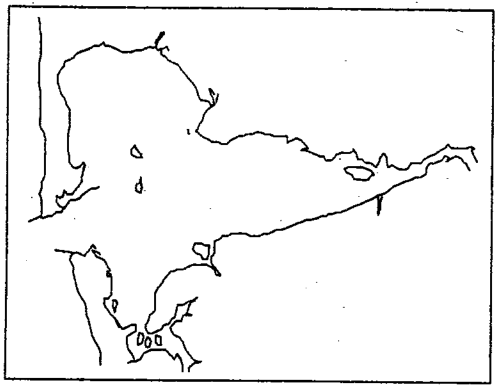
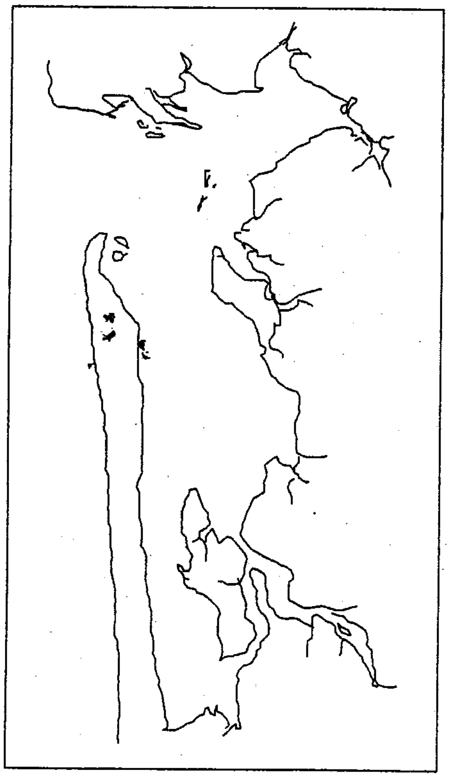


**FINAL**

**MARCH 31, 1992**

# Supplemental Environmental Impact Statement

## USE OF THE INSECTICIDE CARBARYL TO CONTROL GHOST AND MUD SHRIMP IN OYSTER BEDS OF WILLAPA BAY AND GRAYS HARBOR





Washington Department of Fisheries
Washington Department of Ecology

Olympia, Washington

**Accessibility Options**

*If you need this document in a format for the visually impaired, call Water Quality at 360-407-6600. Persons with hearing loss can call 711 for Washington Relay Service.*

*Persons with a speech disability can call 877-833-6341.*

Ecology publication no. 92-10-206

# F I N A L

## SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT

## USE OF THE INSECTICIDE CARBARYL TO CONTROL

## GHOST AND MUD SHRIMP

## IN OYSTER BEDS OF

## WILLAPA BAY AND GRAYS HARBOR

Washington Department of Fisheries
Washington Department of Ecology

Prepared for Citizens,
Citizen Groups, and Government Agencies

in Compliance with

The State Environmental Policy Act of 1971
Revised Code of Washington 43.21.C

Date of Issue: March 1992

STATE OF WASHINGTON
DEPARTMENT OF FISHERIES

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY

March 31, 1992

The insecticide carbaryl (trade name "Sevin") has been used in Washington marine/estuarine waters since 1963 to control burrowing shrimp on commercial oyster grounds with approval of the Washington Departments of Fisheries and Ecology. In 1985, the two departments issued a Final Environmental Impact Statement (FEIS) concerning the use of carbaryl in Willapa Bay and Grays Harbor. In addition to reviewing available information, the FEIS identified several areas of potential environmental impacts for which insufficient information was available.

Since 1985, carbaryl application has been allowed provided that research be conducted to address the concerns raised in the FEIS. A Draft Supplemental EIS (SEIS) was issued in February 1989 to present the results of this research and additional information that had since become available. In response to public comments and because of concerns expressed by staff of the two agencies, the Draft SEIS was substantially rewritten and reissued for public comment in January 1991.

The attached document represents the Final SEIS. It incorporates changes made to the Draft in response to public and agency comments. We wish to thank those who took the time to review and comment upon the draft.

Duane E. Phinney
Habitat Management Division Chief
SEPA Responsible Official
Department of Fisheries

Michael Llewelyn
Program Manager
Department of Ecology

## FACT SHEET

<u>Title:</u> Use of the insecticide Carbaryl to control ghost and mud shrimp in oyster beds of Willapa Bay and Grays Harbor

<u>Oyster Growers' Proposed Action:</u> The action proposed by the oyster growers (the proponents of this Supplemental Environmental Impact Statement) is the annual application of the pesticide carbaryl ("Sevin") to control burrowing shrimp on up to 800 acres of privately owned or leased oyster growing grounds in Willapa Bay and Grays Harbor. This proposed action represents a change from the 1985 Final Environmental Impact Statement which had as the proposed action: "Annual application of the pesticide sevin to control ghost and mud shrimp on up to 400 acres of oyster growing grounds in Willapa Bay and Grays Harbor".

<u>Preferred Alternative:</u> The preferred alternative of the co-lead agencies is the development and use of an Integrated Management Plan. With this approach, sites are evaluated on a site-by-site basis and control, growout, and harvesting methods which are most appropriate are applied to each site. The goal of the management plan is to find suitable alternatives for shrimp control in order to significantly reduce or eliminate the use of carbaryl while maintaining a viable oyster industry. An IMP committee was formed and began meeting in February 1991.

<u>Project Location:</u> Willapa Bay and Grays Harbor.

<u>Proponent:</u>
Willapa Bay - Grays Harbor Oyster Growers Association
c/o Coast Oyster Company
P. O. Box 166
South Bend, Washington 98586

<u>Lead Agency/Responsible Official:</u>
Washington Department of Fisheries
Duane E. Phinney, Chief
Habitat Management Division
115 General Administration Building
Olympia, WA 98504

Washington Department of Ecology
Mike Llewyln, Program Manager
Mail Stop PV-11
Olympia, WA 98504

<u>Contact Persons:</u>
Tom Northup, Department of Fisheries
331 State Highway 12
Montesano, WA 98563
(206) 249-4628

Bill Backous, Department of Ecology
Mail Stop LU-11
Olympia, WA 98504
(206) 753-4089

Licenses and Permits Required:

Department of Fisheries
Shellfish Pest Control Permit
WAC 220-20-010(16)

Department of Ecology
Short-term Modification of Water Quality Standards Permit
WAC 173-201

Principal Contributors:

Eric Hurlburt, Department of Fisheries; Russ McMillan and Marvin Vialle, Department of Ecology -- Editing of First Draft.

Steve Barry and Kurt Fresh, Department of Fisheries, and Bill Young, Department of Ecology -- Preparation and Editing of Final Draft and Final SEIS.

Daniel Cheney and Richard Wilson, BioAquatics International -- Preparation and Production of First Draft.

David Armstrong, Brett Dumbauld and Daniel Doty, University of Washington School of Fisheries -- Crab and Shrimp Research and Assessment.

Charles Simenstad and Jeff Cordell, University of Washington Fisheries Research Institute -- Epibenthic Research and Assessment.

Greg Hueckel, Brian Benson, Dan Pentilla, Anne Reaman, Kevin Li and Ray Buckley, Department of Fisheries -- Marine Fish Research and Assessment.

Mark Carr, Steve Schroder and Kurt Fresh, Department of Fisheries -- Marine Fish Bioassay and Assessment

Date of Issuance of Final Supplemental EIS: February 1992

Nature of Final Actions: Decisions by the Department of Fisheries to issue or deny Pest Control Permits and the Department of Ecology to issue Water Quality Permits regarding the use of carbaryl.

Type and Timing of Subsequent Environmental Review: No further SEPA review is anticipated.

Location of Background Data: Washington Department of Fisheries
115 General Administration Building; Olympia, WA 98504

Costs: Single copies of this document may be obtained free of charge from the Washington Department of Fisheries while supplies last. The cost of additional copies will depend on costs of reproduction and mailing.

# DISTRIBUTION LIST

## FEDERAL AGENCIES

U. S. Army Corps of Engineers
Environmental Resources Section
P. O. Box C-3755
Seattle, WA 98124

U. S. Environmental Protection Agency
1200 6th Avenue
Seattle, WA 98101

U. S. Fish and Wildlife Service
Ecological Services
2625 Parkmont Lane S. W.
Olympia, WA 98502

Nat. Marine Fisheries Service
Environmental and Technical Services Division
847 NE 19th Avenue, Suite 350
Portland, OR 97232

## STATE AGENCIES

Department of Ecology
Environmental Review PV-11
Olympia, WA 98504

Department of Wildlife
Habitat Management Division GJ-11
Olympia, WA 98504

Parks and Recreation Commission
Environmental Coordination Section KY-11
Olympia, WA 98504

Department of Natural Resources
Division of Marine Land Management QW-21
Olympia, WA 98504

Dept. of Social & Health Serv.
Water Supply and Waste Section LD-11
Olympia, WA 98504

Dept. Planning and Community Affairs GH-51
Olympia, WA 98504

Department of Agriculture
Attn: Dr. John Pitts AX-41
Olympia, WA 98504

## COUNTIES

Pacific Co. Planning Dept.
P. O. Box 68
South Bend, WA 98586

Grays Harbor County Planning and Building
P. O. Box 390
Montesano, WA 98520

Grays Harbor Regional Planning
2109 Sumner
Aberdeen, WA 98520

## CITIES

City of Long Beach
P. O. Box 310
Long Beach, WA

City of Raymond
230 2nd
Raymond, WA 98577

City of South Bend
1st and Willapa
P. O. Box 34
South Bend, WA 98586

City of Aberdeen
200 E. Market
Aberdeen, WA 98520

City of Hoquiam
717 K
Hoquiam, WA 98520

City of Westport
506 N. Montesano
P. O. Box 505
Westport, WA 98595

## NEWSPAPERS

Aberdeen Daily World
P. O. Box 269
Aberdeen, WA 98520

Seattle Times
P. O. Box 70
Seattle, WA 98111

Seattle Post Intelligencer
101 Elliott Ave. West
Seattle, WA 98121

Chinook Observer
P. O. Box 427
Long Beach, WA 98631

Daily Olympian
P. O. Box 407
Olympia, WA 98507

Willapa Harbor Herald
P. O. Box 706
Raymond, WA 98577

<u>OTHER</u>

Washington Environ. Council
4516 University Way NE
Seattle, WA 98105

Friends of the Earth
4512 University Way NE
Seattle, WA 98105

Mr. Lynn Cornelius
Nature Conservancy
1601 2nd Ave. Suite 910
Seattle, WA 98101

N. W. Indian Fisheries Commission
2625 Parkmont Lane, S. W.
Olympia, WA 98502

Mr. Bob Borjacas
Shoalwater Tribe
P.O. Box 130
Tokeland, WA 98590

Mr. Tim Smith
P. C. O. G. A.
1023 S. Adams Street #129
Olympia, WA 98501

Willapa Bay - Grays Harbor Oyster Growers Association
c/o Coast Oyster Company
P. O. Box 166
South Bend, Washington 98586

Washington Dungeness Crab Association
c/o Ernie Summers
Star Route 1, Box 137
Grayland, WA 98547

Mr. Bill Hammons
P. O. Box 516
Tokeland, WA 98590

Mr. Ray Nelson
2723 Tokeland Rd.
Tokeland, WA 98590

Mr. Lee Wiegardt
Wiegardt and Sons
P. O. Box 298
Ocean Park, WA 98640

Coast Oyster Co., Inc.
520 Corporate Center Suite 101
Bellevue, WA 98005

Richard L. Wilson
Bay Center Mariculture Co.
P. O. Box 356
Bay Center, WA 98527

Willapa Hills Audubon Society
3326 Col. Hts. Road
Longview, WA 98632

Ms. Pamela Croker-Davis
P. O. Box 462
Olympia, WA 98507

Mr. Brady Engvall
Star Route Box 700
Aberdeen, WA 98520

E. H. Bendiksen Co.
P. O. Box 127
South Bend, WA 98586

R and B Oyster
P. O. Box 321
Bay Center, WA 98527

Nisbet Oyster Company
P. O. Box 355
Bay Center, WA 98527

Timberland Regional Library
415 Airdustrial Way SW
Olympia, WA 98501-5799

T A B L E  O F  C O N T E N T S

## LIST OF FIGURES

## LIST OF TABLES

## I. EXECUTIVE SUMMARY

This is a supplemental environmental impact statement (SEIS) to the final environmental impact statement (FEIS) prepared in 1985 on the use of the insecticide carbaryl (tradename SEVIN) to control burrowing shrimp in Willapa Bay and Grays Harbor.

### A. The proposed action

The proposed action by the oyster growers of Willapa Bay and Grays Harbor is the annual application of the pesticide carbaryl on up to 800 acres of privately owned or leased oyster growing grounds in Grays Harbor and Willapa Bay. The purpose of the application of carbaryl is to control ghost shrimp and mud shrimp on the oyster growing grounds. This proposed action represents a change from the 1985 FEIS which had as the proposed action: "Annual application of the pesticide sevin to control ghost and mud shrimp on up to 400 acres of oyster growing grounds in Willapa Bay and Grays Harbor".

### B. Rationale for use of Carbaryl

Two burrowing shrimp species, mud shrimp and ghost shrimp, are found in Willapa Bay and Grays Harbor. Both are abundant, have generally similar life histories, but differ in feeding and burrowing habits. They modify the substrate by sorting and loosening sediments. Oyster growers, some University of Washington (UW) researchers, and some Washington Department of Fisheries (WDF) biologists familiar with oyster cultural practices have observed that oyster shell and oysters on the sediment surface sink or become buried, and seed oysters are smothered in areas that have high densities of burrowing shrimp. Oyster growers have found that control of burrowing shrimp populations is necessary for commercial oyster culture to be economical and that application of carbaryl is an effective method of control.

### C. Background

Carbaryl has been used to control burrowing shrimp on oyster beds in the State of Washington since 1963. While it is commonly used to control pests on agricultural lands, its use in marine environments is limited in Washington to controlling burrowing shrimp. Between 1975 and 1981, WDF, in cooperation with the Washington Department of Agriculture (DOA) and Environmental Protection Agency (EPA), developed a review and approval policy for the use of carbaryl. This policy allowed carbaryl application in estuarine areas of the state under a special permit. Permit conditions and guidelines, and the entire label for carbaryl, are reprinted and summarized in the 1985 FEIS.

The FEIS was prepared for the shrimp control program by WDF and the Washington Department of Ecology (DOE) in response to increasing public and agency concern over possible impacts of carbaryl to plants and animals other than the target species. The FEIS reviewed the problem and also identified additional concerns.

Since 1986, carbaryl applications were allowed in Willapa Bay and Grays Harbor under the condition that research directed at concerns noted in the FEIS be completed. Research results and additional observations were to be summarized in an SEIS. The principal purpose of the SEIS is to provide updated information needed to properly condition water quality certifications and Chemical Pest Control permits issued by DOE and WDF, respectively.

The format for the SEIS was based on an outline prepared by WDF and DOE in April 1988 and modified in May 1988. With minor exceptions, that outline is the same as the table of contents of this SEIS. A detailed summary of the 1985 FEIS is included as an appendix in the SEIS. If more information is required, particularly on literature published prior to 1984, the 1985 FEIS should be consulted.

**D. Impacts of carbaryl treatment**

Much of the general assessment of impacts related to carbaryl usage was provided in the 1985 FEIS. The SEIS focuses on specific issues and concerns that are summarized below. In general carbaryl-related studies have focused on short-term, acute affects.

- <u>Transport of carbaryl:</u> Carbaryl is applied to oyster tracts during low tide and when wind velocity is low. During incoming tides, a portion of the carbaryl is carried off the sprayed tract in the direction of the tidal flow. This involves the movement of carbaryl in solution and in suspension. Particle transport in suspension appears to be most important and stops when carbaryl fragments settle out of the water column. Studies monitoring tidal water flowing off sprayed tracts detected carbaryl at distances of up to 1,700 feet from test tracts and 1-naphthol, the breakdown product of carbaryl, up to 225 feet from tracts, under what was a "worst-case" scenario.

- <u>Persistence of carbaryl:</u> Data presented in the literature gives a mixed picture of persistence. It shows that carbaryl and 1-naphthol persist in water or sediments for periods ranging from a few days to over a year in sediments, depending on environmental conditions. Analyses of sediment samples taken in 1989 (WDOA Laboratory, 1990) found that carbaryl concentrations decreased from mean values of 41 to 83 ppm on the day of treatment to 0.7 to 14.5 ppm 24 hrs after treatment. Although probable sample contamination confused results, carbaryl concentrations were very low after 16 days (about 0.02 ppm or less) and probably below the detection limit (0.002 ppm) after 28 days. The results suggest that carbaryl concentrations in sediments decrease rapidly during summertime conditions.

- <u>Effects on plants and animals</u>

  <u>Plants:</u> Only a few studies dealing with the effects of carbaryl on aquatic plants are available. None of these studies directly assesses impacts in estuarine systems or deals with key species (e.g., eelgrass) found in Willapa Bay and Grays Harbor. Direct physiological impacts (e.g., mortality, decline in growth) to plants are unlikely. Spraying carbaryl could increase the biomass of aquatic plants by firming and increasing the density of sediments. However, some of these "benefits" may be offset by oyster culture practices (e.g., harvesting by dredge).

  <u>Invertebrates, General:</u> Carbaryl will kill a number of invertebrate species, including crab, burrowing shrimp, and polychaete worms. Crustaceans appear to be most sensitive to carbaryl. The $LC_{50}$s for various invertebrates tested in 24-96 hr exposures ranged from 0.03-7.3 ppm, depending on the species and life stage tested. Some invertebrates will be killed in off-tract areas due to carbaryl transport. Treated beds are recolonized by smaller crustaceans and worms within 24 hrs of spraying and by crabs within two weeks after treatment, when carbaryl concentrations in sediments are below $LC_{50}$s for all species tested.

  <u>Dungeness Crab:</u> Carbaryl is highly toxic to Dungeness crab. It affects crab by direct contact and when crab feed on shrimp killed by carbaryl. Crab losses occur primarily in intertidal areas on and adjacent to treated tracts on the day of spraying. Minimal losses occur subtidally in drainage channels associated with the tracts. Residual impacts (more than 24-hr after treatment) were not evident. Recent research indicates that oysters provide habitat for juvenile Dungeness crab. Impacts of the application of carbaryl on Dungeness crab are mitigated for by the replacement of burrowing shrimp habitat with oyster habitat. The habitat generated by oyster culture practices appears to more than offset crab killed by carbaryl spraying.

Epibenthic Invertebrates: These animals are small organisms which live on or near the sediment surface and are important food items for salmon and other animals. A survey of a treated and a control tract to assess short-term affects of carbaryl application showed there was an increase in total epibenthic densities in both areas after carbaryl application. There were differences in the densities between treated and control tracts of some individual epibenthic taxa. For example, densities of cumaceans and *Corophium* on the treated tract were less than on the control two weeks after treatment. Because of the limited scope of the sampling design, it was not possible to separate the effects of carbaryl on the epibenthos from those of other factors. Possible long-term affects were not studied.

Fish: There are a variety of finfish species found over the oyster beds of Willapa Bay and Grays Harbor. Many occur seasonally, such as juvenile salmonids which are most abundant in the late spring. Some fish are trapped during low tides in shallow pools on the flats. Carbaryl, applied directly in these pools, is toxic to the fish. Some off-tract mortalities may also occur, but they are probably insignificant in subtidal areas where fish are concentrated. The reported lethal concentrations for both adult and juvenile fish are, in general, an order of magnitude greater than those affecting crustaceans.

There was concern that fish feeding upon ghost shrimp, worms and other animals killed by carbaryl application could also be affected. Results of bioassay trials demonstrated that there was a low risk of toxic effects to fish due to eating contaminated animals.

Birds: Bird species coming in contact with carbaryl in the time between spraying and when the bed is covered by the incoming tide are mainly gulls. Agency observers have not seen dead or distressed birds on the sprayed beds, even though heavy feeding activity occurs at times on the treated beds. There is no evidence in the literature suggesting that ingestion of dead or dying organisms contaminated with the quantities of carbaryl typically reported in Willapa Bay and Grays Harbor will have acute effects on birds. The potential for significant sublethal impacts, such as to reproductive capability, is unknown but unlikely.

- Potential for human ingestion and contamination -- There is no significant risk of direct or indirect (i.e., in drinking water) human exposure to carbaryl in Willapa Bay or Grays Harbor. The general human health risk is reported to be slight, even under the most severe exposure conditions.

**E. Alternatives**

1. Oyster growers proposal.
2. Integrated Management Plan, the preferred alternative.
3. No application of carbaryl, maintenance of existing ground culture methods.
4. No application of carbaryl, alternative growout options.
5. Carbaryl treatment at historical scale.

## II. BACKGROUND

### A. Recent History of Carbaryl Applications in Marine Waters

The first experiments with marine application of carbaryl were on the east coast in the late 1950's and early 1960's to control oyster drills. Since that time, marine use of carbaryl has been limited to control of burrowing shrimp in Washington State and Tillamook Bay, Oregon. Carbaryl is the only known large-scale method to control burrowing shrimp, and is authorized for use in freshwaters to control insect pests on rice (Sevin product label).

#### 1. Use in Washington State

Prior to 1984, treatment was limited to 300 acres in Willapa Bay and 100 acres elsewhere in the state, primarily in Grays Harbor; during this period, 10 pounds/acre (active carbaryl) were sprayed. WDF also permitted one treatment in Puget Sound -- 14 acres in Liberty Bay in 1982. After 1984, carbaryl was applied at 5 to 7.5 pounds/acre.

Following the El Nino[1] of 1982-83, a significant increase in shrimp abundance occurred. As a result, EPA and the state agencies authorized treatment of up to 600 acres in Willapa Bay and 200 acres elsewhere in the state. Treatment over seed oysters as well as on bare ground was also authorized. Treatments during 1963-89 were restricted to July and August with one exception- late June 1988, and to beds meeting the shrimp density and locational requirements specified in the EPA permit. For information on treatment details prior to 1984 consult the 1985 FEIS.

#### 2. Use in Oregon State

Carbaryl was used from 1964 to 1981 by several growers in Tillamook Bay, Oregon who were suffering oyster losses attributed to burrowing shrimp. These growers were farming about 3,000 acres of privately held oyster beds. Most of the culture was on the bottom, with several growers attempting off-bottom culture similar to Washington oyster producers (Hayes, Hayes Oyster Company; Faudskar, Marine Extension Agent, 1988, personal communications).

---

[1] A periodic change in the direction of water currents near the equator modifying upwelling, water temperature and productivity along the coast of North America.

Tillamook oyster growers noted in the early 1960's that mud and ghost shrimp appeared to interfere with oyster cultivation. Beginning in 1964 about 100 acres were treated annually with carbaryl (Hayes and Faudskar, 1988, personal communications; Bakalian, 1985).

In early 1982, three oyster growers sought a permit to spray carbaryl on 140 acres. In August, 1982, the state granted the permit. This was appealed by environmental groups and one year later, the Oregon Court of Appeals upheld the permit (Bakalian, 1985).

The Oregon Land Use Board of Appeals (LUBA) and the Appeals Court dealt with the issue of carbaryl spraying versus State land-use planning standards. LUBA said the state's finding that organisms affected by carbaryl would "regenerate rapidly" was not supported by reliable evidence and had been made without addressing the question of how organisms outside the target area would be affected. LUBA dismissed reliance on studies performed in Washington State. In 1984, the Oregon Court of Appeals issued an opinion affirming LUBA's decision. It required an impact assessment to be preceded by an adequate biological inventory. Since no state or private funds were available, this action halted the proposed spraying (Bakalian, 1985).

The principal culture areas in Tillamook Bay have changed since shrimp were recognized as a production problem. The one large grower reported that he lost his prime grounds to burrowing shrimp and subsequently moved most of his operation to less productive grounds in the inner bay (Hayes, Hayes Oyster Company, 1988, personal communication). One off-bottom grower recently wrote that he has been unable to produce a commercial crop, partially because of high shrimp densities (Faudskar, 1988; Faudskar, 1988, personal communication). He also stated that juvenile oysters died when they were removed from off-bottom trays and placed onto shrimp infested ground (Faudskar, 1988).

**B. Present Status**

WDF authorizes and regulates carbaryl application under WAC 220-20-10(16). Use must comply with provisions of the Washington State Special Local Needs Pesticide Registration No. WA760021 issued by EPA through the Washington Department of Agriculture under authority of section 24 (c) of the Amended Federal Insecticide, Fungicide, and Rodenticide Act.

The 1985 FEIS (Section 2.3) listed WDF criteria for use and application of carbaryl. Criterion 4 states that carbaryl can only be applied when beds are "dry". The intent of this criterion is to begin treatment after the bed has been uncovered by the receding tide and water has drained from the bed to the maximum extent possible. The on-site WDF representative authorizes treatment when this critierion has been met. Nevertheless, on some beds ponds of water may remain due to topographical irregularities. When a bed does not drain as much as expected, carbaryl application may be either rescheduled or the bed remarked so that the inadequately drained portion is excluded from treatment that day. Small channels continue to drain some beds during and after carbaryl application until the incoming tide begins to re-flood the bed.

Carbaryl is highly toxic to the targeted shrimp species and the oyster industry has used it to treat prime oyster grounds since 1963 (see the Summary and the 1985 FEIS for a history of shrimp control leading to the use of carbaryl as the primary control). For the past several years DOE has granted water quality modifications for carbaryl applications under WAC 173-201-035(8)(e).

Carbaryl affects some non-target invertebrate and fish species. Of major concern are the incidental mortalities of Dungeness crab. Studies of the fate and impact of carbaryl in Grays Harbor and Willapa Bay have been sponsored by resource agencies and the oyster industry. This work has followed up research needs identified in the 1985 FEIS.

## C. Justification for Use of Carbaryl to Control Burrowing Shrimp

### 1. Introduction

Burrowing shrimp have been observed to have four general affects on oyster culture. These are: 1) loss of seed due to covering or smothering by sediment; 2) a similar loss of adult oysters; 3) operational difficulties, particularly with off-bottom culture; and 4) a reduction in growth rate and/or condition of the oysters that is apparently due to feeding competition with shrimp. All shellfish growers interviewed for this document have observed affects (1) to (3). Growers have noted that restrictions on the amount of acreage treated with carbaryl have resulted in the loss of what could be productive oyster ground. The FEIS estimated that a revenue loss of $5 million and 300 jobs could occur without a means to control burrowing shrimp. The following assessment presents a picture of the relationship between burrowing shrimp and various aspects of oyster culture (for example, economics).

## 2. Seed Losses

Losses of seed will negatively impact the profitability of an oyster farm. Of the area treated with carbaryl from 1984-88, seed beds accounted for 44% (range 17% to 86%) of the total with the remainder being applied to harvest beds and other growing areas such as off-bottom culture sites (Tufts, 1988, personal communication).

Scientifically controlled experiments which demonstrate that excessive oyster seed losses are the result of burrowing shrimp have not been accomplished. However, based on their accumulated experience over the years, oyster growers believe burrowing shrimp impacts are obvious. A number of biologists and others familiar with the situation have accepted the causality of the seed loss/burrowing shrimp relationship. Experiments by Tufts of WDF and Dumbauld of the UW to better quantify the magnitude of the impact of burrowing shrimp on oyster survival are in progress.

Some observations by Tufts (personal communication) on yield for seed beds were made recently near Long Island in Willapa Bay. The yield from one-half acre test plots within a bed seeded in 1986 were compared to the level of carbaryl treatment (i.e., lbs/acre of carbaryl). Results were as follows:

| Carbaryl Treatment (lbs/acre) | Yield (Bushels/0.5 acre) |
|---|---|
| 10 | 870 |
| 7.5 | 795 |
| 5.0 | 775 |
| control | 587 |

This information suggests that higher yields were obtained from the treated plots. However, because initial seed densities were not precisely known, results could have been due to differences in beginning seed densities.

Growers planting seed on grounds with burrowing shrimp densities exceeding 15 per $m^2$ generally experience losses of over 40% of young oysters. Seed losses exceeding approximately 40% result in costs exceeding the harvest revenues. This relationship is illustrated in Figure 1, in which volume, dollar yield, and seed loss are plotted against the density of burrowing shrimp (seed loss information obtained from Hayes, Coast Oyster Company; Nisbet, Nisbet Oyster Company; Wiegardt, Wiegardt & Sons, Inc.; Wilson, Bay Center Mariculture Co., 1988, personal communications.)

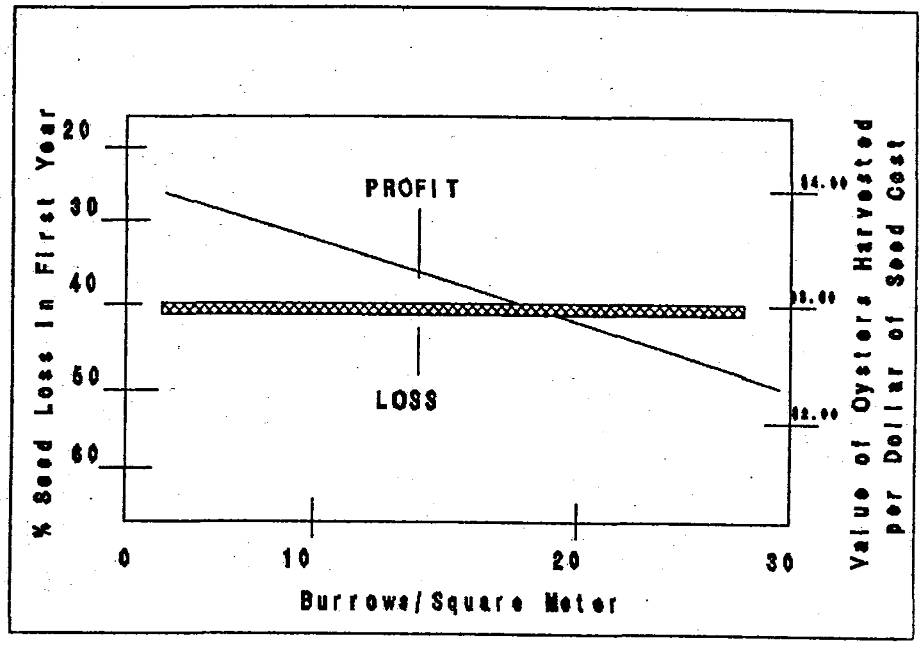



**Figure 1.** A general model illustrating how profitability is related to burrow density of shrimp and seed loss on seed beds (from Hayes, Nisbet, Wiegardt and Wilson, 1988, personal communications).

### 3. Losses During Growout

Larger oysters on growout beds containing burrowing shrimp are also affected by siltation. However, because larger oysters are not as susceptible to burial as the seed oyster, there is a tendency to let shrimp infestation proceed to higher densities (Wilson, Bay Center Mariculture Co., 1988, personal communication). Burrow counts on treated growout beds are usually about twice the density reported on seed beds (Tufts, 1990).

### 4. Losses in Off Bottom Culture

Oyster growers who use off-bottom methods report that shrimp directly impact their yields. Shrimp soften the substrate and thus destabilize any structure or stake placed upon or within this medium. Perhaps the greatest impact of burrowing shrimp reported by those utilizing longline culture is loss of oysters which fall from the suspended cluster. For example, one grower who had 200 lines over 2 acres, sustained a 30% loss of oysters in soft sediments which he attributed to shrimp activity. Another grower noted that without carbaryl control, his long-line operation would be reduced by one-half in a few years, due, in part, to additional operating costs (Engvall, 1989, personal communication; Nisbet, Jambor and Tufts, 1988, personal communications).

**5. Treatment Acreage**

Willapa Bay has a total intertidal and subtidal area of about 79,000 acres. About 40,000 acres is intertidal and shallow subtidal bedlands, of which approximately 26,000 acres are classified (Figure 2). For tax purposes, Pacific County classifies privately owned or leased oyster lands in Willapa Bay according to their use. Class I beds are used to grow oysters from seed through harvest. Class II beds are known as "fattening" beds. Seed oysters are usually not planted on these beds, rather oysters are transplanted to the beds for growout (i.e., fattening) and then harvested. Class III beds are seed beds; seed oysters are planted and then transplanted to growout areas, typically after two years.

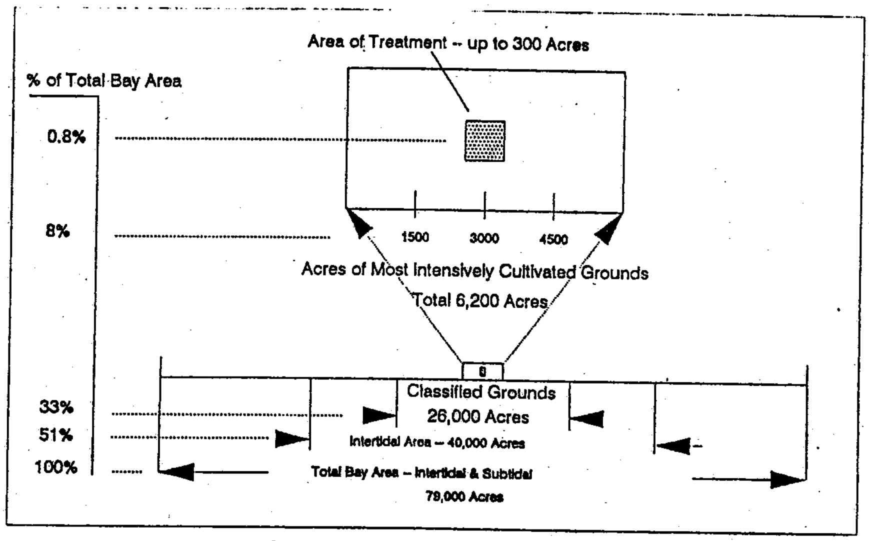



**Figure 2.** Intertidal flats, oyster culture grounds, productive oyster grounds and proposed treatment grounds in Willapa Bay (Benson, 1988a; Willapa Development Corporation, 1986; Shotwell, 1977; Wilson, 1988, personal communication).

Applications for carbaryl treatment permits in Willapa Bay and Grays Harbor are made by the oyster growers. In general, growers prefer to treat areas early in the cycle of increasing shrimp abundance. This is so that during the time a crop is on the bed, shrimp do not increase in abundance to the point where they destroy a substantial percentage of the oysters (Wilson and Hayes, personal communications, 1990). Areas scheduled for treatment each year are generally determined by the growers based upon their priorities, although WDF conducts inspections to ascertain that beds meet the qualifying criteria. Generally, only the highest value beds (growout and good seed beds) with burrow counts exceeding $10/m^2$ are treated. Burrow counts on treated beds from 1984-86 averaged 30 burrows/$m^2$ (range 8 to 123) (Hurlburt, 1986b; Creekman and Hurlburt, 1987; Tufts, 1989).

The treatment frequency of individual oyster beds varies considerably. Tufts (1983) reported that the average time between treatments from 1963 and 1980 was 6 years, ranging from 3 to 18 years. The frequency of treatment depends to a large extent on the rate at which shrimp re-infest beds. This rate is highly variable and depends on such physical and biological factors as the species of burrowing shrimp present, size of the area treated, sediment composition, salinity, current patterns, bed elevation, and annual variation in shrimp survival and recruitment.

Growers typically request treatment of more acreage than is approved. Historically, there has been a 400-acre limit on the annual treatment program. From 1984-1988, growers applied for treatment of an average of 727.8 acres while 422.2 acres were actually treated (Table I). There are several reasons why less acreage may be treated. Request to treat some beds or portions of beds are withdrawn by growers who, because of a restriction on the total pounds of carbaryl (in some years), opted to spray a reduced area at higher concentrations. Treatment of other beds may be withdrawn because of incomplete oyster harvest, as carbaryl cannot be sprayed over oysters less than 2 years before harvest (note: this restriction has been removed from the current special use label). Then, of beds scheduled for treatment, spraying can be limited because individual growers reach their assigned crab kill quotas.

If growers could treat all the acreage with carbaryl that they desired, approximately 800 acres would be treated each year. This is based upon the following rationale (from Hayes, Nisbet, Wiegardt and Wilson, 1988, personal communications). In Grays Harbor, 550 acres require routine treatment while in Willapa Bay 4,100 acres need routine control. If 4,650 total acres (both bays combined) need to be treated an average of every 6 years (i.e., they exceed the minimum burrow count of $10/m^2$), then treating about 775 acres per year would maintain the current acreage under cultivation.

**Table I.** Total acres treated and applied for from 1984-88 (from Hurlburt, 1986 and 1988; Creekman and Hurlburt, 1987; Tufts, 1989 and 1990).

| | Year Treated 1984 | 1985 | 1986 | 1987 | 1988 | Average 1984-88 |
|---|---|---|---|---|---|---|
| <u>Grays Harbor</u> | | | | | | |
| North Bay | - | 68.5 | 43.0 | 39.0 | 78.0 | 45.7 |
| South Bay | 91.8 | 17.0 | - | 35.4 | 50.6 | 39.0 |
| Subtotal | 91.8 | 85.5 | 43.0 | 74.4 | 128.6 | 84.7 |
| <u>Willapa Bay</u> | | | | | | |
| Peninsula | 120.5 | 78.0 | 78.2 | 142.6 | 124.8 | 108.8 |
| North Bay | 246.0 | 228.0 | 206.8 | 153.3 | 146.0 | 196.0 |
| South Bay | 30.0 | - | 70.0 | 63.4 | - | 32.7 |
| Subtotal | 396.5 | 306.0 | 355.0 | 359.3 | 270.8 | 337.5 |
| Total | 488.3 | 391.5 | 398.0 | 433.7 | 399.4 | 422.2 |
| Total Acres applied for | 770.5 | 698.5 | 654.5 | 678 | 837.5 | 727.8 |

## D. Update of activities -- 1985 to present

### 1. Summary of Carbaryl applications

An average of 422.2 acres of oyster lands was treated annually in Willapa Bay and Grays Harbor from 1984 through 1988 (Table I). The acreage treated annually with carbaryl has varied from 0.8% to 1.1% of the total bedland area of the Willapa Bay. The general location of areas treated from 1984 to 1988 is shown in Figure 3.

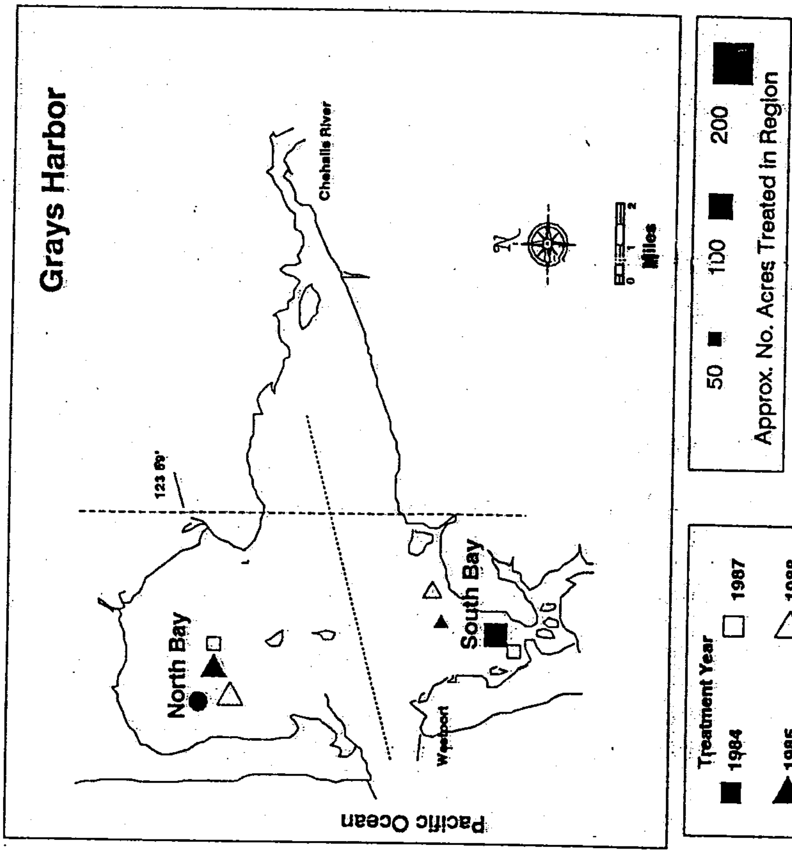
### 2. Pertinent literature and recent research

The published research on carbaryl is quite extensive; however, only a fraction of this work is relevant to estuarine environments. Nevertheless, some is useful in judging the potential for impacts. Pertinent literature is listed in the References section. References were obtained from files of researchers involved in the various carbaryl-related field studies and recent journals and reports at the University of Washington libraries. In addition, computerized data-bases (Agricola, Oceanic Abstracts, Aquatic Science Abstracts, and Chemical Abstracts Search) were searched for recent national or world literature. This literature has been reviewed and summarized in the assessment.

The results of 25 years of research on control of burrowing shrimp are reviewed in the FEIS. Work completed by WDF and the University of Washington (UW) is summarized in Section IX of the SEIS.

**E. Crab Industry Concerns**

Several groups or individuals, particularly commercial Dungeness crab industry representatives, have expressed concern regarding the use of carbaryl as a control method. The level of industry concern is understandable since the crab fishery is, along with oyster production, one of the major economic activities in Willapa Bay and Grays Harbor. Crab fishers fear that carbaryl application may kill enough juvenile crab to significantly affect commercial fishery harvests. Impacts to Dungeness crab are considered in Section III.H.



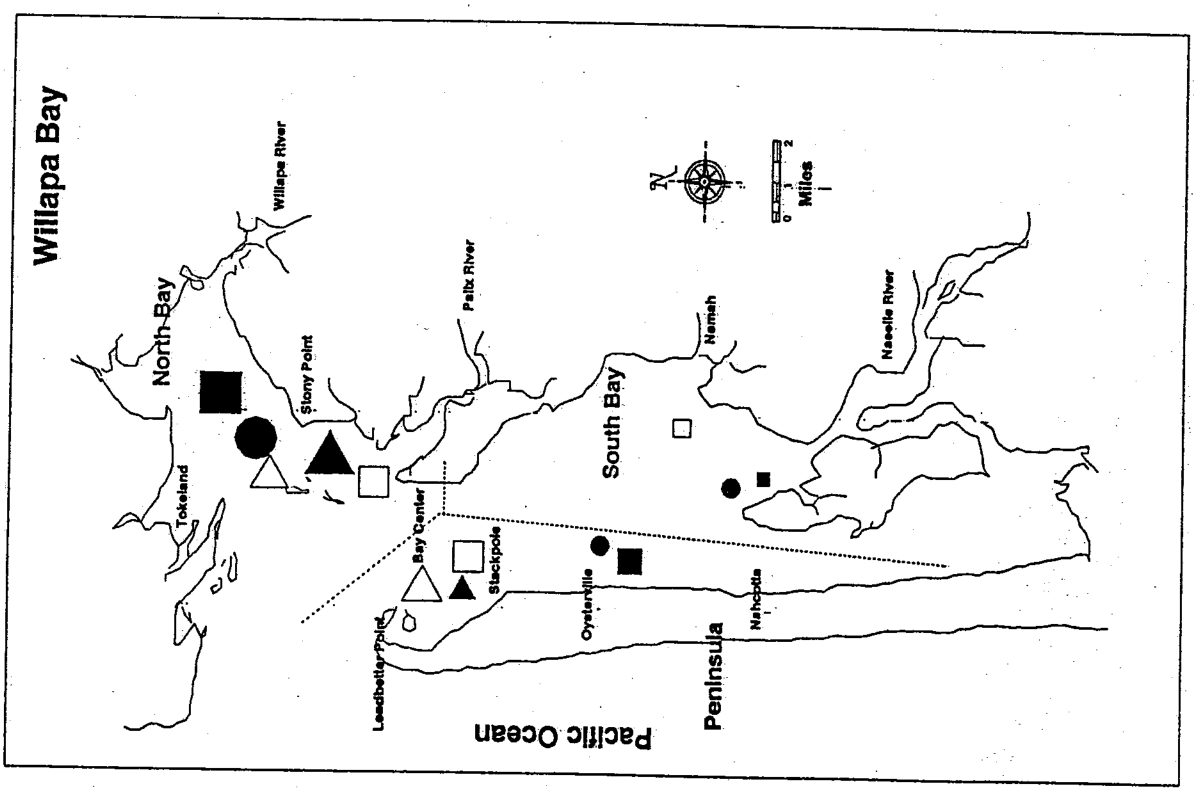




Figure 3.

Willapa Bay and Grays Harbor:

Relative Locations and Extent

of Treatment Areas, 1984-88

## III. ANALYSIS OF UNRESOLVED ISSUES

This section discusses questions or issues which were identified following publication of the FEIS, and in subsequent "scoping" meetings and hearings. It reviews information obtained since publication of the FEIS.

### A. The biology of burrowing shrimp and oyster communities.

#### 1. Burrowing Shrimp

The two burrowing shrimp species targeted by carbaryl applications in Willapa Bay and Grays Harbor are ghost shrimp, *Callianassa californiensis*, and mud shrimp, *Upogebia pugettensis*. Principal features of the biology of these animals were reviewed extensively in the FEIS. Recently published information and reassessments of earlier studies are considered here.

##### a. General biology

##### (1) Distribution and abundance

The distribution of ghost and mud shrimp has been studied in several Oregon estuaries by Bird (1982) and Posey (1985a; 1985b). Similar patterns occur in Willapa Bay and Grays Harbor.

Ghost shrimp create dense beds in the mid-intertidal of many Oregon and Washington sandflats, and are usually not as abundant in the lower intertidal and subtidal. Mud shrimp are more common further from the mouths of estuaries (Bird, 1982).

Swinbanks and Luternauer (1987) and Swinbanks and Murray (1981) described the distribution of burrowing shrimp on a Fraser River Delta (British Columbia) tidal flat. Burrow densities for both shrimp species were highest at lower intertidal levels immediately inshore of an extensive bed of eelgrass, *Zostera marina*. The highest densities of ghost shrimp burrows (350-450 burrow openings/$m^2$) occurred in strips of clean, sandy sediments while mud shrimp burrows were most abundant (30-80 burrow openings/$m^2$) in patches of muddy sands. On tidal flats of the Fraser River Delta as a whole, sediment type did not consistently correlate with burrow density of either shrimp, whereas tidal elevation did. Posey (1985a; 1986b) has shown that predation may also be important in limiting the distribution of ghost shrimp (see below).

MacGinitie (1934) suggested that colonies of ghost shrimp in California (Elkhorn Slough) are cyclic in abundance. This cycle may take as long as 10 years, depending on factors such as distance from the ocean and presence of other macro-invertebrates. Such cyclic changes were not observed in Oregon estuaries (Bird, 1982; Posey, 1985a, 1985b), but they are a feature of other decapod populations (Cheney and Mumford, 1986).

Population surveys of burrowing shrimp have not been conducted in Willapa Bay or Grays Harbor, but it is apparent that they inhabit a substantial portion of the intertidal and shallow subtidal areas of both bays. The biomass of each shrimp species can exceed 2.0 $kg/m^2$ (about 8,900 lbs/acre) while densities can vary widely between estuaries -- from less than $2/m^2$ to over $700/m^2$ (Bird, 1982; Posey, 1985a). In Willapa Bay, burrow densities at two locations (Cedar River and Palix River) ranged up to $400/m^2$ for both species, averaging $136/m^2$ for mud shrimp and $192/m^2$ for ghost shrimp. A positive relationship between burrow count and shrimp density was observed for both species with 1.9 burrows/mud shrimp and 4.2 burrows/ghost shrimp. Average dry weights per individual were 2.9 g (± 2.5g) for ghost shrimp and 7.3 g (± 5.7 g) for mud shrimp (Dumbauld, UW School of Fisheries, 1988, personal comm.).

**(2) Feeding behavior and burrows**

The feeding behavior of burrowing shrimp has a marked effect on the sediments and productivity of surrounding waters. Mud shrimp are suspension feeders, feeding on phytoplankton, zooplankton, bacteria and detritus that are suspended in the water column (Posey, 1985a). Other examples of suspension feeders are the Pacific oyster, bay mussel, barnacles and many polychaetes (Wolff, 1983).

Ghost shrimp are selective deposit feeders and isolate their food particles by sorting, rasping or sucking food from the surfaces of sediment particles. Benthic microalgae and bacteria are important sources of food (Wolff, 1983). Although classified as deposit feeders, a substantial portion of their food may come directly from the water column (Bird, 1982).

Mud shrimp build shallow U-shaped or Y-shaped burrows. On the other hand, ghost shrimp construct complex, deep, and more temporary burrows (Suchanek, 1985).

The rate at which burrowing shrimp (*C. japonica* and *U. major*) moved water through their burrows was measured by Koike and Mukai (1983) and Mukai and Koike (1984) under simulated, in-situ conditions. Estimated flow rates created by burrowing shrimps at 20.5 degree C were 0.7 to 1.5 liters per day for ghost shrimp and 0.3 to 0.8 liter per day for mud shrimp. Water volumes 1.5 to 3.5 liters were cycled through burrows daily by burrowing shrimp in the tropics (Colin, et al., 1986). These flows result in large quantities of sediment being sorted through the subsurface galleries of burrowing shrimp. In samples taken 10 cm above the bottom, the suspended sediment load of water over shrimp infested ground was about 3 times that found over control (non-shrimp) areas. Suchanek (1983) measured quantities of up to 2.59 $kg/m^2/day$ for a shallow-water tropical species. These observations implied Callianassids make a major contribution to total suspended particles (Colin, et al., 1986).

**(3) Reproduction and recruitment**

Ghost shrimp mature at 18 to 24 months and egg bearing females may be less than 30 mm in total length. Female ghost shrimp in the Pacific Northwest are egg bearing from May to August. Mud shrimp delay reproduction until their third year. Smaller egg bearing mud shrimp, females are more than 60 mm in total length (Bird, 1982). Mud shrimp are egg bearing during winter and early spring (October to March) (Bird, 1982; Dumbauld, UW, 1988, personal communications).

The annual rate of recruitment of ghost shrimp to Oregon estuaries was correlated with density of adult shrimp. Larval recruitment tended to be greatest to areas where there were established adult populations; juveniles were most abundant in areas with fewer adults present (Bird, 1982).

**b. Interactions with other plants and animals**

In the early 1970's, it was suggested that frequent resuspension of sediments by deposit feeders such as burrowing shrimp had an important influence on the types and densities of other organisms (Rhoads and Young, 1970). Experiments by Murphy (1985) demonstrated that California ghost shrimp created levels of turbidity and sediment destabilization that reduced growth and survival of quahog clam, *Mercenaria mercenaria*. Ghost shrimp sift sediments continuously for food, with significant sediment turnover and transport (MacGinitie, 1934). Studies in Discovery Bay, Jamaica showed that suspension-feeders were excluded from areas dominated by Callianassid shrimp. Shrimp destabilized the sediment and increased turbidity; as a result, settlement and growth of suspension-feeders was inhibited, infaunal diversity was reduced, and growth declined (Aller and Dodge, 1974).

Posey (1986, 1985a, 1985b) and Bird (1982) studied several key responses of macrofauna in a dense intertidal bed of ghost shrimp. Although some animals, such as the amphipod *Eobrolgus*, appeared to benefit from the activities of ghost shrimp, the numbers of most sedentary organisms decreased as shrimp densities increased. When ghost shrimp become dense enough, they are able to exclude macrofauna such as polychaetes and amphipods (Bird, 1982). Posey suggested that dense populations of ghost shrimp primarily affected other macrofauna through disruption of sediments, with sedentary suspension feeders most adversely affected. Posey's evaluation of populations of epibenthic crustaceans occurring at high and low shrimp densities is shown in Table II. An experiment conducted in Willapa Bay in 1989-90 showed that the overall faunal response to the presence of mud shrimp was similar to that for ghost shrimp (Posey et al., 1991). This result was somewhat unexpected given the different burrowing and feeding habits of the two species. They indicated, however, that although they did not make direct comparisons of faunal effects, they suspected the magnitude of the effect of ghost shrimp would be greater.

Available evidence suggests that burrowing shrimp recycle some nutrients that might normally be trapped in sediments. Callianassids ingest organic matter and excrete ammonium and phosphorus that is pumped out of their burrows into the water column. For example, in a study of a saltwater pond in Bermuda, Waselenchuk et al., (1983) concluded that burrowing activities of callianassids released soluble nutrients from sediments and were responsible for 20-35% of the ammonium additions to the pond. Because organic matter produced in the euphotic zone settles primarily on sediments in shallow waters (Smith, 1978 in Koike and Mukai, 1983), it is susceptible to burrowing shrimp activity. Thus, burrowing shrimp may help to recycle nutrients for phytoplankton production. However, this function has yet to be evaluated in Grays Harbor or Willapa Bay.

Burrowing shrimp can affect seagrass distribution and productivity. For example, at St. Croix, U. S. Virgin Islands, Suchanek (1983) found that maximum seagrass

**Table II.** Densities and species numbers of small benthic crustaceans from intertidal flats in Oregon. All data are from summer, 1982-83 (from Posey, 1985a).

| | Shrimp Density* High 100/m² | Shrimp Density* Low 2-3/m² |
|---|---|---|
| Average number of taxa | 39 | 39 |
| Densities (#/m²) | | |
| Tanaids (tube-building) | 335 | 440 |
| Ostracods | 28 | 136 |
| Amphipods | | |
| *Corophium* (tube-building) | 8 | 100 |
| *Eobrolgus* (active burrower) | 40 | 35 |
| *Grandidierella* (tube-building) | 5 | 14 |
| Cumaceans (mobile) | 2 | 44 |

* Measured over a horizontal distance of less than 2 m.

productivity and percent cover were negatively correlated with density of callianasid burrows. Sediment ejected from burrows affected eelgrass by either reducing available light for photosynthesis or physically smothering the grass.

Available evidence is not adequate to quantify the relationship between burrowing shrimp and eelgrass in Grays Harbor and Willapa Bay. Observations by Tufts (1990) and others (e.g., S. Barry, WDF, personal communication) suggest that burrowing shrimp, especially ghost shrimp, can adversely affect eelgrass in Willapa Bay. In areas where ghost shrimp are abundant, little or no eelgrass is observed. They report that eelgrass populations may increase in areas where ghost shrimp populations have been reduced by carbaryl treatment. Mud shrimp, on the other hand, may have less of an adverse impact since they are often observed in eelgrass beds.

**c. Predators and Value of Burrowing Shrimp as Prey**

Examination of predator diets in the field by Posey (1985, 1986b) indicated that at least two species commonly ate shrimp: cutthroat trout, *Salmo clarkii*, and staghorn sculpin, *Leptocottus armatus*. In laboratory trials, Dungeness crab, also ate ghost shrimp. Posey suggested that predation by staghorn sculpin was the factor that limited the sub-tidal range of dense ghost shrimp populations. Undoubtedly, ghost shrimp are prey for a variety of other fish and shellfish species and may constitute an important dietary component of some animals.

**d. Ecology of oyster dominated communities**

A diverse assemblage of plants and animals is associated with oyster beds. These include animals attached to the shell, such as red algae and mussels, in addition to those animals living under and around the shell, such as crabs and various fish species. The community composition of oyster dominated communities is a reflection of the diversity of micro-habitats associated with oysters. This contrasts sharply with the more homogeneous habitats of bare mud and sand flats.

The importance of commercial oyster grounds as habitat for some of the animals of Grays Harbor and Willapa Bay has been partially addressed by work completed for the SEIS. In particular, Dungeness crab and epibenthic animals (i.e., those living on the surface of the sediments) were studied (see appropriate sections of this document).

There are numerous factors which probably exert an influence on communities associated with oyster shell in Willapa Bay and Grays Harbor. These factors have not been specifically evaluated for west coast oyster beds. However, it is possible to gain some insight into what factors might be important in Willapa Bay and Grays Harbor by using information from the east coast (i.e. Galtsoff, 1964). Important elements that appear to affect the nature and extent of oyster dominated communities include physical factors, such as the character of the bottom, sedimentation and temperature; biological factors, such as food, predators and disease; and other factors, such as pollution. Oysters grow well on a hard, rocky bottom or on semihard mud firm enough to support their weight. Shifting sand and soft mud are usually unsuitable for oysters. A firm bottom of fine gravel, sand, mud or any combination of these three provides optimum conditions (Quayle, 1969). Sedimentation is also important, and rapid settling of suspended material can be highly destructive to an oyster community. Ideal conditions are found when silt does not settle on live oysters (Galtsoff, 1964).

**2. Conclusions**

Burrowing shrimp, particularly ghost shrimp, are considered "foundation species" because of their ability to control and structure the community. Ghost shrimp may lower the level of entrained organic material in sediments and process so much sediment that they control sediment grain size, transport, mixing, and deposition. High density populations may negatively impact other populations of animals or plants. On the other hand, mud shrimp generally do not have a marked impact on sediment mixing and deposition, and often occur in eelgrass beds. Both species of shrimp function in the recycling of nutrients and organic material, and as prey for fish, other invertebrates and birds. These functional characteristics are poorly defined and quantified in Willapa Bay and Grays Harbor. Research is being conducted by the UW to address various aspects of burrowing shrimp community interactions.

## B. The transport and persistence of carbaryl in estuarine water and sediment.

The distribution and persistence of carbaryl applied to oyster beds in Willapa Bay and Grays Harbor were major issues in the environmental evaluation. The key factors affecting the fate of carbaryl are briefly discussed in the summary to the FEIS.

### 1. Transport of carbaryl

#### a. Mechanics of transport

Carbaryl is applied to oyster grounds as a wettable powder. Pure carbaryl (specific gravity of 1.23) has a relatively low solubility in water (120 ppm at 30 C, or 0.012 g/100 ml), but is more soluble in many organic solvents (Mount and Oehme, 1981). In the manufacturing process, carbaryl is first milled and then mixed with clay particles (approximately 18 percent) and a wetting agent (2 percent) which results in the 80 percent active mixture (Hopson, 1988, Rhone-Poulenc Agri. Co., personal communication). Fragments of powdered carbaryl vary in size with most falling between 3 and 40 microns or within the size range of silt. Particles are mostly rounded or blocky crystalline in shape. These properties are important because they determine whether transport is possible with a given fluvial energy level. Some carbaryl particles will be carried in the advancing front of the incoming tide. In order to be transported by water, carbaryl fragments must move by traction[2] or

[2] A mechanical method of transport where the particles slide, roll, or make short jumps along the bottom.

suspension[3]. Particle transport will alternate between the two as velocity and turbulence of the water changes. Particles most likely to be transported are those on elevated features above the bottom such as shell material or eelgrass. As the tidal height increases, velocity near the bottom will decrease and reduce transport. Some carbaryl may also be transported on the water surface "microlayer".

**b. Review of sampling studies**

The transport of carbaryl in Willapa Bay and Grays Harbor has been assessed in many studies carried out between 1962 and 1988 (see the FEIS for studies completed prior to 1984). These studies have been conducted on the incoming tide following spraying; the fate of carbaryl on succeeding tides is not well understood. Sampling carried out between 1985-86 followed the incoming plume of water and measured carbaryl concentrations at the leading edge of the plume. (It should be noted that sampling the leading edge of the plume, especially as it leaves a treated tract, probably represents a worst-case situation or maximum concentrations of carbaryl that would be observed.) By sampling this first "flush" of the sprayed area, the same water mass was essentially followed. An example of the sampling procedure employed is illustrated in Figure 4. The leading edge of the tide transports carbaryl fragments across the bed in the direction of the tidal flow. Elevated concentrations may occur in surface and bottom water layers at the margin of the flow (Figure 5). As illustrated in Figure 6, once an area is innundated by the tide, concentrations of carbaryl appear to persist for only about 20 to 30 minutes (Tufts 1990).

The direction of carbaryl transport will directly depend upon how each tract that is sprayed refloods. In many cases, this will be easy to predict. For example, a bed with a steady gradient, will flood from its lowest to its highest point. In this situation, carbaryl should be transported away from adjacent subtidal channels. There are a number of factors that will influence the ability to predict how a bed refloods, including the direction of wind-driven or tidal currents, lack of a clear gradient, and irregular elevations. Effects of wind driven currents should be minimal since carbaryl is never sprayed when wind speeds are in excess of 10 mph.

---

[3] A means of transport where particles are lifted above the bottom and carried in the water column.

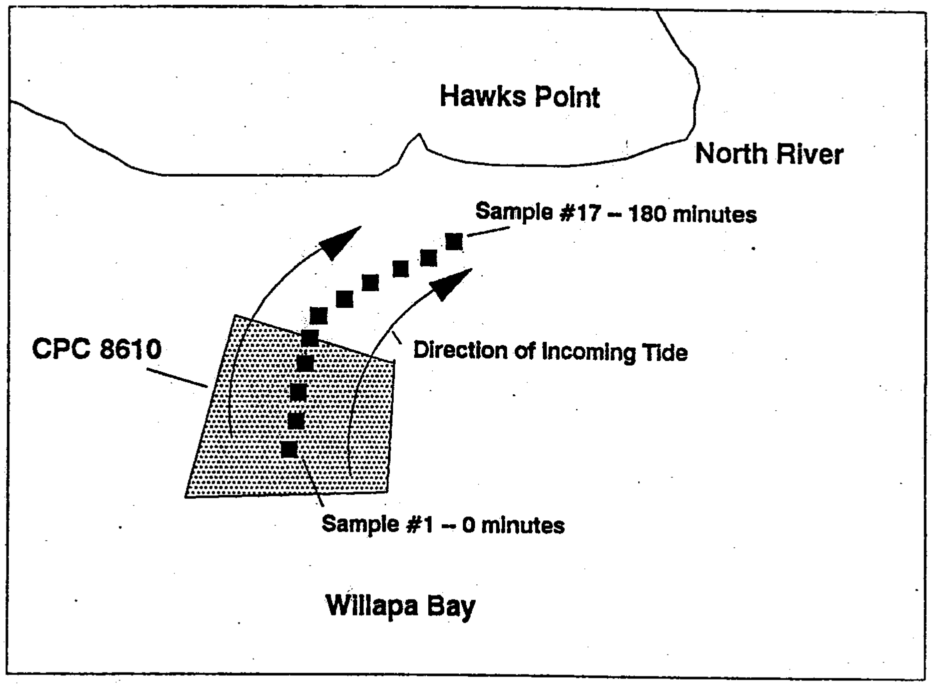
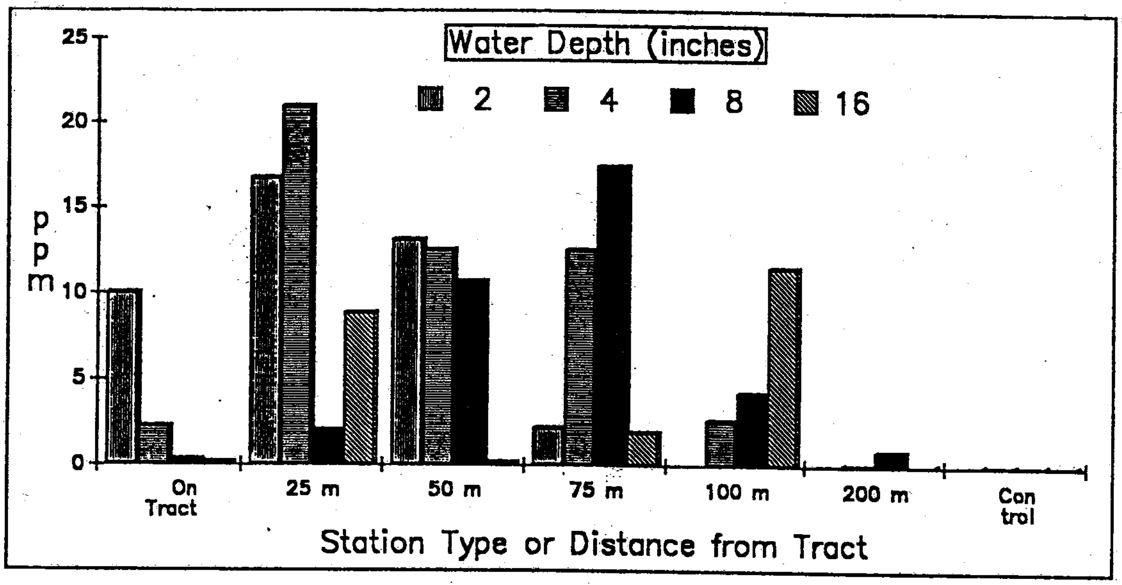



**Figure 4.** Sample plan from 1986 Willapa water quality studies of North River station CPC 8610. Both fixed and "plume" following stations were used (from Tufts, 1989).

Sampling in 1987 revealed that a change in tidal direction across a bed can modify the concentration of carbaryl (Figure 7). Relatively high amounts of carbaryl result from the convergence of two tidal plumes crossing different areas of the sprayed ground (Doty, et al., 1988b; WSDA, 1988; WDF, 1988).

Studies conducted in 1985 demonstrated that carbaryl could be carried off treated beds by the incoming tide. Concentrations of carbaryl in the center of a Bay Center tract ranged up to 5.2 ppm. Off the tract in the leading edge of the incoming tide, the maximum concentration of carbaryl was 7.9 ppm at a distance of 170 yards from the boundary of the tract, while 50 yards further out it was 2.5 ppm (Creekman and Hurlburt, 1987).

In 1986, three treated tracts were sampled. Carbaryl concentrations ranged from 3.2 to 26.2 ppm at water depths up to three inches. Carbaryl concentrations below the minimum detectable level (0.1 ppm) were initially reached at distances of 750, 675, and 450 feet from each tract. Concentrations of 1-naphthol exceeded 0.1 ppm at distances of 0, 225, and 150 feet from the



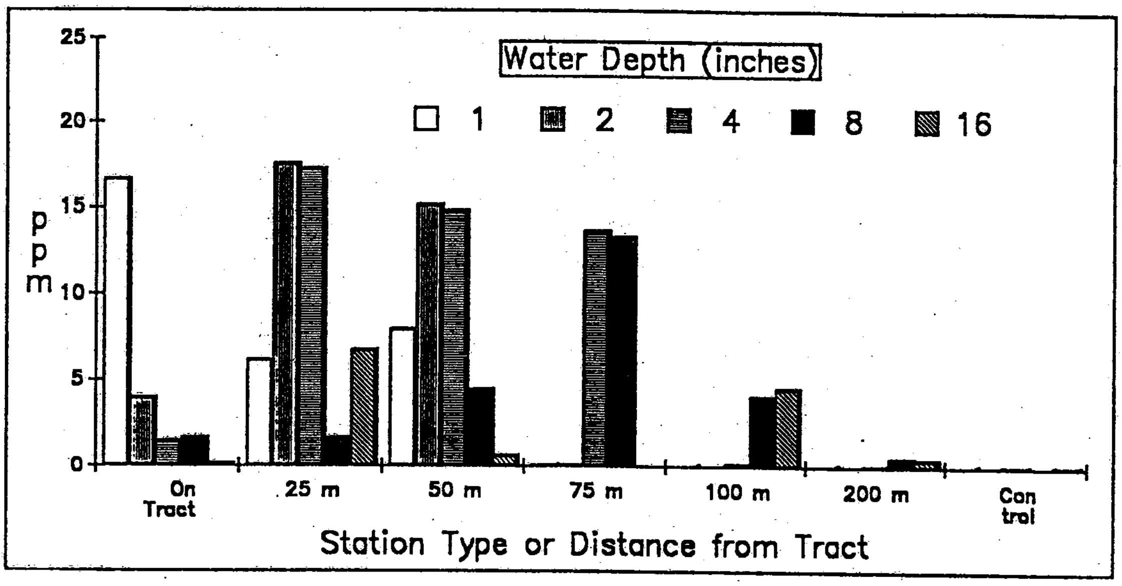




**Figure 5.** Concentrations of carbaryl in the top (upper figure) and bottom (lower figure) layer of water sampled at increasing water depths at the Palix bed (CPC 8825) (Doty et al. 1990).

edge of each tract, respectively, although values of 0.1 ppm were sometimes obtained much further off tract (Tufts, 1989). Explanations for these results were not provided by Tufts (1989).

Locations of stations sampled during 1988 to measure off tract concentrations of carbaryl are shown in Figure 7. Results are displayed in Figure 5 for the top and bottom

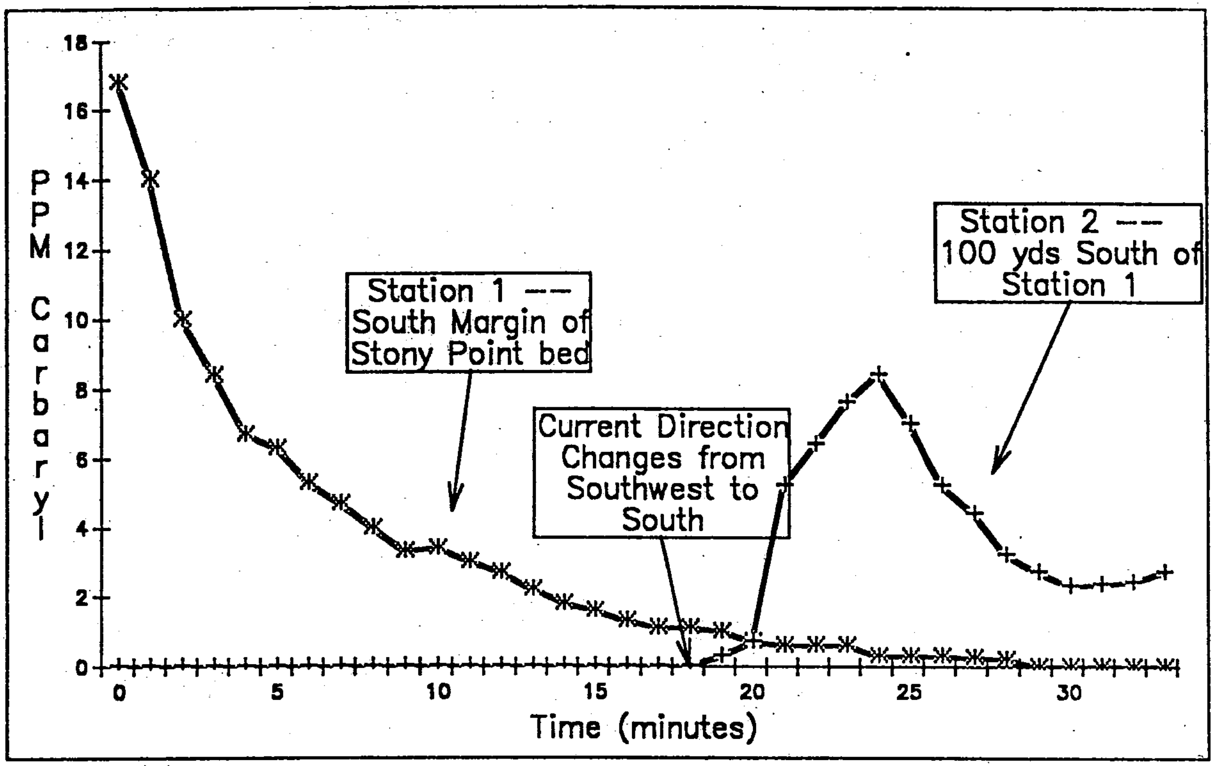



**Figure 6.** Carbaryl (ppm) in water at two stations near the Stony Point treatment bed, Willapa Bay. The time axis is in reference to the initial point of tidal innundation (Tufts, 1990).

water layers (WSDA, 1988; WDF, 1988). At the furthest station off tract (approximately 219 yards), carbaryl concentrations ranged from 0.3 to 1.3 ppm, depending upon the depth of the water at the time the sample was taken. Analyses by WSDA showed that concentrations of 1-naphthol at this station were 0.003 to 0.92 ppm. Interestingly, carbaryl concentrations at the control station ranged from 0.005 to 0.063 ppm, suggesting that either the station or the sample was contaminated with carbaryl (e.g., the equipment used to collect samples could have been contaminated). The entire 1988 data set is included in the Appendices.

Other evidence is available showing that carbaryl particles are transported off-tract. Tufts (1989) reported reduced shrimp burrow counts in relation to pre-spray observations up to 300 feet from the boundary of the sprayed tract and in the direction of the tidal flow. In addition, crabs placed in the direction of the tidal plume in summer 1988 experienced high mortalities up to 300 feet from the sprayed area (Doty, et al., 1988b).

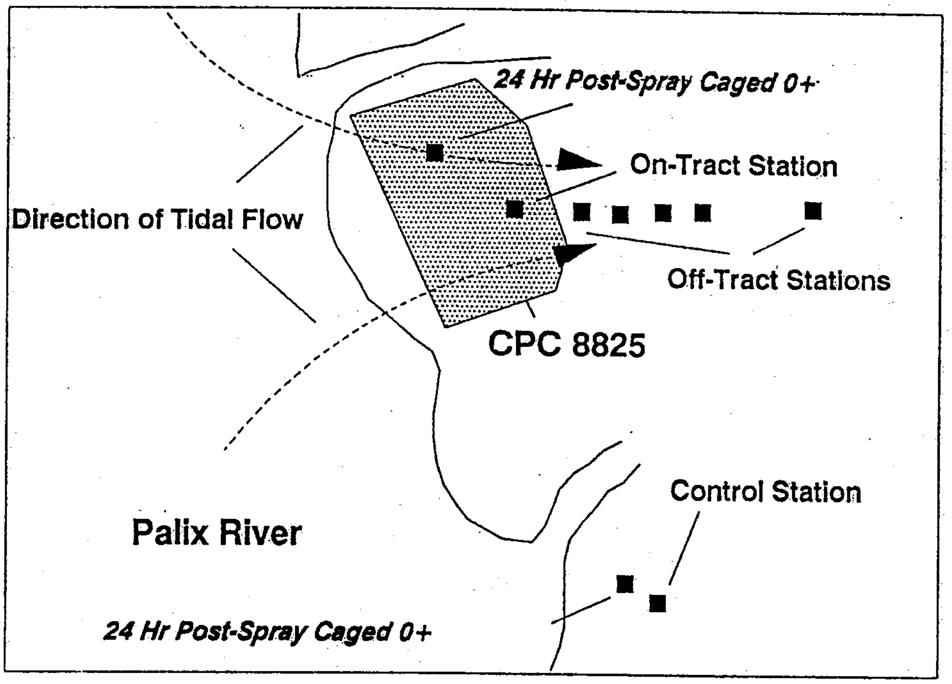



**Figure 7.** Representative illustration of sample station locations for the 1988 water quality study on the Palix bed tract CPC 8825. The control station was about 1/2 mile from the treatment tract (from WDF, 1988 and Doty, Dumbauld and Armstrong, 1988b).

In summary, the fate of transported carbaryl depends on the tidal flow velocity and pattern. Carbaryl particles continue to be transported as long as a certain velocity and turbulence is present near the sediment-water interface. In most situations, the transport of carbaryl particles will follow a predictable pattern with transport occurring from the lower to the higher elevations of beds. Factors that can affect the predictability of carbaryl transport include the direction of wind-driven or tidal currents and lack of a consistent gradient on a bed. The highest concentrations appear to occur where different tidal plumes converge. As tidal energy decreases, carbaryl fragments begin to settle. The settling of particles is based on physical properties of the particles; larger and more rounded carbaryl fragments will settle before smaller and flattened ones. Dilution and degradation decrease initial concentrations of settled particles (see following section).

## 2. Persistence

Persistence is a term often applied to compounds that have a lingering toxicity which can be transmitted from treatment areas and possibly throughout the food chain. Persistence is characteristic of many pesticides and is an issue of concern in relation to carbaryl treatment of oyster lands. Data available from the 1960's indicated that persistence of carbaryl in environments such as those characteristic of Willapa Bay and Grays Harbor in summertime was relatively short. This was a primary reason for selection of carbaryl (WDF, 1970).

### a. Literature reports

Many studies dealing with persistence are reviewed and referenced in the FEIS. The following are summaries of recent or unreported (since the FEIS) studies on persistence in aquatic environments:

- In an alkaline, aqueous solution carbaryl hydrolyses to form 1-naphthol, methylamine and carbon dioxide. The half-life of carbaryl increases from 15 min. at pH 10 (20 degrees C) to 10.5 days at pH 7 (20 degrees C). Persistence of carbaryl in soil is governed by biological and chemical factors; carbaryl is chemically unstable at high pH and biologically unstable at low pH (5.0) (Larkin and Day, 1985).

- Carbaryl persistence has generally been found to be greater under nonflooded conditions than in flooded conditions. In the alluvial soils of a rice field, the half-life of carbaryl under flooded conditions was 13 days as compared to 23 days under nonflooded conditions (reviewed in Rajagopal, et al., 1984).

- Loss of 1-naphthol from the water was much greater from an aquarium tank containing sea water and mud than from tanks without mud. This was due to 1-naphthol adsorption to the mud. Carbaryl persisted for three weeks in mud, but 1-naphthol did not. Rupture of the naphthyl ring to produce $CO_2$ and possibly methane was the prominent pathway of 1-naphthol degradation (reviewed in Rajagopal, et al., 1984).

- Retention of carbaryl (0.01 to 0.1 mg/kg) in sediments for over one year was reported in a study of experimental ponds in Maine. This extreme persistence was believed due to acid pH, adsorptive capacity, anoxic conditions of the bog sediments (which reduced microbial decomposition), and low water temperatures (near 0 degrees C from October to May). Under these conditions the chemical was expected to be quite stable (Gibbs, et al., 1984).

- In a model ecosystem study the maximum concentration of carbaryl detected in water after addition of 3 ppm to the soil was 0.3 ppm; this fell to 0.0076 ppm after 22 days. About 60% of the carbaryl was tightly bound to the soil. The half-lives of carbaryl in various aquatic environments varied from 1.3 days in a fish aquarium to 5.8 days in mountain streams (reviewed in Rajagopal, et al. 1984).

- The following are half-lives of carbaryl in sea water at a pH of 8 at varying temperatures (from TRW Corp., 1981): 3.5 C -- 1 month; 17 C -- 4.8 days; 20 C -- 3.5 days; and 30 C -- 1 day. The same report calculated a photolysis half-life for carbaryl (in 10 cm water depth) of about 60 hours.

- Based upon burrow count observations taken 11 months apart and Oregon Department of Fisheries and Wildlife records on treatment frequency, Buchanan et al. (1985) suggested that there might be longterm persistence of carbaryl. However, based upon experiences in Grays Harbor and Willapa Bay, recovery of burrowing shrimp populations to pre-treatment levels within 11 months would be highly unlikely, unless a strong year-class recruits soon after treatment. Moreover, results of recent sediment analyses show that carbaryl is not persistent (see following paragraphs). Therefore, it is very unlikely that reduced burrow counts indicated carbaryl was persistent as suggested by Buchanan.

Studies dealing with persistence of carbaryl were performed in diverse environments. Available information shows that carbaryl dissolves slowly in water and more rapidly in the presence of organic materials. A wide range of products are produced as carbaryl degrades, including 1-naphthol and various intermediates, $CO_2$ and methane (Rajagopal, et al., 1984). Reported degradation rates for carbaryl and 1-naphthol to reach 0.1 to 0.01 ppm ranged from less than a day under optimum conditions to more than a year. For example, persistence (residues of 0.08 to 0.2 ppm) of up to 42 days in estuarine sediments at 7.5 to 14.5 C was reported by Karinen, et al. (1967).

Degradation of carbaryl is sensitive to the pH of the medium. It is chemically unstable under alkaline conditions and undergoes rapid hydrolysis at a pH above 7.0. At an alkaline pH and in an aqueous solution carbaryl hydrolyzes to form 1-naphthol, methylamine and carbon dioxide (Larkin and Day, 1985). In one test, about 50% of carbaryl in sea water at 20 degrees C and a pH of 9.0 was hydrolyzed in 4 days while in another test, carbaryl was hydrolyzed to 1-naphthol at a rate of 20%/day at 20 C and a pH of 8 (Larkin and Day, 1985). 1-Naphthol was also chemically unstable at a pH greater than 8. The rate of hydrolysis of carbaryl and 1-naphthol increases with temperature; in seawater, 93% was hydrolyzed after eight days at 28 C as compared to only 9% at 3.5 C (Rajagopal, et al., 1984).

Also, sunlight affects the degradation of carbaryl, especially in the aquatic environment. Hydrolysis of carbaryl to 1-naphthol was accelerated as temperature increased from 4 to 28 degrees C and when carbaryl was exposed to sunlight. 1-Naphthol was also degraded in sea water by increased temperature and light. Photodecomposition probably accounts for some loss of carbaryl in surface waters (Rajagopal, et al., 1984).

Finally, microorganisms can help degrade carbaryl and 1-naphthol in soil ecosystems. In soils with near neutral pH, the major means of degradation of carbaryl is probably microbial, while in alkaline soils degradation is mediated essentially by chemical means and to a lesser extent by microbial means. Yeasts, fungi, and bacteria isolated from a marine environment convert carbaryl and 1-naphthol to water-soluble products (Rajagopal, et al., 1984). Karinen, et al. (1967) and Rajagopal, et al. (1984) indicated that 1-naphthol was more susceptible to degradation by microorganisms than was carbaryl. Light and microorganisms enhanced the degradation of 1-naphthol in sea water to $CO_2$ and other products (such as salicylic acid) (Rajagopal, et al., 1984).

**b. Willapa Bay and Grays Harbor reports**

To assess persistence, sediment and water samples taken at intervals after carbaryl treatment and direct monitoring of the benthic community can be used. Data on carbaryl and 1-naphthol concentrations in sediments and water samples has been presented in the FEIS and in previous sections of the SEIS. Results of monitoring the benthic community are presented in a subsequent section. There was a wide range in measured values in samples, as might be expected given the diversity of habitat and environmental conditions found in the reported study sites. Johnson (1987) reviewed several, sometimes conflicting, reports and noted particular problems with the methodology used for sediment analyses in Willapa Bay and Grays Harbor. The presence of

1-naphthol in water samples immediately after spraying carbaryl is noteworthy since it is indicative of carbaryl degradation (Creekman and Hurlburt, 1987; Tufts, 1989, 1990; WDF, 1988).

In order to determine the persistence of carbaryl in sediments following commercial treatments, WDF collected sediment samples in 1989 and 1990 from commercial oyster beds in the Palix River and Nemah River areas of Willapa Bay. Samples were analyzed by the Washington State Department of Agriculture pesticide laboratory using high performance liquid chromatography (HPLC) technology. In 1989 sediment samples were collected from beds in the Palix area which were treated (by helicopter) with carbaryl on July 18 at 2.5. 5.0, 7.5 and 10.0 pounds per acre. The 2.5 and 10.0 pounds per acre treatments were experimental and not repeated elsewhere. Samples were also taken from a bed in the Nemah area which was treated with carbaryl on August 30 at 7.5 pounds per acre. During June, 1990 (approximately 11 months later) one set of sediment samples was taken from the Palix area bed that was treated at 5.0 and 7.5 pounds per acre, the same rates at which all commercial carbaryl applications in 1989 were authorized. Control samples were collected about 400 yards away on beds adjacent to those treated. Results of the sediment sample analyses are listed in Table III.

Carbaryl concentrations in the Palix bed treated at 5.0 and 7.5 pounds per acre decreased from initial levels of 35-68 ppm immediately after treatment to 0.65-3.94 ppm after 24 hours. Samples taken 16 days to 59 days after treatment were not substantially different from each other, <0.02 ppm. Carbaryl concentrations in samples taken from the bed sprayed at 10.0 pounds per acre were initially much higher with mean values of 83.5 ppm immediately after treatment and 14.5 ppm and after 24-hours. After 59 days they were comparable to the beds treated at 5.0 and 7.5 pounds per acre. Carbaryl concentrations in samples taken August 30 from the bed in the Nemah area which was treated at 7.5 pounds per acre were similar to those taken from the bed in the Palix area which was treated at 2.5 pounds per acre on July 18 (Table III). This suggests that treatments conducted later in the summer when air, water, and sediment temperatures are typically warmer will result in a faster initial carbaryl degradation rate. No carbaryl was detected in any of the June, 1990 samples (minimum level of detection was 0.01 ppm), however, this result could be biased by natural sediment deposition on the beds over the intervening 9 months.

**Table III.** Results of sediment samples analyzed from Willapa Bay oyster beds, July-September, 1989 and June 1990. Surface sediment samples were taken to a depth of about 3 mm.

| Carbaryl Application (lbs/acre)[2] | Pre-Treatment | Immediately Post-Treatment | After 1 Day | After 16 Days | After 28 Days | After 59 Days | After 11 Mon |
|---|---|---|---|---|---|---|---|
| | Concentrations of Carbaryl Relative to When the Bed was Treated[1] | | | | | | |
| Control | | | | | | | |
| 0.0 | 0.018 | 0.011 | 0.019 | N.D | N.D. | 0.008 | N.D. |
| Palix River Area- Bed B67 | | | | | | | |
| 2.5 | 0.005 | 15.110 | 0.223 | 0.009 | N.D. | 0.009 | - |
| | | 34.780 | 0.338 | 0.011 | | | |
| | | 22.980 | 0.247 | 0.012 | | | |
| 5.0 | 0.008 | 67.850 | 0.651 | 0.033 | 0.008 | 0.008 | N.D. |
| | | 66.530 | 0.668 | 0.021 | | | N.D. |
| | | 53.010 | 0.778 | 0.015 | | | N.D. |
| 7.5 | 0.024 | 45.730 | 1.779 | 0.024 | 0.010 | 0.013 | N.D. |
| | | 35.230 | 3.939 | 0.019 | | | N.D. |
| | | 42.340 | 3.004 | 0.019 | | | N.D. |
| Palix River Area Bed B111-113 | | | | | | | |
| 10.0 | 0.055 | 65.140 | 14.780 | 0.252 | 0.036 | 0.012 | |
| | | 88.860 | 6.130 | 0.081 | | | |
| | | 96.350 | 22.510 | 0.110 | | | |
| Nemah River Area Anderson Bed | | | | | | | |
| 0.0 | 0.005 | 0.004 | 0.006 | N.D. | | | |
| 7.5 | 0.257 | 28.320 | 0.236 | 0.057 | | | |

1- Note: The presence of carbaryl at the control site and prior to treatment suggests that the samples may have been contaminated at some point (see text for explanation).

2- N.D. = Not Detected. The no detect level for the 6/21/90 sample (i.e., 11 months post treatment) was 0.01 ppm while for all other samples it was 0.002 ppm. The Anderson Bed was treated on 8/30/89 and evaluated 15 days after treatment, rather than 16 days. All other beds were treated on 7/18/89.

Some evidence suggests that samples may have been contaminated during sample collection or handling. Carbaryl was present in concentrations of 0.004 to 0.019 ppm in seven of the ten 1989 control samples and in all five of the pre-treatment samples (range: 0.005 to 0.257 ppm). Carbaryl concentrations in the pre-treatment samples increased in exact rank order with the application rates at which the beds were treated. The average carbaryl concentration in pre-treatment samples (0.053 ppm) is almost identical to the average of the samples taken 16 days after treatment (0.051 ppm). These indications of probable sample contamination make it likely that samples taken 16, 28 and 59 days after treatment contained carbaryl in concentrations lower than those actually measured (to the limit of detection of 0.002 ppm).

In summary, these results show that carbaryl in the sediments of oyster beds of Willapa Bay degrades rapidly to very low levels after treatment under summertime conditions.

### 3. Conclusions

Carbaryl transport depends on water velocity and turbulence. Usually, the direction of carbaryl transport will be predictable. The highest carbaryl concentrations will generally be found in the leading edge of the incoming tidal plume as the bed refloods and when convergence of leading edges occurs. Some carbaryl will be carried off-tract as beds reflood with the incoming tide. Measurable levels in the water column have been found up to 1,700 feet off-tract when the leading edge of the incoming tidal plume was sampled. The amount of off-tract transport is undoubtedly variable, depending on site-specific conditions. No water column measurements have been taken on the ebb or succeeding tides. Analyses of sediment samples taken in Willapa Bay demonstrates that carbaryl degrades rapidly under summertime conditions.

## C. The toxicity of carbaryl and its hydrolytic products

Carbaryl has varying degrees of toxicity to plants and animals, and there are resistant and susceptible species in all taxonomic groups. The following section summarizes results of studies in which acute and chronic effects of carbaryl poisoning were tested on a range of species. A large share of the studies are small-scale static laboratory assessments, using carbaryl dissolved in an organic solvent. Very few field studies relevant to estuarine conditions have been conducted.

### 1. Effects on aquatic plants

Aquatic plants are an important biological resource in Willapa Bay and Grays Harbor. They range from single celled phytoplankton and benthic algae to large seed-bearing eelgrass and marsh plants. Twenty-nine taxa of macroalgae have been collected in Grays Harbor (Thom, 1984a). Thom (1984b) reported that eelgrass contributed the largest proportion of organic carbon production in the Grays Harbor estuary followed by benthic algae, marsh plants and phytoplankton.

There are few studies dealing with the effects of carbaryl on aquatic vegetation, and none dealing specifically with any of the key plant species (e.g, eelgrass) found in Grays Harbor and Willapa Bay. None of the studies that have been conducted found evidence of irreversible physiological impacts on aquatic plants. In controlled laboratory experiments, Kentzer-Baczewska, et al. (1984) found that exposures of 10 ppm of both carbaryl and 1-naphthol for two hours reversibly inhibited cell multiplication, production of chlorophyll-a and uptake of inorganic carbon by green and blue-green algae. There was little or no change at 1 ppm carbaryl and an intermediate response at 5 ppm. Hanazato and Yasuno (1987) could not detect a direct effect of carbaryl on the phytoplankton communities in ponds.

Ramachandran, et al. (1984) measured long-term (>24 h) effects of low concentrations (50 ppb) of carbaryl on the net photosynthesis and dark respiration activities of six tropical marine algae. Each was tested in small aquaria (200 ml) containing filtered sterile seawater (31 ppt) incubated in-situ at 30° C. There was increased respiration in four of six macrophytes, but photosynthesis was apparently not affected.

As indicated by the above studies, it is highly unlikely that carbaryl will have direct, irreversible physiological impacts on aquatic plants in the two estuaries. Carbaryl is an insecticide and as such its activity should not significantly interfere with the physiology of aquatic plants. When ghost shrimp (and to a lesser extent mud shrimp) are removed, sediments become firmer and denser. If conditions are otherwise suitable, the quantity of some aquatic plants could increase on these areas with the change in the substrate. Some oyster culture practices such as harvesting by dredge will eliminate some eelgrass and offset some of the increase resulting from the change in habitat.

### 2. Effects on invertebrates, other than crab

Carbaryl is generally more toxic to aquatic invertebrates than to vertebrates. Effects of carbaryl exposure in aquarium-type bioassays on a number of species were reviewed by several authors and are summarized in Table IV (see also FEIS).

#### a. Literature reports

Most studies dealing with effects on invertebrates have dealt with acute toxicity to freshwater or terrestrial forms. All were carried out under long exposure times

**Table IV.** Carbaryl and 1-naphthol $LC_{50}$'s for selected invertebrate species (from summary data in Capaldo, 1987; Mount and Oehme, 1981; Johnson, 1987).

| Species | Exposure Time (hr) | $LC_{50}$ (ppm) Carbaryl | $LC_{50}$ (ppm) 1-naphthol |
|---|---|---|---|
| **ARTHROPODS** | | | |
| Amphipod (Gammarus) | 24 | 0.040 | -- |
| Mud shrimp larvae | 24 | 0.03-0.16 | 6.2-13.7 |
| Ghost shrimp larvae | 48 | 0.17-0.47 | 16.6-22.1 |
| Ghost shrimp adult | 24 | 0.13 | 6.6 |
| Dungeness crab larvae | 24 | 0.08 | -- |
| Dungeness crab juvenile | 24 | 0.076 | -- |
| Dungeness crab adult | 24 | 0.49 | 37.0-60.0 |
| Fiddler crab larvae | 24 | 0.1 | -- |
| **MOLLUSKS** | | | |
| Bay mussel larvae | 48 | 1.4-2.9 | 0.8-2.2 |
| Pacific oyster larvae | 48 | 1.5-2.7 | 0.6-1.1 |
| Juvenile cockle clams | 96 | 3.75 | -- |
| Adult cockle clams | 24 | 7.3 | -- |

and static laboratory conditions or in field conditions dissimilar to those in the project area. Usually an organic solvent, such as acetone, was used to dissolve the carbaryl. Reports published since 1984 relevant to application in aquatic environments, such as Willapa Bay, are summarized below:

- Zoeae (larvae) of the fiddler crab, *Uca minax*, were exposed to 0.1 to 1 ppm carbaryl (27% liquid Sevin) in seawater contained in small beakers. Mortalities were seen within 12 hours at the highest dose, with behavioral changes within 2 hours (Capaldo, 1987).

- Carbaryl reduced the fecundity of a common freshwater snail at a concentration of 11 ppm. There was also a reduction in hatching of eggs and survival of young snails as the dose increased from 1 to 11 ppm (Singh and Agarwal, 1986).

- Conti (1987) found that the 48 h $LC_{50}$ of carbaryl for the lugworm, *Arenicola marina,* was 7.2 ppm. Of the structures studied, the gills and epidermal receptors were the most sensitive sites of the lugworm, while the thoracic epidermis was the most resistant.

- The densities of amphipods in ponds treated with carbaryl were reduced to near $0/m^2$. The subsequent failure of amphipods to return in large numbers was suggested as being due to any of three possible factors: 1) toxicity of persistent carbaryl residues, 2) intense predation, or 3) reproductive failure of the species at low numbers (Gibbs, et al., 1984).

- Sublethal effects of carbaryl on Spruce budworm, *Choristoneura fumiferana*, larvae were studied by Alford and Holmes (1986). Pupal weights of individuals fed 10 ppm of carbaryl were significantly less than untreated individuals, and larval development was extended after exposure to 17 ppm, the highest sublethal dose tested.

**b. Studies in Willapa Bay and Grays Harbor**

Much of the work in the project area has dealt with impacts of carbaryl on burrowing shrimp and crab. The direct effects of carbaryl on crab are discussed beginning on page 55. Short-term impacts of carbaryl on some invertebrates were quantified by Hueckel, et al. (1988) by sampling seven 200 $m^2$ transects on three treated tracts. They estimated that if 800 acres were treated, 1.5 million invertebrates (with a 95% confidence interval of 2.6 million and excluding burrowing shrimp) would be killed (Table V). Mortality was highly variable between tracts, as evidenced by the large confidence intervals. Total mortality estimates are conservative since they only include organisms which were on the surface immediately after spraying (see also comments on page 42).

Information on the effects of carbaryl on burrowing shrimp comes from studies of: 1) the off-tract dispersal of carbaryl particles, and 2) the efficacy of different carbaryl application rates. Stations as far

**Table V.** Invertebrate mortalities identified in seven 200 $m^2$ transects conducted on oyster tracts in Willapa Bay and Grays Harbor immediately following carbaryl application (Hueckel, et al., 1988).

| Invertebrates | Avg/m2 | 95% C.I.[1] | Avg/acre | 95% C.I.[1] |
|---|---|---|---|---|
| Ghost/mud shrimp | 1.387 | 5.762 | 5,613 | 23,318 |
| Nereid worms | 0.352 | 0.644 | 1,425 | 2,606 |
| Crangon shrimp | 0.088 | 0.057 | 356 | 231 |
| Scale worms | 0.025 | 0.077 | 101 | 312 |
| Dungeness crab[2] | 0.014 | 0.036 | 57 | 146 |
| Nemertina | 0.002 | 0.010 | 8 | 40 |

[1] Confidence interval.
[2] Includes all size groups.

as 400 feet (122 m) from the margin of sprayed tracts near the Cedar-North River (carbaryl in water measured at 0.6 ppm) and at Nahcotta (carbaryl <0.1 ppm) showed reduced burrow counts after treatment. Off-site reductions in burrow counts generally correlate well with measured carbaryl concentrations in water samples (Tufts, 1989).

A long-term study reported by Tufts (1990) suggests there is a fairly uniform response of burrowing shrimp to carbaryl. These observations (summarized in Figure 8) show that there is an immediate impact of treatment,

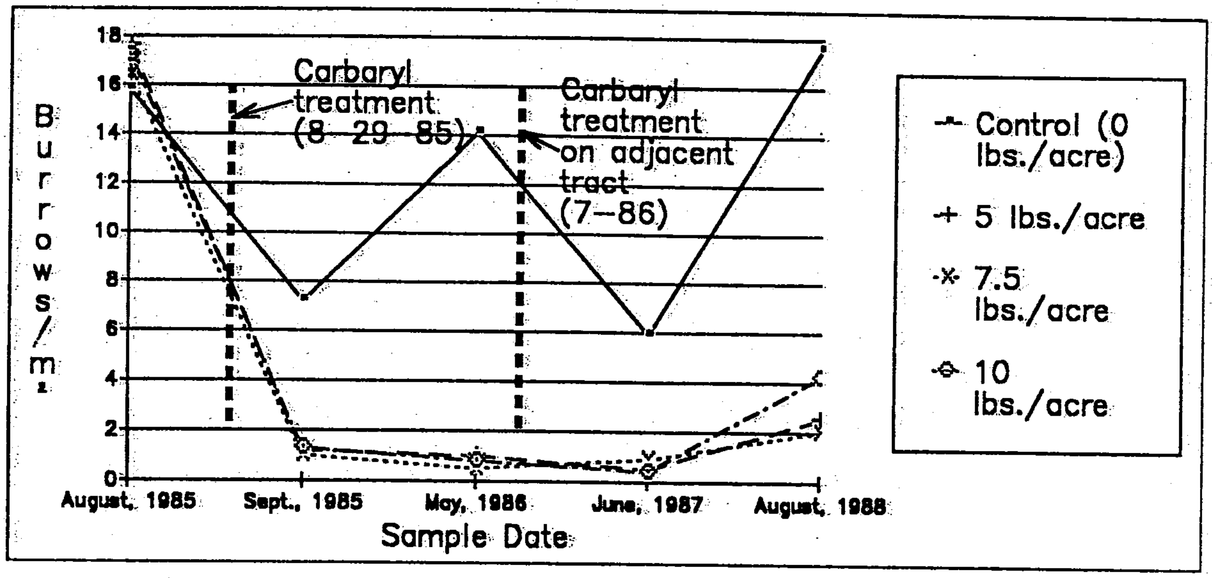



**Figure 8.** Temporal changes in the density of burrowing shrimp burrows at various carbaryl application rates (from Tufts 1990).

a subsequent period of low densities and an increase in densities occurring by year 3. Burrow counts were highly variable in the untreated control, probably reflecting seasonal or natural variations.

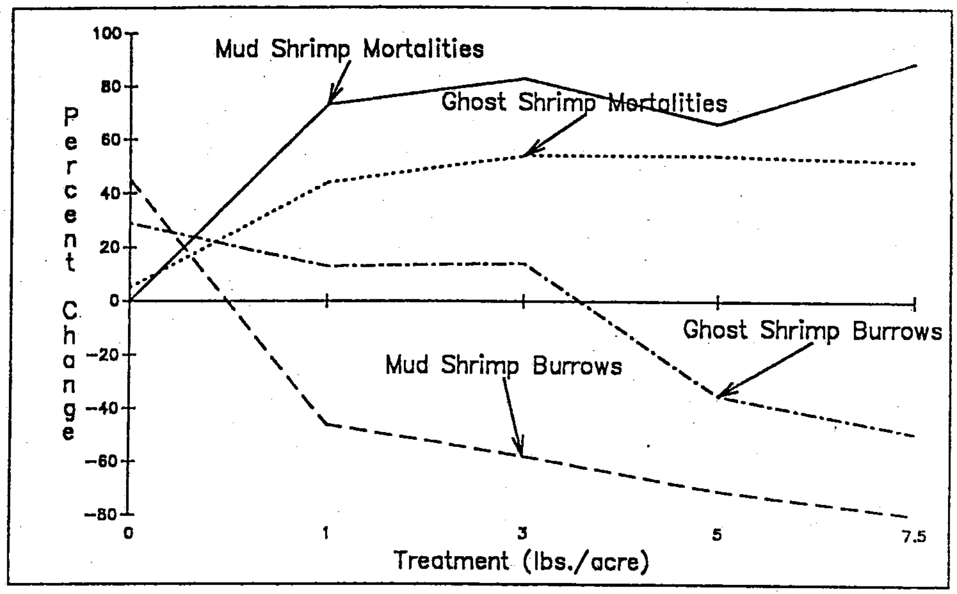



**Figure 9.** Density of burrowing shrimp burrows versus carbaryl application rate (from Dumbauld et al., 1989).

Creekman and Hurlburt (1987) found little difference in the percent shrimp kill resulting from the application of 5, 7.5 and 10 lbs/acre (Table VI). Tufts (1990) described similar results for large-scale spraying of 4, 5 and 7.5 lbs/acre in Willapa Bay and Grays Harbor. Results of small-scale studies testing the influence of low application rates were variable (Dumbauld et al., 1989). They indicated carbaryl was less efficient when applied at lower concentrations, particularly when ghost shrimp were the target (Figure 9). A 70 to 100%

**Table VI.** The effect of carbaryl application rate and timing on percent change in burrow counts (ghost and mud shrimp) measured two weeks after treatment (Creekman and Hurlburt, 1987).

| Month Sprayed | Mud Temp. | Pounds/Acre Sevin 0 | 5 | 7.5 | 10 |
|---|---|---|---|---|---|
| May | 54 F | +45 | + 1 | -12 | -33 |
| June | 62 F | +16 | -61 | -80 | -87 |
| July | 62 F | +18 | -86 | -94 | -92 |
| August | 61 F | -36 | -92 | -93 | -93 |

reduction in shrimp or burrow count was never achieved for ghost shrimp. This level of reduction could be achieved when mud shrimp were the target even at an application rate of 1 lb/acre. These experiments were repeated in 1989 with application rates of 0.5, 1.5 and 5.0 pounds/acre. Carbaryl was more effective on ghost shrimp than on mud shrimp in this experiment, but burrow count reductions of 80% or more were achieved only at 5 lbs/acre. Growers maintain that lower concentrations can be effective on beds that are of a higher elevation and when the air temperature is warmer.

### 3. Effects on fish

Carbaryl has varying degrees of toxicity to fish. Table VII summarizes $LC_{50}$ values of carbaryl for various fish from a variety of aquarium-type bioassay studies.

#### a. Literature reports

**Table VII.** Carbaryl and 1-naphthol $LC_{50}$'s for selected fish species (from data summaries in Mount and Oehme, 1981; and Johnson, 1987)

| Species | Exposure Time (hrs) | $LC_{50}$ (ppm) Carbaryl | $LC_{50}$ (ppm) 1-naphthol |
|---|---|---|---|
| Shiner perch juvenile | 24 | 3.8 - 4.0 | 1.3 - 1.8 |
| English sole juveniles | 24 | 3.2 - 5.2 | 2.4 - 2.7 |
| Three-spine stickleback | 24 | 5.5 - 7.7 | 2.8 - 3.5 |
| Brown trout | 48 | 1.5 | -- |
| Coho salmon juveniles | 24 | 2.95 | -- |
| Rainbow trout | 96 | 4.38 | -- |

While the acute toxic effects of carbaryl on fish have been intensively investigated, few experiments have addressed potential biochemical effects. Recent reports containing observations relevant to fish are summarized below:

- The acute toxicity of 11 chemicals fed to rainbow trout (*Oncorhynchus mykiss*) fry was measured by Marking, et al. (1984). The 96 hour $LC_{50}$s for carbaryl ranged from 0.94 to 1.74 ppm.
- Arora and Kalshrestha (1985) exposed the freshwater fish *Channa striatus* in aquaria for 2 to 30 days to 10-20 ppm of carbaryl. Acid phosphatase activity increased with duration of exposure at the higher concentration of carbaryl and decreased at the lower concentration. Alkaline phosphatase activity declined at both concentrations.
- Kulshrestha and Arora (1984) examined sublethal effects of carbaryl on ovaries of *Channa striatus*.

They reported little or no histopathological change in ovaries following 2 to 30 day exposures at 10 and 20 ppm of carbaryl.

- Sastry and Siddiqui (1985) tested effects of four concentrations (0.1, 1, 10 and 100 ppm) of carbaryl on the rate of uptake of two sugars and an amino acid by the intestine of *Channa striatus*. All concentrations decreased the rate of transport of nutrients.

- Beitinger and Freeman (1983) reviewed several experiments in which behavioral responses to carbaryl were reported. In a simple two-choice test, sheepshead minnow (*Cyprinodon variegatus*) did not avoid carbaryl at concentrations of 0.1, 1.0 and 10.0 ppm. Under the same test conditions, mosquitofish significantly avoided carbaryl at a concentration of 10 ppm, but did not avoid either 1.0 or 0.1 ppm when the alternative choice was "clean" water or 1.0 ppm of carbaryl.

The above results are difficult to relate to the natural environment of Willapa Bay and Grays Harbor. Experiments were carried out in small static volumes of fresh or filtered water where fish were held for 24 hours or longer in a toxic solution. Most laboratory and field studies used carbaryl dissolved in an organic solvent such as acetone; however, both soluble and particulate forms of carbaryl occur on treated tracts. Conditions similar to the static bioassays are found in Willapa Bay and Grays Harbor at the time of spraying when some fish are trapped in shallow tidal pools.

**b. Carbaryl-induced estuarine fish mortalities.**

Many marine fish species pass their early life stages in estuaries. Concern was expressed about the possible impacts of carbaryl on marine fishes such as sole and lingcod found in Willapa Bay and Grays Harbor. Mortalities of small fish trapped in shallow pools by the outgoing tide and directly exposed to carbaryl treatment have been reported (see the FEIS).

Investigations of marine fish mortalities on treated tracts were conducted by Tufts (1990) and Hueckel et al. (1988). The purpose of these studies was to gain an understanding of the level of impact that could occur. These studies were clearly limited in their scope (e.g., each study was only conducted in one year and was limited in the amount of area sampled).

Tufts (1990) reported the principal variable affecting marine fish losses was the area of treated oyster beds covered by sea water > 2 inches deep (termed "marine fish habitat") at low tide. This ranged from 0 to 50%. Of the 434 acres treated in 1987, 67 acres were classified as marine fish habitat. In a survey of 25 tracts (using single 10 by 100 foot transects) treated in 1987, the total number of fish killed was 19/acre over the 434 acres of treated tracts or 120/acre on the 67 acres of "marine fish habitat." Most fish (81%) and all flatfish were seen on one tract at Oysterville, in which 40% of the total area (42 acres) was classified as marine fish habitat.

**Table VIII.** Fish identified in seven 200 $m^2$ transects conducted on oyster tracts in Willapa Bay and Grays Harbor following carbaryl application (from Hueckel, et al, 1988).

| Fish species | Avg/$m^2$ | 95% CI* | #/Ac | 95% CI* |
|---|---|---|---|---|
| Saddleback gunnel | 0.049 | 0.062 | 198 | 251 |
| Staghorn sculpin | 0.036 | 0.079 | 146 | 320 |
| Bay goby | 0.031 | 0.063 | 125 | 255 |
| Three-spined stickleback | 0.004 | 0.004 | 16 | 57 |
| Starry flounder | 0.001 | 0.004 | 4 | 16 |

* Confidence interval + or - average value.

Hueckel, et al. (1988) estimated that about 489 fish/acre (range 160 to 900/acre) were killed on tracts as a result of carbaryl applications. Their estimate was based on an assessment of seven 200 $m^2$ transects on three treated tracts (two tracts in Willapa Bay and one in Grays Harbor). The two tracts sampled in Willapa Bay contained 20% to 98% "marine fish habitat" -- i.e. water 2" to 6" in depth (Hueckel, 1987) (Table VIII). The fish mortalities reported on treated oyster grounds by Tufts (1990) and Hueckel, et al. (1988) included starry flounder, shiner perch, blennies, sculpins, gobies, and sticklebacks.

Hueckel, et al. (1988) expressed concern over fish concentrated in shallow channels adjacent to treated tracts during low tide periods (see Section F.1, Quantitative assessment of fish populations). They noted carbaryl levels in these channels have not been adequately measured, and drainage from tracts into channels could expose some marine fish and invertebrates to lethal or sublethal levels of carbaryl. Results of crab cage studies (page 59) and observations by biologists during treatment monitoring indicate some mortality can occur in intertidal channels but that there is little or no mortality in adjacent subtidal channels. Since fish are less susceptible to carbaryl than crab, it is unlikely that significant mortality of fish occurs in off-tract subtidal areas. However, the possibility that sublethal affects occur in these areas cannot be ruled out with existing information.

**c. Food organisms utilized by estuarine fish**

Food organisms consumed by fish common to the project area were identified by WDF from trawl samples taken in summer, 1988 (Hueckel, et al, 1988). Before and after treatment, English sole fed on a variety of polychaetes, the tanaid *Leptochelia savignyi*, the harpacticoid *Longipedia* sp., and the gammarid *Corophium ascherusicum*. Shiner perch fed primarily on ostracods, tanaids, the caprellid *Cumella vulgaris*, and the gammarids *C. ascherusicum* and *Photis* sp. Kelp greenling ate tanaids, nereid polychaetes, *Photis* sp., *Corophium* spp., nudibranchs, caprellids and crangon shrimp. Staghorn sculpin foraged primarily on tanaids, ghost and mud shrimp, crabs, and nereid polychaetes.

The most notable difference in the diet of fish before and after treatment was an increase in the importance of *Corophium* spp. and polychaetes and a decrease in tanaids. This may be due to the fact that *Corophium* and polychaetes are especially sensitive to carbaryl, and more subject to scavenging by the fish.

**d. Carbaryl and 1-naphthol in fish and food organisms**

**Table IX.** Average carbaryl concentrations in burrowing shrimp and annelid worms collected following treatment, 1986 (from Tufts, 1989).

| Carbaryl, rate of application | Burrowing Shrimp Carbaryl (ppm) | Annelid Worms Carbaryl (ppm) |
|---|---|---|
| 10 lbs/acre | 13.8 | 75.7 |
| 7.5 lbs/acre | 8.7 | 57.0 |
| 5 lbs/acre | 5.3 | 58.6 |

WDF measured concentrations of carbaryl associated with shrimp, crab, and polychaetes (Table IX) following treatment of several tracts in 1986 (Hurlburt, 1986b; Creekman and Hurlburt, 1987). Carbaryl in shrimp from a bed treated in 1985 with 7.5 lbs/acre was 4.5 ppm immediately after spray application and about 0.3 to 0.5 ppm 24 to 96 hours later. In a related study, carbaryl was measured in shrimp obtained from sites with three application rates: 5 lbs/acre -- 7 ppm; 7.5 lbs/acre -- 8 ppm; and 10 lbs/acre -- 9.5 ppm (Creekman and Hurlburt, 1987). Much higher levels were found in a 1984 study by Hurlburt (1986b). A single sample of ghost shrimp tissues contained 24.9 ppm while a small Dungeness crab contained 41.9 ppm. A follow up study was completed in 1986 to measure carbaryl concentrations in shrimp and worms taken from a site in Willapa Bay treated at 5, 7.5 and 10 lbs carbaryl/acre. These data are shown in Table IX; there was generally an increase in carbaryl content of burrowing shrimp and worms as the quantity of carbaryl applied per acre increased. The higher concentrations in worms were probably due to carbaryl particles adhering to the mucus layer of the animals.

**e. Toxicity of poisoned food organisms to fish.**

WDF conducted two bioassay experiments to assess if estuarine fish were adversely impacted by eating food contaminated with carbaryl. In the first 25 day experiment adult and juvenile shiner perch were fed food (80% Oregon Moist Pellets and 20% clam meat) containing 0, 1000 and 10,000 ppm carbaryl once per hour over a six-hour period (one tidal cycle). The total quantity of food fed to the fish was 5% of their body weight. An exmination of the stomach contents of some of the fish fed 10,000 ppm of carbaryl demonstrated that these fish had indeed consumed the test food. No mortalities occurred although sub-lethal effects were noted at 10,000 ppm. During the fifth and sixth feedings at 10,000 ppm the adult fish did not feed as vigorously and surplus food was observed in the tank. Within minutes of the sixth feeding the majority of the fish had turned on their sides and were motionless for 30 seconds or more. The fish had recovered after 20 minutes. The investigators suggested that carbaryl in solution from the surplus food may have caused the aberrant behavior.

In the second bioassay, shiner perch, juvenile English sole and adult speckled sanddab were fed food containing carbaryl at concentrations of 0, 100, 300, 600 and 1000 ppm. Fish were fed over a simulated two-tide cycle and held for 16 days after the feeding. Mortalities occurred in some of the test and control animals as a result of complications resulting from handling, starvation, disease, and possibly for other reasons. Because of these problems, some experimental standards were not maintained. Although it was impossible to isolate the effects of carbaryl from other sources of mortality, the investigators believed that carbaryl was probably not the cause of most mortalities.

Reports generally indicate that carbaryl in solution or suspension in the water is toxic to fish in 24 to 48 hour exposures, at concentrations ranging from 1 to 20 ppm. For example, Stewart, et al. (1967) found that the 24-hr EC50 sensitivities of English sole and shiner perch, two of the species tested in feeding studies described above, to carbaryl and 1-naphthol in solution ranged from 1.3 to 5.2 ppm. The WDF studies described above suggest that fish need to consume carbaryl at much higher concentrations than the EC50's in order to be adversely affected. As shown in Table IX, the concentrations of carbaryl in contaminated food in Willapa Bay are much less than that needed to adversely impact fish consuming this food. Thus, mortalities resulting from the consumption of food items contaminated with carbaryl are unlikely.

**4. Effects on birds**

A major animal group potentially affected by aerial application of carbaryl in Willapa Bay and Grays Harbor is birds. Most birds appear to have considerable resistance to carbaryl with reported acute $LD_{50}$ values of: pigeons -- 1,000 to 3,000 mg/kg; young mallards -- 2,179 mg/kg; and Canadian geese -- 1,790 mg/kg (Mount and Oehme, 1981).

The prolonged affects of carbaryl in the diet of birds has been assessed for several bird species. Carbaryl was given to Japanese quail from the day of hatching to 14 weeks of age at 50 to 1,200 ppm dietary levels. There were no changes in blood chemistry or cholinesterase, but dopamine levels were elevated at 600 and 1,200 ppm. Higher dietary levels of carbaryl (900 to 1,200 ppm) reduced hatchability and fertility. No teratogenic or fetotoxic effects were observed. Studies of natural populations have indicated no direct effects on reproductive biology or feeding behavior, or changes in nesting conditions (Mount and Oehme, 1981).

While birds are common, and sometimes abundant on oyster beds immediately after treatment, they are represented by a limited number of species. The birds are dominated by gulls, mainly the Glaucous Winged or Western, or a hybrid of these two species. Crows are also common, and shore-birds have been seen occasionally on recently sprayed beds. Shorebirds present during the spray time could include:

Dunlins; Blackbellied Plovers; Dowitchers (both species depending on the time of spraying); Ruddy Turnstones; and possibly Whimbrels (which were probably identified as Curlews in the 1985 EIS). Carbaryl application occurs between peak migration periods.

Based on the levels of carbaryl necessary for toxic affects and the measured levels of residual carbaryl (up to 25mg/kg body weight) on the shrimp, it is highly unlikely for a bird to ingest toxic levels of carbaryl during the period between spraying and until coverage by the incoming tide. For example, a 1 kilogram (2.2 pound) seagull would have to ingest 40 kilograms (22 pounds) of shrimp (this would be about 5,500 shrimp at 7 g each) to reach a carbaryl level of 1000 mg/kg body weight. Similarly, it is unlikely that toxic quantities of contaminated shrimp would be transferred by regurgitation from parent gulls to their offspring.

One concern raised in the 1985 EIS was the possible reduction in prey species for the birds dependent upon an intertidal food source. These prey species are generally the same epibenthic and infaunal organisms consumed by many resident and migratory fish species (see page 43). Work completed by the University of Washington in 1988 (Simenstad and Cordell, 1988) indicated that the density of all epibenthos 24 hours and two weeks after carbaryl treatment was greater on the treatment than on the control (Table X). There was an indication that some individual taxa of epibenthos might be affected by carbaryl.

**5. Conclusions**

There is little relevant scientific information available that can be used to directly evaluate impacts of carbaryl spraying on aquatic plants in estuaries, especially key species such as eelgrass. Direct physiological impacts are unlikely. The application of carbaryl may have a positive influence on some plants if shrimp removal results in an improvement in habitat conditions (e.g., due to stabilization of sediments). The benefits of carbaryl application may be offset, at least in part, by some oyster culture practices.

Carbaryl will kill a number of invertebrate species, including Dungeness crab, burrowing shrimp, and polychaete worms; crustaceans appear to be most sensitive. Mortalities of burrowing shrimp and other invertebrates were largely site-specific and confined to the immediate spray area, but some mortality has been observed as far as 700 feet off treated areas. Sublethal effects reported in insects include reduced larval growth rates and decreases in larval size. No sublethal dose information was found for estuarine invertebrates. There also do not appear to be persistent effects, as indicated by the occurrence on treated beds of smaller crustaceans and worms within 24 hrs after treatment and recolonization by crabs within two weeks. In general, impacts to invertebrates other than crab and shrimp are poorly documented, particularly with respect to differing habitat types. Impacts appear to be highly site-specific.

Pilot studies have shown that carbaryl will kill marine fish trapped in shallow pools on treated tracts. However, studies were not of a sufficient scope to adequately assess the magnitude of impacts. Lethal concentrations for fish are generally an order of magnitude greater than those affecting Dungeness crab and ghost shrimp. Studies of off-tract mortality have not been conducted. Although some mortality may occur in intertidal drainage channels, signficant mortality in subtidal areas is unlikely. Results of bioassay trials demonstrated that carbaryl should not adversely affect fish feeding on prey items contaminated with carbaryl.

Several bird species come in contact with carbaryl in the time between spraying and when the bed is covered by the incoming tide. There is no evidence suggesting ingestion of organisms contaminated with levels of carbaryl typically reported in Willapa Bay and Grays Harbor has acute harmful effects on birds.

**D. Potential for human effects from carbaryl**

There is an extensive body of information on effects of carbaryl, reviewed most recently by Cranmer (1986). Cranmer (1986) appraised the potential of nervous system, reproductive, and disease risk in experimental systems and humans exposed to carbaryl. His conclusions were as follows:

- Nervous system -- Carbaryl is a very potent nervous system poison in insects; vertebrate species are very resistent. Forced oral exposures in excess of 200 mg/kg carbaryl are required to kill mammals. Sublethal doses of carbaryl (10 to 100 mg/kg) can produce a profound but rapidly reversible effect on nervous system function of a variety of vertebrate animals. Delayed and irreversible effects have not been observed in vertebrate species including man. Dietary exposure presents no risk of nervous system toxicity.

- Reproduction -- The potential of carbaryl to produce reproductive effects has been studied in numerous animal species. Structural effects were seen at doses approaching the $LD_{50}$. Risk of reproductive toxicity in humans is likely to be vanishingly small since all observed effects required exposure levels producing obvious nervous system damage.

- Genetic changes -- At high doses, usually toxic to test systems, carbaryl can produce changes in or disruption of gene structures. And, although numerous tests have been conducted, no data from mammalian systems supports the connection that carbaryl usage poses a hazard to future generations of mammals. Note: EPA characterizes carbaryl as a weak mutagen (EPA, Pesticide Fact Sheet, 1985).

- Cancer risk -- A number of long-term cancer studies have been conducted with carbaryl. These studies have used rats, mice and dogs. No increased cancer formation has been attributed to carbaryl in any of these studies. Some nitrited carbaryl compounds are cancer-causing at high doses, but carbaryl, when given at the same time as nitrite has not been shown to induce or promote cancer. However, a 1987 EPA Health Advisory stated "data from laboratory studies are inadequate to determine if carbaryl can increase the risk of cancer in humans".

- Immune system and infectious disease risk -- Carbaryl, when given at doses producing subclinical nervous system symptoms has been reported to produce a variety of effects on the immune system which are reversible and non life-threatening. Lifetime exposure to carbaryl has not resulted in increased infectious disease or cancer in rats and mice. Epidemiologic studies have not linked carbaryl exposures with Reyes Syndrome or any other viral disease. Carbaryl is capable, in tissue culture systems, of enhancing viral growth, but these studies present unresolved problems in extrapolating to human risk effects. Therefore, carbaryl does not appear to represent a risk factor to human immune systems or intensification of infectious disease.

- Human exposure -- Human exposure to carbaryl via respiratory and skin routes has been studied in individuals involved in the manufacture, formulation, packaging and, distribution and application of carbaryl for some 25 years of the product's commercial life. Other studies have provided data on the toxic and nontoxic effects of carbaryl following oral ingestion by humans. Despite general availability, high volume and diverse use, reports on incidents of carbaryl poisoning, even including suicide attempts, indicate extremely rare incidence of mortality. Epidemiological studies have not demonstrated delayed nervous system effects, abnormal sperm, or viral enhancement in humans exposed to carbaryl.

- Risk Analysis -- The possibility of cancer risks due to carbaryl exposure are limited to concentrated nitrited carbaryl. Even when highly speculative theoretical exposures to nitrited carbaryl are evaluated the risks calculated are vanishingly small and well below the accepted levels of concern to regulatory agencies.

The FEIS briefly reviewed potential carbaryl impacts to man. An extensive review (1977) of human exposure to carbaryl revealed no significant effects in the U. S. over a 20 year period (Mount and Oehme, 1981; and USDA, 1985).

There is no production of carbaryl in Pacific County, nor are any of the chemicals used in its production believed to be used in the region. Carbaryl used for the control of burrowing shrimp is applied to areas of exposed estuarine mudflats. Its transport off the sprayed tracts is confined to a limited area, and concentrations in the overlying saltwater diminish rapidly. No domestic ground and surface water supplies in the region will be contaminated unless they are strongly infiltrated with saltwater from a source immediately adjacent to a sprayed tract. No such infiltrated sources exist in the Willapa Bay/Grays Harbor region.

## E. Epibenthic prey organisms on oyster beds

An important group of invertebrates that inhabit oyster beds in the project area are the epibenthos[4]. These organisms are important prey resources for many estuarine fishes, such as juvenile salmon and flatfish, and shorebirds, such as Dunlin and sandpiper species (Simenstad and Cordell, 1989). Some information on epibenthos and infauna is presented in the FEIS (see Summary section). Studies of coastal populations of epibenthic invertebrates (other than those associated with evaluating impacts of carbaryl) have been conducted in the Columbia River Estuary (Simenstad, 1984) and Grays Harbor (Cordell and Simenstad, 1981).

### 1. Recovery following treatment

There are several studies that provide information on the impacts of carbaryl on the epifauna and infauna of Willapa Bay and Grays Harbor. Several of these (Hurlburt, 1986b; Dumbauld, 1987; Tufts, 1990) are of limited use because they were incompletely analyzed and interpreted. Hurlburt (1986b) reported the most obvious change in samples of an infaunal community in Willapa Bay was a decrease in numbers of the polychaete *Pectinaria granulata*, which declined from 7.8 per core to less than one, 24 hours and 60 days after treatment. Eight subsamples analyzed from a 1985 study

[4] These are the small, sometimes microscopic animals living on or near the surface of the substrate.

showed total densities of selected epifauna and small infauna differing on treated and control plots before and after treatment; a short-term decline in densities occured on treated samples (Dumbauld, 1987; Tufts, 1990).

The best available information on the impacts of carbaryl on epibenthic animals is provided in Simenstad and Cordell (1989). The intent of their study was to provide an indication of whether carbaryl impacts epibenthic animals and, if it does, what level of impact may occur. The study was limited in scope (e.g., only one treatment and one control site were sampled on three occassions over two weeks). Moreover, it did not address cummulative effects over larger areas, where recolonization might be limited, and was not designed to be indicative of infaunal organisms on the site.

The study consisted of collecting epibenthic and near-surface infaunal prey organisms from oyster beds in Willapa Bay in June and July, 1988. One control and one treatment plot were sampled one day prior to carbaryl treatment, during the flood tide immediately after treatment (24 hrs), and one full tidal series (2 weeks) after treatment. The physical conditions of treatment and control sites were considered to be equal. Density and biomass of a number of species and life stages were measured.

Data for all samples is provided in the Appendix and summarized in Table X. A diverse assemblage of epibenthic crustaceans typified the intertidal flats in treatment and control areas. These were dominated by 40 taxa of harpacticoid copepods, 5 of which were comparatively abundant. Total densities of epibenthos averaged between 4,200 and 20,300 organisms/$m^2$. On both treatment and control plot, the total densities of epibenthos increased between the time of treatment (late June-early July) and two weeks later (Table X). The total density of epibenthic invertebrates was greater on the treated plot than on the control plot each of the three times samples were taken (i.e., pre-treatment, 24-hr after treatment, and two weeks after treatment).

Changes in densities of specific epibenthic crustacean taxa with respect to plot type (treatment versus control) and time period (pretreatment, immediately after treatment, and two weeks after treatment) varied with the taxa being considered. For some taxa, densities were greater on the treated plot compared to the control. For example, the density of *Tisbe*, a harpacticoid copepod, two weeks after treatment was 894 animals/$m^2$ on the treatment plot and 778 animals/$m^2$ on the control plot. The density of *Paralaophonte*, another harpacticoid copepod, was higher on the treatment plot than on the control site both

**Table X.** Summary results of the 1988 Willapa Bay epibenthic study conducted by Simenstad and Cordell (1989).

| Sample Period | Density (Numbers /m$^2$) | | | | |
|---|---|---|---|---|---|
| | Total # | *Paralaophonte* | *Tisbe* | *Corophium* | *Cumella vulgaris* |
| **A. Carbaryl Treatment Site** | | | | | |
| One Day Prior to Treatment | 7,927.8 | 400.0 | 305.6 | 27.8 | 57.8 |
| 24 Hours After Treatment | 13,416.7 | 1,022.1 | 122.2 | 188.9 | 933.3 |
| Two Weeks After Treatment | 20,266.7 | 1,972.3 | 894.5 | 5.6 | 88.8 |
| **B. Control Site** | | | | | |
| One Day Prior to Treatment | 4,166.7 | 50.0 | 166.7 | 5.6 | 105.6 |
| 24 Hours After Treatment | 6,150.0 | 349.9 | 366.7 | 16.7 | 272.2 |
| Two Weeks After Treatment | 15,494.4 | 1,416.7 | 777.7 | 61.1 | 1,116.7 |

immediately after treatment and two weeks after treatment (Table X). In some cases, even though densities on the treated plot were greater than on the control plot, the percentage change in densities from one time period to the next was considerably different on the treated plot than on the control plot. For example, the density of *Paralaophonte* on the treatment plot increased by about five times between the pretreatment sample and the sample taken two weeks later. On the control plot, density of this same taxa increased by a factor of nearly 28 over the same time period.

For some of the other taxa, densities on the treatment plot declined relative to the pre-treatment sample. For example, the density of *Tisbe* on the treatment plot declined immediately after treatment while over the same time period the density on the control plot increased. Two weeks after treatment, the densities of cumaceans and gammarid amphipods (*Corophium* sp.) declined on the treatment site but not on the control plot (Table X).

Observed differences in densities of epibenthic taxa on the treated and control plots could be the result of carbaryl application or a function of natural factors not related to carbaryl, such as physical changes in the sediment condition or environmental factors.

### 2. Conclusions

The epibenthos is made up of small organisms which live on or near the surface of the substrate. These animals are generally abundant in Willapa Bay and Grays Harbor, and many are important food items for a number of predators.

A limited survey of treated and control tracts showed that carbaryl application did not result in the mortality of most or all epibenthic invertebrates on a treated tract. There was an increase in total densities on both plots after carbaryl application, with greater densities on the treated tract. This is in contrast to carbaryl's impacts on marine fish, Dungeness crab, some benthic invertebrates, and burrowing shrimp; carbaryl kills most or all of these animals on treated tracts within a short period after treatment. However, some individual taxa may have been adversely impacted by carbaryl (e.g., some harpacticoids and cumaceans), suggesting that impacts of carbaryl depend to some extent on the taxa of epibenthic invertebrate. It was not possible to determine if the observed changes in density of epibenthos were a result of carbaryl application or other factors (e.g., environmental fluctuations). In order to more completely define any effects of carbaryl on the epibenthos in Willapa Bay and Grays Harbor, further studies would be needed.

## F. The use of oyster beds and intertidal areas by fish

### 1. Quantitative assessment of fish populations

English sole, shiner perch, and sanddabs comprised over 82% of the fish of potential recreational and commercial importance captured during trawl sampling in shallow and deep water channels during low tide adjacent to oyster beds in Willapa Bay and Grays Harbor in the summer 1988 (Hueckel, et al., 1988). These species were present in significantly greater densities and biomass than the other species captured. Other species caught (which comprised >0.5% of the numerical composition) included Pacific tomcod, white seaperch, sandsole, Northern anchovy, starry flounder, and lingcod in both estuaries, and walleye surfperch and greenling in Willapa Bay. The average fish densities decreased steadily from May to September in both estuaries, probably due to heavy natural mortalities suffered by young-of-the-year fish. Results of beam trawl sampling in Willapa Bay and beach seine sampling in Grays Harbor did not detect significant differences in species composition or densities of fish which colonized tracts before and after carbaryl treatment (Appendix IX). Information on the effects of carbaryl on fish is provided beginning on page 42.

## G. Food Web Impacts

Detailed studies of food webs and the effects of carbaryl on food webs have not been explicitly conducted within Grays Harbor and Willapa Bay. Therefore, in order to assess potential impacts of carbaryl application on food webs, existing information on the plants, animals and ecology of the two estuaries was examined. This included such information as the food habits of marine fish, ecology of burrowing shrimp, and the composition of the infaunal and epifaunal invertebrates associated with mud flats. This material was used to develop ideas about what changes could be expected to food webs as a result of perturbing intertidal areas with carbaryl treatments. To verify whether the notions presented below are reasonable, further study is needed regarding the food webs in Willapa Bay and Grays Harbor and how they would be affected by carbaryl.

A food web is the trophic network of plants, animals and microbes, associated with a habitat or area. Each element of the food web provides food to one or more organisms in the same or higher trophic levels. In the food web, energy flows from lower trophic levels (e.g., autotrophs and microbes) to higher trophic levels (consumers). Within a particular ecosystem, such as the waters of Grays Harbor or Willapa Bay, are a number of different food webs. Nutrients can be exchanged both within a food web and between food webs by physical and biological processes.

The food webs most affected will be those associated with a bed or tract that is treated with carbaryl. Individual beds treated with carbaryl vary considerably with respect to physical and biological attributes. For example, variation exists in the sediment composition, the type and quantity of attached vegetation, the species of shrimp inhabiting the area, and the density of shrimp. Further, the character of the areas that surround treated tracts may also have a major influence on the food webs affected. Surrounding areas range from bare sand/mud flats to dense eelgrass beds to heavily populated oyster beds with attached vegetation. Consequently, the food webs potentially affected by carbaryl application will depend on the particular bed that is treated.

The most obvious effect of carbaryl treatment will be a dramatic reduction in the abundance of burrowing shrimp. Burrowing shrimp are an important component of the mud/sandflat system because of their ability to control and structure the community. As a result of the decline in the abundance of shrimp, certain changes can be expected, depending to a considerable extent on the species of shrimp. In the case of ghost shrimp, the shrimp significantly affect sediment composition and quality; mud shrimp have much less of an impact on sediment structure. Thus, removal of ghost shrimp will stabilize sediment and perhaps result in changes in the grain size. As a result, colonization of ghost shrimp beds by other species of plants and animals such as eelgrass, clams and amphipods can be expected, in addition to commercial quantities of cultured oysters.

Both species of shrimp also influence the cycling of nutrients and organic matter. Consquently, as a result of removal of the shrimp, other pathways of cycling nutrients and organic matter will occur.

Burrowing shrimp also serve as food for other invertebrates, fish, and birds. Shrimp on beds treated with carbaryl will be lost as a food source. Thus, predators of shrimp, such as cutthroat trout and staghorn sculpin, will have to switch to alternate food sources or forage a short distance off the affected tract, but these are very versatile and moblie predators which not be significantly affected.

Organisms on treated beds, such as polychaetes, cottids, flatfish and crabs will be killed by carbaryl spraying. It is also possible that sublethal effects can occur (e.g., a reduction in swimming performance of some fish) that causes some animals to be more vulnerable to predation than they were prior to treatment. The loss of these animals will affect predator-prey relationships and energy flow of food webs in the affected areas. Because carbaryl is not persistent, the direct effects of carbaryl should be short term.

The net effect of carbaryl treatment and the concommitant increase in oyster biomass on areas treated with carbaryl will be the development of a food web that is characteristic of an oyster bed. The increase in structural (i.e., habitat) complexity afforded by the oysters should allow a community to develop that is more diverse than those of bare sand/mud flats or seed beds. Energy pathways, trophic relationships and means of nutrient cycling will be characteristic of oyster beds and likely will be more complex than the previous food webs. The food web associated with the oyster bed will not be static but will evolve with time as the oysters increase in size, are harvested and replanted, and as shrimp recolonize the oyster bed. The food web can thus be expected to eventually revert towards one characteristic of a burrowing shrimp community. It is not possible to predict whether the food web associated with the oyster community is a positive or negative change from what existed previously. It will clearly be different.

The previous discussion focused on impacts to relatively discrete areas of Willapa Bay and Grays Harbor- i.e., individual beds or tracts. However, effects on food webs also need to be considered within the context of these estuaries as a whole. It is possible that because of the relatively small percentage of the bay treated with carbaryl in any one year that impacts to the food webs would be minimal. On the other hand, burrowing shrimp may have an important function in the bay as a whole so that removal of a small percentage of them could have a disproportionate effect. To date, after 27 years of carbaryl applications, there have been no obvious indications of any such impacts, although no formal monitoring program exists. Clearly, an increased understanding of the role of the shrimp in these estuaries as a whole is needed before an understanding of potential impacts to food webs in the estuaries is possible.

## H. Evaluation of the impacts on Dungeness crab.

### 1. Recent information on the biology of Dungeness crab

Research conducted in Grays harbor and off the Washington coast indicates that Dungeness crab breed offshore in the open ocean (Armstrong, et al. 1984). Following egg hatching and pelagic larval growth, many megalopae (final planktonic larval stage) are carried inshore by tidal and wind-driven currents and enter estuaries from April to June. These "young-of-the-year" (YOY) or 0+[5] crab use intertidal habitats such as eelgrass and oyster beds during most of the summer and usually move into adjacent sloughs and subtidal areas when they reach a size of 20 to 30 mm. Some YOY crab continue to settle on intertidal flats through the summer (Doty, et al., 1988a). They reach approximately 30 to 40 mm in carapace width by early fall and overwinter in the extensive network of drainage channels in estuaries (Doty, et al., 1987; Armstrong, et al. 1984).

### 2. Juvenile Dungeness crab on oyster beds

#### a. Timing of Recruitment

Initial settlement of juvenile crab in Willapa Bay has occurred as early as mid-April, with peak recruitment during May and June. Smaller numbers of 0+ crab apparently settle in the intertidal from July through September. The intertidal area supports mainly 0+ crabs (young of the year) less than 30 mm carapace width. In June and July 93% - 100% of the intertidal crab were 0+

[5] Crabs are separated into 0, 1, 2, 3 or 4 year age groups. A plus "+" is added for crabs collected between any one age group. For example, 0+ crabs are larger young of the year animals taken in the late summer that may have settled out of the plankton in May or June.

YOY. The data suggests that YOY crab begin to leave the intertidal areas during mid-summer to take up residence in subtidal channels after reaching a carapace width of 25-30 mm (Doty, et al., 1987; Doty, et al., 1988a). A similar pattern of recruitment and migration of 0+ crab was also observed in Grays Harbor and Puget Sound (Dumbauld and Armstrong, 1987).

**b. Intertidal Crab Density and Abundance**

Work carried out in Willapa Bay, Grays Harbor, and Puget Sound has demonstrated the importance of intertidal areas to newly settled Dungeness crab. Dumbauld and Armstrong (1987) reported that abundances of 0+ crab in Grays Harbor were up to an order of magnitude greater in intertidal areas than in subtidal areas of the estuary. This was especially true in the few months immediately after settlement (Dumbauld and Armstrong, 1987). Lower predation rates, increased food and habitat availability appear to be major factors controlling abundance and distribution of small crabs in intertidal areas (Table XI).

In one Grays Harbor study, Armstrong, et al., (1984), found that the number of crab in intertidal areas dropped from about 1 million/ha (405,000/acre) in May to 20,000 to 100,000/ha (8,000 to 40,000/ac) by June-September. The reduced numbers found in summer were thought to be mainly a result of high natural mortalities (76 to 98 %) in May to June (Armstrong, et al. 1984). These data are comparable to observations made in Willapa Bay as part of carbaryl mortality studies (see below).

**Table XI.** Average 1983-1986 population estimate of YOY crab in Grays Harbor.

| Month | Population Estimate (millions) |
|---|---|
| May | 370 |
| June | 124 |
| July | 22 |
| August | 11 |
| September | 11 |

**c. Subtidal Crab Density and Mortality**

Assessments have been made of crab densities in subtidal channels adjacent to treatment plots. Estimates prior to treatment ranged from 2,000 to 4,000 crab/ha. These values were comparable to those from other areas of the bay obtained as part of a more extensive trawl survey funded by Washington Sea Grant (Doty, et al., 1987).

Subtidal 1+ juvenile mortalities from 1986 trawl samples taken in channels adjacent to treatment areas yielded few dead or moribund crabs. Slightly over 1% of the crabs were found dead in trawls at the Stony Point site; less than 1% were dead in trawls taken at the Palix River tract; and no mortality was observed at the Oysterville tract. These results were similar to the 1985 trawl sampling (Doty, et al., 1987).

**d. Habitat Type Versus Crab Density and Mortality**

Dungeness crab densities as a function of habitat type were assessed by the UW from 1984-88. The results of these studies clearly demonstrated that cover in the form of shell or eelgrass had a consistent and significant impact on crab densities. Crab were not recovered from bare mud or sand bottoms. A summary of research conducted since 1983 follows:

- Armstrong, et al. (1984) documented YOY crab habitat preferences and estimated abundances in a limited intertidal area of Grays Harbor. No YOY crab were found on bare sand or mud. The highest numbers were found on shell or eelgrass covered bottom.

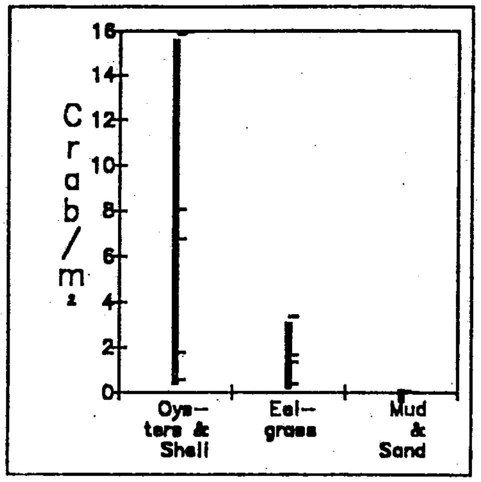



**Figure 10.** High and low crab densities versus substrate for control and treatment tracts in Willapa Bay (from Doty, et al., 1988).

- Hurlburt (1986) found that the concentrations of juvenile crab during July-August were highest (0.43/$m^2$) where algae was attached to oyster shell, in the presence of eelgrass, or where both formed most of the bottom cover. Lower densities (0 to 0.04 /$m^2$) were found on bare ground, or where seed or adult oysters were present without large amounts of attached algae.

- During 1986 sampling at Stony Point (SP86), the estimated crab density immediately before spraying was 1.14/$m^2$ in shell areas (14% cover) and 0 on bare shell-free, intertidal areas. Similarly, on the Palix River (PA86) site immediately before spraying, the density of crab per $m^2$ was 0.79 in shell (7.2% cover), 0.11 in eelgrass (49.6% cover), and 0 in mud. In general, the density of 0+ crab found in areas with cover of either oysters or eelgrass was significantly higher than in areas without cover (Doty, et al., 1987).

- The mean densities of crab were again estimated in 1987 and 1988 from three substrate types (open sand/mud, shell, and eelgrass) on Palix and Stony Point study sites. Crab density in oyster habitat was always higher than that found in eelgrass habitat within each sample area; crab were never found in open mud/sand samples (Figure 10). Initial settlement densities were as high as 16 crab/$m^2$ in shell and 3 crab/$m^2$ in eelgrass, but declined to 2-6 crab/$m^2$ in oysters and 0-1 crab/$m^2$ in eelgrass from mid-July through September (Figure 11) (Doty, et al., 1988a; 1988b).

- Research by Doty et al. (1988a; 1988b) revealed that the number of 0+ crab found on a bed depends on the type of habitat, the extent of the habitat on the site and the magnitude of settlement. For example, differences in crab density between two beds were attributable to differences in the amount of oyster seed and shell cover available. The first bed, with an average coverage of 58%, had a crab density of 3.09/$m^2$, while the second, with a coverage of 12%, had 0.67/$m^2$

In summary, research by the UW suggests that oysters are the most important habitat for newly settled crab followed by eelgrass and bare mud. Oysters planted on sites at commercial levels should provide approximately 8,400 ac (3,400 ha) of cover within the Willapa Bay estuary. Doty, et al. estimated that during early July, 35 to 76 million age 0+ crab were present on 6,000 acres of the most intensely cultured ground in Willapa Bay (Doty, et al., 1990).

**e. Field Evaluations of the Effects of Carbaryl on Crab**

Virtually all 0+ crab are killed on tracts treated with carbaryl. Doty et al. (1987) sampled in the intertidal areas of three treatment areas 24 hours after carbaryl application and found that crab densities were reduced 66% to 100% from the previous day. All crab found in samples were dead, apparently as a result of carbaryl application.

Post-spray assessments at all three sites indicated some recovery. Crab densities increased to about 1 crab/$m^2$ in late July. This was most likely due to movement of larger 0+ crab onto the site from adjacent areas rather than new settlement (Doty, et al., 1988a). There was also recolonization of treated tracts in 1986 within 1

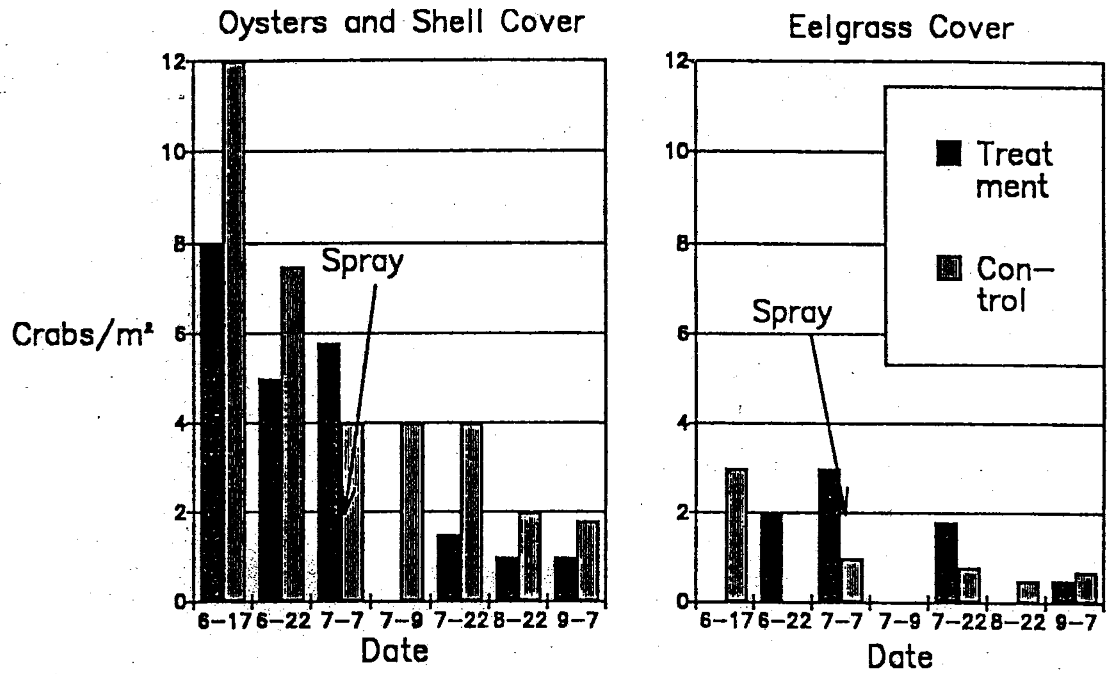



**Figure 11.** Mean density (crab/$m^2$) of Dungeness crab at intertidal control and carbaryl treatment sites for several combined stations (from Doty, Dumbauld and Armstrong, 1988a).

month of spraying reported by Doty, et al., (1987).

Recent research completed by the UW (Doty et al., 1989) demonstrated that the WDF methodology for assessing the number of YOY crab killed (these are done by making visual transect counts the day following treatment) greatly underestimates the actual YOY kill. This disparity is even greater when ground cover, such as eelgrass or oyster shells, are present. WDF YOY crab kill estimates are too low by a factor of 6 to 40 and perhaps even higher when more realistic survival rates are employed. The study also concluded that the shell habitat generated by the oyster industry mitigates for the impacts to the crab population (see section G-4 for quantification of these impacts).

**f. Cage Studies**

Experiments to evaluate the on- and off-site effects of carbaryl treatment on caged juvenile and adult crab have been conducted by WDF and the UW. Juvenile 1+ crab placed in cages in subtidal channels at shallow depth (-1 m MLLW) along the perimeter of two treated sites in 1986 exhibited little mortality when examined 24 hours after spray. One crab was found dead among 71 placed in five cages at a site on the Palix River. No crab died in cages set in slightly deeper water (-2 to -3 m at MLLW) at Stony Point.

More variable results were obtained when cages containing 1+ crab were placed in intertidal drainage channels directly on sprayed areas. At the Palix River site (PR86) crab mortalities were 40% and 45% in two cages set in one shallow slough. No mortality was seen in 2 cages placed in another drainage slough on the same site. All caged crabs in sloughs on the Stony Point (SP86) site were healthy and active when checked 24 hours after spray (Doty, et al., 1987). Similar results were obtained in a 1987 crab cage study (Doty, et al., 1988a).

In 1988, a "worst case" condition was evaluated to measure the kill of 0+ crab during an incoming tidal plume. Mortalities ranged from 82% to 100% on-tract and up to 100 m off tract; 8.5% at 200 m off tract; and 4.5% at a control station. In a companion study, plastic mesh bags containing 0+ crab were placed on treatment and control sites 24 hours after spraying and recovered two weeks later to examine effects of sediment pesticide retention on crab mortality. There was no significant difference in survival between treatment and controls (Doty, et al., 1988b; Doty, et al., 1989).

**g. Feeding Studies**

Several crab feeding experiments were completed between 1985 and 1988 to address, in part, the observed mortality of crabs that move up onto treated beds immediately after spray application. Tufts (1990) reported that average mortalities of crab were 7% to 80% within 24 hours after ingesting carbaryl in food at concentrations of 43 to 167 mg/kg. Average mortalities declined at higher water temperatures. For example, no mortalities were noted for 62 mg/kg dose at 18° C vs 40% mortalities at 7 to 8° C. Feeding experiments completed in 1988 showed a significant difference in crab mortality between cages (38% mortality at the 7.5 lbs/acre treatment) and cages with non-contaminated controls (Students t test, $p < 0.001$). Results of a test comparing mortalities of crabs fed mud shrimp that were sprayed with carbaryl at 7.5, 5 or 3 lbs/acre showed no significant differences among the treatments (Dumbauld and Doty, 1988; Doty, et al., 1989). These studies show that crab are killed by ingesting or perhaps by contacting contaminated food.

**3. The loss of juvenile crab and recolonization.**

The loss of juvenile crab on treated beds has been the subject of considerable attention. WDF manages carbaryl applications to minimize crab losses. In recent years this has been done in part by assigning crab-kill quotas to the growers individually or by setting an overall quota. If the quota is exceeded, further treatment is stopped. WDF estimates crab mortalities by sampling (walking transects) each sprayed plot approximately 24 hours after treatment. Estimated mortalities are then converted to sublegal adult equivalents (SLAe). Ten YOY crab are counted as one SLAe, and 3 one year olds count as one SLAe (Hurlburt, 1986b; Creekman and Hurlburt, 1987). The WDF SLAe index most effectively measures losses of larger 1+ and 2+ crab but underestimates losses of YOY crab. Research conducted by the UW indicated YOY survivability to a preharvest or SLAe size is considerably less than the 10% figure used by WDF. A comparison of WDF and UW crab survival estimates is given in Table XII.

**Table XII.** Comparison of WDF and University of Washington crab survival estimators (from Wainwright, 1989, Personal Communications, School of Fisheries; Armstrong, et al. 1987).

| Age Class Range | % Survival WDF | % Survival UW |
|---|---|---|
| 0+ to 1+ | 10.0% | 3.4 to 8.1%<br>avg. 5.6% |
| 1+ to 2+ | 33.3% | 16.2 to 19.5%<br>avg. 17.9% |
| 0+ to 2+ | 3.3% | 0.6 to 1.6%<br>avg. 1.1% |

Table XIII shows WDF SLAe estimates for crab kills during carbaryl treatments from 1984-88 (see also Appendix Table XV). Creekman and Hurlburt (1987) noted the risk of crab mortality was unpredictable, both year-to-year and between areas. High losses were observed where crab kills had been historically low while low kills occurred in areas with historically high kills. The highest risk appears to be along the perimeters of beds where older crab 1+ can readily move from sloughs onto the beds at high tide.

**4. Net effect on crab**

As discussed above, 100% of the crabs on tracts treated with carbaryl will be killed as will a portion of the crabs located off-tract. Doty et al. (1990) estimated that there

**Table XIII.** Estimated mortalities of sublegal adult crabs on treated beds in Willapa Bay and Grays Harbor (from Hurlburt, 1986; Creekman and Hurlburt, 1987; and Tufts, 1989 and 1990).

**A. Total Mortalities**

| | Year Treated | | | | | Average |
|---|---|---|---|---|---|---|
| | 1984 | 1985 | 1986 | 1987 | 1988 | 1984-88 |
| Grays Harbor | | | | | | |
| North Bay | | 3459 | 728 | 1073 | 1198 | 1615 |
| South Bay | 1754 | 518 | | 1555 | 662 | 1122 |
| Willapa Bay | | | | | | |
| Peninsula | 4424 | 9007 | 3025 | 1864 | 5036 | 4671 |
| North Bay | 2879 | 6291 | 4542 | 5235 | 4742 | 4738 |
| South Bay | 434 | | 846 | 1569 | | 950 |
| Total | 9491 | 19275 | 9141 | 11296 | 11638 | 12168 |

**B. Mortalities per Acre**

| | Year Treated | | | | | Average |
|---|---|---|---|---|---|---|
| | 1984 | 1985 | 1986 | 1987 | 1988 | 1984-88 |
| Grays Harbor | | | | | | |
| North Bay | | 50.5 | 16.9 | 27.5 | 15.4 | 27.6 |
| South Bay | 19.1 | 30.5 | | 43.9 | 13.1 | 26.6 |
| Willapa Bay | | | | | | |
| Peninsula | 36.7 | 115.5 | 38.7 | 13.1 | 39.1 | 48.6 |
| North Bay | 11.7 | 27.6 | 22.0 | 34.1 | 32.5 | 25.6 |
| South Bay | 14.5 | | 12.1 | 24.7 | | 17.1 |
| Average | 19.4 | 49.2 | 23.0 | 26.0 | 28.8 | 28.8 |

were 35.5 million (1986) to 75.5 million (1987) age 0+ crab on the approximately 6,000 acres of oyster grounds under intense culture in Willapa Bay. They also estimated that the annual carbaryl treatments resulted in the loss of about 4-5% of this population and that losses of older crab, primarily age 1+, constituted less than 0.3% of the Willapa Bay population. However, the replacement of burrowing shrimp beds with areas of oysters provides young crabs with high quality rearing habitat. Because this habitat serves to shelter the young crab from predators and rigorous physical conditions, it increases the probability that more crab will survive to enter the fishery than would occur on high-density burrowing shrimp or eelgrass grounds (i.e., if the oyster shell was not there).

The net effect of carbaryl application and oyster culture was computed as the number of crab killed by carbaryl and the gains resulting from the addition of oyster habitat (Table XIV). Estimates of crab losses were based on data obtained from UW studies completed in 1986-89 (Doty, et al, 1988a; 1988b; Doty, et al., 1989) extrapolated to a six year average treatment interval. The bed used to rear seed to full growout (termed the "seed bed") is assumed to be harvested and reseeded every three years. The bed with remnant shell ("growout bed") is harvested and replanted

**Table XIV.** Projected carbaryl-related losses and gains of subharvestable (2+) adult crab. These estimates are based on average net gain/loss data from samples taken 1986-88. Calculations are described on the next page.

| | Treatment Condition: Seed Oysters | Treatment Condition: Remnant Shell | All Beds |
|---|---|---|---|
| 1 Kill/ac of YOY (0+) crab on bed prior to treatment | 4,470 | 3,162 | -- |
| 2 Kill of YOY crab in upflow drift area beyond 1 ac tract | 1,609 | 1,138 | -- |
| 3 Total enhancment of YOY (0+) crab/ac on treated bed in 6 years | 26,964 | 28,725 | -- |
| 4 Total "best case" YOY (0+) crab/ac on eelgrass in 6 years | 17,004 | 17,004 | |
| 5 Estimated average survival of 0+ crab to 2+ | 1.10% | 1.10% | -- |
| 6 Kill/acre of subharvestable (2+) equivalent crab | | | |
| 7 Crab on bed | 66.9 | 47.3 | -- |
| 8 Crab migrated after treatment | 20.5 | 20.5 | -- |
| 9 Enhancment of subharvestable (2+) crab/ac | 296.6 | 316.0 | -- |
| 10 Estimated subharvestable (2+) crab/ac without oyster culture | 187.0 | 187.0 | -- |
| 11 Net gain or (loss) of subharvestable crab/ac | 22.2 | 61.1 | |
| 12 Average % treated 1984-88 | 44% | 56% | 100% |
| Treatment of 400 Acres | | | |
| 13 Acres to be treated | 176 | 224 | 400 |
| 14 Net gain | 3,906 | 13,692 | 17,598 |

every two years. Losses subtracted from the total enhancement (Step 3, Table XIV) were: 1) the initial mortality estimate for all 0+ crabs on treated beds; 2) a percentage estimate of off-tract kills; and 3) the potential crab production in the absence of oyster culture for ground containing 100% eelgrass cover with an average of 0.7 0+ crabs per $m^2$. This assumes 44% of the ground treated with carbaryl will have been seeded prior to spray. If a higher percentage of seeded ground is sprayed, the YOY kill will increase. Spraying over seed has occurred since 1984 when it was first allowed on a emergency basis.

Estimated 0+ crab losses immediately after treatment and cumulative gains of crab differed between culture practice and bed type. Both bed types (seeded or with remnant oysters) produced a gain in total crab enhanced versus those killed on initial treatment and both exceeded the potential production on eelgrass alone. Based upon these calculations, there is a net gain of 2+ crab during the six year average interval between treatments (Table XIV). This indicates there is an overall net benefit to estuarine populations of juvenile crab through the addition of oyster habitat to the intertidal region. Thus, impacts of

**Description of Calculations Used in Table XIV.**

1 Number taken from the 1986 (treatment year) YOY loss figure in Table 18a.

2 Treatment drift on average 16 acre square plot, 835 foot long side, in the upflow direction only, extending an average of 300 feet beyond tract boundary = 5.8 acres or about 36% of the total.

3 Number from the 1991 cumulative YOY gain figure in Table 18a.

4 Assumes 100% eelgrass cover (with 0.7 YOY crab/$m^2$) or 2,833 crab/ac/yr.

5 Using University of Washington survival percentages shown in Table 12 for 0+ to 2+ crab.

6 Mortalities of those crab which are immediately harvestable by the fishery.

7 Multiplies items 1 and 2 times item 5.

8 Estimated 2+ crab equivalents as reported during WDF surveys in 1984-88, from Table 14.

9 Multiplies item 3 times item 5.

10 Multiplies item 4 times item 5.

11 Item 9 less items 7, 8 and 10.

12 Percent of total treated area noted as "seed bed" or "growout" bed in WDF reports from 1984-88.

13 Total acreage times item 12.

14 Item 11 times item 13.

carbaryl application on crab appear to be mitigated for by replacing burrowing shrimp habitat with oysters.

## 5. Conclusions

1) Normally YOY crabs suffer high mortalities due to natural predation, particularly on exposed mudflats. Few crab survive without cover on bare mud and sand bottoms.

2) Ground culture of oysters (and to a lesser extent long-line culture) results in a large amount of shell material being added to the bottom. Oyster culture enhances the intertidal environment for young crab. Oyster habitat offers protective cover for up to 16 YOY/$m^2$ at first settlement. Average densities of YOY throughout the summer range from 1.6 to 3.3/$m^2$ on beds in Willapa Bay. Assuming 6,000 acres of intertidal area under oyster culture, an estimated 35 to 76 million age 0+ crab would be produced on this area.

3) One hundred percent of the Dungeness crab on tracts treated with carbaryl will be killed; some crab will also be killed in off-tract areas. The YOY crab kill has been greatly underestimated by WDF's kill assessment methodology, especially when spraying over seed oysters.

4) Impacts of the application of carbaryl appear to be mitigated for by the replacement of burrowing shrimp habitat with oysters. Oysters provide young crabs with shelter from predators and rigorous physical conditions. This increases the probability that more crab survive to enter the fishery than on high-density burrowing shrimp or eelgrass grounds. UW research indicates that the oyster habitat generated by the oyster industry provides an overall net benefit to crab populations.

## IV. ALTERNATIVES, INCLUDING THE PROPOSED ACTION AND THE PREFERRED ALTERNATIVE

### A. ALTERNATIVE 1 -- OYSTER GROWERS' PROPOSAL

The oyster growers propose to treat up to 800 acres of privately owned or leased intertidal areas (600 acres per year in Willapa Bay and 200 acres per year in Grays Harbor) with carbaryl in order to control burrowing shrimp. The application rate will be 10 lbs/acre or less of carbaryl as a wettable powder.

The growers rationale for the acreage of carbaryl to be treated annually under this alternative is outlined in Section IIC. Treatment of acreage at this level would insure maximum control of shrimp populations on prime oyster grounds and probably enable the oyster industry to expand. Production would increase because beds would be more productive and because of the addition of new grounds. Impacts to water quality and the biota can be expected to increase accordingly. Crab populations may increase as a result of new or enhanced habitat.

### B. ALTERNATIVE 2 -- INTEGRATED MANAGEMENT - THE PREFERRED ALTERNATIVE

The integrated management strategy for controlling mud and ghost shrimp incorporates elements similar to the Integrated Pest Management (IPM) concept commonly applied to the control of land-based agricultural pests. These steps are:

1. Understanding the life cycle of the pest and its impacts on the ecosystem and target crop.

2. Establishing economic thresholds.

3. Monitoring and assessing general ecosystem trends.

4. Implementing the appropriate combination of cultural, mechanical, genetic, biological or chemical controls as necessary to maintain tolerable thresholds.

5. Evaluating control strategies, including economic and environmental impacts.

The integrated management approach for Willapa Bay and Grays Harbor is predicated on the idea that each oyster bed which meets the criteria of non-viability due to the presence of mud and/or ghost shrimp will be evaluated on a case by case basis. Control, growout and harvesting methods will be applied that are appropriate and feasible for that particular location.

Implementation of integrated management approach is expected to be accomplished through the development of a Management Plan (MP). WDF, DOE, and DOA (with DOA as the nominal lead agency) in cooperation with the oyster industry, county governments, and other interested public and private groups or individuals will develop the IMP. A committee was formed to develop the IMP and began meeting in February 1990. The goal of the IMP is to achieve a significant reduction or a complete elimination of carbaryl use in a manner which will assure the continued viability of the industry. The IMP will emphasize the search for a suitable, non-chemical alternative of shrimp control (see Appendix XI).

## C. ALTERNATIVE 3 -- NO CARBARYL APPLICATION / MAINTENANCE OF EXISTING GROUND CULTURE METHODS

Without carbaryl application, the impacts associated with crab and fish mortalities and the effects on the benthos would not occur. The carbaryl treatment permits would be withdrawn, and all monitoring activities associated with carbaryl treatment would cease. The associated economic costs of treatment and monitoring would also cease.

Unless a suitable alternative was found, this alternative would have negative impacts on the oyster industry. Production on the most productive oyster grounds would be expected to gradually decline (personal communications, 1988 -- Hayes, Coast Oyster Company; Nisbet, Nisbet Oyster Company; Wiegardt, Wiegardt & Sons, Inc; and Wilson, Bay Center Mariculture). The productivity of the beds would vary with some limited areas having production close to present levels, but the general trend over most of the grounds would be a marked decline within a 5 to 10 year period. (Hayes, 1988, Coast Oyster Company, personal communication).

In the absence of other management strategies to deal with the increased shrimp populations and/or mitigative approaches to supply shell habitat, the loss of oyster shell could also eventually lead to a reduced capability of the habitat to support the population densities of juvenile crab that are presently found in those areas (see Heuckel, et al., 1988; Dumbauld and Doty, 1988).

**D. ALTERNATIVE 4 -- NO CARBARYL APPLICATION / ALTERNATIVE GROWOUT OPTIONS**

Although most growers insist that this is not a viable alternative, off-bottom culture methods have been mentioned as a suitable alternative to ground culture of oysters, thereby alleviating the need for shrimp control. Off-bottom growout methods are well suited for production of a specialty oyster and/or growout on beds having high current or wave forces. They have become quite common in Willapa Bay and Grays Harbor. They are not, however, preferred by growers for the majority of oyster culture grounds in either area. Production costs are higher for off-bottom culture than for bottom culture (Nisbet, 1988 and 1989, personal communications). Of the growers surveyed that use off-bottom culture, (Faudskar, Engvall, Jambor and Nisbet, 1988, personal communications), none stated that it is economically feasible on shrimp infested ground.

**E. ALTERNATIVE 5 -- STATUS QUO: CARBARYL TREATMENT AT HISTORICAL SCALE**

Up to 400 acres per year of intertidal oyster grounds in Willapa Bay and Grays Harbor would be treated with carbaryl at a maximum application rate of 8.0 lbs/acre. The number of acres and application rate will be determined by WDF. Both ground and long-line cultivated oysters would be treated using helicopter applied spray and hand-held sprayers. At this level of treatment, the loss of some of the most productive oyster grounds could occur.

## V. MITIGATION

The following is a discussion of mitigation for losses of non-target species due to the application of carbaryl. Because there are gaps in our knowledge about the effects of carbaryl, this discussion cannot be exhaustive. It is anticipated that the IMP Committee will review existing data and perhaps recommend other mitigation measures.

### A. General Mitigation Measures

#### 1. Modifying timing of application

WDF permits currently limit spraying to July and August. Some adjustment of treatment timing may reduce the incidental crab mortalities associated with carbaryl treatment. Data from 1985 surveys indicate that later treatments reduce crab mortalities: in July an average of 92.6 crabs/acre were killed while in August 57.9 crab per acre were killed. There was a similar reduction in crab kill in 1988 between July and August spray periods (Hurlburt, 1986b; Creekman and Hurlburt, 1987). The potential timing window, based on a number of factors including temperature, crab and shrimp recruitment and downstream migration of salmonids is shown in Figure 12.

Also, moving the timing window to a point after peak shrimp recruitment could be very effective in reducing rate of recolonization. Increasing the separation of treatment timing from peak abundance periods of juvenile fish stocks also may reduce impacts to fish. However, during the fall, the lowest tides occur at night making helicopter spraying impossible. Lower temperatures may result in reduced shrimp kill and longer toxic persistence of carbaryl in the water column and sediments.

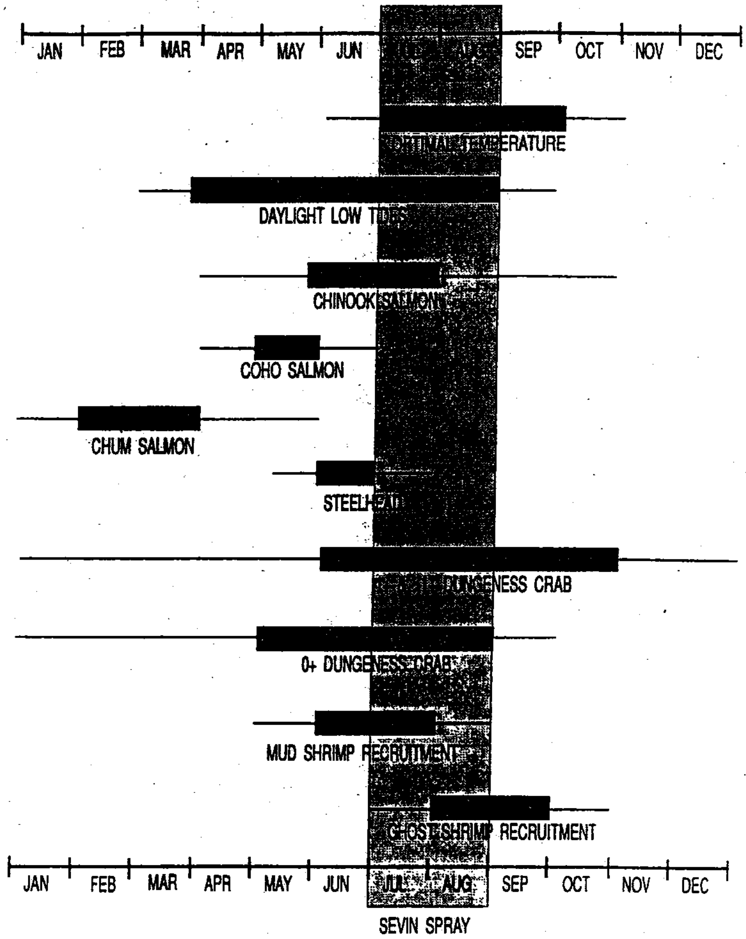



**Figure 12.** Timing of various physical and biological events in Willapa Bay and Grays Harbor which can influence optimum timing for carbaryl treatment. Broad bars indicate peak periods of activity (from Dumbauld and Doty, 1988).

**2. Reduced application rates**

Information developed by WDF and the University of Washington indicates that a treatment rate of 7.5 pounds per acre effectively controls both ghost and mud shrimp. However, experimental applications at a rate of 5 lbs/acre yielded mixed results and indicates that there is a greater chance that rates lower than 7.5 lbs/acre will not be as effective at controlling shrimp populations (see Figure 9). Tests of reduced carbaryl concentrations on large commercial tracts (Tufts, 1990) were effective at 4 and 5 lbs/acre, although treatments were conducted under ideal conditions. There appeared to be no significant reduction in Dungeness crab mortalities resulting from using less carbaryl.

Growers report mixed results using the 5.0 lb/acre application rate. The 5.0/acre rate appears to be least efficient when applied during cool weather, or when there is short-term exposure of the beds during low tide, or when applied to ghost shrimp (Hayes, Coast Oyster Company, 1988, personal communication). Nevertheless, to control mud shrimp, which have more permanent burrows, data collected thus far on lower treatment rates suggests 5.0 lbs/acre may be quite effective. The effectiveness of carbaryl at killing both species of shrimp may be substantially reduced by increasing the amount of cover (shell and/or eelgrass) on the bed (Tufts, 1990, personal communication).

#### 3. Reducing off-tract dispersal of carbaryl

The off-tract contamination of intertidal areas is, in part, mitigated by conditions stated in treatment permits which require buffer zones and application during low-water and low wind conditions. However, some off-tract dispersal of carbaryl is inevitable. Procedures to reduce dispersal could be addressed in controlled trials as part of a future application program. These procedures could include, for example, direct injection of carbaryl into sediment, or application of controlled particle size formulations. In addition, monitoring activities on the day of spray by on-site WDF personnel should be reviewed and, if possible, guidelines developed which could reduce the amount of carbaryl transported off-tract from some beds as they drain during and following treatment.

### B. Aquatic Plants

It is very unlikely that carbaryl will directly impact aquatic plants. As a result, mitigation measures do not appear to be necessary.

### C. Non-Target Invertebrates

#### 1. Sessile Organisms

Most invertebrates that occupy the same habitat as burrowing shrimp, such as polychaetes, are susceptible to death due to carbaryl. Carbaryl applications cause temporary reductions in these populations. These losses are unavoidable and constitute a temporary loss to the food web. Short of not applying carbaryl, there is no obvious means to eliminate or reduce losses to non-target sessile invertebrates.

#### 2. Epibenthic Invertebrates

There is no data dealing with long term impacts of carbaryl application to epibenthic invertebrates in Willapa Bay and

Grays Harbor. As is the case with sessile organisms, short term losses of epibenthic organisms are unavoidable and constitute a temporary loss to the food web. Short of not applying carbaryl, there is no way to eliminate or reduce losses of these organisms.

#### 3. Dungeness Crabs

A thorough discussion of the impacts to Dungeness crab populations and mitigation afforded by oyster culture is contained in Section III H. It appears that short-term crab losses are substantially mitigated over the long term by replacement of burrowing shrimp habitat with oyster culture. Nonetheless, losses of young-of-the-year crab can be reduced by decreasing or eliminating spraying over seed oysters.

### D. Birds

Scavengers like gulls and crows consume carbaryl-laced invertebrates following carbaryl spraying operations. Available information indicates that acute and long-term impacts on birds that ingest carbaryl are unlikely. However, the studies that produced this data were not specific for the birds that could be affected by carbaryl application in Willapa Bay and Grays Harbor. Sub-lethal impacts, such as to reproductive capability, also are unlikely. Mitigation does not appear to be necessary.

### E. Finfish

Losses of finfishes, primarily juveniles, due to carbaryl application have been documented. The magnitude of fish losses on these treated tracts is dependent upon the amount of marine fish habitat available on the tract, which varies greatly. There is also the potential for some losses off-tract due to off-tract dispersal of carbaryl.

One method that had a high potential for mitigating losses is to prepare tracts prior to treatment so that beds will drain as completely as possible, thus reducing ponding. This would also reduce the off-tract transport of carbaryl.

## VI. INFORMATION NEEDS

The proposed action of this SEIS is the application of the pesticide carbaryl to control burrowing shrimp on oyster growing grounds in Willapa Bay and Grays Harbor. Information obtained to date has shown that the application of carbaryl will have some environmental impacts. The most obvious of these is the mortality of Dungeness crab on and adjacent to treated areas. The habitat generated by oyster culture practices provides high quality habitat for young of the year crab and appears to more than offset the crabs killed by the carbaryl. It may be possible to mitigate for crab losses by avoiding spraying over seed oysters. Alternatively, treatment could be delayed until late summer by which time YOY crab have mostly vacated intertidal areas.

Other impacts that have been identified include the loss of fish and invertebrates on treated tracts. All fish that occur in pool habitat on treated tracts are killed by carbaryl; some mortality also occurs in intertidal drainage channels on and near sprayed beds. Invertebrates are more sensitive to the affects of carbaryl than fish. Some invertebrates will be killed on treated tracts but mortality appears to depend on the taxa involved. For example, polychaetes are particularly susceptible to carbaryl.

It is highly unlikely that carbaryl directly impacts key estuarine plant species. There may be some benefit to plant populations as a result of the change in the habitat resulting from the removal of burrowing shirmp. But, this benefit is probably offset, at least in part, by some oyster culture practices such as harvesting by dredge. The potential for human health risk is slight as is the likelihood that birds are directly impacted by carbaryl application.

Several issues are much less clear than the ones discussed above. Further research is necessary to more completely understand these issues and thus improve the management of shrimp populations on oyster lands. The issues that are discussed below are listed not as **requirements** but as **recommendations**. Additional work must be considered within the context of how the shrimp population on oyster lands is to be managed, costs of the recommended studies, and the benefits expected to be gained by obtaining the information.

1. Marine fish mortality. Although losses of marine fish on sprayed tracts have been estimated, these estimates have very high confidence intervals. It is recommended that the methods used to produce these estimates be reconsidered in an effort to improve marine fish mortality estimates on sprayed tracts.

   It is unlikely that significant mortalities of marine fish occur off the treated tracts in the adjacent subtidal drainage channels because carbaryl is typically dispersed away from these areas, diluted and breaks down quickly. Nevertheless, it is recommended that direct evaluation of the potential for lethal and sublethal effects of carbaryl on fish in drainage channels be conducted because of the large numbers of fish, some of which are economically important, that can occur in these channels.

2. Impacts on epibenthic invertebrates and the benthic infauna. A preliminary analysis of potential impacts of carbaryl on epibenthic animals was conducted in 1989. However, this study was limited in its ability to assess impacts by the small number of sites that were evaluated. In addition, because sampling was only conducted up to two weeks after carbaryl application, it was not possible to examine the potential for longer term impacts. Because epibenthic animals are an important component in the diet of many marine fish species (e.g., juvenile salmonids, herring, and smelt), it is recommended that a more thorough investigation of carbaryl's possible effects on epibenthic animals be conducted.

Studies of the effects of carbaryl on the benthic infauna community in Willapa Bay and Grays Harbor to date have also been limited in scope. Initial studies by WDF in 1984 consisted of one site with no untreated control. A more complete set of samples taken in 1985 (still at one location but including a control) and those from a well replicated but small scale experiment conducted in 1988-1990 as part of a Phd. dissertation project at the University of Washington are currently being processed. Preliminary results suggest that the primary long term impact is due to the removal of the shrimp and not the short term influence of carbaryl. However, ecosystem level effects will require a more complete study as noted in the food web section below.

3. Food web impacts. The removal of ghost and mud shrimp from mud flats and the addition of oysters changes the food web structure on treated tracts. The significance of these changes on individual, treated tracts or within the ecosystem as a whole is unknown. Resolving this issue would require an understanding of highly complex ecosystem processes about which little is known in Willapa Bay and Grays Harbor, including nutrient cycling and energy pathways. It is recommended that a more thorough evaluation of food web impacts be conducted. It should be recognized that some of the research that would be needed to enhance our understanding of this issue is longterm, expensive, and highly complex. Other relatively, inexpensive shorter term work that could be conducted to enhance our understanding of carbaryl's effects on food webs includes quantifying the plants and animals associated with oyster beds.

4. Impacts to aquatic plants. Aquatic plants should not be directly impacted by carbaryl application. However, there have been no direct experiments dealing with plant species found in the two estuaries. It is recommended that simple experiments be conducted to verify that plants are not directly impacted.

5. <u>Sublethal impacts on birds.</u> Some bird species ingest contaminated shrimp and other organisms following carbaryl application with no obvious observable impact (i.e., mortality or change in behavior). However, it is possible that some sublethal impacts (e.g., impacts to reproductive capability) could occur as a result of the consumption of these food items. It is recommended that work be conducted to identify and quantify bird species present during and immediately after carbaryl applications and investigate the possbility of sub-lethal effects.

## VII. REFERENCES

The following are references to literature related to the use of carbaryl in aquatic systems published in the 1984-89 period, and other documents containing information relevant to the FSEIS. Most carbaryl-related literature published prior to 1985 and dealing with estuarine or marine systems is referenced in the FEIS. More comprehensive literature lists and reviews are found in Cranmer, 1986; Mount and Oehme, 1981; Rajagopal, et al., 1984.


Alford, A. R., and Holmes, J. A. 1986. Sublethal effects of carbaryl, aminocarb, fenitrothion, and *Bacillus thuringiensis* on the development and fecundity of the spruce budworm (Lepidoptera: Tortricidae). Journal of economic entomology. 79(1):31-34.

Aller, R. C. and R. E. Dodge. 1974. Animal-sediment relations in a tropical lagoon, Discovery Bay, Jamaica. J. Mar. Res. 32:209-232.

Armstrong, D. A., D. R. Gunderson, C. Rogers and K. R. Carrasco. 1984. Juvenile Dungeness crab population dynamics offshore and in estuaries: Review of literature and analysis of data (1983). Report fo the Seattle District U.S. Army Corps of Engineers, 75 p.

Arora, N. and Kalshrestha, S. K. 1985. Effects of chronic exposure to sublethal doses of two pesticides on alkaline and acid phosphatase activities in the intestine of a fresh water teleost, *Channa striatus*. (Channidae). ACTA HYDROCHIM. HYDROBIOL. 13(5):619-624.

Bakalian, Allan B. 1985. The use of Sevin on estuarine oyster beds in Tillamook Bay, Oregon. Coastal Zone Management Journal. 13(1):49-83.

Beitinger, Thomas L. and Leslie Freeman. 1983. Behavioral avoidance and selection responses of fishes to chemicals. Residue Reviews. 90:35-55.

Benson, Brian. 1988a. Willapa Bay contour/habitat map. Lotus 123 spreadsheet. Washington Department of Fisheries, Marine Fish Program.

Benson, Brian. 1988b. Preliminary report on the potential impacts of Sevin on marine fish. Washington Department of Fisheries, Marine Fish Program. 5 p.

Bird, Edward M. 1982. Population dynamics of Thalassinidean shrimps and community effects through sediment modification. Ph.D. Thesis. University of Maryland. 150 p.

Buchanan, D. V., D. L. Bottom and D. A. Armstrong. 1985. The controversial use of the insecticide Sevin in Pacific Northwest estuaries: Its effects on Dungeness crab, Pacific oysters, and other species. In: Proceedings of the Symposium on Dungeness Crab Biology and Management, Anchorage, Alaska. Oct. 9-11, 1984. pp. 401-417.

Carr, Mark. 1988. Preliminary study resuts on the effects of the pesticide Sevin ingestion on three species of marine fish. Washington Department of Fisheries, Olympia, WA. 11 p.

Capaldo, P. S. 1987. Effects of carbaryl (Sevin) on the state I zoeae of teh red-jointed fiddler crab, *Uca minax* (LeConte). Estuaries. 10(2):132-135.

Cheney, D. and T. Mumford, Jr. 1986. Puget Sound Publication Series: Harvest of Shellfish and Seaweeds in Puget Sound. Washington Sea Grant. 180pp.

Colin, P. L., T. H. Suchanek and G. McMurtry. 1986. Water pumping and particulate resuspension by callianassids (Crustacea: Thalassinidea) at Enewetak and Bikini atolls, Marshall Islands. ENEWETAK ATOLL: ASPECTS OF THE MARINE ENVIRONMENT., BULL. MAR. SCI., vol. 38, no. 1, pp. 19-24.

Conti, E. 1987. Acute toxicity of three detergents and two insecticides in the lugworm, *Arenicola marina* (L.): A histological and a scanning electron microscopic study. AQUAT. TOXICOL., vol. 10, no. 5-6, pp. 325-334.

Cranmer, M. F. 1986. Carbaryl. A toxicological review and risk analysis. NEUROTOXICOLOGY (USA) ,7/1 (247-328).

Creekman, Laura L. and E. F. Hurlburt. 1987. Control of burrowing shrimp on oyster beds in Willapa Bay and Grays Harbor 1985. Washington State Department of Fisheries. Special Shellfish Report No. 3. 27 p.

Doty, Daniel C., D. A. Armstrong, and B. R. Dumbauld. 1987. The impact of the insecticide Sevin to local populations of Dungeness crab (*Cancer magister*) in Willapa Bay, 1986. School of Fisheries, University of Washington. 34 p.

Doty, Daniel C., B. Dumbauld and D. Armstrong. 1988a. Mortality of Dungeness crab, *Cancer magister*, exposed to the pesticide Sevin in Willapa Bay during summer 1987. School of Fisheries, University of Washington. Summary report, 18 p.

Doty, Daniel C., B. Dumbauld and D. Armstrong. 1988b. Unpublished data from Willapa 1988 surveys. School of Fisheries, University of Washington.

Doty, D. C., D. A. Armstrong and B. R. Dumbauld. 1990. Comparison of carbaryl pesticide impacts on Dungeness crab (*Cancer magister*) versus benefits of improved refuge habitat derived from oyster culture in Willapa Bay, WA. Willapa Bay/Grays Harbor Oyster Growers Association; Washington Department of Fisheries; Washington Department of Ecology; Pacific County Conservation District; and Washington Sea Grant.

DTED. 1987. The aquaculture industry in Washington State: An economic overview. Washington State Department of Trade and Economic Development, Olympia, WA.

Dumbauld, Brett. 1987. Benthic analysis, letters to Dennis Tufts and Eric Hurlburt.

Dumbauld, Brett and D. A. Armstrong. 1987. Potential mitigation of juvenile Dungeness crab loss during dredging through enhancement of intertidal shell habitat in Grays Harbor, Washington. School of Fisheries, University of Washington. FRI- UW-8714. 64 p.

Dumbauld, Brett and Dan Doty. 1988. University of Washington Sevin research Grant. Centennial clean water fund: quarterly report. 10 p.

EPA. 1985. Pesticide Fact SHeet: Carbaryl. U.S. Environmental Protection Agency, Fact Sheet No. 21. Office of Pesticide and Toxic Substances, Washington D.C.

Faudskar, John. 1988. Letter to Herschel Pendell, Oregon Dept. of Agriculture, dated Oct. 24, 1988.

Galtsoff, P. S. 1964. The American Oyster. U. S. Department of the Interior, Fishery Bulletin, Vol. 64. 480 p.III.B.4.

Gibbs, K. E., Mingo, T. M. and Courtemanch, D. L. 1984. Persistence of carbaryl (Sevin-4-oil)) in woodland ponds and its effects on pond macroinvertebrates following forest spraying. Dep. Entomol., Univ. Maine, Orono, ME 04469, USA. CAN. ENTOMOL. 116(2):203-213.

Hanazato, T. and Yasuno, M. 1987. Effects of a carbamate insecticide, carbaryl, on the summer phyto- and zooplankton communities in ponds. Environmental pollution. Series A: Ecological and biological. 48(2):145-159.

Hueckel, Greg. 1987. Sevin spraying in Willapa Bay and Grays Harbor. Washington Department of Fisheries, Marine Fish Program. 5 p.

Hueckel, Greg, B. Benson, D. Pentilla, A. Reaman, K. Li and R. Buckley. 1988. Pilot studies on Sevin impacts to marine fish in Willapa Bay and Grays Harbor in 1987 - 1988. Washington Department of Fisheries. Unpublished report.

Hurlburt, Eric. 1986a. Minimizing crab kills during Sevin treatment. Memorandum to oyster growers, dated 16 July, 1986. Wash. Dept. of Fish. 4 p.

Hurlburt, Eric F. 1986b. Control of burrowing shrimp on oyster beds in Willapa Bay and Grays Harbor 1984. Washington State Department of Fisheries. Special Shellfish Report No. 2. 40 p.

Hurlburt, Eric F. 1987. Assessment of Dungeness crab kill from Sevin spraying. Memorandum. Washington State Department of Fisheries.

Hurlburt, Eric. 1988. Chemical analysis of Sevin in water. Washington Department of Fisheries.

Johnson, Art. 1987. Review of data on Sevin. Washington Department of Ecology. 31 p.

Karinen, J. F., J. G. Lamberton, N. E. Ntweart and L. C. Terriere. 1967. Persistence of Carbaryl in the marine estuarine environment, chemical and biological stability in aquarium systems. J. Agr. Food Chem. 15:148-156.

Kentzer-Baczewska, A., Kosakowska, A. and Falkowski, L. 1984. Effect of carbaryl and 1-napthol on selected phytoplanktonic algae. Symposium of the Baltic Marine Biologists Rostock (GDR) 31 Aug 1981. Pol. Acad. Sci., Inst. Oceanol., ul Powstanocow Warszawy 55, 81-967, Sopot, Poland. LIMNOLOGICA.

Koike, I. and H. Mukai. 1983. Oxygen and inorganic nitrogen contents and fluxes in burrows of the shrimps *Callianassa japonica* and *Upogebia major*. MAR. ECOL. (PROGR. SER.)., vol. 12, no. 2, pp. 185-190.

Kulshrestha, S. K. and Arora, N. 1984. Impairments induced by sublethal doses of 2 pesticides in the ovaries of a fresh water teleost *Channa striatus*. Toxicol. Lett. (Amst). 20(1):93-98.

Larkin, M. J. and Day, M. J. 1985. The effect of pH on the selection of carbaryl-degrading bacteria from garden soil. The Journal of applied bacteriology. 58(2):175-185.

MacGinitie, G. E. 1934. The natural history of the *Callianassa californiensis* Dana. Am. Midl. Nat. 15:166-177.

Marking, L. L., Bills, T. D. and Crowther, J. R. 1984. Effects of five diets on sensitivity of rainbow trout (*Salmo gairdneri*) to eleven chemicals (antimycin, carbaryl, chlorine, copper sulfate, sodium cyanide, formalin, malathion, Noxfish, permethrin, salicylanilide 1, lampricide 3-trifluoromethyl

Mount, Michael and Frederick W. Oehme. 1981. Carbaryl: A literature review. Residue Reviews, 80: 1-65.

Mukai, H and I. Koike. 1984. Pumping rates of the mud shrimp *Callianassa japonica*. J. OCEANOGR. SOC. JAPAN., vol. 40, no. 4, pp. 243-246.

Murphy, Richard C. 1985. Factors affecting the distribution of the introduced bivalve, *Mercenaria mercenaria*, in a California lagoon -- the importance of bioturbation. J. of Marine Research. 43:673-692.

Oregon Dept. of Agriculture. 1988. Letter to John Faudskar, Marine Extension Agent, from Bill Rompa, dated July 18, 1988.

Posey, M. H. 1985a. The effects upon the macrofaunal community of a dominant burrowing deposit feeder, *Callianassa californiensis*, and the role of predation in determining its intertidal distribution. Ph.D. Thesis. University of Oregon. 119 p.

Posey, M. H. 1985b. Community changes associated with dense beds of a burrowing deposit feeder. ESTUARIES. vol. 8, no. 2B, p. 62A.

Posey, M. H. 1986a. Changes in a benthic community associated with dense beds of a burrowing deposit feeder, *Callianassa californiensis*. MAR. ECOL. (PROG. SER.)., vol. 31, no. 1, pp. 15-22.

Posey, M. H. 1986b. Predation on a burrowing shrimp: Distribution and community consequences. J. EXP. MAR. BIOL. ECOL., vol. 103, no. 1-3, pp. 143-161.

Posey, M.H., B.R. Dumbauld, and D.A. Armstrong. 1991. Effects of a burrowing shrimp, *Upogebia puggettensis* (Dana), on abundances of macro-infauna. J. EXP. MAR. ECOL., vol. 148, pp. 283-294.

Postma, H. 1967. Sediment transport and sedimentation in the estuarine environment. pp. 158-179. In: Lauff, G. H. (ed.). Estuaries. American Association for the Advancement of Science, Publication No. 83. Washington, D. C.

Quayle, D. B. 1969. Pacific oyster culture in British Columbia. Fisheries Research Board of Canada. Bulletin 169. 192 pp.

Rajagopal, B. S., G. P. Brahmaprakash, B. R. Reddy, U. D. Singh and N. Sethunathan. 1984. Effect and persistence of selected carbamate pesticides in soil. Residue Reviews. 93:2-199.

Ramachandran, S., Rajendran, N., Nandakumar, R. and Venugopalan, V.K. 1984. Effect of pesticides on photosynthesis and respiration of marine macrophytes. AQUAT. BOT. 19(3-4)395-400.

Rhoads, D. C. and D. K. Young. 1970. The influence of deposit feeding organisms on sediment stability and community trophic structure. J. Mar. Res. 28:150-178.

Sastry, K. V. and Siddiqui, A. A. 1985. Effect of the carbamate pesticide Sevin on the intestinal absorption of some nutrients in the teleost fish, *Channa punctatus*. Environ. Toxicol. Lab., WATER AIR SOIL POLLUT. 24(3):247-252.

Shotwell, J. Allan. 1977. The Willapa estuary. Background studies for the preparation of a management plan. Department of Public Works. Planning Division. Pacific County, Washington.

Simenstad, C. A. 1984. Epibenthic Organisms of the Columbia River Estuary. Final Report on the Epibenthic Organisms Work Unit of the Columbia River Estuary Data Development Program. 53 p + appendices.

Simenstad, C. A. and J. R. Cordell. 1989. Effects of Sevin Application on Littoral Flat Meiofauna: Preliminary Sampling on Willapa Bay, June-July, 1988. University of Washington, Fisheries Research Institute.

Simenstad, C. A., J. R. Cordell, R. C. Wissmar, K. L. Fresh, S. L. Schroder, M. Carr, G. Sanborn and M. E. Burg. 1988. Assemblage structure, microhabitat distribution, and food web linkages of epibenthic crustaceans in Padilla Bay National Estuarine Research Reserve, Washington. NOAA Technical Report Series OCRM/MEMD. University of Washington, Fisheries Research Institute, FRI-UW-8813.

Singh, D. K. and Agarwal, R. A. 1986. Toxicity of pesticides to fecundity, hatchability and survival of young snails of *Lymnaea acuminata*. ACTA HYDROCHIM. HYDROBIOL. 14(2):191-194.

Stanley, D. J and D. J. P. Swift. 1976. Marine sediment transport and environmental management. Wiley: New York. 602 p.

Stewart, N.E., R.E. Milleman, and W.P. Breese. 1967. Acute toxicity of the insecticide SEVIN and its hydrolytic product 1-Naphthol to some marine orgranisms. Trans. Am. Fish. Soc. 96: 25-30.

Suchanek, T. 1985. Thalassinid shrimp burrows: ecological significance of species-specific architecture. Proc. 5th Intern. Coral Reef Congress, Tahiti. Vol 5. 205-210.

Suchanek, Thomas H. 1983. Control of seagrass communities and sediment distribution by *Callianassa* (Crustacea, Thalassinidea) bioturbation. Journal of Marine Research. 41:281-298.

Swinbanks, D. D. and J. L. Luternauer. 1987. Burrow distribution of thalassinidean shrimp on a Fraser Delta tidal flat, British Columbia. J. PALEONTOL., vol. 61, no. 2, pp. 315-332.

Tagart, J. V., B. E. Short, and W. G. Clark. 1986. Grays Harbor lingcod study: final report. Washington Dept. of Fisheries, Battelle Memorial Institute Pacific Northwest Laboratories Contract No. B-N6826-A-H. 14 p + tables and figures.

Thom, Ronald M. 1984b. Primary production in Grays Harbor estuary, Washington. Bull Southern Calif. Acad. Sci. 83(2):99- 105.

Thom, Ronald M. 1984a. Composition, habitats, seasonal changes and productivity of Macroalgae in Grays Harbor estuary, Washington. Estuaries. 7(1):51-60.

TRW Corp. 1981. Environmental fates and impacts of major forest use pesticides. EPA Contract No. 68-02-3174, Work Assignments 13, 14 and 62.

Tufts, D. F. 1983. Affidavit. Washington State Department of Fisheries, Willapa Shellfish Laboratory.

Tufts, D. F. 1984. "Long-term" effects of the insecticide Sevin on the benthic community of intertidal oyster lands in Willapa Bay. Washington Department of Fisheries. Preliminary draft.

Tufts, D. F. (ed.). 1989. The use of the insecticide Sevin to control burrowing shrimp in Willapa Bay and Grays Harbor in 1986. Washington Department of Fisheries. Special Shellfish Report No. 4.

Tufts, D. F. (ed.). 1990. Control of burrowing shrimp in Willapa Bay and Grays Harbor in 1987. Washington Department of Fisheries. Special Shellfish Report No. 5. Draft report.

U.S.D.A. 1985. Final environmental impact statement as supplemented: USDA Gypsy Moth Suppression and Eradication Projects. U. S. Department of Agriculture. Forest Service -- Animal and Plant Health Inspection Service. Washington, D. C.

Waselenchuk, D.G., E.A. Matson, R.N. Zajac, F.C. Dubbs, and J.M. Tramontano. 1983. Geochemistry of burrow waters vented by a bioturbating shrimp in Bermudian waters. Marine Biology 72: 219-225.

WDF, 1970. Ghost shrimp control experiments with Sevin 1960 through 1968. Washington Department of Fisheries. Technical Report No. 1. 61 p.

WDF, 1988. Water quality sampling data. Washington Department of Fisheries, unpublished report.

Weber, F. H. and F. A. Rosenberg. 1984. Interactions of Carbaryl with estuarine bacterial communities. Microb. Ecol. 10:257-269.

Willapa Aquaculture Council. 1988. Profile of aquatic farming in the Willapa region: Economic costs and benefits of selected crops. Pacific Mountain Private Industry Council. 58 p.

Willapa Development Corporation. 1986. Aquaculture in Willapa Bay: A plan for development. 90 p. + appendices.

Willapa Aquaculture Council. 1987. Economic profile of aquatic farming in the Willapa region: Shellfish production. Washington Department of Trade and Economic Development. 18 p + appendices.

WSDA, 1988. Water quality sampling data and methodology, Willapa Bay. Washington Department of Agriculture, Dairy and Food Laboratory.

## VIII. APPENDIX -- OYSTER CULTURE HISTORY AND 1988 STUDIES

### A. Background and history of oyster culture in Willapa Bay and Grays Harbor.

Willapa Bay and Grays Harbor are large estuaries located on the southwest coast of the State of Washington. These extremely productive water bodies yield over 50% of the state and 9% of the U. S. annual harvest of oysters. The majority of oysters are raised directly on the substrate from the subtidal to about the +3.5 foot level in the intertidal region. There are a total of 25,622 acres of classified[6] oyster grounds in Willapa Bay and 700 acres in Grays Harbor. Pacific County and the State of Washington own about 1,000 acres in Willapa Bay, the remainder of the lands are privately held. Of the private land in Willapa Bay 6,200 acres are in the I to III Class or the moderate to high quality growout and harvest beds (Willapa Development Corporation, 1986; Willapa Aquaculture Council, 1987 and 1988; Hayes, 1988, per. comm.). In addition, WDF manages 10,000 acres of state-owned oyster reserves which were originaly set aside to supply seed oysters for the industry. The Department of Natural Resources (DNR) also leases some additional subtidal, as well as intertidal areas for the cultivation of shellfish in the two bays.

Oyster cultivation began in Willapa Bay before statehood (1889). Oysters were cultivated by obtaining native oyster seed from the "natural oyster beds" and moving them to other intertidal areas controlled by various growers and companies. At the time of statehood the new constitution claimed all tidelands as state property. The first legislative session (1889-1890) allowed those oyster growers, who had been transferring the shellfish to other intertidal areas, the right to purchase these lands. These were refered to as the "artifical oyster beds" as opposed to the "natural oyster beds" which remained under state ownership. The ownership obtained under this initial action by the legislature was transferable (Shotwell, 1977).

In 1895 the Washington Legislature acted to permit the sale of state tidelands to be used exclusively for the planting of oysters. The Bush and Callow Acts permitted private ownership of these intertidal areas. These original acts were modified occasionally by the State Legislature. In 1919, the acts were changed so that any edible shellfish could be cultivated on the private lands, it was no longer limited to oysters. In 1927 a limiting clause was inserted which retained oil, gas and mineral rights for the state on the privately held land.

---

[6] Lands classified by Pacific County in the mid-1960's for tax purposes according to their value in oyster production. The classes are graded from Class I -- most productive, to Class V -- least productive.

In 1935 the legislature precluded any additional sale of shellfish culture areas but preserved all of the rights which had been acquired under the original acts (Shotwell, 1977).

During the period from 1900 to 1926 the oyster industry declined due to failure in culturing the native oyster, high mortalities of introduced Eastern oysters, and market competition with adult Eastern oysters which were being shipped from the east coast. The introduction of the Pacific oyster in the late 1920's started what was basically a new industry (Shotwell, 1977). In Willapa Bay the private acreage increased, reaching current levels through purchase of oysterland held by Pacific County and eligible state tideland which had not been purchased prior to this period (WDC, 1986).

After introduction of the Pacific oyster, production increased through the 1930,s and into the 1940,s. From 1940 to 1947 production averaged on or about 8 million pounds per year in Willapa Bay or two to three times the average annual volume during the the last fifteen years (Figure 13). A steady decline in production and land area in cultivation began in the late 1940's, and continued into the mid 1970's (Shotwell, 1977).

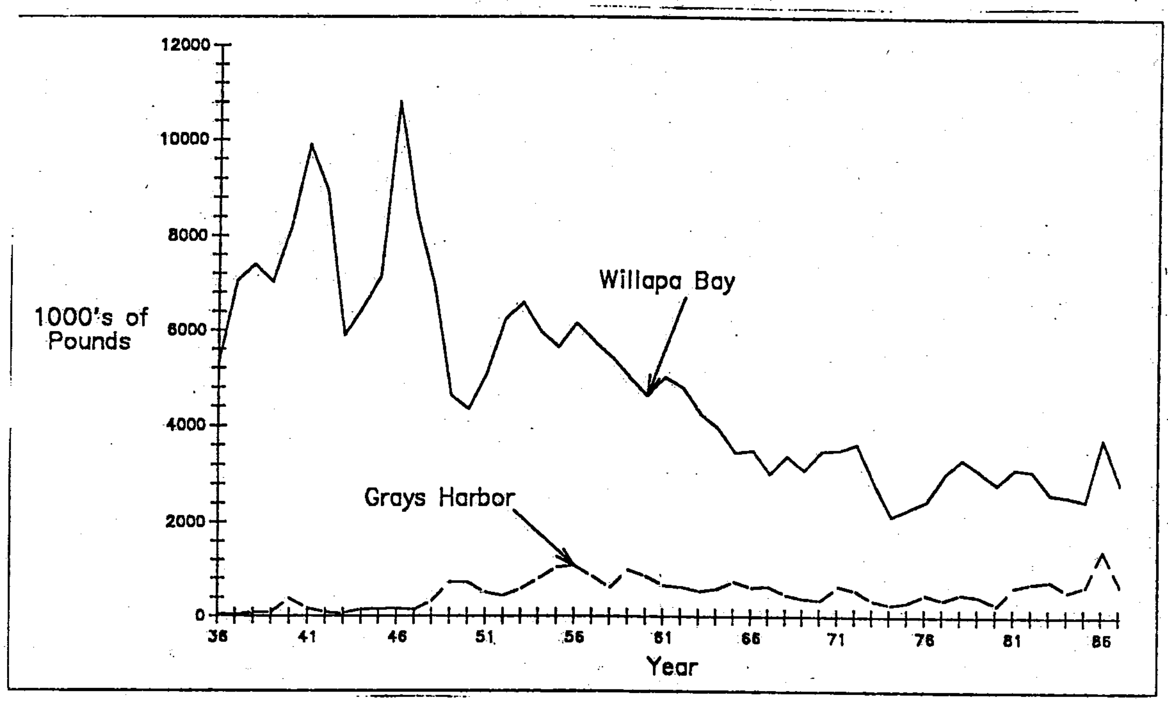



**Figure 13.** Pacific oyster production in pounds of meat harvested annually from Willapa Bay and Grays Harbor (Willapa Development Corporation, 1986).

Figure 14 illustrates the current situation with intertidal oyster grounds in Willapa Bay. The oyster industry is now using about 10,000 acres or approximately 40 % of the original area deeded by the state for the cultivation of shellfish. Nearly 12,000 acres or 45 % of the private intertidal grounds are no longer in production, but still are considered potentially productive (Shotwell, 1977). About 4,000 acres (15 %) were considered by Shotwell (1977) to have never been useable or productive.

The once productive areas were lost or abandoned by the oyster growers for several reasons. While, the uncertainty and expense of a seed supply, and changes in ocean productivity forced a reduction in cultivated area in the late 1960's and early 1970's, the major decline from 1950 to 1965 was largely due a sudden supply of lost cost canned oysters from the Orient which reduced the markets for Washington oysters and their value. The oyster growers also believe the decline in productivity of the oyster beds was due to the presence of two burrowing shrimp species: the ghost shrimp (*Callianassa californiensis*) and the mud shrimp (*Upogebia pugettensis*). These shrimp are indigenous to estuaries of the Pacific Northwest and occupy the same intertidal zone as the oyster, eelgrass and juvenile Dungeness crab.

Oyster growers found burrowing shrimp to cause substantial oyster mortalities, especially on the more productive grounds. Those farmers whose lands were affected by shrimp had to either cease production or concentrate production on remaining unaffected grounds, if they had land available. From the mid 1940's to the early 1960,s much of the once cultivated and deeded oysterland became shrimp infested (WDF, 1970; Hayes -- Coast Oyster Company, Wiegardt -- Wiegardt & Sons; Wilson -- Bay Center Mariculture, 1988, personal communications).

The techniques in use today for growing oysters in Willapa Bay and Grays Harbor include bottom (or ground) culture[7], long-line systems[8], and rack and bag techniques[9]. Most oysters in Pacific and Grays Harbor Counties are grown by ground culture. Several oyster growers combine culture techniques. Approximately 60% of 14 Willapa growers participating in recent surveys employed ground culture, about 20 % used some type of off bottom technique, and 20% used some combination of

---

[7] Oyster shell with young oysters or seed attached which are spread directly onto the ground and left to grow for 1 to 4 years.

[8] Oyster or scallop shell with attached oyster seed are strung on to light rope which is then suspended 1 to 2 feet off the bottom from vertical poles driven into to the sediment at 4 to 6 foot intervals.

[9] Single oysters grown off the ground in trays or plastic mesh bags which are placed on wooden, plastic or metal racks.

the two. These 14 growers produce 95% of the total harvest from the bay (Willapa Aquaculture Council, 1987; and DTED, 1987).

The major use of shellfish lands in Willapa Bay and Grays Harbor is to grow the oyster from the seed[10] size up through the second or third year. At this time the oysters are transplanted from the seed grounds and bedded out on harvest beds (also called fattening beds). Some growers use the same bed for the duration of the three to four year grow-out cycle without transplanting. Intertidal ground used for growing oysters over the entire culture period is usually intermediate in quality between the seed and fattening areas (Wilson, 1988, personal communication).

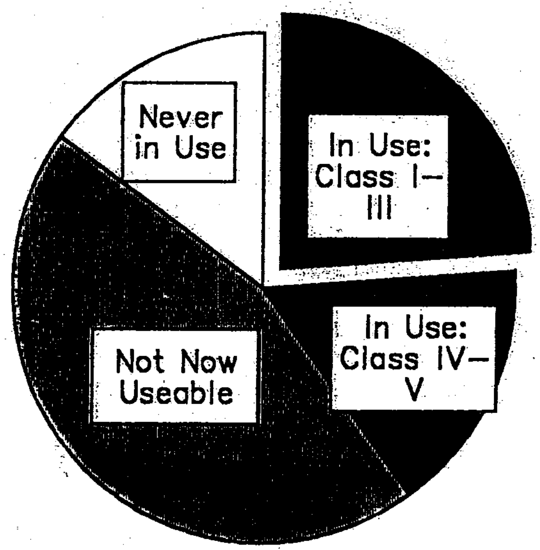



**Figure 14.** Current use of intertidal oyster lands in Willapa Bay (Willapa Development Corp., 1986).

Most of the domestically grown oysters in Pacific and Grays Harbor Counties as well as other areas of Washington State are shucked or opened and put into glass or plastic jars for the fresh market. This type of production requires the ability to economically produce large volumes of oysters. Oysters are also grown for the "half-shell market," and are presented opened and resting on the shell, and usually consumed raw. The bulk of the half-shell market is in restaurant consumption; however, the fresh shucked oyster has the largest share of the marketplace (growers estimate 90%) (Willapa Aquaculture Council, 1988).

During the latter half of 1986, and continuing to the present, Willapa Bay growers have had strong product demand, principally in the fresh shucked market. Oyster production in both Willapa Bay and Grays Harbor production has increased since the late 1970's. The increase in Grays Harbor was largely made possible by restoration through treatment of shrimp (Hayes, Coast Oyster Company, 1988, personal communication). Approximately 50% (over 2.5 million pounds) of the state production comes from Willapa Bay and Grays Harbor. These two

---

[10] This is an oyster up to about 1 inch in length, also called spat when attached to a "mother shell" or "cultch."

areas are producing about nine percent of the nation's oysters (Willapa Aquaculture Council, 1988).

Recent published surveys of Willapa Bay growers found expenses for the oyster farms average about 91% of sales. Labor is about 50% of a grower's costs. Growers made capital investments within the last few years of about $9.5 million in the area. Conservatively, annual production expenditures of about $8 million are needed to maintain the inventory of oysters on the beds. These growers found about 49% of their needs for goods and services in the local area, spending about $600,000 annually in direct services, and had 630 FTE (full-time equivalent) employees. On the average, employees found 86% of their needs for goods and services in Pacific County. Aquaculture payrolls provide 76% of the employee's family income, with about $5 million spent annually in Pacific County from these payrolls (Willapa Aquaculture Council, 1988; and DTED, 1987). For these employees and the County as a whole, shellfish culture is a significant factor in the economic health of the community.

**B. Concentrations of Carbaryl and 1-Naphthol in Water Samples Collected at the Palix River Tract on June 20, 1988 (WDF and WSDA, 1988).**

| Distance from Treated Tract (m) | Water Depth (inches) | Depth of Sampling | Time of Sample (PDT) | PPM in Water Samples Carbaryl WDF | WSDA | 1-Naphthol |
|---|---|---|---|---|---|---|
| On Tract | 1 | Surface | 1101 | 13.7 | 16.7 | 0.3 |
| | 2 | Surface | 1103 | 3.1 | 4.0 | 0.2 |
| | 2 | Bottom | 1103 | 8.3 | 10.1 | 0.3 |
| | 4 | Surface | 1105 | 1.5 | 1.5 | 0.1 |
| | 4 | Bottom | 1105 | 2.2 | 2.3 | 0.1 |
| | 8 | Surface | 1111 | 0.7 | 1.7 | <0.1 |
| | 8 | Bottom | 1111 | 0.7 | 0.37 | <0.1 |
| | 16 | Surface | 1130 | 0.3 | 0.19 | <0.1 |
| | 16 | Bottom | 1130 | <0.1 | 0.25 | <0.1 |
| 25 | 1 | Surface | 1102 | 6.3 | 6.2 | 0.2 |
| | 2 | Surface | 1104 | 9.7 | 17.6 | 0.3 |
| | 2 | Bottom | 1104 | 15.7 | 16.8 | 0.3 |
| | 4 | Surface | 1109 | 19 | 17.3 | 0.2 |
| | 4 | Bottom | 1109 | 16 | 21.0 | 1.7 |
| | 8 | Surface | 1121 | 2.5 | 1.7 | <0.1 |
| | 8 | Bottom | 1121 | 2.8 | 2.1 | <0.1 |
| | 16 | Surface | 1138 | 5.2 | 6.8 | 0.2 |
| | 16 | Bottom | 1138 | 5.2 | 8.9 | 0.2 |
| 50 | 1 | Surface | 1106 | 12.6 | 8.0 | 0.1 |
| | 2 | Surface | 1107 | 13.4 | 15.2 | 0.3 |
| | 2 | Bottom | 1107 | 13.2 | 13.2 | 0.3 |
| | 4 | Surface | 1109 | 11.5 | 14.9 | 0.1 |
| | 4 | Bottom | 1109 | 12.4 | 12.6 | 0.1 |
| | 8 | Surface | 1123 | 6.3 | 4.5 | <0.1 |
| | 8 | Bottom | 1123 | 12.4 | 10.8 | 0.1 |
| | 16 | Surface | 1140 | 0.8 | 0.67 | <0.1 |
| | 16 | Bottom | 1140 | 0.8 | 0.25 | <0.1 |
| 75 | 1 | Surface | 1114 | 0.7 | 0.071 | 0.1 |
| | 2 | Surface | 1115 | <0.1 | 0.12 | <0.1 |
| | 2 | Bottom | 1115 | 1.9 | 2.24 | 0.2 |
| | 4 | Surface | 1118 | 13 | 13.7 | 0.2 |
| | 4 | Bottom | 1118 | 9.9 | 12.6 | 0.1 |
| | 8 | Surface | 1121 | 17.3 | 13.4 | 0.1 |
| | 8 | Bottom | 1121 | 16.2 | 17.5 | 0.2 |
| | 16 | Surface | 1140 | 2.8 | NA* | <0.1 |
| | 16 | Bottom | 1140 | NA | 2.0 | NA |

| Distance from Treated Tract (m) | Water Depth (inches) | Depth of Sampling | Time of Sample (PDT) | PPM in Water Samples Carbaryl WDF | WSDA | 1-Naphthol |
|---|---|---|---|---|---|---|
| 100 | 1 | Surface | 1117 | 1 | 0.018 | 0.2 |
| | 2 | Surface | NA | NA | NA | NA |
| | 2 | Bottom | NA | NA | NA | NA |
| | 4 | Surface | 1118 | 0.2 | 0.18 | 0.1 |
| | 4 | Bottom | 1118 | 4.4 | 2.7 | 0.2 |
| | 8 | Surface | 1122 | 5.1 | 4.1 | 0.1 |
| | 8 | Bottom | 1122 | 4.6 | 4.3 | 0.2 |
| | 16 | Surface | 1141 | 4.9 | 4.6 | 0.1 |
| | 16 | Bottom | 1141 | 5.1 | 11.6 | <0.1 |
| 200 | 1 | Surface | 1124 | 1.3 | 0.016 | 0.1 |
| | 2 | Surface | NA | NA | NA | NA |
| | 2 | Bottom | 1124 | 0.6 | 0.003 | 0.2 |
| | 4 | Surface | 1125 | 0.6 | 0.034 | 0.1 |
| | 4 | Bottom | 1125 | 2.4 | 0.07 | 0.1 |
| | 8 | Surface | 1128 | 2.3 | 0.55 | <0.1 |
| | 8 | Bottom | 1128 | 1.5 | 0.92 | 0.1 |
| | 16 | Surface | 1145 | 0.3 | 0.48 | <0.1 |
| | 16 | Bottom | 1145 | 0.3 | 0.03 | <0.1 |
| Control | 1 | Surface | 1058 | <0.1 | 0.005 | 0.1 |
| | 2 | Surface | 1103 | <0.1 | 0.007 | <0.1 |
| | 2 | Bottom | 1103 | 0.1 | 0.008 | <0.1 |
| | 4 | Surface | 1108 | <0.1 | 0.059 | <0.1 |
| | 4 | Bottom | 1108 | <0.1 | 0.031 | <0.1 |
| | 8 | Surface | NA | NA | 0.005 | NA |
| | 8 | Bottom | NA | NA | 0.038 | NA |
| | 16 | Surface | NA | NA | 0.044 | NA |
| | 16 | Bottom | NA | NA | 0.063 | NA |

* NA - no water samples were collected at these depths or station points.

**C. Fish caught in beam trawl, beach seine, and gill net samples in non-treated and carbaryl treated areas in Willapa Bay and Grays Harbor during 1987 and 1988 (Hueckel, et al., 1988).**

BEAM TRAWL: BAY CENTER, WILLAPA BAY - 6/29/88

| FISH SPECIES | NON-TREATED | TREATED |
|---|---|---|
| | N=1 no./msq | N=1 no./msq |
| English sole | .169 | .140 |
| greenling | .007 | .002 |
| saddleback gunnel | .021 | .021 |
| lingcod | .005 | .002 |
| snake prickleback | .030 | .037 |
| starry flounder | 0 | .009 |
| staghorn sculpin | .025 | .062 |
| threespine stickleback | 0 | .009 |
| shiner perch | .028 | .025 |
| perch (juvenile) | 0 | .046 |
| tube-snout | 0 | .002 |
| TOTAL | .285 | .355 |

BEACH SEINE: NORTH BAY (7/24/87) AND ELK RIVER (8/10/87), GRAYS HARBOR

| FISH SPECIES | North Bay NON-TREATED (no./set) | North Bay TREATED (no./set) | Elk River NON-TREATED (no./set) | Elk River TREATED (no./set) |
|---|---|---|---|---|
| | N=3 | N=3 | N=1 | N=3 |
| English sole | | | 0.0 | 0.7 |
| chinook salmon | 0.3 | 1.7 | 0.0 | 0.3 |
| greenling | | | 0.0 | 0.7 |
| saddleback gunnel | | | 8.0 | 3.7 |
| Pacific herring | 1.0 | 0.3 | | |
| bay pipefish | 0.3 | 0.0 | 0.0 | 0.3 |
| rockfish | 0.3 | 0.0 | | |
| starry flounder | | | 0.0 | 1.3 |
| staghorn sculpin | 0.3 | 0.0 | 4.0 | 10.7 |
| threespine stickleback | 1.7 | 0.3 | 31.0 | 6.0 |
| shiner perch | 85.3 | 0.7 | 136.0 | 102.0 |
| white perch | 4.7 | 0.0 | 0.0 | 0.3 |
| surf smelt | 87.3 | 61.7 | 0.0 | 0.7 |
| TOTAL | 181.2 | 64.7 | 179.0 | 126.7 |

GILL NET: NORTH BAY (7/24/87) AND ELK RIVER (8/10/87), GRAYS HA[illegible]

| FISH SPECIES | North Bay NON-TREATED (no./set) | North Bay TREATED (no./set) | Elk River NON-TREATED (no./set) | Elk River TREATED (no./set) |
|---|---|---|---|---|
| | N=2 | N=2 | N=1 | N=1 |
| chinook salmon | 0.0 | 1.0 | | |
| staghorn sculpin | | | 0.0 | 2.0 |
| shiner perch | 0.0 | 7.0 | 8.0 | 28.0 |
| pile perch | 0.0 | 1.5 | | |
| walleye perch | 0.5 | 2.5 | | |
| white perch | | | 5.0 | 5.0 |
| TOTAL | 0.5 | 11.0 | 13.0 | 35.0 |

**Beam Trawl:** Wilcoxon Signed Rank Test, T+ = 21.5, T(.05) = 8, 47. Do not reject Ho:

**Beach Seine** - areas combined :Wilcoxon Signed Rank Test, T+ = 58.5, T(.05) = 17, 74. Do not reject Ho:

**Gill Net** - areas combined: Wilcoxon Signed Rank Test, T+ = 0, T(.10) = 0, 15. Reject Ho:

**D. Sampling data on effects of carbaryl application on littoral flat meiofauna: preliminary sampling on Willapa Bay, June-July 1988 (Simenstad and Cordell, 1989).**

Table 1. Occurrence (% density) of epibenthic taxa at Sevin treatment (ST) and control (SC) littoral flats, Willapa Bay, June-July 1988.

| Taxa | Pre-application 29 June 1988 | | Immediate post-application 1 July 1988 | | Two-week post-application 12 July 1988 | |
|---|---|---|---|---|---|---|
| | ST | SC | ST | SC | ST | SC |
| Turbellaria | | 0.1 | 0.1 | 0.4 | 0.3 | |
| Nematoda | 1.4 | 4.5 | 6.0 | 4.2 | 9.3 | 16.5 |
| Polychaeta | 5.3 | 2.9 | 18.1 | 4.1 | 14.9 | 9.5 |
| Oligochaeta | 0.2 | 1.1 | 2.2 | | 1.7 | 1.7 |
| Mesogastropoda | 0.3 | 0.3 | <0.1 | | | |
| Opisthobranchia | | 0.1 | | | <0.1 | |
| Bivalvia | | 0.5 | 1.1 | 0.8 | 1.1 | 2.2 |
| Acarina | | | | | | |
| Halacaridae | 0.5 | 0.4 | 0.5 | 0.1 | 0.7 | 0.1 |
| Crustacea | | | | | | |
| Cladocera | | | | | | |
| Polyphemidae | | | | | | |
| *Evadne nordmanni* | | | | | <0.1 | |
| *Podon leuckarti* | 3.0 | 17.7 | 0.9 | 4.2 | 0.1 | 0.1 |
| Podocopa | 0.3 | 0.3 | 1.0 | 1.1 | 1.8 | 1.2 |
| Copepoda | | | | 0.1 | | |
| Calanoida | 0.8 | 1.6 | 0.2 | 0.8 | | |
| Calanidae | | | | | | |
| *Calanus* sp. | | 0.1 | | | | |
| Pseudocalanidae | | | | | | |
| *Pseudocalanus* sp. | 0.1 | 0.1 | <0.1 | | | <0.1 |
| Stephidae | | | | | | <0.1 |
| Centropagidae | | | | | | |
| *Centropages abdominalis* | 0.2 | | <0.1 | 0.5 | <0.1 | <0.1 |
| Temoridae | | | | | | |
| *Eurytemora americana* | 7.4 | 4.6 | 1.6 | 2.8 | 2.7 | 0.6 |
| Acartidae | | | | | | |
| *Acartia* sp. | 34.1 | 36.1 | 17.1 | 45.8 | 6.7 | 3.5 |
| Harpacticoida | 0.4 | 1.2 | 0.8 | 0.7 | 0.7 | 0.5 |
| Tegastidae | | 0.1 | | | | |
| Longipediidae | | | | | | |
| *Longipedia* sp. | 2.5 | 3.9 | 3.0 | 4.9 | 12.1 | 15.5 |
| Ectinosomatidae | 4.4 | 1.3 | 1.9 | 0.8 | 2.0 | 2.3 |
| Harpacticidae | | | | | | |
| *Harpacticus spinulosus* | 0.4 | 0.8 | <0.1 | 1.1 | 0.5 | 1.8 |
| *H*. sp. *obscurus* gp. | | 0.4 | | | 0.1 | |
| Tisbidae | | | | | | |
| *Tisbe* spp. | 4.6 | 5.9 | 1.3 | 7.6 | 7.0 | 6.8 |

Table 1—cont'd.

| Taxa | Pre-application 29 June 1988 | | Immediate post-application 1 July 1988 | | Two-week post-application 12 July 1988 | |
|---|---|---|---|---|---|---|
| | ST | SC | ST | SC | ST | SC |
| Tachidiidae | | | | | | |
| *Microarthidion littorale* | 1.6 | 0.3 | 0.6 | 0.5 | 0.3 | 0.4 |
| *Tachidius triangularis* | 2.6 | 2.4 | 0.5 | 1.8 | 0.7 | 1.6 |
| *Danielssenia typica* | 0.1 | | 1.3 | | 0.1 | 0.1 |
| Laophontidae | 0.1 | 0.3 | 0.2 | 0.2 | 0.4 | 0.5 |
| *Paralaophonte congenera* | 7.1 | 1.1 | 7.6 | 5.7 | 9.7 | 9.2 |
| *Heterolaophonte longisetigera* | 0.4 | 0.1 | 0.4 | 0.1 | 0.6 | 0.3 |
| Ameiridae | | | | | | |
| *Ameira longipes* | 4.8 | 0.1 | 3.9 | 1.1 | 4.8 | 0.9 |
| Cletodidae | 0.1 | | 0.1 | | 0.2 | 0.3 |
| *Enhydrosoma* sp. | 0.1 | | | | | |
| *Huntemannia jadensis* | 0.1 | <0.1 | 0.2 | 0.1 | 0.1 | |
| *Leimia vaga* | 0.1 | 0.1 | | | <0.1 | |
| *Acrenhydrosoma karlingi* | 0.1 | 0.1 | 0.8 | | 0.4 | |
| Diosaccidae | | | | | | |
| *Amonardia normani* | 0.4 | | 0.2 | 0.5 | 2.3 | 1.4 |
| *Diosaccus spinatus* | | | | | | <0.1 |
| *Amphiascus* sp. | 2.5 | 0.8 | 1.1 | 0.3 | 1.4 | 0.5 |
| *A. minutus* | | | | 0.1 | | |
| *Stenhelia* sp. | | 0.1 | | 0.1 | <0.1 | 0.1 |
| *S. peniculata* | 0.4 | | 2.2 | | 0.8 | 0.4 |
| *S.* cf. *inopinata* | 0.6 | | 1.6 | | 1.5 | 1.5 |
| *Typhlamphiascus pectinifer* | 1.2 | 0.9 | 6.6 | 0.1 | 9.0 | 1.0 |
| *Amphiascoides* sp. A | 0.8 | 0.3 | 1.0 | 0.2 | 0.2 | 0.9 |
| *Robertsonia* sp. | | | 0.2 | | | |
| *R. proponqua* | | 0.3 | | | | |
| *R.* cf. *knoxi* | 2.5 | 0.5 | 3.9 | 1.4 | 2.1 | 5.6 |
| Canthocamptidae | | | | | | |
| *Bryocamptus* sp. | | 2.7 | | | | |
| *Mesochra* sp. | 2.8 | 0.1 | 0.2 | | 0.5 | 0.1 |
| Thalestridae | | | | | | |
| *Dactylopodia vulgaris* | 0.2 | | <0.1 | | 0.1 | <0.1 |
| *D. crassipes* | | | 0.1 | | | |
| *D. tisboides* | | | 0.2 | 0.1 | | |
| *Paradactylopodia* sp. | | 0.1 | | 0.1 | 0.1 | |

Table 1—cont'd.

| Taxa | Pre-application 29 June 1988 ST | Pre-application 29 June 1988 SC | Immediate post-application 1 July 1988 ST | Immediate post-application 1 July 1988 SC | Two-week post-application 12 July 1988 ST | Two-week post-application 12 July 1988 SC |
|---|---|---|---|---|---|---|
| *P. serrata* | | | <0.1 | 0.1 | | |
| *Parathalestris* | | | | | | |
| *californica* | | | | | | <0.1 |
| *Diarthrodes* sp. | 1.4 | 2.0 | 0.8 | 0.6 | 0.7 | 1.9 |
| Parastenheliidae | | | | | | |
| *Parastenhelia* | | | | | | |
| *hornelli* | | | | | 0.1 | |
| Cyclopoida | 0.4 | 0.3 | 0.1 | 0.9 | 0.5 | 0.2 |
| Oncaeidae | | | | | | |
| *Oncaea* sp. | | | | | | <0.1 |
| *Corycaeus anglicus* | | 0.1 | | | <0.1 | |
| Oithonidae | | | | | | |
| *Oithona similus* | | 0.1 | | | | |
| Cyclopinidae | 0.1 | | | 0.2 | | 0.1 |
| Balanomorpha | 1.1 | 0.3 | 0.3 | 1.0 | 0.3 | 0.2 |
| Cumacea | | | | | | |
| Leuconide | 0.1 | | | | | |
| *Leucon* sp. | 0.1 | 0.1 | 0.9 | | 0.4 | 2.1 |
| Diastylidae | | | | | | |
| *Diastylis* sp. | | | | 0.1 | | <0.1 |
| Nannastacidae | | | | | | |
| *Cumella vulgaris* | 1.0 | 2.5 | 7.0 | 4.4 | 0.4 | 7.2 |
| Tanaidacea | | | | | | 0.1 |
| *Leptochelia savignyi* | | 0.1 | 0.2 | 0.1 | 0.1 | 0.3 |
| Isopoda | | | | | | |
| Idoteidae | | | | | | <0.1 |
| Munnidae | | | | | | |
| *Munna* sp. | | 0.1 | | | | |
| Amphipoda | | | | | | |
| Gammaridea | 0.8 | | <0.1 | | | |
| Ampithoidae | | | | | <0.1 | |
| Corophiidae | | | | | | |
| *Corophium* sp. | 0.4 | 0.1 | 1.2 | 0.3 | <0.1 | 0.4 |
| *C. acherusicum* | | | 0.3 | | | |
| Eusiridae | | | | | | |
| *Pontogeneia* sp. | 0.1 | 0.1 | <0.1 | 0.1 | | 0.1 |
| *P.* sp. cf. *rostrata* | 0.3 | | | | | <0.1 |
| Anisogammaridae | | | | | | |
| *Anisogammarus* | | | | | | |
| *pugettensis* | | | | | | <0.1 |
| Isaeidae | | | | | | |
| *Photis* sp. | | | 0.3 | | | |
| Caprellidea | 0.1 | | | 0.1 | | <0.1 |
| Caprellidae | | | | | | |
| *Caprella* sp. | 0.1 | | 0.4 | | <0.1 | |

Table 2. Summary of densities (no. $m^{-2}$) of epibenthic organisms at Sevin treatment (ST) and control (SC) littoral flats in Willapa Bay, Washington, immediately before, after and two weeks after application of Sevin, June-July 1988.

| Taxa | Pre-application 29 June 1988 ST | Pre-application 29 June 1988 SC | Immediate post-application 1 July 1988 ST | Immediate post-application 1 July 1988 SC | Two-week post-application 12 July 1988 ST | Two-week post-application 12 July 1988 SC |
|---|---|---|---|---|---|---|
| Total Harpacticoida | | | | | | |
| mean | 3339.2 | 1095.1 | 5450.2 | 2570.8 | 11878.2 | 8301.8 |
| s.d. | 6594.1 | 2253.2 | 6835.9 | 3027.4 | 12654.9 | 8235.7 |
| *Longipedia* sp. | | | | | | |
| mean | 66.7 | 83.3 | 266.7 | 105.6 | 405.5 | 855.6 |
| s.d. | 122.3 | 160.8 | 307.5 | 155.9 | 301.1 | 490.5 |
| *Tisbe* sp. | | | | | | |
| mean | 305.6 | 166.7 | 122.2 | 366.7 | 894.5 | 777.7 |
| s.d. | 443.1 | 202.9 | 116.5 | 461.5 | 1272.1 | 821.1 |
| *Paralaophonte congenera* | | | | | | |
| mean | 400.0 | 50.0 | 1022.1 | 349.9 | 1972.3 | 1416.7 |
| s.d. | 578.1 | 103.2 | 1193.3 | 757.3 | 1309.7 | 1375.4 |
| *Robertsonia* sp. cf *knoxi* | | | | | | |
| mean | 200.0 | 22.3 | 516.7 | 83.3 | 416.6 | 866.7 |
| s.d. | 359.3 | 55.1 | 601.9 | 160.4 | 306.2 | 1146.6 |
| Total Cumacea | | | | | | |
| mean | 94.5 | 111.2 | 1055.5 | 277.8 | 177.7 | 1444.5 |
| s.d. | 184.6 | 240.5 | 1519.4 | 621.7 | 215.8 | 1121.9 |
| *Cumella vulgaris* | | | | | | |
| mean | 57.8 | 105.6 | 933.3 | 272.2 | 88.8 | 1116.7 |
| s.d. | 131.9 | 222.9 | 1402.9 | 604.1 | 140.8 | 861.7 |
| Total Gammaridea | | | | | | |
| mean | 116.9 | 11.2 | 233.4 | 33.5 | 11.2 | 77.9 |
| s.d. | 328.4 | 35.2 | 558.9 | 105.5 | 35.2 | 145.2 |
| *Corophium* sp. | | | | | | |
| mean | 27.8 | 5.6 | 188.9 | 16.7 | 5.6 | 61.1 |
| s.d. | 47.2 | 17.6 | 448.7 | 52.7 | 17.6 | 92.4 |
| *Pontogeneia* sp. cf *rostrata* | | | | | | |
| mean | 22.3 | 5.6 | 5.6 | 5.6 | 0 | 5.6 |
| s.d. | 70.3 | 17.6 | 17.6 | 17.6 | | 17.6 |
| Total Density | | | | | | |
| mean | 7927.8 | 4166.7 | 13416.7 | 6150.0 | 20266.7 | 15494.4 |
| s.d. | 9026.8 | 2039.7 | 9245.3 | 5806.1 | 10458.1 | 6615.6 |
| coef. var. | 1.14 | 0.49 | 0.69 | 0.94 | 0.52 | 0.43 |

## E. Preliminary study results on the effects of the ingestion of the pesticide Sevin on three marine fish species (Carr, 1988).

No mortalities occurred in any of the treatments of the first bioassay over the 25 days the exposed fish were monitored. During this exposure, both adult and juvenile shiner perch were given food over a six hour simulated tidal cycle period that contained SEVIN concentrations in excess of 10,000 ppm. Dr. William Roth, Washington Department of Agriculture, Dairy and Food Laboratory, Seattle, verified the concentration in the highest diet fed at 10.650 ppm carbaryl as determined by high pressure liquid chromatography. Ingestion of SEVIN-laden food at that concentration was confirmed when one of the two populations each of juvenile and adult shiners were sacrificed 30 minutes after their last feeding and the amount of food within their GI tract determined. The average ration ingested by the adults at this concentration was 1.17% of their body weight. The average ration ingested by the juveniles was 0.75%. These values are very close to those that have been observed in shiners that have been collected in the wild. The water temperature at the time of dosage was 15.1° C, averaged 13.9° C (s.d. 1.574) over the 25 days of this outdoor exposure and varied from a high of 18.1° C to a low of 10.6° C, near experiment termination.

Possible sublethal effects were noted only in the highest concentration. All the populations readily fed on the delivered pellets during the first four feedings. During feedings five and six the adults did not feed as vigorously and surplus food was seen on the bottom. The juveniles were more interested in food than the adults during feeding bouts five and six but these groups also had surplus food on the bottoms of their enclosures at the end of feeding six. Within minutes of the sixth feeding, the majority of the adults fed 10.000 ppm SEVIN pellets had turned over on their sides and were motionless for 30 seconds or more. These fish recovered, but were lethargic and commonly flashed or lay on their sides. After about 20 minutes, all the fish regained their equilibrium and were slowly swimming in an upright position. No other signs of stress or unusual behavior were apparent for the remainder of the bioassay. Because of the surplus food on the tank bottoms, in-solution concentrations of carbaryl are suspected as responsible for the aberrant behavior observed.

In the second bioassay, conducted indoors at 20°C with an upper SEVIN concentration dosage limit of 1000 ppm with shiners, English sole juveniles, and speckled sanddab adults and following a simulated two-tide cycle feeding exposure, no mortalities that could be directly attributed to SEVIN were observed. All three species readily fed on the delivered pellets during both feeding periods. The indoor water temperatures averaged 19.9° C (s.d. 0.420) and ranged from 19.4 to 20.8 over the 16-day monitoring.

During the course of the second bioassay, mortalities did occur, but most were obviously unrelated to SEVIN. Of 20 dead shiners from a total test population of 300 animals, five died of obvious dissolved gas problems, two were stressed prior to the start of the experiment, one died of unknown causes, and twelve in the "100" ppm tote died of an apparent contagious bacterial problem that killed 54 juveniles in an adjacent stock holding quadrant. The latter problem developed in the second half of the monitoring when detritus buildup from surplus food provided an excellent medium for bacterial growth. No mortalities occurred with the speckled sanddabs at any point in their confinement. With the English sole pre-test, pre-existing conditions created a marginal test animal, with some of those used suffering from borderline starvation going into the test. Of 21 animals selected, 10 control and 11 test, two of the controls died in the four-day period preceding the test. Though their health was shaky, it was within ASTM standards and the consensus was to use them. Two more fish in the controls that were noted as distressed by their camouflage coloration died just after the start of the exposure, to be followed by one more obvious starvation fish in the controls and one in the test groups. At this time an extreme buildup of surplus food produced a deep bottom layer of anaerobic detritus leading to an apparent localized anoxic environment. In an attempt to remove that layer, one English sole in the 1000 ppm pen was accidentally injured and later died as a result of contact with the cleaning siphon. Additional deaths of two fish in the 1000 ppm test tote and one fish in the control were attributed to the combination of the localized condition and prior stress of starvation. The above-listed mortalities in the English sole controls exceed ASTM standards and negate legitimately using their results; however, as those animals that survived in both totes were the healthiest at the start, readily distinguishable by size and coloration, fed actively on the spiked diet, and subsequently thrived without apparent effect, it was felt they reflected an accurate picture if completely health animals could be used in a re-test.

**F. Estimated crab density and population, and survival projections (from WDF and UW 1984-88 surveys).**

**Table XV.** Subharvestable (2+) crab mortalities estimated from crab kills reported on oyster lands treated with carbaryl in 1984-88 (from Hurlburt, 1986b; Creekman and Hurlburt, 1987; Tufts, 1989 and 1990; Wainwright, 1989, pers. comm.).

| Treatment Year | Treatment Total Acres | Total Crab Kill | Percent Kill by Age Group %0+ | %1+ | %2+ |
|---|---|---|---|---|---|
| 1984 | 490.0 | 38,410 | 84% | 10% | 6% |
| 1985 | 391.0 | 59,933 | 10% | 88% | 1% |
| 1986 | 398.0 | 16,286 | 8% | 55% | 37% |
| 1987 | 433.7 | 44,053 | 62% | 28% | 10% |
| 1988 | 403.4 | 34,557 | 43% | 42% | 16% |
| Means | 423.2 | 38,648 | 41% | 45% | 14% |
| Mean # crabs/age group | | | 15,985 | 17,252 | 5,411 |
| Expected 2+ survival* | | | 1.1% | 17.9% | 100.0% |
| Mortalities per age group in 2+ equivalents | | | 176 | 3,088 | 5,411 |
| Total mortalities in 2+ equivalents | | | | | 8,675 |
| Total average 2+ equivalent mortalities/acre | | | | | 20.5 |

* From UW average survival data, ?.

**Table XVI.** Estimated density and population of 0+ crab using constant mean density values for each habitat category. Seed was placed in July 1986, prior to treatment (from Doty, Dumbauld, and Armstrong, 1988b).

| Year<br>Habitat<br>Category<br>by % cover | Percent of ground covered per ha | Area Covered ($\#m^2$/ha) | Avg. Crab Density[1] # crab/$m^2$ | Population Estimate<br>Crab/ha[2] | Net Gain or (Loss) Crab/ha |
|---|---|---|---|---|---|
| July 1986: Immediately before treatment | | | | | |
| Heavy shell (Cover > 50%) | 4% | 400 | 3.0<br>3.3 (16) | 1,200 | |
| Medium shell (>10% and <50%) | 61% | 6,100 | 1.6<br>3.6 (63) | 9,760 | |
| Eelgrass (>10% an shell cover <10%) | 2% | 200 | 0.4 | 80 | |
| Open mud/sand (Cover <10%) | 33% | 3,300 | 0.0<br>(39) | 0 | |
| Total Estimated Crab Population Killed, July, 1986: | | | | 11,040 | (11,040) |
| July 1987: 1 year after treatment | | | | | |
| Heavy shell (Cover > 50%) | 10% | 1,000 | 3.0<br>3.3 (16) | 3,000 | |
| Medium shell (>10% and <50%) | 67% | 6,700 | 1.6<br>3.6 (63) | 10,720 | |
| Eelgrass (>10% an shell cover <10%) | 3% | 300 | 0.7 | 210 | |
| Open mud/sand (Cover <10%) | 20% | 2,000 | 0.0<br>(39) | 0 | |
| Total Estimated Crab Population: July, 1987: | | | | 13,930 | 2,890 |
| July 1988: 2 years after treatment | | | | | |
| Heavy shell (Cover > 50%) | 13% | 1,300 | 3.0<br>3.3 (16) | 3,900 | |
| Medium shell (>10% and <50%) | 60% | 6,000 | 1.6<br>3.6 (63) | 9,600 | |
| Eelgrass (>10% an shell cover <10%) | 5% | 500 | 0.7 | 350 | |
| Open mud/sand (Cover <10%) | 22% | 2,200 | 0.0<br>(39) | 0 | |
| Total Estimated Crab Population: July, 1988: | | | | 13,850 | 16,740 |

[1] The mean crab densities used for this example were obtained by combining all samples taken in July, 1988 and computing a mean density for each habitat category. Value is given as the mean plus or minus the standard deviation, with the sample size in parenthesis.
[2] Population estimated from the coverage per ha multiplied by the annual mean crab density.
[3] Crab/ha gain or loss in year sampled plus the number from the previous year.

**Table XVII.** Density and population of 0+ crab using constant mean density values. Remnant shells and eelgrass were placed on the ground at the time of treatment, July 1986; planting occurred in autumn 1986 (Doty, Dumbauld and Armstrong, 1988b).

| Year<br>Habitat Category by % cover | Percent of ground covered per ha | Area Covered (#m²/ha) | Avg. Crab Density[1] # crab/m² | Population Estimate Crab/ha[2] | Net Gain or (Loss) Crab/ha |
|---|---|---|---|---|---|
| July 1986: immediately before carbaryl treatment | | | | | |
| Heavy shell (Cover > 50%) | 1% | 100 | 3.0 ±3.3 (16) | 300 | |
| Medium shell (>10% and <50%) | 31% | 3,100 | ±3.6 1.6 (63) | 4,960 | |
| Eelgrass (>10% an shell cover <10%) | 51% | 5,100 | 0.5 ±1.3 (32) | 2,550 | |
| Open mud/sand (Cover <10%) | 17% | 1,700 | 0.0 (39) | 0 | |
| Total Estimated Crab Population Killed, July, 1986: | | | | 7,810 | (7,810) |
| July 1987: 1 year after treatment | | | | | |
| Heavy shell (Cover > 50%) | 16% | 1,600 | 3.0 ±3.3 (16) | 4,800 | |
| Medium shell (>10% and <50%) | 54% | 5,400 | 1.6 ±3.6 (63) | 8,640 | |
| Eelgrass (>10% an shell cover <10%) | 15% | 1,500 | 0.5 ±1.3 (32) | 750 | |
| Open mud/sand (Cover <10%) | 15% | 1,500 | 0.0 (39) | 0 | |
| Total Estimated Crab Population: July, 1987: | | | | 14,190 | 6,380 |
| July 1988: 2 years after treatment | | | | | |
| This ground was harvested in April, 1988; just prior to the peak recruitment period in May/June, 1988. | | | | | |

[1] The mean crab densities used for this example were obtained by combining all samples taken in July, 1988 and computing a mean density for each habitat category. Value is given as the mean plus or minus the standard deviation, with the sample size in parenthesis.

[2] Population estimate from coverage per ha or ac multiplied by the annual mean crab density.

[3] Crab/ha gain or loss in year sampled plus the number from the previous year.

**Table XVIII.** The annual net loss and cumulative gain of YOY crab on treated seed and growout beds -- data were derived from Table XVI and Table XVII (from Doty, et al., 1988b).

| Year | Crab/ha Seed bed[1] | Crab/ha Growout[2] | Crab/ac Seed bed[1] | Crab/ac Growout[2] |
|---|---|---|---|---|
| a. Table data: cumulative totals. | | | | |
| 1986 | (11,040) | (7,810) | (4,470) | (3,162) |
| 1987 | 13,930 | 14,190 | 5,640 | 5,745 |
| 1988 | 27,780 | 28,380 | 11,247 | 11,490 |
| 1989 | 38,820 | 42,570 | 15,717 | 17,235 |
| 1990 | 52,750 | 56,760 | 21,356 | 22,980 |
| 1991 | 66,600 | 70,950 | 26,964 | 28,725 |
| b. Table data: cumulative totals with 1986 losses subtracted in 1987 (from net gain or (loss) column). | | | | |
| 1986[3] | (11,040) | (7,810) | (4,470) | (3,162) |
| 1987 | 2,890 | 6,380 | 1,170 | 2,583 |
| 1988 | 16,740 | 20,570 | 6,777 | 8,328 |
| 1989 | 27,780 | 34,760 | 11,247 | 14,073 |
| 1990 | 41,710 | 48,950 | 16,887 | 19,818 |
| 1991 | 55,560 | 63,140 | 22,494 | 25,563 |
| c. Table data: same as above less estimated cumulative YOY production in eelgrass assuming 100% cover (at 0.7 YOY crab/yr) and estimated off-tract crab kill -- figured at 36% of the on-tract kill. | | | | |
| 1986 | (22,014) | (17,622) | (8,913) | (7,134) |
| 1987 | (15,084) | (10,432) | (6,107) | (4,223) |
| 1988 | (8,234) | (3,242) | (3,334) | (1,312) |
| 1989 | (4,194) | 3,948 | (1,698) | 1,599 |
| 1990 | 2,736 | 11,138 | 1,108 | 4,509 |
| 1991 | 9,586 | 18,328 | 3,881 | 7,420 |

1 This bed would be harvested and replanted with seed in early 1989 and 1992. YOY crab population estimates for 1989 to 1991 are based on 1986 to 1988 estimates.

2 This bed would be harvested and replanted with transplant oysters in early 1988 and 1990, and harvested and prepared for treatment in early 1992. YOY crab population estimates for the 1988 to 1991 period are based on 1987 production values.

3 Both beds were treated in July, 1986, and would, for this example, be treated again in the summer of 1992.

## IX. APPENDIX -- SUMMARY OF THE 1985 FEIS

This section summarizes the principal findings and conclusions of the Final Environmental Impact Statement, "Use of the Insecticide Sevin to Control Ghost and Mud Shrimp on Oyster Beds in Willapa Bay and Grays Harbor," published in June, 1985.

### A. Description of the proposed action

Oyster growers proposed to continue using the insecticide carbaryl (Sevin) to control burrowing shrimp on oyster beds in Willapa Bay and Grays Harbor. Normally no more than 300 acres would be treated per year in Willapa Bay and no more than 100 acres would be treated in Grays Harbor.

#### 1. Background of carbaryl usage

Carbaryl has been used on oyster beds in Washington since 1963 to control burrowing ghost and mud shrimp.

#### 2. Control of carbaryl use

Carbaryl is one of the most widely used pesticides in the United States. It is used extensively to control insects on fruit and vegetables, and in forests. It is also applied to pets and livestock to control insect pests. Wetable carbaryl is applied to infested oyster beds in a water base by helicopter or by hand sprayers. Because it is toxic to marine crustaceans, the Washington Department of Fisheries (WDF), in cooperation with the Washington Department of Agriculture (DOA), and the U. S. Environmental Protection Agency (EPA), developed a review and approval policy for carbaryl application. This policy resulted in criteria for permit issuance and application of carbaryl.

### B. Existing environmental conditions

Carbaryl is used to control ghost and mud shrimp in both Grays Harbor and Willapa Bay. Both water bodies were discussed in this section.

#### 1. Willapa bay

##### a. Physical Environment

###### (1) Geography

Willapa Bay encompasses about 100 square miles or 79,000 acres at mean high water. It contains extensive areas of tidal flats. More than 50% of the total area covered at high tide is exposed at low tide.

### (2) Water Quality

Willapa Bay is generally considered to be among the most biologically productive estuaries of the Pacific Coast of the United States. Unpolluted water and good circulation account for this productivity and resulting commercial and recreational benefits.

Principal water quality factors of Willapa Bay are shown in Table XIX.

### (3) Estuarine Sediments

Oyster bed sediments consist of 78% medium to fine sands with low percentages of silt, organics, volatile solids, etc.

**Table XIX. Water Quality Features of Willapa Bay**

| Feature | Range of Values |
|---|---|
| Temperature | 3° C to 20.4° C on the Willapa River; 7.2° C to 17.4° C at Toke Pt; high of 21.4° C at the WDF Shellfish Laboratory at Nahcotta. |
| Dissolved Oxygen | Generally above 6 mg/l; occasionally levels of 5 mg/l are recorded in the Willapa River; usual summer levels are 6 to 8 mg/l. |
| Salinity | Ranges from 7.5 ppt on the surface to 25 ppt at 20 feet at same time and place; salinities near the entrance to the Bay are 30 ppt or more. |
| Turbidity | 2 to 30 JTU in the open bay, with averages of 6.6 JTU on the surface and 8.0 JTU at 20 feet. |

## b. Estuarine Biota

### (1) Plankton

Little information is available on plankton in Willapa Bay. The phytoplankton, planktonic algae, probably is made up of diatoms, dinoflagellates, and microflagellates. These algae are an important source of food for oysters and clams, and zooplankton (see below).

The zooplankton, planktonic animals, contains larvae of many benthic animals, and species that are planktonic their entire lives. Dungeness crab (*Cancer magister*) larvae appear in the zooplankton in the spring; other zooplankton include oyster larvae and copepods.

### (2) Benthic Biota

**(a) Plants**

Much of Willapa Bay supports beds of eelgrass - *Zostera marina* and *Z. nana*. Eelgrass provides shelter for juveniles of many species including Dungeness crab, flatfish, perch, and Pacific herring (*Clupea harengus*). Tidal flats east of the North Beach Peninsula, north and west of Long Island, and surrounding the Nemah River channel are classified by the Washington Department of Ecology (DOE) as "Areas of Major Biological Significance" (AMBS) for the eelgrass *Z. marina*.

**(b) Invertebrates**

Benthic invertebrates in Willapa Bay are limited to species which are tolerant of wide variations in salinity and temperature. The distribution of these species is also dependent upon sediment distribution. Common in the mud and silt bottoms of the bay are many polychaete worm species, the small clam *Macoma balthica*, the eastern soft shell clam (*Mya arenaria*), cockles (*Clinocardium nuttalli*), and the Pacific (*Crassostrea gigas*) and native or Olympia (*Ostrea lurida*) oysters. In limited gravelly areas, Manila (*Venerupis japonica*), littleneck (*Protothaca staminea*) and butter (*Saxidomus giganteus*) clams are found. Blue mussels (*Mytilus edulis*) and barnacles are common on solid surfaces such as rocks, piling and oyster shell.

All Willapa Bay tide flats and shallow channels, seaward of the highway river crossings are AMBS for Dungeness crab and Pacific oysters.

**(3) Finfish**

The tributaries of Willapa Bay provide spawning grounds for salmon and trout. Salmon also originate from WDF operated hatcheries. They migrate through Willapa Bay at various times of the year, and use it as a nursery area much of the year.

Herring, smelt and anchovies also use Willapa Bay and are a source of food for salmon and other larger fish. The south arm of Willapa Bay near Oysterville and the west side of Long Island are listed an AMBS for herring spawning.

Green and white sturgeon are found in Willapa Bay. Sturgeon feed on smaller fish and benthic invertebrates such as ghost shrimp, amphipods and mollusks. DOE has designated the deeper channels of southern Willapa Bay, the Willapa River and the Naselle River as AMBS for sturgeon.

WDF has conducted trawls to collect juvenile lingcod (*Ophiodon elongatus*) for transplant experiments. Many of the trawls were made over intertidal areas and in locations -- and most lingcod were caught near Grassy Island. WDF biologists reported finding juvenile lingcod trapped on oyster beds by the out-going tide.

Flat-fish also use Willapa Bay as a nursery area. The Willapa River between Range Point and South Bend is designated as an AMBS for starry founder.

**(4) Birds**

Willapa Bay is an important feeding and resting area for a large variety of birds. Willapa Bay includes the Willapa National Wildlife Refuge which contains 9,600 acres of Federal land and open water and 10,000 acres of state tideland and water. Many areas in Willapa Bay have been mapped as AMBS for several waterfowl and shorebird species.

**(5) Mammals**

Harbor seals and gray whales have been observed in Willapa Bay. Several isolated sandbar areas within the bay are harbor seal haulout grounds designated as AMBS.

**c. Willapa Bay Fisheries**

Willapa Bay supports a number of commercial and recreational fisheries. The largest and most valuable fisheries are oysters, Dungeness crab, and salmon. Also, important is the sturgeon fishery.

**(1) Dungeness Crab**

The Dungeness crab fishery is one of Pacific County's most important industries along with forest products, cranberries, oysters and salmon. Annual crab landings from Willapa Bay and their landed values averaged 374,000 pounds and $258,000 respectively in the 10 year period from 1975 through 1984. The Willapa Bay contribution to the total coastal catch ranged from 3 to 14%.

(2) Oysters

Oyster culture has traditionally been Willapa Bay's principal marine fishery. Approximately 37,000 acres are classified as private oyster lands by Pacific County. An additional 10,000 acres of intertidal flats is managed by WDF as "Oyster Reserve" lands. Since the beginning of the carbaryl program, about 2,200 acres have been sprayed in the bay, excluding repeat treatments. Of this, about 80 to 90% (1870) acres are top quality fattening ground. About 75% of the fattening beds have been treated at least once since 1963.

Oyster harvests in Willapa Bay have in the period 1975-84 averaged 2,849,000 pounds or 326,000 gallons of shucked meats, having a wholesale value of $4,923,000. The combined Willapa Bay and Grays Harbor production in 1984 was 366,000 gallons with a wholesale value of $7.1 million. The 28 oyster companies in the region employed over 600 people and had a payroll of $3.9.

**2. Grays Harbor**

Grays Harbor differs from Willapa Bay in several important aspects. Because of the greater use by industry and humans, it has been subject to more research and study -- especially in recent years by the U. S. Army Corps of Engineers (COE) and the DOE. The FEIS relies heavily on those studies.

**a. Physical Environment**

Grays Harbor occupies about 91 square miles or 54,708 acres at MHHW. Of this area, 53 square miles (33,606 acres) are exposed at mean lower low water (MLLW).

The estuary is a partially mixed system where in the summer tides dominate over river flows causing nearly complete mixing of fresh and salt water. Portions of the inner Harbor have a history of pollution.

**b. Estuarine Biota**

**(1) Plants**

Macro-algae is limited by the availability of stable hard substrate for attachment. Eelgrass occurs throughout Grays Harbor below Aberdeen. Areas in western North Bay and between Point New and Hoquiam are designated AMBS for the eelgrass *Z. marina*.

**(2) Invertebrates**

Planktonic and benthic invertebrates in Grays Harbor are similar to those described for Willapa Harbor in Section IX.B.1.b.(2)(a). The DOE has designated all tidal flats and shallow channels from inside the harbor entrance to Cosmopolis as AMBS for Dungeness crabs.

**(3) Finfish**

The fishes of Grays Harbor are essentially the same as described for Willapa Bay. No AMBS for fish has been designated in the vicinity of the oyster flats in North and South bays.

**(4) Birds**

A variety of bird use Grays Harbor and AMBS for various species are located throughout the harbor. Species of waterfowl and shorebirds occur in large concentrations during spring and fall migration periods.

**(5) Mammals**

Marine mammals are observed in Grays Harbor throughout the year. The harbor seal in the most abundant. The DOE designated five areas in North Bay, six in "Central" Bay and one in South Bay as AMBS for harbor seal haul out grounds.

**c. Grays Harbor Fisheries**

In contrast to Willapa Bay, annual landings of fish and shellfish in Grays Harbor are relatively low. The most important species are salmon, Dungeness crab, and oysters.

**(1) Dungeness Crab**

Grays Harbor is an important rearing area for juvenile Dungeness crab. However, only relatively small commercial catches of crab are made in the harbor. Annual crab landings from Grays Harbor and their landed values averaged 42,000 pounds and $23,000 respectively in the 10 year period from 1975 through 1984. The Grays Harbor contribution to the total coastal catch are about 1%.

**(2) Oysters**

Oyster culture is not as extensively practiced in Grays Harbor as it is in Willapa Bay. About 600 acres of intertidal bottom land are used for oyster culture, or about 2% of the total tidelands in the Harbor. Since the beginning of the carbaryl program, permits were issued for treatment of a maximum of 100 acres per year. Oyster harvests in Grays Harbor have in the period 1975-84 averaged 506,000 pounds or 58,000 gallons of shucked meats, having a wholesale value of $832,000 in the 10 year period from 1975 through 1984.

### 3. Willapa Bay/Grays Harbor common elements

#### a. Burrowing Shrimp

Both species of burrowing shrimp are indigenous to and very abundant in Willapa Bay and Grays Harbor. Ghost and mud shrimp are shrimp-like crustaceans. They live in the sediments, and construct and maintain extensive burrow complexes which range from 10 to 20 inches in depth. The principal features of the animals are listed below.

**Ghost shrimp --**

- Pale pink body with a large broad abdomen. The first pair of legs have well-developed claws that are slightly dissimilar in the females or very unequal in the males. Mature adults range from 2 to 4 inches in length.

- Preferred habitats are clean, well-sorted sand -- excavated sediments and feces are deposited at burrow entrances, forming conspicuous mounds which gradually raise the level of the tidal flat.

- Feed by continually digging in sandy sediments and accumulating food particles on specialized feeding arms. The arms are then cleaned to ingest food particles.

- The breeding period is late spring to early summer. Larval development is in nearshore coastal areas, which are carried into the estuaries during summer high tides. Growth rates range from about 16 to 22 mm per year.

- Predators may limit lower range on beaches. The staghorn sculpin *Leptocottus armatus* is an important predator.

**Mud shrimp --**

- About the same size or larger than ghost shrimp in Willapa Bay. It is usually bluish in color, with claws of equal size.

- Prefer a muddier habitat with sediments that are less well sorted than ghost shrimp; but can coexist with ghost shrimp.

- Are suspension feeders and filter detritus and organic particles from water pumped through the burrows. Secrete organic material to cement the burrow walls and deposit undigested organic material as feces at the burrow entrances.

- Cause less sediment disturbance than ghost shrimp and apparently less effect on other invertebrates.

- Breed in winter months and post-larva settle to the bottom in late winter and early spring. Females grow by about 1 inch per year.

Burrowing shrimp contribute substantial biomass to the intertidal community. Ghost shrimp were estimated in one Oregon-based study at 3.1 pounds/$yd^2$ or 15,004 lbs/acre; mud shrimp were found at up to 4.9 lbs/$yd^2$ (23,643 lbs/acre). The biomass in a single Willapa Bay sample was estimated to be 6,655 to 8,319 lbs/acre. Preliminary observations by WDF and others suggest that increased burrowing shrimp abundance reduces diversity and abundance of other infaunal organisms. A more detailed account of burrowing shrimp biology is found in Section III.

**b. Dungeness Crab**

The Washington coastal Dungeness crab fishery is the state's largest crustacean fishery with average landings of around 6.2 million pounds annually. The average landed value of the coastal fishery is about $9.3 million based on an ex-vessel price of $1.50 /lb. Between 100 and 150 vessels and up to 450 people participate in the fishing -- harvest and processing.

The general biology of the Dungeness crab is as follows:

- Breeding and early development in the open ocean.

- Many megalopae (final planktonic larval stage) are carried into the estuaries in the spring.

- o Young-of-the-year crab (YOY) grow rapidly during the summer and early fall.
- o Most of the young crab return to the ocean in the late fall to overwinter in the coastal waters. Some may migrate back into the estuaries in the following spring.

Additional detailed information from recent Dungeness crab research in Willapa Bay and Grays Harbor is presented in the supplement.

**c. Birds**

Several studies of the food habits of birds have been conducted in the Willapa Bay/Grays Harbor area. The results of these studies are summarized in Table XX.

**Table XX.** Feeding Habits of Birds

| Bird type | Feed types |
|---|---|
| Waterfowl | Feed on aquatic plants including eelgrass, salt marsh plant seeds, and small invertebrates. |
| Sandpipers | Feed on oligochaetes, salt marsh seeds and small arthropods. |
| Dunlins | Mostly invertebrates such as annelid worms, amphipods, and insect larvae. |
| Other shorebirds | Important food items are amphipods, small clams, annelid worms, insects and salt marsh seeds. |
| Terns | Feed on a variety of fish -- esp. shiner perch. |

**d. Threatened and Endangered Species**

Three species of birds and one whale that are listed as federally and state threatened or endangered species have been observed in Willapa Bay and Grays Harbor.

**e. Estuarine Food Webs**

Examples of food webs presented include the consumption of detritus by ghost shrimp which are preyed upon by staghorn scuplins.

## C. Impacts of carbaryl

The insecticide carbaryl (1-napthyl-N-methylcarbamate) is sold under the trade name Sevin 80S by the Union Carbide Company. The use of carbaryl by oyster growers in Willapa Bay and Grays Harbor is regulated by EPA under a Special Local Needs Pesticide Registration (EPA SLN No. WA-760021). The applications are supervised under pest control permits issued by WDF.

### 1. Chemical behavior of carbaryl

There is a reduction in the concentration of carbaryl after application on the oyster grounds. This is due to a variety of factors including chemical decomposition and dilution in incoming tides. The general behavior of carbaryl is summarized in Table XXI.

**Table XXI.** Summary of Physical and Chemical Factors

| Feature | Action on carbaryl |
|---|---|
| Solubility in water | Less than 1% |
| Chemical decomposition | Hydrolysis to 1-naphthol, with further degradation to carbon dioxide ($CO_2$) |
| Physical factors affecting decomposition | Temperature -- carbaryl decomposition increases as temperature increases; pH -- most rapid decomposition at pH 8.2; dissolved oxygen -- high concentrations accelerate breakdown. |
| Biological factors affecting chemical breakdown | Degraded by yeasts and filamentous algae; marine bacteria are not effective. |

The concentration of carbaryl has been measured in field applications on plots in Washington and Oregon. The results of these experiments are summarized in Table XXII.

### 2. Effects of carbaryl on marine life

Carbaryl is especially toxic to arthropods, such as shrimp and crab, and has varying toxicity to other organisms. The breakdown product 1-naphthol can also be toxic.

#### a. Plants

Growth of diatoms and other benthic or planktonic algae may be temporarily inhibited by treatments of oyster tracts. There are no data on effects on eelgrass or macroalgae.

**b. Invertebrates**

A variety of estuarine organisms have been experimentally exposed to carbaryl in the laboratory and in the field. In general, carbaryl is less toxic to polychaetes and mollusks than arthropods. Young of the year Dungeness crabs and ghost shrimp are also more sensitive than older adult crab. The results of several experiments are summarized in Table XXIII.

**Table XXII.** Carbaryl Content in Water Samples and Sediments

| Location | Temperature (degrees C) | Media Measured | Change in Concentration |
|---|---|---|---|
| Aquaria | 8 | Mud | 10% of original content hydrolyzed |
| Aquaria | 20 | Mud | 55% of original content hydrolyzed |
| Yaquina Bay | 7.5 - 14.5 | Mud | 10.7 to 3.8 ppm within 24 hours; 1 ppm after 8 days; 0.1 ppm after 42 days |
| Quilcene Bay(10 lb/acre application) | Not given | Water | 1.55 ppm average in 1st 1/2 inch of water column at incoming tide; 0.08 ppm surface and 0.11 ppm bottom, when water depth was 6 inches |
| Willapa Bay(10 lb/acre application) | 16 to 20 | Water | 10.6 ppm in 1st inch of water; 0.001 to 0.002 ppm after 30 min (water depth 14 inches) |

**Table XXIII.** Effects of carbaryl on Invertebrates

| Organism | Test Conditions | Findings |
|---|---|---|
| Polychaetes | Field spray | Caused worms to leave burrows |
| " | Lab experi. -- 1 ppm | Reduced feeding activity |
| Bivalve shellfish | Field spray, 5 and 10 lbs/acre | Gaper clam populations reduced by 58 and 69% on sprayed tracts. |

| | | |
|---|---|---|
| " | Lab experi. -- 24 to 96 hr bioassays | Blue mussel, Pacific oyster and cockle $LC_{50}$s were 2.3 to 7.3 ppm |
| " | Lab experi. -- 1 to 10 ppm | Normal egg development in oysters reduced or stopped |
| " | Field spray, 10 lbs/acre | No oyster mortalities in juveniles or adults |
| Burrowing shrimp | Field trials | Mortalities within 30 minutes after exposure |
| " | Lab experi. -- 24 hr bio-assay | $LC_{50}$ was 0.03 to 0.09 ppm. |
| Dungeness crab | Lab experi. -- 24 hr bio-assay | $LC_{50}$ was 0.55 to .70 ppm |
| " | Feeding trials -- fed cockles exposed to 1 ppm carbaryl | Irreversible paralysis within six hours after feeding |
| " | Cage experiments -- during and 24 hr after spraying | During spray -- 1 out of 6 died; 1 day after spray -- 2 out of 29 died. |

**(1) Benthic Community Impacts**

The effects of carbaryl on benthic communities is reviewed for both laboratory and field conditions. Carbaryl sprayed in the field produces an initial peak and then declining concentration in sediments. Invertebrates may be affected by carbaryl exposures for a period of days to several weeks.

The reduction of burrowing shrimp due to carbaryl application and subsequent oyster production results in increased abundance and diversity of organisms associated with the oyster beds. As shrimp densities increase, densities of other invertebrates and eelgrass coverage decline. The rate of recovery to a condition found prior to high shrimp densities depends on the life cycle and rate of colonization of the new recruits.

**(2) Dungeness Crab**

Data are presented on the mortalities of Dungeness Crab due to carbaryl application. The estimated average crab kill from 1977 through 1984 (all ages combined) was 41.8 per acre or 10,461 per year. The highest number (about 38,500) were killed in 1984.

**(3) Finfish**

No tests have been conducted on the toxicity of carbaryl to the fish found in Willapa Bay or Grays Harbor. Mortalities of small fish directly exposed to carbaryl do occur on treated beds. Several workers have studied the effects of carbaryl on fish. These observations are summarized in Table XXIV.

Carbaryl treatments could also indirectly effect salmonids and other fish by reducing the amount of feed. These impacts are thought to be minimized by restrictions on the area that can be sprayed each year, and limited the timing of spray application to periods of low salmonid abundance.

**(4) Birds**

Birds can consume carbaryl in the form of contaminated invertebrates and fish. However, several experimental studies indicate that birds require high levels of carbaryl ingestion before acute effects are seen. Carbaryl is not accumulated in the tissues, except at the highest non-lethal dosages and is rapidly metabolized.

**Table XXIV.** Effects of carbaryl on Fish

| Fish type | Test Conditions | Findings |
|---|---|---|
| Juvenile coho salmon | Standing water bioassay at 20 C for 48 hours in 25 ppt. | Median tolerance limits were 0.997 ppm. |
| " | Static bioassay, 96 hour test at 13 C. | $LC_{50}$ was 0.764 ppm. |
| Rainbow trout | " | Median tolerance limits were 1.6 ppm. |
| Threespine stickleback | " | Median tolerance limits were 10.4 ppm. |
| White mullet | Static bioassay, 24 hour test. | $LC_{50}$ was 4.25 |
| Longnose killifish | " | $LC_{50}$ was 1.75 |

No mortalities of any bird species have been observed by WDF personnel or other agency staff during carbaryl treatment in Willapa Bay and Grays Harbor, nor does there appear to be a detrimental impact to food resources used by birds. Birds are not expected to experience significant impacts from carbaryl use. Additional information, and the supporting studies on this potential impact are discussed in supplement.

**(5) Mammals**

Mammals are not expected to frequent the mud flat spray area. If they did, the high dosages required to produce acute or chronic effects should not be encountered.

**(6) Effects on Humans**

The hazards to humans from sprayed carbaryl are documented from several reports. Carbaryl's potential for causing birth defects, inheritable defects, or cancer was very low. No effects on humans are expected.

**(7) Effects on Food Webs**

Carbaryl application may result in localized impacts on food webs, affecting 0.8% of the tidelands in Willapa Bay and 0.3% in Grays Harbor. Carbaryl is not accumulated by any food web component or transmitted to higher levels in the food chains.

Once it decomposes, no chemically active groups remain the sediments. Therefore, the use of carbaryl is not expected to cause significant impacts on the estuarine ecosystem.

**(8) Economic Effects**

Beneficial economic effects accrue as a result of oyster culture on treated beds. Without treatment, reductions in productivity will reduce the profit to the grower until, at some point, production is no longer economically feasible. Growers estimated that 75 to 80% of the culture grounds would be unusable for oyster culture without treatment. This would eventually cause an annual loss of $5 million and over 300 jobs. Up to 2,000 jobs may be affected indirectly.

**D. Measures to mitigate adverse impacts**

To minimize impacts to crab and the environment, WDF has developed a series of procedures to assess the beds proposed for treatment, to control treatment, and to assess the impacts. Additional suggested mitigation measures include 1) more intensive crab surveys prior to treatment to allow schedule changes when crab numbers are high; 2) using baits to lure crabs from treatment areas; and 3) reducing the concentration of carbaryl.

**E. Unavoidable adverse impacts**

Loss of biota will occur on each tract sprayed. Ghost and mud shrimp will incur severe losses. Incidental losses of other species may be significant locally.

The diversity of organisms on treated beds will be temporarily reduced. There may also be a long-term increase in overall diversity and abundance.

The productivity of foraging areas on the sprayed tracts may be temporarily reduced. Sprayed tracts are expected to support increased numbers of prey species within less than one year.

**F. Alternatives to the proposal**

See the Alternatives section to the SEIS.

## X. APPENDIX -- SUMMARY OF STUDY METHODOLOGIES

### A. Washington Department of Fisheries Studies

#### 1. Sediment and Water Chemistry

<u>1984 Study Report -- Hurlburt, 1986</u>

Water samples were taken on July, 1984 from two tracts (treated with 7.5 lbs/area) in Willapa Bay to measure carbaryl dilution as treated flats were covered by flooding tide. Water was sampled when the flooding tide reached a depth of one inch. Samples were collected over the next four hours as the water depth increased to 76 inches. Additional samples were obtained at 6, 12, and 24 inches off the bottom four hours after beginning of flood. Six replicate samples were taken at each sample time and depth. The replicates were split and one set of three was analyzed for carbaryl using gas chromatography (GC) with a detection limit of 0.0001 ppm. Samples processed for GC were not acidified, and were held for 4 days prior to analysis. Colorimetric analysis for carbaryl and 1-naphthol, with a detection limit of 0.1 ppm, was used for the other set of three replicates. These samples were acidified in the field to pH 4.5.

<u>1985 Study Report -- Creekman and Hurlburt, 1987</u>

The 1985 study was conducted to determine if carbaryl (sprayed at a rate of 7.5 lbs/acre) was carried off the sprayed tract by the incoming tide. Water samples were collected in the Bay Center area on July, 1985. The path of the incoming water was followed and samples were taken at 100 or 150 foot intervals from the center of the treated tract. Four samples were taken at each station in water 1.5 to 6 inches deep. Sampling continued for 700 feet in the treated area and 650 feet onto the adjacent untreated ground. A total of 13 samples were taken over a 71 minute period. Each sample was collected one inch above the bottom with a plastic squeeze bottle held above a sheet-metal plate that prevented agitation of the mud bottom. They were placed in glass bottles containing sufficient 4% acetic acid to reduce the pH of the sample to 4.5 to 5.0. All samples were stored in an ice-filled chest until they reached the laboratory where they were refrigerated at about 2 C. Analysis was done using a colorimetric technique as noted in the 1984 report.

<u>1986 Study Report -- Tufts, 1989</u>

Water sampling was carried out at four sites in July 1986 to assess the transport of carbaryl off the treatment tracts. The methodology was the same as reported in Creekman and Hurlburt, 1987.

An indirect assessment was made of carbaryl transport by assessing burrow counts at sample sites up to 800 feet shoreward of one sprayed tract (Cedar River). At each site a single count of burrows per 1/4 $m^2$ was made immediately before treatment and then 2 to 3 weeks later. There was no control assessing other possible factors in burrow counts or figure showing the location of the station in relation to the actual spray area.

<u>1987 Study Report -- Tufts, 1990</u>

The objective of the 1987 water chemical analysis was to determine the dilution pattern of carbaryl washed from two treated tracts -- CPC 8708, near Stony Point and CPC 8716A, next to the Palix River. Two stations were established at Stony Point: station 1 -- on the southern boundary of the ; and station 2 -- located 300 feet south of Station 1. Stations 3 to 5 were spaced 120 apart on a north-south line 300 feet from the west end of the Palix tract. Samples were taken 1/2 inch off the bottom during the incoming tide at 1 inch depth increments until the water was 18 inches deep. Water samples were also collected from tidal pools and streams on three sprayed tracts. All sampling was done on July 10, 1987. Water sampling and analysis methodology was the same as reported in Creekman and Hurlburt, 1987.

<u>1988 Study Report -- see University of Washington study methods</u>

**2. Pre-treatment assessment of crab risk**

<u>1984 Study Report -- Hurlburt, 1986</u>

This work was done to assess the population of YOY crab on beds prior to full-scale carbaryl treatment. Four oyster tracts proposed for spraying in Willapa Bay and one in Grays Harbor were examined with pretreatment quantitative surveys. Plot sizes ranged from 200 sq ft to 12.8 acres, most were 1000 square feet. One to three replicates were made per tract. The small YOY crab were very difficult to see and count, and were usually hidden. An attempt was first made to bait young crab from under algae, eelgrass, or shell cover so they could be counted. This was not effective so small test plots were hand-treated with carbaryl. After about 30 minutes, counts of dead crab were made.

**3. Chumming experiments**

<u>1984 Study Report -- Hurlburt, 1986</u>

These experiments tested the effectiveness of chumming to reduce crab losses. Bait in the form of 500 lbs of fish carcasses was placed in 3 to 10 feet of water in a slough next to a 1 acre test plot. Another 1 acre plot was not chummed and served as a control. Following baiting, both plots were treated by hand with carbaryl at a concentration of 10 lbs / ac. On the next low tide, dead or moribund crab were counted, sexed and measured. No crab counts were made prior to chumming or spraying. The feeding rate of bait by crabs was also tested. Five ringnets holding 40.5 lbs of bait were placed on the bottom downstream from the larger chum mass. These nets were about 30 ft apart in water 3 feet deep. These nets were recovered after 24 hours and the bait was reweighed. Water samples were also taken to measure dissolved oxygen concentrations above the chum. The results of this small-scale experiment prompted a larger-scale chumming effort using fish carcasses and waste oysters on six tracts in Willapa Bay and one tract in Grays Harbor.

1985 Study Report -- Creekman and Hurlburt, 1987

One study was conducted to determine the relative effectiveness of various kinds of bait in attracting juvenile Dungeness crab. This test was carried out in June, 1985 in Grays Harbor. Baits tested were "green" and "red" rockfish, Dover sole, starry flounder, true cod and oyster meats. Eight of ten possible bait combinations were tested in paired tests. Bait was paced in ringnets and the number of crab on the nets was recorded at various time intervals.

### 4. Benthic community studies

1984 Benthos Study -- Tufts, 1984

Three 5-acre tracts that had been treated with carbaryl in the Stackpole area of Willapa Bay were surveyed for epifauna and infauna. One 3-acre and one 2-acre intertidal bed in the same area were surveyed as control sites. One bed had not been previously treated with carbaryl, had few burrowing shrimp, and was planted with oysters. The other control tract had high densities of burrowing shrimp and no oysters. The treatment tracts had each a single spray application within a three year period beginning in 1978. Within each control and treatment tract, six stations were sampled for surface-dwelling macrofauna and infauna. Macrofauna were sampled from a 1/4 $m^2$ area, preserved, identified and weighed. Infauna were collected to a depth of 17.5 cm with a 182 $cm^2$ core, washed through a 1 mm sieve, and the retained animals were identified, counted and weighed. Each station, except for one set of three infaunal replicates, was represented by a single sample. A total of 36 surface samples and 54 infaunal samples were collected. Results from this study were summarized in the FEIS.

1984 Study Report -- Hurlburt, 1986

These studies stemmed from concern about the possible affects of carbaryl on the community of bottom dwelling invertebrates. The only known prior study of this question had been by Tagatz et al. (1979) [reviewed in FEIS] which studied the affects of carbaryl and triethylene glycol solutions on the development of animal communities under laboratory conditions. No studies are known of invertebrate assemblages in areas used for oyster culture from any West Coast area. The study area was at Stackpole Harbor on the Long Beach Peninsula near the entrance to Willapa Bay. carbaryl spraying has been carried out in the area since 1963, and this location is representative of oyster culture areas in Willapa Bay. The sample site was a 5 acre portion of an oyster bed that had been treated with carbaryl in 1978. The shrimp hole count was 4 holes/$m^2$ in 1982. At the time of pretreatment inspection in 1984, oyster seed had been planted on the ground, and the shrimp hole count was 30 to 33 /$m^2$. Six sites were sampled on the tract immediately prior to carbaryl treatment, 24 hours after treatment and about 60 days later. There was no untreated control site. At each site 182 $m^2$ cores and 1/4 m surface quadrats were taken -- these samples were not analyzed.

<u>1985 Study Report -- Creekman and Hurlburt, 1987</u>

The purpose of the benthic sampling in 1985 was to assess short-term changes in oyster bed benthic communities associated with carbaryl treatments. A recolonization study was done on a treated tract with an adjacent oyster bed used as a control. A transect line was established through treated and untreated tracts located near Bay Center on Willapa Bay. Five sites were sampled in each tract immediately before and after carbaryl treatment, and 15 days, 30 days and 5.5 months after treatment. Five randomly selected core samples were taken at each site. These cores were 4 cm in diameter by 10 cm in length. A total of 200 core samples were taken. These samples were washed on a 0.5 mm mesh sieve, and those animals retained on the sieve were preserved in alcohol for identification, counting and weighing. To date a single sample series (4 samples) has been analyzed (Dumbauld, 1987).

### 5. Carbaryl in poisoned shrimp and affected animals

<u>1984 Study Report -- Hurlburt, 1986</u>

Single specimens of ghost shrimp and young Dungeness crabs killed by carbaryl were collected immediately after spraying on July, 1984 from two spray tracts in Willapa Bay. These animals were analyzed for carbaryl content by gas chromatography. There were no data given on how these samples were handled.

<u>1985 Study Report -- Creekman and Hurlburt, 1987</u>

Poisoned shrimp were assayed for their carbaryl content to determine the persistence of the carbaryl in the dead shrimp (see also 1984 data). Dead and dying shrimp treated at 7.5 lbs carbaryl per acre were collected immediately after spraying. Sixteen untreated shrimp were collected as a control. Control and treated shrimp were divided into subsamples of 4 each. One subsample was immediately frozen to prevent further carbaryl decay while the remaining shrimp were placed in a screen box on the tide flats at Nahcotta. This simulated dead shrimp left on the treated oyster beds while preventing predation. Subsamples of these shrimp were removed at 24, 48, 72 and 96 hours and immediately frozen. All the frozen shrimp were analyzed for carbaryl by the Washington State Department of Agriculture Food and Drug Laboratory in Seattle.

<u>1986 Study Report -- Tufts, 1989</u>

Dead or dying shrimp and annelid worms treated at 5, 7.5 and 10 lbs carbaryl per acre were collected from a treated WDF plot at Nahcotta immediately after spraying. No shrimp or annelid worms were taken from an untreated control site. These samples were frozen immediately and analyzed for carbaryl by the Washington State Department of Agriculture Food and Drug Laboratory in Seattle.

**6. Reduced application rates**

<u>1985 Study Report -- Creekman and Hurlburt, 1987</u>

This work follows up earlier studies made in the early 1960's. Four test sites were chosen on commercial oyster beds selected for treatment -- Cedar River, Palix River, Naselle River (Anderson bed), and Stackpole -- all in Willapa Bay. In May four, 4m x 4m plots were established at each site. Three plots were treated at 5, 7.5 or 10 lbs/acre carbaryl, while one subplot received no treatment. This experiment was repeated in June at the Cedar River, Stackpole and Anderson sites, and in July at the Anderson bed. In August, the same application rates were used on 1.2 acre plots. Four 1 $m^2$ quadrats were randomly selected within each plot. The number of shrimp burrows in each quadrat were counted as an index of the shrimp density. These counts were made immediately prior to spraying and at various intervals after spraying. In addition to shrimp counts, 100 $cm^2$ core samples were taken from randomly selected locations at each site to assess the abundance and diversity of infauna. These were taken prior to spray; and 24 hours, 2 and 4 weeks, and 6 months after spray. These were washed in a 0.5 mm screen and the retained animals were preserved in formalin for later processing. Other information collected included air and water temperatures, percent vegetation cover, and bottom sediment (for particle analysis).

1986 Study Report -- Tufts, 1989

This study was carried out to determine if carbaryl applied at 5 or 7.5 lbs per acre would be as effective as 10 lbs per acre. Three commercial oyster beds and one WDF-owned tract in the Nahcotta area were tested. Prior to carbaryl treatment, and 24 hours after treatment, counts were made of the numbers of shrimp burrows per $m^2$. Counts of crab mortalities were made 24 hours after treatment on transects randomly distributed over each tract. The treated area for each application rate generally ranged from 1/2 to 2.5 acres. These tracts were sprayed July 5 and 11, and August 5.

1987 Study Report -- Tufts, 1990

The methods were reported in the above reports and in summary form were as follows: Four half acre plots were marked out and in August of 1985, carbaryl was applied to three of these in concentrations of 5, 7.5 and 10 pounds per acre. One plot was untreated. The entire area containing these four study plots was planted with hatchery seed in April of 1986. Examination of the sites prior to and after the spraying and planting assessed the number of shell (cultch) pieces per meter, the seed oysters per shell, the total oyster per meter, percent eelgrass cover, eelgrass turion number (last sample only) and shrimp burrows per meter. Detailed sampling of each of the tracts was preformed one month after the seed was planted (May 1986), and at one and two year intervals from the time of planting (summer of 1987 and 1988). Certain of these results are reported here and in other sections of this report; however, seed loss and oyster production elements of this study were flawed by the inability of the study team to assess seed density immediately after planting.

**7. Seed loss on treated vs untreated grounds**

1987 Study Report -- Tufts, 1990

See summary above for reduced application rates.

**8. Shrimp Emergence**

1985 Study Report -- Creekman and Hurlburt, 1987

This experiment assessed emergence of poisoned shrimp from sprayed tracts. Immediately after treatment, and 24 and 48 hours later, the number of shrimp affect by treatment and the number of shrimp burrows per $m^2$ was estimated. All burrows and emerging shrimp within a 2/3 $m^2$ circular hoop were counted at intervals of about 25 feet along a diagonal transect between the Palix River channel and Goose Point. Following these counts, four 0.37 $m^2$ plots were randomly chosen to monitor emergence of poisoned shrimp. All dead shrimp were counted and removed. Each plot was then covered with a 4 inch high mesh cage to retain emerging shrimp and prevent predation on them. Newly emerged shrimp were counted under the trays 24 and 48 hours after treatment.

### 9. Feeding Toxicity of Poisoned Shrimp to Crab

1985 Study Report -- Creekman and Hurlburt, 1987

Three experiments were conducted to assess 1) the time to death, 2) the lethal dose of carbaryl for Dungeness crab, and 3) the behavior of crab poisoned by carbaryl. In the first experiment, four crab were each fed about 5, 10, 20 or 40 gm of shrimp treated at 7.5 lbs/acre of carbaryl. Four crabs were used as controls and were not fed poisoned shrimp. All crab were held in running seawater for three weeks. The second experiment was a short-term feeding trial lasting 24 hours. Five crab were fed about 100 gm of poisoned shrimp from beds treated at 5, 7.5 or 10 lbs/acre of carbaryl. Shrimp from these beds contained average carbaryl concentrations of 7.1, 8.0 and 9.6 ppm respectively. Five additional non-treated crabs were held as controls. A third experiment was carried out in which 2 crab were fed pink shrimp (*Pandalus jordani*) dipped in a concentrated solution of carbaryl. Mortalities and behavior changes were monitored in the treated crabs from each experiment.

1987 Study Report -- Tufts, 1990

These were experiments to assess the toxicity of carbaryl ingestion to crab. The study objectives were to: 1) determine carbaryl $LD_{50}$, and 2) asses the affects of water temperature on lethal dose. Experiments were carried out from January through March 1987, using crab with a average CW of 133 mm. Crab (held individually in containers of static sea water) were fed with carbaryl-laced food (1.5 g of white fish flesh or oyster meat) and observed at hourly intervals for about 8 hours. A control group was also fed non-contaminated food. They were then placed in flowing ambient (7.4 to 9.3° C) or heated (19 to 18.5° C) sea water. Carbaryl concentrations tested were 43, 62, 83, 128 and 167 mg/kg (calculated). No samples were taken to measure the concentration of carbaryl that might have been dispersed in the water as the crabs fed.

### 10. Feeding Toxicity of Poisoned Shrimp or Feed to Fish

WDF recently completed bioassays to assess the affects of carbaryl in food on estuarine fish (Carr, 1988, Appendix IX). The following is a summary of the experimental approach.

Two experiments were carried out at the WDF Pt. Whitney Shellfish Laboratory in Fall, 1988. In the first experiment two size groups of shiner perch (3 to 6 g yearling, and 10 to 23 g adults) were given a diet containing 100, 300, 500, 600, 1,000, 6,000 and 10,000 ppm carbaryl and a control diet with no carbaryl. There were 15 fish of each size period per treatment and control. The food was a prepared moist pellet made of 20% Manila or geoduck clam meat, 80% Oregon Moist Pellet (OMP), with the appropriate amount of carbaryl (added as 80% active Sevin). The concentration of carbaryl in each batch of food assessed with a gas chromatograph method by the Washington Department of Agriculture. Each group of fish was held in a large "tote" box supplied with flowing seawater at about 13 to 14 C. Fish were fed 6 times to satiation (5 to 7% of body weight) over a 6 hour period. During each feeding bout the fish were observed to see if they were actively ingesting the food. To verify that ingestion occurred, two of the groups receiving 10,000 ppm feed were killed and examined. A second experiment tested shiner perch (15 to 16 g adults) at 0, 100, 300, 600 and 1000 ppm carbaryl; and English sole and sanddab at 0 and 1000 ppm. There were 30 fish in each treatment and control group, held in tote boxes at 20 C. These fish were feed for six hours, had a six hour period of no feeding, and then were again fed for six hours (a total of 20% of weight). Mortalities and behavioral changes in the control and treatment groups were noted in each experiment.

**11. Marine fish studies**

<u>1986 Study Report -- Tufts, 1989</u>

To assess the impact of carbaryl on marine fish, counts of dead fish and estimates of the potential fish habitat on each treatment tract were made by a WDF biologist. Ten by 100 foot transects were made on each spray tract to estimate the percentage of area covered by water 2-4 inches or greater depth. A total of 25 tracts were assessed in Willapa Bay and Grays Harbor. Any dead or dying fish were counted and noted as to species and numbers. Data were compiled, but no statistical summaries were completed.

<u>1987 Survey -- Hueckel (1987)</u>

This was a preliminary assessment of fish kills due to carbaryl treatment. Quantitative assessments of fish and invertebrate kills stranded at low tide on the oyster tracts were carried out on July 10, 1987 at Stony Point in Willapa Bay and on July 14, 1987 in North Bay and Grays Harbor. Four separate 100 m by 2 m transects on 10 and 26 acre tracts were conducted by two WDF biologists at Stony Point, and three separate 100 m by 2 m transects on a 35 acre tract were conducted by two WDF biologists in North Bay. All transects were carried out at least 20 to 30 min following the application of carbaryl. This data is displayed in Table 9 in Hueckel, et al., (1988). A 100 foot beach seine and 75 foot variable mesh gill net was used to catch fish in North Bay in a channel adjacent to a sprayed oyster tracts in about 2 m of water.

1988 Marine fish studies -- Hueckel, et al. (1988)

The beam trawl sampling for these studies was facilitated through a cooperative agreement with the University of Washington School of Fisheries in studies on crab mortalities related to applications of Sevin. This study was funded by the Willapa Bay and Grays Harbor Oyster Growers Association, Washington Sea Grant, and the Conservation Commission.

Quantified sampling of fish was carried out in shallow and deep water channels adjacent to tidal flats in Willapa Bay and Grays Harbor. A total of 190 transect tows, using a 2.3 m beam trawl, and varying in length from 130 m to 530 m were made during the May-September, 1988 period in predetermined strata in both estuaries. A determination was made of the numerical composition, densities, and biomass of fish species captured which are under the management jurisdiction of WDF, in these areas. The short-term recolonization of fish onto carbaryl treated tracts was examined by quantifiable gillnet and beach seine sampling in Grays Harbor in 1987, and beam trawl sampling in Willapa Bay during 1988. A total of six gillnet and 10 beach seine samples were made in North Bay and Elk River (southern Grays Harbor) areas during the July-August period. Two beam trawl samples were conducted at Bay Center during June.

Samples to determine the pre- and post-spray ingestion of organisms susceptible to carbaryl by marine fish were obtained by beam trawl sampling of fish on an oyster tract in Willapa Bay 16 hours before and 12 hours after treatment on June 29, 1988. Stomach contents from these fish were weighed, and identified to the lowest possible taxon and enumerated in the laboratory. Prey items were ranked by the Index of Relative Importance (IRI), calculated as IRI = FO(N+W), where FO is the percentage frequency of occurrence of each prey item, N is the numerical percentage of each prey item contributing to the total diet, and W is its percentage of the weight.

**12. Effect of carbaryl on sturgeon catches**

1986 Study Report -- Tufts, 1989

Catch and effort data from 1981 to 1986 were analyzed to determine if there was a relationship between carbaryl application and sturgeon harvest trends. Average catch per unit of effort (CPUE) data were compiled for four-day periods before, during and after treatment. A variation of CPUE by 20% or more between any four-day period was considered a "significant change". This method was based only on landing tickets submitted by fishermen, and does not account for unsuccessful fishing trips that resulted in no landings.

## B. University of Washington Studies

### 1. Crab studies

<u>1985 Sea Grant study -- Creekman and Hurlburt, 1986</u>

This was an early study carried out under UW SeaGrant funding. A series of trawls were made on treatment tracts and in adjacent channels near the Palix River and at Stony Point to determine if moribund crab were migrating off the beds before dying or being washed off the beds. All trawls were made parallel to the shore using a small beam trawl. All crab captured were counted, sexed and measured. Any dead or abnormal crab were noted.

<u>1986 DOE study -- Doty, Armstrong and Dumbauld, 1987</u>

Study Sites

Three sites were selected with the following characteristics:

Stony Point -- 13.4 ha seed bed with an even distribution of oyster seed on a mud substrate. Shell cover was 14%, eelgrass cover was 1%, and the bed elevation was about +0.5 feet (MLLW)..
East of Oysterville -- 10.9 ha bed with a 70% eelgrass and 5% oyster shell cover. The elevation of this bed was about -1.2 feet.

Palix Channel, near Bay Center -- a 26.7 ha bed, with an eelgrass cover of 50% and shell cover of 7%. The bed elevation was about 0 feet.

Each site was treated with 7.5 lbs carbaryl per acre on July, 1986.

Intertidal Survey

The intertidal crab survey was begun during the last minus tide series in June, 1986 and continued at monthly minus tide intervals through September, 1986. Samples were also taken immediately before and 24 hours after carbaryl treatment to observe the immediate effects of the spray.

Samples were randomly collected from all habitat types at each site. Three to five quadrat samples were collected from each habitat type. A 0.25 $m^2$ frame was placed on the bottom and the degree of shell, eelgrass, and macroalgae cover within the quadrat was estimated. the sample area was then excavated 3 to 5 cm deep and screened in a 3.0 mm (1/8 inch) mesh net and rinsed. The remaining material was sorted, Dungeness crab were removed and measured for carapace width (CW) to the nearest 0.1 mm. Crab with CW greater than 15 mm were sexed. The mean density (crab/$m^2$) was calculated for each habitat type and sample period, and densities for the three substrate types were compared statistically.

The extent of total substrate coverage at the Stony Point and Palix River study sites was estimated by walking randomly arrayed transects with the 0.25 $m^2$ quadrat and randomly sampling every 20 - 40 m. Eelgrass and oyster shell cover was estimated and recorded. The mean of these values for each substrate type was used as a multiplier to derive the total area covered by each within the treatment site. These values were used to estimate the population of crab on each study site (see 1988 study methods for additional comments on this approach).

Subtidal Surveys

Beam trawls were completed to assess pre-treatment and post-treatment crab density in the subtidal channels adjacent to the treatment area an the extent of crab mortality associated with carbaryl treatment in those areas.

Crabs were sampled with a 3 m plumb staff beam trawl with an fishing width of 2.3 m following protocol developed for Dungeness crab surveys in Grays Harbor and Puget Sound. In all trawls taken, crab were counted, CW was measured to the nearest mm, and sex was determined. In addition, selected trawls were processed for fish species. Fish were sorted by species, counted and weighted to the nearest gram. The area swept by the trawl and density of crab per hectare were calculated. Size composition and population information for crabs caught was generated using programs available from the National Marine Fisheries Service in Seattle, WA.

Cage Studies

Cage experiments were completed at the Stony Point and Palix River spray sites to monitor the effects of carbaryl beyond the treatment tract. Juvenile (1+) crab from pre-treatment trawls were collected and placed in shrimp pots (10-20 crabs/pot). The entrance ports to the pots were blocked. Immediately prior to carbaryl treatment, the cages were placed in subtidal channels around the perimeter of the treatment area. Several cages were placed in intertidal drainage sloughs, directly on the treatment areas. The cages were retrieved 24 hours after carbaryl treatment, and mortalities were recorded.

<u>1987 Studies -- Doty, Dumbauld and Armstrong, 1988</u>

## Sample Sites

Sampling was done at 6 sites from May through September, 1987. Three areas were selected as controls to monitor crab populations. Two of the sites, Stony Point (SP86) and Palix River (PR86), were treated with carbaryl in 1986 and were selected on the assumption that there were not residual toxic effects of carbaryl one year after spray, and that they would not be treated again through the course of the study. A third control area near Nahcotta (NHC) was selected to monitor crab recruitment in the southern portion of the estuary. Three treatment sites were selected at Stony Point (WB8706), Palix River (WB8716) and west of Needle Point (in the Anderson area, WB8721) to monitor the impacts of carbaryl applications in 1987. The Stony Point and Needle Point sites were seed beds; the Palix River site with mainly sand/mud with a sparse cover of eelgrass and no shell at the time of treatment.

## Intertidal Survey

The number of crab killed by carbaryl treatment was determined by multiplying density estimates within the predominant habitat at each site by the total area of habitable substrate on the site. Mean crab density was derived from intertidal samples immediately prior to the treatment using techniques described in the 1986 report (Doty, Armstrong and Dumbauld, 1987). The extent of total substrate coverage was estimated by walking randomly arrayed transects and visually estimating the coverage within a 0.25 $m^2$ quadrat every 5 to 10 m . Mean coverage was then used as a multiplier to derive the total area covered on each site. No living crab were found in samples 24 h after treatment so 0+ mortality was presumed to be 100% on treatment sites.

## Cage Studies

In 1987, some preliminary cage experiments were initiated to determine if older 1+ crab feed on carbaryl contaminated shrimp and subsequently die. Crab ranging from 25 to 90 mm carapace width were caught in channels adjacent to site PR87 prior to treatment and put in 22 cages (15-20 per cage). These cages were then placed in three locations in and around the NS87 immediately after spray. Mud shrimp killed by carbaryl on the PR87 site were placed in half of the cages (10 shrimp per cage). Eight cages (4 with shrimp, 4 without shrimp) were placed directed on the treatment site during the first incoming tide after spray. Eight more cages (same configuration) were placed along a channel adjacent to the treated area about 50 m from the edge of the treatment site, and six control cages (3 cages with shrimp, 3 without) were placed across a channel 200 m away from the treatment site. The cages were inspected 24 hours later, dead crab and the number of shrimp eaten were recorded. High mortality in some control cages was noted as probably being due to placement too high on the bed in an area without pooled water, causing partial desiccation of crab during the next morning low tide.

## 1988 UW Crab Studies -- Doty and Dumbauld, 1988

This work followed up on several studies that were reported in 1987, with some additional work done in cooperation with WDF biologists (see Hueckel, et al., 1988).

### Intertidal Survey

A one time bay-wide intertidal survey of treated and untreated oyster beds was made at Needle Point, Nahcotta (1987 station), Stackpole, site near Bay Center on the Palix River -- 5 sites. Sampling following up 1986 and 1987 surveys to assess net YOY crab losses or gains was carried out at two sites -- Stony Point and the Palix (Nisbet bed). Mean crab density was determined using techniques described in the 1986 report (Doty, Armstrong and Dumbauld, 1987).

### Subtidal Survey

See Hueckel, et al. (1988).

### Cage Studies

Cage experiments were carried out in conjunction with water quality plume studies at the Palix site (Nisbet bed). This was done to determine the acute impacts of carbaryl to crab in the first flood tide after spray application. YOY crab captured prior to treatment were placed in net mesh cages (10 per cage). Five cages each were placed at the water quality sampling stations (see below) immediately after treatment, and recovered 24 hours later. In addition, 24 hours after treatment, 6 more cages were set in the center of the treatment tract and 6 were placed in a control site (Figure 7). These cages were recovered two weeks later. The total number and number of dead crabs were counted in each cage.

### Water sampling

The University of Washington, WDF and WSDA collaborated on sampling and analysis for carbaryl and 1-naphthol. This study was carried out to assess the concentration of these chemicals in relation to distance from a spray tract and water depth. Samples were taken in a shallow plume of water flowing off the bed in the incoming tide immediately after treatment. Stations were near the center of the tract, and 25, 50, 75, 100 and 200 off the tract, and at a control point about 1/2 mile to the southeast (or upstream in the Palix channel). Two samples each were taken at the surface and bottom in water 1, 2, 4, 8 and 16 inches deep (there was no bottom sample in the 1 inch depth, and other depths at certain stations -- see section IX. Each sample was collected one inch above the bottom with a plastic squeeze bottle. They were placed in glass bottles containing sufficient 4% acetic acid to reduce the pH of the sample to 4.5 to 6.0. All samples were stored in an ice-filled chest until they reached the laboratory where they were refrigerated at about 2 C. Analysis on 1/2 of the samples was done using a colorimetric technique as noted in the 1984 report. The remainder of the samples were analyzed by the WSDA Dairy and Food Laboratory using a high pressure liquid chromatography (HPLC) method as follows (WSDA, 1988):

- Fifty ml samples were extracted in a separatory funnel with 50 ml, 40 ml and 40 ml of dichloromethane.
- The combined dichloromethane extract was filtered through anhydrous sodium sulfate and evaporated to a volume of 5 - 8 ml in a Kuderna-Danish Evaporative Concentrator.
- The concentrate was evaporated just to dryness with the aid of a gentle current of air and slight warming.
- The residue was dissolved in 2.0 ml mobile solvent and the solution was filtered through a 0.45 micron syringe filter.
- Appropriate aliquots were injected for the HPLC determination. Mobile solvent was used for dilutions when necessary.
- HPLC conditions:
  Beckman Altex 110 pump
  Altex $C_8$ column
  Hitachi F-1000 fluorescence detector
  Wavelength - Excitation 290 nm, Emission 350 nm
  Mobile solvent - Acetonitrile/water (40:60 %)
  Flow rate 1.0 ml/min.
- Recovery from spiked seawater samples.

| Added | Recovery |
|---|---|
| 0.1 ppm | 96.6% |
| 5.2 ppm | 95.8% |

The analysis results are summarized in section IX.

<u>Pacific County Conservation District -- Dumbauld and Doty, 1988</u>

This was a companion project to the 1988 oyster grower funded studies. Objectives included a study of the life history and ecology of burrowing shrimp, examination of the efficacy of several carbaryl concentrations, and further work on the extent of feeding by older 1+ crab on intertidal flats and degree of crab mortality caused by feeding on dead shrimp. A total of 196 quantitative intertidal samples for burrowing shrimp and 666 intertidal crab samples were taken. Shrimp were sampled at approximately biweekly interval at two stations (Palix and Tokeland areas) in June and August, and a single station (Palix) in July and September. A single set of samples were also taken in the Oysterville, Stackpole, Ellen Sands, and Bone River areas for length comparisons. Samples were taken by removing a 0.125 $m^2$ sediment core to a depth of 50 cm. Shrimp were measured and sexed and females with eggs were noted. A subsample was saved for later laboratory analyses of wet weight, dry weight, egg count and volume.

Experiments to assess the efficacy of reduced carbaryl application rates were completed at each of two locations in Willapa Bay selected for shrimp species and density. Four carbaryl concentrations (1, 3, 5, and 7.5 lbs/acre) were tested against a control in plots measuring 4 m on a side. Treatments were interspersed randomly within each of four replicate plots. Shrimp were removed in a 0.125 $m^2$ core within each plot 24 to 48 hours after spray. Burrow counts were taken on the day of treatment and at periods of one and two months.

Two crab feeding trials were completed in mid-summer. In the first experiment, crab were fed with contaminated shrimp collected on a commercially sprayed bed (7.5 lbs/acre) and compared with controls fed with non-contaminated shrimp. In a second trial, crab with fed with shrimp collected from plots treated at 3, 5, and 7.5 lbs/acre (taken during the carbaryl efficacy experiment) and mortalities were compared with non-contaminated controls. Both experiments were run with mud shrimp. None of the shrimp were assessed for carbaryl content.

Net Crab Gains and Loss Analysis (Doty, Armstrong and Dumbauld, 1989)

A sample procedure to calculate net loss or gain of 0+ crab on treated sites was provided in data developed by Doty, Dumbauld and Armstrong (1988a and b) from plots on the Palix River (PR86) and at Stony Point (SP86).

- Oyster seed was planted on the Stony Point bed, in early 1986; the Palix River bed had a remnant cover of oyster shell. Both beds were treated July, 1986.

- Estimates were made prior to treatment, for eelgrass, shell and open cover and the number of 0+ crabs.

- Transplanted oysters were placed on the Palix bed for fattening in late 1986, after spraying.

- Eelgrass and shell cover, and 0+ recruitment were measured in the summer of 1987 on both sites; and in the summer of 1988 on the seed bed site.

o Total crab densities were calculated from multiple samples of each habitat type and sampling period, and a constant mean crab density was determined.

o The total number of crabs per hectare (ha)[11] was determined by multiplying the mean crab densities times the areal coverage of the respective habitat type, and then summing these crab/h2a estimates. These annual totals are shown in Table XVI and Table XVII (Appendix, page 94).

### 2. Epibenthos Studies

Epibenthic studies -- Simenstad and Cordell, 1988

In June and July, 1988 two tracts were sampled in Willapa Bay, with ten samples taken randomly at three sample periods within each tract. The sampling protocol was as follows:

| Sampling Period | Sample Tract* SC | Sample Tract* SS |
|---|---|---|
| One day prior to carbaryl treatment | X | X |
| One tidal cycle after carbaryl treatment | X | X |
| One tidal series (2 weeks) after carbaryl treatment | X | X |
| Total Samples | 30 | 30 |

* SC = carbaryl tract control; distant tract near the Bone River with similar burrowing shrimp composition, sediment structure, exposure, etc. SS = carbaryl spray tract.

Carbaryl treatment was on June 29, 1988.

The epibenthos was sampled at each site during flood tide, when approximately 1 m of water covered the bottom. The laminar or lower turbulent layer over 179 $cm^2$ of the sediment surface was sampled with a battery-powered epibenthic suction pump equipped with 0.130-mm mesh screening over replacement water ports. This device has been shown to effectively sample most epibenthic crustaceans in similar habitats (Simenstad, et al., 1988). All samples were preserved in formalin, sorted, weighed and identified to species and life stage (for a detailed methodology, see Section IX, part E).

[11] One hectare (ha) equals 10,000 $m^2$, or 2.47 acres.

### 3. Grays Harbor Mitigation Studies

Dumbauld and Armstrong (1987) reported on the results of experiments carried out in Grays Harbor as part of a U.S. Army Corps of Engineers contract. The specific tasks are summarized as follows:

- Map the aerial distribution and amount of shell cover using a hovercraft vessel and conduct ground truthing to supplement previous helicopter surveys.
- Determine the characteristics of shell cover best suited as crab habitat and monitor the utilization of this cover by juvenile Dungeness crab at several locations.
- Construct several test plots, each containing a different amount and/or configuration of shell at suitable locations, and monitor utilization by juvenile Dungeness crab.
- Compare the results of the mitigation experiment with those from the shell field survey and develop cost estimates for a full scale mitigation effort based on crab utilization (i.e., cost per crab).

## XI. APPENDIX -- INTEGRATED PEST MANAGEMENT PLAN DEVELOPMENT COMMITTEE WORKPLAN AND LIST OF COMMITTEE MEMBERS

An Integrated Management Plan (IMP) for the control of burrowing shrimp infestation on oyster culture sites in Willapa Bay and Grays Harbor, Washington, is being developed as the preferred alternative.

The purpose of the IMP is to: 1) explore and test alternatives to carbaryl application for the control of burrowing shrimp, 2) to reduce or eliminate, where possible, practical and economical, the use of carbaryl as a pest control method, and, 3) to integrate all practical control methods and applicable oyster culture technology with appropriate time/space control strategies, in order to maintain historical levels of commercial oyster production and to expand production where possible.

The IMP will be developed under the direction and cooperation of the Washington State departments of Ecology (WDOE), Fisheries (WDF) and Agriculture (WSDA). A draft IMP will be prepared by the state agencies, the oyster industry, Grays Harbor and Pacific County representatives and other pertinent contributors. A committee to develop the IMP was formed in February 1991 and has been meeting regularly since. That element of the draft IMP involving carbaryl application will be completed prior to the 1992 "carbaryl spray season", using available scientific information. Experimentation and analysis of control methods in the field will begin during 1992, in coordination with traditional burrowing shrimp infestation control. When adopted by the state, the final IMP will be used to manage burrowing shrimp control practices on commercial oyster culture grounds in Grays Harbor and Willapa Bay.

The draft IMP will address the following areas:

1. Study and evaluate current oyster (culture) practice techniques. The evaluation will include a discussion of each culture practice and its relative dependence on carbaryl use in the management plan area. The evaluation will include suitability criteria, including economics, for each practice type in the management area. Pest management systems for terrestrial agricultural operations will be evaluated and incorporated in the IMP where applicable.

2. Evaluate the current carbaryl treatment program, past "experimental" carbaryl applications, and explore potential alternative methods of carbaryl application. Modification of existing application methods and procedures (timing, concentrations, delivery, etc.) will be considered. Monitoring and evaluation procedures will be designed where

necessary. Changes in the existing program will be evaluated for burrowing shrimp control effectiveness and suitability.

3. Study and evaluate non-carbaryl burrowing shrimp control methods or harvest techniques. State agencies will consult with appropriate resources to determine biological, chemical and/or mechanical alternatives which may be used. Appropriate methods will be selected and tested in the field by the oyster industry in coordination and cooperation with state agencies. Potential funding sources will be identified and pursued jointly by the agencies and the oyster industry.

4. Findings will be summarized and ranked. Ranking will be based on applicability to the plan area, cost effectiveness as it relates to commercial oyster production and potential beneficial or detrimental impacts to the environment.

## GRAYS HARBOR/PACIFIC COUNTIES
## BURROWING SHRIMP MANAGEMENT COMMITTEE MEMBERS

Mr. James Atkinson
Willapa National Wildlife Refuge, U.S. Fish & Wildlife Service
HC01, Box 910
Illwaco, WA 98624 Phone: 206-484-3482

Mr. Steve Barry
Washington State Department of Fisheries, Coastal Field Station
331 St. Highway 12
Montesano, WA 98563 Phone: 206-249-4628,
Scan: 321-6129

Mr. Troy Colley (Grays Harbor County)
330 Pioneer Avenue West
Montesano, WA 98563 Phone: 206-249-5900

Mr. Jim DeShazo
Washington State Department of Wildlife
905 E. Heron
Aberdeen, WA 98520 Phone: 206-533-9335,
Scan: 234-2600

Mr. Brady Engvall (Grays Harbor County)
Brady's Oysters
HCR 76, Box 700
Aberdeen, WA 98520 Phone: 206-268-0077

Mr. Bruce Gardner (Pacific County)
Rt. 2, Box 645
Raymond, WA 98577 Phone: 206-942-3302,
Home: 942-5703

Mr. Paul Huffman (Grays Harbor County)
Quinault Tribal Office
P.O. Box 189
Taholah, WA 98587

Mr. Denny McGaughy (Grays Harbor County)
P.O. Box 391
Montesano, WA 98563 Phone: 206-249-4413

Dr. John L. Pitts, Chairman
Aquatic Farm Program Manager, Market Development Division
Washington State Dept. of Agriculture

406 General Administration Bldg., KU-14
Olympia, WA 98504 Phone: 206-586-2777,
Scan: 321-2777

Ms. Kathleen Sayce (Pacific County)
P.O. Box 91
Nahcotta, WA 98637 Phone: 206-665-5292
206-642-3908 (Work M,T,Th)

Mr. Dick Sheldon (Pacific County)
Box 365
Ocean Park, WA 98640 Phone: 206-665-4886

Mr. Ernie Summers (Pacific Harbor County)
Star Route 1, Box 137
Grayland, WA 98547 Phone: 206-267-1051

Mr. Jim Walls, Vice Chairman (Grays Harbor County)
Columbia Pacific RC & D
2109 Sumner Avenue
Aberdeen, WA 98520 Phone: 206-533-4648

Dr. Richard Wilson (Pacific County)
Box 356
Bay Center, WA 98527 Phone: 206-875-6172

Mr. Art Yoshioka (Pacific County)
Pacific County Economic Development Council
P.O. Box 352
408 Second Street
Raymond, WA 98577 Phone: 206-942-3629 or
206-642-9330
Scan: 541-1330

Mr. Bill Young Washington
State Department of Ecology
7272 Cleanwater Lane, LU-11
Olympia, WA 98504-6811 Phone: 206-586-5551
Scan: 321-5551

EVERGREEN STUDENT COMMITTEE AIDES

Ms. Karen Riener
P.O. Box 10323
Olympia, WA 98502 Phone: 206-943-1371

Ms. Susan Campbell
1139 Garrison N.E.
Olympia, WA 98506 Phone: 206-943-4575

## XII. APPENDIX -- SUMMARY OF AGENCY AND PUBLIC COMMENTS AND RESPONSES TO THE DRAFT SEIS

This section summarizes written comments and the responses to the DSEIS (Draft dated January 30, 1991). The responses are grouped according to the comment writer. The paragraph and page number refer to the <u>comment</u> letter that was received, not paragraph and page number in the SEIS. Comment letters received on this draft follow these responses.

1. RESPONSE TO WASHINGTON DEPARTMENT OF AGRICULTURE

a. p. 1, para 2: Agree. Document appeared to be or was inconsistent in several areas. Document has been revised accordingly.

b. p.1, para 3: Section VI has been expanded to more accurately characterize needs for further information.

c. p.1, para 4:

1) Figure 4 was deleted from the final report because the scientific validity of the results was questionable due to the experimental design and sampling methodology that was employed.

2) Integrated Management Plan (IMP) is incorporated into the SEIS as Appendix XI. Note was added to fact sheet and section IV B indicating that the IMP development committee has been formed and began meeting in February, 1991.

d. p.1, para 5: The agencies do not agree that the first draft of the SEIS (February, 1989) should be used as the final SEIS. Agency concerns about interpretations of study results, as used to assess impacts in areas of major biological concern, were the primary reasons for the decision to rewrite the first draft of the SEIS.

e. Attachment, p.1, para 1: Do not agree the SEIS fact sheet should be amended to explain how the 400 acre limit was originally established. Cedric Lindsay, retired Assistant Director of the WDF Shellfish Program, was contacted on this subject. Mr. Lindsay stated that the 400-acre limit was established primarily because of concerns about the kill of Dungeness crab and the political sensitivity of the crab kill. He also stated that an additional consideration was that only limited WDF staff time was available to supervise the program. He noted that some oyster growers were unhappy with the 400 acre limit when it was originally set.

f. Attachment, p.1, para 3: Paragraph reworded to state goal. As requested, IMP work plan will be added as an appendix with comment that the committee has formed and began meeting in February, 1991.

g. Attachment, p.1, para 4: "waters" changed to "areas".

h. Attachment, p.1, para 5: Text reworded to reflect "worst-case" sampling protocol was probably used.

i. Attachment, p.2, para 1: Do not agree paragraph requires further amplification or is misleading.

j. Attachment, p.2, para 2: Because of these and comments from other sources, the aquatic plant sections have been reworked in an effort to address some concerns. However, conclusive studies which could directly verify that carbaryl has no significant effects on aquatic plants have not been accomplished.

k. Attachment, p. 2, para 3: Sentence reworded to indicate some invertebrates will be killed off tract.

l. Attachment, p.3, para 1: Data is not available to address the question.

m. Attachment, p.3, para 2: Reference to "shell" changed to oyster(s). (Note: This change has been made throughout the document, where appropriate.) Present wording of last sentence accurately reflects conclusion stated by Doty, et al (1990).

n. Attachment, p. 3, para 3: Do not agree. The possibility of long-term impacts to epibenthic organisms have not been addressed.

o. Attachment, p.3, para 4: Data is not available to address these questions.

p. Attachment, p.3, para 5: Change made similar to that suggested.

q. Attachment, p.3, para 6: "Unreplicated" was deleted.

r. Attachment, p. 3 para 7: Agree. Words "generally" and "unfortunately" were deleted.

s. Attachment, p.4, para 1: Suggestion noted; "general" is an appropriate description given the nature of the information from which this relationship was derived.

t. Attachment, p.4, para 2: 34,500 changed to 40,000. Believe definition of intertidal is unnecessary.

u. Attachment, p.4, para 3: "approved" added.

v. Attachment, p.4, para 4: Suggested addition is considered unnecessary.

w. Attachment, p.4, para 5: Disagree with the conclusion and suggestion. Statement on page 14 is considered to accurately characterize the situation. Sentence 2 of paragraph 2 on p. 23 was deleted.

x. Attachment, p. 4, para 6: Last sentence is not considered "editorial"; no change was made.

y. Attachment, p. 4, para 7: Cited literature was checked and found to be in error; changes made to text accordingly. Suggestion to add comparisons of filtration rates of oysters, clams, etc. was rejected because comparisons under conditions similar to Willapa Bay are unavailable and therefore of debatable value.

z. Attachment, p.5, para 1: Refer to para c of this section.

aa. Attachment, p.5, para 2: Sentence modified.

ab. Attachment, p.5, para 3: Do not agree that the section implies carbaryl is spread indiscriminately. However, a clarifying paragraph was inserted into the text on p. 24 and a sentence was added to the summary on p. 27.

ac. Attachment, p.5, para 4: There is an apparent mis-communication. Persistence data was not collected by Hurlburt and Tufts during the spring, 1986. The word possibly was added.

ad. Attachment, p.5, para 5: Last sentence of para 2 on pg. 30 was deleted since it stated the obvious.

ae. Attachment, p.6, para 1: Two sentences similar to that suggested were added to the last para on p. 34.

af. Attachment, p.6, para 2: Refer to para j of this section.

ag. Attachment, p.6, para 3: Transect size noted in text as suggested.

ah. Attachment, pg.6, para 4: Paragraph 1 on p. 52 corrected to reflect that significant differences were <u>not</u> found in pre-treatment and post-treatment trawls and seine sampling.

ai. Attachment, p.7, para 1: Paragraph re-written to clarify difference between inter-tidal and sub-tidal channels.

WDF personnel monitoring carbaryl applications have often observed dead and/or highly stressed fish in off-tract intertidal channels during treatments. These channels continue to drain after treatment until the bed refloods. Obviously, some carbaryl is transported via drainage water to sub-tidal channels, although dilution probably minimizes potential fish impacts.

aj. Attachment, p.7, para 2: Paragraph re-written. Agree that crab cages and trawl studies indicate very low probability of fish mortality in sub-tidal channels. See paragraph ai above.

ak. Attachment, p.8, para 1: Largely agree; sections on aquatic plant impacts have been re-written. Suggestions on research priorities and off-tract impacts noted.

al. Attachment, p.8, para 2: "Determine" omitted. Do not agree text is inconsistent with conclusions, although paragraph on p. 52 has been re-worded to characterize research needs.

am. Attachment, p.8, para 3: Disagree. Burrowing shrimp play an important role in the ecosystem, regardless of the reasons for burrowing shrimp population increases which have apparently occurred in recent times. Focus of the SEIS is on the situation "as is".

an. Attachment, p.8, para 4: As is noted in section VI, the answer to this question can only be determined by research which would undoubtedly be costly and take many years to complete.

ao. Attachment, p.8, para 5: Suggestions noted. Refer to para an above.

ap. Attachment, p.9, para 1: Do not agree that the section is "doublespeak". Paragraph 3 of food web section was partially rewritten.

aq. Attachment, p.9, para 2: Page 62 (section H4) has been partially rewritten. However, do not agree that the section misrepresented the work of Doty, et al. Do not agree that the figure substantially added to the understanding of the section. It essentially duplicates Table XIV.

ar. Attachment, p.9, para 3: Correction made.

as. Attachment, p.9, para 4: "Objective" changed to "goal"; "phase-out" changed to "elimination". Believe suggested rewording is otherwise unnecessary.

at. Attachment, p. 9, para 5: Agree; paragraph changed to reflect belief that mitigation for direct impact to aquatic plants is unnecessary.

au. Attachment, p. 10, para 1: Paragraph modified to indicate mitigative efforts appear to be unnecessary, but that the possibility of sub-lethal effects cannot be entirely discounted.

av. Attachment, p. 10, para 2: Section VI has been expanded. See paragraph C of this section.

## 2. RESPONSE TO BAY CENTER MARICULTURE

a. Page 1, para I: Do not agree that the data indicates sample analysis was inaccurate or that samples were contaminated. Paragraph 2, page 25 re-worded to indicate distances off-tract at which sample values below 0.1 ppm were initially obtained and that 1-naphthol values of 0.1 ppm were found in some samples much farther off-tract.

Do not agree the carbaryl transport section leaves the impression that carbaryl transport is "dangerous and unpredictable". However, a clarifying paragraph was added.

b. Page 1, para II: Clarifying note on probable sample contamination added to Table III. Carbaryl contamination levels in the "control" samples were stated correctly; contamination levels in "pre-treatment" samples were added (0.005 to 0.257 ppm).

Until recent years treatments were conducted at 10 lbs carbaryl per acre. The treatments conducted in 1989 at 2.5 and 10 lbs per acre were experimental. It was considered appropriate to collect data from these applications so that data would then be available from tracts treated at 2.5, 5.0, 7.5 and 10.0 pounds per acre.

c. Page 2, para III: 34,500 changed to 40,000. Note added to Figure 2 indicating some of the ground is shallow sub-tidal.

d. Page 2-3, para IV: Sections on eelgrass have been extensively re-written. Agree that it appears unlikely that carbaryl has a significant adverse effect on eelgrass. However, given the importance of eelgrass in estuarine ecology, it is reasonable to suggest that a study to determine impacts should be conducted.

Figure 4 was deleted from the final report because of problems in methodology and sampling. Observations on burrowing shrimp - eelgrass relationships have been noted in the re-written text. The relationship has not been scientifically documented.

e. Page 3, para V: The source of WDF authority to regulate carbaryl application is RCW 75.58. The source of DOE's authority is RCW 90.48. Carbaryl is both a form of pollution and a discharge. The waters over private ground are waters of state, i.e., a public resource. The amount of time the pesticide resides in the water column is not considered in these determinations. Agriculture is defined in RCW 90.48; the definition does not include aquaculture/oyster culture. The authority to require an EIS/SEIS is contained in RCW 43.21C. The reader is also referred to the SEPA Handbook. WAC's 197-11-xxx referenced do not exempt the carbaryl treatment program from the EIS/SEIS process.

f. Page 4, para VI: Disagree that the Simenstad and Cordell study demonstrates the "non-problem" of carbaryl's effect on epibenthic species. The study was very limited, short-term and acknowledged as such by the authors. Additional studies of the impact of epibenthos and carbaryl should include evaluating the affects of burrowing shrimp on the epibenthos (i.e., a control) and compared to the impact of carbaryl treatment. Disagree with the comments which imply lack of objectivity on the part of WDF and DOE staff who prepared the January 30, 1991 draft SEIS.

g. Page 4, para VII: The Food Web Impacts section was prepared by WDF and DOE staff because this area of concern (as identified in the scoping document) was not addressed <u>at all</u> in the draft document prepared by industry. Do not agree that the section is confusing or misleading. Agree that the topic is complex and that there is scant information on which to evaluate either the impacts of carbaryl or of burrowing shrimp to the overall ecology of estuaries.

h. Page 5, para VIII; comment 1: Statement added to section III A1 indicating shrimp populations inhabit a substantial part of the intertidal and shallow sub-tidal area of Willapa Bay and Grays Harbor.

i. Page 5, para VIII, comment 2: 7.5 pounds changed to 10.0 lbs. on page 65. 7.5 pounds changed to 8.0 lbs on page 67.

j. Page 5, para VIII, comment 3: Living oyster shell replaced with oyster habitat, oyster culture or oysters, as appropriate.

k. Page 6, para VIII, comment 1: Disagree. These need not be enumerated in an executive summary.

l. Page 6, para VIII, comment 2: Estimated revenue and number of job losses added to section II C 1.

m. Page 6, para VIII, comment 3: "Privately owned or leased" added to section II C 5.

n. Page 6, para VIII, comment 4: References were checked and errors in values were corrected. "Per day" was correct.

o. Page 6, para VIII, comment 5: This figure was intentionally deleted. See response to WDA; para 1 C.

p. Page 6, para VIII, comment 6: Partially agree. Last paragraph modified to reflect significant fish mortality in sub-tidal area appears unlikely, but possibility of sub-lethal affects cannot be discounted.

q. Page 6, para VIII, comment 7: The reader is referred to Doty, et al, December, 1990, sections 3.4.4. and 4.2.2. Carbaryl movement off-tract has been well documented. During routine monitoring of carbaryl applications WDF biologist have observed dead or stressed fish in off-tract intertidal drainage channels.

r. Page 6, para VIII, comment 8: Section H4 has been partially re-written to include the Doty, et al report information indicating that an estimated 35.5 million (1986) to 75.5 million (1987) age 0+ of crab were found on the oyster beds. The section fairly summarizes Doty et al's report.

s. Page 7, para VIII, comment 1: Believe the graph essentially duplicates the content of Table XIV and is therefore redundant.

t. Page 7, para VIII, comment 2: Section IV D changed to reflect that oyster growers insist off-bottom culture is a non-viable alternative.

u. Page 7, para VIII, comment 3: Section V 2 up-dated using results of more recent experiments.

v. Page 7, para VIII, comment 4: Last 2 sentences of section VD were deleted. Seagulls have been observed to at least partially vacate beds following carbaryl treatment when humans are present.

w. Page 7, para VIII, comment 5: Disagree. The oyster grower proposal to double the amount of carbaryl applications make additional information in certain areas highly desirable. By law applicants, i.e. the oyster growers, may be required to provide relevant information (WAC 197-11-100).

x. Page 7, para XI. Disagree - except where changes have been made as indicated above.

3. **RESPONSE TO WIEGARDT BROTHERS, INC.**

a. Page 1, para 1,2,3: Many observers, including some state agencies biologists and oyster growers have noted that dense burrowing shrimp populations result in the loss of or precludes eelgrass. However, scientific documentation of this is not currently available. It has also been observed that dredging operations during oyster harvest results in loss of eelgrass. The direct effect of carbaryl on eelgrass, as is indicated in the final SEIS, does not appear to be of significant concern.

b. Page 1, para 4: That oyster growers operate on private land as well as land leased from the state or counties has been added to the document.

4. **RESPONSE TO COLUMBIA RIVER CRAB FISHERMAN'S ASSOCIATION**

a. Paragraphs 1-4: Comments noted. Specific references to the document are needed in order to address the issues of about which the commentor is concerned.

b. Para 5: Potential impacts to birds have not been scientifically documented. Observations indicate that consumption of carbaryl-contaminated shrimp by birds is not a problem. Section VD was modified.

c. Para 6: Scientifically questionable research has been eliminated from the SEIS. Disagree with conclusion 2.

d. Paras 7,8: Disagree with the implication that agency personnel responsible for finalizing the SEIS are partial or biased.

5. **RESPONSE TO NISBET OYSTER CO.**

a. Page 1, section I: Text of SEIS in sections IA, II C 5 and IV A changed to indicate carbaryl is applied to privately owned and leased ground. The already lengthy title of the SEIS was not changed.

b. Page 1, section II: Refer to response to Bay Center Mariculture, para e.

c. Pages 1-2, section III: Section IV D modified.

d. Page 2, section IV: See response to Bay Center Mariculture, paragraph g. Scientific information is needed to address the question adequately.

e. Page 2, section V: Sections III C 1 and V B were partially re-written.

f. Page 3, section VI: Comments, objection and opinions noted. A new section on the history of the carbaryl treatment program was not considered necessary for the purposes of the SEIS.

## 6. RESPONSE TO WASHINGTON STATE PARKS AND RECREATION COMMISSION

a. Page 1, paras 1-2: Opposition to expansion of the carbaryl treatment program noted. Suggestion on research needs noted. A function of the Integrated Pest Management Plan (IPMP) committee is to further identity and prioritize research needs.

b. Page 1, paras 4-5; Page 2, paras 1-2: Except perhaps to very minor extent burrowing shrimp harvest is not a viable option for the oyster industry because economic injury occurs at population levels too low to sustain commercial harvest. Also, the market for burrowing shrimp is unstable and currently depressed. A primary function of IPMP development process is to identify and evaluate alternatives to carbaryl.

## 7. RESPONSE TO EAST POINT SEAFOOD COMPANY

Comments noted. Similar comments received from others have resulted in modifications to the SEIS.

## 8. RESPONSE TO UNIVERSITY OF WASHINGTON BIOLOGIST

a. Page 1, comment 1: Cite for Figure 5 changed.

b. Page 1, comment 2: Clarifying note added to Table III.

c. Page 1, comment 3: Reference cite changed.

d. Page 2, comment 1: Reference cite changed.

e. Page 2, comment 2: Changes were not considered essential.

f. Page 2, comment 3: Believe qualifiers are necessary because the study was of limited scope and duration. One of two references to "limited" was deleted.

g. Page 2, comment 4: Last sentence of section III H 2 b deleted.

h. Page 2, comment 5: "Limited" deleted.

i. Page 2, comment 6: Agree. Paragraph changed.

j. Page 2, comment 7: Comments noted. Additions were not considered essential to the SEIS. It is acknowledged, however, that carbaryl-related mortalities to age 0+ crab are highly dependent on the presence of cover (in the form of oysters, oyster shell, etc.) on the plot and the relative recruitment strength of age 0+ crab.

k. Page 2, comment 8: This is appreciated.

l. Page 2-3, comment 9: Agree. Sections referring to eelgrass impacts have been re-written.

m. Page 3, comment 1: Section was re-written.

n. Page 3, comment 2: Noted.

o. Page 3, concluding para: Section VI was extensively re-written.

9. **RESPONSE TO U.S. FISH AND WILDLIFE SERVICE**

Letter acknowledged.

10. **RESPONSE TO COAST OYSTER COMPANY**

a. Page 1, para 2: Disagree that agency staff responsible for preparation of the SEIS are biased.

b. Page 1, paras 3-7: The final SEIS contains revisions or clarifications in some areas. Other comments were noted.

11. **RESPONSE TO ALLIED AQUATICS**

a. Page 1, para 1: Although additional information is needed to more completely characterize impacts in some areas, currently available information indicates significant adverse environmental impacts are unlikely (section VI).

b. Page 1, para 2: Disagree. Direct physiological impacts on aquatic plants are unlikely. However, research in this area is recommended (see section VI).

c. Page 1, para 3: Disagree. Although some off-site transport and dilution does occur, evidence indicates that chemical breakdown is the reason for the relatively short persistence of carbaryl.

d. Page 2, para 1: Agree that more information is needed to assess potential impacts to benthic and epibenthic invertebrate species. Results of one short-term study indicates no overall catastrophic impacts, but that some species are impacted. Moreover, some species are impacted more than others.

e. Page 2, para 2: Research indicates that impacts to crabs are offset by the presence of oysters which provides shelter for young-of-the-year crab, thereby increasing survival. WDF Pest Control Permits issued to oyster growers contain provisions on carbaryl application procedures which mitigate the crab kill.

f. Page 2, para 3: Disagree that data is needed. Carbaryl applications are conducted during July and August, thereby avoiding the salmonid smolting period. Some salmonids are present in the estuaries but should have completed the transition from freshwater to saltwater (they have smolted).

g. Page 3, para 1: Comment noted. Carbaryl is applied to privately owned land which is generally inaccessible to the public. The probability of public content with carbaryl, through either active or passive means is considered to be very low. Nonetheless, through an oversight, the Department of Ecology has not required notification procedures for carbaryl applications. In the future, the Department of Ecology will require public notification procedures which are consistent with those required for aquatic pesticide applications. The Departments of Ecology and Fisheries appreciate this being brought to our attention.

h. Page 3, para 2: Comment noted.

C. ALAN PETTIBONE
Director

STATE OF WASHINGTON
DEPARTMENT OF AGRICULTURE
406 General Administration Bldg., AX-41 • Olympia, Washington 98504-0641 • (206) 753-5063

March 19, 1991

Mr. Duane Phinney, Chief
Habitat Management
Washington State Dept. of Fisheries
3939 Cleveland Avenue, AX-11
Olympia, Washington 98504

Dear Mr. Phinney:

Enclosed, find WSDA comments regarding the SEIS on Burrowing Shrimp Control in Willapa Bay and Grays Harbor. I appreciate the one week extension in order to complete the review and submit comments.

I found the document lacking in consistency, as the "fact sheet", "background" and "section" conclusions do not reflect the text of the document in many instances. The casual reader who might read only the "summaries", would determine that serious problems exist regarding carbaryl control of shrimp. The complete text would need to be examined to find a more objective treatment of this subject, although, the sections on "eelgrass" and "food web" are inconsistent even within the SEIS text itself.

The five points listed at the end of the SEIS suggest the need for new or additional information collection, but the text of the SEIS does not indicate that problems exist that warrant expanded research. If issues are of concern, it seems that the agency should prioritize these issues and proceed to collect data through the marine biology staff. "Concerns" in limbo will not lead to solutions to the problem of burrowing shrimp control, especially when "concerns" do not seem well founded.

Please note that two figures from the SEIS completed in 1989, were omitted in this WDF draft SEIS. Those figures (enclosed) depict conditions that should be presented graphically in the SEIS document. Also, please print the IMP work plan (enclosed) in total, so that readers will know that the preferred alternate is in process.

I submit that the 1989 Final SEIS is a more complete, clear and concise document. The 1989 version should be re-submitted and used as the SEIS. It was my understanding that there were concerns with regard to the "tone" of the 1989 document and that 2 - 3 weeks' work would have corrected any "tonal" problems. The present SEIS is flawed far beyond tone, and should be replaced by the "tonally" revised original version.

If you have any questions, please call me at 586-2777.

Sincerely,

MARKET DEVELOPMENT DIVISION

John L. Pitts
Aquatic Farm Program Manager

JLP:1
Enclosures
cc: C. Alan Pettibone
Mary Toohey
Judith Freeman, WDF
Mike Llewlyn, WDOE
Tim Smith, P.C.O.G.A.

Fact Sheet - Oyster Growers Proposed Action - Suggest that the basis for the 400 acres proposed in EIS be stated in this fact sheet. For those not familiar with the EIS, it would appear that this SEIS "growers" proposal is at odds with EIS' 400 acres in some scientifically founded manner. The existing evidence does not suggest that 400 or 800 acres is determined by scientific data, but by political and economic realities for the considered allocation.

Fact Sheet - sentence two - Preferred alternative section, strike "Recently" and state: "This approach has also been supported by the oyster growers". The decision by agency directors to proceed with the Integrated Management Plan (IMP) was made in February, 1990 and the oyster growers concurred in a meeting with state agencies in March, 1990. Ten months to develop this draft SEIS and the oyster growers 3/90 decision is not "recently".

Fact Sheet - sentence four - The GOAL of the management plan is to find suitable alternatives for burrowing shrimp control in order to reduce or eliminate carbaryl while maintaining an economically viable oyster industry in the region. (See enclosed management plan protocol approved by state agencies: WDOE, WDF, WSDA). Please print the approved IMP in the final SEIS as a matter of record, and state that the Burrowing Shrimp Management Committee has been formed, and is proceeding with its appointed charge.

Page 1, C: Background - Change sentence to read "This policy allowed carbaryl application on exposed private and public intertidal grounds of the state under a special permit". If you prefer, use language found in this document on page 8, "Criterion 4 states that carbaryl can only be applied when beds are 'dry'". The use of "estuarine waters" in this background section is confusing, contradictory to SEIS document text and mis-informs the reader as to the application practices regarding burrowing shrimp control.

Page 2, D: Impacts of Carbaryl Treatment - Strike "recent" and state, "A study monitoring....". The statement, "1,700 feet from test tracts" is out of context and imparts an impression, not reflected in balance of SEIS document; change to "...found up to 1,700 feet off tract in a worst-case condition when the leading edge of the incoming plume was sampled (see p. 33, draft SEIS). One-napthal, the breakdown product of carbaryl, was found up to 225 feet from the tracts."

Page 2, D: What are "some of the off-tract impacts" that "may occur following carbaryl application"? Does it kill fish, birds, shrimp, crab "off-tract"? Are the impacts significant? How far "off-tract" before you stop seeing "impacts"? This statement in the summary does not reflect the SEIS text, therefore, misrepresents the data in the document and gives the casual reader a false sense of "impacts".

Page 3, Plants - Strike "On the other hand, aquatic plants could be adversely affected IF carbaryl causes mortality or negative sublethal effects." This might be the opinion of the author, but the text does not reflect this effect as even a minor consideration. This statement should not appear as a comment in the Summary as it is of minor importance, if an issue at all. More than twenty-seven years of carbaryl use and WDF observation does not indicate that eel grass is negatively impacted at sites treated for burrowing shrimp infestation. I have contacted Dr. Ron Thom (Battelle), Dr. Tom Mumford (DNR), and Diane Dolstad (WSDA), all having knowledge of aquatic plants, and none of them indicate that problems exist related to pesticide use. Suggest that you strike this section and contact experts (above) as well as Dr. Ron Phillips (BEAK Associates), and others who have expertise in aquatic plant physiology. This might be an area that WDF would wish to prioritize for further investigation, but nothing cited in the SEIS indicates that there is a problem with carbaryl use and eel grass.

Page 3, Invertebrates - What "effects" have been observed on caged crab "700 feet off treated areas"? Were these lethal effects, behavioral effects, other? If they were behavioral effects, could they not reflect the caged condition?

Page 3, Invertebrates - List effects in summary.
- Last sentence in this section - How often are "sediments...below LC50's for all species tested"? Is this the vast majority of the time (>80%), most of the time (>51%), or rarely (<20%), when you see "re-colonization"?

Page 3-4 - Dungeness Crab - Last sentence - change "shell" and "more than" to, "The living oyster bed habitat generated by oyster culture practices offset the crab killed by carbaryl application through habitat creation." See "Armstrong" work, referred to in this document.

Page 4 - Epibenthic Invertebrates - There is nothing in the SEIS text that directly states that long term studies are needed due to information gaps in existing literature. Strike "Longer term impacts were not studied", as it suggests to the "summary" reader that a suggested problem exists. If you know what those "long-term impacts" are, state those facts.

Page 4 - Fish - Indicate the order of magnitude of intoxication of fish found in shallow pools. The effect on the estuarine fish populations is limited in duration and numbers. Show impacts as a percent of total population of fishes in the estuary.

Page 10 - pp 2 - Add, "However, oyster growers, UNIVERSITY RESEARCHERS, SOME STATE AGENCY PERSONNEL, AND OTHERS, believe burrowing shrimp impacts are obvious."

Page 10 - pp 3 - Note to Editor - If "unreplicated" study is noted in this one place for emphasis, then all studies should be clarified as "unreplicated" or "replicated" so that consistent information is given. Suggest that you strike "unreplicated" in this paragraph.

Page 10, pp 4 - "In general" and "Unfortunately" are editorial comments which reflect a tonal discrimination which should not exist in the SEIS.

Page 11 - Figure 1 - Strike "generalized" or state more specifically what is meant. Suggest, "A model to illustrate....".

Page 12 - 5 - The text and Figure 2 should be consistent at either 34,500 or 40,000 acres, whichever is more accurate. How do you define intertidal? Suggest that readers may use variable definitions, which need to be clarified for consistency in SEIS text. Provide definition of intertidal in SEIS.

Page 13 - pp 3 - add "....than is ultimately APPROVED and treated."

Page 13 - pp 4, add, "....the current acreage under cultivation CONSIDERING EXISTING BURROWING SHRIMP INFESTATION IMPACTS."

Page 14, #2. - Pertinent literature - The sentence, "The published research on carbaryl is quite extensive; however, only a small fraction of this work is relevant to estuarine environments" on this page contradicts the statement in the middle of page 23, of draft SEIS, "This section focuses on a portion of the very large body of literature on carbaryl, much of which augments or substantiates information given in the SEIS, or provides further clarification of key issues". Suggest that the text on page 23 is more accurate, please strike second half of first sentence, page 14, #2.

Page 15, top parpagraph: The last sentence is an editorial view and should be re-written. Suggest: "THIS RESEARCH WAS CARRIED OUT IN HETEROGENEOUS FIELD CONDITIONS. LIKE MOST FIELD RESEARCH, THE RESULTS WERE, AT TIMES, CONTRADICTORY."

Page 19 - top of page - Flow (filtration) rates of burrowing shrimp are listed. How does this compare with filtration rates of oysters, mussels, and other bivalves? Information should be given for comparison for SEIS reader understanding.

Page 21 - Eel grass narrative - Figure 4. (Tufts, 1988b) page 24, of the Original Draft SEIS, February 8, 1989, was an excellent figure depicting the presence of eel grass in areas of carbaryl post-treatment. Strongly suggest that you include that figure with this text so that readers can gain an understanding of eel grass in treated and non-treated areas (Fig. 4, enclosed).

Page 24 - Footnote #3, the scientific definition of "transportation" does not imply "for a considerable period of time" as is stated in the footnote. Strike "considerable".

Page 27 - The "In summary" is misleading to the reader. It implies that transport is taking place over a long period of time, when in fact, the energy available for this event is measured in a matter of minutes. This entire section gives the impression that carbaryl is spread throughout the water column and distributed in all directions. Special effort should be made to explain that carbaryl is carried into higher tidal areas and not distributed laterally or even in a "reverse" direction, defying the energy and direction of the tidal flow. Strongly suggest re-write of this and subsequent section.

Page 28 - 2, Persistence - Suggest re-write as follows: "Persistence is a term often applied to compounds that have lingering toxicity which MAY be transmitted from treatment areas and POSSIBLY through the food chain. Persistence is characteristic of many pesticides, but is highly variable, depending on environmental conditions and the specific character of the pesticide. THIS HAS BEEN AN ISSUE THAT HAS BEEN RAISED in relation to carbaryl treatment of oyster lands, EVEN THOUGH data available from the 1960's indicates that persistence of carbaryl in environments.....was relatively short EVEN IN THE COLDER TEMPERATURES WHICH OCCUR DURING THE SPRING. (Refer to work done by Hurlburt and Tufts, WDF, Spring 1986, pers. comm. 1991)

Page 30, pp 2, - "None of the above studies were conducted in estuarine conditions comparable to Willapa Bay and Grays Harbor", should also state language from original SEIS, February 8, 1989: "BUT THESE STUDIES HELP TO

DEFINE THE FACTORS NECESSARY FOR BREAKDOWN OF THE CARBARYL AND 1-NAPTHOL." Work is frequently extrapolated from similar, but not totally "comparable" conditions in order to understand chemical and physical phenomenon which are consistent in a variety of conditions. The format used and the impression given in this SEIS, is not consistent with accepted protocols for juried scientific literature.

Page 24, 1 - aquatic plants - Please add, "OBSERVATION OF TREATED AND NON-TREATED BURROWING SHRIMP AREAS ARE QUITE CLEAR WITH REGARD TO AQUATIC PLANTS. AREAS HEAVILY INFESTED WITH SHRIMP ARE DEVOID OF EEL GRASS. EEL GRASS OFTEN RE-ESTABLISHES IN TREATED AREAS IF OTHER SUITABLE TIDAL AND ENVIRONMENTAL CONDITIONS ARE CONDUSIVE TO EEL GRASS PRODUCTION."

Page 34 - last paragraph - This is double speak: "Studies...suggest that significant negative impacts on aquatic plants do not occur", yet the author states, "The impacts of carbaryl on aquatic plants cannot be assessed with existing information". This paragraph is not consistent with scientific reasoning. Strike all sections (including the "summary of SEIS") that state that carbaryl is a concern for eel grass. This section on aquatic plants appears to affect a problem, when one does not exist. Refer to comments keyed to page 3, "Plants", in this WSDA discussion on the Draft SEIS. Qualified aquatic botanists and toxicologists should be consulted prior to a re-draft of this section.

Page 36 - last paragraph - Include 200 m2 in sentence, ".....by sampling seven 200 m2 transects on three treated tracts."

Page 42 - Carbaryl-induced estuarine fish mortalities: "Hueckel, et. al. (1988) also expressed concern over fish concentrated in shallow water adjacent to treated tracts during low tide periods (see Sec. F.1). Add; PAGE 51, (so that readers can find reference)". Note that on page 51, it states, "The average fish densities decreased steadily from May to September in both estuaries, probably due to heavy natural mortalities suffered by young-of-the-year fish." And, "Fish density and biomass were significantly higher from treated tracts than from non-treated tracts in Willapa Bay and Grays Harbor (Appendix IX)." How does the conclusion on page 42, "expressed concern", match with the material referred to on page 51, "natural mortalities" and "significantly higher", given the fact that the carbaryl spray season in July and August. Suggest that Hueckel statement is inconsistent with information found in Appendix IX, Draft SEIS.

Page 42 - Carbaryl-induced estuarine fish mortalities - "They noted carbaryl levels in these channels have not been adequately measured, and drainage from tracts into the channels could expose some marine fish and invertebrates to lethal or sublethal levels of carbaryl." Please refer to WSDA comments keyed to Draft SEIS, pages 24, 27, 28, on "transport" and "persistence", and know that carbaryl is limited in direction, distribution, concentration and time, with regard to movement in the estuarine waters. The suggestion that fishes in the channels are at risk is at odds with WDF statements that fishes trapped in tide pools on tracts are the fish at risk.

Page 42 - Carbaryl-induced estuarine fish mortalities - "Results of crab cage studies (page 58) indicate toxic levels in intertidal channels may occur." See page 58, "Juvenile 1+ crab placed in cages in subtidal channels at shallow depth along the perimeter of two treated sites in 1986 exhibited little mortality when examined 24 hours after spray. One crab was found dead among 71 placed in five cages at a site on the Palix River. No crab died in cages set in slightly deeper water at Stony Point." It seems that the page 42 sentence stating, "indicate toxic levels in intertidal channels may occur" was inserted to amplify an "expressed concern" in preceeding sentence about estuarine fishes which was not valid, based on text in Draft SEIS. Suggest re-write of this section to reflect information. Suggest strike sentence referring to "crab cage studies", as physiology of crab and fish and reaction to carbaryl are not comparable. Also, see page 43,e. "Toxicity of poisoned food organisms to fish", and note that carbaryl intoxicated shrimp could more likely be implicated in fish mortality, but tests on page 44 show that, "carbaryl was probably not the cause of most mortalities" and, "Thus, mortalities resulting from the consumption of food items contaminated with carbaryl are unlikely."

Page 45 - Conclusions - "Available information is not adequate to evaluate the impacts of carbaryl spraying on aquatic plants in estuaries." "Negative impacts may occur if growth, reproduction and survival of the plants is affected." There is nothing in the text that indicates this conclusion, therefore, strike this paragraph. Suggest WDF set this issue as a priority for WDF investigation. Suggest that WDF also investigate "off-tract" impacts, if, as stated in pp. 3 of conclusion, it is a concern. The text of Draft SEIS does not suggest that conclusion.

Page 51 - 2. - Conclusions - Missing words in second to last sentence. The suggestion that additional studies be done, does not match text of Draft SEIS or the preceeding sentences in this conclusion. Suggest WDF prioritize concerns and investigate "possible effects".

Page 53 - Food Web Impacts - "Burrowing shrimp are an important component of the mud/sandflat system because of their ability to control and structure the community." How "important", as a "component" of the "system", the "shrimp" really are, in the light of persistent and expanding shrimp infestation which results in destruction of other plants and animals, is questionable. I do not believe that the "important" statement is accurate or realistic, given the dramatic anthropogenic changes that have occurred in these estuaries in the past 75 - 100 years, i.e. clear cutting, predator loss, siltation, dredging, etc. All indications are that the artificial changes have predisposed a condition for un-natural, un-controlled expansion of burrowing shrimp to the detriment of other organisms and to the estuary itself.

Is not the "cycling of nutrients and organic matter" by the burrowing shrimp population explosion, considered a detriment to the food web itself? There are numerous examples in wildlife management where a predator is eliminated and the prey species "eats itself out of house and home". (Refer to the Kaibab deer population after removal of cat and wolf predators.)

Page 54 - Food Web - "It is not possible to predict whether the food web associated with the oyster community is a positive or negative change from what existed previously." Suggest the author look at historical levels of oyster populations pre and post white man. Suggest the author look at pre-shrimp infestation levels of oyster production in the estuarine environments. Suggest the author examine the micro-environments at the site of oyster culture vs. sites of shrimp infestations, to compare biomass and concomitant "food web" dynamics.

Suggest that the last paragraph of the food web section is double-speak. The sentence that makes the most sense is, "To date, there have been no indications of any such (positive or negative) impact in either direction". The author could sum up this entire section in that one sentence, with "To date" being 27 years of testing and experience as a reference.

Page 62 - Net effect on crab - This section is not an accurate representation of the Doty et. al., work, sited in this section. Suggest that conclusion of that work be printed in toto, to replace this section of the Draft SEIS. Figure 13 (Doty, et al), from the February 8, 1989, Draft SEIS, was a clear and concise representation of the projected cumulative net loss or gain of YOY crab on treated tracts, and should be included in the Final SEIS (enclosed).

Page 63 - Statements #1 and #2 are missing from the text. Statements #5 and #6 are repeated on page 64.

Page 66 - Last paragraph of Alternative 2 <u>should</u> read" "The goal of the IMP is to achieve a reduction or elimination of carbaryl use, where and when possible, in a manner which will assure the continued economic viability of the oyster industry." Please include the IMP work plan (enclosed) in the Final SEIS. State that the committee has been appointed and is working on their assigned tasks and will make recommendations to the state agencies as part of their charge.

Page 69 - Aquatic Plants - Add <u>not</u> - The existing information is <u>NOT</u> inconclusive regarding the impact of carbaryl on aquatic plants. See previous statements on this subject.

Page 70 - Birds - What evidence has been presented in this SEIS or in the EIS that indicates that birds are a problem? Refer to EIS statements on birds for the gypsy moth and grasshopper carbaryl treatment for terrestrial agriculture. To suggest that scarecrows and noise cannons be used here, is to suggest that there is a problem. Strike bird diversion suggestions.

Page 71 - Additional needs - Comments related to the five listed "additional information needs" are found throughout this WSDA comments letter. I do not believe that any of these suggestions can be justified based on information found in the EIS or this draft SEIS. I sat through a number of SEIS planning and scoping meetings, and did not hear that these five items were high priorities.

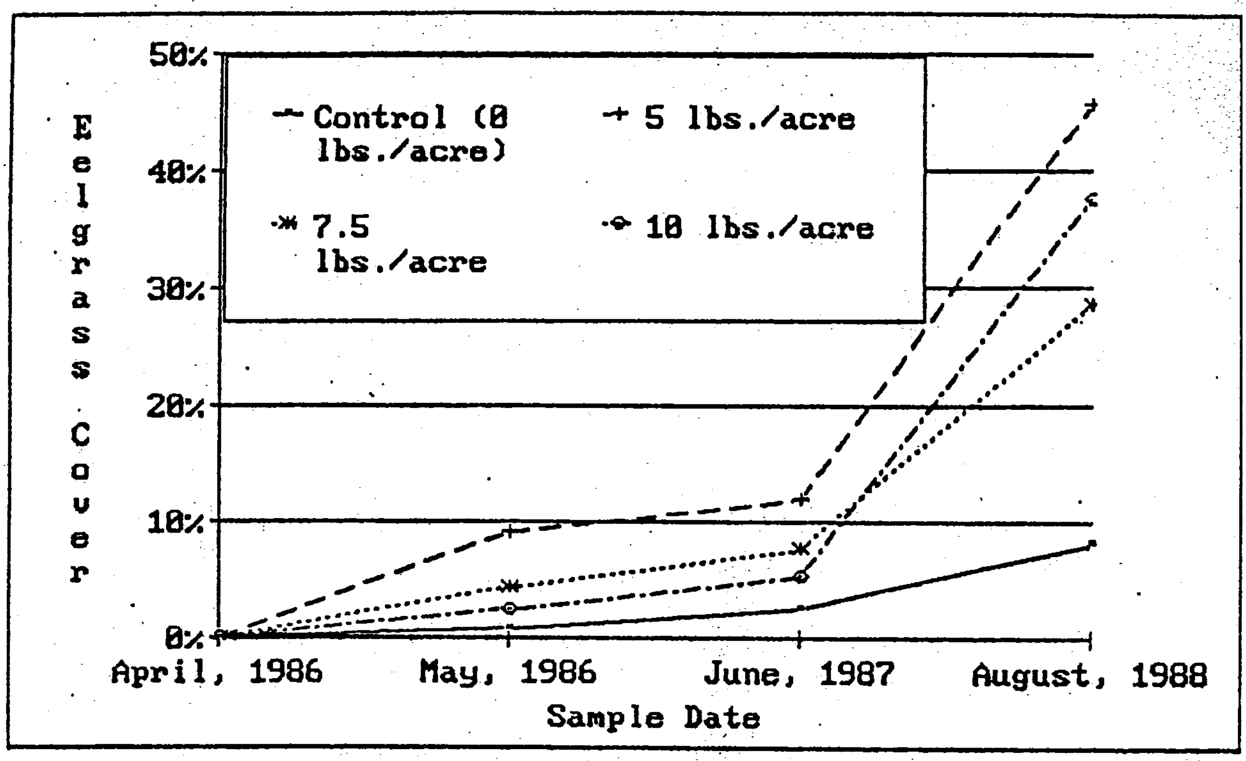



**Figure 4.** Eelgrass percent cover on control and treated (5, 7.5 and 10 lbs carbaryl/acre) tracts, in south Willapa Bay where shrimp density /$m^2$ (after treatment) was 8 - 18 on control and 1 to 4 on treatment tracts (from Tufts, 1988b).

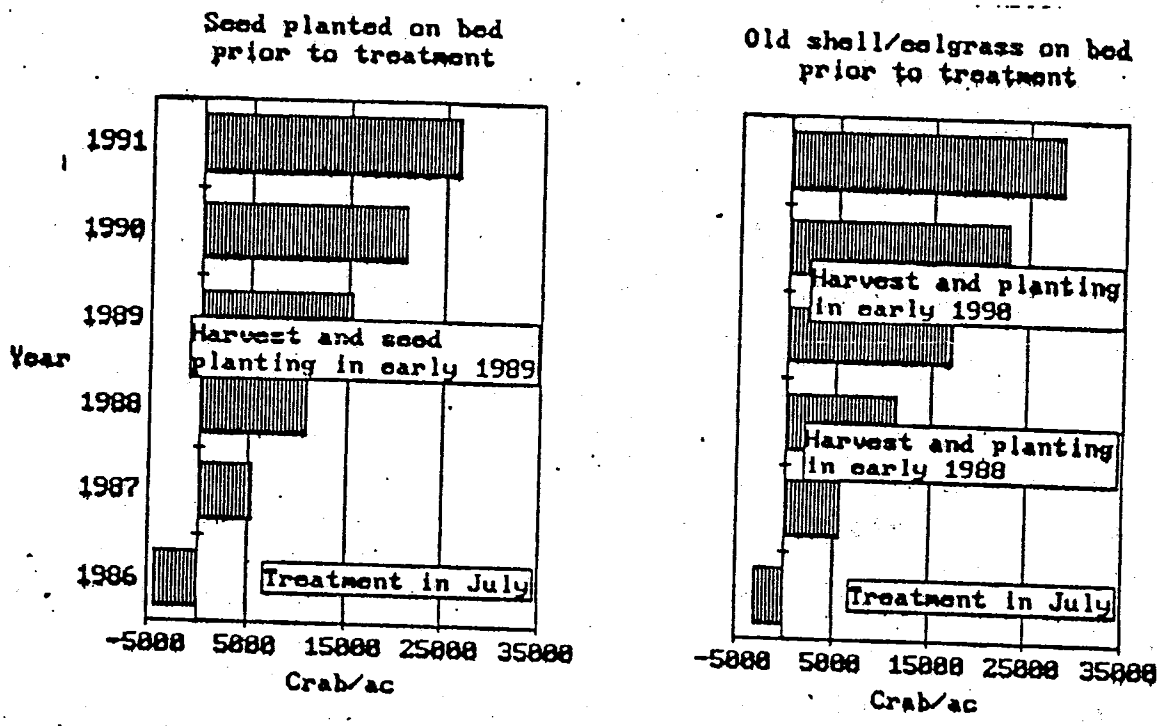



**Figure 13.** Projected cumulative annual net loss or gain of YOY crab on two sprayed tracts. Densities per ha are shown in relation to base values prior to treatment in 1986, through 1991, assuming constant annual recruitment density (from Doty, et al., 1988b).

The draft IMP will address the following areas:

1. Study and evaluate current oyster practice techniques. The evaluation will include a discussion of each culture practice and its relative dependence on carbaryl use in the management plan area. The evaluation will include suitability criteria, including economics, for each practice type in the management area. Pest management systems for terrestrial agricultural operations will be evaluated and incorporated in the IMP where applicable.

2. Evaluate the current carbaryl application program, past "experimental" carbaryl application, and explore potential alternative methods of carbaryl application. Modification of existing application methods and procedures (timing, concentrations, delivery, etc.) will be considered. Monitoring and evaluation procedures will be designed where necessary. Changes in the existing program will be evaluated for burrowing shrimp control effectiveness and suitability.

3. Study and evaluate non-carbaryl burrowing shrimp control methods or harvest techniques. State agencies will consult with appropriate resources to determine appropriate biological, chemical and/or mechanical alternatives which may be used. Appropriate methods will be selected and tested in the field by the oyster industry in coordination and cooperation with state agencies. Potential funding sources will be identified and pursued jointly by the state agencies and the oyster industry.

The Development of an Integrated Management Plan (IMP) for the Control of Burrowing Shrimp Infestation at Oyster Culture Sites in Willapa Bay and Grays Harbor, Washington State.

The purpose of the IMP is to: 1) explore and test alternatives to carbaryl application for the control of burrowing shrimp, 2) to reduce or eliminate, where possible, practical and economical, the use of carbaryl as a pest control method, and, 3) to integrate all practical control methods and applicable oyster culture technology with appropriate time/space control strategies, in order to maintain historical levels of commercial oyster production and to expand production where possible.

The IMP will be developed under the direction and cooperation of the Washington State Departments of Ecology (WDOE), Fisheries (WDF) and Agriculture (WSDA). A draft IMP will be prepared by the state agencies, the oyster industry, Grays Harbor and Pacific County representatives and other pertinent contributors. That element of the draft IMP involving carbaryl application will be completed prior to the 1991 "carbaryl spray season", using available scientific information. Experimentation and analysis of control methods in the field will begin during 1991, in coordination with traditional burrowing shrimp infestation control. When adopted by the state, the Final IMP will be used to manage burrowing shrimp control practices on oyster culture grounds in Grays Harbor and Willapa Bay.

4. Findings will be summarized and ranked. Ranking will be based on applicability to the plan area, cost effectiveness as it relates to commercial oyster production and potential beneficial or detrimental impacts to the environment.

lajlp198

## GRAYS HARBOR/PACIFIC COUNTIES
## BURROWING SHRIMP MANAGEMENT COMMITTEE MEMBERS

Mr. James Atkinson
Willapa National Wildlife Refuge
U.S. Fish & Wildlife Service
HC01, Box 910
Ilwaco, WA 98624
(206) 484-3482

Mr. Steve Barry
Washington State Dept. of Fisheries
Coastal Field Station 331
Highway 12
Montesano, WA 98563
(206) 249-4628
SCAN: 321-6129

Mr. Troy Colley (Grays Harbor County)
330 Pioneer Avenue West
Montesano, WA 98563
(206) 249-5900

Mr. Jim DeShazo
Washington Dept. of Wildlife
905 E. Heron
Aberdeen, WA 98520
(206) 533-9335
SCAN: 234-2600

Mr. Brady Engvall (Grays Harbor County)
Brady's Oysters
HCR 76, Box 700
Aberdeen, WA 98520
(206) 268-0077

Mr. Bruce Gardner (Pacific County)
Rt. 2, Box 645
Raymond, WA 98577
(206) 942-3302 (work)
(206) 942-5703 (home)

Mr. Paul Huffman (Grays Harbor County)
Quinault Tribal Office
P.O. Box 189
Taholah, WA 98587

Mr. Denny McGaughy (Grays Harbor County)
P.O. Box 391
Montesano, WA 98563
(206) 249-4413

Dr. John L. Pitts, Chairman
Aquatic Farm Program Manager
Market Development Division
Washington State Dept. of Agriculture
406 General Administration Bldg., KU-14
Olympia, WA 98504
(206) 586-2777
SCAN: 321-2777

Ms. Kathleen Sayce (Pacific County)
P.O. Box 91
Nahcotta, WA 98637
(206) 665-5292 (home)
(206) 642-3908 (work-M,T,Th)

Mr. Dick Sheldon (Pacific County)
Box 365
Ocean Park, WA 98640
(206) 665-4886

Mr. Ernie Summers (Pacific Harbor County)
Star Route 1, Box 137
Grayland, WA 98547
(206) 267-1051

Mr. Jim Walls, Vice Chairman, (Grays Harbor County)
Columbia Pacific RC&D
2109 Sumner Avenue
Aberdeen, WA 98520
(206) 533-4648

Dr. Richard Wilson (Pacific County)
Box 356
Bay Center, WA 98527
(206) 875-6172

Mr. Art Yoshioka (Pacific County)
Pacific County Economic Development Council
P.O. Box 352
408 Second Street
Raymond, WA 98577
(206) 942-3629 or (206) 642-9330
SCAN: 541-1330

Mr. Bill Young
Washington State Dept. of Ecology
7272 Cleanwater Lane, LU-11
Olympia, WA 98504-6811
(206) 586-5551
SCAN: 321-5551

**Evergreen Student Committee Aides:**

Ms. Karen Riener
P.O. Box 10323
Olympia, WA 98502
(206) 943-1371

Ms. Susan Campbell
1139 Garrison N.E.
Olympia, WA 98506
(206) 943-4575

lajlp400
3/12/91

## GRAYS HARBOR/PACIFIC COUNTIES
## BURROWING SHRIMP MANAGEMENT COMMITTEE MEMBERS

Mr. James Atkinson
Willapa National Wildlife Refuge
U.S. Fish & Wildlife Service
HC01, Box 910
Ilwaco, WA 98624
(206) 484-3482

Mr. Steve Barry
Washington State Dept. of Fisheries
Coastal Field Station 331
Highway 12
Montesano, WA 98563
(206) 249-4628
SCAN: 321-6129

Mr. Troy Colley (Grays Harbor County)
330 Pioneer Avenue West
Montesano, WA 98563
(206) 249-5900

Mr. Jim DeShazo
Washington Dept. of Wildlife
905 E. Heron
Aberdeen, WA 98520
(206) 533-9335
SCAN: 234-2600

Mr. Brady Engvall (Grays Harbor County)
Brady's Oysters
HCR 76, Box 700
Aberdeen, WA 98520
(206) 268-0077

Mr. Bruce Gardner (Pacific County)
Rt. 2, Box 645
Raymond, WA 98577
(206) 942-3302 (work)
(206) 942-5703 (home)

Mr. Paul Huffman (Grays Harbor County)
Quinault Tribal Office
P.O. Box 189
Taholah, WA 98587

Mr. Denny McGaughy (Grays Harbor County)
P.O. Box 391
Montesano, WA 98563
(206) 249-4413

Dr. John L. Pitts, Chairman
Aquatic Farm Program Manager
Market Development Division
Washington State Dept. of Agriculture
406 General Administration Bldg., KU-14
Olympia, WA 98504
(206) 586-2777
SCAN: 321-2777

Ms. Kathleen Sayce (Pacific County)
P.O. Box 91
Nahcotta, WA 98637
(206) 665-5292 (home)
(206) 642-3908 (work-M,T,Th)

Mr. Dick Sheldon (Pacific County)
Box 365
Ocean Park, WA 98640
(206) 665-4886

Mr. Ernie Summers (Pacific Harbor County)
Star Route 1, Box 137
Grayland, WA 98547
(206) 267-1051

Mr. Jim Walls, Vice Chairman, (Grays Harbor County)
Columbia Pacific RC&D
2109 Sumner Avenue
Aberdeen, WA 98520
(206) 533-4648

Dr. Richard Wilson (Pacific County)
Box 356
Bay Center, WA 98527
(206) 875-6172

Mr. Art Yoshioka (Pacific County)
Pacific County Economic Development Council
P.O. Box 352
408 Second Street
Raymond, WA 98577
(206) 942-3629 or (206) 642-9330
SCAN: 541-1330

Mr. Bill Young
Washington State Dept. of Ecology
7272 Cleanwater Lane, LU-11
Olympia, WA 98504-6811
(206) 586-5551
SCAN: 321-5551

Evergreen Student Committee Aides:

Ms. Karen Riener
P.O. Box 10323
Olympia, WA 98502
(206) 943-1371

Ms. Susan Campbell
1139 Garrison N.E.
Olympia, WA 98506
(206) 943-4575

lajlp400
3/12/91

BAY CENTER MARICULTURE
POST OFFICE BOX 303 • BAY CENTER, WASHINGTON

5 March 1991

Mr. Duane E. Phinney
Washington Department of Fisheries
115 General Administration Building
Olympia, Washington 98504

Re: DRAFT 1991 SEIS - Comments

Dear Mr. Phinney,

I have many areas of concern relating to the major modification of this SEIS draft. I will first discuss some of the major topics then list specific problems by page. These first sections generally present to the reader contradictions, misleading use of data, imbalance in reporting on scientific studies, and emphasize non-problems.

I. Carbaryl transport: pp. 2, 25 and 33:

There appears to be a critical misinterpretation of data and thus misleading statements in the carbaryl transport sections. It is my understanding that the testing procedure for the 1986 samples, had a limit of 0.1 ppm thus this concentration should not be used. Tuff's 1989 report shows this limitation was reached at 750, 600, and 300 feet from the tract boundary in the 3 "worst case" areas sampled. A review of the data also shows the inaccurate nature of the 0.1 ppm level when 0.0 ppm is reached long before the 0.1 ppm measure occurs. Also, if the testing proceedure had been reliable at less than 0.2 ppm then the 1-Naphthol could have been reported at over 2000 feet in all three tests after reaching 0.0 ppm in much shorter distances. With the contamination problems encountered in later studies at these low levels, this data should be carefully reviewed and the testing limits stated.

A general comment on carbaryl particle transport: It has to be understood that the energy for transport, if it occurs at all, is only available for several minutes as the initial water encroaches during the incoming tide. The tests have confirmed this and therefore to speculate or infer that carbaryl is being spread in all directions is misleading to the general reader. The whole section on transport leaves the impression it is dangerous and unpredictable which has not been shown to be the case.

II. Persistence of Carbaryl: pp. 2 and 28-33:

The information in Table III would make many readers wonder why the beds to be sprayed show low carbaryl levels before treatment and why the control plot shows low concentrations with no spray. It might suggest to some that there is carbaryl on all areas all the time. This is not the case. By being stored together or from other means these samples received some contamination as stated on the next page. But the reader would have trouble applying this to the table. The fact is that the average of all the prespray samples (before any chemical is applied) is higher (0.060 ppm) than the average of all the samples taken at 16 days on the treated beds (0.047 ppm). The data is still very useful, for example, by showing that generally there is over a 90 percent reduction in 24 hours and all treated areas are back to the contamination level (or zero) in 16 days. However, the contamination remarks on p. 33 should be associated with the table as it is misleading as stated. The authors also misrepresent the contamination data by stating the concentrations in some selected control and pre-treatment samples as 0.004 to 0.019 when they are actually 0.004 to 0.257. Also, on the subject of persistence why were the ten pounds per acre results used in the summary to represent the high end of the values, when this concentration has not been used except on this one test?

III. Intertidal acreage (p.12).

The 34,500 acres should be defined and consistant with Fig. 2 (at 40,000 ac). The problem here is defining intertidal. If the limits of definition are from mean lower low to a given high tide (mean higher high) I seem to remember the intertidal would be around 42,000 acres. If it included all exposed ground with extreme tides it is considerably greater. If a good part of the unfilled diked tideland is included several thousand more acres are added. Pick one you like. The range is probably from 35,000 to over 48,000 acres. Also, a portion of the privately owned (classified) grounds were or are now subtidal and they are included in Fig. 2 as if they were intertidal.

IV. The non-problem with eelgrass:

A major theme throughout this document (pp.3,33,34,45,46,69,71) is the repeated suggestion that the pesticide carbaryl somehow negatively impacts this plant. Carbaryl was first synthesized in 1953 (was a natural plant extract prior to this time) and is used for the control of "150 major pests on 120 crops, including field crops, forage, vegetables, fruit, nuts, shade trees, ornamentals, forests, lawns, turf, and rangeland as well as control of pests of domestic animals" (Ref: Handbook of Pesticide Toxicology. Vol 3. 1991). There is not the slightest indication that carbaryl has a deleterious effect on eelgrass or any grasses or plants. On page 34 the authors suggest these plants could die or be stricken with sublethal problems. Eelgrass grows best on the oyster grounds that have been maintained by spraying. It is irresponsible and I would think an embarrassment to the technical expertise of the authors, to cling to this idea without any indication of a problem. To make matters worse these same people have taken this non-problem and suggested more study is needed.

On the other hand a big problem does exist with the destruction of hundreds if not thousands of acres of eelgrass by the burrowing shrimp. This is downplayed throughout this draft of the SEIS. In pursuit of subordinating this easily documented and recognizable problem, it would appear the graph ( Fig. 4 in the 1990 final) showing the eelgrass return after spraying relative to unsprayed tracts (should be on p.21 or so) was eliminated. I have seen this exact situation, i. e. the eelgrass returning to previously barren areas after the ghost shrimp have been removed. This recovery to eelgrass and oyster ground takes several years if the ghost shrimp had totally taken over the bed and had removed all the fine material (clastics, clay and organics) from the substrate. The eelgrass theme as presented in the document is incorrect and provides another misleading situation to most who read this draft.

V. Agency authorization to impose restrictions: p.8

WDF's role in regulating carbaryl use should be further explained. The EPA label seems clear with the duties of WDF well defined. A potential conflict would seem to arise between WAC 220-20-10(16) and later RCW's. WAC 220-20-10(16) while giving the director the authority to adopt rules for many things was superceeded by RCW 75.08.030. This RCW would seem to take away this authority, vested in the previous WAC (with exception of the reporting subsection, g) with respect to those in the private sector involved in aquaculture. Furthermore, other RCW's would seem to indicate a much different role for WDF such as RCW 75.58.010 which mandates cooperation between WDF and the Department of Agriculture for the control of diseases (which as stated extends to "pests" - e.g. such as burrowing shrimp). Why is this not discussed in this draft?

DOE derives its legal authority under chapter 90.48 RCW and the associated chapter 173-201 WAC, i.e. 173-201-035(8)(e). Is the spraying of carbaryl a form of pollution and is it a discharge? Do these laws apply if the chemical does not leave the area over private ground and is only in the water column for a matter of minutes? Do they apply if oyster culture as an agricultural activity requires the treatment to keep these private culture areas in production (RCW 90.48.450)?

It has never been explained what legal basis was used to require the EIS and SEIS for the use of carbaryl to control burrowing shrimp. This authority should be stated in this document. Would WACs 197-11-835(4), 197-11-850(1-8), 197-11-855(4) under the SEPA rules exempt the carbaryl treatment from a formal EIS?

It would seem important for both WDF and DOE to clearly explain, in the final SEIS, their interpretation for the legal authority in the matter of carbaryl useage for burrowing shrimp control.

VI. Epibenthic prey organisms: pp.48-51, p.71

One of the concerns after the final EIS in 1985 was what effect the carbaryl treatment had on this important group of small invertebrates. Simenstad of the UW (using funds from the oyster growers) set up a standardized series of tests to determine the fate of these organisms on a sprayed tract and a control plot which was not treated. The results seem clear (Table X) however, this draft of the SEIS downplays the research work and the numerous hours of sampling and analysis. If there had been greatly decreased numbers 24 hours after spraying and if these populations had stayed depressed relative to the control plot there could be reason for concern and perhaps further testing. This was not the case and probably to the dismay of those who promoted this non-problem the numbers in four of the five species sampled actually increased substantially, relative to the controls, the day after treatment. Additional studies to pursue the non-problem of the carbaryl effect on the epibenthic prey species again are totally unwarrented and efforts might be better directed to what negative impacts the burrowing shrimp have on the epibenthic zooplankton and phytoplankton. Most likely the shrimp are consuming or just destroying large numbers of these organisms which would be indicated by the abrupt increase immediately after the shrimp have been killed. The people working on this document seem extremely critcal of any research that does not support their original concerns and assumptions. This is not healthy in terms of management decisions which should be based on objective observation and then backed by scientific determinations.

VII. Food Web Impacts (pp.52-54)

In general this new, unreferenced, sophomoric section has little to do with the document as a whole. If there is a purpose, it would seem to be to promote the value of the burrowing shrimp and to suggest that carbaryl is disrupting the food web. It is confusing at best and very misleading to most who are not somewhat familiar with the dynamic complex relationships involved with trophic levels, predator-prey relationships and other complex cycles in the estuary. If the authors of this section truly wanted to explore this topic with some depth they could speculate further on questions such as:

- What impact (by direct intervention into the food chain and by physical degradation) would an expanding billion plus burrowing shrimp inhabiting tens of thousands of acres have on the primary productivity of Willapa Bay? In turn, what effect does this intrusion into the food chain have on the other consumer groups such as salmonids and crabs?

- By all indications the shrimp have expanded greatly over the past fifty years. Why? What has happened to the natural predators? Have management decisions decreased the numbers of certain prey species (e.g. sturgeon, salmon, crabs, etc.) and upset the balance and thus the food chain?

VIII. Comments on particular items:

pp. 1 and 9: One large missing piece of information is the areal extent of the shrimp infestations in the two bays. The reader should realize that the shrimp have taken over thousands of acres of intertidal (and some sub-tidal) habitat. In Willapa Bay it would appear that at least half of the intertidal (20,000 acres) and much of the shallow subtidal (? 10,000 acres) are dominated by dense or expanding populations of burrowing shrimp. This shrimp expansion, by historical account, has occurred since the late 1940 period and until this time the damage they cause to the natural fauna and flora has largely gone unnoticed by those who are charged with their management. It is important for the reader to understand that the proposed control of new infestations on a few hundred acres is only an indication of expanding populations and their control on a relatively small area of the bay. If and when the total impact from the burrowing shrimp is realized, this document and the few who wrote it will be judged as having done a disservice to future management of these estuaries. This real and proveable problem is probably the result of man caused actions and thus should be examined from the standpoint of a human solution.

pp. 1 and 65: To my knowledge the oyster industry never proposed 7.5 lbs. of carbaryl per acre. The two places where the proposal is stated differ on this point.

pp. 3 and 64: "living oyster shell"; This oxymoron should be changed to living oysters. The living oysters on the bed provide the habitat while most scattered shell lays flat on the ground and becomes buried. The vertical projection of living oysters becomes the protection for juvenile crabs and a host of other plants and animals. Pages 22 and 57 also use oyster shell instead of oysters.

p.4: Fish: If WDF is stating that important commercial and recreational fish are killed they should give the type and relative numbers in this summary.

p. 9: Left out the estimated loss of jobs if carbaryl is not used to control shrimp (p. 9 of 1990 final draft).

p. 12: I feel that it is important to let the reader know that the majority of acreage used to farm oysters, in Willapa Bay, is privately owned and thus is classified for county tax purposes. This should be stated clearly so others will know the oyster growers are concerned about not losing their valuable (and taxable) farmland to burrowing shrimp.

p. 19: Rate of flow for the mud shrimp seems far too low. My observations of this species as they pump in shallow water would indicate 0.5 - 1 liter per minute. This should be checked.

p.21: Original Fig. 4 missing (attached).

p. 41: Hueckel's work, in my judgement has many serious scientific problems. However, small fish may be killed if they are present in the water areas over the beds. Why does this section ignore the trawls the UW did after spraying in the adjacent channels and over the beds which I think had no indication of mortalities? How can authors suggest, and again mislead the reader, (page 42) that fish could be exposed to lethal or sublethal levels of carbaryl in these channels? A remark like this should have some scientific justification and in this case there would appear to be none.

p. 54: It is stated that some carbaryl will end up in subtidal drainage channels and may cause mortality. Again, this is one of the many statements in this document that has no scientific basis. Carbaryl cannot move against the current which would keep it out of the drainage channels on the incoming tide.

p. 63: A major conclusion to the five year UW study was that the farming of oysters contributes the major protective habitat for small crabs in the first year. What is present in this draft is not a fair conclusion to this UW research. I suggest the authors at least make available the main UW conclusions (p. 54 in the final rept, or p. 76 of the draft, Doty, et al. 1989) and give the following numbers in this summary. That the 2,400 ha containing commercial oyster crops contribute 35 to 76 million crab per year (c.f. eelgrass habitat is 4 to 6 times lower per unit area and barren shrimpy ground contains basically none) and to keep the oyster ground in production the yearly carbaryl treatment would kill 1 to 4 million of these. The net gain would be 34 to 72 million young crab. Since the total farmed acreage is closer to 4000 ha (approx. 10,000 ac) the net gain should be

55 to 118 million young crab. This would seem to be a substantial mitigative exchange and there would be a serious negative impact on the crab industry if the oyster ground acreage were reduced by not controlling the burrowing shrimp. The conclusions to the UW work should mirror their report(s) in a professional manner without editorial selection.

p. 64 or so. Why was Fig. 13 from the original SEIS draft omitted? It illustrates the above conclusion of the UW by showing the contribution an oyster bed would make in numbers of young crab in the years after it is sprayed. This is very important information that the reader of this document should have available in a graph form (attached).

p. 66: Off bottom culture techniques are not an alternative to shrimp control. This is misleading.

p. 68: The UW tests gave contradictory results on reduced rates relative to the two species.

p. 70: Regarding the use of scarecrows and oyster personnel to drive away gulls from feeding on the dead and dying shrimp: Why mitigate a non-problem or non-effect? The majority of gull feeding are on successive tides after the initial spraying when the concentration is greatly reduced. Have any of the people who wrote this tried to chase off a flock of hungry gulls when food is present? Would not certain agency personnel be more equivalent to scarecrows than oystermen?

p. 71: The last section "Additional Information Needs" has a similar title to the last minute addition to the final 1985 EIS. That 1985 addition by WDF has cost the oyster industry tens of thousands of dollars and hundreds of hours of time to work on what basically turned out to be non-problems. However, the 1985 questions were to some extent valid if not timely. In contrast, the 1991 version of additional needed studies are not only groundless but as I have stated in the various sections above, have no substantiating evidence that they are problems or that they have not been answered in the research already completed. It would seem that those persons or agencies who suggest such needs should be accountable for supplying the scientific evidence that there is an undeniable problem and that it has long term negative effects.

pp. 86-80: Very hard to read.

IX. General:

This draft SEIS does not represent the true impact of the use of carbaryl in the farming of oysters. It does not put into perspective the extent of the burrowing shrimp infestation and its effect on not only oyster grounds but other biological elements of the estuary. This draft does not allow the reader to realize that the farmed oyster grounds are the least damaged and most naturally productive intertidal areas of the two bays due in large part to the control of the destructive burrowing shrimp. The person reading this draft does not get a clear idea that there have been no longterm negative impacts from the use of carbaryl over the past twenty-seven years. In fact, the number of scientific studies over the past 26 years may represent the most researched specific use of a pesticide in the country. On the other hand there are many positive results which have resulted from the control of shrimp (not only for the oyster but for many other important species). These often have either been deleted from the document or are obscured in the subjective verbiage. An impact statement should present a true picture of what has and will happen. This draft illustrates the problem when an attempt is made to draw conclusions to support original non-substantiated concerns when there is no supportive scientific evidence. The draft SEIS has been transformed from a fairly objective technical document to a shallow somewhat dogmatic editorial. In short the draft SEIS does not represent the true environmental impacts.

I hope this draft will be objectively reviewed in a professional manner by responsible agency people, in coordination with those who have knowledge and experience in this situation, before it is presented in its final form. In its current form this draft SEIS will prove to be an embarrassment (if not a dangerous miscalculation of and to management actions) for the agencies which have created it.

Sincerely,

Richard L. Wilson, PhD
President

cc.

Dr. Judith Freeman
Michael Llewelyn
Steven C. Marshall
Richard Murakami
Dr. John Pitts

attachments

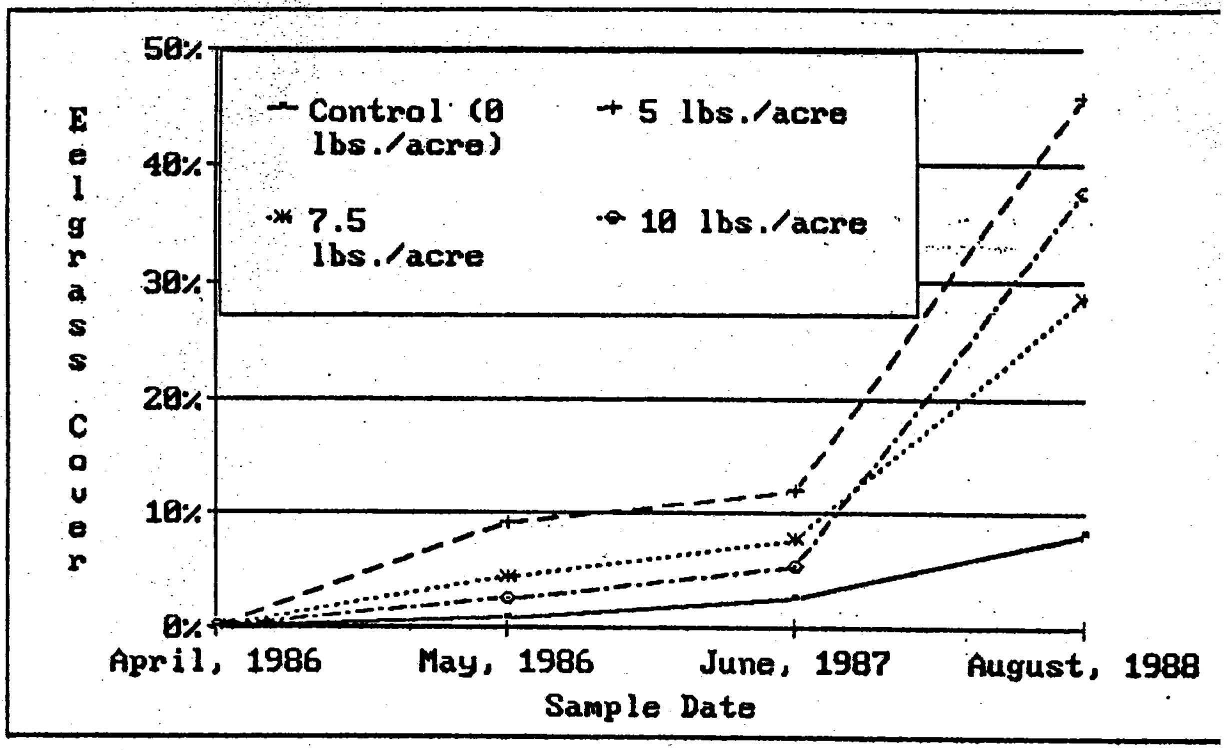



**Figure 4.** Eelgrass percent cover on control and treated (5, 7.5 and 10 lbs carbaryl/acre) tracts, in south Willapa Bay where shrimp density /m² (after treatment) was 8 - 18 on control and 1 to 4 on treatment tracts (from Tufts, 1988b).

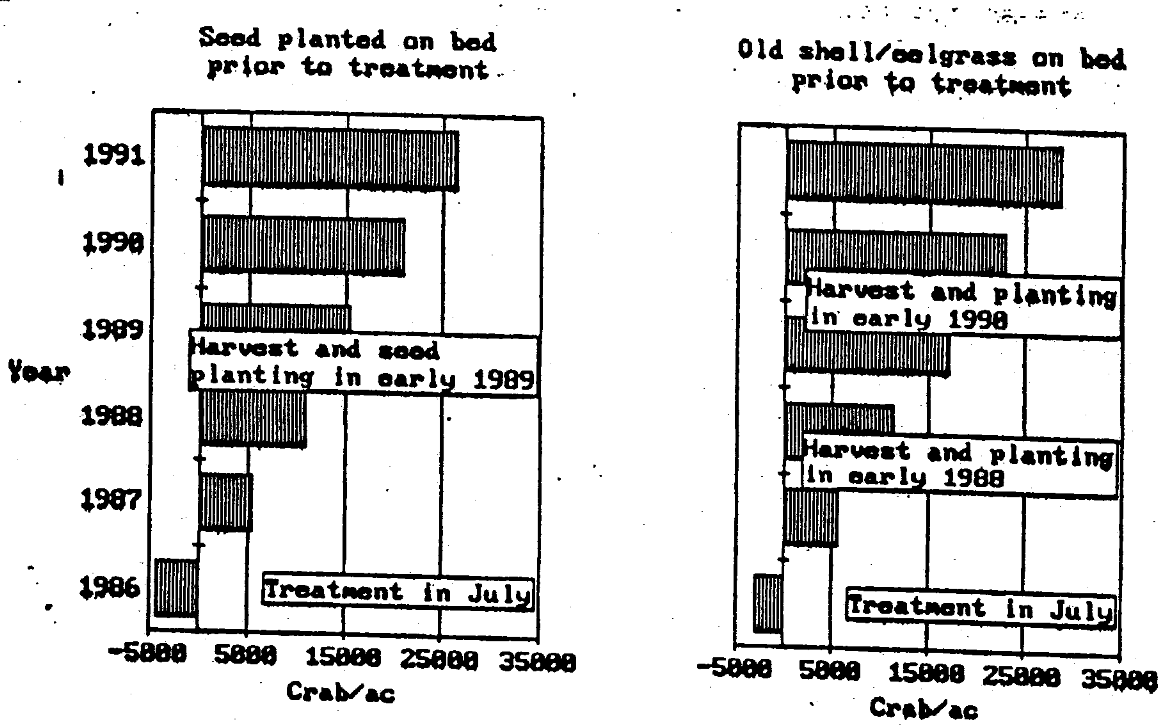



**Figure 13.** Projected cumulative annual net loss or gain of YOY crab on two sprayed tracts. Densities per ha are shown in relation to base values prior to treatment in 1986, through 1991, assuming constant annual recruitment density (from Doty, et al., 1988b).

Wiegardt Brothers

Growers, Packers, and Distributors of
**Pacific Oysters**
P.O. Box 309, Ocean Park. WA 98640
(206) 665-4111 FAX: (206) 665-4950

JOLLY ROGER

March 5, 1991

Mr Duane Phinney
Washington Department of Fisheries
115 General Administration Building
Olympia, Wa 98504

RE: Draft 1991 Carbaryl SEIS

Dear Mr. Phinney:

I am responding to the Department of Fisheries version of the carbaryl SEIS. I am amazed at the way the problem is treated...the manipulation of data and the special effort to make new problems that are not problems nor have ever been considered problems. Specifically, I refer to eelgrass. Other items are slipped in helter skelter.

We, the oyster growers, spent over $100,000 drawing together crab information and data as requested by your department. On my copy of our DSEIS I do not find the request for new information you so randomly talk about. It is a sad shame so much research was done by and for oyster growers only to find it totally disregarded.

I worry about your sudden interest in eelgrass. By 1970 every oyster grower and responsible Department of Fisheries person knew that the main evidence that shrimp ground was converting to oyster beds was the new patches of eelgrass showing on the ground. Areas of puffy sand were now full beds of eelgrass. Vast areas of eelgrass have been lost to shrimp. As any area is sprayed it will start to grow eelgrass. This is such common knowledge that I wonder if Fisheries is full of "Dry Lab" scientists and no one has any creditable knowledge of occurring events on the tidelands. Eelgrass is not a problem with carbaryl. It never has been. Twenty seven years of spraying has proven it to aid and encourage eelgrass growth. I cannot help but wonder if these people are scientists, misinformed individuals, or somebody trying to make trouble. Who writes so freely of a carbaryl-eelgrass problem?

I worry about the integrated management idea on page 65, item 5: "Control, grow out and harvesting methods will be applied that are appropriate and feasible for that particular location." This almost sounds like the "comrades" will form a commune and tell the grower how to grow his oysters. It is not state supported. Our own company has been growing oysters continually since 1874. A large investment is made in tidelands, oysters, equipment and buildings.

It should be pointed out this is private ground. Rights were made by the first legislature in 1889. It should not be confused with other lands. We have every right to our land that a dairy farmer has to his. You should make this known.

Our company sprays an average of 90 acres per year. This made possible a payroll of $2,239,000 in our small community. It is a shame you overlook this impact on what is known as a poverty belt in Washington State.

I do hope when the final SEIS is written wiser scientific heads will review the scientific literature available in our earlier SEIS. I feel it could be possible to make a game of writing these EIS's. I can think of a number of new ideas to throw in at the start of each new book.

Very Truly Yours,

Lee J Wiegardt
President
Wiegardt & Sons

C·R·C·F·A
COLUMBIA RIVER
CRAB FISHERMAN'S ASSOC.
P.O. BOX 718 • ILWACO, WA 98624

March 9, 1991

**Response by Columbia River Crab Fishermans Association to January 30, 1991, draft SEIS on use of Carbaryl to control Burrowing Shrimp in Willapa Bay and Grays Harbor.**

The short time allotted between its distribution and comment deadline precludes a lengthy analysis by our association. I have read the document and its accompanying June 1985 EIS and offer the following comments:

Our association anticipated an SEIS that would be definitive in our concern areas and offer a solid overview of the carbaryl issue. We assumed, knowing of the research conducted by the University of Washington and others, that this SEIS would be scientifically correct and answer our questions on the specific impacts on intertidal habitat. It is my understanding that this is the purpose of the EIS process. This SEIS, however, fails this test.

While the reader does get a broad overview, conflicting statements and indifinitive comments by the author tend to leave questions connected to conclusions offered. Could - probably not - might be - may be - could be - appear to be - it is likely - etc., are phrases found throughout the document's sections on impacts.

Sections dealing with salmon and plants show conflicting conclusions. I find no evidence of a relationship between aquarium testing and an open bay situation. Yet a conclusion is drawn that there are problems. Statements on plants also claim further studies are needed, common observation provides that information and certainly leaves no doubts. In these and other instances this SEIS seems more to promote additional studies and Department wish list projects than to address questions it was originally designed to answer.

Example: The comment concerning having oystermen scare gulls and crows away from treated beds also leaves the impression a problem exists. Other related sections state the opposite. Birds consume the majority of fresh-killed shrimp. Is it sensible to leave them lie for the crab to consume and be killed when no hint of bird problem exists? This and other like suggestions inserted by the author have no place in this SEIS.

My conclusion after studying this SEIS is this:

1. The research done for the EIS was inconclusive and/or shoddily done, producing information with questionable reliablility, or that
2. The author intentionally set out to cloud the SEIS and render it impotent as a reference.

So as to not waste the effort put into the preparation of this SEIS I suggest that the document be edited and re-written by an impartial body with lead personnel, contributing studies and research to the project, signing off on the results of their contributions.

I would expect a re-written SEIS to be definitive and supply the information we need to finally resolve the carbaryl issue.

Respectfully,

Richard N. Sheldon

Richard N. Sheldon
President, Columbia River Crab Fishermens Association

NISBET OYSTER CO.
STAR ROUTE BOX 146
SOUTH BEND, WASHINGTON 98586
(206) 875-6629

8 March 1991

TO: Mr. Duane Phinney
Habitat Management Division/SEPA Responsible Official
Washington Department of Fisheries
115 General Administration Building
Olympia, Washington 98504

RE: The second draft SEIS; USE OF THE INSECTICIDE CARBARYL TO CONTROL GHOST AND MUD SHRIMP IN OYSTER BEDS OF WILLAPA BAY AND GRAYS HARBOR

Dear Mr. Phinney,

The purpose of this letter is to express my concerns and give comment to the second draft SEIS before revision to the final SEIS document.

I. A person picking up the document for review who is relatively new to the issue cannot tell what the relationship is between the proponents of the proposed action and the ownership of the oyster beds involved in the action.

While ownership is touched on on page 79,the linkage is not explained. I feel that it is very important to state at the very beginning that the proposed action is sought on privately owned ground (oyster beds), and not state owned property en mass.

This could be very suitably dealt with by inserting the word PRIVATE in the proposed title of the final. The proposed amended title to read;
USE OF THE INSECTICIDE CARBARYL TO CONTROL GHOST AND MUD SHRIMP IN PRIVATE OYSTER BEDS OF WILLAPA BAY AND GRAYS HARBOR

This point should also be noted on the fact sheet under Oyster Growers' Proposed Action.

II. It is unclear to me on page 8 under the heading B. Present Status, what the WDF and DOE role is regarding the use use of carbaryl and its regulation. I would like to see their legal authority more fully explained with regard to carbaryl useage.

III. On page 11, 4. Losses in Off Bottom Culture

To paraphrase,this section states that according to oyster growers who use this method of culture extensively burrowing shrimp destabilize the culture technique both

NISBET OYSTER CO.
STAR ROUTE BOX 146
SOUTH BEND, WASHINGTON 98586
(206) 875-6629



physically and economically. It is also noted here that without carbaryl control one longline operation would be reduced by one-half in a few years. This section clearly infers that off-bottom culture is costly and does not lend itself as being economically feasable on shrimp infested beds. Those beds with existing off-bottom culture and that are being encroached upon by burrowing shrimp must be treated if they are to remain economically viable.

Why then on page 66, Section D, Alternative 4 - No Carbaryl Application/Alternative Growout Options state that; "Several alternative approaches such as longlines or rack-and-bag culture are available which could possibly supplement or replace existing bottom culture for oysters (see also the 1985 EIS) ".

Why even promote this in the beginning of this section as an alternative and then go on to state in the last sentence, "Of the off-bottom growers surveyed (Faudskar, Engvall, Jambor and Nisbet, 1988, personal communications), none stated off-bottom culture is economically feasable on shrimp infested grounds.

This last sentence will suffice for addressing Section D. The preamble to this section is misleading.

IV. Pages 52-54 deal with Food Web Impacts.

This section to me wanders off into the unknown, is unreferenced and contributes nothing to the document.the way it is presented and the direction it takes.

This could have been an extremely important section in my opinion if the author had chosen to take on the obvious question. What happens to primary productivity and the food chain when an exploding population of burrowing shrimp is left unchecked?

V. Eelgrass- To me the document lays inuendo that more study is needed to determine carbaryls effect on eelgrass and other marine vegetation. There has never been any indication that carbaryl has any affect on eelgrass. It is used worldwide on many grasses and marine vegetation without damage.

The document downplays however the positive effect carbaryl has on the subsequent promotion and recruitment of eelgrass beds.

NISBET OYSTER CO.
STAR ROUTE BOX 146
SOUTH BEND, WASHINGTON 98586
(206) 875-6629



VI. Possible under the heading Oyster Culture History in VIII. Appendix there should be a new heading on the carbaryl spraying history.

Most of the footnotes for this new section could come from WDF' Shellfish Lab in Nacotta. I think somewhere in this document it should be noted that the spray program was based on need. A need to control burrowing shrimp on a particular bed at a particular time in the planting-harvesting process. The problem has to my knowledge never been dealt with from a population biology standpoint.

If whole populations of burrowing shrimp that had risen to pest levels within growing area confines were eliminated in a timely manner, to ensure much lowered recruitment levels whole areas could go many years with no treatment at all. This would have the effect of the possibility of reduced carbaryl levels overall.

Major populations within growing area confines need to be identified. Encroachment into the State oyster reserves needs to be identified in this document as well.

In conclusion page 65 Integrated Management. I object to the statement that the Management Plan (MP) has as one of its objectives to achieve a significant reduction in carbaryl use or a complete phase out of carbaryl use in a manner which will assure the continued viability of the industry.

The use of carbaryl has not been found to be significantly detrimental to the estuarine environment in any way. Its use as a method of controlling burrowing shrimp should in no way be eliminated or targeted for elimination. We can only hope that other strategies can be found that are equally as effective for dealing with this problem that threatens our estuaries and industry.

Thankyou for your attention to these comments.

Sincerely,

David H. Nisbet
Nisbet Oyster Co.

cc; management plan members Dick Wilson
Brady Engvall

JAN TVETEN
Director

STATE OF WASHINGTON
WASHINGTON STATE PARKS AND RECREATION COMMISSION
*7150 Cleanwater Lane, KY-11 • Olympia, Washington 98504-5711 • (206) 753-5755*

March 11, 1991

TO: Duane E. Phinney, Chief, Habitat Management, W.D.F

FROM: Mike Ramsey, Assistant Chief, Environmental Coord., WSP&RC Ramsey

SUBJECT: SEIS - CARBARYL CONTROL OF BURROWING SHRIMP

Brian Hovis and I have reviewed the SEIS on the use of Carbaryl and found it to be informative. However, there are some issues that require further study. I have included these comments for your response in the FEIS.

We do not favor expanding the area where Sevin is used. Although the oyster grower's problems are well documented, the SEIS left too many questions unanswered. Besides the many questions that the SEIS left unanswered, I am convinced that Carbaryl is poison. Carbaryl kills invertebrates (page 3, para. 3) and under certain circumstances it will kill vertebrates (page 41, para. 4).

We encourage research on the burrowing shrimps. I hope the life history and ecology part of the University of Washington studies in progress will add to our understanding of how burrowing shrimp affect the health of the ecosystem. For instance, is the burrowing important for nutrient recycling and oxygenation of the sediment? Although this function has not been evaluated in Grays Harbor or Willapa Bay, the SEIS does present evidence that it happens elsewhere (page 21, para. 1). Also, invertebrates recolonize treated areas, but what becomes of species diversity? Research may answer questions and provide alternatives to the use of poison.

Of all the alternatives, Alternative "2" seems the most reasonable. However, it is uncertain whether or not Alternative "2" would allow the area treated with Sevin to be expanded. Doubling of the treated area seems excessive.

If Alternative "2" is chosen, I hope the IMP committee will consider all the alternatives to Sevin. For instance, how seriously have the oyster growers considered the harvest of burrowing shrimp? The SEIS mentions that oyster grounds are being abandoned because of burrowing shrimp (page 8, para. 4). Are the oyster growers contracting with shrimp harvesters to remove and sell the shrimp? Brian informs me that oyster growers argue that the burrowing shrimp market is too small for any substantial decrease in the burrowing shrimp population. If the market is too small, then what are the oyster growers doing to encourage an expansion of that market? It would seem that the oyster growers's distribution system might help develop a larger market.

-continued-

Another alternative to Sevin, which was not mentioned in the SEIS, is the use of non-toxic methods of shrimp control. It is our understanding that Sylvia Yamada at Oregon State University is soliciting funding for a project using tarps to smother the shrimp. Have the oyster growers requested a proposal from her? Have they requested proposals from other universities?

Thank you for the opportunity to review the SEIS. I am hopeful that alternatives to Sevin are available. If you have any questions, then please contact Brian Hovis at 753-4847.

BH\a:\carbaryl.mem

cc: Dave Heiser, Chief, Environmental Coordination
Brian Hovis, Shellfish Biologist

East Point seafood company

Box 127, South Bend, Washington
Telephone: Area Code 206, TRinity 5-5507

March 11, 1991

MR. DUANE PHINNEY
HABITAT MANAGMENT DIVISION/SEPA RESPONSIBLE OFFICIAL
WASHINGTON STATE DEPT. OF FISHERIES
115 GENERAL ADM. BLDG.
OLYMPIA, WA 98504

RE; THE USE OF CARBARYL FOR THE CONTROL OF GHOST AND MUD SHRIMP IN WILLAPA BAY AND GRA HARBOR.

The oyster land in Willapa Bay is privately owned with some land being leased from the state.

In past years, hundreds of acres of land used for oyster culture have been lost to prod tion because of the shrimp problem. This barren ground doesn't even contain eel grass which it would if shrimp infestation didn't exist. Which would give habitat for crab an etc.

We shouldn't have set rules on the amount of acres (400) if more acreage is needed for a given year---it should be decided on the shrimp problem not otherwise (political).

We feel there was less repeat spraying when 10# seven was used than 7.5 & 5lbs. The weather, (temp.) tide elevation, and contact time of seven should be considered in deciding the amount to be used. Long line and tray culture is not feasable in shrimp infested ground.

For the oyster industry to maintain its production at its present level, it would need to spray as many acres if not more per year until another method is found.

Harry Taylor

HARRY TAYLOR
EAST POINT SEAFOOD CO.

UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON 98195

School of Fisheries WH-10
(206) 543-5559

3-15-91

Duane E. Phinney
Habitat Management Division
Washington Department of Fisheries
115 General Administration Building
Olympia, Washington 98504

Dear Duane,

I would like to offer the following comments on the latest draft SEIS for carbaryl use in Grays Harbor and Willapa Bay. I apologize for not sending them before the March 11 deadline, but spoke with Steve Barry who suggested that he was still interested and that I send them to you anyway. I did not review the previous version and so make no comments on differences between the 2 documents or material that may have been left out in this update, but feel that in general this version reads fairly well. I offer the following more specific comments:

Page 26, Figure 5 This data appears to be the same information used in our (UW) crab mortality experiment in which case our final report (Doty et al. 1990) or the previous report should be cited along with credit to WDF and WDA.

Page 32, Table III Although all of the methods are stated in the appendices in this version it seems to me that brief reference would be helpful in the main text, particularly when the reader needs the information for immediate interpretation e.g. that the top ?? 3mm of sediment were sampled as is the case in this table.

Page 37, paragraph 3 Dumbauld and Doty (1988) is really Dumbauld, Armstrong and Doty (1989). This should be changed to Dumbauld et al. (1989) throughout the document.

Page 39, Figure 9 I think the data for this graph comes from our (UW) study Dumbauld et al (1989).

Page 50, Table X Error estimates should be given if possible in this table and the numbers after the decimal point are unnecessary.

Page 51 The discussion of the epibenthos study has so many qualifiers that it appears to be useless. If it is the authors opinion that it is useless then say so, if not let the reader decide. I agree again that follow-up studies to Simenstads' work should be carried out, but the qualifiers only need to be used once.

Page 55 paragraph 2 The last sentence is unclear. We believe that 0+ crab move off the intertidal flats when they reach a given size (5th or 6th instar). They probably reach a size where predators found in the subtidal are no longer a threat so that the added foraging time provided by continuous submersion is of greater advantage than the protection afforded by intertidal habitat.

Page 56 first sentence We hardly view our trawl efforts as "limited" this qualifier is unnecessary.

Page 60 first paragraph I disagree with the last 2 sentences. Both WDF and our (UW) experiments conclusively showed that crab can be killed by ingesting contaminated shrimp, and furthermore that there is no statistically detectable advantage in decreasing the rate of carbaryl application with regard to crab mortality. Just because you can't accept the null hypothesis does not mean the results weren't conclusive. A dead crab is a dead crab.

Page 60 last paragraph This information could be more useful if the data was divided by year class. I guess I would expect interannual differences in 0+ kill given differing settlement densities, different intertidal habitats (shell, no shell), and the problems with the WDF assessment method for these crab. If there are also differences in the locations of larger 1+ and >1+ crab killed by year, it would be interesting to see if they correlate to UW trawl information.

Page 68, Figure 12 I have enclosed an updated copy of my original which inludes corrected shrimp recruiment periods for your use

Page 69, paragraph 4 The statement that it would be "prudent to minimize contact with aquatic plants" is absurd given the practical reality of the spray program. The large section (page 34) and great emphasis placed on future study of potential impacts to aquatic plants seems unnecessary given the data presented. I agree that little or no information exists on impacts to local algae and plants and specifically to eelgrass which appears to be the focus of concern, however the mode of action for the pesticide and previous information suggest that, at best, the plants might suffer a decline in photosynthetic activity for the brief period that they are exposed on the day of application. There is no evidence to my knowledge that even remotely suggests mortality or significant impact. While money could be spent to perform a relatively simple study pesticide effects alone, I would argue that it would be put to far better use by also including the effect of the shrimp on these plants, which as pointed out elsewhere in the SEIS is likely to be far more significant and may indeed cause mortality and habitat loss.

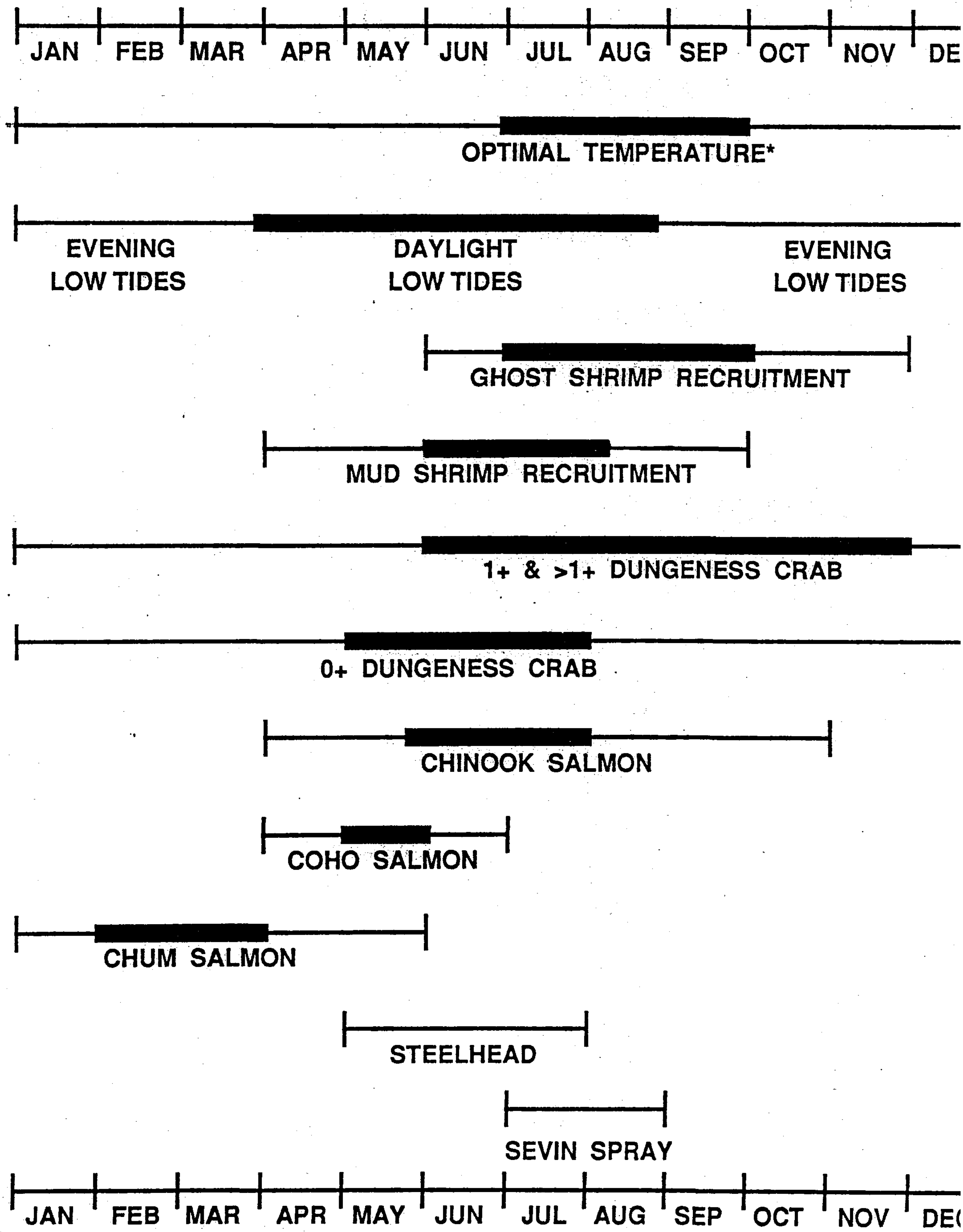
Page 70, Paragraph 4 Gull scarecrows???

Page 71, paragraph 4 UW study scheduled for completion in March 1991 has been extended to June 1991

Finally and perhaps most importantly I would suggest that the last paragraph addressing additional information needs be either greatly expanded on, or at least qualified in terms of intention. While there is unquestionably a large gap in our information on carbaryl and estuaries, it seems unreasonable to expect the proponents of the project to even begin to answer these information needs as stated. Question #4 is extremely open ended and will most likely never be answered in entirety, given both natural and human influences on decadal and even geologic time scales. I would suggest that some thought be directed towards much more specific needs to satisfactorily address continued agency concerns. The word "key" in number 1 for example should be defined (we know enough to say Zostera or Ulva). Not even the word "key" appears in # 2 and 3 and again I think we know enough to better define who?? and furthermore what?? is significant impact. Agreeably some of the specifics and risks are and will continue to be unknown, but these should be stated clearly. Perhaps my comment relates more to the policy decisions made by the agencies based on the SEIS after the final version is accepted, but the open ended nature of this final paragraph will most assuredly allow for equally open ended policy discussions and therefore tough policy decisions in the future.

Sincerely,

Brett R. Dumbauld
Fisheries Biologist


JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
OPTIMAL TEMPERATURE*
EVENING LOW TIDES
DAYLIGHT LOW TIDES
EVENING LOW TIDES
GHOST SHRIMP RECRUITMENT
MUD SHRIMP RECRUITMENT
1+ & >1+ DUNGENESS CRAB
0+ DUNGENESS CRAB
CHINOOK SALMON
COHO SALMON
CHUM SALMON
STEELHEAD
SEVIN SPRAY

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Fish and Wildlife Enhancement
2625 Parkmont Lane SW, Bldg B
Olympia, Washington 98502
206\753-9440 FTS 434-9440

March 11, 1991

Duane E. Phinney
Habitat Management Division, SEPA
Responsible Official
Washington Department of Fisheries
115 General Administration Building
Olympia, Washington 98504

RE: Supplemental Environmental Impact Statement - Use of the Insecticide Carbaryl to Control Ghost and Mud Shrimp in Oyster Beds of Willapa Bay and Grays Harbor (EIS 91/0174)

Dear Mr. Phinney:

The Fish and Wildlife Service (Service) will be unable to review the above referenced document.

Eventually, the proposed project may be subject to permits for which the Service has review responsibilities. Accordingly, our comments do not preclude an additional and separate evaluation by the Service, pursuant to the Fish and Wildlife Coordination Act (16 U.S.C. 661, et seq), or other relevant statutes. In the review of projects, the Service may concur, with or without stipulations, or object to the proposed work, depending on specific development practices which may impact fish and wildlife resources.

In the event that such permits do become necessary, we encourage the project sponsor to contact our office (above phone/address), prior to permit application. We may be able to give guidance on design criteria which will facilitate the permit-review process.

We appreciate notification of this project and the opportunity to comment.

Sincerely,

David C. Frederick
Field Supervisor

gg/kr

COAST OYSTER COMPAN
1200 Robert Bush Drive, Highway 1
P.O. Box 1
South Bend, Washington 985
(206) 875-5557 • FAX (206) 875-55

February 22, 1991

Duane E. Phinney
Habitat Management Division
Washington Department of Fisheries
115 General Administration Building
Olympia, Washington 98504

Dear Mr. Phinney,

I am writing to respond to the departments draft of the Supplemental Environmental Impact Statement of January 30, 1991.

I have read all subsequent studies that have been done regarding carbaryl and shrimp. This one is by far the most slanted of them all. It almost seems that the author is biased for some reason.

I will not respond in detail to the study at this time, because other members of the industry will be doing so.
But I would like to comment on the study, as it pertains to the economic importance of the oyster industry.

The shellfish industry is the second largest employer in Pacific County and is the largest employer in South Bend. Coast Oyster Company alone, employs 350 employees at the peak of the season and has a year round average of over 200 emplyees.

A reader of this report would not come away believing that controlling ghost shrimp was an important factor to our industry and to the economy of the state of Washington.

The oyster industry has commissioned an economic study of our industry that takes into account our shrimp problem. The study should be completed in about 90 days and I will supply you with a copy at that time.

In closing, I strongly urge you to review and correct your work so that it will be an accurate portrayal of the scientific findings and of industry practices. The form that it is in currently, will surely be an embarassment, once it comes under scrutiny.

Best regards,

Tom Hayes, Regional Operations Manager
COAST OYSTER COMPANY

TH:gc

ALLIED AQUATICS

4426 BUSH MOUNTAIN DR. S.W.
OLYMPIA, WASHINGTON 98502
TELEPHONE: (206) 357-3285

ALLIED AQUATICS
OF WASHINGTON, INC.

March 5, 1991

Duane E. Phinney
Habitat Management Division
Washington Department of Fisheries
115 General Administration Bldg.
Olympia, Wa. 98504

TO : Duane E. Phinney

SUBJECT : Supplemental Draft E.I.S. - Carbaryl Applications

Although we find a need to control ghost and mud shrimp within oyster beds your supplemental E.I.S. contradicts current fisheries practices already being mandated by your department. The E.I.S. sacrifices other saltwater organisms at the expense of a commercial industry. We do not see this same type of attitude when your department deals with troublesome aquatic plant species in waters under the jurisdiction of the Department of Fisheries.

PAGE THREE --- EFFECTS ON AQUATIC PLANTS

No studies have been done concerning this issue on key species found within the projected treatment sites. We oppose the use of the material until such studies within estuarine systems is completed and reviewed. Your department has totally overlooked the impacts on all vegetation found within the sites. Within the Lake Washington water system your department has fought furiously to not allow aquatic plant control on the basis of possible destruction of valuable fish habitat. Your department has gone so far as to totally deny the use of bottom barriers in waters under your jurisdiction. Your denial of the use of aquatic weed control techniques is directly related to possible impacts both long and short term to the fisheries of the area caused by the control of such aquatic macrophyte populations. However you totally ignore both the long and short term effects of the use of carbaryl on plant species within the proposed treatment sites. If your office is not concerned over impacts to the salt water aquatic plants then your same opinions must be raised concerning freshwater macrophytes. Until such studies confirm that there is no adverse effect to plant species within the treatment sites alternative control measures should be adopted.

PAGE TWO --- PERSISTENCE OF CARBARYL

"sediment samples taken in 1989 found that carbaryl concentrations

"THE LAKE MANAGEMENT SPECIALIST"

decreased from mean values of 41 to 83 ppm on the day of treatment to .7 to 14.5 ppm 24 hrs after treatment. Two weeks after treatment, mean concentrations in the sediment range from .02 to .15 ppm. while one month later they were .008 to .036 ppm." Your conclusions that "carbaryl concentrations in sediments decrease rapidly over time under summertime conditions" is misleading. The simple daily flushing of the treatment site by tidal action is not taken into consideration. In all likelihood the material within the first few days is simply being redeposited within the entire bay area. Yes the concentrations do decrease within the treatment site but the decrease is more likely being caused by dilution then by metabolic breakdown. In order to determine the true breakdown of the material within the site a portion of the site needs to be isolated from the tidal action.

PAGE THREE --- INVERTEBRATES IN GENERAL

In all likelihood the 24 hour concentration of .7 to 14.5 ppm. will eradicate all invertebrates from the site. Since you have identified .03 to 7.3 ppm as lethal doses, you fail to identify the species and percentages of invertebrates that recolonize the area in comparison to species and numbers present prior to treatment. Your office has stated in many situations that it has grave concerns on the effects of aquatic herbicides and algalcides on invertebrates and plankton at the time of treatment. Yet those same concerns are not adequately addressed when you propose the use of carbaryl. If the impact of carbaryl to invertebrates is not a major concern then why is it such a burning issue when it comes to aquatic weed control?

PAGE THREE --- DUNGENESS CRAB

Your office has evaluated the mortality of the Dungeness crab as acceptable. However when reviewing the potential human health hazards caused by macrophyte beds within residential shoreline areas of Lake Washington you totally disregard the issue as a human concern. Here you are willing to sacrifice the Dungeness crab for an environmental gain within the oyster population, yet you fail to accept the need for control of macrophyte colonies at the expense of human health. Somehow human health priorities must far exceed any other concern your department must have. If your office can justify the loss of the Dungeness crab then it must also be willing to accept short term loss of weed beds to ensure public safety.

PAGE FOUR --- FISH

The supplemental E.I.S. does not address the concerns associated with the exposure of salmonids to carbaryl. The effects on smoltification cannot be ignored. Over the past few years your office has raised grave concerns over the use of copper compounds when controlling algae blooms and the effects such may have on smoltification. In fact a saltwater challenge test was conducted using the aquatic herbicide Aquathol K some years ago to appease your concerns. Yet in this situation no concern is mentioned. Why then is there so much concern over the materials currently being used for aquatic weed control and the effects on smoltification when you fail to address the issue with carbaryl. I am aware of no such information generated covering smoltification and carbaryl. Until such times as the data can be generated we have grave concerns about its long term impact to the saltwater fisheries in species associated with smoltification.

PAGE FIVE --- POTENTIAL FOR HUMAN INJESTION AND CONTAMINATION

We see no preventive notification program to inform residents abutting the shoreline and within 2000 ft of the application that such an activity is taking place. We see no delineation of the area by buoys to warn the public entering the area of the application. People using the public waters have the right to know what is taking place in the waters they may be swimming, fishing or boating in. There is no notification process mentioned at all in the E.I.S. We strongly suggest that the current notification process adopted by the Department of Ecology concerning herbicide use for aquatic weed control be adopted as part of this E.I.S. and instituted during the 1991 season. We see this area of public notification as a major flaw within the current system utilized for carbaryl applications.

PAGE 41 --- CARBARYL INDUCED ESTUARINE FISH MORTALITIES

Your office has determined that between 120 to 900 fish are killed per acre within marine fish habitat following a carbaryl application. This number appears to be acceptable within established guidelines set forth by your department. In fact we have no concerns over the issue except that you have established a zero fish mortality rate when aquatic herbicides are used within waters under your jurisdiction. These two figures seem to contradict themselves in one instance you are accepting up to a 900 fish mortality rate when in the other you accept zero.

We appreciate the opportunity to make comment on the E.I.S. Please feel free to contact our office if we can assist you in any way.

Sincerely,

Douglas Dorling
President

DD/mkd