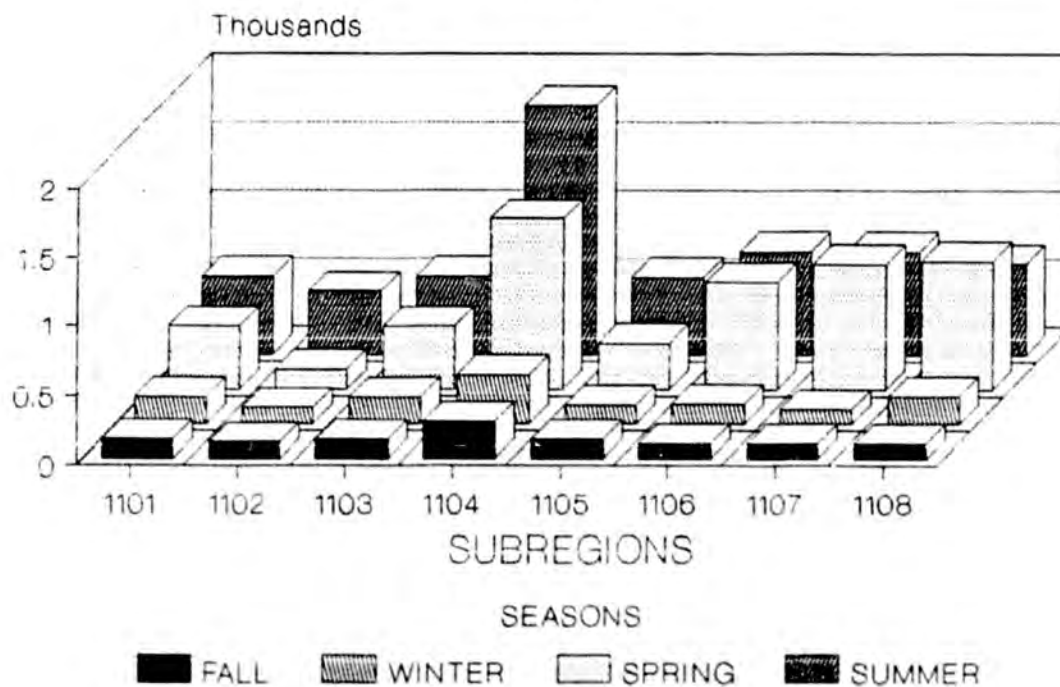


Figure 7

SHELLFISH VULNERABILITY TO OIL SPILLS REGION 12

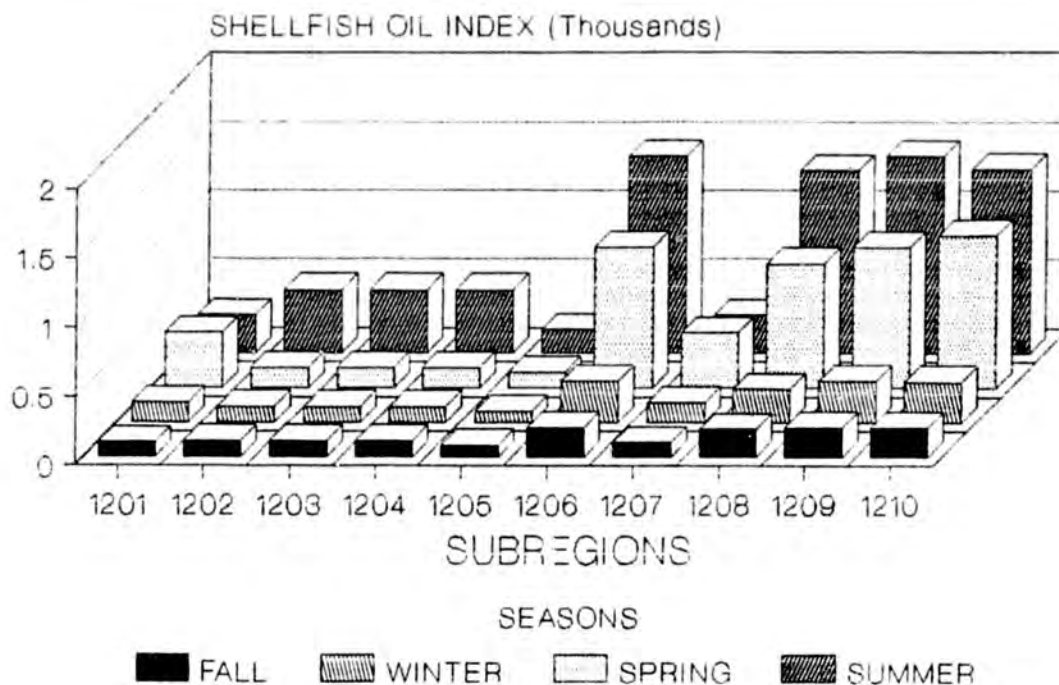


Figure 8

SHELLFISH VULNERABILITY TO OIL SPILLS REGION 14

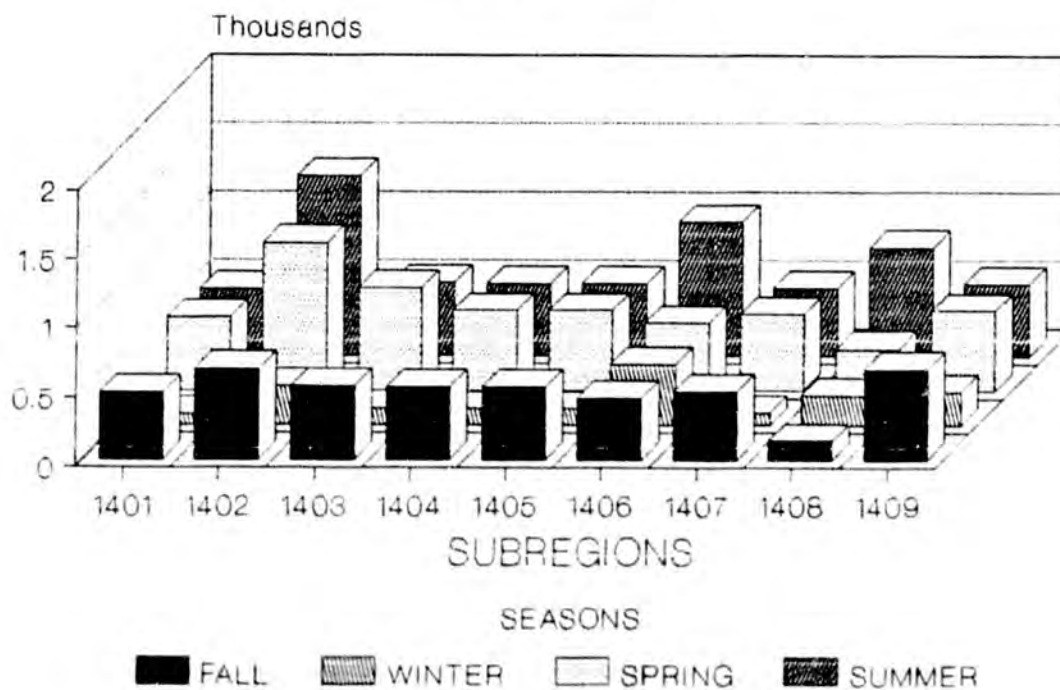
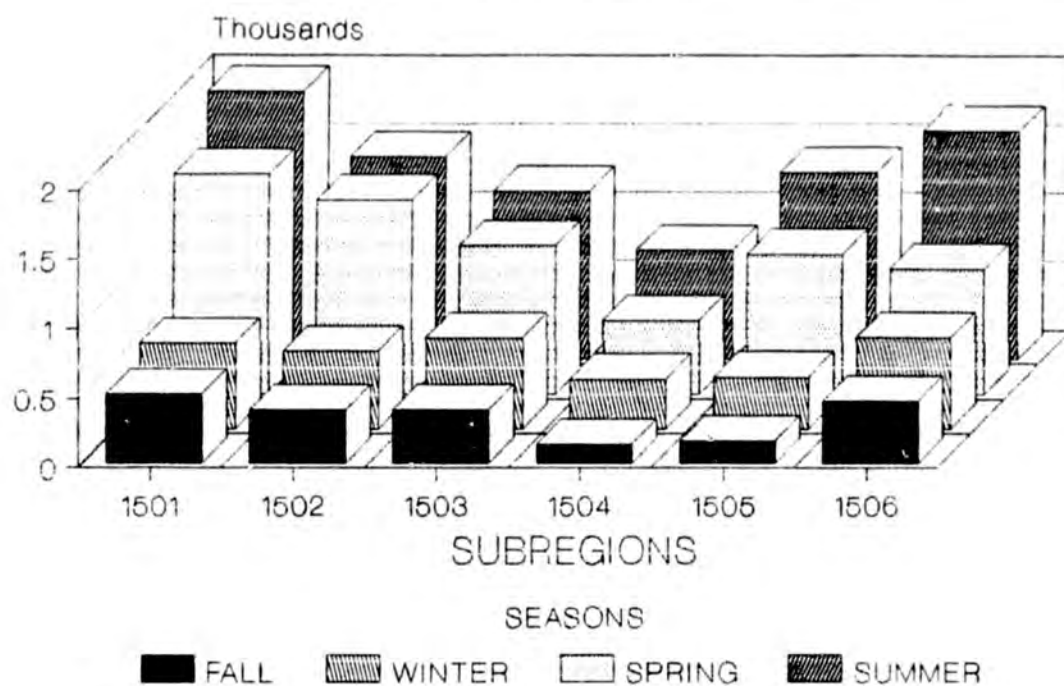


Figure 9

SHELLFISH VULNERABILITY TO OIL SPILLS REGION 15



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APPENDIX A

FACTOR AND COMPOSITE SCORING FOR EACH SPECIES

Common Name: Pacific Oyster
Scientific Name: Crassostrea gigas

Adult/Juvenile Habitat:

Reference:
Score SP: 5
SU: 5
FA: 5
WI: 5

Location of Larvae: pelagic larvae for 3-4 weeks

Reference: Cumbow, 1978
Score SP: 0
SU: 3
F: 3
W: 0

Location of Eggs: eggs float until fert.(after 10-15hrs)

Reference: Quayle, 1988
Score SP: 0
SU: 5
F: 0
W: 0

WA Population Conc.: found throughout WA marine waters

Reference: WDOF, 1989
Score: 1

Length of Spawning: July and August

Reference: Ricketts et al., 1985
Score SP: 0
SU: 3
FA: 0
WI: 0

Relative Signif.WA Pop.: Native to Japan

Reference: Rickets et al., 1985
Score: 0

Population Size in WA: several million lbs. harvested annually

Reference: WDOF, 1989
Score: 1

Reproductive Potential: up to 2 mill. per season

Reference: Cumbow, 1978
Score: 1

Age at Sexual Maturity: probably similar to native oyster

Reference:
Score: 1

COMPOSITE RANKING

Spring: 15
Summer: 96
Fall: 15
Winter: 15

Common Name: Olympia Oyster
Scientific Name: *Ostrea lurida*

Adult/Juvenile Habitat:

Reference:

Score SP: 5
SU: 5
FA: 5
WI: 5

Location of Larvae: see Pacific Oyster

Reference:

Score SP: 0
SU: 3
F: 3
W: 0

Location of Eggs: females retain eggs for about 2 wks

Reference: Cumbow, 1978

Score SP: 0
SU: 5
F: 0
W: 0

WA Population Conc.: a few areas in S. Puget Sound only

Reference: WDOF, 1989

Score: 5

Length of Spawning: June and July

Reference: Brittell et al., 1976

Score SP: 0
SU: 3
FA: 0
WI: 0

Relative Signif. WA Pop.: Alaska to California

Reference: Kozloff, 1973

Score: 1

Population Size in WA: threatened population

Reference: Brittell et al., 1976

Score: 5

Reproductive Potential: approx. 250,000 per season

Reference: Cumbow, 1978

Score: 3

Age at Sexual Maturity: six months

Reference: Ricketts et al., 1985

Score: 1

COMPOSITE RANKING

Spring: 60
Summer: 456
Fall: 60
Winter: 60

Common Name: Pacific Razor Clam
Scientific Name: *Siliqua patula*

Adult/Juvenile Habitat: intertidally to -30 feet

Reference: Cumbow, 1978

Score SP: 3

SU: 3

FA: 3

WI: 3

Location of Larvae: pelagic larvae for about 4 wks

Reference: Cumbow, 1978

Score SP: 3

SU: 3

F: 3

W: 0

Location of Eggs: egg becomes larvae in 1.5 - 10 days

Reference: Cumbow, 1978

Score SP: 5

SU: 5

F: 5

W: 0

WA Population Conc.: found on only a few beaches in WA

Reference:

Score: 5

Length of Spawning: Spring thru Fall, primarily Spring

Reference: Cumbow, 1978

Score SP: 5

SU: 5

FA: 5

WI: 0

Relative Signif. WA Pop.: Aluetins to N. California

Reference: Cumbow, 1978

Score: 1

Population Size in WA: abundant (approx. 15 million)

Reference: Ayers & Simons, 1989

Score: 1

Reproductive Potential: six to ten million

Reference: Cumbow, 1978

Score: 1

Age at Sexual Maturity: two years

Reference:

Score: 3

COMPOSITE RANKING

Spring: 480

Summer: 480

Fall: 480

Winter: 30

Common Name: Geoduck
Scientific Name: *Panope generosa*

Adult/Juvenile Habitat: intertidally to -360 feet

Reference: Goodwin and Pease, 1987

Score SP: 1

SU: 1

FA: 1

WI: 1

Location of Larvae: pelagic larvae for about 4 wks

Reference: Cumbow, 1978

Score SP: 3

SU: 3

F: 0

W: 3

Location of Eggs: egg becomes larvae in 1.5 - 10 days

Reference: Cumbow, 1978

Score SP: 3

SU: 3

F: 0

W: 3

WA Population Conc.: found in many locations

Reference:

Score: 1

Length of Spawning: Late Winter to early Summer

Reference: Goodwin and Pease, 1987

Score SP: 3

SU: 0

FA: 0

WI: 3

Relative Signif. WA Pop.: AK to Scammons Lagoon

Reference: Ricketts et al., 1985

Score: 1

Population Size in WA: two to three million lbs. harvested

Reference: Goodwin, 1973

Score: 1

Reproductive Potential:

Reference:

Score: 1

Age at Sexual Maturity:

Reference:

Score: 3

COMPOSITE RANKING

Spring: 132

Summer: 6

Fall: 6

Winter: 132

Common Name: Butter Clam
Scientific Name: *Saxidomus giganteus*

Adult/Juvenile Habitat: intertidally to -60 feet

Reference: Cumbow, 1978

Score SP: 3

SU: 3

FA: 3

WI: 3

Location of Larvae: pelagic larvae for about 4 wks

Reference: WDOF, 1978; Cumbow, 1978

Score SP: 0

SU: 3

F: 3

W: 0

Location of Eggs: egg becomes larvae in 1.5 - 10 days

Reference: Cumbow, 1978

Score SP: 0

SU: 3

F: 0

W: 0

WA Population Conc.: found in many locations

Reference:

Score: 1

Length of Spawning: Summer

Reference: Cumbow, 1978

Score SP: 0

SU: 3

FA: 0

WI: 0

Relative Signif. WA Pop.: AK to Monterey

Reference: Ricketts et al., 1985

Score: 1

Population Size in WA:

Reference: Goodwin & Shaul, 1978

Score: 1

Reproductive Potential:

Reference:

Score: 1

Age at Sexual Maturity:

Reference: see other species

Score: 3

COMPOSITE RANKING

Spring: 18

Summer: 144

Fall: 18

Winter: 18

Common Name: Native Little Neck
Scientific Name: *Protothaca staminea*

Adult/Juvenile Habitat: intertidally to -60 feet

Reference: Cumbow, 1978

Score SP: 3

SU: 3

FA: 3

WI: 3

Location of Larvae: pelagic larvae for about 4 wks

Reference: WDOF, 1978; Cumbow, 1978

Score SP: 3

SU: 3

F: 0

W: 0

Location of Eggs: egg becomes larvae in 1.5 - 10 days

Reference: Cumbow, 1978

Score SP: 3

SU: 3

F: 0

W: 0

WA Population Conc.: found in many locations

Reference:

Score: 1

Length of Spawning: Spring and early Summer

Reference: Ricketts et al., 1985; Cumbow, 1978

Score SP: 3

SU: 3

FA: 0

WI: 0

Relative Signif. WA Pop.: Aluetins to Baja

Reference: Ricketts et al., 1985

Score: 1

Population Size in WA: super abundant

Reference: Ricketts et al., 1985

Score: 1

Reproductive Potential:

Reference:

Score: 1

Age at Sexual Maturity: two years

Reference: Ricketts et al., 1985

Score: 3

COMPOSITE RANKING

Spring: 144

Summer: 144

Fall: 18

Winter: 18

Common Name: Manila Clam
Scientific Name: *Venerupis japonica*

Adult/Juvenile Habitat:

Reference:

Score SP: 3
SU: 3
FA: 3
WI: 3

Location of Larvae: pelagic larvae for about 4 wks

Reference: WDOF, 1978; Cumbow, 1978

Score SP: 0
SU: 3
F: 3
W: 0

Location of Eggs: egg becomes larvae in 1.5 - 10 days

Reference: Cumbow, 1978

Score SP: 0
SU: 3
F: 0
W: 0

WA Population Conc.: found in many locations

Reference:

Score: 1

Length of Spawning: Summer

Reference:

Score SP: 0
SU: 3
FA: 0
WI: 0

Relative Signif. WA Pop.: B.C. to So. California

Reference: Ricketts et al., 1985

Score: 0

Population Size in WA: abundant

Reference: Ricketts et al., 1985

Score: 1

Reproductive Potential:

Reference:

Score: 1

Age at Sexual Maturity:

Reference: see other species

Score: 3

COMPOSITE RANKING

Spring: 15
Summer: 120
Fall: 15
Winter: 15

Common Name: Horse Clam
Scientific Name: *Tresus nuttalli*

Adult/Juvenile Habitat: intertidally to -60 feet

Reference: Cumbow, 1978

Score SP: 3

SU: 3

FA: 3

WI: 3

Location of Larvae: pelagic larvae for about 4 wks

Reference: WDOF, 1978; Cumbow, 1978

Score SP: 0

SU: 3

F: 3

W: 0

Location of Eggs: egg becomes larvae in 1.5 - 10 days

Reference: Cumbow, 1978

Score SP: 0

SU: 3

F: 0

W: 0

WA Population Conc.: found in many locations

Reference:

Score: 1

Length of Spawning: Summer

Reference: Cumbow, 1978

Score SP: 0

SU: 1

FA: 0

WI: 0

Relative Signif. WA Pop.: B.C. to Scammons Lagoon

Reference: Ricketts et al., 1985

Score: 1

Population Size in WA:

Reference: Goodwin & Shaul, 1978

Score: 1

Reproductive Potential:

Reference:

Score: 1

Age at Sexual Maturity: two years

Reference: Ricketts et al., 1985

Score: 3

COMPOSITE RANKING

Spring: 18

Summer: 60

Fall: 18

Winter: 18

Common Name: Horse Clam
Scientific Name: Tresus capax

Adult/Juvenile Habitat: intertidally to -60 feet

Reference: Cumbow, 1978

Score SP: 3

SU: 3

FA: 3

WI: 3

Location of Larvae: pelagic larvae for about 4 wks

Reference: WDOF, 1978; Cumbow, 1978

Score SP: 3

SU: 0

F: 0

W: 3

Location of Eggs: egg becomes larvae in 1.5 - 10 days

Reference: Cumbow, 1978

Score SP: 0

SU: 0

F: 0

W: 3

WA Population Conc.: found in many locations

Reference:

Score: 1

Length of Spawning: Winter

Reference: Cumbow, 1978

Score SP: 0

SU: 0

FA: 0

WI: 1

Relative Signif. WA Pop.: AK to Central Calif.

Reference: Ricketts et al., 1985

Score: 1

Population Size in WA:

Reference: Goodwin & Shaul, 1978

Score: 1

Reproductive Potential:

Reference:

Score: 1

Age at Sexual Maturity: two years

Reference: Ricketts et al., 1985

Score: 3

COMPOSITE RANKING

Spring: 18

Summer: 18

Fall: 18

Winter: 60

Common Name: Eastern Soft Shell
Scientific Name: *Mya arenaria*

Adult/Juvenile Habitat: primarily intertidal as adults
Reference: Brousseau, 1987; Scapti, 1984
Score SP: 5
SU: 5
FA: 5
WI: 5

Location of Larvae: pelagic larvae for about 4 wks
Reference: WDOF, 1978; Cumbow, 1978
Score SP: 3
SU: 3
F: 3
W: 3

Location of Eggs: egg becomes larvae in 1.5 - 10 days
Reference: Cumbow, 1978
Score SP: 3
SU: 3
F: 3
W: 0

WA Population Conc.: a few N. Puget Sound bays only
Reference: Mills & Solomon, 1983; WDOF, 1989
Score: 5

Length of Spawning: Bimodal in Sp/Su and early Fa
Reference: Brousseau, 1987
Score SP: 1
SU: 1
FA: 1
WI: 0

Relative Signif. WA Pop.: AK to Elkhorn Slough
Reference: Ricketts et al., 1985
Score: 0

Population Size in WA: Port Susan area only
Reference: Mills & Solomon, 1983
Score: 5

Reproductive Potential:
Reference:
Score: 1

Age at Sexual Maturity:
Reference: see other species
Score: 3

COMPOSITE RANKING

Spring: 156
Summer: 156
Fall: 156
Winter: 65

Common Name: Cockles
Scientific Name: Clinocardium nuttalli

Adult/Juvenile Habitat: subtidally to -60 feet

Reference: Cumbow, 1978

Score SP: 3

SU: 3

FA: 3

WI: 3

Location of Larvae: pelagic larvae for about 4 wks

Reference: WDOF, 1978; Cumbow, 1978

Score SP: 0

SU: 3

F: 3

W: 0

Location of Eggs: egg becomes larvae in 1.5 - 10 days

Reference: Cumbow, 1978

Score SP: 0

SU: 3

F: 0

W: 0

WA Population Conc.: found in many locations

Reference:

Score: 1

Length of Spawning: Summer

Reference: Cumbow, 1978

Score SP: 0

SU: 3

FA: 0

WI: 0

Relative Signif. WA Pop.: Bering Sea to Baja

Reference: Ricketts et al., 1985

Score: 1

Population Size in WA: common

Reference: Cumbow, 1978

Score: 3

Reproductive Potential:

Reference:

Score: 1

Age at Sexual Maturity: two years

Reference: Ricketts et al., 1985

Score: 3

COMPOSITE RANKING

Spring: 24

Summer: 192

Fall: 24

Winter: 24

Common Name: Pink Scallop
Scientific Name: *Chlamys hericus* (or *rubida*?)

Adult/Juvenile Habitat: primarily found at 40 - 60 meters

Reference: Mottet, 1979

Score SP: 0

SU: 0

FA: 0

WI: 0

Location of Larvae: larvae are pelagic

Reference: Mottet, 1979; Zahradnik, 1985

Score SP: 1

SU: 0

F: 1

W: 0

Location of Eggs: eggs settle to bottom/adhere to fem

Reference: Mottet, 1979

Score SP: 0

SU: 0

F: 0

W: 0

WA Population Conc.:

Reference:

Score: 1

Length of Spawning: March and Sept.

Reference: Zahradnik, 1985

Score SP: 1

SU: 0

FA: 1

WI: 0

Relative Signif. WA Pop.: West Coast Canada & U.S.

Reference: Mottet, 1979

Score: 1

Population Size in WA: very abundant

Reference:

Score: 1

Reproductive Potential: extremely high

Reference: Mottet, 1979

Score: 1

Age at Sexual Maturity: one - two years

Reference: Mottet, 1979

Score: 3

COMPOSITE RANKING

Spring: 12

Summer: 0

Fall: 12

Winter: 0

Common Name: Rock Scallop
Scientific Name: Hinnites multirugous

Adult/Juvenile Habitat: found at 0 - 50 meters

Reference: Mottet, 1979

Score SP: 1
SU: 1
FA: 1
WI: 1

Location of Larvae: larvae are pelagic, approx. 1mo.

Reference: Mottet, 1979; Malachowski, 1988

Score SP: 1
SU: 1
F: 1
W: 1

Location of Eggs: eggs settle to bottom/adhere to fem

Reference: Mottet, 1979

Score SP: 1
SU: 1
F: 1
W: 1

WA Population Conc.:

Reference:

Score: 3

Length of Spawning: May/June & Sept. - Dec.

Reference: Malachowski, 1988

Score SP: 1
SU: 1
FA: 1
WI: 1

Relative Signif. WA Pop.: Aluetins to So. CA

Reference: Mottet, 199

Score: 1

Population Size in WA: not abundant enough for commercial

Reference: Mottet, 1979; Bourne, 1988

Score: 5

Reproductive Potential: extremely high

Reference: Mottet, 1979

Score: 1

Age at Sexual Maturity: one - two years

Reference: Mottet, 1979

Score: 3

COMPOSITE RANKING

Spring: 48
Summer: 48
Fall: 48
Winter: 48

Common Name: Weathervane Scallop
Scientific Name: Pecten caurinus

Adult/Juvenile Habitat: found at depths >10 fathoms

Reference: Cumbow, 1978

Score SP: 0

SU: 0

FA: 0

WI: 0

Location of Larvae: larvae are pelagic

Reference: Mottet, 1979

Score SP: 0

SU: 1

F: 0

W: 0

Location of Eggs: eggs settle to bottom/adhere to fem

Reference: Mottet, 1979

Score SP: 0

SU: 0

F: 0

W: 0

WA Population Conc.:

Reference:

Score: 3

Length of Spawning: mid-Jan thru June

Reference: Robinson, 1984

Score SP: 1

SU: 1

FA: 0

WI: 1

Relative Signif. WA Pop.: So. AK to San Francisco

Reference: Mottet, 1979

Score: 1

Population Size in WA: not abundant enough for commercial

Reference:

Score: 5

Reproductive Potential: extremely high

Reference: Mottet, 1979

Score: 1

Age at Sexual Maturity: one - two years

Reference: Mottet, 1979

Score: 3

COMPOSITE RANKING

Spring: 12

Summer: 24

Fall: 0

Winter: 12

Common Name: Bay Mussel
Scientific Name: *Mytilus edulis*

Adult/Juvenile Habitat:

Reference: Ricketts et al., 1985

Score SP: 5

SU: 5

FA: 5

WI: 5

Location of Larvae: pelagic larvae for about 3 wks

Reference: Bayne, 1976

Score SP: 3

SU: 0

F: 3

W: 3

Location of Eggs: pelagic eggs

Reference: Seed, 1976

Score SP: 0

SU: 0

F: 3

W: 3

WA Population Conc.: found in marine bays of WA

Reference: WDOF, 1989

Score: 1

Length of Spawning: late Fall or Winter

Reference: Ricketts et al., 1985

Score SP: 0

SU: 0

FA: 3

WI: 3

Relative Signif. WA Pop.: northern temperate regions

Reference: Ricketts et al., 1985

Score: 1

Population Size in WA: tremendous abundance

Reference: Ricketts et al., 1985

Score: 1

Reproductive Potential: high

Reference: Bayne, 1976

Score: 1

Age at Sexual Maturity: one or more years

Reference: Seed, 1976

Score: 3

COMPOSITE RANKING

Spring: 30

Summer: 30

Fall: 156

Winter: 156

Common Name: California Mussel
Scientific Name: *Mytilus californianus*

Adult/Juvenile Habitat:

Reference: Ricketts et al., 1985

Score SP: 5

SU: 5

FA: 5

WI: 5

Location of Larvae: pelagic larvae for about 3 wks

Reference: Bayne, 1976

Score SP: 3

SU: 3

F: 3

W: 3

Location of Eggs: pelagic eggs

Reference: Seed, 1976

Score SP: 3

SU: 3

F: 3

W: 3

WA Population Conc.: found outer coast and straits

Reference: WDOF, 1989

Score: 1

Length of Spawning: throughout year

Reference: Ricketts et al., 1985

Score SP: 0

SU: 0

FA: 0

WI: 0

Relative Signif. WA Pop.: AK to So. Baja

Reference: Ricketts et al., 1985

Score: 1

Population Size in WA: abundant

Reference:

Score: 1

Reproductive Potential: high

Reference: Bayne, 1976

Score: 1

Age at Sexual Maturity: one or more years

Reference: Seed, 1976

Score: 3

COMPOSITE RANKING

Spring: 30

Summer: 30

Fall: 30

Winter: 30

Common Name: Squid
Scientific Name: *Loligo opalescens*

Adult/Juvenile Habitat:

Reference: Recksiek & Frey, 1978

Score SP: 1
SU: 1
FA: 1
WI: 1

Location of Larvae: surface to bottom in WA waters

Reference: Recksiek & Frey, 1978

Score SP: 1
SU: 1
F: 0
W: 0

Location of Eggs: eggs laid in nearshore; sink to bot

Reference: Recksiek & Frey, 1978

Score SP: 1
SU: 0
F: 0
W: 1

WA Population Conc.:

Reference: Recksiek & Frey, 1978

Score: 1

Length of Spawning: winter/spring

Reference: Recksiek & Frey, 1978

Score SP: 3
SU: 0
FA: 0
WI: 3

Relative Signif. WA Pop.:

Reference: Recksiek & Frey, 1978

Score: 1

Population Size in WA:

Reference:

Score: 1

Reproductive Potential: 6,500

Reference: Recksiek & Frey, 1978

Score: 5

Age at Sexual Maturity: 14 lunar months

Reference: Spratt, 1978

Score: 3

COMPOSITE RANKING

Spring: 132

Summer: 6

Fall: 6

Winter: 114

Common Name: Octopus
Scientific Name: Octopus dofleini

Adult/Juvenile Habitat: 0 to >100ft; <50ft. in SP to mate

Reference: Mottet, 1975; Cumbow, 1978

Score SP: 3

SU: 1

FA: 1

WI: 1

Location of Larvae: larvae in water column

Reference: Mottet, 1975

Score SP: 1

SU: 1

F: 1

W: 1

Location of Eggs: eggs laid in dens mostly at depths

Reference: Mottet, 1975

Score SP: 1

SU: 1

F: 1

W: 1

WA Population Conc.: known to occur in many locations

Reference: Mottet, 1975

Score: 1

Length of Spawning: hatching occurs throughout year

Reference: Mottet, 1975

Score SP: 0

SU: 0

FA: 0

WI: 0

Relative Signif. WA Pop.:

Reference: Mottet, 1975

Score: 1

Population Size in WA:

Reference:

Score: 3

Reproductive Potential: 30,000 to 100,000

Reference: Mottet, 1975

Score: 3

Age at Sexual Maturity: 1.5 to 2 yers

Reference: Mottet, 1975

Score: 3

COMPOSITE RANKING

Spring: 24

Summer: 8

Fall: 8

Winter: 8

Common Name: Northern Abalone
Scientific Name: *Haliotis kamschatkana*

Adult/Juvenile Habitat: intertidally to 15 meters

Reference: Mottet, 1978

Score SP: 3

SU: 3

FA: 3

WI: 3

Location of Larvae: pelagic larvae, short period

Reference: Mottet, 1975

Score SP: 0

SU: 3

F: 3

W: 0

Location of Eggs: eggs in water column for short period

Reference: Mottet, 1975

Score SP: 0

SU: 3

F: 0

W: 0

WA Population Conc.: occurs in aggregations

Reference: Ricketts et al., 1985

Score: 3

Length of Spawning: June through August

Reference: Mottet, 1978

Score SP: 0

SU: 3

FA: 0

WI: 0

Relative Signif. WA Pop.: B.C., WA and OR

Reference: Mottet, 1978

Score: 3

Population Size in WA: rare; no commercial harvest

Reference: Mottet, 1978

Score: 5

Reproductive Potential: 1,000 to several million

Reference: Mottet, 1978

Score: 1

Age at Sexual Maturity: four years

Reference: Ricketts et al., 1985

Score: 5

COMPOSITE RANKING

Spring: 48

Summer: 384

Fall: 48

Winter: 48

Common Name: Sea Cucumber
Scientific Name: *Parastichopus californicus*

Adult/Juvenile Habitat: 0 to 80m.; <20m in SU to spawn
Reference: Mottet, 1976a; Cameron, 1985
Score SP: 1
SU: 3
FA: 1
WI: 1

Location of Larvae: same habitat as adult
Reference: Cameron, 1985
Score SP: 3
SU: 3
F: 1
W: 1

Location of Eggs: 4-11m MLW near where spawning occurs
Reference: Cameron, 1985
Score SP: 3
SU: 3
F: 0
W: 0

WA Population Conc.:
Reference: Mills & Solomon, 1983
Score: 1

Length of Spawning: late Su through Su
Reference: Mottet, 1976a; Cameron, 1985
Score SP: 1
SU: 1
FA: 0
WI: 0

Relative Signif. WA Pop.: B.C. to Mexico
Reference: Mottet, 1976a
Score: 1

Population Size in WA:
Reference:
Score: 1

Reproductive Potential: a guess
Reference:
Score: 3

Age at Sexual Maturity: 4+ years
Reference: Cameron, 1985
Score: 5

COMPOSITE RANKING

Spring: 80
Summer: 96
Fall: 8
Winter: 8

Common Name: Red Sea Urchin
Scientific Name: *Strongylocentrotus franciscanus*

Adult/Juvenile Habitat: typically 5-10 m.; up to 125m.

Reference: Mottet, 1976b

Score SP: 1

SU: 1

FA: 1

WI: 1

Location of Larvae: planktonic for 2 months

Reference: Mottet, 1976b

Score SP: 3

SU: 3

F: 0

W: 0

Location of Eggs: eggs have a floating stage

Reference: Mottet, 1976b

Score SP: 5

SU: 0

F: 0

W: 0

WA Population Conc.: rocky substrates with current/kelp

Reference: Mottet, 1976b

Score: 3

Length of Spawning: Spring

Reference: Mottet, 1976b; Cumbow, 1978

Score SP: 3

SU: 0

FA: 0

WI: 0

Relative Signif. WA Pop.: North Pacific; sc. to Baja in EPac.

Reference: Mottet, 1976b

Score: 1

Population Size in WA: abundant; annual harvest >1 million lbs.

Reference: Cumbow, 1978

Score: 1

Reproductive Potential: 100,000 to 2 million

Reference: Mottet, 1976b

Score: 1

Age at Sexual Maturity: four to six months

Reference: Mottet, 1976b

Score: 1

COMPOSITE RANKING

Spring: 168

Summer: 6

Fall: 6

Winter: 6

Common Name: Green Sea Urchin
Scientific Name: *Strongylocentrotus droebachiensis*

Adult/Juvenile Habitat: to 70 fathoms

Reference: Mottet, 1976b

Score SP: 1

SU: 1

FA: 1

WI: 1

Location of Larvae: Planktonic for 2-3 months

Reference: Mottet, 1976b

Score SP: 3

SU: 0

F: 0

W: 3

Location of Eggs: eggs have a floating stage

Reference: Mottet, 1976b

Score SP: 5

SU: 0

F: 0

W: 5

WA Population Conc.:

Reference:

Score: 3

Length of Spawning: Winter or Early Spring

Reference: Mottet, 1976b

Score SP: 1

SU: 0

FA: 0

WI: 1

Relative Signif. WA Pop.: Circumpolar

Reference: Mottet, 1976b

Score: 1

Population Size in WA: abundant; dominant sea urchin in Puget Sound

Reference: Mottet, 1976b

Score: 1

Reproductive Potential: 100,000 to 2 million

Reference: Mottet, 1976b

Score: 1

Age at Sexual Maturity: four to six months

Reference: Mottet, 1976b

Score: 1

COMPOSITE RANKING

Spring: 60

Summer: 6

Fall: 6

Winter: 60

Common Name: Dungeness Crab
Scientific Name: Cancer magister

Adult/Juvenile Habitat: fished at depths of <60 fathoms
Reference: Monaco and Emmett, 1988
Score SP: 1
SU: 1
FA: 1
WI: 1

Location of Larvae: larval period 4 mo., with daily mig
Reference: Monaco and Emmett, 1988; Cumbow, 1978
Score SP: 5
SU: 5
F: 0
W: 5

Location of Eggs: eggs remain on females
Reference: Monaco and Emmett, 1988
Score SP: 0
SU: 0
F: 1
W: 1

WA Population Conc.:
Reference: Monaco and Emmett, 1988
Score: 1

Length of Spawning: late Winter to Spring
Reference: Ricketts et al., 1985
Score SP: 1
SU: 0
FA: 0
WI: 1

Relative Signif. WA Pop.: AK to So. CA
Reference: Ricketts et al., 1985
Score: 1

Population Size in WA: ave. yield, 36 million pounds
Reference: Monaco and Emmett, 1988
Score: 1

Reproductive Potential: up to 2.5 million
Reference: Monaco and Emmett, 1988
Score: 1

Age at Sexual Maturity: most at 3 years
Reference: Monaco and Emmett 1988
Score: 3

COMPOSITE RANKING

Spring: 42
Summer: 6
Fall: 6
Winter: 48

Common Name: Red (Rock) Crab
Scientific Name: Cancer productus

Adult/Juvenile Habitat:

Reference: Orensanz & Gallucci, 1988
Score SP: 3
SU: 3
FA: 3
WI: 3

Location of Larvae: larvae in bay shallow waters

Reference: Orensanz & Gallucci, 1988
Score SP: 0
SU: 5
F: 5
W: 5

Location of Eggs: eggs held on females that move deep

Reference: Orensanz & Gallucci, 1988
Score SP: 0
SU: 3
F: 3
W: 0

WA Population Conc.:

Reference:
Score: 1

Length of Spawning: Su and Fall

Reference: Orensanz & Gallucci, 1988
Score SP: 0
SU: 1
FA: 1
WI: 0

Relative Signif. WA Pop.: AK to Baja

Reference: Ricketts et al., 1985
Score: 1

Population Size in WA: not abundant enough for commercial

Reference: Ricketts et al., 1985
Score: 3

Reproductive Potential:

Reference:
Score:

Age at Sexual Maturity: < 1 yr. after settlement

Reference: Orensanz & Gallucci, 1988
Score: 1

COMPOSITE RANKING

Spring: 18
Summer: 66
Fall: 66
Winter: 18

Common Name: Spot Shrimp
Scientific Name: *Pandalus platyceros*

Adult/Juvenile Habitat:

Reference: Sloan, 1987

Score SP: 1

SU: 1

FA: 1

WI: 1

Location of Larvae: in shallower waters

Reference: Sloan, 1987

Score SP: 3

SU: 3

F: 3

W: 3

Location of Eggs: eggs held on female

Reference:

Score SP: 1

SU: 1

F: 1

W: 1

WA Population Conc.: commerc. densities only in Hood C.

Reference: Bumgarner, 1983

Score: 5

Length of Spawning: assuming spawning in Sp/early Su

Reference:

Score SP: 3

SU: 3

FA: 0

WI: 0

Relative Signif. WA Pop.:

Reference:

Score: 3

Population Size in WA: 95 mt harvested in '81 and '82

Reference: Bumgarner, 1983

Score: 3

Reproductive Potential:

Reference:

Score: 3

Age at Sexual Maturity:

Reference:

Score: 3

COMPOSITE RANKING

Spring: 130

Summer: 220

Fall: 10

Winter: 10

Common Name: Coon Stripe Shrimp
Scientific Name: *Pandalus danae*

Adult/Juvenile Habitat:

Reference: Wicksten, 1984
Score SP: 1
SU: 1
FA: 1
WI: 1

Location of Larvae: in shallower waters

Reference: Sloan, 1987
Score SP: 3
SU: 3
F: 3
W: 3

Location of Eggs: eggs held on female

Reference:
Score SP: 1
SU: 1
F: 1
W: 1

WA Population Conc.:

Reference:
Score: 3

Length of Spawning: assumming spawning in Sp/early Su

Reference:
Score SP: 3
SU: 3
FA: 0
WI: 0

Relative Signif. WA Pop.:

Reference:
Score: 3

Population Size in WA:

Reference:
Score: 3

Reproductive Potential:

Reference:
Score: 3

Age at Sexual Maturity:

Reference:
Score: 3

COMPOSITE RANKING

Spring: 130
Summer: 220
Fall: 10
Winter: 10

Common Name: Side Shrimp
Scientific Name: *Pandalopsis dispar*

Adult/Juvenile Habitat:

Reference: see other local shrimp species

Score SP: 1
SU: 1
FA: 1
WI: 1

Location of Larvae: in shallower waters

Reference: Sloan, 1987

Score SP: 3
SU: 3
F: 3
W: 3

Location of Eggs: eggs held on female

Reference:

Score SP: 1
SU: 1
F: 1
W: 1

WA Population Conc.:

Reference:
Score: 3

Length of Spawning: assuming spawning in Sp/early Su

Reference:
Score SP: 3
SU: 3
FA: 0
WI: 0

Relative Signif. WA Pop.:

Reference:
Score: 3

Population Size in WA:

Reference:
Score: 3

Reproductive Potential:

Reference:
Score: 3

Age at Sexual Maturity:

Reference:
Score: 3

COMPOSITE RANKING

Spring: 182
Summer: 308
Fall: 14
Winter: 14

Common Name: Pink Shrimp
Scientific Name: *Pandalus jordani* and *P. borealis*

Adult/Juvenile Habitat:

Reference: see other local shrimp species

Score SP: 1
SU: 1
FA: 1
WI: 1

Location of Larvae: in shallower waters

Reference: Sloan, 1987

Score SP: 3
SU: 3
F: 3
W: 3

Location of Eggs: eggs held on female

Reference:

Score SP: 1
SU: 1
F: 1
W: 1

WA Population Conc.:

Reference:

Score: 3

Length of Spawning: assuming spawning in Sp/early Su

Reference:

Score SP: 3
SU: 3
FA: 0
WI: 0

Relative Signif. WA Pop.:

Reference:

Score: 3

Population Size in WA:

Reference:

Score: 3

Reproductive Potential:

Reference:

Score: 3

Age at Sexual Maturity:

Reference:

Score: 3

COMPOSITE RANKING

Spring: 72
Summer: 126
Fall: 0
Winter: 0

DRAFT FINAL REPORT

PETROLEUM TOXICITY RELATIONSHIPS
FOR THE WASHINGTON COMPENSATION SCHEDULE

by

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March 11, 1991

This Draft Report is Under Review by the Oil Toxicity Subcommittee of the Oil Spill Compensation Schedule Scientific Advisory Board. Some changes to this report will be made, but the basic approach described for ranking oils will remain unchanged.

*Supporting document
for oil toxicity ranking
part of model.*

CONTENTS

I. Origins of the Washington Compensation Schedule	1
Washington and Alaska Legislative Contexts	1
Some Connections to Federal Law	4
II. Elements of the Proposed Approach to Defining Petroleum Toxicity	5
Petroleum Products Shipped on Washington Waters	5
The Changing Nature of Prudhoe Bay Crude	10
Toxicity Relationships for the Washington Compensation Schedule: Overview	14
Categories of Injury Not Considered	17
III. Procedures for Scoring Petroleum Products	19
Formula for Relative Acute Chemical Toxicity	19
Aqueous Solubility	20
Aromatic Hydrocarbon Content	24
Acute Toxicity Scores	26
Scale for Mechanical Toxicity	32
Persistence Scale: Overview	38
Scale for Persistence	43
A Note on Combining Toxicity Scores with Other Resource Values	47
IV. Potential Injury to Marine Environments Associated with Oil Spills: A Review of the Literature	50
Acute Chemical Toxicity	50
Prudhoe Bay Crude	55
Gasoline, Kerosene and Jet Fuel	56
Distillate Fuel Oils	57
Residual Fuels	58
Mechanical Toxicity	59
Injury to Birds and Mammals	62
Injury to Intertidal Organisms	64
Persistence of Oils in the Marine Environment	65

Gasolines, Kerosenes and Jet Fuels	65
No. 2 Fuel Oils	66
Prudhoe Bay Crude	67
Residual Fuels	69
Notes	74
References	76
Appendix I	
Appendix II	

List of Figures

Figure 1	Boiling point range of fractions of crude petroleum ..	11
Figure 2	Solubilities of normal alkane, cycloalkane, and aromatic hydrocarbons in water	22
Figure 3	Frequency Distribution of API Gravity of Crude Oils ..	33
Figure 4	Schematic Representation of Spilled Oil Persistence ..	39
Figure 5	Acute toxicity of some aromatic hydrocarbons for selected marine macro-invertebrates and fish	52
Figure 6	Oil Viscosity and API Gravity for Crudes with High API Gravity or Pour Point	61
Figure 7	Refined Oil Viscosity and API Gravity	61

List of Tables

Table 1	Petroleum and Petroleum Products Accounting for the Great Majority of Shipments on Washington Waters ...	7
Table 2	Hydrocarbons dissolved in water equilibrated with oil samples	12
Table 3	Concentration of C ₁₂ -C ₂₄ n-Paraffins and Aromatic Hydrocarbons in Reference Oils and the 10% Water-Soluble Fractions (WSFs) Prepared from Them	13
Table 4	Categories of Potential Injury For Oil Spills in the Marine Environment	16
Table 5	Aqueous Solubilities for Key Constituents of Lower Molecular Weight Aromatic Hydrocarbons Found in Petroleum Products	23
Table 6	Physical characteristics and chemical properties of several crude oils	25
Table 7	Percent Weight Composition of 1-, 2-, 3- and Higher than 3-ring Aromatic Hydrocarbon Compounds in Selected Petroleum Products	27
Table 8	Relative Scores for Acute Toxicity Based on Product Type	28
Table 9	Acute Toxicity Class Assignments for Petroleum Products	31
Table 10	Representative API Gravities for Petroleum Product Classes Hauled in Washington Waters	34
Table 11	Mechanical Toxicity Class Assignments for Petroleum Products	37
Table 12	Percent-Weight Composition in Oils of Some Higher Molecular Weight Compounds Likely to Persist in the Marine Environment	42
Table 13	Scale Values for Persistence of Oils in Various Marine and Estuarine Habitat Types	46

Petroleum Toxicity Relationships
for the Washington Compensation Schedule

by

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I. Origins of the Washington Compensation Schedule

Washington and Alaska Legislative Contexts

In 1989, the Washington State Legislature created a new method for determining compensation for damages resulting from oil spills. Existing law had already provided that, in the case of any unlawful discharge of oil into waters of Washington (covered under Laws of Washington RCW 90.48.320), the responsible party is liable not only for a penalty for each incident, but must also pay compensation for any adverse environmental, recreational, aesthetic, or other effects caused by the spill (RCW 90.48.366). The new feature added in 1989 was that the amount of compensation could be determined in one of two ways: either by a detailed resource assessment or by use of a compensation schedule¹.

The purpose of the compensation schedule (now under development by the Department of Ecology) is to provide adequate compensation for "unquantifiable damages or damages not quantifiable at reasonable cost." The amount of compensation assessed is a per gallon charge of not less than one dollar and

not more than fifty dollars per gallon of oil spilled (RCW 90.48.366), to be determined by a formula based on the characteristics of the oil spilled and the sensitivity of the receiving environment (RCW 90.48.366(1)(2)). The compensation schedule is to take into account:

Characteristics of the oil spilled, such as toxicity, dispersibility, solubility, and persistence, that may affect the severity of the effects on the receiving environment, living organisms, and recreational and aesthetic resources [RCW 90.48.366(1)]

The sensitivity of the affected area as determined by such factors as: (a) the location of the spill; (b) habitat and living resource sensitivity; (c) seasonal distribution or sensitivity of living resources; (d) areas of recreational use or aesthetic importance; (e) the proximity of the spill to important habitats for birds, aquatic mammals, fish, or to species listed as threatened or endangered under state or federal law; and (f) other areas of special ecological or recreational importance, as determined by the department... [RCW 90.48.366(2)]

The model for this provision is a similar provision in a 1977 Alaska oil spill compensation law (AS 45.03.758)², and development of the Washington approach was influenced by a similar underlying philosophy. The legislative findings of the Alaskan statute assert in part that:

the exact nature and extent of oil pollution can be neither documented with certainty nor precisely quantified on a spill-by-spill basis; however, in light of the magnitude of harm which may be caused..., and the vital importance of (the natural resources) to the economic future of the state and its quality of life, ...substantial civil penalties should be imposed for the discharge of oil and to insure that the public does not bear substantial losses from oil pollution for which, because of its subtle, long-term or unquantifiable nature, compensation would not otherwise be received...[AS 45.03.758(a)]

Similarly the Washington legislature has found that:

oil spills can cause significant damage to the environment and natural resources held in trust by and for the people of

this state. Some of these damages are unquantifiable, and others cannot be quantified at a reasonable cost. Both quantifiable and unquantifiable damages often occur despite prompt containment and cleanup measures. Due to the inability to measure the exact nature and extent of certain types of damages, current damage assessment methodologies used by the state inadequately assess the damage caused by oil spills. (1989 Washington Laws, C. 388, Section 1).

The Alaska Dept. of Environmental Conservation (ADEC) was directed by its legislation to promulgate regulations establishing a schedule of civil penalties which vary in relation to the toxicity, degradability and dispersal characteristics of the oil, and the sensitivity and productivity of the receiving environment [AS 45.03.758 (b) and (d)]. ADEC ultimately developed a simple formula in which scores for an oil's relative toxicity, dispersibility and degradability are averaged and multiplied by a base charge rate (derived on a per-gallon basis and depending on the sensitivity of the receiving environment). This calculation is then multiplied by the volume of oil spilled but not recovered to determine a total charge for the spill (See Appendix I).

In applying this formula to crude oil spills ADEC adjusts the toxicity and degradability factors by an additional factor determined by the oil's specific gravity³. In applying the formula to spills of refined products the toxicity factor is adjusted by a second factor based on the oil's total content of aromatic hydrocarbons. Values for the unadjusted factors were pre-specified for relevant oil types by sorting a list of petroleum products utilized or produced in Alaska into categories of high, medium or low toxicity, degradability and dispersibility, and then assigning numerical values between 0 and

1 to each category. (See Appendix II, which is taken from Rubin [1989].)

As Rubin notes, whether or not the simple relationship among these factors utilized in the Alaska formula actually explains the relative differences in damages observed in different oil spills is an empirically testable question. No such evidence has been presented in support of the Alaska formula, however. A review of the extensive literature on oil spill fate and effects which has appeared since the Alaska law was developed (summarized below), indicates nevertheless that underlying physical and chemical properties like those identified in the Alaska approach can be associated in a general way with the propensity of oil spills to cause environmental harm.

Some Connections to Federal Law

Both the Alaska and Washington approaches have connections to ideas contained in federal law. The concept of relying on toxicity, degradability and dispersibility factors in scoring relative oil spill damage appears to come originally from the now superseded Federal Water Pollution Control Act (33 U.S.C. 1254) which stated that:

...[T]he owner or operator of any vessel, onshore facility, or offshore facility, from which there is discharged any hazardous substance determined not removable...shall be liable...to the United States for either one or the other of the following penalties...(aa) a penalty in such amount... based on the toxicity, degradability, and dispersal characteristics of the substance...[or] (bb) a penalty determined by the number of units discharged multiplied by the amount established for each such unit... [33 U.S.C. 1254 Sect. 1321(b)(2)(B)(iii)].

The idea of utilizing a unit charge approach as an alternative compensation mechanism to field-study based damage assessments continues to find support in federal law. CERCLA (The Comprehensive Environmental Response and Liability Act of 1980) specifies that:

standard procedures for simplified assessments requiring minimal field observations, including establishing measures of damages based on units of discharge or release or units of affected area [be developed, as well as]...alternative protocols for conducting assessments in individual cases to determine the type and extent of short- and long-term injury, destruction, or loss. Sec. 301(c)(2)].

More recently, NOAA, under authority granted by the 1990 Oil Pollution Act, has announced its intention to explore use of "a phalanx of [simplified natural resource damage assessment] procedures, including a schedule or table estimating damages based on certain parameters of the spill..." (Federal Register 55:53479, December 28, 1990). The Washington Compensation Schedule is a unit-of-discharge-based approach of this type. The remainder of this report is devoted to developing petroleum toxicity relationships for use in the Washington Compensation Schedule.

II. Elements of the Proposed Approach to Defining Petroleum Toxicity

Petroleum Products Shipped on Washington Waters

Production and shipping activities in the Washington petroleum industry are summarized in "Washington State Petroleum Markets Data Book," a 1989 publication of the Washington State Energy Office (WSEO).

The pattern of oil shipments on Washington waters over the past decade is such that a relatively small number of product classes capture the great majority of shipments which pose a risk of spills (See Table 1)

Table 1. Petroleum and Petroleum Products Accounting for the Great Majority of Shipments on Washington Waters
(Source: WSEO 1989; and Chadbourne and Leschine 1989)

-
- Alaskan crude (Prudhoe Bay)
 - finished motor gasoline
 - leaded and unleaded
 - distillate fuel oil
 - nos. 1, 2 and 4 fuel oils
 - nos. 1 and 2 diesel fuel oils
 - kerosene type jet fuel
 - residual fuel oil
 - no. 6 fuel oil (Bunker C)
 - "Navy Special" fuel oil (no. 5 fuel oil)
-

Eighty-five percent of all crude oil entering the state is Alaskan crude. Of the remaining 15%, two-thirds is from foreign sources, primarily Indonesia and Canada. Ninety-eight percent of all crude deliveries are by tanker. (Canadian crude generally is delivered via the Trans Mountain Pipeline.) 1988 vessel shipments of crude oil are practically fully accounted for as the sum of Alaskan shipments (141.1 million barrels) and Indonesian shipments (7.7 million barrels). The only other source of tanker shipments greater than 1 million barrels for 1988 was Australia (1.5 million barrels).

Total refinery production for the years 1981-1988 was dominated by unleaded gasoline (252 million barrels in total) followed by leaded gasoline (225 million barrels). Leaded gasoline production is falling but still significant (nearly twice as much unleaded gasoline was produced in 1988 as leaded). Distillate fuel oils (224 million barrels), residual fuel oil (160 million barrels) and kerosene-type jet fuel (144.5 million barrels) make up the vast majority of the remainder of liquid products production.

Most gasoline and distillate deliveries from Washington refineries to final markets or distribution terminals in the Northwest are via the Olympic Pipeline. But 1.6 million barrels of gasoline and 1.2 million barrels of distillates were delivered to regional destinations via tanker or barge in 1987. There are also minor foreign imports of these products to the Portland area, utilizing the Columbia River, and refined products are delivered via the Columbia as far as Pasco, in Eastern

Washington. The bulk of residual fuels can be assumed to leave refineries by tanker or barge. Also, fuels in all categories are exported to foreign countries by vessel. Of the 9.3 million barrels of refinery products exported in 1988, 3 million barrels were distillate fuels (principally to Japan), 2.2 million barrels were residual fuels (principally to Canada), 1.6 million barrels were jet fuels (divided between Japan and Canada), and 700,000 barrels were gasolines (also shipped to Japan and Canada). For the purpose of deriving oil spill scoring formulas it appears feasible to work with the following classes:

- Crude oil (Prudhoe Bay crude)

and four classes of refined products derived largely from Prudoe Bay/Alaska North Slope Crude:

- Gasoline (including both leaded and unleaded)
- Kerosene and jet fuel (including non-kerosene type jet fuels, and including no. 1 fuel oil)
- No. 2 fuel oil (including diesel)
- Residual fuel oil (including no. 5 fuel oil, Bunker C, gas oils)

Data in WSEO's Data Book indicate that in recent years the combined volumes of Prudhoe Bay crude oil (PBC), leaded and unleaded gasolines, kerosene-type jet fuel, distillate fuel oil and residual fuel oil has comprised some 90% of the crude oil and refined petroleum products shipped around Washington coastal waters. We propose to consider only these products in developing the compensation schedule. We also propose to treat leaded and

unleaded gasolines together as one product. In 1988 unleaded gas amounted to 2/3 of the total gasoline produced, and the percentage of leaded gasolines will continue to drop in future years. Furthermore, we know of no fundamental difference which would require treating them as two categories in this initial stage. As can be seen from the distillation diagram provided in Figure 1, these product classes cover well the full range of products derivable from crude oil through the refining process.

The Changing Nature of "Prudhoe Bay Crude". A series of chemical characterizations of Prudhoe Bay crude oil were completed during the mid 1970s when it became clear it would soon be tankered in large quantities into the lower 48 states. Analyses were made on a PBC sample supplied by the American Petroleum Institute (API), representing a 'typical' sample from the original production field. These analyses showed the PBC to be an intermediate gravity, high sulfur, high nitrogen oil that contains a relatively high percentage of aromatic hydrocarbons. Table 1 of McAuliffe (1987) [reproduced here as Table 2] shows that the concentrations of various aromatics in sea water equilibrated with PBC are greater than aromatic concentrations in waters equilibrated with several other crudes. Anderson et al. (1987) give concentrations of several aromatics in PBC and sea water soluble fractions of the PBC (Table 3). Earlier characterizations of the PBC are given by Clark and Brown (1977).

Predictions of a 1983 Oil & Gas Journal article were that by 1985 about 15% of the north Alaskan oil tankered south would

FRACTIONAL DISTILLATION DISTRIBUTION

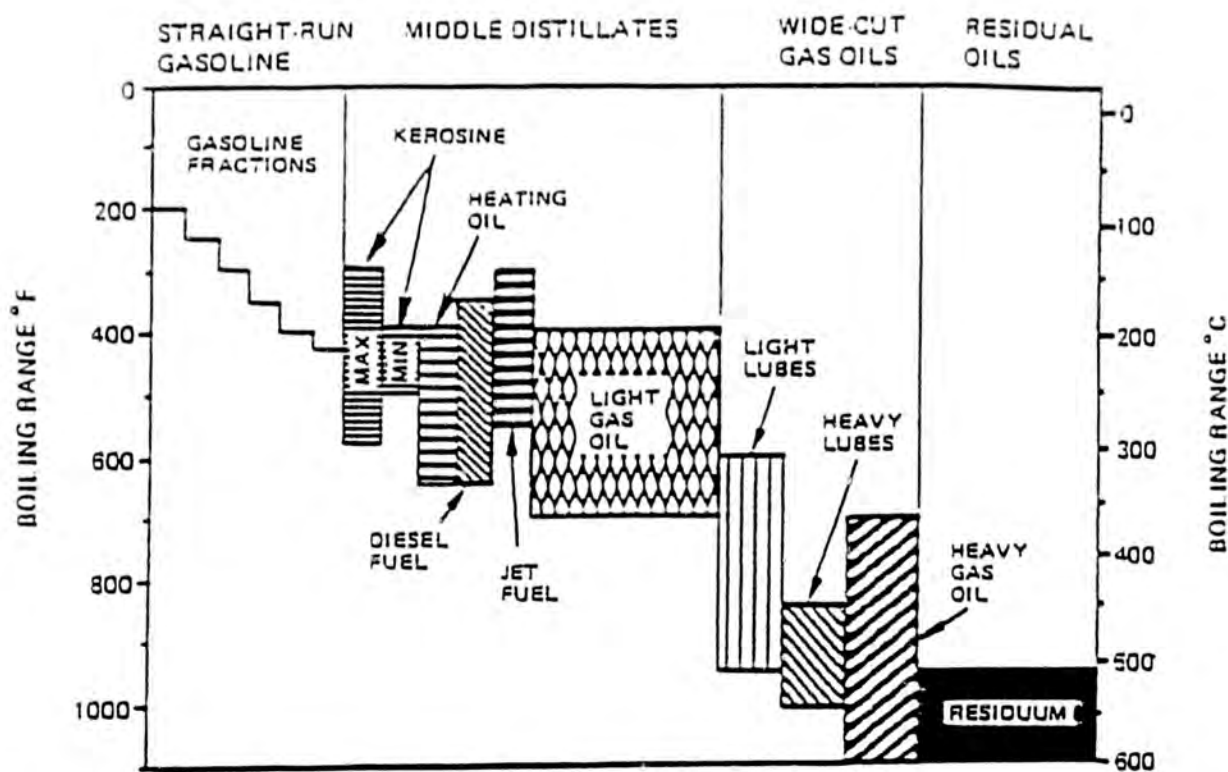


FIGURE 1 Boiling point range of fractions of crude petroleum.

NOTE: Bunker oil (not shown) is an oil of high viscosity used as a fuel oil. A given bunker oil may be a mixture of two or more of the distillate cuts shown in the figure or it may be a residual oil from a distillation run.

SOURCE: Adapted from Bureau of Naval Personnel by R.C. Clark and Brown (1977).

Table 2. Hydrocarbons dissolved in water equilibrated with oil samples
(concentrations in mg/L)

Crude oil Water salinity Produced source Hydrocarbons	Murcan Sea (McAuliffe ¹)	La Rosa Sea	South Louisiana 2% NaCl (Anderson et al. ¹)	Kuwait 2% NaCl	Cook Inlet Sea (Rice et al. ¹)	Prushoe Bay Sea
Methane	—	.26	—	—	.31	—
Ethane	.22	2.01	.34	.21	3.63	.01
Propane	2.15	3.65	3.01	3.30	10.70	.79
Isobutane	.30	.76	1.29	.90	1.90	.33
n-Butane	2.38	1.38	2.26	3.66	5.02	1.50
Isopentane	1.03	.60	.70	.98	1.02	.40
n-Pentane	1.34	.60	.49	1.31	1.11	.56
Hexanes + cyclopentane	.35	.50	.33	.59	.96	.50
n-Hexane	.50	.15	.09	.39	.21	.13
Methylocyclopentane	.35	.11	.21	.19	.63	.22
Benzene	6.08	3.30	6.75	3.26	3.10	9.30
Cyclohexane	.41	.19	—	—	.30	.24
n-Heptane	.33	.10	.06	.09	.16	.11
Methylocyclohexane	.21	.16	.11	.08	.42	.21
Toluene	6.16	2.80	4.13	3.62	4.10	6.58
Ethylbenzene	.82	.11	—	—	.15	.49
m-, p-Xylene	1.94	.34	1.56	1.58	1.06	1.58
o-Xylene	1.01	.15	.40	.67	.45	.52
Trimethylbenzenes	.75	.30	.76	.73	.29	.34
C ₇ -C ₈ Alkanes	8.43	9.48	8.79	10.38	24.19	3.59
C ₉ + C ₁₀ Saturates	2.67	1.57	.98	1.24	3.13	1.51
Total Saturates	11.10	11.11	9.77	11.62	27.37	5.10
Benzene + Toluene	12.74	6.10	10.88	6.98	12.20	15.88
Dimethylbenzenes (C ₈)	3.77	1.46	1.96	2.25	1.36	2.59
Trimethylbenzenes (C ₉)	.75	.30	.76	.73	.29	.34
Naftalenenes (Table 2)	—	—	.20	.07	—	—
Biphenyls, Fluorenes, and Phenanthrenes (Table 2)	—	—	.01	.01	—	—
Total Aromatics	16.76	7.86	13.60	9.96	14.25	18.31
Total Hydrocarbons	27.87	19.97	23.37	21.57	41.62	23.90
Benzene/hexane	12	22	75	12	39	72
Toluene/heptane	19	28	69	40	26	60
Benzene + toluene Total aromatics × 100	73	78	80	70	35	84
Benzene + toluene Total C ₇ + hydrocarbons × 100	64	66	75	62	70	78
Total aromatics Total hydrocarbons × 100	60	39	53	46	34	79

1. All analyses performed at Chevron Oil Field Research Company
2. Included with benzene
3. Included with m-, p-xylene
4. Saturated (alkane plus cycloalkanes)

SOURCE: McAuliffe (1987)

Table 3. Concentrations of C₁₂-C₂₄ n-Paraffins and Aromatic Hydrocarbons in Reference Oils and the 10% Water-Soluble fractions (WSFs) Prepared From Them

Name of Compound	S. Louisiana		Kuwait		No. 2 Fuel Oil		Bunker C		Fudhoe Bay	
	Whole Oil (%)	WSF (ppb)	Whole Oil (%)	WSF (ppb)	Whole Oil (%)	WSF (ppb)	Whole Oil (%)	WSF (ppb)	Whole Oil (%)	WSF ^a (ppb)
n-paraffins										^b
C ₁₄	0.44	10	0.46	<0.5	0.02	5.0	0.11	0.0	0.36	
C ₁₅	0.48	10	0.41	<0.5	1.06	7.0	0.11	0.9	0.37	
C ₁₆	0.54	12	0.43	0.6	1.20	8.0	0.15	1.2	0.36	
C ₁₇	0.41	9	0.42	0.8	0.98	6.0	0.12	1.9	0.34	
C ₁₈	0.30	7	0.28	0.5	0.60	4.0	0.10	1.0	0.30	
Total C ₁₂ -C ₂₄ n-paraffins	3.90	89	4.00	2.9	7.38	47	1.26	12	4.40	2.93
Aromatics										
Benzene	^c	6,750	^c	3,360	^c	550	^c	40	^c	36.1
Toluene		4,130		3,620		1,040		80	0.93	55.5
Alkylbenzenes ^d		760		730		970		110	3.19	53.8
Naphthalene	0.04	120	0.04	20	0.40	840	0.10	210	0.16	1.6
1-methylnaphthalene	0.08	60	0.05	20	0.82	340	0.28	190	0.21	2.4
2-methylnaphthalene	0.09	50	0.07	8	1.89	400	0.47	200	0.25	
Dimethylnaphthalenes ^d	0.36	60	0.20	20	3.11	240	1.23	200	0.80	1.4
Trimethylnaphthalenes ^d	0.27	8	0.19	3	1.84	30	0.80	100	0.40	0.6
Diphenyls ^d	<0.01	2	<0.01	1	0.16	20	<0.01	1	^c	^c
Fluorenes ^d	0.02	3	<0.01	3	0.36	20	0.24	11	^c	^c
Phenanthrenes ^d	0.06	4	0.04	3	0.53	20	1.11	23	0.39	0.3
Dibenzothiophenes ^d	0.02	1	0.01	1	0.07	4	<0.01	1	0.13 ^d	^c
Total aromatics	0.94	11,948	0.60	7,789	9.18	4,562	4.31	1,166	6.54	151.7
Total hydrocarbons measured	4.92	12,037	4.60	7,792	16.56	4,609	5.57	1,178	10.94	154.6
Total hydrocarbons present (IR analysis)		19,800		10,400		8,700		6,300		141

NOTE: Hydrocarbon concentrations in the oils are given as percent (g/100 ml.) and in the WSFs as parts per billion (µg/l.) in 20 o/oo seawater.

^a30 o/oo seawater in a flowing system.

^bIndividual n-paraffin concentrations were very low.

^cNot measured.

^dTotal of several isomers.

SOURCE: J.W. Anderson et al. (1974), R.D. Anderson (1975), and Dean et al. (1980).

consist of other than the oil from the original Sadlerochit formation:

Alaska North Slope production has recently been running at the rate of 1/6 million b/d. Almost all of this is vintage North Slope crude from the original discovery formation, the Sadlerochit. However, Kuparuk, a new crude stream of different quality, is blended with the North Slope at a rate of some 120,000 b/d at Trans Alaska Pipeline's pump station No. 1 in the Alaskan Arctic. At this rate Kuparuk hardly has a discernible effect on the North Slope stream from the refinery perspective, according to some operators. But the contribution of Kuparuk is scheduled to double by early 1985. ... Farther down the road another possible contributor to the North Slope stream is crude oil from the West Sak River sand, also in the Prudhoe Bay/Kuparuk area (Aalund 1983, p. 71).

This blending of oils from other formations may result in some modest changes in chemical composition, so we suggest using the term "Alaskan North Slope Crude" (ANSC) to distinguish current crude composition from that of the original pure Prudhoe Bay crude. Legal obstacles have tied up all data on composition of oil aboard the Exxon Valdez, and we know of no recent analyses. Although some more current chemical analyses of the actual 'typical' ANSC being delivered during the 1990s are desirable and should be encouraged, they are not mandatory before establishing an initial compensation schedule for unquantifiable damages.

Toxicity Relationships for the Washington Compensation Schedule: Overview

Leschine and Rubin (1989) outlined a general approach for scoring the relative propensity of an oil spill to cause environmental harm. The suggested approach was based on consideration of environmental sensitivity, oil toxicity,

resource values, and "the state of nature" at the time the spill occurred. To make such an approach consistent with the findings of oil spill fate and effects research, they suggested that several distinct categories of potential harm should be considered separately. Then the relative severity of effects in each category can be estimated, and the results combined to give a qualitative estimate of the spill's overall impact on the environment. This is the approach we develop in this report. A review of the literature on laboratory and field studies of marine oil spills suggests that as many as seven different types of adverse environmental effects could be considered (Table 4).

Table 4. Categories of Potential Injury for Oil Spills in the Marine Environment (adapted from Leschine and Rubin 1989)

Potential biological harms:

- mechanical toxicity (smothering, coating of wildlife)
- acute chemical toxicity
- persistence (proxy for chronic toxicity)
- tainting of marine food organisms
- bioaccumulation and biomagnification
- chemoreception interference

Potential non-living resource harm:

- fouling (shorelines, fixed structures, boat hulls, etc.)
-

The Washington Compensation Schedule (as proposed below) deals explicitly with three of the oil spill-related phenomena listed in Table 4: acute chemical toxicity, mechanical toxicity and persistence.

In modeling the relative importance of each of these three effects we have tried to identify, where feasible, those underlying physical and chemical characteristics which, other things being equal, appear to account best for differences among petroleum products in their relative propensities to cause each type of harm. These characteristics are treated in a way which allows us to locate specific petroleum product types of importance to commerce in Washington on a series of numerical scales, corresponding to each type of harm. When adjusted on the basis of habitat-related considerations and combined with environmental sensitivity measures, these scale values allow us to score, on a unit-of-discharge basis, particular spills with respect to the (unquantifiable) environmental harm they are likely to cause, as directed by RCW 90.48.366. The details are developed in subsequent sections of this document.

Categories of Injury not Considered

Because the mechanisms of shoreline fouling and mechanical toxicity appear to be similar, and because the potential for fouling also appears to be related to persistence, we do not develop any specific chemical or physical properties of petroleum products specific to their fouling potential. But relative habitat vulnerabilities are used to distinguish between

mechanical toxicity occurring on the sea surface and that which could occur along shorelines or in subtidal areas.

Other factors not treated explicitly are bioaccumulation and biomagnification, chemoreception interference and the tainting of marine food organisms. Scientists in recent years have grown more aware of the importance of chemical signals used by some marine organisms to locate food and/or mates, and to avoid predators (the phenomenon called 'chemoreception'). Concern has been raised that oil spills might interfere with salmon's ability to use these subtle chemical signals to return to their spawning streams. A series of studies on chinook salmon homing in fresh water and coho salmon homing in marine waters have been carried out, to determine whether or not short-term exposure to crude oil has any deleterious effect on homing success. The studies are summarized by McAuliffe (1987). The adult salmon showed a tendency to avoid the oil, and scientists noted no significant differences in percent return or return times between controls, oil, dispersed oil, or dispersant-treated groups of fish after forced exposure for short times at relatively high oil concentrations.

The tainting of marine food organisms following an oil spill is expected to be closely monitored by food and health agencies. Any losses of food resources due to tainting can be included in quantifiable damages, and so will not be considered in developing this compensation schedule for unquantifiable damages. In a similar vein, many higher trophic level marine organisms have shown the ability to biodegrade hydrocarbons rather rapidly (NAS,

1985), thus limiting possible biomagnification of the hydrocarbons. Lower trophic level organisms with little if any ability to degrade hydrocarbons, such as shellfish, may evidence biomagnification of concentrations. In such cases, noticeable tainting seems likely, and loss of the resource would then be included under quantifiable damages.

III. Procedures for Scoring Petroleum Products

In this section we present the numerical relationships we have developed to score the propensity of oils to cause acute or mechanical toxic effects, or to persist in the environment when spilled into marine waters.

Formula for Relative Acute Chemical Toxicity

The literature review we conducted (summarized in Sec. IV below) suggests that relative differences in the acute chemical toxicity of different crude oils and petroleum products are best explained by 1) differences in their contents of 1-, 2- and 3-ring aromatic hydrocarbon compounds; 2) apparent differences in the absolute toxicities of these classes of compounds; and 3) differences in the solubilities in seawater among these compounds. Since the empirical studies cited rely on direct exposure of test organisms to water soluble fractions (WSFs) of the oils, it appears reasonable to assume as a first approximation that the absolute toxicities of 1-, 2- and 3-ring aromatic fractions are the same, and that relative differences in observed toxicities of the parent oils are explained by relative differences in their aromatic contents and in the aqueous

solubilities of these aromatic compounds. These assumptions lead directly to the computation of relative scores for acute toxicity for the parent PBC and for each of the four petroleum product classes identified earlier.

The approach we take involves calculating the weighted average of the portions of whole oil composed of 1-, 2- and 3-ring aromatic compounds (percent-weight), with weighting defined by aqueous solubility. That is, letting

SOL_i = solubility in seawater of i-ring aromatic hydrocarbons,

and

$PCT-WT_i$ = percent-weight of i-ring aromatic hydrocarbons in crude oil or refined product, $i = 1, 2, 3$,

then

$$(1) \text{ Relative Acute Toxicity} = SOL_1 \cdot PCT-WT_1 + SOL_2 \cdot PCT-WT_2 + SOL_3 \cdot PCT-WT_3.$$

The rationale for this approach is captured in a general way in the National Academy's 1985 report:

The simplest aromatic compounds are...among the most toxic compounds of crude and refined oil, and as they are also the most soluble, their impact on the marine environment is greater than simple mass balance considerations would imply (NAS 1985, p. 278).

Following the findings of the numerous laboratory studies reviewed, solubility in seawater appears to be the most appropriate factor to apply in modifying the mass-balance relationship among aromatic compounds, given the objective of reflecting relative differences in observed acute toxicity.

Aqueous Solubility. The relationship between aqueous solubility and number of carbon atoms in hydrocarbon compounds is

well-illustrated in Fig. 2, from McAuliffe (1987). In general, the solubilities of individual compounds will vary with temperature, salinity and organic matter content of the waters in which they are dissolved. Mackay et al. (1983) note furthermore that seawater solubility will generally be 70-80% of freshwater solubility. The values for the solubility of particular aromatic hydrocarbons which we apply in calculations based on formula (1) [see Table 5] are those of McAuliffe (1987; see Fig. 2).

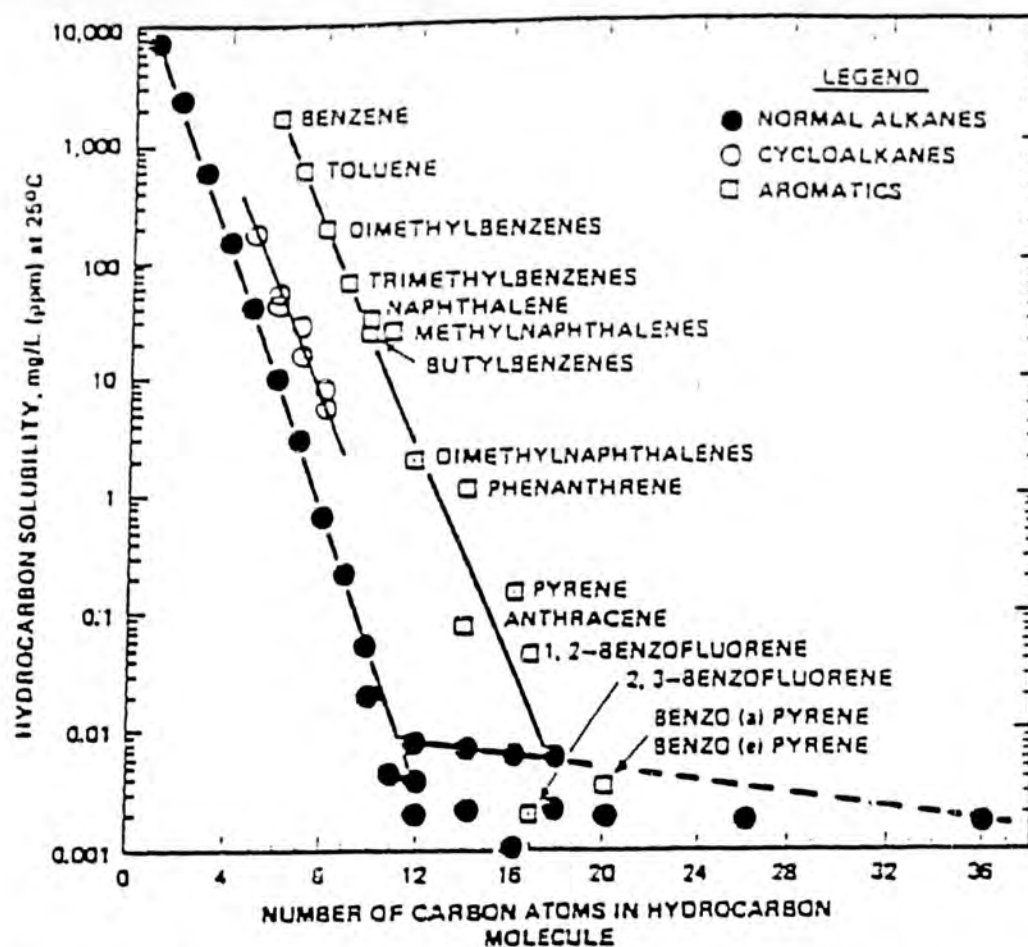


FIGURE 2 Solubilities of normal alkane, cycloalkane, and aromatic hydrocarbons in water (data from McAuliffe, Baker, Wauchope and Getzen, Sutton and Calder, Button, Eganhouse and Calder, Price, Schwartz and Wasik, and Mackay and Shiu).

SOURCE: McAuliffe (1987)

Table 5. Aqueous Solubilities (mg/L at 25°C) for Key Constituents of Lower Molecular Weight Aromatic Hydrocarbons Found in Petroleum Products [source: McAuliffe 1987, Fig. 1]

<u>Aromatic Hydrocarbon Type</u>	<u>Aqueous Solubility (mg/L)</u>	<u>Vapor Pressure¹ (atm @ 25°C)</u>
Monoaromatics		
benzene	1,100	.125
toluene	500	.374
Diaromatics		
naphthalene	30	.0001
Triaromatics		
phenanthrene	1.2	9×10^{-7}
4-Ring Compounds		
pyrene	<.2	-

¹ Values taken from U.S. DOI 1987, Vol. II, Appendix C.

The value for pyrene is reported to underscore the rapid diminution which solubilities undergo as molecular weight increases. Although higher molecular weight compounds may also be highly toxic in an absolute sense, they are not likely to be present in high concentrations in water soluble fractions due to their low solubilities. Because compounds which are highly soluble are also highly volatile (see Table 5), under most conditions the acute toxic effects of concern are likely to be of importance for time periods ranging from only hours to days. They also may tend to be highly localized in that actual concentrations of dissolved hydrocarbons under oil slicks in open waters (and away from the slick interface) are likely to be quite low (McAuliffe 1987).

Aromatic Hydrocarbon Content. Aromatic hydrocarbon contents of PBC, Bunker C, and no. 2 fuel oils are reported by Clark and Brown (1977) (see Table 6). Coleman et al. (1984), who conducted chemical assays on the water soluble fractions of gasoline and kerosene, find that extremely high concentrations of lower molecular weight aromatics occur in the WSFs of these products (37 - 95% by weight of compounds in the unleaded gasoline WSF tested, and 99% by weight for the WSF of the kerosene tested). They, like other authors, caution however that the contents of gasolines and kerosenes can be highly variable depending on the raw source, and the degree of processing and blending. Also, the products they tested are unlikely to have been refined from PBC. Finally, it should be noted that gasolines themselves are

Table 6. Physical characteristics and chemical properties of several crude oils

Characteristic or Component	Crude Oil		
	Prudhoe Bay ^a	South Louisiana ^b	Kuwait ^b
API gravity (20°C) (*API)*	27.8	34.5	31.4
Sulfur (wt %)	0.94	0.25	2.44
Nitrogen (wt %)	0.23	0.69	0.14
Nickel (ppm)	10	2.2	7.7
Vanadium (ppm)	20	1.9	28.
Naphtha fraction ^c (wt %)	23.2	18.6	22.7
Paraffins	12.5	8.8	16.2
Naphthenes	7.4	7.7	4.1
Aromatics	3.2	2.1	2.4
Benzenes	0.3 ^d	0.2	0.1
Toluene	0.6	0.4	0.4
C ₈ aromatics	0.5	0.7	0.8
C ₉ aromatics	0.06	0.5	0.6
C ₁₀ aromatics	--	0.2	0.3
C ₁₁ aromatics	--	0.1	0.1
Indans	--	--	0.1
High-boiling fraction ^e (wt %)	76.8	81.4	77.3
Saturates	14.4 ^f	56.3	34.0
n-paraffins	5.8 ^g	5.2	4.7
C ₁₁	0.12	0.06	0.12
C ₁₂	0.25	0.24	0.28
C ₁₃	0.42	0.41	0.38
C ₁₄	0.50	0.56	0.44
C ₁₅	0.44	0.54	0.43
C ₁₆	0.50	0.58	0.45
C ₁₇	0.51	0.59	0.41
C ₁₈	0.47	0.40	0.35
C ₁₉	0.43	0.38	0.33
C ₂₀	0.37	0.28	0.25
C ₂₁	0.32	0.20	0.20
C ₂₂	0.24	0.15	0.17
C ₂₃	0.21	0.16	0.15
C ₂₄	0.20	0.13	0.12
C ₂₅	0.17	0.12	0.10
C ₂₆	0.15	0.09	0.09
C ₂₇	0.10	0.06	0.06
C ₂₈	0.09	0.05	0.06
C ₂₉	0.08	0.05	0.05
C ₃₀	0.08	0.04	0.07
C ₃₁	0.08	0.04	0.06
C ₃₂ plus	0.07	0	0.06
Isoparaffins	--	14.0	13.2
1-ring cycloparaffins	9.9	12.4	6.2
2-ring cycloparaffins	7.7	9.4	4.5

Characteristic or Component	Crude Oil		
	Prudhoe Bay ^a	South Louisiana ^b	Kuwait ^b
3-ring cycloparaffins	5.5	6.8	3.3
4-ring cycloparaffins	5.4	4.8	1.8
5-ring cycloparaffins	--	3.2	0.4
6-ring cycloparaffins	--	1.1	--
Aromatics (wt %)	25.0	16.5	21.9
Benzenes	7.0	3.9	4.8
Indans and tetralins	--	2.4	2.2
Dinaphthenobenzenes	--	2.9	2.0
Naphthalenes	9.9	1.3	0.7
Acenaphthenes	--	1.4	0.9
Phenanthrenes	3.1	0.9	0.3
Acenaphthalenes	--	2.8	1.5
Pyrenes	1.5	--	--
Chrysenes	--	--	0.2
Benzothiophenes	1.7	0.5	5.4
Dibenzothiophenes	1.3	0.4	3.3
Indanothiophenes	--	--	0.6
Polar materials ^h (wt %)	2.9	8.4	17.9
Insolubles ⁱ	1.2	0.2	3.5

NOTE: These analyses represent values for one typical crude oil from each of the geographical regions; variations in composition can be expected for oils produced from different formations or fields within each region.

^aAdapted from Thompson et al. (23) and Coleman et al. (24).

^bFrom Pancirov (25).

^cFraction boiling from 20° to 205°C.

^dReported for fraction boiling from 20° to 150°C.

^eFraction boiling above 205°C.

^fReported for fraction boiling above 220°C.

^gPrudhoe Bay crude oil weathered 2 weeks to duplicate fractional distillation equivalent to approximately 205°C n-paraffin percentages from gas chromatography over the range C₁₁-C₃₂ plus for the Prudhoe Bay crude oil sample only (R. C. Clark, Jr., unpublished manuscript, 1966).

^hPolar materials: clay-gel separation according to ASTM method D-2007 (10; part 24) using pentane on unweathered sample.

ⁱInsolubles: pentane-insoluble materials according to ASTM method D-893 (10; part 23).

*API gravity = 141.5/ (specific gravity at 60°F or 16°C) - 131.5.

SOURCE: R.C. Clark and Brown (1977). Numbers in parentheses in footnotes above are reference numbers in R.C. Clark and Brown (1977).

currently undergoing reformulation as a result of air pollution concerns. As the Western States Petroleum Association noted in a recent publication, "Many of the reformulated gasolines feature lower volatility ... and higher oxygen content [achieved] by adding the oxygenate, methyl tertiary-butyl ether" (WSPA 1990). Lacking better data at this time however, we utilize the values Coleman et al. report in Table 7 below.

Acute Toxicity Scores. The values listed in Tables 5 and 7 lead directly to relative acute toxicity scores for each of the five products listed in Table 7, computed by means of Formula (1) above. These are listed in Table 8 below.

Table 7. Percent Weight Composition of 1-, 2-, 3- and Higher than 3-ring Aromatic Hydrocarbon Compounds in Selected Petroleum Products.

<u>Aromatic hydro- carbon type</u>	<u>PBC¹</u>	<u>Bunker C¹</u>	<u>No. 2 Fuel Oil¹</u>	<u>Gasoline²</u>	<u>Kerosene^{2,3}</u>
Monoaromatics	8.4	6	22.2	48.6	13.7
Diaromatics	10.0	3.3	5.9	1	5.7
Triaromatics	3.1	11.6	-	-	-
Greater than 3-ring	4.5	3.2	.9	-	-

1. Calculated from Tables 4 and 6 of Clark and Brown (1977). Reported values of aromatic contents of some of the products listed vary to some extent from source to source.
2. Taken from Coleman et al. (1984), Table 3.
3. Values for JP-5 jet fuel derived by Sink et al. (1984) in a separate study are similar to those reported for kerosene. But for reasons explained in the test we treat jet fuels as equivalent to gasoline in acute toxicity potential.

Table 8. Relative Scores for Acute Toxicity Based on Product Type.

<u>Product Type</u>	<u>Raw Score</u> ¹
PBC	95.4
Bunker C	67.1
No. 2 Fuel Oil	246.0
Gasoline	534.9
Kerosene	152.4
Kerosene-type Jet Fuel	NA

¹ Calculated from Formula 1 in text and data in Tables 5 and 7.

The scores in Table 8 reflect, on the basis of an empirical theory which is developed in some detail below, expected relative differences in the acute toxicities of different product types. The theory, laid out briefly above, relates expected acute toxicity to the relative abundances of certain classes of compounds in the spilled oil. It is still necessary however to relate these scores to the level of injury from acute toxicity expected to occur following a spill of each type of product, all other things being equal. To do this, we utilize the scale for toxic effects developed by Dethier in a separate study for DOE, with slight modifications:

<u>Habitat Class No.</u> ⁴	<u>Expected Level of Injury</u>
5	Destruction of most or all susceptible organisms in the area affected by the spill
4	Death or significant population decline of a large proportion of the susceptible organisms
3	Death or loss of a moderate proportion of these organisms, or broad sublethal effects
2	Moderate, mostly sublethal effects
1	Little injury
0	Spill of a non-acutely toxic substance (e.g. vegetable oil)

To convert the raw scores in Table 8 to the scale values above, we first associate 0 raw score points with 0 on the scale above. Then, based on the findings of field and laboratory studies noted elsewhere, we assign gasoline (535 points in Table

8) to toxicity class 5. Simiarly, based on the reports of jet fuel spills into Des Moines Creek, Washington discussed below, we assign kerosene-type jet fuel (no raw score) to toxicity class five. The other product types are then assigned to acute toxicity classes on the basis of linear interpolation. The results appear in Table 9.

Table 9. Acute Toxicity Class Assignments for Petroleum Products
(see text for derivation.)

<u>Product Type</u>	<u>Rescaled Value</u>	<u>Class Assignment via Upward Rounding</u> ¹
PBC	.89	1
Bunker C	.63	1
No. 2 fuel Oil	2.30	3
Gasoline	5.00	5
Kerosene	1.42	2
Kerosene-type Jet Fuel	5.00	5

1. For specification of the marine and estuarine habitats associated with each habitat class in relation to their sensitivity to the acute toxic effects of spilled oil see M. Dethier (1990). We assign marine open waters not adjacent to shorelines and without significant bird populations to habitat class 4. The rating is based on effects on planktonic organisms, and was developed in consultation with Dethier.

Scale for Mechanical Toxicity

Following the conclusion of our review of the literature on mechanical toxicity (see below), we use API gravity to scale the five classes of petroleum products with respect to their relative propensity to cause mechanical toxicity to wildlife. Smith (1968) classified more than 7,000 crude oils with respect to their API gravities and other properties. The resulting distribution (Fig. 3) suggests that a scale ranging from 10 to 65 degrees API gravity is sufficient to cover most crude and refined petroleum products likely to be spilled in Washington waters. By this scaling, the lower the API gravity (i.e., the higher the specific gravity), the more likely the product is to cause mechanical toxicity. Representative API gravity values for the five classes of products treated in this report are presented in Table 10.

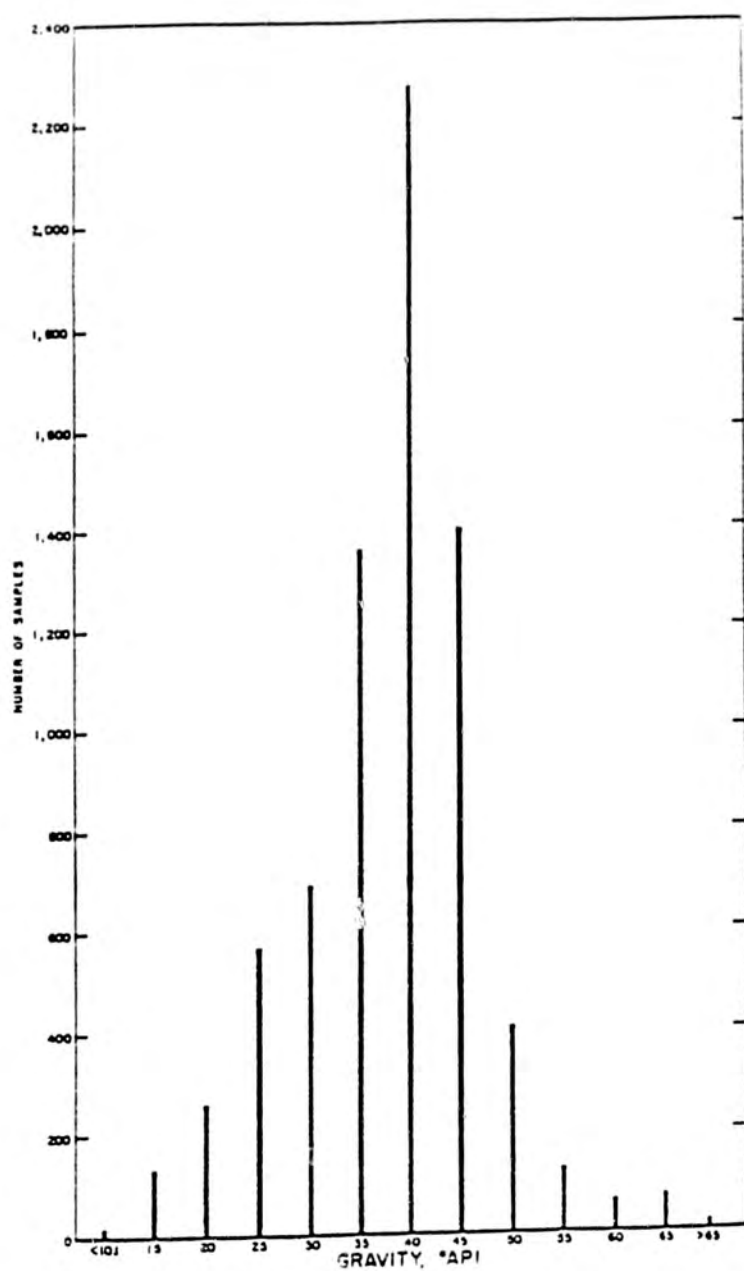


FIGURE 3 Frequency Distribution of API Gravity of Crude Oils (7,386 samples).

SOURCE: Smith (1968)

Table 10. Representative API Gravities for Petroleum Product Classes Hauled in Washington Waters.

<u>Product</u>	<u>API Gravity</u> ¹
Prudhoe Bay Crude	27.8
Bunker C	13.0
No. 2 fuel oil	31.6
Kerosene	41.5
Gasoline	62.4
Kerosene-type jet fuel	35.8 - 56.7

¹ Values for PBC, no. 2 fuel oil and kerosene from Clark & Brown (1977). Value for Bunker C is an average of four values reported by Bobra (1989). Gasoline value is reported as "typical" for unleaded gas by Bobra, who is also the source for the range of values for jet fuel.

As with acute toxicity, it is still necessary to associate the values in Table 10 with the level of injury from mechanical toxicity which we would expect to result from a spill of each type of oil. This is done by reference to the same five-point scale of injury used for acute toxicity.

As a glance at Table 10 shows, a Bunker C spill would be expected to have the greatest potential (all other things being equal) for mechanical toxicity, while a gasoline spill would be expected to exhibit the least such potential. On the basis of the extreme volatility and very low density of gasoline, we judge spills of gasoline (or still lighter products) to exhibit essentially no mechanical toxicity and assign them to toxicity class 1.

To determine the appropriate assignment for the upper end of the mechanical toxicity scale (i.e., for products with API gravity equal to or lower than that of Bunker C) we make reference to the 1988 Nestucca spill off Grays Harbor, in which some 225,000 gallons of Bunker C oil were spilled. As is well known, sea birds are among the most susceptible of wildlife populations to the effects of mechanical toxicity. Although the actual bird mortalities resulting from the Nestucca spill are as of this writing still subject to some dispute, it is known that nearly 9,000 dead birds were recovered. This number is about one-fourth the number of dead bird recoveries made following the Exxon Valdez crude oil spill, even though the spill was only about 2.5% as large. This justifies a 5 rating for spills of Bunker C or heavier oils in our judgment. Having thus bounded

the ends of the scale, the other class assignments can then be determined by linear interpolation (see Table 11).

Table 11. Mechanical Toxicity Class Assignments for Petroleum Products

<u>Product Type</u>	<u>Rescaled Value</u> ¹	<u>Class Assignment</u> via <u>Upward Rounding</u> ³
PBC	3.56	4
Bunker C	5	5
No. 2 fuel Oil	3.24	4
Kerosene	2.44	3
Gasoline	1	1
Kerosene-type jet fuel	2.44 ²	3

1. Values calculated by a two-step process. First degrees API were converted to specific gravity (S.G.) via the formula $^{\circ}\text{API} = 141.5/\text{S.G.} - 131.5$. Then linear interpolation was used to rescale results to a 1-5 scale.
2. The API gravity value for kerosene is taken as a representative value for kerosene-type jet fuel.
3. For specification of the marine and estuarine habitats associated with each habitat class in relation to their sensitivity to the mechanical effects associated with spilled oil see M. Dethier (1990). We assign marine open waters not adjacent to shorelines and without significant bird populations to habitat class 3, in consultation with Dethier. Definitions of scale values appear in the text.

Persistence Scale: Overview

We reviewed available data on the persistence of several types of oil products spilled around the Washington coast and the literature on the persistence of the main oil product types transported around Washington when spilled in other temperate coastal regions (see below). We propose a scale for persistence which ranges from a few hours to a few days for gasolines, kerosenes and jet fuels, to several months to several years (ultimately to more than a decade) for no. 2 fuel oils, for Alaskan North Slope crude oil, and for residual, heavy, Bunker C or no. 5 and no. 6 fuel oils (see Figure 4). For the products heavier than jet fuels, interaction with sediments becomes important; for this reason we develop multiple ranges of persistence to account for different habitat types. At the minimum, one could have two ranges of persistence, a shorter range for open, exposed, high energy rocky coastal areas and a longer range for more protected, low energy fine sediment areas like bays and marshes. Use of the information developed by M. Dethier on differences in the propensity for oil to persist in relation to habitat type makes it feasible to distinguish among five different ranges of persistence on the basis of habitat type.

Unlike the treatment we accorded to chemical and mechanical toxicity above, we utilize a purely judgmental approach to generate a numerical scale to represent relative differences in oil persistence. Limitations in available data do not permit us to focus on specific classes of compounds present in oils and to

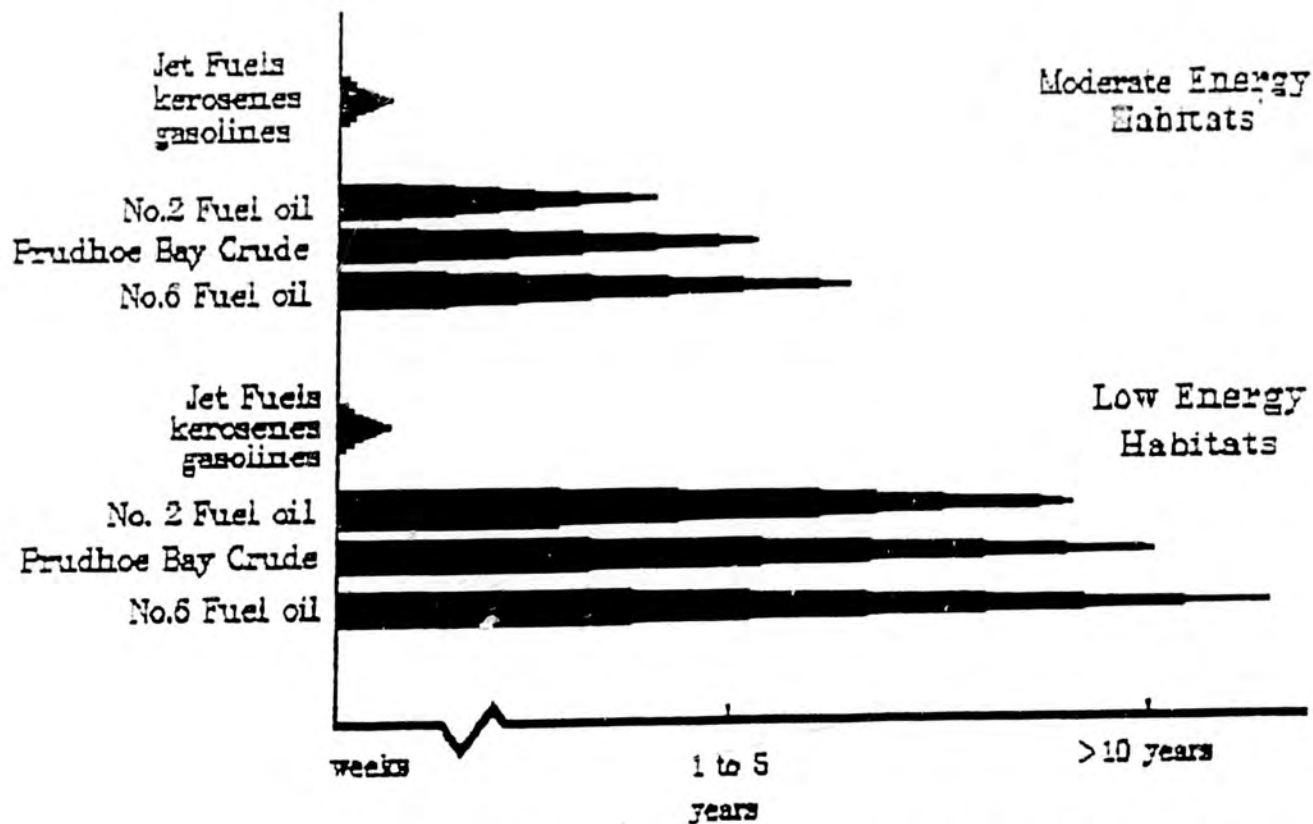


FIGURE 4 Schematic Representation of Spilled Oil Persistence

base the scaling on the relative abundances of these compounds in parent oils and in refined petroleum products, as we did for acute toxicity. While the heavier weight aromatic and aliphatic compounds, with their correspondingly low solubilities and vapor pressures, are found in post-spill studies to be the compounds which persist longest in the environment, analytical difficulties hamper accurate characterization of their abundance in whole oils. Such data as we have been able to glean from published analyses are suggestive of the general relationships among oils in their tendencies to persist as indicated by our review, but are neither complete nor definitive enough to justify their use in numerical scaling.

Clark and Brown (1977) provide a breakdown of the heavier weight chemical constituents in the oil types most likely to persist in the environment following spills (represented in our classification scheme by PBC, no. 2 fuel oil, and Bunker C). Other literature we reviewed suggests that the most persistent hydrocarbon compounds will be the aromatics with 3 or more rings, the straight-chain n-paraffins in the C₂₂ and greater range (Clark et al. 1978), the branched non n-alkane compounds in the C₂₅ and greater range (Cretney et al. 1978), and such non-aromatic compounds as the cycloparaffins of 3 or more rings. As a general rule, cyclic and branched compounds could be expected to persist longer than straight-chain compounds and aromatics would be expected to persist longer than aliphatics.

A partial listing of persistent hydrocarbon compounds found in PBC, no. 2 fuel oil and Bunker C is presented for illustrative

purposes in Table 12. But a great many nitrogen, sulfur, oxygen and other non-hydrocarbon compounds not shown here are also found in oil (Clark and Brown [1977] and NAS [1985]), many of which are also quite persistent. We note that the ordering implied in Table 12: no. 2 fuel oil, PBC, Bunker C, in order of increasing propensity to persist in the environment, is nevertheless consistent with that suggested by the literature review, presented in Sec. IV below.

Table 12. Percent-Weight Composition in Oils of Some Higher Molecular Weight Compounds Likely to Persist in the Marine Environment (Source: Clark and Brown, 1977)

<u>Hydrocarbon Compound Type</u>	<u>No. 2 Fuel Oil</u>	<u>PBC</u>	<u>Bunker C</u>
3-ring and greater aromatics	0.9	7.6	14.8
C ₂₂ and greater n-paraffins	0	1.47	0.65
3-ring and greater cyclo- paraffins	4.5	10.9	7.9
TOTAL	5.4	19.97	23.35

Scale for Persistence. In order to account for the effects of habitat type in determining the relative propensity of oils to persist in the marine environment, we again utilize Dethier's classification scheme for the marine and estuarine habitats of Washington. In addition to providing the toxicity ratings utilized above, she also sorts the 35 habitat types she describes into five classes on the basis of their propensity to retain oil once it enters as the result of a spill. Dethier defines these classes by their expected oil retention time (assuming an undefined mixed-cargo spill) as follows:

<u>Habitat Class No.</u>	<u>Expected Oil Retention Time</u>
5	more than 10 years
4	5 - 10 years
3	1 - 5 years
2	1 month to 1 year
1	days to weeks

The extremes in this classification are represented by an exposed sandy beach (the only habitat type in Dethier's class no. 1), where no oil would be expected to persist beyond a few weeks, and protected mudflats, muddy bays, deep subtidal muds, estuarine lagoons and the other habitat types grouped into Dethier's class no. 5, where highly persistent oils would be expected to persist for more than 10 years. Generally speaking, it is the habitat energy regime that defines the differences among these classes, which are taken to be independent of the type of oil spilled.

In order to integrate this numerically scaled information on habitat-specific differences in the propensity to retain oil with qualitative information on relative differences in the propensity of different petroleum products to persist in the environment, it is necessary to scale the latter information as well. To do this we define a second, habitat-independent scale for oil persistence as follows:

<u>Associated Persistence Time Under the Most Scale Value Unfavorable Environmental Circumstances</u>	
5	more than 10 years
4	5 - 10 years
3	1 - 5 years
2	1 month to 1 year
1	days to weeks

Using this scale, we can now assign numerical values to each petroleum product class on the basis of its habitat-independent propensity to persist in the environment once spilled:

<u>Oil Type</u>	<u>Points for Persistence</u>
gasoline, kerosene, jet fuel	1
no. 2 fuel oil	2
PBC	5
Bunker C	5

The two 1-5 scales, and the rules we use in combining the scales in Table 13, are intended basically to reflect the following assumptions:

- 1) The very low persistence of gasoline, kerosene and jet fuel is unaffected by habitat type;
- 2) On exposed sandy beaches (habitat class 1) the persistence of all oils is on the order of days to weeks, with gasoline persisting for perhaps only hours, and with PBC and Bunker C persisting for weeks.
- 3) In all but the most energetic environments, no. 2 fuel oil is less persistent than PBC, which is in turn less persistent than Bunker C. PBC is more like Bunker C in persistence than no. 2 fuel oil is like PBC; and
- 4) When persistence is determined by the interaction between habitat type and oil type (habitat classes 2-5 and oil types PBC, no. 2 fuel and Bunker C) the significance of persistence for any oil type increases as a multiple of habitat class.

The process of combining the habitat-dependent scores with the oil type-dependent (and habitat-independent) scores is basically one of multiplication, with the exception of the circumstances described in Assumption 1 (for oils in the lowest habitat-independent persistence class) and Assumption 2 (for habitats in the lowest persistence class). See Table 13.

Table 13. Scale Values for Persistence of Oils in Various Marine and Estuarine habitat types.

<u>Habitat Class</u> ¹	<u>OIL TYPE</u>			
	Gasoline, Kerosene jet fuel	No. 2 fuel oil	PBC	Bunker C
1	1	1	1	1
2	1	4	10	10
3	1	6	15	15
4	1	8	20	20
5	1	10	25	25

¹ For specification of the marine and estuarine habitat types associated with each class in relation to their tendencies to retain oil within them, see M. Dethier (1990). Open water areas not adjacent to shorelines are assigned to habitat class 1.

A Note on Combining Toxicity Scores with Other Resource Values

Three types of detrimental effects associated with oil spills -- acute and mechanical toxicity and persistence -- have now been subjected to numerical scaling intended to represent differences in the degree of each effect observed in the field and in laboratory studies. The result permits differentiation among petroleum products with respect to their potential to cause acute or mechanical toxic effects, and differentiation among combinations of petroleum products and habitat types with respect to the tendency for particular petroleum products to persist in particular habitat types once spilled.

Before the goals outlined by the legislation can be met, these results must be combined with the results of other efforts underway within or under sponsorship of DOE to attach similarly scaled values to the marine and estuarine resources of Washington which are sensitive to oil spill damage.

We have already alluded to the work of M. Dethier, which was used extensively in the development of the persistence ratings. Dethier's work also includes other measures not utilized in the present analysis, such as habitat sensitivity to acute and mechanical toxicity and ratings of habitat types on the basis of such factors as their primary and secondary productivity support value. In addition, DOE personnel are now developing a number of indicators of the value of various zones within the state with respect to the support they provide for marine birds and mammals, fin and shell fisheries, recreation, and other resources.

While the final formula for assigning an overall score to a spill could have many possible forms, the idea underlying this work is basically that of extending the approach taken in developing the persistence scores above to other elements of this ongoing work. In essence, a score for 'persistence potential' of the oil spilled (on a 1-5 scale) is multiplied by a score representing the propensity of oil to persist in the habitat type in which the spill occurs (also on a 1-5 scale). The resulting scores range in theory from a low value of 1 to a high value of 25.

The suggested extension of this approach is to multiply scaled resource values in each class (on 1-5 scales) by the value representing the type of toxicity which most affects each resource type. Thus fishery values (on 1-5 scales) would be multiplied by acute toxicity scores, while marine mammal and bird values (also on 1-5 scales) would be multiplied by mechanical toxicity scores. The results would then be added across categories⁵. Situations where multiple habitat types were affected or where resources were thought to be sensitive to both types of toxic effects could be handled by appropriate averaging or by allocation of the total spill volume.

To illustrate, a simple hypothetical example is presented. It includes a proposed method for translating the final scores into the dollars-per-gallon scale required by the legislation. The final transformation to dollars involves linear scaling, but there is no a priori reason why this last step should follow a linear model. The underlying value function should represent the

underlying value society places on avoiding spills of increasing severity on a per-gallon basis⁶. A variety of non-linear forms could be utilized, including logarithmic exponential, or logistic forms.

EXAMPLE:

- 1) Crude oil is spilled in zone X during season Y.
- 2) It affects a single habitat type H, which has the following sensitivities (after Dethier):

	<u>Classification</u>
Propensity of oil to persist	3
Propensity for acute toxic effects	4
Propensity for mechanical effects	5

- 3) In zone X during season Y, the resource values are (after DOE):

Birds	5
Fisheries	3
Marine mammals	4
Recreation	2

- 4) The crude oil spilled is rated as follows (after this document):

Acute toxicity potential	1
Mechanical toxicity potential	4
Persistence potential	5

To score the spill, we assume that birds, mammals and recreation are affected primarily by mechanical toxic effects, while fisheries are affected primarily by acute toxicity. The score for the spill is then computed as

$$\text{SCORE} = [\text{BIRD VALUE} + \text{MAMMAL VALUE} + \text{RECREATION VALUE} + \text{HABITAT MECH INJURY POT'L}] * \text{MECH TOX POT'L} + [\text{FISH VALUE} + \text{HABITAT ACUTE TOX INJURY POT'L}] * \text{ACUTE TOX POT'L} + \text{PERSIST POT'L} * \text{PERSIST}$$

PROPENSITY =

$$[5+4+2+5]*4 + [3 + 4]*1 + 5*3 = 86 \text{ points.}$$

In theory, the spill could have scored as few points as 7 points (all values set to 1) or as many as 175 points (all values set to 5). Using a linear transformation which maps 7 points to \$1/gallon and maps 175 points to \$50/gallon, we can calculate that this spill would cost out at about \$24/gallon.

IV. Potential Injury to Marine Environments Associated with Oil Spills: A Review of the Literature

In this section we review the literature on harmful effects associated with oil spills, as background to the scoring systems developed above for dealing with these effects in the Washington Compensation schedule.

Acute Chemical Toxicity

Toxicities of various crude oils and refined products to marine organisms have been examined in numerous laboratory and field studies. The literature is reviewed by Neff (1979); Rice et al. (1979); Neff and Anderson (1981); National Academy of Sciences (NAS 1985); McAuliffe (1987) and Anderson et al. (1987). Our sense of the voluminous literature which has been devoted to documenting the acute toxic effects of oil is that a reasonable scientific consensus has been reached supporting the summary of Anderson et al. (1987) who state:

Indirect evidence from a number of sources strongly indicate that the single class of compounds producing mortality at the lowest concentration is the diaromatics referred to as naphthalenes. Phenanthrenes (triaromatics) are equally toxic, but much lower concentrations are found in water extracts or mixtures of dispersed oil (water phase). While

monoaromatics have been shown to be less toxic than naphthalenes, they are found at much higher concentrations in fresh crude oils and their WSF. Therefore, the compounds likely to produce most of the toxicity when oil is mixed with water are the mono and diaromatics (Anderson et al. 1987, p. 235).

This summary is similar to that of the 1985 NAS report:

Toxic effects from petroleum exposure vary widely and for reasons that are not well understood. Certainly these have to do with the complexity of its chemical composition, with different products or even crude oils differing markedly in their chemical makeup. Another factor is the variability in sensitivity to oil found among marine organisms, differing not only with the species (Figure 5-1; [included here as Fig. 5] but even for life-cycle stages (Figure 5-2). While it is generally true that the younger stages of organisms are more sensitive to petroleum hydrocarbons, there are exceptions. Unfortunately, not many studies have compared the sensitivity of organisms at various life stages under identical experimental conditions for any one species.

While the absolute toxicity of petroleum hydrocarbons appears to be greater for the higher-molecular-weight compounds (for example, 3- and 4-ring aromatics), most of the toxic effect of petroleum in water is thought to be due to the lower-molecular-weight (C_{12} - C_{24}) n-paraffin compounds and to the monoaromatic fraction, for the simple reason that these compounds are the most water-soluble (Chapter 3, Table 3-4; [included here as Table 3]). From examinations of the concentrations present in water-soluble fractions (WSF), it is clear that the contribution of compounds higher in molecular weight than the alkylnaphthalenes is very small and may be insignificant in terms of producing acute toxicity (NAS 1985, p. 372).

We propose that, if data from field or lab studies of toxicities of Prudhoe Bay crude and products derived from it are not available, predictions or rankings of expected toxicities should be made based on estimates or measurements of the concentrations of one-, two- and three-ringed aromatic hydrocarbons present in each product.

Despite the importance of tanker shipments of Prudhoe Bay crude oil, we note that the toxic effects data listed for it in

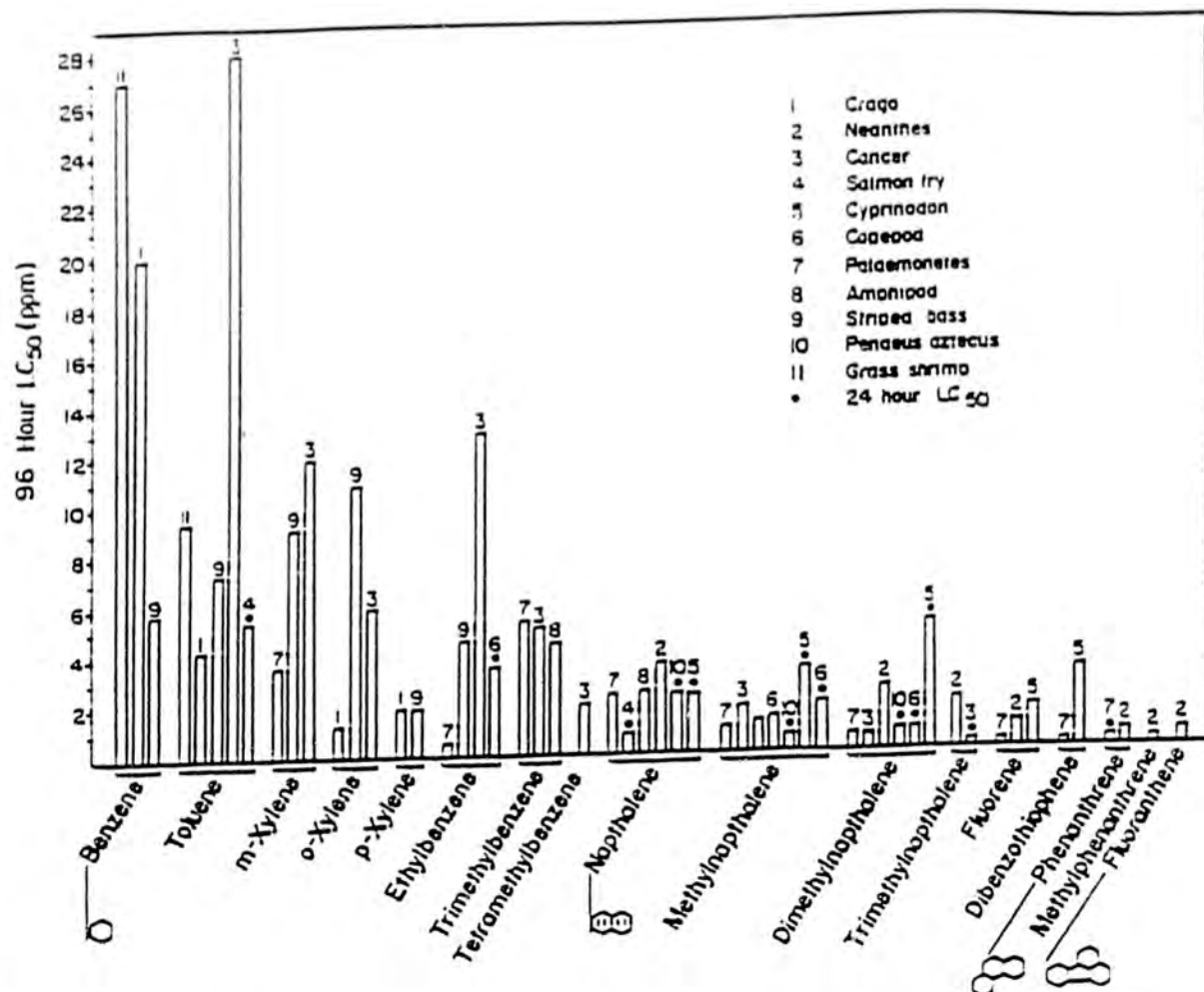


FIGURE 5 Acute toxicity (24- and 96-hour LC_{50} static tests) of some aromatic hydrocarbons for selected marine macro-invertebrates and fish

SOURCES: Caldwell et al. (1977), Benville and Korn (1977), Neff et al. (1976), R.E. Thomas and Rice (1979), Young (1977), Rossi and Neff (1978), Ott et al. (1978), and W.Y. Lee and Nicol (1978).

the CERCLA "Type A" damage assessment procedures are actually data measured by Rice et al. (1979) for the response of 39 species of Alaskan marine organisms to Cook Inlet Alaskan crude oil, which has lower aromatic content (Table 2). Data on the toxicity of PBC to Pacific Northwest organisms from studies following the Exxon Valdez spill have been tied up in legal proceedings and are unlikely to be available to the public for several more years.

Toxicities of Prudhoe Bay crude oil to a variety of marine species have been determined previously under laboratory conditions. Pearson et al. (1985) studied the effect of PBC and chemically dispersed oil on Pacific herring egg fertilization, hatching and larval abnormalities. Anderson et al. (1987) determined the relative toxicities of fresh PBC and dispersed PBC oil fractions to the shrimp Pandalus danae and the fish Ammodytes hexapterus (sand lance). McAuliffe (1987) summarizes many API-sponsored bioassays and behavioral studies of effects of PBC or fractions of it on a variety of marine organisms. Particular attention was paid to possible effects on salmon species.

A number of studies report the toxicities of water soluble fractions (WSF) of PBC (or ANS) to a variety of marine organisms. We know of no studies of toxicities of WSFs of any refined petroleum products derived from the PBC. There are several reasons for using the WSF instead of a crude oil itself. Operationally, studies are easier to reproduce when one is not contending with variable losses of oil itself to container walls, with variable extents of emulsions/droplets/supersaturations,

etc. Second, toxicities of oil components are related to their water solubilities -- due at least in part to the fact that marine organisms have large quantities of water passing over their gills and other vulnerable surfaces. Also, the high lipid/water partition coefficients of hydrocarbons favor rapid hydrocarbon transport from the aqueous phase into lipid rich components like the biological membranes or other lipid pools in organisms. It is therefore generally believed that the dissolved hydrocarbons cause immediate toxic effects on marine and fresh water organisms (McAuliffe 1987).

Non-experts must realize however that hydrocarbon concentrations in WSFs depend upon how the WSF was produced--in static or flow-through systems, by what degree of mixing, etc. So, comparison of hydrocarbon contents of WSFs prepared in different studies are usually not valid. As Neff and Anderson (1981) note:

It should be recognized that the WSF is a purely artificial mixture and is not meant to precisely simulate the conditions of hydrocarbon composition and concentration in the water column under oil spilled in the marine environment. Equilibration conditions in nature are quite different from those used to produce the WSF. The WSF represents a compromise. It is a means of generating a highly reproducible oil-in-water mixture and therefore is extremely useful for comparing the relative toxicity of different crude and refined petroleum to marine organisms. (Neff and Anderson 1981, p. 17).

It must be noted further that recent studies have suggested that water column toxicity per se, particularly for crude oil spills in the open ocean, is unlikely to be as important as sediment (acute) toxicity and, when oil comes into direct contact with seabirds, marine mammals or other vulnerable organisms, the

effects of mechanical toxicity. Table 3 (from McAuliffe 1987) shows for example that actual hydrocarbon concentrations under oil slicks tend to be several orders of magnitude lower than the LC_{50} s for the organisms tested in laboratory studies. But acute toxic effects wherever and whenever they occur are likely to be mediated by the same underlying factors, and as Rice et al. (1979) note, concentrations can increase dramatically in semi-enclosed environments and in waters at the slick interface.

Prudhoe Bay Crude. Table 2 shows that water soluble fractions of North Slope Alaskan crude oils contain several times higher amounts of benzenes, toluene and dimethyl benzenes than WSFs of five other crude oils. Table 6 (from Clark & Brown 1977) shows that the PBC has several times higher concentrations of benzenes, naphthalenes & phenanthrenes as do the API South Louisiana and Kuwait reference crude oils.

Data given in Malins and Hodgins (1981, p. 1277) showed flatfish sand sole embryos and larvae developed high percentages of abnormalities when exposed to fresh and weathered PBC in various ways at concentrations of several hundred ppb. Results of other exposures of PBC to marine organisms are given by Anderson et al. (1987) and by McAuliffe (1987).

The relatively high total and 1- and 2-ring aromatic hydrocarbons and high sulfur contents plus exposure tests lead us to rule out a low toxicity ranking for PBC. Most probably a medium-range ranking is appropriate.

Gasoline, Kerosene and Jet Fuel. Quantitative information linking gasoline toxicity to marine organisms to underlying product compositional characteristics appears to be generally lacking. The Alaskan Penalty Table (See Appendix I) lists gasoline, kerosene and several common jet fuels as highly toxic. The National Contingency Plan does not list gasoline but does accord kerosene and benzene its highest toxicity rating. The CERCLA Type A model appendices (U.S. DOI 1987, Vol. II) assign identical toxicities to all petroleum products however, based on Rice et al.'s studies of Cook Inlet crude oil. Clark and Brown (1987; p. 23) describe the gasoline fraction from PBC as composed of 15.9% aromatics and 36.8% naphthenes (percent volume).

In November of 1985 and again in April of 1986, Des Moines Creek, which flows into Puget Sound, experienced jet fuel spills causing serious fish kills. On November 28, 1985 a 31,000 gallon discharge of Jet A fuel from the Olympic Pipeline Company facility killed all of the salmon and trout in Des Moines Creek from the discharge site to the mouth of the creek - 2.5 miles (Kittle 1986). On April 6, 1986 7,000-8,000 gallons of Jet A fuel were discharged from the Northwest Orient Airlines fuel farm near the headwaters of Des Moines Creek. The damage assessment indicated that all the salmon and trout in the creek were killed for a distance of 3 miles downstream from the discharge (Kittle and LeVander, 1986). These spills support a high toxicity rating for jet fuels.

Distillate Fuel Oils (taken as equivalent to no. 2 fuel oils).

The Alaskan penalty table gives this category of oil products the highest toxicity -- 1.0 on scale of 0.25 to 1.0. Rice et al. (1979), in the extensive study whose data form the basis for numbers in the CERCLA Type A model tables, found no. 2 fuel oil to be consistently more toxic to a variety of marine organisms than Cook Inlet crude oil (although the particular no. 2 tested was probably not derived from Cook Inlet crude). Rice et al. say "Observed toxicity of the no. 2 fuel oil was probably caused by small concentrations of highly toxic di-aromatic hydrocarbons."

Neff and Anderson (1981; p. 20) showed that the total naphthalenes and toxicity of the water soluble fraction of four API oils both decreased in order: no. 2 fuel oil, Bunker C residual oil, South Louisiana crude oil and Kuwait crude oil.

Table 6 (from Clark & Brown 1977) shows the initial PBC to be high in content of 2- and 3-ring aromatics compared to API South Louisiana and Kuwait crudes, and Table 3 (from McAuliffe 1987) shows that the water soluble fraction of PBC contains more aromatics than WSFs of five other crudes. We would therefore expect no. 2 fuels derived from PBC to be relatively high in both aromatics and toxicity. We know of no data on toxicity of No. 2 fuel oils derived from PBC, but the detailed compositional data of Coleman et al. (1973) show that distillation cuts of PBC in the no. 2 fuel oil boiling range are indeed rather rich in aromatics. A well-documented no. 2 fuel oil spill in Buzzards Bay, Massachusetts proved to be toxic to intertidal organisms for several years (Sanders et al. 1980).

Residual Fuels (no. 6 Fuel Oil, Bunker C, etc.) The Alaskan penalty table assigns this product category a rating of 0.5 on scale of 0.25 to 1.0. There is no ranking in the National Contingency Plan.

We could find no data on chemical composition or biological effects of any residual fuel derived from PBC -- all effects data seem to be from the API Bunker C fuel oil derived from Venezuelan crude (composition given in Clark and Brown 1977) and an apparently different API reference Bunker C whose composition is given on p. 144 of NAS (1985).

Neff and Anderson (1981, p. 20) reported for the four API reference oils that total naphthalene concentrations in WSFs and relative toxicities both decreased in the same order: no. 2 fuel oil, Bunker C residual oil, South Louisiana crude and Kuwait crude.

Table 3 lists concentrations of some n-paraffins and aromatic hydrocarbons in these four reference oils and compares them with concentrations in fresh PBC, but gives no data for composition of any Bunker C derived from PBC. The residual oil composition listed by Coleman et al. (1983) for PBC derived fractions shows the residual to have both high sulfur and naphtheno-aromatic content.

Given that the PBC starting crude is enriched in aromatics vs. other crudes and that the heavier aromatics will be enriched in the residual fuels, we feel the residual fuels derived from

PBC will most likely be at least as toxic as the API Bunker C "standard."

Mechanical Toxicity - Smothering, Coating, etc.

This type of harm to biota is most important for seabirds, certain mammals, and intertidal or subtidal organisms in the aftermath of large spills or when oil enters protected coves and bays.

The importance of mechanical toxicity (principally in the coating of waterfowl, seabirds and marine mammals by oil directly or by oil-water emulsifications) was underscored by the 1989 Exxon Valdez spill. As many as 300,000 seabirds may have perished, along with more than 1,000 sea otters out of a population estimated at 13,000 (Nichols 1990). The potential for significant and costly-to-remove shoreline fouling was also demonstrated by the spill. The biggest single expenditure of the \$2 billion Exxon spent in post-spill response appears to have been the cost of deploying cleanup crews and equipment to deal with the nearly 1,000 miles of oiled shoreline left by the spill.

We propose to use scales for this effect based on API gravity or viscosity of the products spilled, for several reasons:

- (1) API gravity and viscosity are properties routinely specified for all oil products;
- (2) Other properties which affect this sort of harmful action can be at least semi-directly related to these properties (see below); and
- (3) The physical and chemical nature of an oil product changes rapidly in the several days following a spill, with evaporation/dissolution of lighter, more soluble

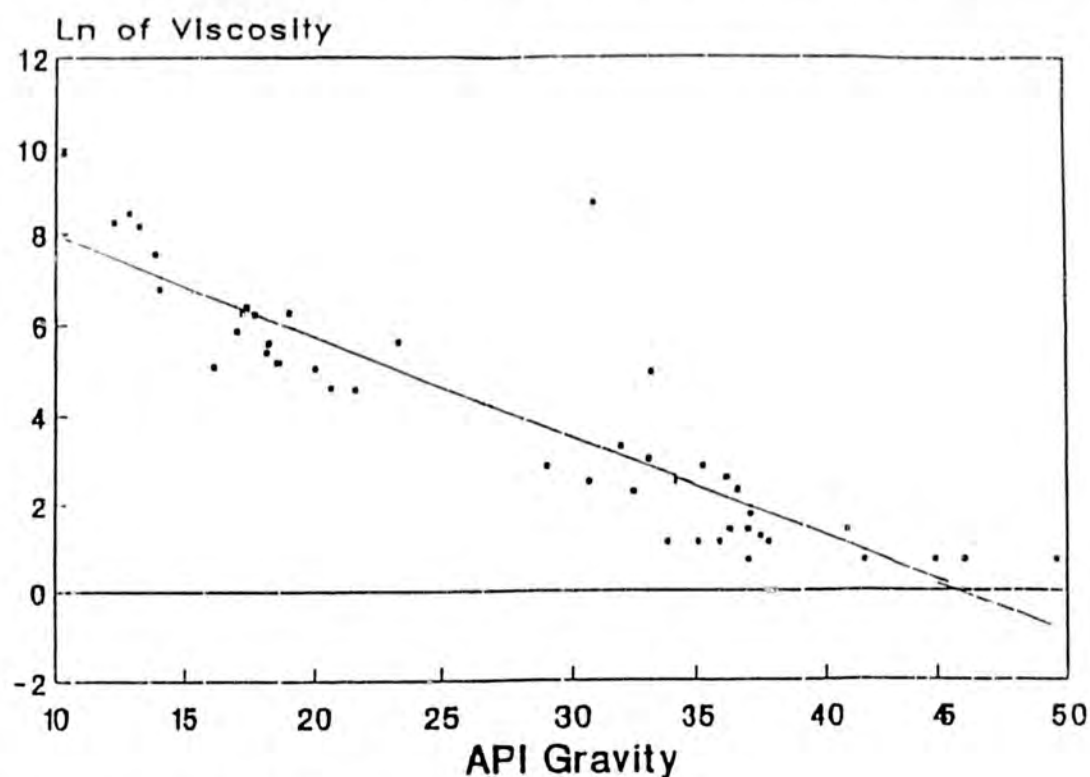
or biodegradable components. These changes with time tend, to first approximation, to affect both viscosity and density in similar ways. For example, loss of lighter, more soluble components tends to increase both viscosity and density of the remaining oil.

Figures 6 and 7 show empirically a relationship between API gravity or density and viscosity of a variety of crude oils and refined products. The API gravity scale definition is such that more dense oils have lower API gravity numbers (around 10), while less dense oil products have larger API gravities (around 60 for gasolines). The corresponding density or specific gravity range is from around 0.7 to somewhat more than 1 gram/cm³ for gasolines to heavy residual fuels -- a range of only 0.5 units.⁷

Surface tension is a property of oils which affects its movement and coating behavior, but is not routinely determined (surface tension of pure water is 75 dynes/cm², while the surface tension of pure benzene is 31.6). However, standard physical chemistry equations show that surface tension is directly proportional to density of the liquid. So, surface tension should increase as API gravity decreases. Jordan and Payne (1980, p. 5) note that the oil spreading coefficient varies inversely with molecular weight. Thus the oil spreading coefficient should vary directly with density and increase with decreasing API gravity. It also seems reasonable to assume that, as a first approximation, oil persistence and propensity to cause mechanical coating and harm would increase with products of increasing viscosity and increase with products of greater density (or smaller API gravity).

FIGURE 6

Oil Viscosity and API Gravity for Crudes with High API Gravity or Pour Pt.

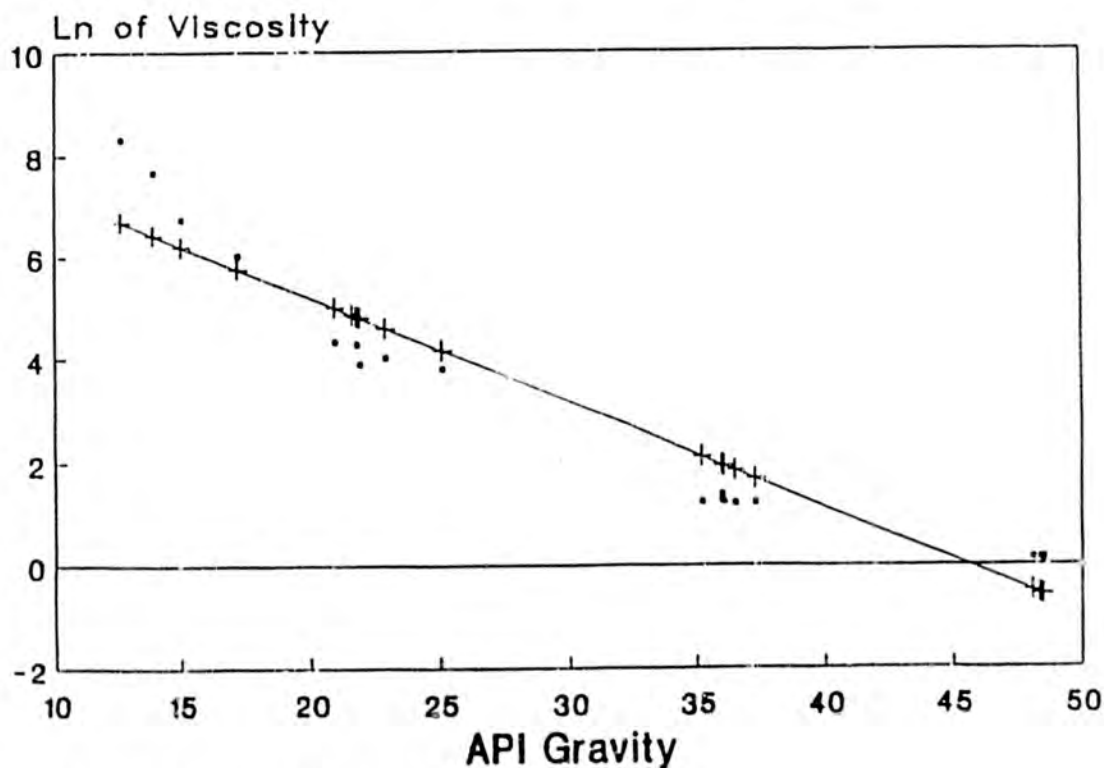


Slope of regression line = $-.22$, $R^2 = .79$

SOURCE: Jonathan Rubin

FIGURE 7

Refined Oil Viscosity and API Gravity



Products include: Kerosine, light gas oil, heavy gas oil, and residual. Slope of Regression line = $-.20$, $R^2 = .92$

SOURCE: Jonathan Rubin

We therefore suggest using scales based on viscosity and API gravity to rank various oil products as to the mechanical toxicity/physical coating harm they might cause. Such rankings might prove misleading if one were to create, from some unusual combination of feedstocks, products of high viscosity but very short persistence, products of low viscosity but very long persistence, or perhaps products with low API gravity but short persistence. Although this might be possible with unusual oil mixtures, we do not feel it likely for products shipped through Washington waters, which are predominantly derived from reasonably well-defined ANS crude.

Injury to Birds and Mammals. Clear evidence of the harm mechanical coatings can do to a variety of sea birds and mammals comes primarily from dead body counts made along beaches or through aerial surveillance after spills. Legal, ethical and logistical problems will always limit scientists ability to carry out rigorous experiments on how much of what kinds of oils it takes to coat and harm large, active, legally protected creatures like seabirds, sea otters and other mammals. It seems pointless to quibble over details -- the general mechanisms of the harmful effects associated with mechanical coatings are now abundantly clear.

Parmenter (1989) gives an excellent summary of the abundance of different types of sea birds and mammals around the Washington coast, and the likelihood that each type might be harmed by oil coatings. The majority of the dead birds killed by the Exxon

Valdez spill were murres, grebes and loons, with the remainder including cormorants, scoters and puffins. Most of the birds drowned, starved or died of hypothermia. In contrast with the over 1,000 dead sea otters collected, only a few seals or sea lions were killed, because unlike otters, they rely on a subcutaneous fat layer instead of fur for insulation, and they do not groom.

After the much smaller Arco Anchorage spill of ANS crude in Port Angeles harbor, 1,917 birds were found dead on beaches or collected oiled but alive and taken to bird treatment centers (Lindstedt-Siva et al. 1987). Grebes comprised 58%, ducks 25% and alcids 12% of the totals. 80% of the captured oiled birds died despite treatment. No mention was made about harm to marine mammals, probably because sea otters are found in only a few small colonies on the open Washington coast off Olympic National Park.

In the 1989 Nestucca spill off Grays Harbor, Washington, 231,000 gallons of no. 6 fuel oil (Bunker C) were spilled (Kittle, 1989). Approximately 10,000 oiled birds were collected during the search and rehabilitation efforts (primarily murres and scoters). About 9,000 of the birds died. It is assumed that many more birds were killed than were collected. There was no evidence of harm to marine mammals, but there was concern about possible harm to raptors that could suffer from feeding on oiled carcasses (DOE, 1989).

Injury to Intertidal Organisms. The relatively small, sessile organisms that live on beaches between high and low tide lines are especially susceptible to being smothered and killed by a blanket of oil washing ashore. Such organisms include seaweeds, eelgrass, starfish, snails, sea urchins, barnacles, and a variety of bivalves (clams, mussels, oysters). We note the great importance of the recreational and commercial harvest of several of these shellfish species in Washington State. Washington produces some 38% of the total U.S. supply of oysters, and clams, geoducks and other shellfish are objects of increasingly popular commercial and recreational harvest. We have the impression that such inter- or subtidal species are more valued in Washington than in Alaska, which seems primarily concerned with protecting salmon, halibut and herring resources. The approximately ten times larger Washington human population and greater accessibility of the coast also suggests great values on recreational use of beaches and on pleasure boating, both of which are affected when beaches, marinas or boats are fouled with a coat of oil.

We know of no scientifically rigorous studies to define exactly how much of different types of oil are needed to smother, foul or coat different intertidal creatures. Studies of the aftermath of the Amoco Cadiz crude oil spill and others show intertidal organisms are certainly susceptible to being harmed by coating of oils. It seems intuitively likely that lighter, more volatile, less persistent, less viscous oil products will cause less mechanical harm than more viscous, denser and more

persistent products. For example, bivalves can close up tightly for the few hours necessary to survive a coating by a short-lived gasoline-like fuel, but could not remain closed long enough for a coating of no. 2 fuel oil or some even more viscous product to disappear. Clams and other intertidal species inside Ediz Hook were found to be narcotized - a potentially injurious condition - by oil from the Arco Anchorage spill (Geselbracht, 1989, p. 34).

Persistence of Oils in the Marine Environment

A combination of reports from short-term field investigations of actual spills and, more rarely, longer-term studies of the fate of oil spills, provides a rationale for the scaling applied to the relative propensity of different oils to persist in the marine environment developed above. A review of the scientific literature, and where appropriate, reports of short-term spill investigations, follows.

Gasolines, Kerosenes and Jet Fuels. The environmental persistence of these products is determined primarily by their rate of evaporation and only secondarily by rates of dissolution and biodegradation. Rates of evaporation are governed by a combination of several compound-specific properties (Henry's law constant, molecular weight, mass transfer coefficient/diffusion coefficient, etc.) and the key environmental variables water and air temperatures and wind speeds and turbulence.

Evaporation rates for the low molecular weight (mostly C₆-C₁₂) compounds predominant in gasolines, kerosenes and jet fuels have been examined under a variety of conditions and shown to be

typically a few hours to a couple of days (Jordan and Payne, 1980; Payne et. al., 1983; numerous references in NAS, 1985; McAuliffe, 1989; Mackay et al., 1983). We know of no detailed scientific studies of evaporation rates of these oil product types specifically from Washington coastal waters (typically 5-15°C), but we feel the local rates can reasonably be expected to be in the range quoted above. This conclusion is supported by the disappearance within a few days of the highly toxic jet fuel which was spilled into Des Moines Creek in 1985 and again in 1986 (Kittle 1986; Kittle and LeVander 1986).

No. 2 Fuel Oils. For the heavier no. 2 fuel oils which are not as rapidly evaporated, dissolution, biological degradation and sedimentation processes all have important impacts on how long the oil persists in the environment.

One spill of about 5,000 barrels of a no. 2 fuel oil (not derived from Alaska North Slope Oil) occurred on 26 April 1971 at a fuel loading dock at Anacortes, Washington (Vagners, 1972). Because this was the first relatively large oil spill in the Washington coastal zone, scientists, regulatory agencies and response teams were all poorly prepared. Studies of the spill fate and effects were poorly organized, incomplete and lacking any actual chemical characterizations. There are no hard data from this spill which can be used to predict the persistence of no. 2 fuel oils in Washington coastal zones. From a few haphazard visual observations, the oil seemed to disappear from shorelines within several weeks.

The most detailed chemical studies of the aftermath of spills of no. 2 fuel oils in a coastal zone are undoubtedly those carried out around Buzzards Bay and Falmouth, Massachusetts (Blumer and Sass, 1972; Teal et al., 1973; Hampson and Moul, 1978; Mayo et al., 1978; Sanders et al., 1980). In these relatively protected intertidal and subtidal mud and salt marsh-type environs, at least traces of the no. 2 fuel oil and effects persisted for 10 years after the spills (Sanders et al., 1980). These studies all stressed the importance of the nature of the sedimentary environment in affecting oil persistence. In contrast to relatively rapid removal of the oils from exposed beaches, once the oil is sedimented or buried, degradation is inhibited due to lower O_2 concentrations and reduced biological activity, and mechanical removal is very slow. The crude oil source for the no. 2 oils spilled in Massachusetts areas was not ANS crude, but these data provide probably the closest analogy in the literature as to what one might expect for no. 2 fuel oil persistence in protected, low energy environs around Washington State. Such areas are to be found in Willapa Bay, Grays Harbor, Nisqually Delta, Padilla Bay, Skagit Bay, and many small bays and harbors within Puget Sound. Persistence of several years up to a decade seems likely in such areas.

Prudhoe Bay Crude. The best predictor for likely persistence of Prudhoe Bay crude oil in the Washington coastal zone comes from observations following the spill of some 5,700 barrels of Alaska North Slope oil from the tanker Arco Anchorage in Port Angeles

Harbor on December 21, 1985. Studies of the aftermath of this spill showed that for the relatively coarse/sandy/open beach areas of Ediz Hook and nearby areas where considerable cleanup agitation was accomplished, most residues and effects of ANSC had disappeared from the sediments within 2-3 years (Miller, 1989; Mancini et al., 1989; Blaylock and Houghton, 1989; Lindstedt-Siva et al., 1987).

Observations of ANSC oil spilled in Prince William Sound from the tanker Exxon Valdez show significant decrease in amounts of visible oil along beaches after one year, but with some oil buried beneath mud and cobbles likely to persist for several years. One important fact evident from the follow up observations however, is the important role bacterial degradation has in degrading the oil, and that one of the best cleanup procedures, although still experimental, may be to 'seed' areas with 'cocktails' of oil-degrading bacteria and enhanced nutrients nitrogen and phosphorous. Microbial degradation of ANSC by water samples from a commercial harbor, oil tanker dock area, and a pristine area of Washington State have been studied by Fedorak and Westlake, 1981).

Compositional changes in ANS crude oil mixed with sediment from near Sequim, Washington were followed for four months by McCain et al. (1978). After an initially rapid decrease of oil contents, changes slowed and amounts seemed to stabilize after four months at about half the initial amounts.

By eight years after the 1978 Amoco Cadiz oil spill, the hydrocarbon content of the sediments had returned to background

levels in all but the most heavily impacted areas. The residues of weathered Amoco Cadiz oil that remained were in the final stages of degradation (Page 1989).

Residual Fuels Equivalent to No. 5, 6 or Bunker C Oils. These heavier, higher density residual oils remain after lighter compounds are distilled off. These residual oils are relatively rich in larger molecules with high boiling points, higher density, very low water solubility, slower bacterial degradation rates and higher amounts of aromatic hydrocarbons with 3 or more aromatic rings. They are expected to tend to sink, accumulate in sediments, and to persist at least as long as their parent crude oil. While generally low in short-term acute toxicity, they may be the major cause of chronic contamination and effects.

There have been four spills of this type of residual oil fraction around the Washington Coast: the wreck of the towed troopship General M.C. Meigs off the open northwest coast on January 9, 1972; the spill from the tanker Mobiloil in the Columbia River on March 19, 1984; the sinking of the MCN #5 barge near Anacortes on January 1988 and the holing of the barge Nestucca off Grays Harbor, Washington in December 1988. Only in the aftermath of the Meigs accident were rigorous chemical studies carried out to define the persistence of the spilled oil (Clark et al., 1978).

Clark et al. reported that "Observations of animal and plant populations and their petroleum hydrocarbon uptake patterns showed early evidence of contamination and the persistence of the

oil spill throughout the study period" (5 years). Only the aliphatic hydrocarbon trends were observed, but the heavier 3-ring and larger aromatic hydrocarbons would be expected to persist even longer.

The sinking of the MCN #5 barge near Anacortes, Washington released some 47,000 gallons of a heavy residual fuel oil which was denser than sea water and which sank upon release. The aftermath of this spill is described by Geselbracht (1989) and by Yaroch & Reiter (1989). Initial visual observations noted that the oil sank out of sight and appeared to cause no major biological harm in the immediate spill area. With little evidence of damage to commercially or recreationally important species, staff of the Washington State Department of Ecology decided not to invoke the MRDA (Marine Resources Damage Assessment) procedures and no large scale study was initiated. Scientists from the Shannon Point Marine Center near Anacortes did collect some specimens of red sea cucumber (a commercially harvested benthic species) from the area of the oil spill, which were oiled externally. They also carried out some preliminary investigations which showed marine sediments from the spill area were contaminated with oil, possibly from the MCN #5 spill. NOAA apparently subsequently provided some funds for further sediment sampling and analysis and a few bioassays, but none of these chemical results are available to us. All we can say is that as expected, some of this heavy residual oil did sink to the sea floor and accumulate in sediments near the spill site.

The tanker Mobiloil ran aground in the Columbia River and released three types of oil: a heavy residual oil; a no. 6 low sulfur fuel oil; and an industrial fuel oil (JRB Associates, 1985). The oil eventually reached Pacific coastal areas as far as 100 km north of the Columbia River mouth. Washington State Department of Ecology staff did activate the MRDA procedures in this case, and supported several studies focused on efforts to determine which resources had been exposed to the spilled oil and whether this exposure has damaged any of the biological resources. Most of these studies could not verify if damage to biological resources had occurred or not (Geselbracht, 1989; JRB Associates, 1985). Krahn et al. (1986) did however clearly show from analyses of metabolites in bile of sturgeon from the Columbia River that these large bottom feeding fish in the river had indeed incorporated hydrocarbons from the oil spill.

JRB Associates (1985) summarize results of chemical analyses of environmental samples performed to see if petroleum in the samples could be chemically fingerprinted to match that originally carried by the Mobiloil. Matches were found at numerous sites in the Columbia River system downstream of the spill site and on the coast as far north as Copalis Beach, 90 km north of the river mouth, for samples collected in March-May 1984. However, neither intertidal samples nor samples more exposed to atmospheric weathering collected in February 1985 conclusively showed the Mobiloil fingerprint. No samples from the subtidal were collected, so the length of persistence in subtidal coastal sediments remains unknown.

In December 1988 the towed barge Nestucca was holed off Grays Harbor and spilled residual oil equivalent to no. 5 or no. 6 fuel. This oil washed up along Washington beaches to the north even up to Vancouver Island and including beaches of the Olympic National Park. Much concern resulted about oil contamination of the beaches; considerable cleanup efforts were made, and most oiled material was removed. To our knowledge, data from studies of the chemical persistence of this oil along the Washington coast are not yet available.

The long term fate of a no. 5 fuel oil spilled in a coastal bay of British Columbia north of Washington State was observed six times during four years after the spill (Cretney et al., 1978). Disappearance of the lower molecular weight and n-alkane components was noted during the first 4 years, but the non-n-alkane components in the C_{25} - C_{30} range seemed more resistant. Aromatic hydrocarbons were not reported. This study of a heavy fuel oil suggests similar oils in nearby Washington State coastal zone would last from one to four years.

Some 2.5 million gallons of Bunker C were spilled into Chedabucto Bay, Nova Scotia in the wreck of the tanker Arrow on 4 February 1970. Chemical residues of this oil and its biological effects have been carefully studied and summarized by Keizer et al. (1978); Thomas (1978); and NAS (1985). Chemical analyses show traces of oil residues from the tanker persisted for over six years in intertidal sediments of the bay, and some organism populations were still stressed, but the bulk of the oil and its effects had disappeared after six years.

Thus, studies of residual oil spills in Washington and British Columbia coastal zones agree with those of aftermath of the tanker Arrow in Nova Scotia that the heavy residual fuel oils will most likely persist for several years in the coastal sediments.

NOTES

1. The details of this approach are described more fully by Leschine et al. (1989).
2. Much of this discussion of the Alaska civil penalty scheme is excerpted from Graham (1989), and Rubin (1989) which should be consulted for further details.
3. More precisely, the oil's API Gravity is used; see Appendix II. API Gravity is derived from specific gravity. It is also strongly related to viscosity. (see Figs. 6 and 7 below.)
4. Patterned after the "mechanical and toxicity sensitivity" (sic) ratings of M. Dethier's report Rankings of Productivity, Diversity, and Oil Sensitivity for Marine and Estuarine Habitat Types in Washington. Note that this usage represents an inversion of the classification system actually developed by Dethier. Whereas she first defined 35 marine and estuarine habitat types and then rated each on the 1-5 scale of her report, we take the scale values as representing distinct classes with respect to susceptibility into which habitat types can then be sorted. (The wording of the definitions is modified slightly for consistency with this report.)
5. In technical terms the scoring model we are developing is a version of the multilinear model described by Edwards and von Winterfeldt (1986). The critical assumption is that both differences in the value attached to spills of a more versus less toxic oil in a given habitat and differences associated with a spill of the same oil type in a more versus less sensitive habitat type are entirely accounted for by differences in associated values in the tables. Specialists will recognize this as a special case of the condition known as "multilinear difference independence" (Edwards and von Winterfeldt 1986, p. 326 ff.).
6. Numerous procedures exist to develop numerical weights reflective of the relative importance a decision maker might attach to the influence of one factor versus another in scoring formulas. All depend to some extent on decision-maker supplied inputs. Elicitation procedures are described in detail by Edwards and von Winterfeldt (1986). The assumption that scores can be combined additively, with or without weights, depends on a condition Edwards and von Winterfeldt term "additive difference independence." Essentially we are assuming that societal or decision-maker concern for each of these four aspects of unquantifiable oil spill damage is unaffected by the extent of damages in the other three categories. See pp. 326 ff. of their book.

7. Specific gravity and API gravity or density are related by the formula $\text{Degrees API} = 141.5 / \text{sp. gr. } 60^{\circ}/60^{\circ}\text{F} - 131.5$. The material spilled in the 1989 MCN #5 barge spill had a specific gravity of 1.086, translating into an API gravity of -1.21, and making it a highly unusual product to be encountered in a marine oil spill.

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Appendix I

ALASKA'S CLASSIFICATION OF PETROLEUM, PETROLEUM PRODUCT, AND BY-PRODUCT TOXICITY used in the assessment of civil penalties for spills of the above, from 18 ACC 75 Article 5.

- I. Highly Toxic (toxicity factor 1.0)
 - A. numbers 1,2 and Arctic diesel fuel and heating oil;
 - B. jet aviation fuels A and B;
 - C. motor gasoline including aviation gasoline;
 - D. kerosene; and
 - E. stationary turbine fuels;
- II. Moderately Toxic (toxicity factor 0.75)
 - A. waste oil and waste oil mixtures;
 - B. lubricating oil;
 - C. jet fuels other than those specified in (I)(B) of this subsection; and
 - D. crude oil;
- III. Less Toxic (toxicity factor 0.5)
 - A. bunker and residual fuel oils; and
 - B. hydraulic fluids;
- IV. Relatively Nontoxic (toxicity factor 0.25)
 - A. asphalts;
 - B. tars; and
 - C. other petroleum, petroleum products, and by-product not listed in (I) - (III) of this section.

To determine the toxicity factor for a specific crude oil, the toxicity factor 0.75 is multiplied by:

(API gravity of the crude oil) / 30.

ALASKA'S CLASSIFICATION OF PETROLEUM, PETROLEUM PRODUCTS, AND BY-PRODUCTS DEGRADABILITY used in assessment of civil penalties for spills of the above, from 18 AAC 75 Article 5.

I. Low Degradability (degradability factor 1.0)

- A. asphalt;
- B. tar;
- C. bunker and residual fuel oils; and
- D. other petroleum, petroleum products, and by products not otherwise listed in (II.) or (III.) of this section;

II. Moderate Degradability (degradability factor 0.5)

- A. hydraulic fluids;
- B. lubricating oil;
- C. waste oils and waste oil mixture; and
- D. crude oil;

III. High Degradability (degradability factor 0.25)

- A. motor gasoline, including aviation gasoline;
- B. numbers 1, 2 and Arctic diesel fuel and heating oil;
- C. jet and stationary turbine fuels; and
- D. kerosene.

To determine the degradability factor for a specific crude oil, the degradability factor is multiplied by:

$30/(\text{API gravity of the crude oil}).$

ALASKA'S CLASSIFICATION OF PETROLEUM, PETROLEUM PRODUCT AND BY-PRODUCT DISPERSIBILITY used to assess civil penalties for spills of the above, from 18 AAC 75 Article 5.

- I. Highly Dispersible (dispersibility factor 0.15)
 - A. motor gasoline, including aviation gasoline;
 - B. all jet fuels;
 - C. kerosene;
 - D. numbers 1,2 and Arctic diesel fuel and heating oil;
 - E. hydraulic fluids; and
 - F. stationary turbine fuels;
- II. Moderately dispersible (dispersibility factor 0.5)
 - A. emulsified oil mixtures;
 - B. lubricating oils;
 - C. waste oil and waste oil mixtures: and
 - D. crude oils;
- III. Low Dispersibility (dispersibility factor 1.0)
 - A. bunker and residual fuel oils;
 - B. asphalts;
 - C. tars; and
 - D. other petroleum, petroleum products, and by-products not otherwise listed in (I) or (II) of this section.

Appendix II - Definitions

Aqueous Solubility

Aqueous solubility can be determined from Henry's law, $CP = HC$, where P is pressure in atmospheres, C is concentration in solution, and H is Henry's law constant.¹

Aromatic Hydrocarbons²

Aromatic hydrocarbons...contain one or more aromatic (benzene) rings connected as fused rings (e.g., naphthalene) or lined rings (e.g., biphenyl). Petroleum contains many homologous series of aromatic hydrocarbons consisting of unsubstituted or parent aromatic structures (e.g., phenanthrene) and like structures with alkyl side chains that replace hydrogen atoms. Alkyl substitution is most prevalent in 1-, 2-, and 3-ringed aromatics, although the higher polynuclear aromatic compounds (>3 rings) do contain alkylated (1-3 carbons) side groups. The polycyclic aromatics with more than 3 rings consist mainly of pyrene, chrysene, benzanthracene, benzopyrene, benzofluorene, benzofluoranthene, and perylene structures. The naphthenoaromatic compounds consists of mixed structures of aromatic and saturated cyclic rings. This series increases in importance in the higher boiling fractions along with the saturated naphthenic series. The naphthenoaromatics appear related to resins, kerogen, and sterols. Petroleum generation usually involves the formation of some naphthenoaromatic structures.

¹National Research Council (NRC), Oil in the Sea: Inputs, Fates, and Effects (Washington: 1985, National Academy Press), p. 273.

²This is taken in whole from the NRC, p.18.

Flash Point

The flash point of petroleum or a petroleum product is the lowest temperature to which the product must be heated to give off sufficient vapor to cause the vapor above the sample to mix with air and, ignite by a specified flame.⁴

Fuel Oils⁵

Domestic fuel oils are those used primarily in the home and include kerosene, stove oil, and furnace fuel oil; they are distillate fuel oils. Diesel fuel oils are also distillate fuel oils, but residual oils have been successfully used to power marine diesel engines, and mixtures of distillates and residuals have been used on locomotive diesels. Heavy fuel oils include a variety of oils ranging from distillates to residual oils that must be heated to 260° C (500°F) or more before they can be used. In general, heavy fuel oils consist of residual oils blended with distillates to suit specific needs. Included among heavy fuel oils are various industrial oils; when used to fuel ships, heavy fuel oil is called bunker oil.

Pour Point

The pour point of an oil is defined as the lowest temperature at which movement of oil is observed to flow.⁶

Surface and Interfacial Tension

Surface tension is a measure of the forces acting at a boundary between two phases; if the boundary is between a liquid and a solid or between a liquid and a gas

⁴American Society for Testing and Materials (ASTM), *1982 Annual Book of Standards*, part 23 - Petroleum Products and Lubricants (1), sect. D56, Easton MD.

⁵This comes in entirety from Speight, pp. 439.

⁶ASTM, part 23, sect. D97.

(air) the attractive forces are referred to as surface tension, but the attractive forces between two immiscible liquids are referred to as interfacial tension.⁷

Viscosity

Viscosity is the most important single fluid characteristic governing the motion of petroleum products.⁸ It is a measure of the internal resistance to motion of a fluid by the forces of cohesion between molecules or molecular groupings. Viscosity may be defined as the force in dynes required to move a plane of 1-cm² area at a distance of 1 cm from another plane of 1-cm² area a distance of 1 cm in 1 second.⁹ Viscosity is a function of temperature, pressure, and rate of shear. Spill viscosity increases with weathering as evaporation removes the lighter fractions, and decreases with increasing temperature.¹⁰ Fluidity is the reciprocal of viscosity.

Volatility

The volatility of a liquid or liquified gas may be defined as its tendency to vaporize, that is to change from the liquid to the vapor or gaseous state.¹¹ The vapor pressure controls the evaporation rate and air concentration of hydrocarbons, and therefore, the fire hazard in the vicinity of oil spills.

⁷This paragraph comes, in entirety, from Speight, p. 89.

⁸Speight, p.81.

⁹Speight, p. 81.

¹⁰NRC, p. 272.

¹¹Speight, p. 95.

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#4

CHAPTER 173-183 WAC

PREASSESSMENT SCREENING REGULATIONS

173-183-010 Purpose
173-183-020 Authority
173-183-030 Applicability

173-183-100 Definitions

173-183-200 Preassessment Screening
173-183-210 Incident Discovery and Reporting
173-183-220 Initial Site Evaluation
173-183-230 Preassessment Screening Committee
173-183-240 Preassessment Screening Committee Duties
173-183-250 Preassessment Screening Options
173-183-260 Participation
173-183-270 Annual Report

173-183-300 Appeal

} decision
body that
decides what
to do after
a spill - RDA
or table approach

WAC 173-183-010 Purpose.

The purpose of this chapter is to establish a formal preassessment committee and screening process for evaluating resource damages resulting from oil spills to waters of the state causing the death of, or injury to, fish, animals, vegetation, or other resources of the state. The Marine Resource Damage Assessment (MRDA) committee, utilizing the preassessment screening process, shall determine whether a detailed resource damage assessment investigation should be conducted or whether the compensation schedule authorized under RCW 90.48.366 and 90.48.367 should be used to assess damages.

WAC 173-183-020 Authority.

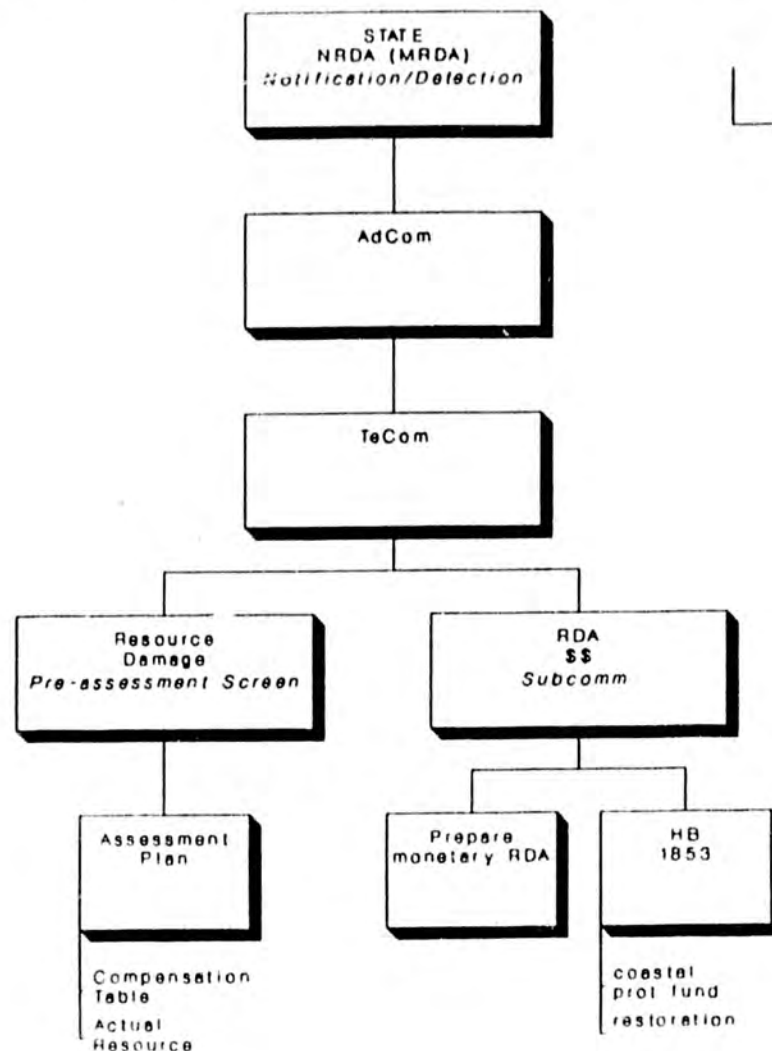
This regulation implements chapter 90.48.368 RCW of the Water Pollution Control Act, as amended in 1987, 1989 and 1991, and includes in part the Clean Water Act, 33 U.S.C. 1251-1376, which the legislature has empowered the department to implement.

WAC 173-183-030 Applicability.

This chapter shall apply to all petroleum discharges into the waters of the state. Under this chapter, the department may require or take any and all actions necessary to investigate and assess damages from those releases.

NATURAL RESOURCE DAMAGE ASSESSMENT

Integration of 1853 & 1854 Into MRDA



Federal
NRDA

*Committee structure
for dealing when
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RDA*

COMP TABLE →

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account and can
only be used on
Resource - not
people or generic
studies*

RCW 90.48.142 & Sec. 311 Clean Water Act

WAC 173-103-100 Definitions

- (1) "Adequate compensation" means the amount determined sufficient to compensate for the loss or diminution in value of unquantifiable damages or damages not quantifiable at a reasonable cost.
- (2) "Adverse environmental effect" means any detrimental impact on the well being or usefulness of a public resource.
- (3) "Compensation schedule" means the set of procedures used to determine the monetary value owed to the state as compensation for unquantifiable damages or for damages not quantifiable at a reasonable cost, developed under the guidelines provided in RCW 90.48.366.
- (4) "Committee" means the preassessment screening committee established under RCW 90.48.368.
- (5) "Damaged resource" means a resource that has sustained injury as result of an oil discharge.
- (6) "Damages" means the amount of monetary compensation necessary to (a) restore any damaged resource to its condition before sustaining injury as a result of an oil discharge, to the extent technically feasible, including any loss in value incurred during the period between injury and restoration in cases where damages are quantifiable at a reasonable cost, or (b) adequately compensate for the loss or diminution in value as determined by the compensation schedule rules provided in this chapter in cases where damages are unquantifiable or not quantifiable at a reasonable cost.
- (7) "Department" means the department of ecology.
- (8) "Director" means the director of the department of ecology.
- (9) "Discharge" means any spilling, leaking, pumping, pouring, emitting, emptying, or dumping.
- (10) "Fund" means the state coastal protection fund as provided in RCW 90.48.390 and 90.48.400.
- (11) "Immediate removal" means the timely dispersal, containment or elimination of oil(s) in a manner which helps prevent significant injury or damage to public resources.
- (12) "Injury or injuries" means a measurable adverse change, either long- or short-term, in the chemical or physical quality or the viability of a natural resource resulting either directly or indirectly from exposure to a discharge of oil.
- (13) "Loss in services" means a temporary or permanent reduction in the ability of the resource to provide its use or benefit to the public or to other resources.
- (14) "Loss in value or lost value" of a damaged resource means the amount equal to the sum of consumptive, nonconsumptive, and indirect use values, as well as lost taxation, leasing, and licensing revenues during the period between injury and restoration; indirect use values may include existence, bequest, option, and aesthetic values.
- () "Marine Resource Damage Assessment (MRDA) Committee"
- (15) "Oil" or "oils" means oil, including gasoline, crude oil, fuel oil, diesel oil, lubricating oil, sludge, oil refuse, liquid natural gas, propane, butane oils distilled from coal, and other liquid hydrocarbons regardless of specific gravity, or any other petroleum related product.
- (16) "On scene coordinator" (OSC) means the department official who supervises the spill response team and compiles the initial report concerning the facts

and circumstances of the spill for the department.

(17) "Person" means any political subdivision, government agency, municipality, industry, public or private corporation, copartnership, association, firm, individual, or any other entity whatsoever and its owner, operator, master, officer or employee of a ship.

(18) "Potentially liable party" means the person or persons who may be liable for damages resulting from an oil spill.

(19) "Preassessment screening" means the investigation and determination of the facts and circumstances surrounding an oil spill which are used to determine whether a damage assessment investigation should be conducted, or alternatively, whether the compensation schedule will be used to assess damages.

(20) "Public resources" or "publicly owned resources" means any natural, recreational, aesthetic or other property held in trust by and for the people of this state.

() "Resource Damage Assessment (RDA) Coordinator"

(21) "Reasonable cost" for a damage assessment means a cost that is anticipated to be less than the amount of damages that may have occurred or may occur.

(22) "Receiving environment" means waters of the state where resources are injured or likely to be injured by an oil spill.

(23) "Restoration or enhancement projects or studies" means an activity that is intended to restore or replace environmental, recreational, or aesthetic resources, either to conditions prior to the injury or to the extent technically feasible, as such conditions are determined by the department, for the benefit of Washington's citizens.

(24) "Scientific Advisory Board" means the advisory group established by the department to assist in development of the compensation schedule as required by RCW 90.48.366.

(25) "Ship" means any boat, ship, vessel, barge, or other floating craft of any kind.

(26) "Technical feasibility or technically feasible" means that given available technology, a restoration or enhancement project can be successfully completed at a cost that is not disproportionate to the value of the resource before the injury.

(27) "Spill" means any leaking, pumping, pouring, emitting, emptying, dumping or discharge.

(28) "Unquantifiable damage" means any diminution in value of a public resource that cannot be measured in a manner which ensures that the people of the state will be adequately compensated for any short-term and long-term damages sustained as a result of an oil spill.

(29) "Waters of the State" shall include lakes, rivers, ponds, streams, inland waters, underground water, salt waters, estuaries, tidal flats, beaches and lands adjoining the seacoast of the state, sewers, and all other surface waters and watercourses within the jurisdiction of the state of Washington.

WAC 173-183-200 Preassessment Screening.

Preassessment Screening is the investigation and screening of the facts and circumstances surrounding an oil spill prior to any formal designated approach to resource damage assessment. These findings will be used to determine whether a formal damage assessment investigation should be conducted or whether the compensation table (WAC 173-184) will be used to assess the environmental and recreational damages. The purpose of this section is to set forth the procedures for selecting the appropriate option for damage assessment and compensation for environmental damages associated with releases of oil into state waters as defined under chapter RCW 90.48.142.

WAC 173-183-210 Incident Discovery and Reporting.

The state On-scene Coordinator (OSC), or initial Ecology responder, shall provide prompt notice to the Marine Resource Damage Assessment (MRDA) Committee when there is evidence of a discharge of oil into state waters in violation of RCW 90.48.142.

WAC 173-183-220 Initial Site Reconnaissance.

(1) The On-scene-Coordinator (OSC), or initial responder, shall be responsible for:

- (a) the initial determination of the character of the oil(s),
- (b) documentation of the initial location, type of habitat, extent and amount of the discharge, and
- (c) a preliminary analysis of the discharge's potential to cause resource injuries.

(2) The following guidelines describe how the conditions under which a preassessment screening committee will be appointed:

- (a) Oil spills of less than 25 gallons

(i) If in the judgement of the OSC that less than 25 gallons of oil have been discharged, there are no apparent resource injuries or harm, and all appropriate clean up activities have been accomplished the OSC shall inform the Ecology Resource Damage Assessment Coordinator that it may not be necessary to convene a MRDA preassessment screening committee to further evaluate the spill.

(ii) If the Ecology Resource Damage Assessment (RDA) Coordinator determines from the information provided by the OSC that resultant oil exposure and damage to the environment is limited, the RDA coordinator shall advise MRDA and the director that the Resource Compensation Table will automatically be used to determine the appropriate compensation for damage to public resources.

(b) Oil spills of greater than 25 gallons or smaller spills that have not been adequately addressed by the responsible party

(1) If in the judgement of the OSC that more than 25 gallons of oil has been spilled or that the responsible party has inadequately addressed spill control the OSC shall request the Ecology RDA Coordinator to have the MRDA committee initiate the preassessment screening process to determine the appropriate way to address resource damage assessment.

(ii) If the Ecology RDA Coordinator determines from information provided by the OSC that exposure of public resources to the spill has been significant, or the spill has caused or may cause significant resource injuries, the coordinator shall recommend that the department convene a preassessment committee as soon as possible, but no later than 24 hours after the OSC has notified MRDA.

(3) The Resource Damage Assessment (RDA) Coordinator shall prepare a formal request with the Director to appoint a preassessment screening committee based on an evaluation of the information provided by the OSC.

(4) Concurrent with the submittal of a formal request to the director for appointment of a preassessment screening committee (173-183) the MRDA committee (standing in for the preassessment committee until it is appointed) will initiate all other necessary reconnaissance activities to determine:

(a) further identification of resources at risk

(b) whether these public resources are, or may be, adversely affected, taking into consideration preventative or cleanup activities to contain or remove the oil(s) so that there is a reduced possibility of quantifiable damage.

(c) documentation of actual or potential injury to those resources, and

(d) whether additional local, state, federal agencies and Indian Tribes may have interests and jurisdiction over any of the public resources in the receiving environment

173-183-230 Preassessment Screening Committee.

(1) Once the Director has authorized the formation of a preassessment screening committee the department, as chair, shall determine which representatives will be needed on a spill-by-spill basis. One member from each of the departments of fisheries, wildlife, natural resources, and the parks and recreation commission will serve as a core committee to be supplemented by the Department of Health, Emergency Management, as well as other state, federal and local agencies, and tribal and local governments whose presence would enhance the reconnaissance or damage assessment aspects of the spill response.

(2) Each core agency shall provide an alternate member in the event that the primary member is unavailable.

(3) If a representative that has been requested to participate declines to do so, that representative shall provide prompt written notice to the department after 12 hours so that a replacement member may be appointed.

within

(4) Prompt consideration will be given to other local, state, federal, or tribal government requests for participation on a spill-by-spill basis.

173-183-240 Preassessment Screening Committee Duties.

(1) The committee shall convene as soon as possible following appointment.

(2) The preassessment screening process shall occur concurrently with reconnaissance and cleanup activities and that information as well as other relevant or background information pertaining to the resource or its use shall be considered during the preassessment process.

(3) The primary duty of the committee is to determine whether a damage assessment investigation should be conducted under RCW 90.48.367, or alternatively, whether the compensation schedule authorized under RCW 90.48.336 should be used to assess damages.

(4) The committee shall consider the following factors when determining what type of damage assessment should be conducted:

(a) Whether evidence from reconnaissance investigations suggests that injury has occurred or is likely to occur to publicly owned resources;

(b) the potential loss in services provided by resources injured or likely to be injured and the expected value of the potential loss;

(c) whether a restoration project to return lost services is technically feasible;

(d) the accuracy of damage quantification methods that could be used and the anticipated cost-effectiveness of applying each method;

(e) the extent to which likely injury to resources can be verified with available quantification methods; and

(f) whether the injury, once quantified, can be translated into monetary values with sufficient precision and accuracy.

(5) When the committee finds that the conditions of a spill make it likely that a damage assessment study authorized under RCW 90.48.367 may be warranted, the department shall notify the potentially liable party of this decision.

(6) The committee may accept restoration or enhancement projects or studies proposed by the potentially liable party in lieu of some or all of:

(a) the damages calculated from the compensation schedule authorized under RCW 90.48.366; or

(b) the claims from damage assessment studies authorized under RCW 90.48.367.

(7) The department may negotiate with a potentially liable party to perform restoration and enhancement projects or studies which may substitute for all or part of the compensation authorized under RCW 90.48.366 or the damage assessment studies authorized under RCW 90.48.367.

(8) The committee is encouraged to work cooperatively with the potentially liable party, to the greatest extent possible, to increase the efficiency of the damage assessment process. The preassessment screening process shall

provide for the ongoing involvement of the potential liable party.

173-183-250 Preassessment Screening Decision Options

(1) The preassessment committee may utilize either the Compensation Schedule authorized under WAC 173-184 or may chose to initiate a detailed resource damage assessment. *under CERCLA TYPE B*

(2) The Compensation Schedule. The department shall use the compensation schedule to determine the amount of damages if the committee determines that:

(a) Restoration or enhancement of the injured resources is not technically feasible;

(b) damages are not quantifiable at a reasonable cost; and

(c) the restoration and enhancement projects or studies proposed by the potentially liable party are insufficient to adequately compensate the people of the state for resource injuries likely sustained as a result of the oil spill.

(3) Formal Resource Damage Assessment. Damage assessment studies authorized under RCW 90.48.367 may only be conducted if the committee, after considering the factors enumerated in subsection (3) of WAC 173-183-240, determines that the damages to be investigated are quantifiable at a reasonable cost and that proposed assessment studies are clearly linked to quantification of the damages incurred.

(a) When damage assessment studies are approved by the committee, the state trustee agencies responsible for the resource(s) and/or habitat injured or potentially injured as a result of an oil spill shall conduct the damage assessment related to their trustee resources.

(b) The committee shall approve the scope of the damage assessment taking into consideration the factors enumerated in subsection (3) of WAC 173-183-240 and subsection (b) of this section.

(4) As new information becomes available, the committee may reevaluate the scope of damage assessment using the factors listed in subsection (3) of WAC 173-183-240 and subsection (b) of this section, and may reduce or expand the scope of damage assessment as appropriate.

173-183-260 Participation.

In order to efficiently implement 173-183-250 the preassessment committee shall develop public resource damage assessment agreements to facilitate cooperation between state and federal agencies and Indian Tribes. Agreements concerning the use of the appropriate damage assessment methodology for public resources with overlapping or delegated jurisdictions may be negotiated on a case-by-case basis by the committee.

173-183-270 Annual Report.

Actions and decisions on all oil spills must be included in the annual legislative report which incorporates the facts and circumstances surrounding the spill, a brief description of the decisions made for determining damages from the compensation schedule or resource damage assessment, the amount of compensation determined to be owed and the actual amount collected from the responsible party for the oil discharge.

CHAPTER 173-184 WAC

OIL SPILL COMPENSATION SCHEDULE REGULATIONS

- 173-184-010 Purpose
- 173-184-020 Authority
- 173-184-030 Applicability
- 173-184-040 Overview
- 173-184-050 Revisions

- 173-184-100 Definitions

- 173-184-200 The Compensation Schedule
- 173-184-210 Overview
- 173-184-220 Site Evaluation and Scoring Procedures
- 173-184-230 Oil Class Ranking

- 173-184-300 Coastal and Marine Waters Biological Ranking
- 173-184-310 Habitat Vulnerability
- 173-184-320 Bird Vulnerability
- 173-184-330 Fish Vulnerability
- 173-184-340 Mammal Vulnerability
- 173-184-350 Recreation Vulnerability

- 173-184-400 Inland Waters Biological Ranking
- 173-184-410 Habitat Vulnerability
- 173-184-420 Bird Vulnerability
- 173-184-430 Fish Vulnerability
- 173-184-440 Mammal Vulnerability
- 173-184-450 Recreation Vulnerability

- 173-184-500 Freshwater Wetland Biological Ranking
- 173-184-510 Freshwater Wetland Vulnerability
- 173-184-520 Bird Vulnerability
- 173-184-530 Fish Vulnerability
- 173-184-540 Mammal Vulnerability
- 173-184-550 Recreation Vulnerability

WAC 173-184-010 Purpose.

The purpose of this chapter is to establish a compensation schedule that will provide a simple methodology for assessing damages to public resources from oil spills. The intent is to provide an alternate methodology to the extensive and expensive natural resource damage assessments presently being conducted after

oil spills. This chapter provides the methodology for establishing the importance of the public resources affected by the spill and addresses the impacts of oils on the environment via the relative toxicity of the oil released to the environment. Additionally, utilizing the above information, this chapter describes the procedure for determining the appropriate monetary compensation for loss of public resources associated with the spill incident.

WAC 173-184-020 Authority.

This regulation implements the establishment of a resource damage compensation schedule consistent with the provisions of RCW 90.48.366 for the discharge of oil in violation of RCW 90.48 and RCW 90.56. The department, in consultation with the departments of fisheries, wildlife, and natural resources, and the parks and recreation commission, and with the assistance of a scientific and technical advisory boards, shall establish the compensation schedule as a method of assessing damages as the result of an oil spill.

WAC 173-183-030 Applicability.

This chapter shall apply to all petroleum discharges into the waters of the state. Under this chapter, the department may require or take any and all actions necessary to assess damages from those releases.

WAC 173-184-040 Revisions.

The department shall review this chapter at least once every three years and appropriate revisions reflecting new or revised information shall be incorporated into the compensation schedule.

WAC 173-184-100 Definitions. (also refer to WAC 173-183-100 Definitions)

(1) "Coastal environment" means the area incorporating: (a) the splash area, which lies above the extreme high water level of spring tide; (b) the upper shore, which lies between the average high tide level and the extreme high water level of spring tides; (c) the midshore, which lies between the average low tide level and the average high tide level; (d) the lower shore, which lies between the extreme low water of spring tides to the average spring tide level; and (e) the sublittoral fringe, which lies below the extreme low water level of spring tides.

(2) "Estuarine environment"

(3) "Marine environment"

WAC 173-184-200 The Compensation Schedule.

(1) The compensation table is designed to provide a simplified methodology for resource damage assessments. The methodology is based on minimal field observations to determine injury, quantify that injury and determine damages to the waters of the state.

(2) The table is designed around a ranking of environmental and recreational use parameters and how those parameters are adversely impacted by the various

oils transported in the state. The table is designed with the following principles in mind:

(3) The compensation schedule shall reflect adequate compensation for unquantifiable damages or for damages not quantifiable at a reasonable cost for any adverse environmental, recreational, aesthetic, or other effects caused by the oil discharge.

(4) The amount of compensation assessed under this schedule shall be no less than one dollar per gallon of oil spilled and no greater than fifty dollars per gallon of oil spilled.

WAC 173-184-210 Resource Damage Assessment Using the Compensation Schedule

(1) The compensation schedule shall include:

(a) a relative ranking for each of the classes of oil defined in this chapter as determined by their known chemical, physical and mechanical properties, and other properties that may affect the severity and persistence of the impact on the receiving environment, including living organisms and recreational and aesthetic resources;

(b) a relative vulnerability ranking for coastal, marine and inland waters and adjacent wetland environments which takes into account the vulnerability of the following resources to oil spills: habitat, marine birds, marine mammals, fishery species, and recreation; and

(c) a quantitative method for determining compensation for an oil spill based on the oil and environmental rankings designed to compensate the people of this state for those damages that cannot be quantified at a reasonable cost and for those unquantifiable damages that result from oil spills.

(d) a method for taking into account actions taken by the potentially liable party that:

(i) demonstrate a recognition and affirmative acceptance of responsibility for the spill, such as the immediate removal of oil and the amount of oil removed from the environment; or

(ii) enhance or impede the detection of the spill, the determination of the quantity of oil spilled, or the extent of damage, including the unauthorized removal of evidence such as injured fish or wildlife.

173-184-220 Oil Class Ranking.

(1) The purpose of this section is to provide a relative toxicity ranking for each of the classes of oil defined in this chapter. The ranking is based on their known chemical, physical and mechanical properties, as well as other properties that may affect the severity and persistence of the oil on the receiving environment. Six classes of oil are ranked for their propensity to cause environmental harm via acute toxicity, mechanical injury and persistence. These oil classes are:

- (a) Prudhoe Bay crude oil.
- (b) Bunker C.
- (c) No. 2 fuel oil.
- (d) gasoline.
- (e) kerosene, and
- (f) kerosene-type jet fuel.

(2) The relative ranking scores for the classified oils shall be those provided in Table -- . ("Leschine, T., R. Carpenter, and E. Gideon, 1991, Petroleum Toxicity Relationships for the Washington Compensation Schedule, College of Ocean and Fishery Sciences, University of Washington, Seattle").

Table -- . Acute Toxicity, Mechanical Injury and Persistence Relative Ranking Scores for Classified Oils (OIL).

<u>Oil</u>	<u>Acute Toxicity</u>	<u>Mechanical Injury</u>	<u>Persistence</u>		
Prudhoe Bay Crude	1	4	5	10	45.45
Bunker C	1	5	5	11	50.0
No. 2 Fuel Oil	3	4	2	9	40.91
Gasoline	5	1	1	7	31.82
Kerosene	2	3	1	6	27.27
Kerosene-type Jet Fuel	5	3	1	9	

(3) In cases where the spilled oil is not described by any of the classes of oil listed in subsection (1) of this section, the department shall determine the acute toxicity, mechanical injury and persistence scores for the spilled oil for purposes of using the compensation schedule by:

(i) assigning the acute toxicity, mechanical injury and persistence scores of the classified oil best describing the spilled oil, or

(ii) calculating the relative ranking scores using the methodology detailed in Leschine et al. (1991) and information on properties of the spilled oil such as percent-weight of the oil's 1-, 2-, and 3-ring aromatic compounds, the aqueous solubility of these compounds and the specific gravity of the oil.

(1) The purpose of this section is to describe the method of ranking the quality of the marine and estuarine receiving environments and to evaluate the impacts of oil spills on that environment for the purposes of assessing damages via the compensation table.

(2) Estuarine and marine waters, including coastal environments, of Washington were divided into 16 regions and -- subregions. Where appropriate, because of biological differences, open water and shoreline habitats were also identified. These zones and subzones, for purposes of RCW 90.48.366, are designated on the maps attached as appendix 1 of this chapter.

(3) For each subzone a Subregional Vulnerability Score (SVS) was calculated. This score is designed to rate all public resources and evaluate their vulnerability to spilled oil. Vulnerability of resources to oil was determined by the propensity of the oil to cause acute toxicity and mechanical injury as well as rate how long the oil persists in the environment. Seasonal vulnerability was determined by summing the seasonal SVS for marine birds, marine mammals, marine fish, recreational use and habitats. The ranking formula is as follows:

Subregional Vulnerability Score(SVS)_{i,j} =

HVS_i + BVS + MVS + FVS + RVS

where HVS_i = habitat vulnerability score to oil's propensity to cause i

BVS = marine bird vulnerability score

MVS = marine mammal vulnerability score

FVS = fisheries species vulnerability score

RVS = recreation vulnerability score

i = acute toxicity, mechanical injury, or persistence

j = fall, winter, spring or fall

173-184-231 Habitat Vulnerability.

(1) The purpose of this section is to describe the methodology for calculating the Habitat Vulnerability Score (HVS) portion of the Subregional Vulnerability Score (SVS) described in WAC 173-184-230 (c).

(2) The ranking method employs a model to compare the various types of habitats, their sensitivity to each oil class and evaluate acute toxicity, mechanical injury and persistence effects on those habitats in order to establish a Habitat Vulnerability Score (HVS):

Habitat Vulnerability Score(HVS)_i =

$$[(PPS_i + SPS_i + DS_i)/3] * HSS_i)^{-2}$$

where: PPS = primary productivity score
 SPS = secondary productivity score
 DS = diversity score
 j = habitat type

HSS = habitat sensitivity score
 i = acute toxicity, mechanical injury or persistence.

(3) The Habitat Vulnerability Score (HVS) for a habitat type shall be increased by a factor of 1.5 when eelgrass, kelp, salt marsh or predesignated rare habitats are associated with the habitat type.

(4) Thirty-five categories of marine and estuarine habitats were initially ranked (Table --) on a 1-5 basis in terms of primary productivity (PPS), secondary productivity (SPS), and diversity (DS). (Dethier, M. 1990. Rankings of Productivity, Diversity and Oil Sensitivity for Marine and Estuarine Habitat Types in Washington).

Table -- . Relative Ranking Scores for Coastal, Marine, Intertidal and Estuarine Habitats based on Primary Productivity, Secondary Productivity and Diversity.

Habitat Class	Primary Productivity	Secondary Productivity	Diversity
ESTUARINE INTERTIDAL			
(a) open rocky shores	3	3	3
(b) open mixed-coarse beaches & low marsh	3	3	4
(c) open gravel beaches	1	2	1
(d) open sandy beaches	3	4	2
(e) sandy low marshes	4	3	2
(f) mixed-fine beaches and low marshes	5	5	4
(g) saline lagoons	4	3	3
(h) low-salinity lagoons	3	2	2
(i) mud flats	3	3	2
(j) high salt marshes	3	3	2
(k) transition zone wetlands	3	3	2
ESTUARINE SUBTIDAL			
(l) shallow subtidal rock & boulders	4	3	3
(m) deep subtidal rock and boulders	2	4	4
(n) shallow subtidal cobble and mixed-coarse areas	3	3	3
(o) deep subtidal cobble and mixed coarse areas	1	3	2

(p) shallow subtidal sandy or mixed-fine areas	3	4	3
(q) deep subtidal sandy or mixed fine areas	1	3	2
(r) shallow subtidal muddy bays	3	3	2
(s) deep subtidal muddy bays	0	3	2

MARINE INTERTIDAL

(a) exposed and semi-exposed rocky shores	4	5	5
(b) sand-scoured rocky shores	3	4	4
(c) protected rocky shores	3	3	3
(d) semi-exposed cobble and mixed coarse beaches	2	4	4
(e) semi-exposed gravel beaches	1	2	1
(f) exposed sandy beaches	1	3	1
(g) semi-protected mixed-fine beaches	3	4	3
(h) protected mud flats	4	4	2

MARINE SUBTIDAL

(i) shallow subtidal rock and boulders	5	4	5
(j) deep subtidal rock and boulders	2	4	5
(k) deep subtidal cobble and mixed-coarse areas	1	3	2
(l) shallow subtidal mixed-coarse to mixed fine	5	4	4
(m) shallow subtidal gravel or mixed-fine areas	2	3	3
(n) deep subtidal sand	0	2	1
(o) deep subtidal mixed-fine areas	1	3	2
(p) deep subtidal muddy areas	0	2	2

(5) The Habitat Sensitivity Score (HSS) determines the habitat sensitivity to acute toxicity, mechanical injury and persistence. Table -- . lists those scores (Dethier (1991):

Table -- , Relative Rank Scores for Marine and Estuarine Habitats based on Sensitivity to Acute Toxicity, Mechanical Injury and Persistence of Spilled Oil

Habitat Class	Acute Toxicity Score	Mechanical Toxicity Score	Persistence Score
ESTUARINE INTERTIDAL			
(a) open rocky shores	3	4	3
(b) open mixed-coarse beaches & low marsh	3	3	3
(c) open gravel beaches	5	1	2
(d) open sandy beaches	4	3	2
(e) sandy low marshes	4	3	3
(f) mixed-fine beaches and low marshes	4	4	4
(g) saline lagoons	4	4	5
(h) low-salinity lagoons	3	4	5
(i) mud flats	4	2	5
(j) high salt marshes	2	4	5
(k) transition zone wetlands	2	4	5
ESTUARINE SUBTIDAL			
(l) shallow subtidal rock & boulders	3	3	2
(m) deep subtidal rock and boulders	2	2	3
(n) shallow subtidal cobble and mixed-coarse areas	2	3	3
(o) deep subtidal cobble and mixed coarse areas	1	2	3
(p) shallow subtidal sandy or mixed-fine areas	3	3	3
(q) deep subtidal sandy or mixed fine areas	2	3	4
(r) shallow subtidal muddy bays	3	2	5
(s) deep subtidal muddy bays	2	2	5
MARINE INTERTIDAL			
(a) exposed and semi- exposed rocky shores	4	3	2
(b) sand-scoured rocky shores	4	3	2
(c) protected rocky shores	4	3	3

(d) semi-exposed cobble and mixed coarse beaches	3	3	3
(e) semi-exposed gravel beaches	1	5	2
(f) exposed sandy beaches	1	5	1
(g) semi-protected mixed-fine beaches	2	3	4
(h) protected mud flats	2	4	5

MARINE SUBTIDAL

(i) shallow subtidal rock and boulders	3	3	2
(j) deep subtidal rock and boulders	2	2	3
(k) deep subtidal cobble and mixed-coarse areas	2	1	2
(l) shallow subtidal mixed-coarse to mixed fine	3	3	3
(m) shallow subtidal gravel or mixed-fine areas	1	3	2
(n) deep subtidal sand	3	2	2
(o) deep subtidal mixed-fine areas	3	1	4
(p) deep subtidal muddy areas	2	2	5

(6) Subregional habitat vulnerability scores for acute toxicity, mechanical injury and persistence shall be determined by taking the square root of the sum of the weighted habitat vulnerability scores for each of habitat types present in the impacted subregion, where weighting is defined by percent coverage of each habitat type at the time of the spill, as follows:

Subregional Habitat Vulnerability Score (HVS)_i =

insert formula here

where: PC_i = Percent-coverage of habitat-type i
 PPS = primary productivity score
 SPS = secondary productivity score
 DS = diversity score
 i = habitat type

HSS = habitat sensitivity score
 j = acute toxicity, mechanical injury and persistence

173-184-232 Marine Bird Vulnerability.

(1) Each of the marine and estuarine subregions of state waters established in 173-184-231 (b) shall be relatively ranked and scored for marine bird vulnerability to oil spills on a 1 to 5 scale for each season.

(2) Marine bird vulnerability ranking shall take into consideration seasonal presence of species, population status of present species, abundance of present species and species vulnerability to oil spills, where species vulnerability is based on roosting habits, escape behavior, flocking behavior, feeding specialization, population size, reproductive capacity, breeding dispersion, winter dispersion, seasonal exposure to waters where oil spills could occur, and significance of Washington population to total population in each season (Wahl, T.R., S.M. Speich, D.A. Manuwal, K.V. Hirsch, and C. Miller, 1981, Marine Bird Populations of the Strait of Juan de Fuca, Strait of Georgia, and Adjacent Waters in 1978 and 1979. U.S. Environmental Protection Agency, EPA-600/7-81-156).

(3) Marine bird seasonal vulnerability scores for each of the subregions of state waters shall be determined from existing information and based on determinations of the Marine Bird Subcommittee of the Scientific Advisory Board.

(4) Based on the guidance provided in subsection (3) of this section, marine bird seasonal vulnerability scores for the marine and estuarine subregions of state waters are as follows in Table -- :

Table -- . Subregional Marine Bird Vulnerability Score (BVS)

Subregion	Spring	Summer	Fall	Winter
201	3	2	5	4
203	4	3	4	3
204	2	2	2	2
205	2	3	3	2
206	2	2	2	2
207	2	3	3	2
208	2	2	2	2
209	2	2	3	4
301	3	3	5	4
302	1	1	2	1
303	2	3	2	2
304	2	2	3	2
305	2	2	3	3
306	4	2	3	3
307	5	5	4	5
308	2	1	2	2
309	2	2	2	3
310	4	5	4	3
311	3	1	2	4
312	2	3	4	4
313	1	2	3	2
314	3	5	4	3
315	2	2	2	2

316	5	4	4	3
317	2	2	3	2
401	3	5	5	2
501	2	3	4	4
502	2	2	1	3
503	2	1	2	3
504	5	3	4	5
505	5	2	4	5
506	4	2	4	5
507	3	2	2	2
601	5	2	3	4
602	5	2	2	2
603	4	2	3	3
604	4	3	4	4
605	3	3	3	4
607	3	2	2	4
608	4	2	4	4
701	4	2	2	4
703	2	2	2	2
801	2	3	4	3
802	1	1	1	2
901	3	3	3	5
902	3	2	5	4
903	5	4	5	4
1001	2	2	2	2
1002	1	2	2	3
1101	1	1	2	2
1102	1	1	1	1
1103	1	5	2	3
1104	1	1	1	2
1105	1	2	2	2
1106	1	1	1	2
1107	2	1	3	2
1108	1	1	1	1
1201	2	2	2	3
1202	2	1	2	2
1203	2	2	2	3
1205	2	2	2	3
1206	2	2	2	2
1207	2	1	2	2
1208	1	1	2	2
1209	2	1	1	2
1210	2	2	3	4
1401	5	5	5	5
1402	5	5	5	5
1403	5	5	5	5
1404	5	5	5	5
1405	5	5	5	5
1406	5	5	5	5
1407	5	5	5	5
1408	5	5	5	5
1409	5	5	5	5

(in the process of being classified
by the Marine Bird Subcommittee of the

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Scientific Advisory Board)

WAC 173-184-233 Marine Fish Vulnerability.

(1) Each of the designated marine and estuarine subregions of state waters in WAC 173-184-230 (2) shall be relatively ranked and scored for fishery species vulnerability to oil spills on a 1 to 5 scale for each season.

(2) Marine fishery species vulnerability ranking shall take into consideration species present, habitat preference, population status of species present, abundance, fecundity and sensitivity of life stages.

(3) Marine fishery species seasonal vulnerability scores for each of the subregions of state waters shall be determined from existing information and based on recommendations of the fishery species subcommittees.

(4) Based on the guidance provided in subsection (3) of this section, marine fishery species vulnerability ranking scores (FVS) for the marine and estuarine subregions of state waters are as follows in Table -- :

Table -- , Subregional Marine Fishery Species Vulnerability Scores (FVS)

<u>Subregion</u>	<u>Spring</u>	<u>Summer</u>	<u>Fall</u>	<u>Winter</u>
201	(in the process of being classified by Marine Fish Subcommittee, Scientific Advisory Board)			
203				
204				
205				
206				
207				
208				
209				
301				
302				
303				
304				
305				
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WAG 173-184-234 Marine Mammal Vulnerability.

(1) Each of the designated marine and estuarine subregions of state waters described in 173-184-230 (2) shall be relatively ranked and scored for marine mammal vulnerability to oil spills on a 1 to 5 scale for each season.

(2) Scoring shall take into consideration species presence, population status, breeding vulnerability, presence of young, physiological vulnerability, abundance, and other factors influencing species vulnerability.

(3) Marine mammal seasonal vulnerability scores for each of the marine and estuarine subregions of state waters shall be based on existing information and based on determinations made by the marine mammals subcommittee of the Scientific Advisory Board.

(4) Based on the guidance provided in subsection (3) of this section, marine mammal seasonal vulnerability scores for the marine and estuarine subregions of state waters are as follows in Table -- :

Table --. Marine Mammal Vulnerability Scores

<u>Subregion</u>	<u>Spring</u>	<u>Summer</u>	<u>Fall</u>	<u>Winter</u>
201				
203				
204				
205				
206				
207				
208				
209				
301				
302				
303				
304				
305				
306				
307				
308				
309				
310				
311				
312				
313				
314				
315				

(in the process of being classified
by Marine Mammal Subcommittee,
Scientific Advisory Board)

316
317
401
501
502
503
504
505
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601
602
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604
605
606
607
608
701
703
801
802
901
902
903
1001
1002
1101
1102
1103
1104
1105
1106
1107
1108
1201
1202
1203
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1205
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173-184-235 Recreational Vulnerability.

(1) Each of the designated marine and estuarine subregions of state waters described in 173-184-230 (2) shall be relatively ranked and scored on a 1 to 5 scale for each season.

(2) Marine- and estuarine-related scoring shall take into consideration seasonal level of participation in recreational activities, sensitivity of recreational activities to oil spills, number of recreation sites and types of recreational activities in a subregion.

(3) Marine- and estuarine-related recreational activities seasonal vulnerability scores for each of the subregions of state waters shall be determined from existing information and based on recommendations of the Recreation Subcommittee of the Scientific Advisory Board.

(4) Based on the guidance provided in subsection (3) of this section, marine- and estuarine-related vulnerability ranking scores (RVS) for the marine and estuarine subregions of state waters are as follows in Table -- :

Table --. Marine- and Estuarine-related Recreation Vulnerability Scores (RVS)

<u>Subregion</u>	<u>Spring</u>	<u>Summer</u>	<u>Fall</u>	<u>Winter</u>
201	(in the process of being classified by Recreation Subcommittee, Scientific Advisory Board)			
203				
204				
205				
206				
207				
208				
209				
301				
302				
303				
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903
1001
1002
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1104
1105
1106
1107
1108
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1405

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173-184-240 Inland Lakes and Streams

(1) The purpose of this section is to describe the method of ranking the quality of the inland lakes and stream receiving environments and to evaluate the impacts of oil spills on that environment for the purposes of assessing damages via the compensation table.

(2) Inland lakes and streams of Washington were divided into 62 Water Resource Inventory Areas (WRIA). Where appropriate the WRIA regions were subdivided by Department of Fisheries (WDF) stream numbers. These regions and stream designations, for purposes of RCW 90.48.366, are designated on the maps attached as appendix 1 of this chapter.

(3) For each stream or lake a Subregional Vulnerability Score (SVS) was calculated. This score is designed to rate all public resources and evaluate their vulnerability to spilled oil. Vulnerability of resources to oil was determined by the propensity of the oil to cause acute toxicity and mechanical injury as well as rate how long the oil persists in the environment. Seasonal vulnerability was determined by summing the seasonal SVS for birds, mammals, fish, recreational use and habitats. The ranking formula is as follows:

Subregional Vulnerability Score(SVS)_{ij}=

$$HVS_i + BVS + MVS + FVS + RVS$$

where HVS_i = habitat vulnerability score to oil's
propensity to cause i

BVS = bird vulnerability score

MVS = mammal vulnerability score

FVS = fish vulnerability score

RVS = recreation vulnerability score

i = acute toxicity, mechanical injury, or
persistence

j = fall, winter, spring or fall

WAC 173-184-241 Habitat Vulnerability.

(1) The purpose of this section is to describe the methodology for calculating the Habitat Vulnerability Score (HVS) portion of the Subregional Vulnerability Score (SVS) described in WAC 173-184-240 (3).

(2) The HVS ranking method employs a model to compare the various types of habitats, their sensitivity to each oil class and evaluate acute toxicity, mechanical injury and persistence effects on those habitats:

Habitat Vulnerability Score(HVS), =

$$(SO * HI) * HSS_i^{-2}$$

where: SO = stream order
HI = habitat index

HSS = habitat sensitivity score
i = acute toxicity, mechanical injury or
persistence.

(3) For each stream a habitat index (HI) is calculated to determine how the stream varies from the natural pristine condition (see scoring manual for details)

Habitat Index (HI) =

$$HI = [(P1 + P2 + P3 + P4 + P5 + P6)/Np] \times f1 \times f2 \times f3 \times f4$$

where: P1 = barriers to natural fish movement
P2 = urbanization
P3 = condition of riparian vegetation
P4 = condition of floodplain
P5 = land use of watershed
P6 = flow alteration
f1 = channel modifications
f2 = impoundment
f3 = water quality
f4 = streambed condition

(4) The Habitat Vulnerability Score (HVS) for a habitat type shall be increased by a factor of 1.5 when predesignated rare habitats are associated with the habitat type.

(4) Most streams in the state vary to some degree from the natural pristine condition as increased activities within individual watersheds have caused decreased stream and lake habitat quality. In order to account for that degradation prior to using the compensation table a habitat index (HI) was utilized to most closely represent existing stream conditions prior to the oil spill. (Fajen and Wehnes, 1981)

WAC 173-184-242 Bird Vulnerability

(1) Each inland lake and stream established in 173-184-241 (b) shall be relatively ranked and scored for bird vulnerability to oil spills on a 1 to 5 scale for each season.

(2) Bird vulnerability ranking shall take into consideration seasonal presence of species, population status of present species, abundance of present species and species vulnerability to oil spills, where species vulnerability is based on roosting habits, escape behavior, flocking behavior, feeding specialization, population size, reproductive capacity, breeding dispersion, winter dispersion, seasonal exposure to waters where oil spills could occur, and significance of Washington population to total population in each season.

(3) Bird seasonal vulnerability scores for each of the lakes and streams shall be determined at the time of the spill from existing information and based on recommendations of regional and area bird experts.

WAC 173-184-243 Fish Vulnerability

(1) Each freshwater lake and stream as designated in WAC 173-184-240 (2) shall be relatively ranked and scored for fishery species vulnerability to oil spills on a 1 to 5 scale for each season.

(2) Fish species vulnerability ranking shall take into consideration species present, habitat preference, population status of species present, abundance, fecundity and sensitivity of life stages.

(3) Fish species seasonal vulnerability scores for each lake and stream shall be determined at the time of the spill from existing information and will be based on recommendations of regional and area fishery experts.

WAC 173-184-244 Mammal Vulnerability

(1) Each freshwater lake and stream as designated in WAC 173-184-240 (2) shall be relatively ranked and scored for mammal vulnerability to oil spills on a 1 to 5 scale for each season.

(2) Scoring shall take into consideration species presence, population status, breeding vulnerability, presence of young, physiological vulnerability, abundance, and other factors influencing species vulnerability.

(3) Mammal seasonal vulnerability scores for each lake and stream shall be determined at the time of the spill from existing information and will be based on recommendations of regional and area mammal experts.

WAC 173-184-245 Recreation Vulnerability

(1) Each freshwater lake and stream as designated WAC 173-184-240 (2) shall be relatively ranked and scored on a 1 to 5 scale for each season.

(2) Freshwater lake and stream scoring shall take into consideration seasonal level of participation in recreational activities, sensitivity of recreational activities to oil spills, number of recreation sites and types of recreational activities.

(3) Recreational activities seasonal vulnerability scores for each of the freshwater streams and lakes shall be determined from existing information and will be based on recommendations of regional and area recreational experts.

173-184-250 Freshwater Wetlands

(1) The purpose of this section is to describe the method of ranking the quality of the freshwater wetland receiving environment and to evaluate the impacts of oil spills on that environment for the purposes of assessing damages via the compensation table.

(2) Freshwater Wetlands were divided into 4 general classes. These wetland types, for purposes of RCW 90.48.366, are described in appendix -- of this chapter.

(3) For each wetland type a Subregional Vulnerability Score (SVS) was calculated. This score is designed to rate all public resources associated with wetlands and evaluate their vulnerability to spilled oil. Vulnerability of resources to oil was determined by the propensity of the oil to cause acute toxicity and mechanical injury as well as rate how long the oil persists in the environment. Seasonal vulnerability was determined by summing the seasonal SVS for birds, mammals, fish, recreational use and habitats. The ranking formula is as follows:

Subregional Vulnerability Score(SVS)_{i,j} =

HVS_i + BVS + MVS + FVS + RVS

where HVS_i = habitat vulnerability score to oil's propensity to cause i

BVS = bird vulnerability score

MVS = mammal vulnerability score

FVS = fish vulnerability score

RVS = recreation vulnerability score

i = acute toxicity, mechanical injury, or persistence

j = fall, winter, spring or fall

WAC 173-184-251 Habitat Vulnerability.

(1) The purpose of this section is to describe the methodology for calculating the Habitat Vulnerability Score (HVS) portion of the Subregional Vulnerability Score (SVS) described in WAC 173-184-250 (3).

(2) The ranking method employs a model to compare the various types of habitats, their sensitivity to each oil class and evaluate acute toxicity, mechanical injury and persistence effects on those habitats in order to establish a Habitat Vulnerability Score (HVS):

Habitat Vulnerability Score(HVS)_i =

$$(WT * HI) * HSS_i^{1.5}$$

where: WT = wetland type
HI = habitat index

HSS = habitat sensitivity score
i = acute toxicity, mechanical injury or persistence.

(3) Wetland types (WT) are based on the Department of Ecology's 1990 Model Wetlands Protection Ordinance Section 4.4.

(4) The habitat index (HI) is described in WAC 173-184-241(3).

(5) The Habitat Vulnerability Score (HVS) for a habitat type shall be increased by a factor of 1.5 when predesignated rare habitats are associated with the habitat type.

WAC 173-184-252 Bird Vulnerability

(1) Each freshwater wetland established in 173-184-251 (2) shall be relatively ranked and scored for bird vulnerability to oil spills on a 1 to 5 scale for each season.

(2) Bird vulnerability ranking shall take into consideration seasonal presence of species, population status of present species, abundance of present species and species vulnerability to oil spills, where species vulnerability is based on roosting habits, escape behavior, flocking behavior, feeding specialization, population size, reproductive capacity, breeding dispersion, winter dispersion, seasonal exposure to waters where oil spills could occur, and significance of Washington population to total population in each season

(3) Bird seasonal vulnerability scores for each of the lakes and streams shall be determined at the time of the spill from existing information and based on recommendations of regional and area bird experts.

WAC 173-184-253 Fish Vulnerability

(1) Each freshwater wetland as designated in WAC 173-184-250 (2) shall be

relatively ranked and scored for fishery species vulnerability to oil spills on a 1 to 5 scale for each season.

(2) Fish species vulnerability ranking shall take into consideration species present, habitat preference, population status of species present, abundance, fecundity and sensitivity of life stages.

(3) Fish species seasonal vulnerability scores for each freshwater wetland shall be determined at the time of the spill from existing information and will be based on recommendations of regional and area fishery experts.

WAC 173-184-244 Mammal Vulnerability

(1) Each freshwater wetland as designated in WAC 173-184-250 (2) shall be relatively ranked and scored for mammal vulnerability to oil spills on a 1 to 5 scale for each season.

(2) Scoring shall take into consideration species presence, population status, breeding vulnerability, presence of young, physiological vulnerability, abundance, and other factors influencing species vulnerability.

(3) Mammal seasonal vulnerability scores for each freshwater wetland shall be determined at the time of the spill from existing information and will be based on recommendations of regional and area mammal experts.

WAC 173-184-245 Recreation Vulnerability

(1) Each freshwater wetland as designated WAC 173-184-240 (2) shall be relatively ranked and scored on a 1 to 5 scale for each season.

(2) Freshwater wetland scoring shall take into consideration seasonal level of participation in recreational activities, sensitivity of recreational activities to oil spills, number of recreation sites and types of recreational activities.

(3) Recreational activities seasonal vulnerability scores for each of the freshwater wetlands shall be determined from existing information and will be based on recommendations of regional and area recreational experts.

CHAPTER 173-185 WAC

DETERMINATION OF COMPENSATION

- 173-185-010 Purpose
- 173-185-020 Authority
- 173-185-030 Applicability

- 173-185-100 Definitions

173-185-200 Compensation Schedule Approach
173-185-210 On-Scene-Coordinator (OSC) Responsibilities
173-185-220 Preassessment Screening Committee Responsibilities
173-185-230 Determination of Compensation

173-185-300 Modification of Compensation Based on Actions taken by the Responsible Party.

173-185-400 Appeal

173-185-500 Severability

WAC 173-185-010 Purpose The purpose of this chapter is to describe the method for determining appropriate compensation for resource losses

WAC 173-185-020 Authority

WAC 173-185-030 Applicability

WAC 173-185-200 Compensation Schedule Approach.

The purpose of this section is to describe the required procedures for application of the compensation schedule to an oil spill.

WAC 173-185-210 On-Scene-Coordinator (OSC) Responsibilities.

(1) The OSC shall determine:

- (a) identification of liable party
- (b) the quantity and type of oil spilled
- (c) the extent of the spill
- (d) the amount of oil cleaned up

(2) shall provide this information in a timely manner to the preassessment screening committee chair.

WAC 173-185-220 Preassessment Screening Committee Responsibilities.

(1) The preassessment screening chair shall determine in consultation with the OSC and preassessment screening committee:

- (a) the oil effects scores for the spilled oil as provided in WAC 173-000-080,
- (b) subregion(s) exposed to the spilled oil.
- (c) habitat types existing in subregions exposed to the spilled oil.
- (d) percent coverage of each habitat type in each subregion exposed to the spilled oil,
- (e) subregional habitat vulnerability scores for acute toxicity, mechanical injury and persistence as provided in WAC 173-000-090 and

(f) the most vulnerable season during which effects of the spill are expected to continue.

(2) Based on the determinations made by the preassessment screening committee chair described in WAC 173-185-210 and 220, the oil toxicity and the resource vulnerability scores for each subregion exposed to oil as provided in WAC 173-184, compensation for each spill incident applicable under WAC 173-183 to 185 shall be determined.

WAC 173-185-230 Determination of Compensation

(1) Compensation in each subregion is determined using three factors:

- (a) The number of gallons of oil spilled
- (b) The combined toxicity rating for acute toxicity, mechanical injury and persistence
- (c) individual resource vulnerability scores

(2) The following formula is used to determine the appropriate compensation:

Compensation (\$) =

$$\text{No. of gallons spilled} * \text{scaling factor} * \text{OIL}_i * (\text{HVS}_i + \text{BVS} + \text{MVS} + \text{FVS} + \text{RVS})$$

where OIL_i = oil effects score

BVS = marine bird vulnerability score

MVS = marine mammal vulnerability score

FVS = fisheries species vulnerability score

RVS = recreation vulnerability score

HVS_i = habitat vulnerability score

i = acute toxicity, mechanical injury and persistence

(note: scaling factor has yet to be determined)

(3) Where more than one subregion is exposed to spilled oil, compensation shall be calculated using resource vulnerability scores from the most sensitive subregion exposed to the spilled oil.

173-185-300 Modification of Compensation Based on Actions Taken by Responsible Party.

(1) The dollar amount of compensation calculated under WAC 173-185 shall be reduced under the following circumstances:

(a) In cases where spilled oil is recovered within 24 hours of the beginning of a spill, the number of gallons used in the compensation schedule formula shall be the number of gallons spilled minus the number of gallons recovered within 24 hours.

(b) In cases where the potentially liable party takes an action that results in successful protection of special habitat features including eelgrass beds, salt marshes, kelp beds, predesignated rare habitats, and other special features including seal and sea lion haulouts, national and state park

*Not
to
be
used
in
the
rule*

and protected areas, herring spawning areas, salmon concentration areas, and seabird breeding colonies, the amount of compensation calculated under WAC 173-185-230 shall be reduced by the amount that the special feature contributed to the amount of compensation calculated.

(c) In cases where a potentially liable party acts to enhance detection of a spill, determination of the quantity of oil spilled, and/or extent of natural resource damages, the amount of compensation calculated under WAC 173-185-230 shall be reduced by 10%.

(2) In no case shall the modifications to compensation enumerated in subsection (1) of this section result in a reduction of compensation that is less than \$1 per gallon of oil spilled.

(3) The dollar amount of compensation calculated under WAC 173-185-230 shall be increased under the following circumstances:

(a) In cases where a potentially liable party impedes detection of the spill, determination of the number of gallons spilled, and/or extent of resource damages such as the unauthorized removal of evidence such as injured fish or wildlife, the amount of compensation calculated under WAC 173-185-230 shall be increased by 10%.

(b) In cases where the spiller or other potentially liable party takes an action that impedes detection of the spill, determination of the number of gallons spilled, or extent of resource injuries, the amount of savings that may have been realized by the taking the action shall be multiplied by 1.25 and added the amount of compensation calculated in WAC 173-185-230.

(4) In no case shall the amount of compensation exceed \$50 per gallon of oil spilled.

173-185-400 Appeal.

Any person adversely affected by a decision of the department or the preassessment screening committee under this chapter may appeal such decision to the pollution control hearings board pursuant to chapter 43.21B RCW.

173-185-500 Severability.

If any provision of this rule or its application to any person or circumstance is held invalid, the remainder of the rule or application of the provision to other persons or circumstances is not affected.

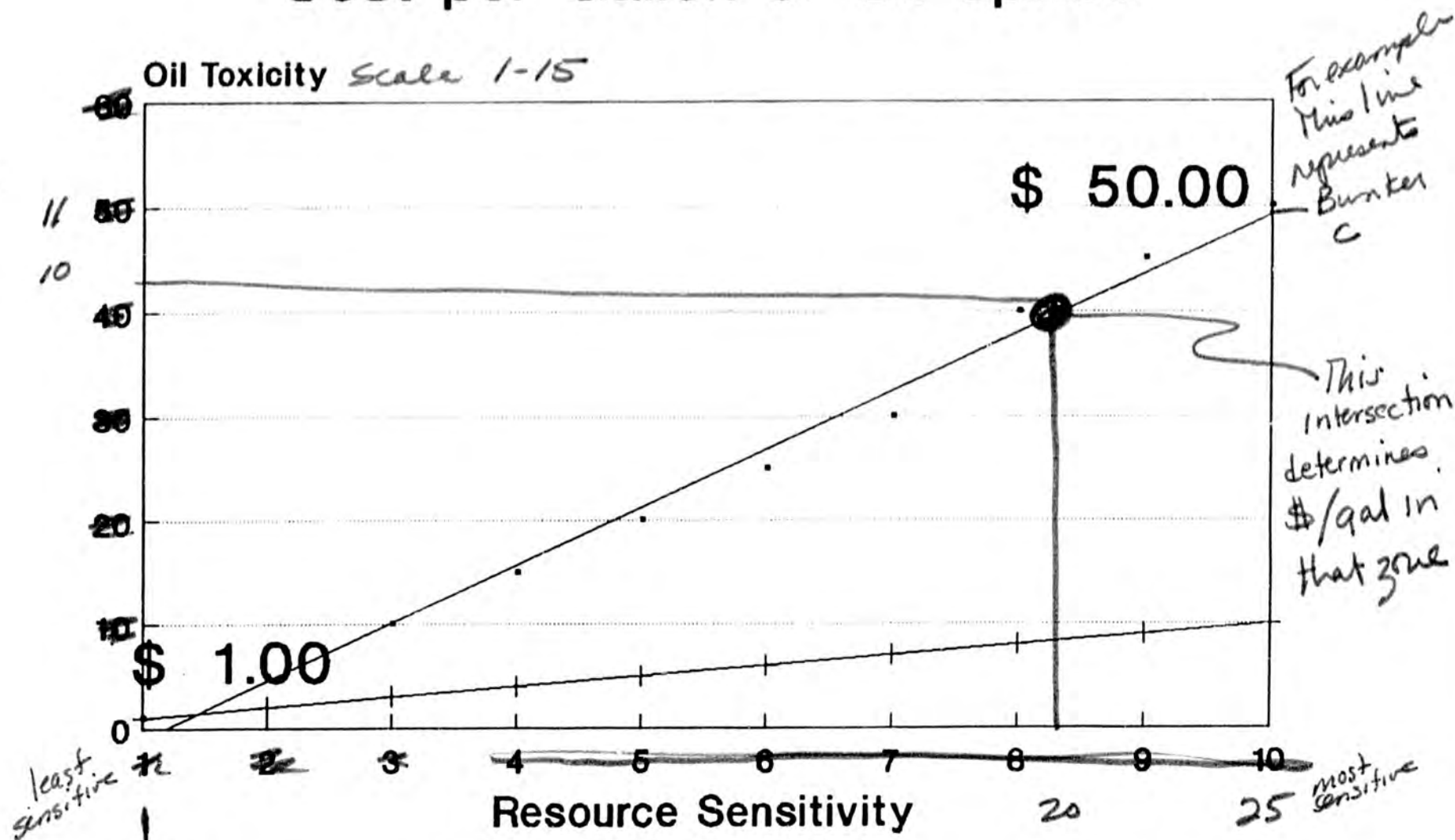
5 Table

We are limited to
\$1-50/gal of oil spilled

This is done by 4
seasons to account
for population shifts
and sensitivities i.e.
spring more sensitive than
Summer

HYPOTHETICAL COMPENSATION TABLE

Cost per Gallon of Oil Spilled



Source: Logan

Once dollar/gal determined we then factor in the action taken by resp. party that may have limited damage, consequently lowering final \$/gal assessment.