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FINAL REPORT

WATER QUALITY DEPENDENT WATER USES IN PUGET SOUND

March 30, 1984

Prepared for:

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TABLE OF CONTENTS

Table of Contents
(cont'd)

1.0 INTRODUCTION

This report is submitted in fulfillment of the first of two tasks within the work assignment entitled "Coordination of Monitoring Efforts in Puget Sound". This first task, "Water Quality Dependent Uses in Puget Sound", was conceived with the following objectives in mind:

- Identify all existing and potential water quality dependent water uses within each of the subregions of Puget Sound as defined by Jones and Stokes (1983).
- Rank the uses in terms of relative importance within each subregion in order to identify to an environmental manager those uses which should be afforded the greatest protection.
- Whenever possible, identify the critical ecosystem elements and water quality factors which are essential to maintain these uses.

A thorough treatment with respect to all of the above objectives for each of the multitude of Puget Sound water uses would require a level of effort far in excess of those contractually allocated to this task. In particular, information on critical ecosystem elements and water quality factors is either unavailable or accessible only by a massive literature search. In order to best meet the needs of the task, an attempt has been made to identify all water quality dependent water uses and address each of them to some extent. The information is formatted in such a fashion as to be amenable to expansion in the future should this effort be expanded or pursued.

Section 2.0 serves to identify the water quality dependent uses and provide some background information on each use. For fisheries resources, general biological information is presented, including habitat, feeding ecology, reproductive strategy, and geographic range. Current and potential fisheries value, both commercial and recreational, is also addressed in terms of harvestable areas, catch statistics, and trends in harvesting. Recreational uses, such as swimming and diving, are considered in terms of distribution of recreational sites throughout Puget Sound.

In Section 3.0 the value of these resources is examined on a regional basis, employing the subregions (Figure 1) of Puget Sound as defined by Jones and

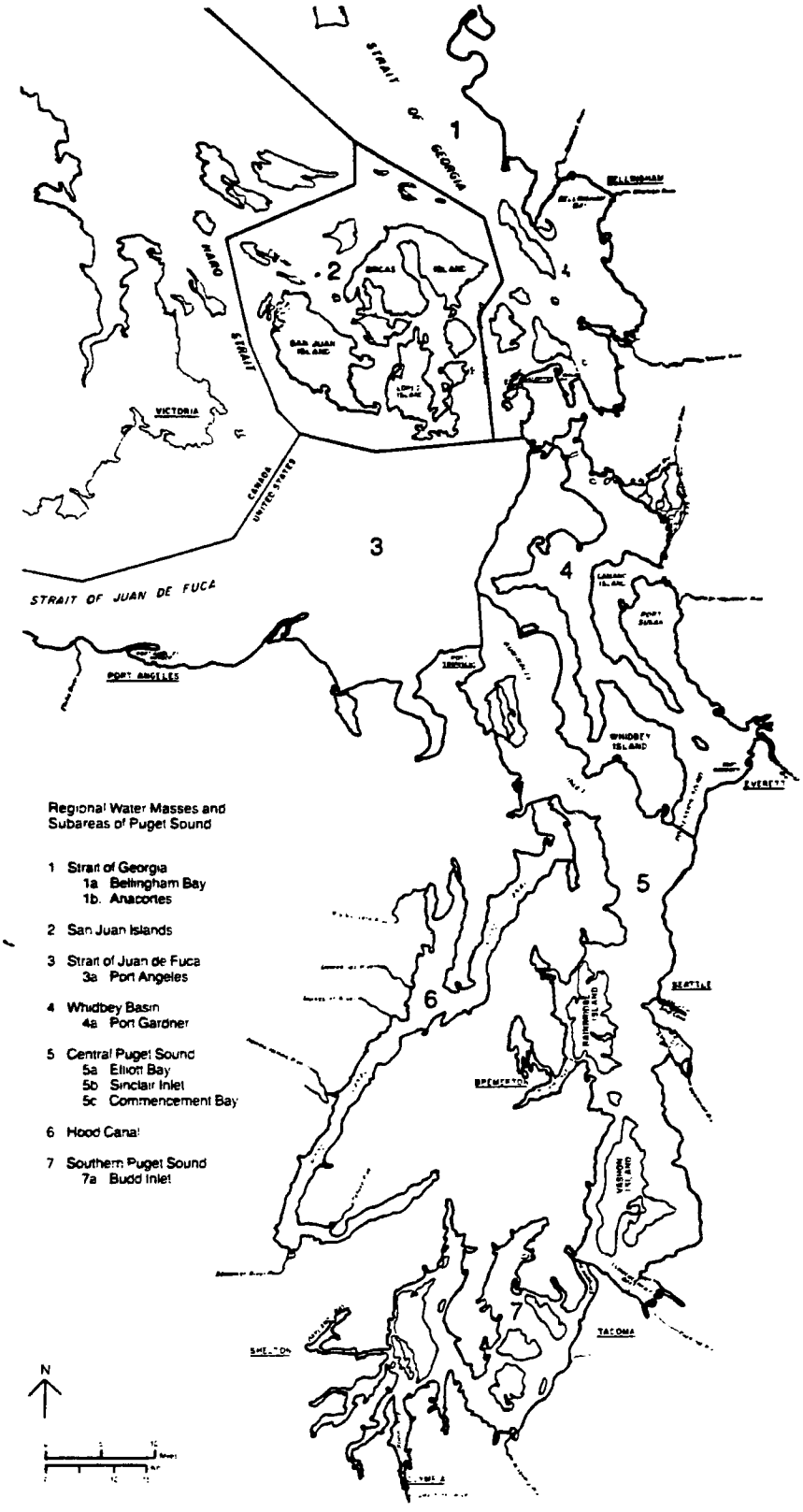


Figure 1

SUBREGIONS OF PUGET SOUND

Source: Jones & Stokes, 1983.

Stokes (1983). Within each region, the relative importance of each use is identified both within the region and to the Sound as a whole. Much of this presentation is in graphical form.

It must be stressed at this point that the water quality uses that have been identified do not represent the complete array of water quality related factors that combine to make the Puget Sound area one of the most attractive and valuable within the United States. Qualities such as aesthetics and personal values to different groups and individuals are also important but are much more difficult or impossible to rank in terms of relative importance. Furthermore, while many species of native animals have been included, these were included primarily to document their relative importance within the Sound in terms of human exploitation. The use of Puget Sound as a habitat to a variety of non-harvested species has not been considered within the scope of this report. However, this value must ultimately be considered in any attempt to manage the complex ecosystem that exists in Puget Sound.

2.0 WATER QUALITY DEPENDENT USES OF PUGET SOUND

The uses of Puget Sound considered dependent upon good water quality fall into the major categories of commercial and sport fishing, aquaculture and recreation. Within each of these major categories numerous individual water uses have been identified. The categories of commercial fishing, sport fishing and aquaculture resources include salmonids, marine fish, shellfish, and aquatic plants. Swimming and diving are included as recreational uses.

2.1 PUGET SOUND SALMONIDS

The family Salmonidae which includes salmon and trout is a diverse and economically valuable group of freshwater, anadromous, and marine fishes. The importance of the salmonid resource in Puget Sound can not be overestimated. In addition to providing the overwhelming proportion of total pounds harvested and total dollar value of all the fisheries, including commercial and recreational harvests, their value to the State goes beyond economic considerations. Historically and today, salmon and steelhead hold important ceremonial and religious values to Native Americans. They are an important source of food and income to many user groups. In addition, they are an essential component of many intricate food webs. Every year thousands of waterfowl overwinter on Puget Sound rivers and streams feeding on the bounty of emerging fry and juveniles. Native trout, sculpin, mammals, birds, and even insect larvae such as caddisflies also feed on the fry. During the spawning runs and following the death of adult salmon and steelhead, gulls, crows, and many bald eagles flock in impressive numbers to feast on the carrion. In the sea, salmonids are a source of food to many fish and marine mammals such as harbor seals and killer whales.

Five species of Pacific salmon can be found in Puget Sound; chinook, coho, chum, pink, and sockeye. The steelhead is a sea-run rainbow trout which also occurs in the Sound. All are anadromous fish which are born in freshwater and migrate to saltwater where they spend the bulk of their adult lives. They return to freshwater, often to their natal streams to spawn and renew this cycle and then usually die.

For all salmonid species, a great wealth of information has been compiled regarding their biology and environmental requirements. Optimum temperatures

for different life stages, adequate quantities of dissolved oxygen particularly for incubating eggs and developing alevins, suitable substrate for egg deposition and development, sufficient water circulation, suitable habitat for spawning and rearing, and an ample supply of food are all important factors in the survival of salmonids. Types of food and habitat preferences are also well known for each species. While each species undoubtedly has additional critical environmental requirements to insure its survival, it is more general factors that threaten all the salmonids. It is commonly recognized that loss of habitat for spawning and rearing by uncontrolled run-off and encroaching development represent the greatest danger to this resource.

During downstream migrations, juveniles undergo a physiological change called smoltification which facilitates the transition to the marine environment. Smolting salmon remain in estuarine areas for periods as long as two or more months. These areas, consequently, constitute critical habitat for salmonid survival. In Puget Sound, essentially every major river outfall support smolts, particularly those with major spawning runs. It is at this stage that the salmonid may be the most sensitive to environmental stress. Besides experiencing significant growth, these fishes are undergoing many chemical and physical changes. It is unknown at this time why many substances which may not have noticeable effects on adults or fry, can be devastating to the smolt (M. Mills, WDF, pers. comm.). It is believed, however that this stage represents the most critical stage in a salmonid's life history.

The management of the salmonid resource in Puget Sound is complex and fraught with numerous biological, political, and economic problems. The ultimate harvest of many mixed stocks must be divided between several user groups which is often disputed and a source of major conflicts. For example, the chinook sport fishery is currently closed in southern and central Puget Sound (Regions 5 and 7) from April through June. This closure was implemented in these areas to resolve chinook harvest share imbalances between Indian and non-Indian users (K. Reidinger, WDF, pers. comm.). Further complicating the problem of dealing with mixed stocks is that as many as five states and Canada manage and harvest this resource. The disparity of each management policy and limitations within each managing agency creates an overwhelming and difficult task to ensure the fair allocation of salmonids.

The culturing of salmon in hatcheries is a very important source of commercial and recreational fisheries. Hatcheries are located throughout the Sound as well as along the Coast. In Puget Sound, yearling salmon are also reared in floating pens and are reported to be valued at 2 to 4 million annually (Solomon and Mills, 1983). Potential expansion of this resource is believed to be considerable within the near future. Most rearing pens are located in Region 7. WDG raises steelhead in hatcheries and rearing ponds for annual stocking of Puget Sound and Olympic Peninsula streams.

Based on the recent increased salmon enhancement funds authorized by Congress in 1980 and pending final agreement between U.S. and Canada on a bilateral fisheries treaty to reduce interception of U.S. stock, WDF believes that overall, the salmon resource will increase (Solomon and Mills, 1983). Salmon abundance, however, may fluctuate from year-to-year due to environmental or harvest-related factors. For example, the El Nino phenomenon is thought to be responsible for a general decline in salmon stock abundance on the Pacific Coast, effecting Puget Sound and coastal salmon returns in 1983 and 1984.

The total Puget Sound commercial salmon fishery harvests an average of approximately 29,000,000 pounds worth over $26,000,000 annually (1979-1983). These statistics represent WDF salmon catch report areas 6 through 13 excluding the Lake Washington system. They do not include any major rivers that drain into Puget Sound since the focus of this exercise was the marine waters within the seven regional divisions of the Sound. Therefore, these figures are extremely conservative.

The recreational fisheries for both salmon and steelhead are also extremely important components of the total fisheries resources. Sport angling for salmon occurs throughout Puget Sound but is particularly heavy in the Strait of Juan de Fuca and in the northern and central Sound (Regions 1, 3 and 5). Table 1 presents the 1980 Washington sport salmon catch, number of angler trips, and salmon caught per trip as reported by Hoines, et al. (1980). Excluding the Strait of Juan de Fuca and the coastal fishery, the remainder of Puget Sound produced 241,002 fish or 38% of the total sport salmon catch (Hoines et al., 1980). The steelhead recreational fishery is primarily concentrated in freshwater with the exception of a few important marine areas such

Table 1

TOTAL 1980 WASHINGTON SPORT SALMON CATCH, NUMBER OF ANGLER TRIPS, SALMON PER TRIP BY MARINE AREAS, AND TOTAL FRESHWATER CATCH*

Region	Marine Area	Number of Salmon					Total Salmon	Marine Angler Trips	Salmon per Trip
		Chinook	Chum	Pink	Coho	Sockeye			
	Ilwaco	15,660	-0-	-0-	143,223	-0-	158,883	96,471	1.65
	Westport-Ocean Shores	28,274	4	22	135,447	1	163,748	109,284	1.50
	LaPush	931	-0-	14	18,201	-0-	19,146	15,367	1.25
	Neah Bay	2,751	1	23	26,716	9	29,500	31,632	0.93
	SUBTOTAL	47,616	5	59	323,587	10	371,277	252,754	1.47
3	Seikiu-Pillar Point	20,591	87	78	18,746	85	39,587	106,765	0.37
3	East Juan de Fuca Strait	47,187	13	12	5,405	46	52,663	137,254	0.38
2,1	San Juan Islands	9,862	-0-	-0-	7,453	-0-	24,457[a]	185,109	0.13
4	Deception Pass, Hope, Camano Is.	12,169	247	73	5,943	-0-	18,432	96,053	0.19
5	Admiralty Inlet	36,082	210	-0-	23,743	37	60,071	201,506	0.30
5	Seattle-Bremerton	31,059	198	-0-	20,852	19	52,128	204,584	0.26
5	Tacoma-Vashon	41,846	240	-0-	15,665	-0-	57,751	194,682	0.30
6	Hood Canal	9,073	334	-0-	4,357	-0-	17,138[a]	85,166	0.20
7	South Puget Sound	37,644	262	-0-	16,007	-0-	53,913	291,772	0.19
	SUBTOTAL	244,022	1,591	163	118,662	187	376,141[b]	1,502,891	0.25
	MARINE TOTAL	292,129	1,596	222	441,758	197	747,418[b]	1,755,645	0.43
	FRESHWATER TOTAL	119,161	-0-	-0-	18,982	43,051	105,461[c]		
	GRAND TOTAL	311,290	1,596	222	460,740	43,248	852,879[b]		

Source: Hoines et al., 1980.

*Current WDF management analyses assume a 20% overestimate in the punchcard sport catch and angler trip estimates. To correct for this bias, multiply all catch and effort estimates by 0.833 (K. Reidinger, WDF, pers. comm.)

[a] Due to lack of sampling data some salmon were unidentified.

[b] Includes 11,516 unidentified salmon.

[c] Includes 23,243 jacks and 1,024 unknown salmon.

as along the south shore of Whidbey Island (Region 4). Therefore, the importance of the steelhead fishery is not adequately reflected in this document since it is concerned with only the marine waters of Puget Sound.

The following is a description of each salmonid species found within Puget Sound. Each description includes a brief summary of its biology, habitat preference, geographic range, and pertinent commercial fishery data. Information concerning any critical life stages is included where supporting data was readily available. It should be stressed that these descriptions represent a cursory summation only. Detailed literature reviews as well as added efforts to contact local experts must be undertaken before enough information on each species as well as the entire salmonid resource can be presented to adequately meet the needs of resource managers.

2.1.1 Chinook (Oncorhynchus tsawytscha)

Geographic Range

In North America, chinook salmon are found from the Sacramento River in California, north to the Arctic. Chinook are found throughout the Sound but are especially common in Regions 1, 2, 4, 5, and 7.

Biology

Adult chinook salmon (4-5 years) occur in Puget Sound beginning in the spring and remain until the summer. There are two spawning runs; the spring chinook which spawns typically in large rivers in August or September and a summer/fall run that spawns by late November, also in large rivers and streams. The spring run is a minor component of the entire chinook resource. Important areas within Puget Sound for chinook runs include Bellingham Bay for hatchery stocks (Region 1), Skagit, Snohomish, and Stillaguamish Rivers for both wild and hatchery stocks (Region 4), Hood Canal for hatchery stocks (Region 6), and the southern Sound also for hatchery stocks (Region 7). Egg survival is dependent upon local stream conditions and can be inhibited by light, turbidity, temperatures, and insufficient dissolved oxygen. Wild eggs hatch from January to March. Fry emerge from February through May and immediately begin downstream migration. Hatcheries release fingerlings through the spring and summer. Some hatcheries release yearlings to ensure better survival. In marine waters, chinook feed on euphausiids, squid, and small fish.

Commercial Fishery-Present and Potential

Annual harvest of chinook salmon in Puget Sound is almost 2,500,000 pounds at a value of approximately $3,500,000 (1979-1983). Hatchery production compensates for the loss of natural stocks in many areas. Hatcheries, however, have not yielded the benefits predicted in recent years. Overall, the resource in terms of absolute numbers, has maintained itself and may be increasing in some areas due to hatchery rearing successes (K. Reidinger, WDF, pers. comm.).

Recreational Harvest

Central and southern Puget Sound (Regions 5 and 7) are currently closed to recreational fishing.

Summary Points - Chinook Salmon

- Regions 1, 4, 5, and 7 are the major harvest areas for chinook in Puget Sound (Figure 2).

- Major spawning and rearing areas occur in Bellingham Bay, Skagit Snohomish and Stillaguamish Rivers, Hood Canal and south Sound. Chinook salmon in smolt stage are found in estuarine environments at the mouths of rivers and streams within these areas (Regions 1, 4, 6 and 7).

- Five year (1979-1983) average of commercial fishery indicates value to be approximately $3,500,000 for almost 2,500,000 pounds.

- Important contacts and sources of information include:

WDF	Paul Sekulich
	Kurt Reidinger
	Michael Fraidenberg
	Richard Geist
	Dale Ward
	Lee Hoines
UW	E. Brannon
Other Organizations	NW Indian Fish Commission
	NW Salmon/Steelhead Council
	Pacific Fisheries Management Council

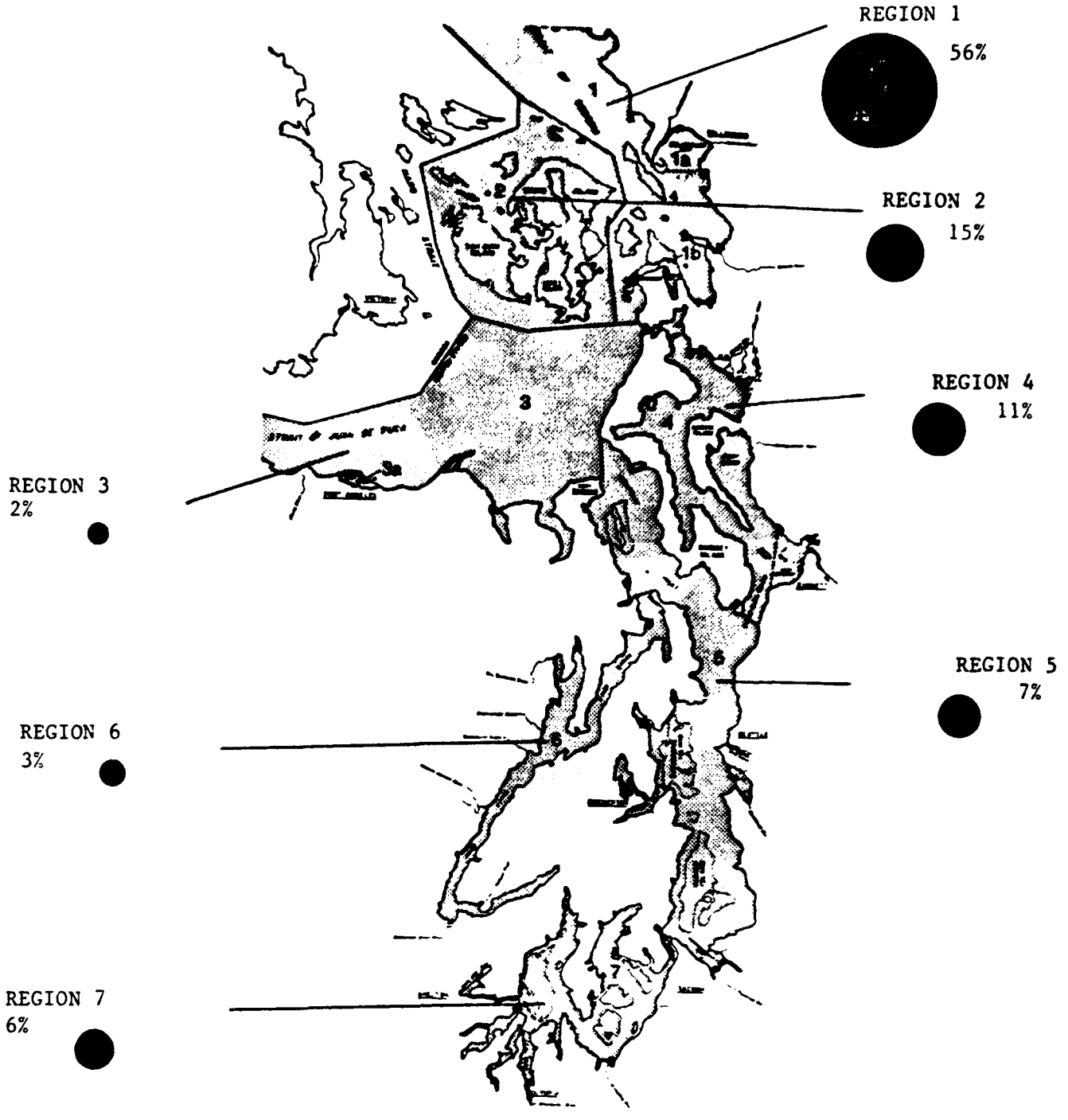


Figure 2

DISTRIBUTION OF CHINOOK SALMON HARVEST IN PUGET SOUND

(based on WDF statistics)

2.1.2 Chum Salmon (Oncorhynchus keta)

Geographic Range

In North America, chum salmon are found from the Columbia north to Alaska. They are found throughout Puget Sound.

Biology

Adult chum salmon (3-5 years) occur in Puget Sound from late September to November. Major run areas include the Skagit, Stillaguamish and Nooksak Rivers (Regions 1 and 4); central and southern Puget Sound (Regions 5 and 7); and Hood Canal (Region 6). Chum spawn in November, December, and January. Egg development is chiefly dependant on temperature (Hart, 1973). Alevins hatch in the spring and fry proceed immediately to the sea. The smolts school in estuarine areas where they remain for several months. At sea, adults feed chiefly on copepods, amphipods, euphausiids, squid, and small fish.

Commercial Fishery-Present and Potential

Annual harvest of chum salmon in Puget Sound is approximately 5,500,000 pounds at a value of about $4,000,000 (1979-1983). Hatchery production compensates for the loss of natural stocks in many areas. Hatcheries, however, have not yielded the benefits predicted in recent years. Overall, the resource in terms of absolute numbers, has maintained itself and may be increasing in some areas (K. Reidinger, WDF, pers. comm.).

Recreational Harvest

Chum salmon are not a popular sport fish because the species does not readily take hook and line. In 1980 total chum salmon sport catch, including marine and fresh water areas, was less than 1600 fish (Hoines et al., 1980).

Summary Points - Chum Salmon

- Regions 1, 4, 5, 6, and 7 are the major harvest areas for chum salmon in Puget Sound (Figure 3).
- Major spawning and rearing areas include the Skagit, Stillaguamish, and Nooksak Rivers, south Sound, and Hood Canal. Chum salmon in smolt stage are found in estuarine environments at the mouths of rivers and streams within these areas (Regions 1, 4, 6 and 7).
- Five year (1979-1983) average of the commercial fishery indicates value to be approximately $4,000,000 for almost 5,500,000 pounds.

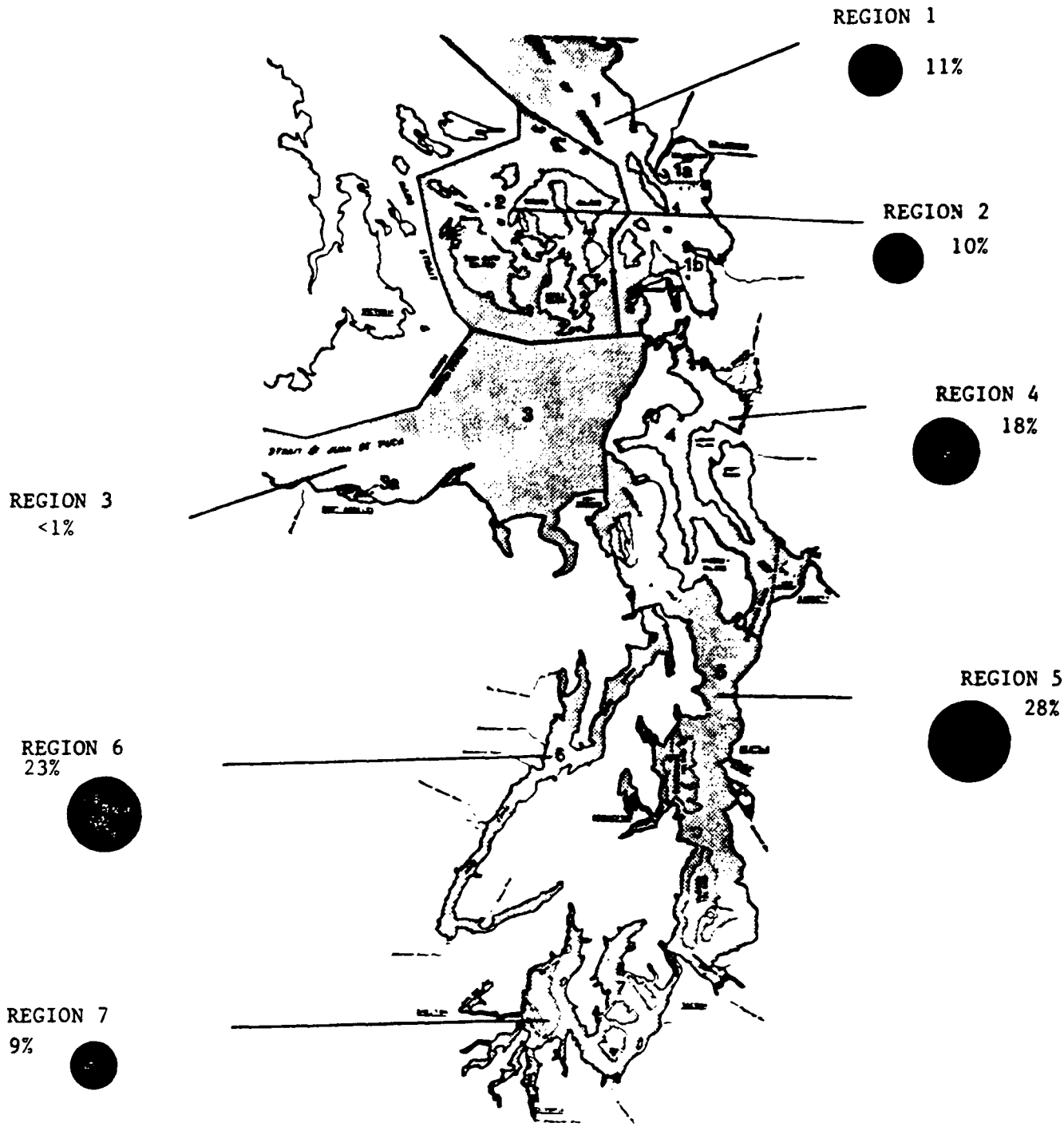


Figure 3

DISTRIBUTION OF CHUM SALMON HARVEST IN PUGET SOUND

(based on WDF statistics)

- Important contacts and sources of information include:

WDF	Paul Sekulich
	Jim Ames
	Dale Ward
	Lee Hoines
UW	E. Salo
	E. Brannon
Other Organizations	NW Indian Fish Commission
	Pacific Fisheries Management Council

2.1.3 Pink Salmon (Oncorhynchus gorbuscha)

Geographic Range

In North America, pink salmon are found from northern California to the Arctic Ocean. They are found throughout Puget Sound. Puget Sound fish include Fraser River (Canada) stocks.

Biology

Adult pink salmon (2 years) occur in Puget Sound in July and August of odd-numbered years. Important run areas include Skagit, Nooksak, Snohomish, and Stillaguamish Rivers (Regions 1, 2, and 4). Pinks spawn in September and October in these rivers and some may spawn in intertidal areas (Hart, 1973). Egg survival depends on temperature, weather, and gravel conditions. After hatching in late February, the fry form large schools and migrate downstream. These schools remain in estuarine areas for months. As adults, pink salmon feed on euphausiids, amphipods, copepods, squid, and small fish. Coho salmon are important predators of pink salmon juveniles and fry.

Commercial Fisheries-Present and Potential

Annual harvest of pink salmon in Puget Sound is approximately 8,000,000 pounds at a value of over $3,000,000. Puget Sound stocks of pink salmon have experienced major declines in productivity in recent years.

The harvest of pink salmon has not benefited from hatcheries like other salmon stocks. The reason for this trend is unclear although coho-pink interactions, insufficient upstream spawners, overfishing, and loss of habitat have all been suggested as causes (K. Reidinger, WDF, pers. comm.).

Recreational Harvest

Recreational fishing for pink salmon is not permitted in Puget Sound waters in order to protect the resource. The total number of pink salmon taken in the sport fishery was only 222 fish. This includes marine and fresh water areas (Hoines et al., 1980).

Summary Points - Pink Salmon

- Regions 1 and 2 are the major harvest areas for pink salmon in Puget Sound (Figure 4).

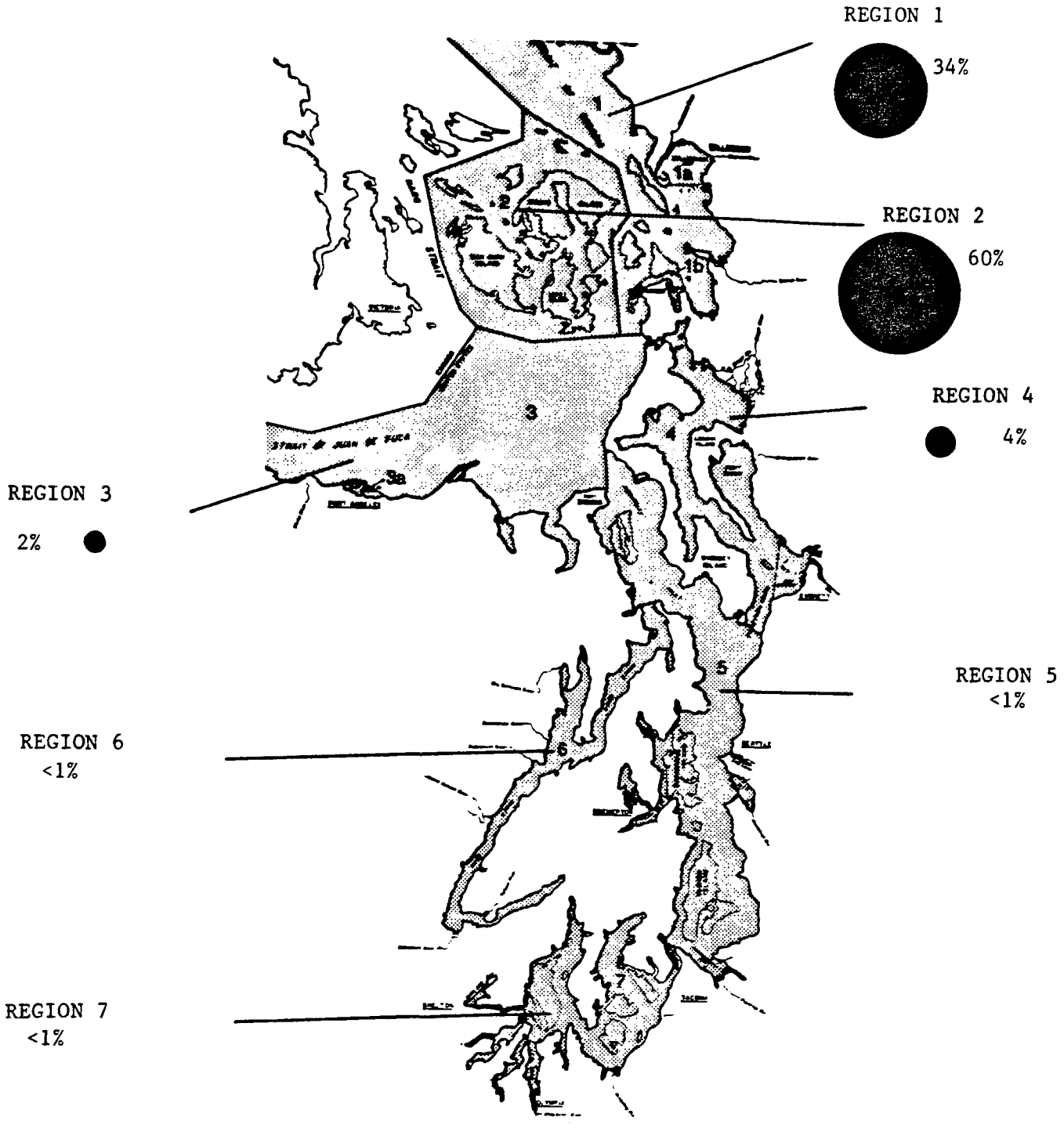


Figure 4

DISTRIBUTION OF PINK SALMON HARVEST IN PUGET SOUND

(based on WDF statistics)

- Major spawning and rearing areas include the Skagit, Nooksak, Snohomish, and Stillaguamish Rivers. Pink salmon in smolt stage are found in estuarine environments at the mouths of rivers and streams within these areas (Regions 1, 2 and 4).

- Five year (1979-1983) average of the commercial fishery indicates the value to be over $3,000,000 for over 8,000,000 pounds.

- Important contacts an sources of information include:

WDF	Paul Sekulich
	Jim Ames
UW	E. Brannon
Other Organizations	NW Indian Fish Commission
	Pacific Fisheries Management Council

2.1.4 Coho Salmon (Oncorhynchus kisutch)

Geographic Range

In North America, coho salmon occur from northern California to Alaska. They are found throughout Puget Sound.

Biology

Adult coho salmon (3 years) are found in Puget Sound from mid-August through October. Important run areas include the Skagit, Stillaguamish, Snohomish for hatchery and wild stocks (Regions 2 and 4), Hood Canal for wild stocks (Region 6), Bellingham and Sammish Bays for hatchery stocks (Region 1), and the southern Sound for hatchery and pen stocks (Region 7). Coho spawn in November, December, and January in very small streams. Survival of eggs depends on water levels, temperature, and gravel conditions. Light will destroy the eggs. Fry emerge in the spring and become territorial in their natal streams. The fry remain in these streams for 13 months, and in the following spring the yearlings migrate to sea. The smolts remain nearshore for the first few months at sea. Adults eat euphausiids, squid, and small fish. Juvenile coho are voracious predators of pink salmon fry and juveniles.

Commercial Fishery- Present and Potential

Annual harvest of coho salmon in Puget Sound is almost 6,000,000 pounds at a value of almost $5,000,000. Hatchery production compensates for the loss in many areas. Hatcheries, however, have not yielded the benefits predicted in recent years. Overall, the resource in terms of absolute numbers, has maintained itself and may be increasing in some areas (K. Reidinger, WDF, pers. comm.).

Recreational Harvest

Recreational harvest of coho salmon in Puget Sound in 1980 amounted to 118,662 fish (Hoines et al., 1980).

Summary Points - Coho Salmon

- Regions 1, 4, 5, 6, and 7 are major harvest areas for coho salmon in Puget Sound (Figure 5).
- Major spawning and rearing areas include the Skagit, Stillaguamish, Snohomish Rivers, Bellingham and Samish Bays, and Hood Canal. Coho salmon in smolt stage are found in estuarine environments at the mouths of rivers and streams within these areas (Regions 1, 2, 4, and 6).

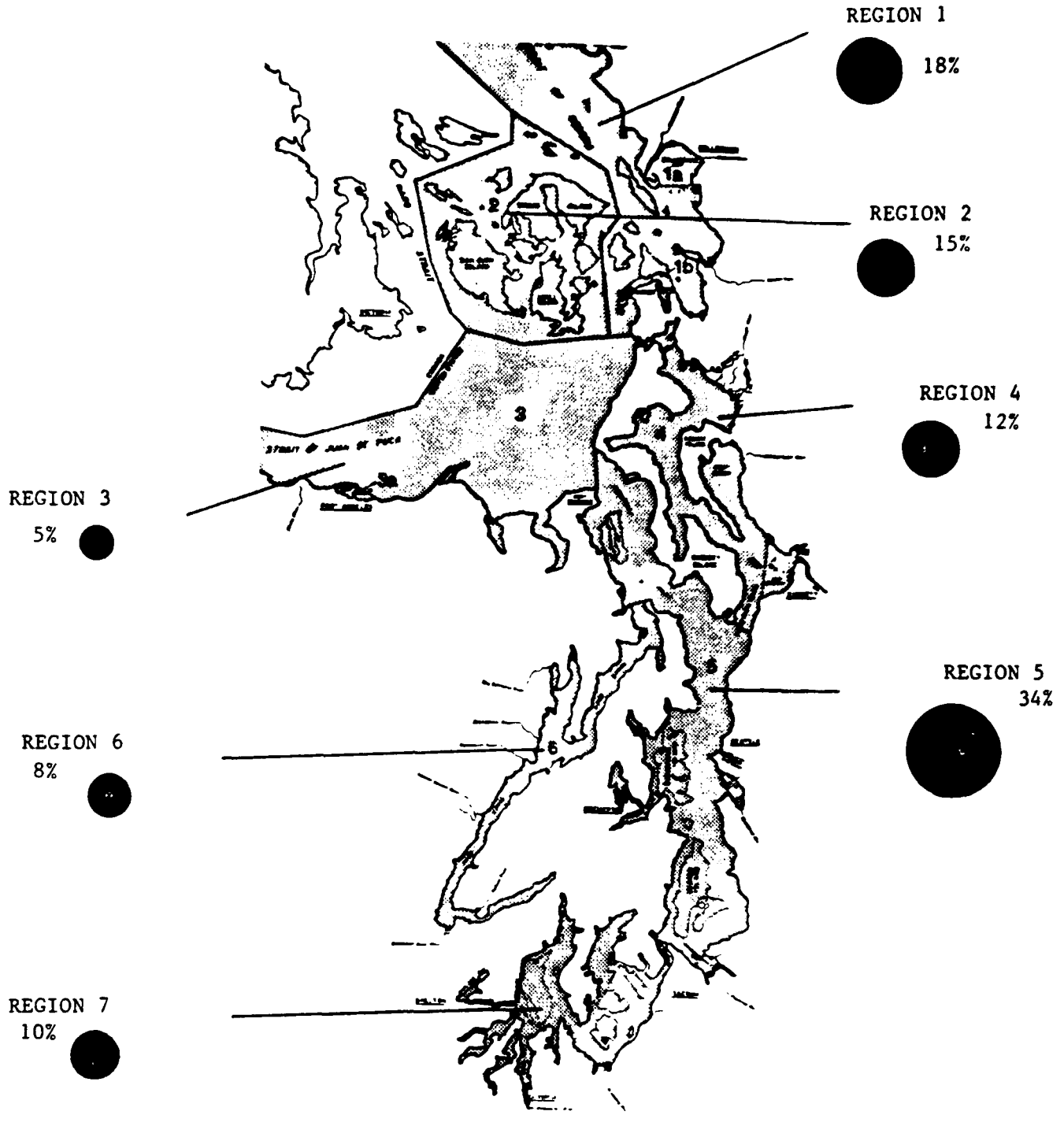


Figure 5

DISTRIBUTION OF COHO SALMON HARVEST IN PUGET SOUND

(based on WDF statistics)

- Five year (1979-1983) average of the commercial fishery indicates the value to be almost $5,000,000 for approximately 6,000,000 pounds.

- Important contacts and sources of information include:

WDF	Paul Sekulich
	Tim Flint
UW	E. Brannon
Other organizations	NW Indian Fish Commission
	NW Salmon/Steelhead Council
	Pacific Fisheries Management Council

2.1.5 Sockeye Salmon (Oncorhynchus nerka)

Geographic Range

In North America, sockeye salmon are found from the Columbia River north to Alaska. Sockeye are common throughout the Sound.

Biology

Adult sockeye salmon (4 years) occur in Puget Sound from June through August. Sockeye are found basically in the northern and central Sound as well as the Strait of Juan de Fuca (Regions 1, 2, 3, 4, and 5). Important spawning runs include the Baker River (Region 4) and the central Sound (Region 5). Sockeye spawn from November to January in the Baker River and the Lake Washington system. Egg survival depends on weather and gravel conditions. Alevins hatch in the early spring and the fry migrate to a fresh water nursery area, usually a large lake, to remain for 1 year. During this time the fry feed chiefly on zooplankton and small insects. After a year, when the temperatures reach 39-45° F (Hart, 1973), the sockeye migrate to sea. Smolt school in estuaries where they remain for several months. Adults feed on crustaceans, euphausiids, amphipods, and copepods.

Commercial Fishery - Present and Potential

Annual harvest of sockeye in Puget Sound is almost 8,000,000 pounds at a value of almost $9,500,000. Hatchery production compensates for the loss of natural stocks in many areas. Hatcheries, however, have not yielded the benefits predicted in recent years. Overall, the resource in terms of absolute numbers, has maintained itself and may be increasing in some areas (K. Reidinger, WDF, pers. comm.).

Recreational Harvest

The recreational sport fishery for sockeye in Puget Sound marine waters totaled 187 fish. While these numbers appear low, the fresh water fishery which includes Lake Washington totaled 43,051 fish in 1980 (Hoines et al., 1980). An additional 43,051 fish of Indian allocation were taken in gillnets. Lake Washington can be a very important source of sport sockeye if fishery escapement goals (350,000 fish) are achieved.

Summary Points - Sockeye Salmon

- Regions 1 and 2 are the most important harvest areas for sockeye salmon in Puget Sound (Figure 6).

- Major spawning and rearing areas include the Baker River and the Lake Washington System. Sockeye salmon in smolt stage occur in estuarine areas such as Salmon Bay and at the mouths of rivers and streams within these areas (Regions 1, 2, and 5).

- Five year annual average (1979-1983) of the commercial fishery for sockeye in Puget Sound is almost 8,000,000 pounds at a value of almost $9,000,000.

- Important contacts and sources of information include:

WDF	Paul Sekulich
	Jim Ames
UW	E. Brannon
	R. Bergner
	R. Thorne
Other Organizations	NW Indian Fish Commission
	NW Salmon/Steelhead Council
	Pacific Fisheries Management Council

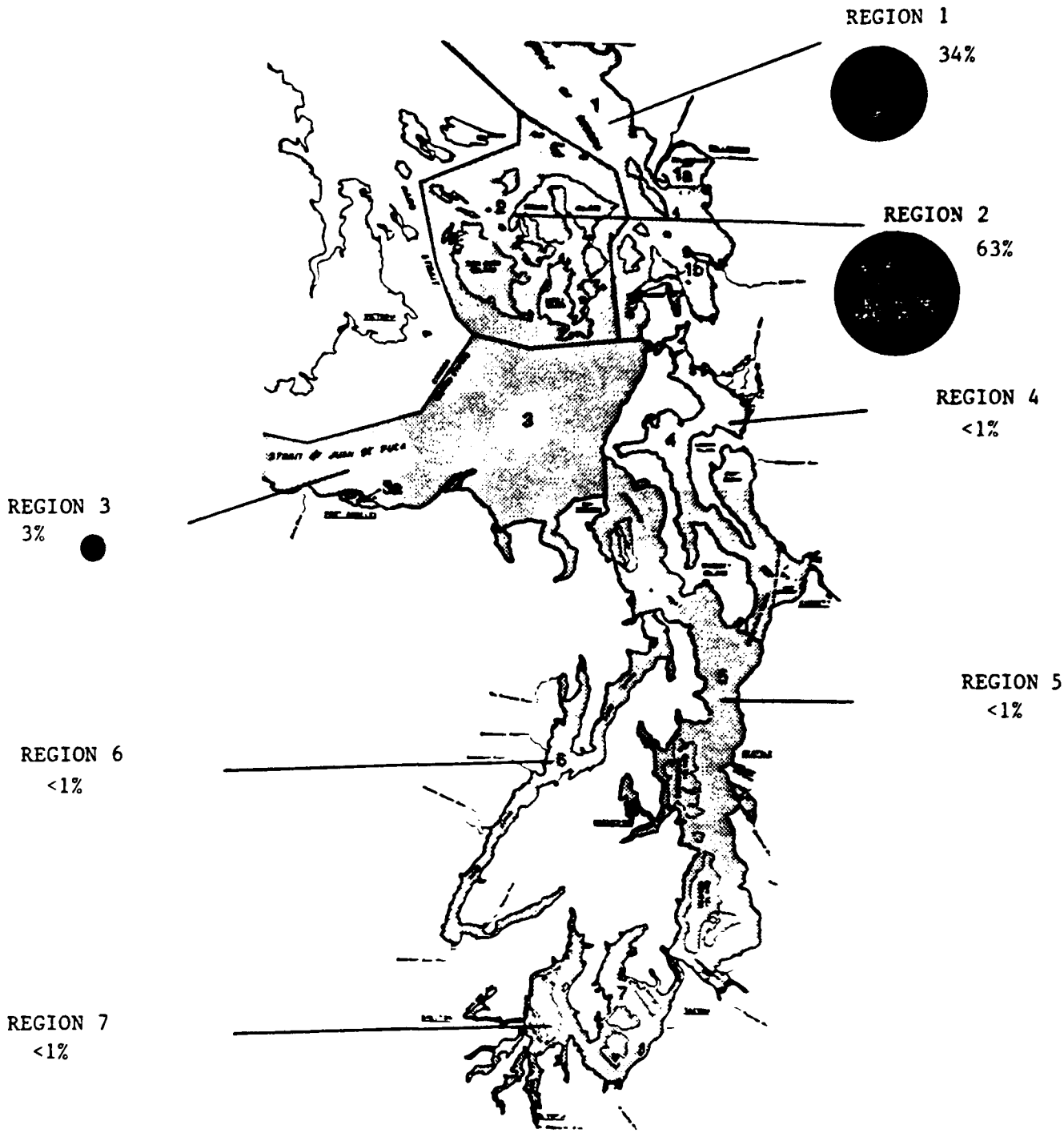


Figure 6

DISTRIBUTION OF SOCKEYE SALMON HARVEST IN PUGET SOUND

(based on WDF statistics)

2.1.6 Steelhead (Salmo gairdneri)

Geographic Range

Steelhead trout can be found from central California extending up the Pacific Coast into Alaska's Aleutian Islands. Steelhead are ubiquitous in Puget Sound.

Biology

There are two races of steelhead found in Puget Sound; winter-run and summer-run fish. The former is much more common in the Sound. Some summer-run fish occur in Puget Sound streams but they are primarily associated with the Columbia River. Adult winter-run steelhead (2-4 years) enter Puget Sound and move upstream into major rivers and tributaries from late autumn throughout the winter, spawning in early spring. Adult summer-run steelhead (2-3 years) travel upstream during the summer months and remain in ponds and streams until the following spring when they also spawn. Spawning for both races usually peaks in March and April in gravel beds within the major tributaries and small rivers throughout the Sound. The steelhead hatchery on Chambers Creek in Tacoma (Region 7) is the primary winter-run steelhead spawning station source for WDG plantings (WDF, et al., 1973). Egg survival depends on temperature, weather conditions, and gravel quality. The incubation period of eggs and larvae ranges from 50 to 150 days during the late winter and spring. Juveniles remain in freshwater for 1-3 years feeding on salmon fry and insects. After this growing period, the juveniles are approximately 6 - 8" in size and they begin their downstream migration. At sea, adult steelhead feed on young fish and crustaceans. Adults may spend as many as five years in the marine environment before returning to freshwater to spawn. Steelhead may survive to spawn a second or third time. Thus a given run of steelhead may be composed of representatives from several brood years.

Commercial Fishing - Present and Potential

Commercial steelhead fishing in Puget Sound is limited to Boldt Case Area Treaty Indians. The Indian tribes manage the steelhead resources on their reservations. most commercial fishing for steelhead occurs in freshwater areas. In Puget Sound, the Green/Duwamish, Snohomish, Skokomish, Nisqually, and the Skagit Rivers are important commercial fishing sites. On reservation fishing in marine waters occurs primarily in the Port Susan area (Region 4) where over 22,000 fish have been harvested from 1979-1983.

Recreational Harvest

Recreation harvest of steelhead occurs principally in freshwater (WDG, unpub.). The Green, Puyallup, Skykomish and Snoqualmie Rivers were the major winter-run steelhead streams for sport fishing in the Puget Sound region from 1978 through 1983 (WDG, unpub). Sport fishing for steelhead in marine waters is extremely limited; a popular marine site is along the south shores of Whidbey Island (Region 4). An average of 630 winter-run fish were taken each year from 1978 through 1983 with over 1,400 fish caught during the 1979-1980 season. Other marine areas in which WDG reports incidental catches of steelhead include the Strait of Juan de Fuca, central Puget Sound, Hood Canal, and the south Sound area near Fox Island.

Summary Points - Steelhead

- Regions 1, 4, 5, 6 and 7 include the major rivers and tributaries for the Indian harvest of commercial steelhead. Port Susan in Region 4 has produced the greatest Indian harvest of steelhead in the past five years (1979-1983).

- Five year (1979-1983) total of the Indian commercial fishing (on and off reservation) is 3,800 of summer-run and 43,000 of winter-run fish (Puget Sound Marine waters only).

- Regions 1, 5, and 6 include the major rivers and tributaries for the recreational harvest of steelhead. Region 4, Whidbey Island, is the major marine sport fishing site in Puget Sound.

- Important contacts and sources of information include:

WDG	Bill Freymond
	Pete Hahn
	Bob Gibbons
	Sam Wright
Other Organizations	NW Indian Fish Commission
	NW Salmon/Steelhead Council
	Pacific NW Steelheaders

2.2 PUGET SOUND MARINE FISH RESOURCES

The marine fish of Puget Sound are extensively utilized, both by commercial and recreational fisheries. Marine fish include all finfish resources other than salmonids. Major Puget Sound marine fish include flatfishes, herring, gadids, rockfishes, perches, and sharks.

In 1983, commercial marine fish landings in Puget Sound were about 25.8 million pounds valued at close to six million dollars. Pacific herring, Pacific cod, walleye pollock, spiny dogfish, Pacific whiting, and flatfish compose the greatest proportion in terms of pounds while Pacific halibut and petrale sole commanded the highest price per pound. The recreational fishing industry is carried out by anglers on boats and piers and by beach seining and jigging. The shore-based recreational fishery consisted of an estimated 312,000 trips in 1981.

The potential for aquaculture of marine fish is unknown. The potential for increased harvest will depend on the management plans of the WDF which are based on estimates of standing stock (where known) and on maximum sustained yield.

The following is a discussion of the major marine fish resources found within Puget Sound. Each description of a species or group of organisms includes a brief summary of its life history, habitat preference, geographic range, and pertinent commercial and recreational fishery data. Information concerning critical life stages or potential fisheries is included where the supporting data were readily available. It should be stressed that these descriptions represent a cursory summation only. Detailed literature reviews as well as added efforts to contact local experts must be undertaken before enough information on individual marine fish and the entire marine fish resource can be presented or ranked in Puget Sound to meet the needs of resource managers.

2.2.1 Pacific Whiting (Hake) (Merluccius productus)

Geographic Range

Pacific whiting occur from the Gulf of California to the Gulf of Alaska (Hart 1973). The genetically distinct population in Puget Sound is abundant throughout the Sound though less common in Hood Canal (Solomon and Mills, 1983).

Biology

The Pacific whiting (hake) is one of the largest marine fisheries in Washington State. The population inhabiting Puget Sound is distinct from the large oceanic population and spawns inside the Sound in Port Susan, the Gulf of Georgia and Carr Inlet (Kimura et al., 1981; Solomon and Mills, 1983). Spawning takes place from January to April and eggs are pelagic (Hart, 1973). Hatching generally occurs in three days. Larval survival is low and fluctuations in this population parameter are believed to be the dominant cause of changes in stock biomass (Bailey and Francis, 1982). Growth is usually rapid and the fish are long lived. Adults may attain lengths of three feet (Hart, 1973). The whiting forms an important link in the trophic structure in marine ecosystems. As a predator, it feeds on herring, anchovy and shrimp, but it is also prey for marine mammals and larger fish (Francis, 1982).

Commercial Fishery - Present and Potential

The average annual (1979-1983) harvest of Pacific whiting in Puget Sound is nearly 12,000,000 pounds with a value of almost $300,000. Almost all the hake harvested in Puget Sound come from Region 4. The annual average harvest from this area in 1979-1983 was 11.5 million pounds; an additional 51,000 pounds was harvested in Region 1. The Region 4 fishery is located near the spawning areas of these fish. WDF (1982) indicates that the hake fishery in Puget Sound is rapidly becoming one of the most important. This is concurrent with a shift from use of the fish as animal food to use for human consumption.

Recreational Fishery

The Pacific whiting forms only a small component of the recreational boat fishery. In 1980 about 27,000 fish were harvested in the Sound.

Summary Points - Pacific Whiting

- Most of the commercial harvest occurs in Region 4 (Figure 7).

- Larval survival appears to be the key indicator of recruitment to fishable stocks. No known water quality information is available. This species is an important link in marine food webs, feeding on anchovy, herring and shrimp and being preyed upon by marine mammals and larger fish.

- The five year average annual harvest (1979-1983) was close to 12,000,000 pounds with a value of almost $300,000.

- Important contacts and sources of information include:

WDF	Bill Clark
	Mark Pedersen
	Dale Ward
	Lee Hoines
	Mary Lou Mills
	R. Costello
	Greg Hueckel

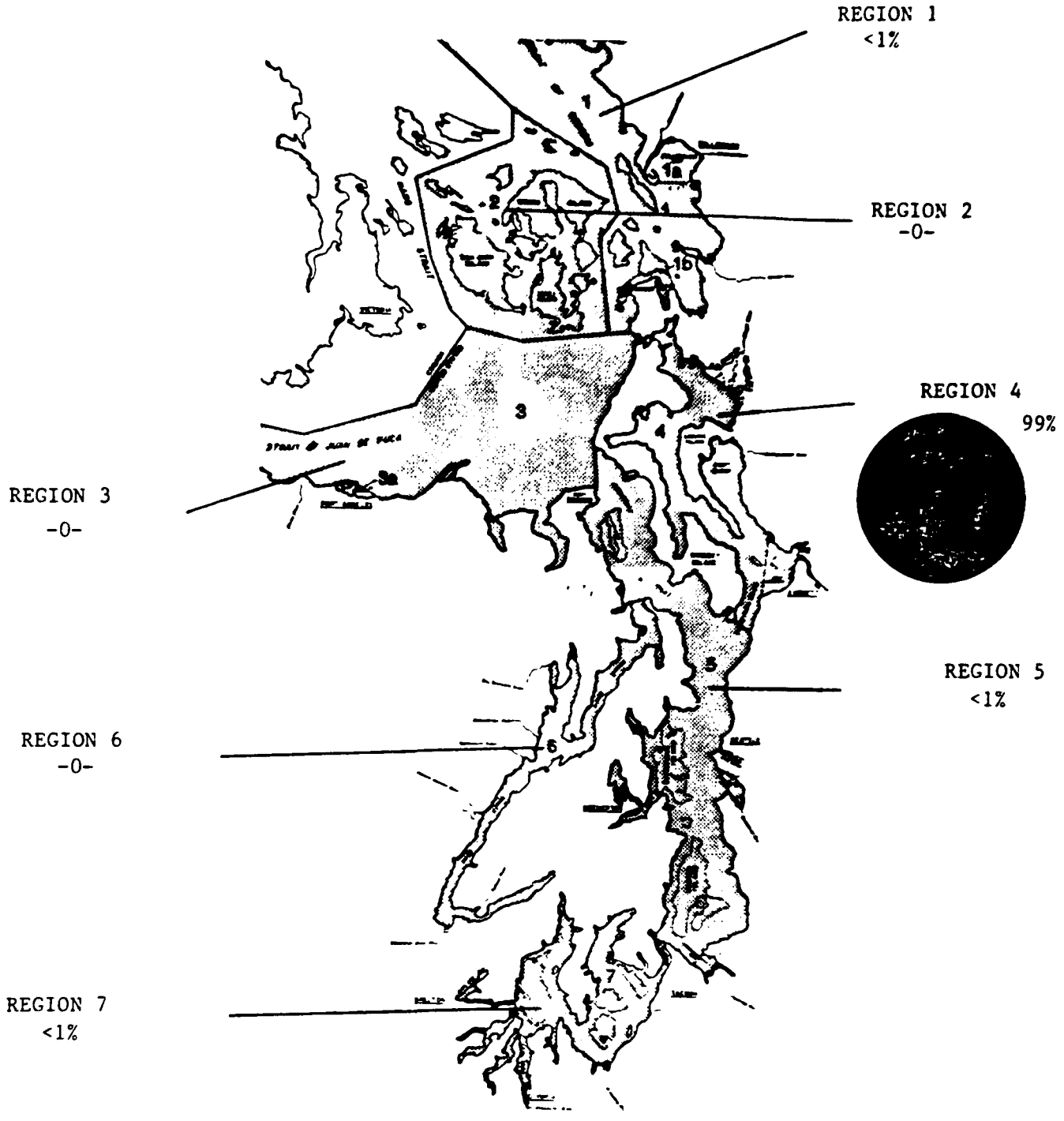


Figure 7

DISTRIBUTION OF PACIFIC WHITING HARVEST IN PUGET SOUND

(based on WDF statistics)

2.2.2 Walleye Pollock (Theragra chalcogramma)

Geographic Range

Pollock occur from central California, around the Pacific Rim to the Sea of Japan (Hart, 1973). In Puget Sound, they are most abundant in Regions 1, 2, 3 and common in other inside waters (Solomon and Mills, 1983).

Biology

Walleye pollock is the most frequently caught sportfish in the inside waters of Puget Sound. It generally occurs in waters 200-500 ft deep and may occur midwater or on the bottom. Spawning aggregations occur in waters 360-480 feet deep in localized areas (Pedersen and DiDonato, 1982). Spawning grounds in the Gulf of Georgia and near Tacoma have been identified (Solomon and Mills, 1983). Eggs are pelagic but little other information on their life history is available. Prey includes small fish and shrimp (Hart, 1973).

Commercial Fishery - Present and Potential

The average (1979-1983) annual harvest of walleye pollock is 700,000 pounds with a value of $80,000. A directed fishery for pollock occurs in the Gulf of Georgia and the western Strait of Juan de Fuca. The annual average catch in Regions 1 and 3 was 675,000 lb and 41,000 lb, respectively.

Recreational Fishery

Pollock are an important fish of the charter and private boat fishery in the central and southern Sound (Regions 4, 5 and 7). In both areas, the recreational fishery is far larger than the corresponding commercial fishery for this species. In Region 7, the fishing area is limited to the area between Fox Island - Port Gibson and through the Tacoma Narrows (Pedersen and DiDonato, 1982).

Summary Points - Walleye Pollock

- Commercial harvest is primarily in Regions 1 and 3, recreational harvest is primarily in Regions 4, 5 and 7 (Figure 8).
- The five year average annual harvest (1979-1983) was around 700,000 pounds with a value of $80,000.

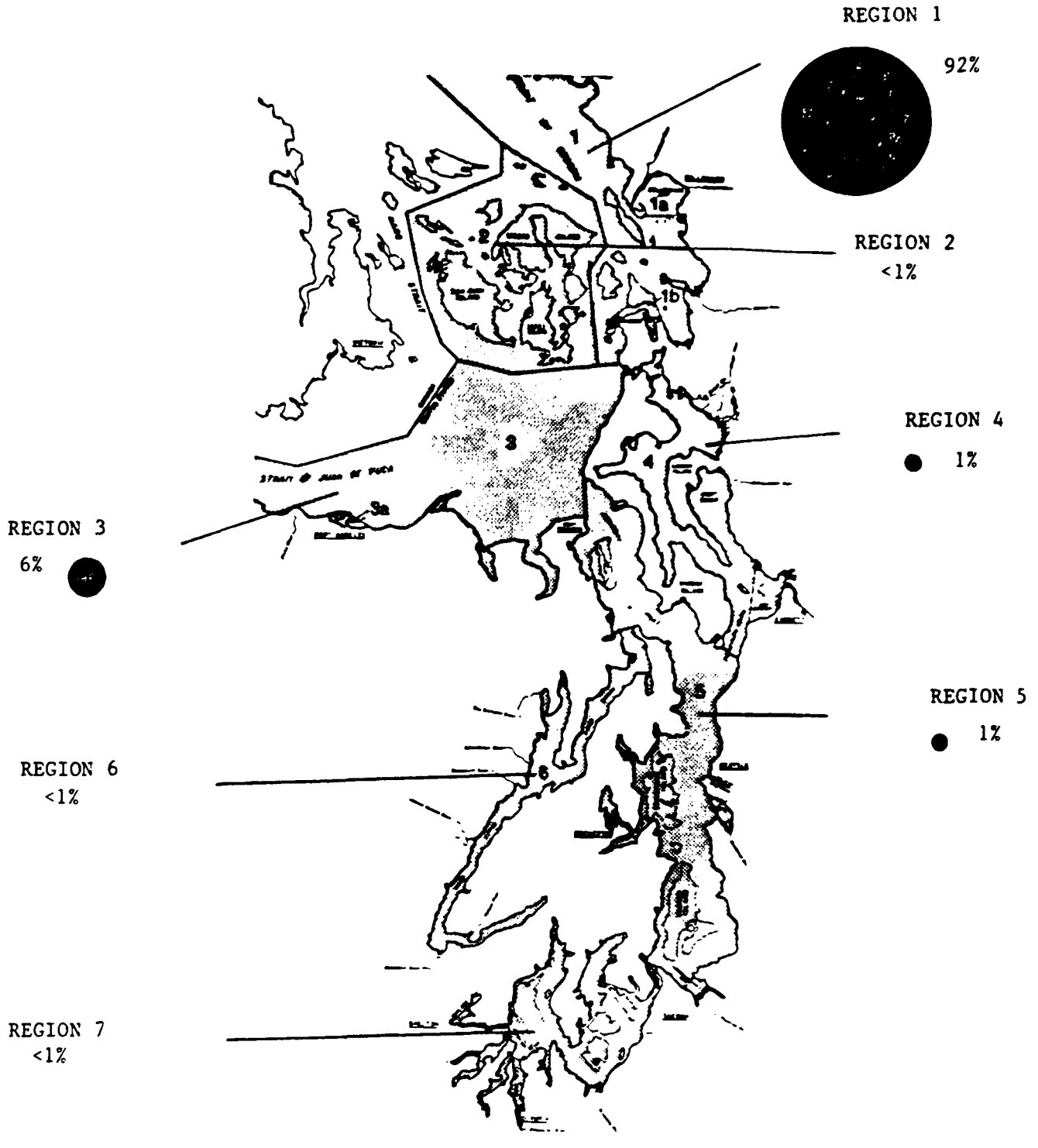


Figure 8

DISTRIBUTION OF WALLEYE POLLOCK HARVEST IN PUGET SOUND

(based on WDF statistics)

- Important contacts and sources of information include:

WDF	Mark Pedersen
	Bill Clark
	Dale Ward
	Lee Hoines
	Mary Lou Mills
	R. Costello
	Greg Hueckel

2.2.3 Pacific Cod (Godus macrocephalus)

Geographic Range

Pacific cod are distributed from southern California around the Pacific Rim to Korea and Japan (Hart, 1973). In Puget Sound, they are far more common in the northern Sound and the Straits than they are in the southern Sound.

Biology

The Pacific cod ranges from 16 inches to three feet in length and in weight from 2-10 pounds. These fishes form congregations before spawning in the winter months. They produce very large numbers of demersal, slightly adhesive eggs (Hart, 1973). Known spawning areas in Puget Sound include Port Angeles, Protection Island, Port Townsend, Port Gamble, Agate Pass, Tacoma, to the Port of Georgia (Solomon and Mills, 1983). The adult fish prefer water depths of 20-200 feet over mixed substrate types. They tend to utilize deeper water in winter and shallower water in summer (Solomon and Mills, 1983). These fishes feed on a wide variety of invertebrates and fish, including herring, walleye pollock and flatfishes (Hart, 1973).

Commercial Fishery - Present and Potential

The average annual (1979-1983) harvest of Pacific Cod in Puget Sound is over 2,400,000 pounds with a value of over $500,000. The bulk of Pacific cod are harvested in Regions 1 and 3. Average annual catch from 1979-1983 was 1.3 million pounds in Region 1 and 539,000 pounds in Region 3. Most of the fishery is a trawl fishery. However, there is a set net fishery in Port Townsend Bay and a commercial line fishery near Port Angeles. This species is subject to wide fluctuations in harvest, probably due to its high natural mortality rate and high fecundity (Pedersen and DiDonato, 1982).

Recreational Fishery

The recreational fishery for cod is substantial, particularly in Regions 3 and 5. In Region 5 the fishing occurs primarily near Possession Point, Jefferson Head, Agate Pass, south Vashon Island and Point Defiance. In Region 3 the fishery has occurred from boats in shallow water in the Straits (Pedersen and DiDonato, 1982).

Summary Points - Pacific Cod

- The majority of the harvest occurs in Regions 1 and 3 (Figure 9).
- The average annual harvest in Puget Sound in 1979-1983 was over 2,400,000 pounds with a value of over $500,000.
- Important contacts and sources of information include:

WDF	Mark Pedersen
	Bill Clark
	Dale Ward
	Lee Hoines
	Mary Lou Mills
	Greg Hueckel
	R. Costello

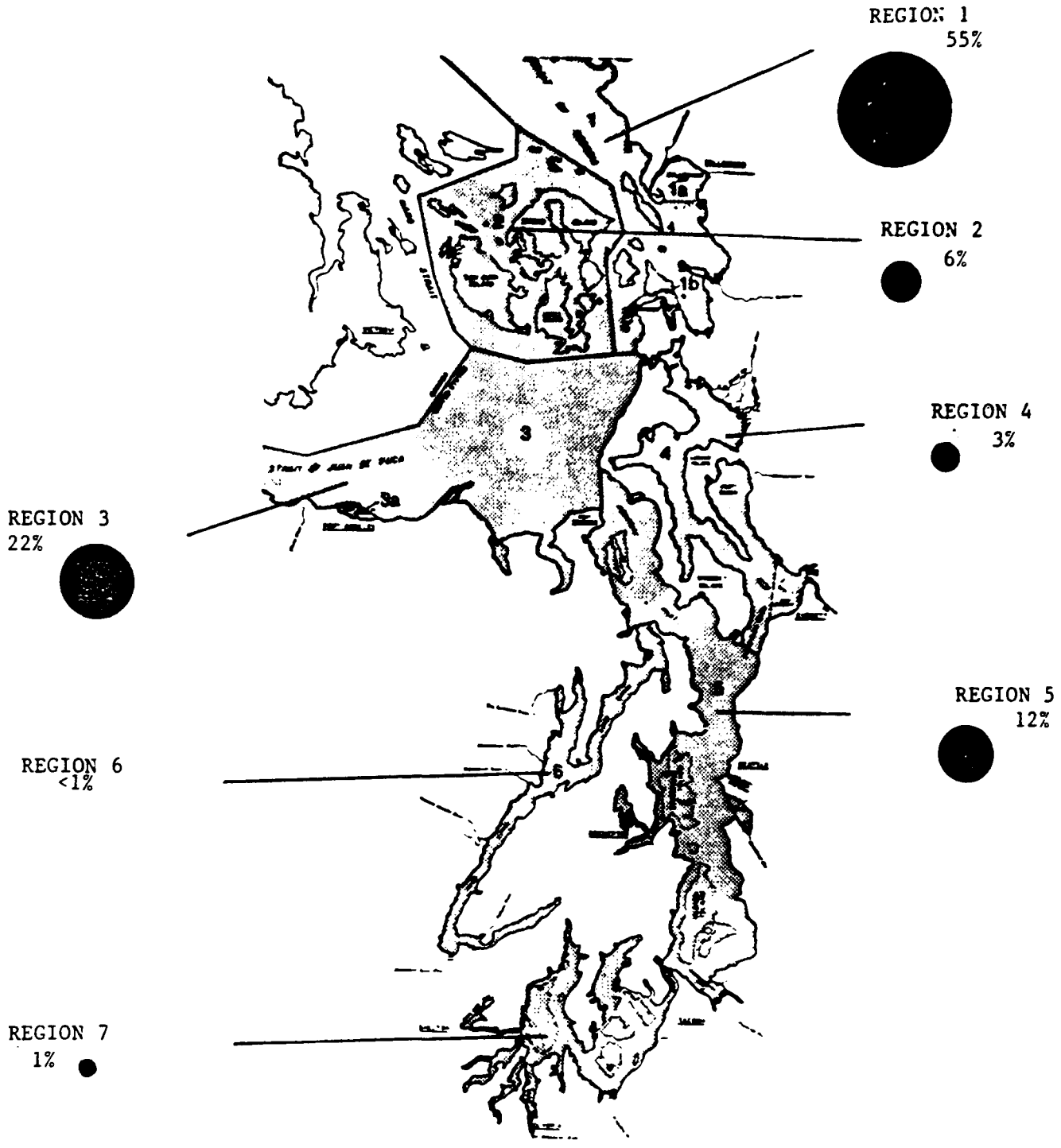


Figure 9

DISTRIBUTION OF PACIFIC COD HARVEST IN PUGET SOUND

(based on WDF statistics)

2.2.4 Pacific Herring (Clupea harengus)

Biology

Pacific herring are the largest component of the bait fish and sac-roe fisheries in Washington State. These small fish have well documented spawning areas and times returning home to specific spawning grounds each year. The Strait of Georgia (Region 1) is the area of highest spawning intensity. Eggs are deposited on marine vegetation in late winter and early spring and hatch in about two weeks depending on temperature. Juvenile fish migrate out of the Sound at about one year of age to offshore feeding grounds, returning as 3-4 year olds to spawn. As adults, the herring migrate annually between summer feeding grounds off the Washington and British Columbian coasts and the winter spawning grounds in the Sound. Herring are an important item in the foods of salmon and other predatory fish such as Pacific whiting (Trumble, 1983).

Commercial Fishery - Present and Potential

The average annual harvest of herring in Puget Sound is 4,000,000 pounds with a value of almost $4,000,000 (1979-1983). There are three commercial herring fisheries. A sac-roe fishery, taking mostly young fish, occurs in the spring in the eastern Strait of Georgia (Region 1). This fishery began in 1973 but was closed in 1981 due to declining biomass. The general purpose fishery (for animal food and commercial bait) takes place from September to February in Bellingham Bay and the San Juan Islands (Regions 1 and 3). There has been a consistent decline in harvest since 1971, though reasons for this are not entirely clear. The sport bait fishery occurs throughout Puget Sound but is more concentrated in the southern Sound and northern Hood Canal/Admiralty Inlet area (Regions 5 and 6) (Trumble, 1983).

There is potential in Puget Sound for a "roe-on-kelp" harvest for the oriental market. This could be accomplished through pen culture or holding of ripe herring prior to egg deposition. However, there are many logistical and politcal problems in the consideration of this type of harvest.

In 1974, the Indian tribes in Washington State were allocated 50% of the salmon, steelhead and herring taken in the state. Total commercial harvest reported includes Indian allocations.

Recreational Harvest

No information on the exploitation of herring by recreational fishermen could be found.

Summary Points - Pacific Herring

- Standing stock information for each type of herring fishery is varied. Information is available in Trumble (1983). Harvest occurs primarily in Regions 1, 5, 6, and 7 (Figure 10).
- The fidelity of herring to certain spawning grounds is considered critical. It is unknown what makes those spawning areas unique. Herring is fed on by a number of commercially important predatory fish.
- The average annual harvest in Puget Sound in 1979-1983 was 4,000,000 pounds with an average value of almost $4,000,000.
- Important sources of information include:

WDF	Robert Trumble
	Bill Clark
	Dale Ward
	Lee Hoines
	Greg Hueckel
	R. Costello

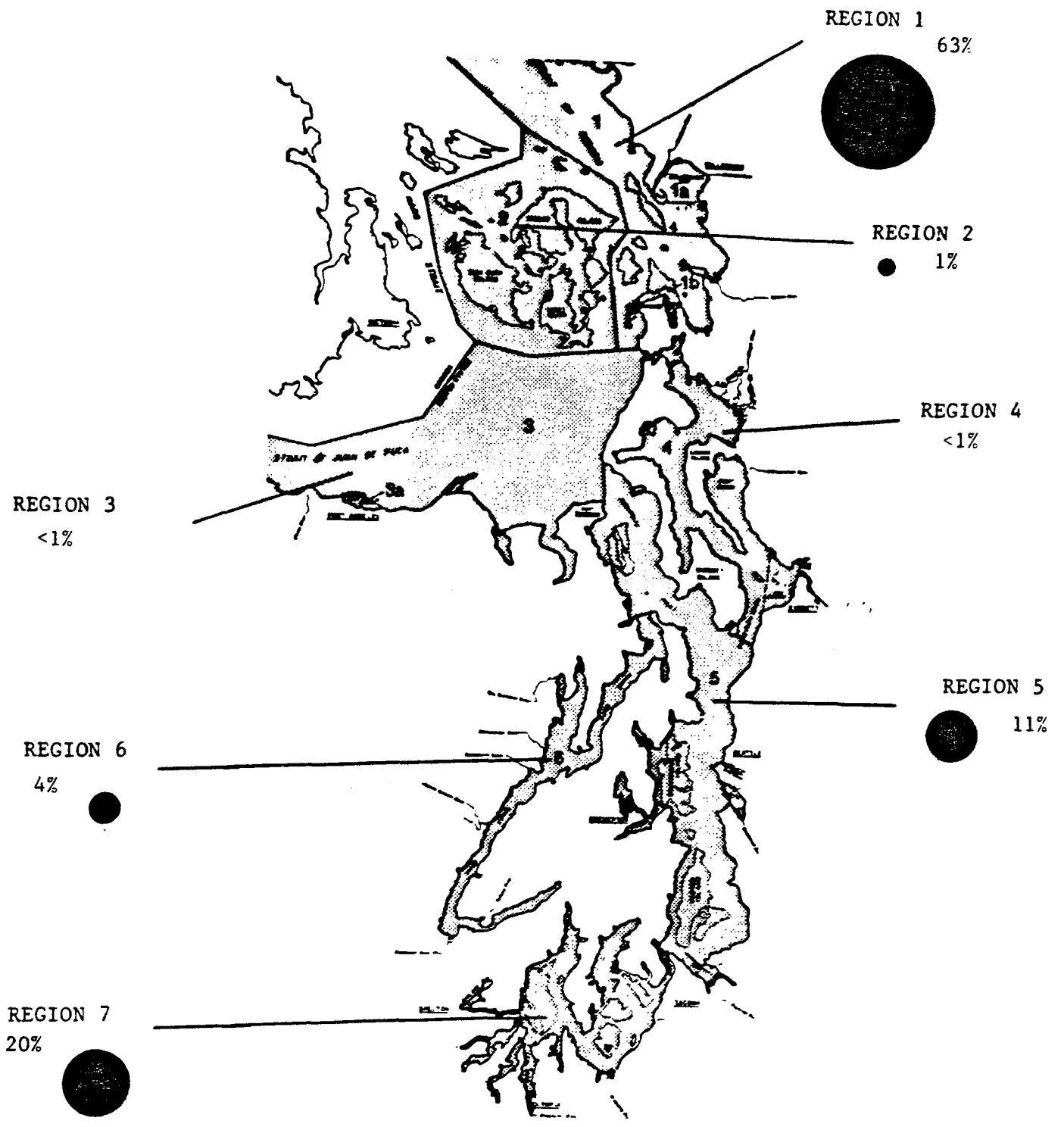


Figure 10

DISTRIBUTION OF HERRING HARVEST IN PUGET SOUND

(based on WDF statistics)

2.2.5 Flatfish

Eleven species of flatfish are harvested commercially and recreationally in Puget Sound. Each of these species range throughout the Sound although relative abundance changes in different regions. None of the flatfish are abundant in Hood Canal; most find their peak abundance in the waters of the northern and central portions of the Sound.

The two species that account for the bulk of the commercial harvest are English sole and starry flounder, which are also the most abundant flatfish in Puget Sound waters (Pedersen and DiDonato, 1982). The commercial harvest of flatfish is generally done by trawling and there are few regions where this activity is directed toward a specific species. Recreational harvest of flatfish is small, with most occurring in the central portion of Puget Sound (Pedersen and DiDonato, 1982).

2.2.6 Starry Flounder (platichthys stellatus)

Geographical Range

Starry flounder are distributed from southern California through the Bering and Chukchi Sea to Korean and Japanese waters (Hart, 1973). In Puget Sound, they are more abundant in the northern Sound (Regions 1 and 2) and the central Sound (Regions 4 and 5) than in other areas.

Biology

The starry flounder, the most abundant shallow water (0-120 ft) flatfish in Puget Sound, inhabits areas of flat sand. Spawning occurs February to March; known spawning areas are in Boundary Bay and Bellingham Bay (Region 1) (Solomon and Mills, 1983). Eggs are pelagic. Females are somewhat larger than males (23.5 inches versus 17 inches) and probably live longer (Hart 1973).

Starry flounder tolerate wide ranges of salinity. Hart (1973) reports that young are taken in the Fraser River and have been found in salinities of 6-10 parts per thousand in California. Feeding is temperature dependent and may cease at low water temperatures. This species feeds primarily on crustaceans, worms, small molluscs, and small fishes.

Commercial Fishery - Present and Potential

Average annual harvest in the northern Sound (1979-1983) was 458,000 pounds and 540,000 pounds in the central Sound (Region 5). Most starry flounder are harvested in Regions 1 and 4; very few are harvested at all in the Hood Canal (Region 6). Average annual harvests from 1979-1983 in Regions 1 and 3 were 444,000 and 291,000 pounds lb, respectively. This is a comparable harvest to that of the previous five years. In Region 3, the bulk of the fishery occurs in Discovery Bay. Trawl grounds for starry flounder in Region 5 are at Utsalady and Saratoga Passage (Pedersen and DiDonato, 1982).

Recreational Fishery

Starry Flounder represent a significant recreational fish species only in Region 5. From 1976-1980 an average of 4,000 pounds was harvested annually, primarily as a result of pier sportfishing (Pedersen and DiDonato, 1982).

Summary Points - Starry Flounder

- The majority of the commercial harvest occurs in Regions 1, 3 and 4 (Figure 11).
- The average annual harvest in Puget Sound (1979-1983) was over 350,000 pounds with a value of over $150,000.
- Important contacts and sources of information include:

WDF	Mark Pederson
	Bill Clark
	Dale Ward
	Lee Hoines
	Mary Lou Mills
	R. Costello
	Greg Hueckel

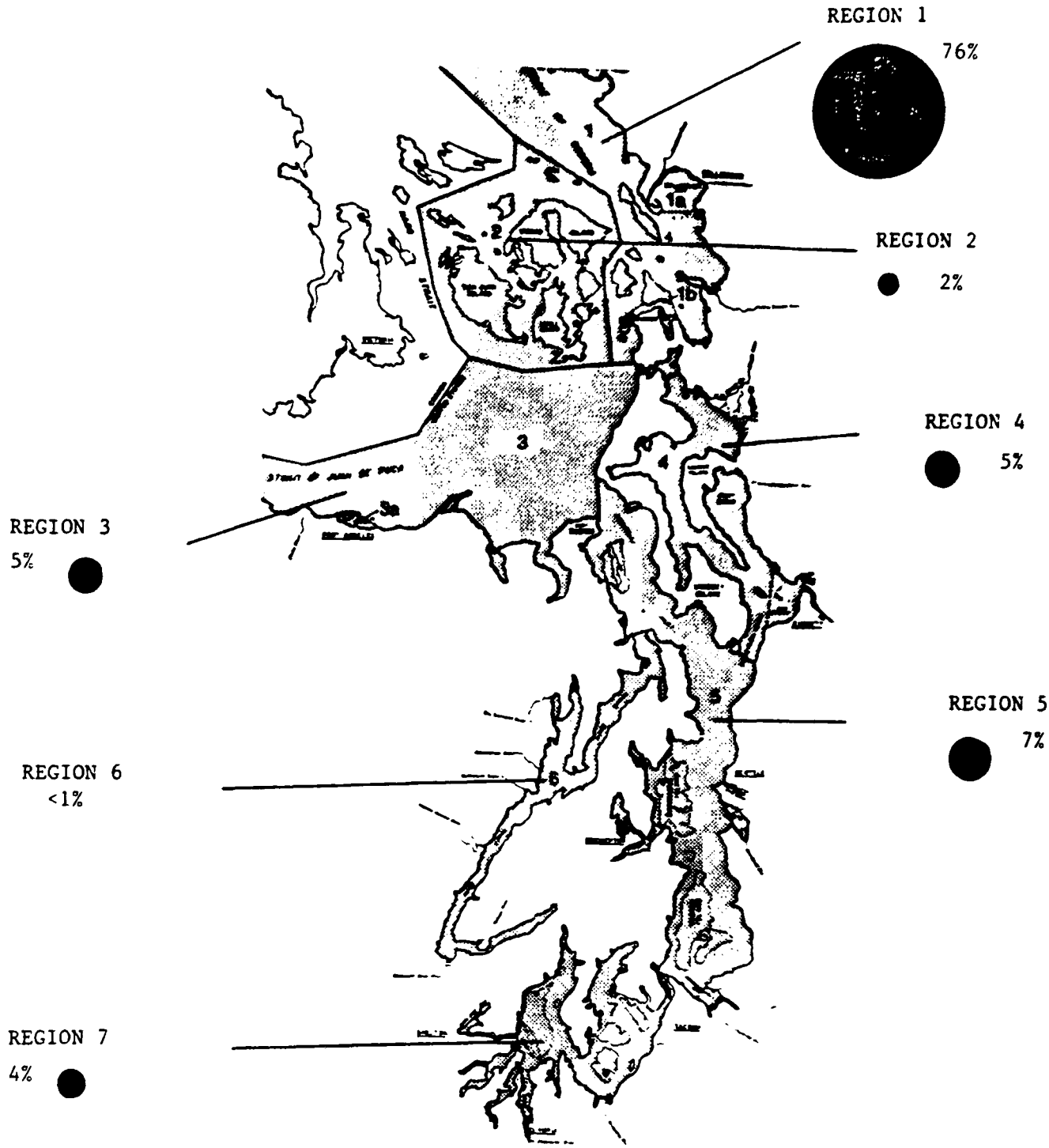


Figure 11

DISTRIBUTION OF STARRY FLOUNDER HARVEST IN PUGET SOUND

(based on WDF statistics)

2.2.7 Dover Sole (microstomus pacificus)

Geographic Range

Dover sole are found from Baja, California to the Bering Sea. In Puget Sound, they are most abundant in the central Sound (Regions 4 and 5) and least abundant in Hood Canal (Region 6) (Solomon and Mills, 1983).

Biology

The Dover sole is one of the most hardy of the flatfish. Preferring soft bottom habitat, this fish is a bottom feeder, specializing in burrowing animals (Hart, 1973). Little of its specific life history is known in Puget Sound, but research has been conducted on other stocks. Spawning occurs off California from November to February. Spawning sites and times in Puget Sound are unknown. Eggs and early larvae are pelagic for several months before settling to the bottom. Once juvenile fish settle to the bottom, migrations are generally not extensive. Off the Washington coast, movements have been noted up to 110 miles northward and 366 miles southward (Hart 1973). Males may live 20 years and attain about two pounds in weight. Females are somewhat longer-lived and larger (Pedersen and DiDonato, 1982). The fish are primarily found around 300 foot depths.

Commercial Fishery - Present and Potential

The average annual harvest of Dover sole in Puget Sound is about 100,000 pounds with a value of over $20,000 (1979-1983). The primary region for harvest of Dover sole is in central Puget Sound (Regions 4 and 5). Trawling grounds primarily used for harvest of this species include Penn Cove, Holms Harbor, Saratoga Passage, Everett Bay, Possession Sound, Edmonds and Port Madison (Pedersen and DiDonato, 1982). The fishery occurs all year peaking in the winter and in waters from 0-500 feet deep. The average landing of Dover sole in the central Sound (Regions 4 and 5) from 1979-1983 was 59,000 pounds annually. The fishery in central Puget Sound has been declining since 1976 for unexplained reasons (Solomon and Mills, 1983).

Recreational Harvest

There is virtually no recreational fishery directed at Dover sole. In 1980, only 52 fish were reported harvested by boat-based anglers in Washington State waters (WDF, 1980).

Summary Points - Dover Sole

- Most are harvested from Regions 1, 4, and 5 (Figure 12).
- The five year average annual (1979-1983) harvest was approximately 100,000 pounds with a value of over $20,000.
- Important contacts and sources of information include:

WDF	Mark Pedersen
	Bill Clark
	Dale Ward
	Lee Hoines
	Mary Lou Mills
	R. Costello
	Greg Hueckel

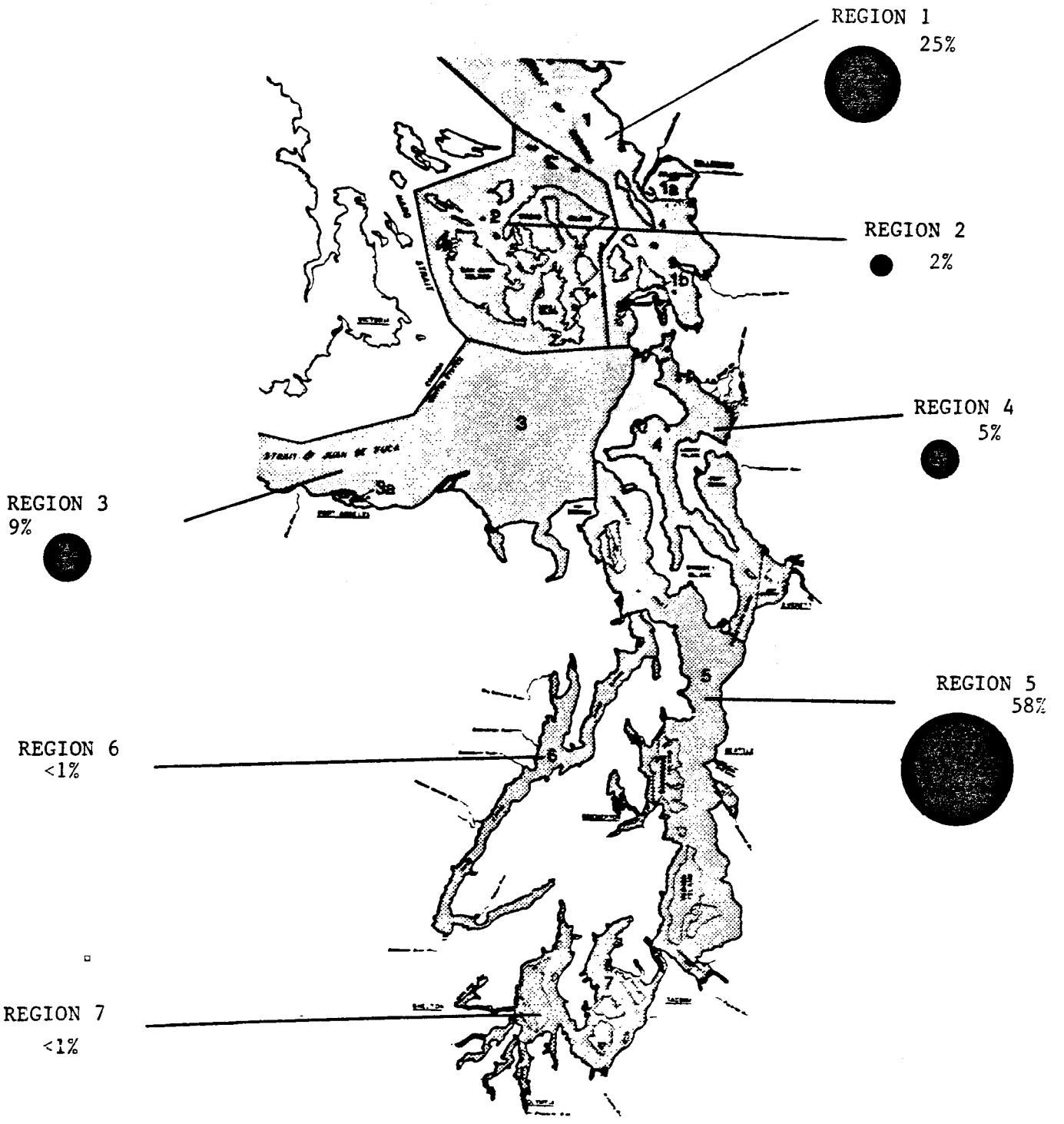


Figure 12

DISTRIBUTION OF DOVER SOLE HARVEST IN PUGET SOUND

(based on WDF statistics)

2.2.8 English Sole (Paraphrys vetulus)

Geographic Range

These fishes are found from Baja, California through the Gulf of Alaska (Hart 1973). They are abundant in all regions of Puget Sound except Hood Canal (Solomon and Mills, 1983).

Biology

English sole is the most abundant species of flatfish in Puget Sound. Spawning, which takes place in winter and early spring, has been recorded in Elliott Bay, Discovery Bay, East Sound and the Gulf of Georgia (Solomon and Mills, 1983). Eggs are pelagic but sink several hours before hatching. Larvae are pelagic for a time, and then become demersal. While fish are young they are often found in very shallow water. As they age, they prefer deeper water (400 ft) over flat mud bottom (Hart, 1973; Solomon and Mills, 1983). This species displays a seasonal depth migration, utilizing shallow waters in summer and deeper waters in winter (Hart 1973). These fishes feed mostly on molluscs, polychaetes,crustaceans and brittle stars, all of which food species are vulnerable to particulate and chemical pollutants (Hart, 1976). Hart (1973) indicates that a key factor in survival of young is development time and transport from spawning grounds to nursery grounds.

Males are much smaller than females, seldom reaching 12 inches in length. Females generally weigh under three pounds and are under 20 inches in length (Pedersen and DiDonato, 1982).

Commercial Fisheries - Present And Potential

The average annual (1979-1983) harvest of English sole is over 1,500,000 pounds with a value of almost $500,000 (1979-1983). English sole are commercially harvested by trawl fishing in all parts of the Sound. The northern and central Sound provides the largest components of the fishery, however, with combined average landings from 1976-1981 in these regions of over 700,000 pounds. In the Straits and Admiralty Inlet regions (Region 3), an average of 87,500 pounds was harvested annually between 1979 and 1983. In the southern Sound (Region 7) English sole are infested by a parasite (Philometra americana) and therefore are unfit for human consumption. The average 323,000 pounds harvested in this region annually (1979-1983) are used as animal food.

In all areas except the central Sound, the harvest levels have been stable for a number of years, and the species is considered fully utilized. In the central Sound, the harvest levels have been slowly declining and lower harvest levels are being recommended (Pedersen and DiDonato, 1982).

Recreational Harvest

The majority of recreational fishing from boat anglers occurs in central Puget Sound. In this area, an average of 1,000 pounds of fish were harvested annually between 1976 and 1980 (Pedersen and DiDonato, 1982).

Summary Points - English Sole

- Most fish are harvested in Regions 1, 2, 4, and 5 (Figure 13).
- A key factor in survival of young is development time and transport to nursery grounds.
- The five year average (1979-1983) annual harvest throughout the Sound was 1.5 million pounds with an average value of almost $500,000.
- Important contacts and sources of information include:

WDF	Mark Pedersen
	Bill Clark
	Dale Ward
	Lee Hoines
	Mary Lou Mills
	R. Costello
	Greg Hueckel

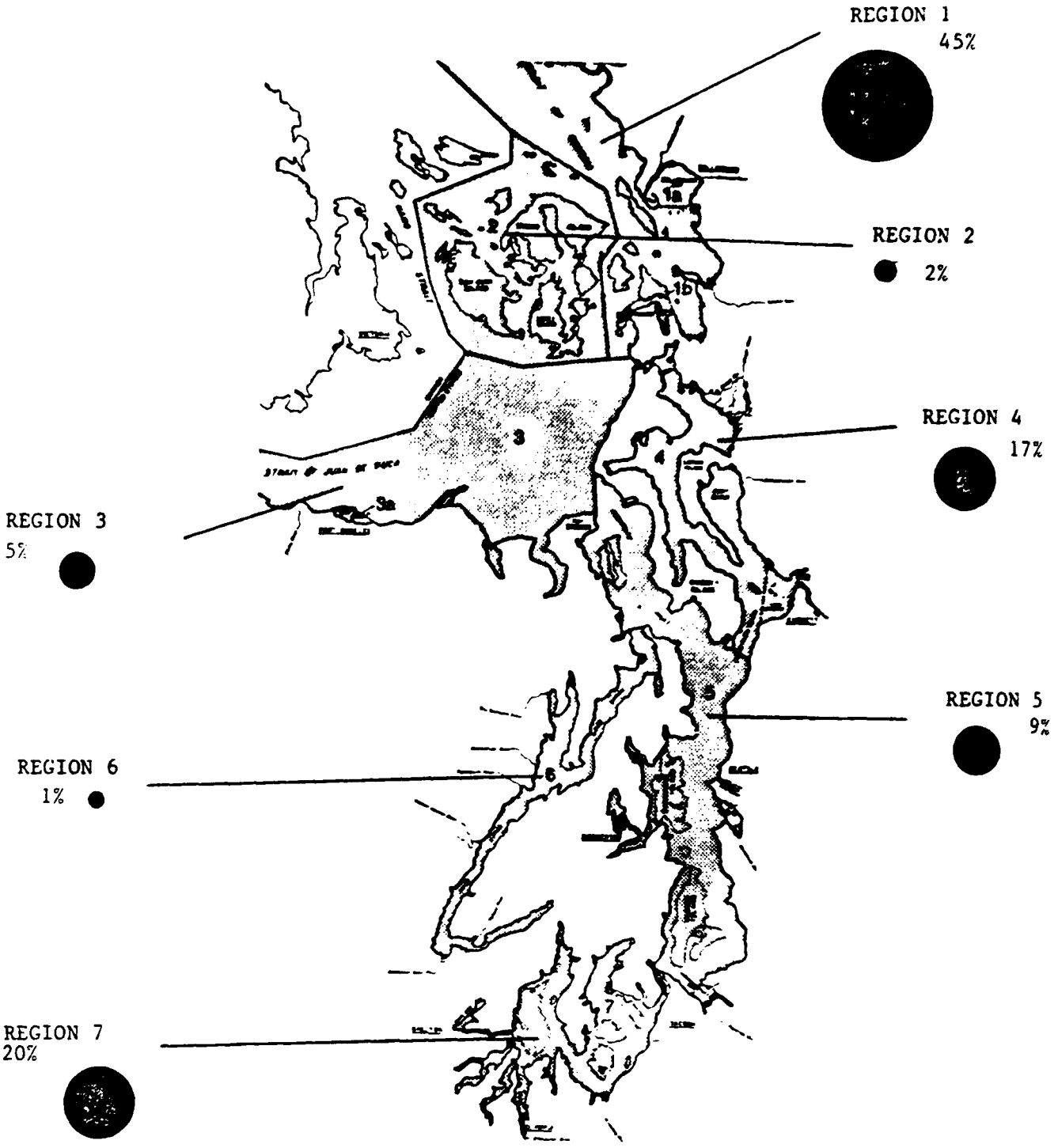


Figure 13

DISTRIBUTION OF ENGLISH SOLE HARVEST IN PUGET SOUND

(based on WDF statistics)

2.2.9 Rock Sole (Lepidopsetta Bilineata)Biology

Rock sole are a shallow water (0-120 ft) species of flatfish preferring flat sand and mud bottom regions. Spawning takes place between February and April in Puget Sound; Killisut Harbor is a known spawning area (Solomon and Mills, 1983). Eggs are demersal and adhesive. The larvae develop in shallow areas. Adult fish feed on benthic invertebrates and small bottom dwelling fish (Hart, 1973). Females are usually larger than males and may grow to 20 inches and four pounds (Pedersen and DiDonato, 1982).

Geographic Range

This species occurs from southern California, throughout the Pacific Rim to Korea and the Sea of Japan (Hart, 1973). In Puget Sound it is abundant only in the northern Sound and the Straits/Admiralty Inlet region (Solomon and Mills, 1983).

Commercial Fishery - Present and Potential

The average annual (1979-1983) harvest of rock sole in Puget Sound is over 250,000 pounds with a value of over $70,000 (1979-1983). The primary regions of trawl fishing for rock sole are in the northern Sound (Region 1) and the Straits/Admiralty Inlet area (Regions 3 and 5). Average annual landings in 1979-1983 in these regions were 140,000 pounds and 70,000 pounds, respectively. There is some directed trawl effort for this species on the west side of Protection Island and near Port Gamble and in the Gulf of Georgia. The peak catch is in the winter months, although the fishery continues year-round (Pedersen and DiDonato, 1982).

Recreational Fishery

The rock sole is fished recreationally by boat and from fishing piers. The bulk of this fishery during 1976-1980 took place in the central Sound (Regions 4 and 5) with 12,000 pounds harvested annually.

Summary Points - Rock Sole

- Primary harvest areas are in Regions 1 and 3 (Figure 14).
- The five year average annual harvest throughout the Sound was over 250,000 pounds with a value of over $70,000.

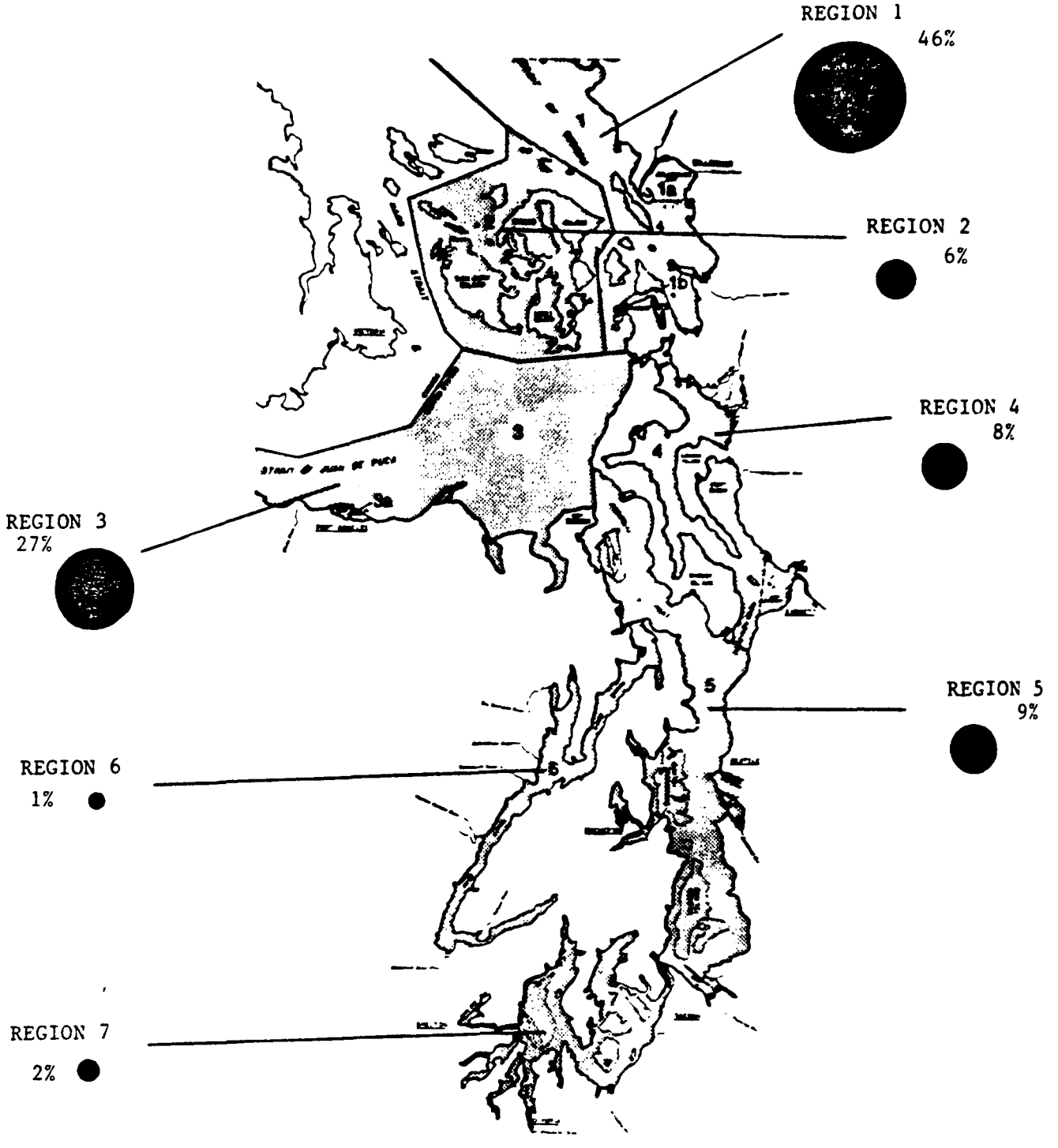


Figure 14

DISTRIBUTION OF ROCK SOLE HARVEST IN
PUGET SOUND

(based on WDF statistics)

- Important contacts and sources of information include:

WDF	Mark Pedersen
	Bill Clark
	Dale Ward
	Lee Hoines
	Mary Lou Mills
	R. Costello
	Greg Hueckel

2.2.10 Sand Sole (Psettichthys melanostictus)

Geographic Range

Sand sole are found from southern California to the Bering Sea (Hart 1973). In Puget Sound, it is abundant only in the northern end of the Sound (Regions 1, 2, and 3), although it is common in all areas except Hood Canal (Region 6).

Biology

The sand sole is a shallow water (30-300 ft) flatfish preferring sandy bottoms. Spawning takes place from January to March; Bellingham Bay is a known spawning area (Solomon and Mills, 1983). Eggs are pelagic and hatch in about five days. These fish feed primarily on small bottom fishes, crustaceans, polychaete worms and molluscs (Hart, 1973). Little is known of its migratory behavior (Pedersen and DiDonato, 1982).

Commercial Fishery - Present and Potential

The average annual (1979-1983) harvest of sand sole in Puget Sound is almost 150,000 pounds with a value of $50,000. The bulk of the commercial trawl fishery takes place in the Gulf of Georgia (Region 1) during the winter months. Sand sole are also harvested in Boundary Bay and Birch Bay. Annual harvest in 1979-1983 in the northern Sound averaged 79,000 pounds while the average harvest in all other regions combined was 58,000 pounds.

Recreational Harvest

Limited amounts of sand sole are recreationally fished throughout the Sound. Average annual catch 1976-1980 was 3,000 pounds in the central Sound and about 1,000 pounds in all other regions (Pedersen and DiDonato, 1982).

Summary Points - Sand Sole

- Most sand sole are harvested in Region 1 (Figure 15).
- The five year average annual harvest throughout the Sound was approximately 150,000 pounds with a value of about $50,000 (1979-1983).
- Important contacts and sources of information include:

WDF	Mark Pedersen
	Bill Clark
	Dale Ward
	Lee Hoines
	Mary Lou Mills
	R. Costello
	Greg Hueckel

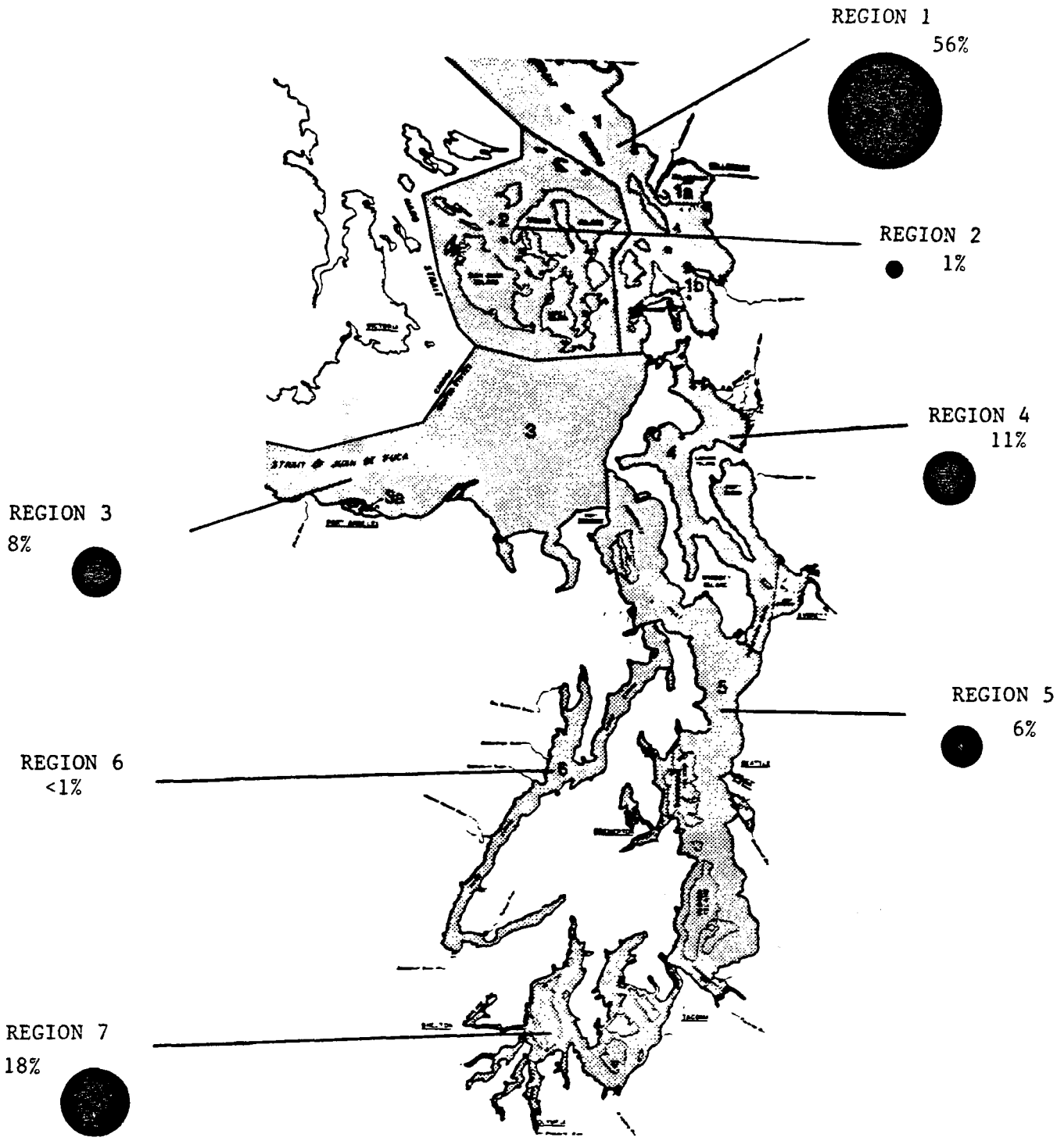


Figure 15

DISTRIBUTION OF SAND SOLE HARVEST IN PUGET SOUND

(based on WDF statistics)

2.2.11 Lingcod (Ophiodon elongatus)

Geographic Range

Lingcod are found from southern California to the northern Gulf of Alaska. They are found throughout Puget Sound. The species does not migrate extensively.

Biology

Lingcod, a member of the Hexagrammidae family, is a valuable component of the recreational and commercial fisheries of Puget Sound. Adult lingcod are found in rocky areas with strong currents in water depths from intertidal to about 600 feet (Bargmann, 1982).

Spawning takes place in late winter and early spring. Spawning has been reported from the intertidal zone to about 100 foot depths. Eggs are demersal in large adhesive masses that are guarded by male fish until they hatch in 1-2 months. Larvae occur in surface waters and are widely dispersed by currents. In June, following approximately two months in surface waters, the larvae become demersal (Bargmann, 1982). During the next six months they inhabit sandy estuarine regions (Pedersen and DiDonato, 1982).

Commercial Fishery - Present And Potential

The average annual (1979-1983) harvest of lingcod is over 200,000 pounds with a value of over $50,000. Landings of lingcod have steadily decreased since 1961 (670,755 pounds) although 1970 and 1980 showed slightly higher landings. Most of the commercial harvest occurs in the Strait of Georgia (Region 1) and in the Strait of Juan de Fuca (Region 3). According to Bargmann (1982) 96% of the Puget Sound catch (1950-1978) came from Regions 1, 2, and 3. Peak landings are August through October (Pedersen and DiDonato, 1982). Since 1980, the season on lingcod has been closed from December 1 to April 14 in an effort to prevent overfishing.

Recreational Harvest

Recreational fishing for lingcod takes place using hook and line or spears. The regions utilized in Puget Sound by recreational fishermen for lingcod are the same as those used by commercial fishermen, although somewhat more recreational than commercial fishing takes place in the inner Sound for this

species. Few data are available on the spearfishing harvest of lingcod. This method of collecting fish has become very popular since the 1960's and lingcod is the most desired fish in this sport (Bargmann, 1982). The bulk of the recreational harvest takes place in the spring months.

Summary Points - Lingcod

- Most are harvested in Regions 1 and 3 (Figure 16).
- The five year average annual harvest throughout the Sound was over 200,000 pounds valued at over $50,000 (1979-1983).
- These fish prefer areas of rocky bottoms with strong currents.
- Important contacts and sources of information include:

WDF	Mark Pedersen
	Bill Clark
	Dale Ward
	Lee Hoines
	Mary Lou Mills
	R. Costello
	Greg Hueckel

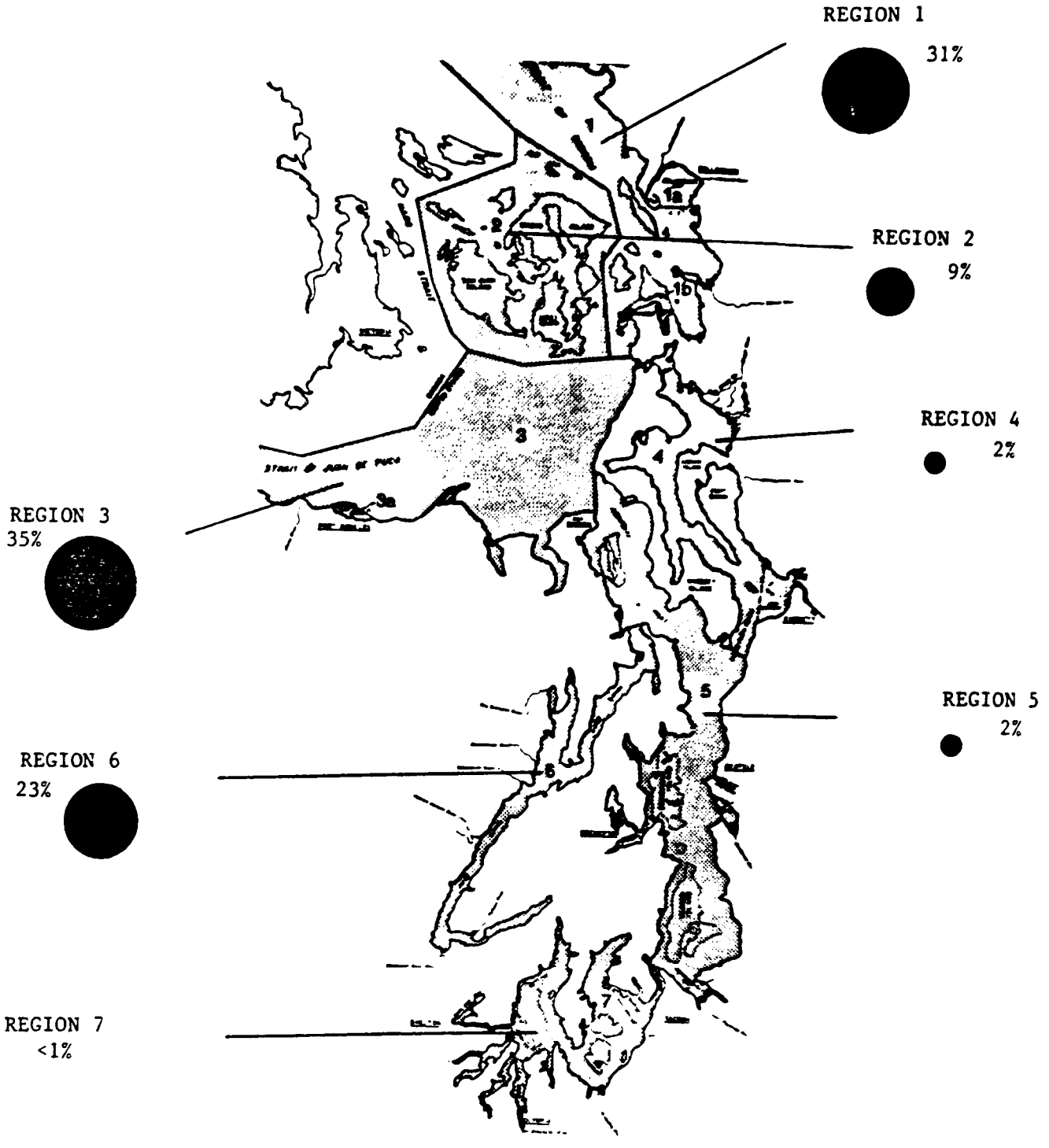


Figure 16

DISTRIBUTION OF LING COD HARVEST IN PUGET SOUND

(based on WDF statistics)

2.2.12 Rockfishes (Sebastes spp.)

Geographic Range

Rockfish are found from southern California to the Gulf of Alaska. In Puget Sound, they are most common in the northern and central Sound (Regions 1,4, and 5) and in the Straits/Admiralty Inlet area (Regions 3 and 5).

Biology

There are eight species of rockfish which make up the bulk of the commercial fishery for this group in Puget Sound. This is a varied group of fish, all of which prefer rocky bottom habitat in up to 500 feet of water. Little is known about the life history of most of these species. They release pelagic embryos near their preferred habitat. Most feed on small fish, molluscs and crustaceans. Although most of the species range from 12-20 inches in length and from 2-8 pounds, the bocaccio and the yellow rockfish grow to over 15 pounds (Pedersen and DiDonato, 1982).

Commercial Fishery - Present and Potential

The average annual (1979-1983) harvest of rockfish in Puget Sound is 225,000 pounds with a value of almost $50,000. The commercial fishery of rockfish utilizes mainly trawling to catch fish and most of the catch is incidental to other species. A directed fishery for quillback and copper rockfish occurs in Admiralty Inlet (Region 3) (Pedersen and DiDonato, 1982). Most fish are harvested in Regions 1 and 3. The average annual harvest between 1979-1983 in Region 1 was 47,000 pounds and 97,000 pounds in Region 3.

Recreational Fishery

Most of the rockfish harvested in Washington State are sport fish. This fishery has undergone a tremendous expansion in recent years. In 1980, 345,000 pounds of rockfish were harvested by boat anglers in Regions 1 and 2 alone. In Regions 4 and 5, 244,000 pounds of rockfish were harvested by boat anglers (Pedersen and DiDonato, 1982).

Summary Points - Rockfish

- Regions 1 and 3 have the largest commercial and recreational catch in the Sound (Figure 17).
- The five year average harvest (1979-1983) was 225,000 pounds with a value of almost $50,000.
- Important contacts and sources of information include:

WDF	Mark Pedersen
	Bill Clark
	Dale Ward
	Lee Hoines
	Mary Lou Mills
	R. Costello
	Greg Hueckel

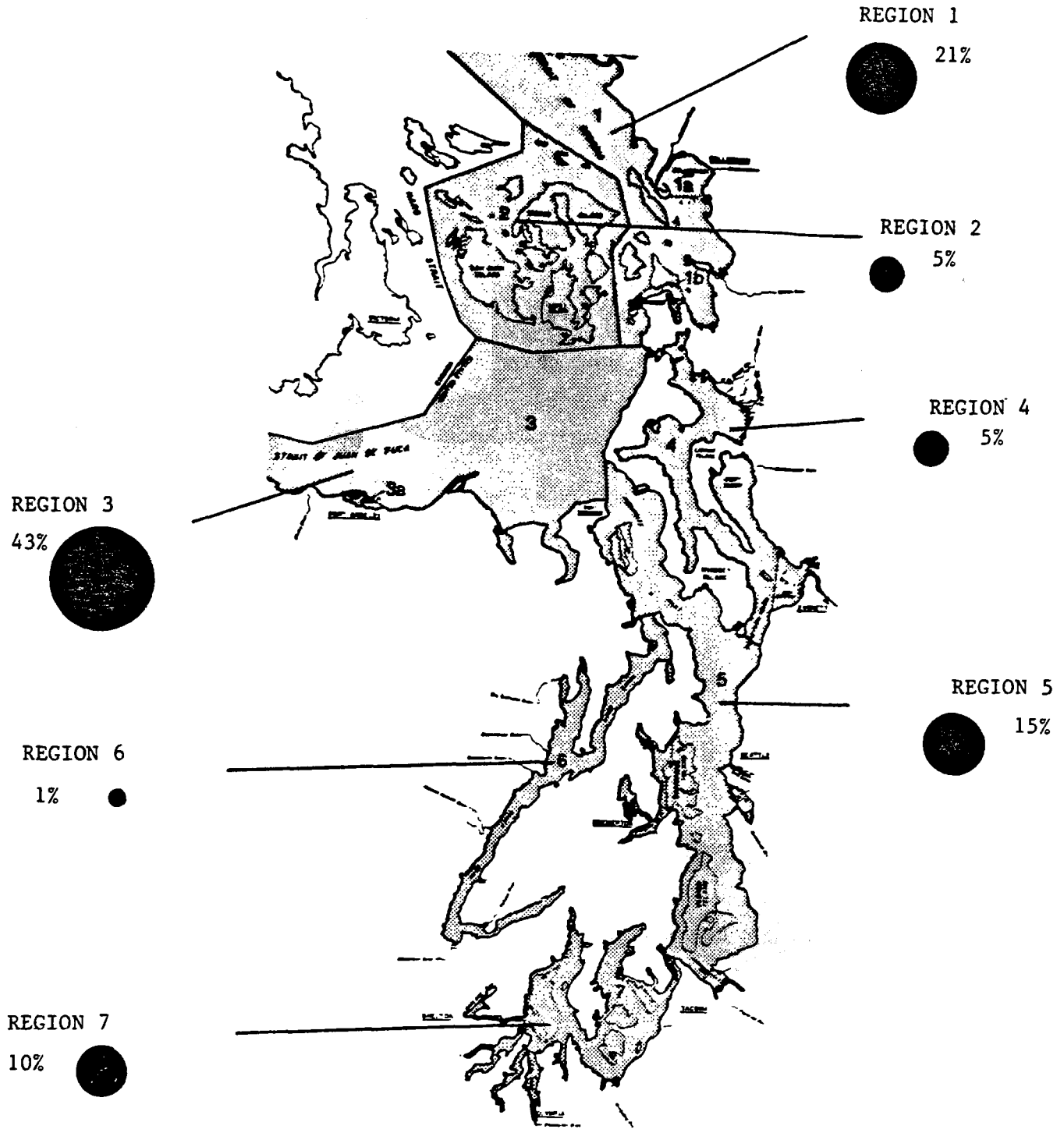


Figure 17

DISTRIBUTION OF ROCKFISH HARVEST IN
PUGET SOUND

(based on WDF statistics)

2.2.13 Miscellaneous Baitfish

Baitfish, other than herring, that are utilized to some extent in Puget Sound include surf smelt (Hypomesus pretiosus), northern anchovy (Engraulis mordax) and candlefish (Ammodytes hexapterus). The only commercial fishery of any size is the surf smelt fishery. This species is also an attractive recreational fish.

Biology

Surf or silver smelt, like herring, spawn at specific locations within Puget Sound. Port Orchard and Saratoga Passage are important spawning sites. Spawning times vary by area and may occur all year-round. These fish require coarse sand-fine gravel (1-8 mm) sediments for spawning in the upper intertidal zone. Eggs are adhesive to gravel and are buried in the upper few centimeters of gravel. The smelt is a shortlived species (1-3 years), and the bulk of the spawning population is two years old (Trumble, 1983).

Known Water Quality Needs and Sensitivities

The requirement for spawning bed sediment grain size is critical, especially since these fish utilize the same spawning areas year after year.

Commercial Fishery - Present and Potential

The average annual (1979-1983) harvest of surf smelt in Puget Sound is about 53,000 pounds with a value of almost $18,000. Commercial harvest of surf smelt occurs through beach seining. Over 60% of the catch is from the Saratoga Passage - Port Susan area (Region 4) and southern Hood Canal (Region 6) and has been consistent from the last decade. Average annual landings (1979-1983) in Region 4 were 26,000 pounds and were 5,200 pounds in Region 6.

Recreational Fishery

Recreational fishing is carried out using dip nets and by jigging. Estimates of recreational catch are not available (Trumble 1983).

Summary Points - Baitfish

- Most smelt are harvested in Regions 1, 4, and 6 (Figure 18).
- The availability of spawning beaches with appropriate sediment sizes appears to be critical.
- The annual average harvest from 1979-1983 of surf smelt in the Sound was about 50,000 pounds for an average annual value of almost $18,000.
- Important contacts and sources of information:

WDF	Ken Trumble
	Dale Ward
	Lee Hoines
	Greg Hueckel
	R. Costello

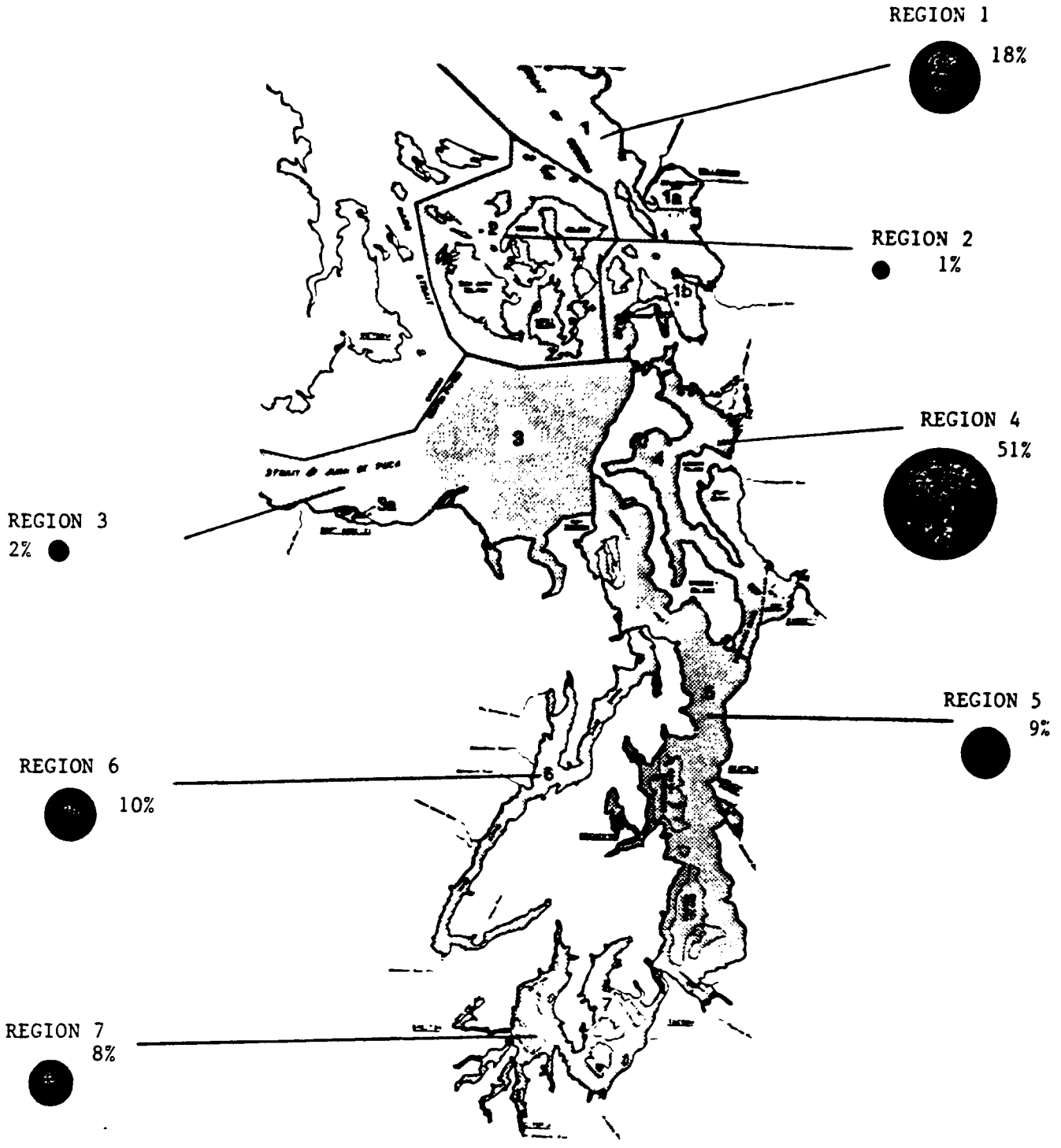


Figure 18

DISTRIBUTION OF SILVER SMELT HARVEST IN PUGET SOUND

(based on WDF statistics)

2.2.14 Surfperches

Biology

Two species of perch are commercially and recreationally utilized in Puget Sound, the striped seaperch (Embiotoca lateralis) and the pile perch (Rhacochilus vacca). Both species occur in very shallow water (up to 100 ft) over various substrates (Solomon and Mills, 1983). They are small fish averaging about a foot in length and 1-2 pounds in weight. They give birth to fully developed young in the spring. Pile perch commonly feed on mussels, clams and barnacles, while seaperch feed on a variety of amphipods, worms and crustacean larvae (Pedersen and DiDonato, 1982).

Commercial Fishery - Present and Potential

The average annual (1979-1983) harvest of surfperches in Puget Sound is 130,000 pounds with a value of $40,000. The fishery for perches utilizes beach seines. Most of the fishery takes place in Regions 5, 6 and 7. The same five year average catches for all species of perch combined in these regions was 88,000 lb, 21,000 lb and 45,000 lb, respectively.

Recreational Fishery

There are few data available for the recreational fishery. Surfperches are caught using beach seines and by pier anglers. Most of the fishing for this species occurs in summer from manmade structures (Pedersen and DiDonato, 1982).

Summary Points - Surfperches

- The greatest harvest takes place in Regions 5, 6, and 7.
- Five year average annual harvest throughout the Sound (1979-1983) was about 130,000 pounds with a value of about $40,000.
- Important contacts and sources of information include:

WDF	Mark Pedersen
	Bill Clark
	Dale Ward
	Lee Hoines
	Mary Lou Mills
	R. Costello
	Greg Hueckel

2.2.15 Spiny Dogfish (Squalus acanthias)

Geographical Range

The spiny dogfish occurs from Baja, California to the Bering Sea. They are common throughout Puget Sound and have no particular preferred habitat (Solomon and Mills, 1983).

Biology

The dogfish, an elasmobranch which is common in Puget Sound, is found in up to 700 ft of water. They are very long-lived fish, with females maturing between 14 and 18 years. The young are born alive after a 22-24 month gestation period. These fish eat a very wide variety of organisms. At least 27 species of fish and 13 species of invertebrates have been documented as foods (Hart, 1973). According to Pedersen and DiDonato (1982), dogfish may school when feeding. The fish in the Sound appear to migrate little and may be an indigenous population (Hart, 1973; Pedersen and DiDonato, 1982).

Commercial Fishery - Present and Potential

The fishery for spiny dogfish is conducted primarily using trawls, set nets and set lines. Over the last eight years set lines have become the major fishing type. About sixty percent of the total annual dogfish harvest in the Sound takes place in Regions 1 and 2 at a combined annual average of 3.1 million pounds. A total annual average of 2.1 million pounds are harvested in the rest of the Sound.

Recreational Fishery

Although there is some sport fishery for this species, it is not large. According to Hoines et al. (1980), 5,200 dogfish were taken in all of Washington State waters in 1980.

Summary Points - Spiny Dogfish

- Most harvest takes place in Regions 1 and 2 (Figure 19).
- The five year average annual harvest (1979-1983) was over 5,000,000 pounds with an average value of about $500,000.

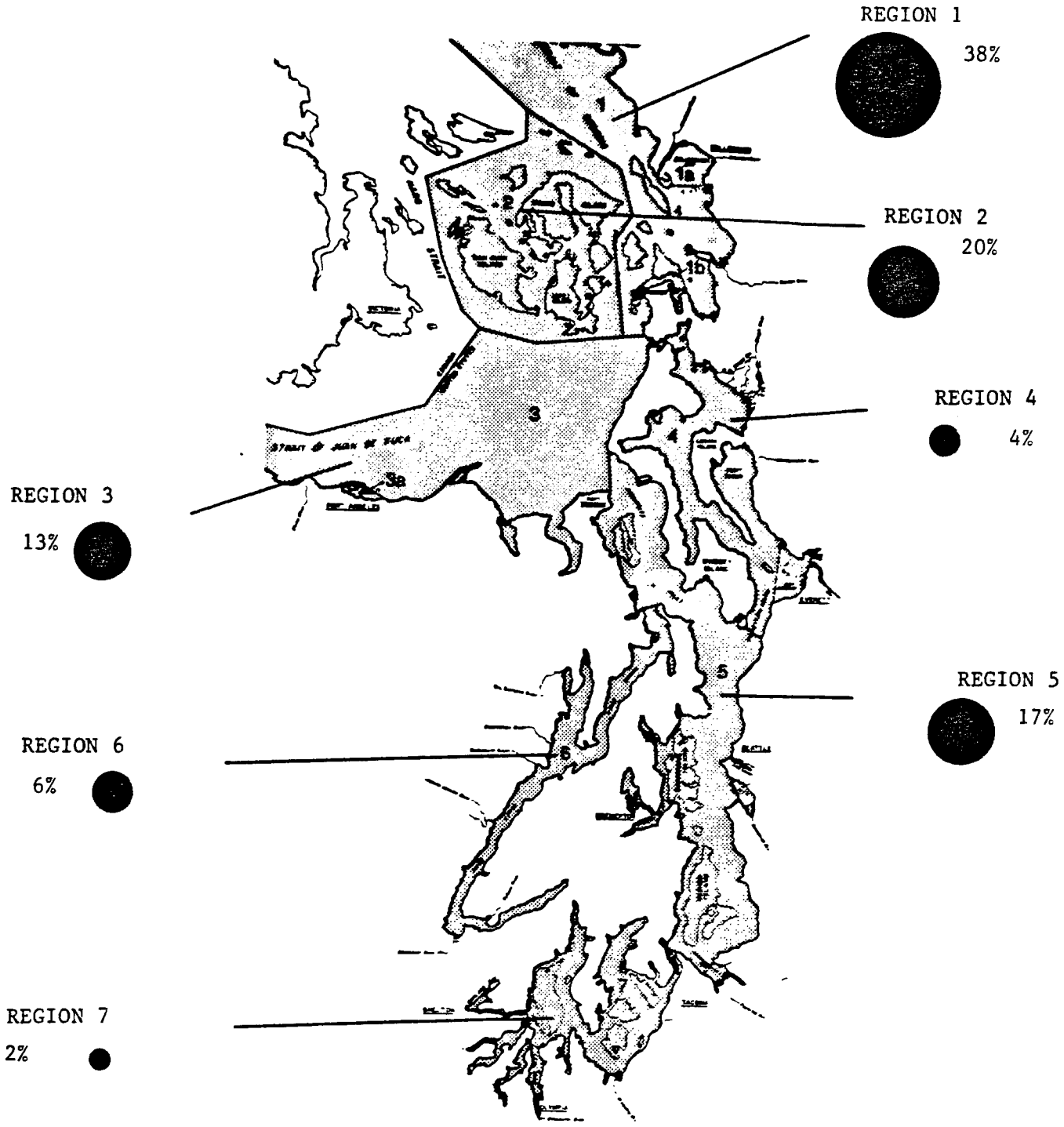


Figure 19

DISTRIBUTION OF SPINY DOGFISH HARVEST IN PUGET SOUND

(based on WDF statistics)

- Important contacts and sources of information include:

WDF	Mark Pedersen
	Bill Clark
	Dale Ward
	Lee Hoines
	Mary Lou Mills
	R. Costello
	Greg Hueckel

2.2.16 Miscellaneous Fish

There are a number of fish species harvested in Puget Sound in low numbers or incidental to other fisheries. These include mackeral, Pacific halibut, sablefish, white sea bass, greenling, ratfish, sculpin, mud shark and skate. Some of these species, such as Pacific halibut and sablefish, occur in much greater numbers and form a larger portion of the Washington State coastal fishery.

2.3 PUGET SOUND SHELLFISH RESOURCES

The shellfish of Puget Sound contribute extensively to commercial and recreational fisheries. By the term "shellfish" is meant the molluscs, echinoderms, and crustaceans that are commercially or recreationally exploited. Major Puget Sound shellfish include hard and softshell clams, crab, shrimp, oysters, and geoducks. Other shellfish harvested include scallops, sea urchins and sea cucumbers, octopus, and squid.

In 1982, commercial shellfish landings in Puget Sound were approximately 8.5 million pounds valued at over three million dollars. Figure 20 depicts the commercial shellfish harvest for years 1972 through 1982 in Puget Sound. Geoducks, hardshell clams and oysters compose the greatest proportion of the harvest in terms of pounds while shrimp, oysters, and crabs yielded the highest price per pound. Recreational harvesting of shellfish include hand digging, diving and sport shrimp and crab pots. WDF estimates that over 500,000 recreational shellfishing trips are made annually in Puget Sound.

Recent closures of shellfish beds as a result of water quality degradation are a cause for concern when considering the current and potential values of shellfish resource. The closures or decertifications are primarily a result of bacterial contamination which is from urban run-off or from municipal, industrial or private sewage treatment plant outfalls. At the present time, the Washington Department of Ecology is working closely with private and public officials to develop policies and procedures to reverse the alarming trend of shellfish decertification. Table 2 presents a list of Puget Sound sites currently restricted from shellfish harvesting. Plans for protecting shellfish habitat include water quality surveys in appropriate areas, study of the nonpoint pollution sources that contribute to shellfish contamination, and reduction or elimination of point source discharges in critical areas.

The following is a discussion of the major shellfish resources found within Puget Sound. Figure 21 depicts the horizontal and vertical distribution of Puget Sound clams, mussels, and oysters. Each description of a species or group of organisms includes a brief summary of its biology, habitat preference, geographic range, and pertinent commercial and recreational fishery data. Information concerning any critical life stages or potential

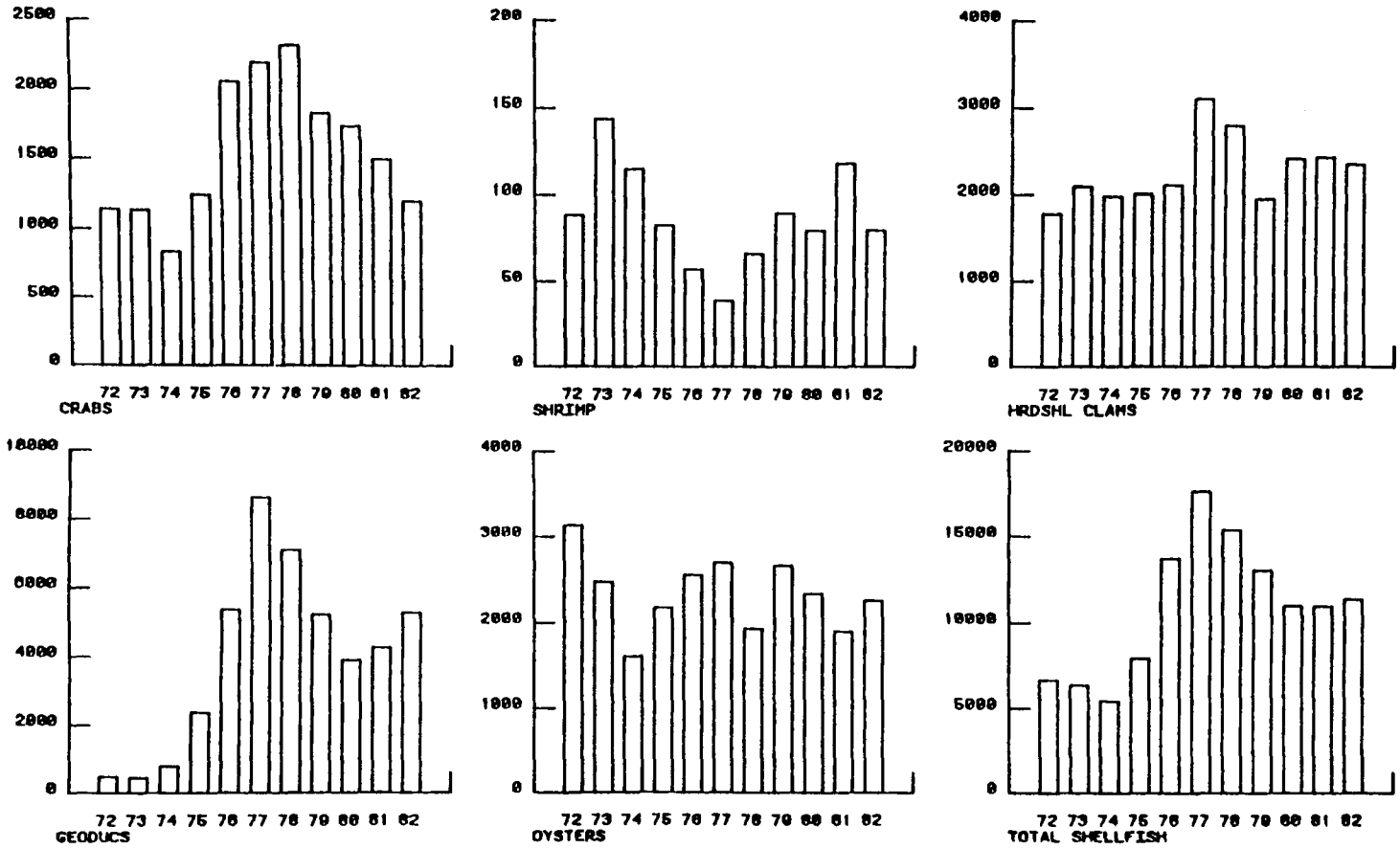


Figure 20

COMMERCIAL PUGET SOUND SHELLFISH CATCH 1972-1982
(pounds of shellfish in 1000s)

Source: WDF, 1983

Table 2

WASHINGTON DECERTIFIED AND UNCERTIFIABLE CULTURE AREAS

Date	Location	Cause
Decertified		
1950s	Dyes Inlet (all)	Bremerton STP
1950s	Sinclair Inlet (all)	Bremerton STP
1950s[a]	Oakland Bay/Hammersly Inlet (in the vicinity of Shelton)	Shelton STP
1950s	Budd Inlet (all)	STP, Deschutes River, Non-Point
1960s	Liberty Bay (east side, near Poulsbo)	Poulsbo, STP, Marina
1960s	Grays Harbor (about ¼, basically the eastern lobe)	STPs, Mills
1960s	Willapa Bay (about 10%, around mouth of Willapa River)	Raymond, South Bend STPs
1968	Port Susan (about 1/3 of the tideflats)	Dairy Runoff in the Stillaguamish, STPs
10/81	Burley Lagoon (all)	Non-Point
03/82	Minter Bay (all)	Non-Point
Conditionally Approved[b]		
03/83	Henderson Inlet (mid-stretch, upper section decertified)	Non-Point
02/83	Lower Eld Inlet	Non-Point
09/83	Penn Cove	STP
Uncertifiable[c]		
	East Shore of Puget Sound from Tacoma to Edmonds, Hartstene Island, North End	STPs, Industrial; Private STP
	East Shore of Vashon Island	STP
	Port Townsend	STP
	Kitsap (near Winslow)	STP
	Appletree Cove (near Kingston)	Sewage Outfall
	Port Gamble	Sewage Outfall
	Everett	STP, Industry, Non-Point
	Bellingham Bay	STP, Mills, Non-Point

[a]Decertified area reduced in 1980 due to installation of secondary treatment.

[b]Closure in effect following a quantity and duration of rainfall determined for a specific site.

[c]Based on review of geoduck beds for lease suitability by WDF and DSHS. This list is not exhaustive.

Source: WDOE, unpub.; J. Lilja, DSHS, pers. comm.

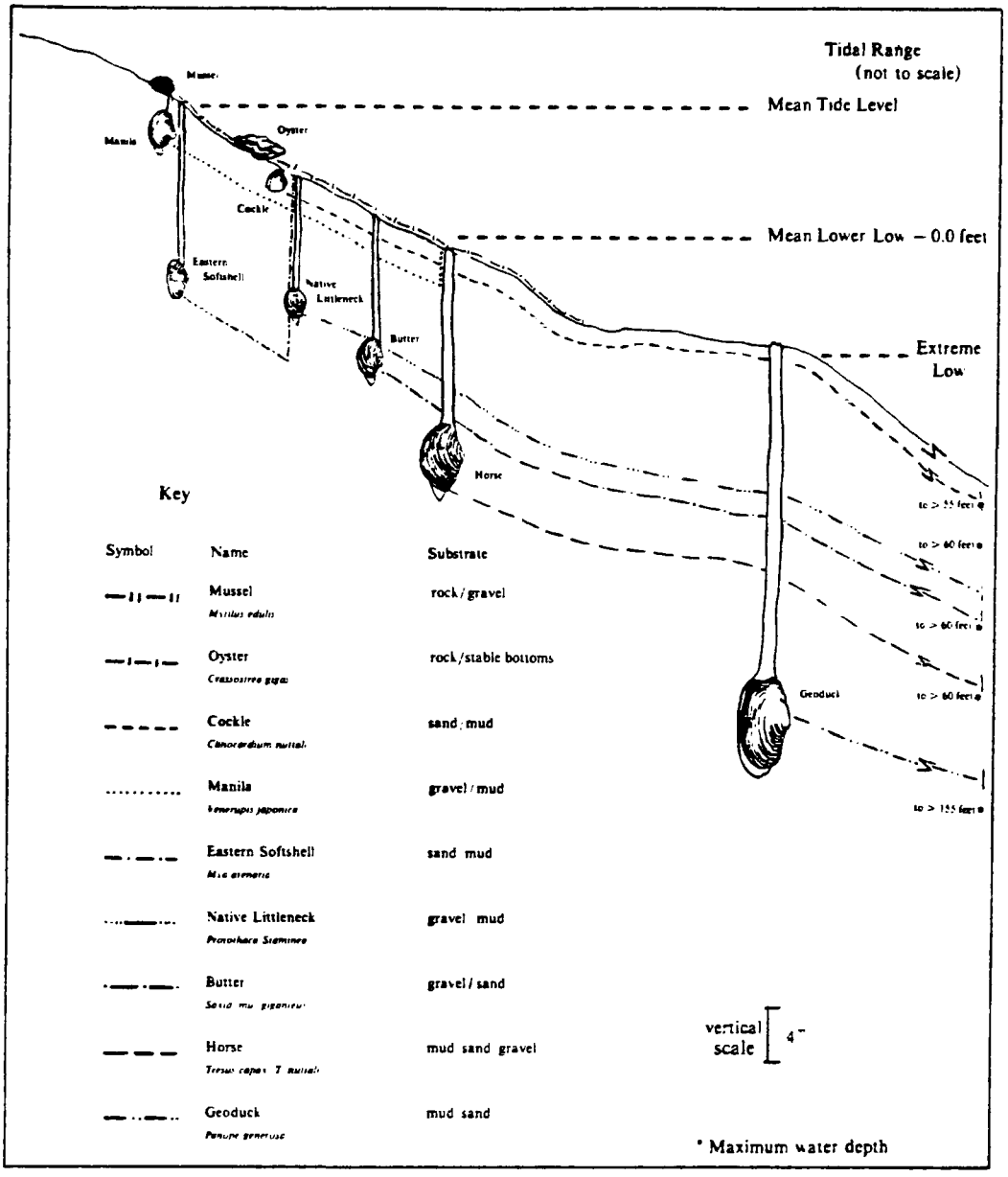


Figure 21

HORIZONTAL AND VERTICAL DISTRIBUTION
OF PUGET SOUND CLAMS, MUSSELS AND OYSTERS

(Magoon and Vining, 1980)

fishery or aquaculture information is included where the supporting data was readily available. It should be stressed that these descriptions represent a cursory summation only. Detailed literature reviews as well as added efforts to contact local experts must be undertaken before enough information on individual shellfish and the entire shellfish resource can be presented or ranked in Puget Sound to meet the needs of resource managers.

2.3.1 Hardshell Clams

Hardshell clam resources in Puget Sound are abundant and provide an important part of the State's commercial and recreational fisheries. Hardshell clams, which include Manila, butter, native littleneck, and horse clams, are found throughout the Sound in intertidal and subtidal areas. Surveys of subtidal waters within the State of Washington have been conducted by the WDF since 1967. Figure 22 illustrates the distribution of major and commercial subtidal clam beds in Puget Sound. Primary subtidal areas for hardshell clams include Island, Jefferson and Kitsap Counties (Regions 3, 4, 5 and 6). Based on these surveys, the subtidal standing crop is estimated to be over 170 million pounds in approximately 5,350 acres. These estimates could increased as more subtidal lands are surveyed. Subtidal harvest of hardshell clams average around 300,000 pounds per year. It is believed that this figure could rise to 2-5 million pounds annually if mechanical harvesting is permitted in more waters and at depths beyond the 25 ft limitation currently imposed.

Goodwin (1980) reported that the abundance and size of subtidal hardshell clam stocks are associated with water depth. Greatest size and abundance occurred in shallow areas, particularly in depths less than 30 feet. Furthermore, the most important beds were found in open water with good current flow.

Intertidal stocks of hardshell clams are more difficult to assess since approximately 60% of all intertidal shoreline is privately owned. Figure 23 presents the distribution of intertidal hardshell clam resources in Puget Sound. Because no standing crop estimates are avilable, this figure may not provide a complete representation of intertidal clam stocks. It is known, however, that intertidal clams comprise the principal component of the commercial hardshell clam harvest. Clam cultivation industries in Washington contribute substantially to the commercial shellfish economy. Clam farms are located throughout Puget Sound, but the major industrial sites are located in southern Puget Sound (Region 7), Hood Canal (Region 6) and Discovery and Sequim Bays (Region 3). Furthermore, many oyster farms will also harvest clams and may select for the production of clams over oysters depending upon the current market conditions.

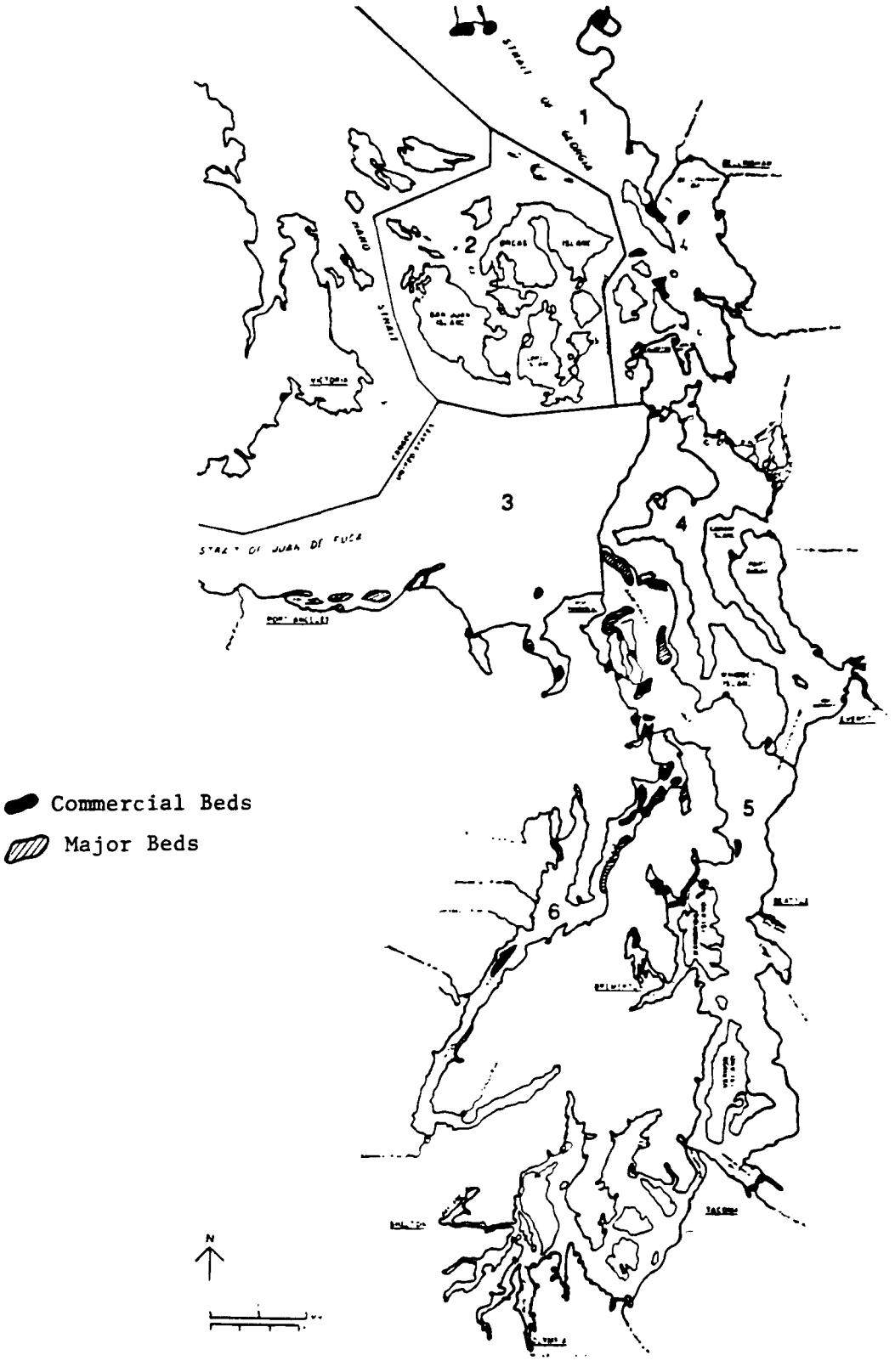


Figure 22

DISTRIBUTION OF SUBTIDAL HARDSHELL CLAMS
IN PUGET SOUND

(OIC, 1981)

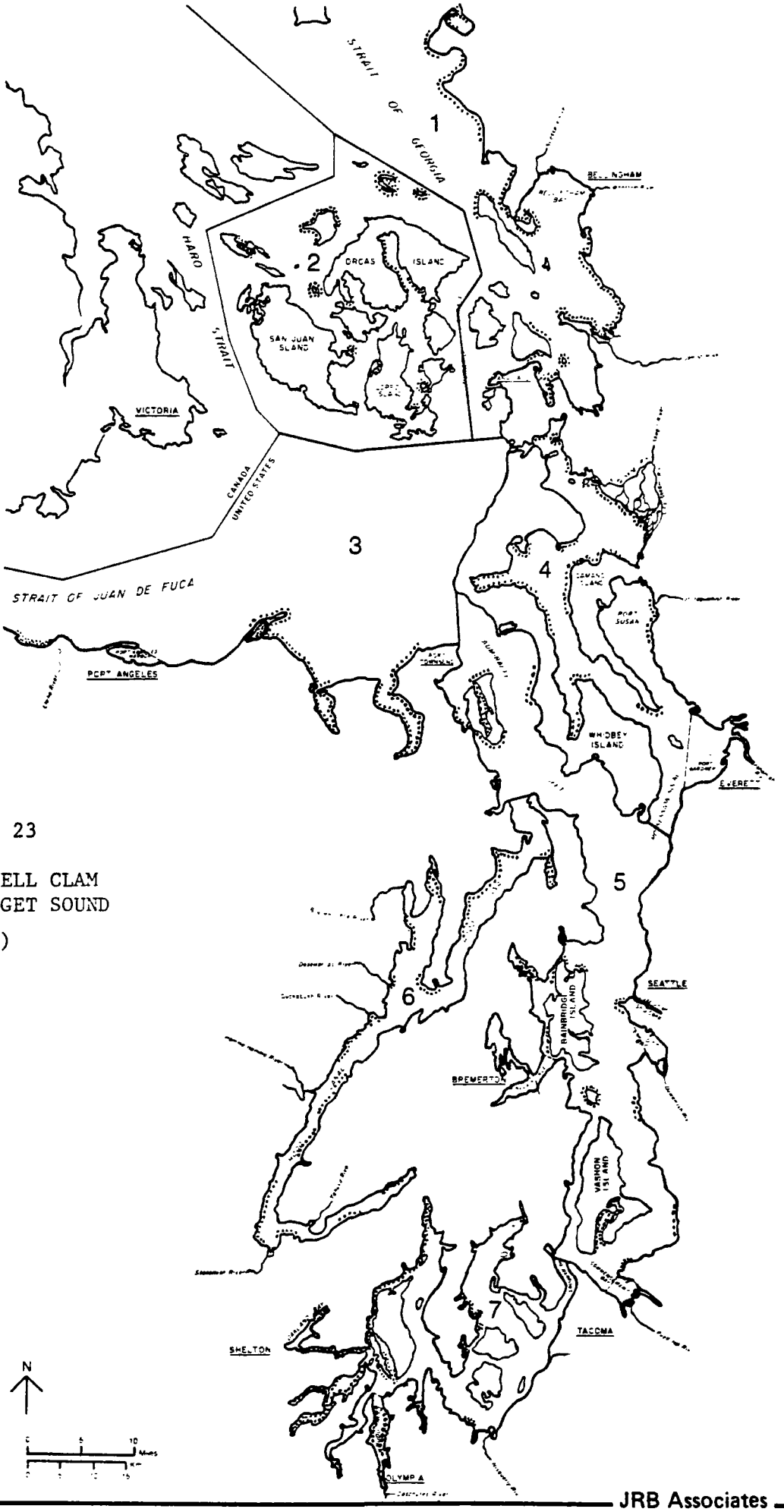


Figure 23

INTERTIDAL HARDSHELL CLAM
DISTRIBUTION IN PUGET SOUND

(OIC, 1981)

Little information is available on recreational harvesting of hardshell clams. WDF surveys are performed only in that portion of Puget Sound east of Dungeness Spit and only during April through August. Tables 3 and 4 show the estimated 1975-1980 personal-use harvest (number of trips and pounds harvested) of hardshell clams by region in Puget Sound.

Clams which are bivalve molluscs are sedentary bottom dwellers. Therefore they are particularly vulnerable to water quality changes and physical alterations of their habitat. Bivalves found in shallow water marine regions are primary consumers of short food chains and feed chiefly on small particulate material. Except as prey organisms, bivalves do not generally reflect interdependent associations with other marine organisms. Predation of bivalves, however, is an important factor in their ecology. Several species of waterfowl, larids, fish and other marine invertebrates are important predators of molluscs.

Table 5 lists the physical, biological and environmental parameters effecting clam and mussel resource distribution. Stanley (1973) summarized the most vital environmental factors effecting bivalves (Figure 24). He concluded that water movement was the most important factor affecting the distribution of shallow water, soft-bottom bivalves because of its effect on the substrate and food availability. In hard-bottom bivalve communities, both the substrate character and water movement are critical environmental factors.

Suspended sediment and large accumulations of organic matter can impair clam growth and survival. Spat are more sensitive to silt deposits than adult clams. Poor water quality (turbidity, sedimentation, and pollutants) can cause clams to reduce pumping or shut down. Smaller clams with higher respiratory rates appear most sensitive to poor water quality conditions (Mottet 1980).

The major hardshell clam species include: Manila, butter, native littleneck and horse clams. Each species is described in more detail in the following sections.

Table 3

ESTIMATED PERSONAL-USE HARVEST EFFORT OF HARDSHELL CLAMS BY REGION
(user trips in 1000s)

Region and Area	1975	1976	1977	1978	1979	1980	Average
Region 1							
Gulf of Georgia	49.0	46.5	46.5	53.1	17.6	8.2	
Bellingham Bay	12.2	6.4	1.4	1.1	1.8	0.8	
Samish Bay	9.2	13.6	12.1	25.1	5.8	4.3	
Padilla & Fidalgo Bays	18.2	5.7	7.6	8.2	4.7	3.8	
	88.6	72.2	67.6	87.5	29.9	17.1	60.5
Region 2							
N. San Juan Islands	3.2	2.1	2.6	4.4	5.8	0.9	
S. San Juan Islands	30.0	15.2	20.6	11.4	18.0	2.5	
	33.2	17.3	23.2	15.8	23.8	3.4	19.5
Region 3							
Saratoga Passage	105.5	116.0	110.7	141.1	0.1	19.3	
Dungeness Bay	31.9	34.0	34.0	50.0	15.9	24.1	
	137.4	150.0	144.7	191.1	16.0	43.4	113.8
Region 4							
Port Susan	5.8	4.2	7.5	20.4	7.1	6.6	8.6
Region 5							
Admiralty Inlet	42.7	56.1	72.2	91.9	12.4	71.3	
Port Gardner & Useless Bay	32.9	41.4	48.0	53.1	7.5	25.1	
Kingston & Port Madison	36.6	48.3	74.6	44.6	21.6	32.5	
Port Orchard	30.7	25.8	28.4	41.8	13.9	25.0	
Vashon/Commencement Bay	47.5	38.6	38.3	19.9	19.4	35.5	
	190.4	210.2	261.5	251.3	74.8	189.4	196.3
Region 6							
Hood Canal (upper)	62.2	83.5	98.5	30.7	40.1	45.8	
Hood Canal (central)	57.5	65.0	79.7	36.1	43.0	43.7	
Hood Canal (lower)	60.0	56.3	60.4	33.9	48.7	44.9	
	179.7	204.8	238.6	100.7	131.8	134.4	165.0
Region 7							
Nisqually-Fox Islands	8.4	17.1	11.3	9.6	9.5	31.2	
Carr Inlet	21.4	17.0	25.0	13.8	18.4	36.1	
Case Inlet	15.8	5.1	5.3	14.5	10.5	15.0	
Budd, Eld, Totten Inlets	17.0	11.6	13.2	8.5	9.7	15.2	
	62.6	50.8	54.8	46.4	48.1	97.5	60.0
TOTAL:	697.7	709.5	797.9	713.2	331.5	491.8	623.7

Source: Hoines et al., 1980

Table 4

ESTIMATED PERSONAL-USE HARVEST OF HARDSHELL CLAMS BY REGION
(in 1000s of pounds)

Region and Area	1975	1976	1977	1978	1979	1980	Average
Region 1							
Gulf of Georgia	128.0	90.0	122.6	140.2	50.2	25.3	
Bellingham Bay	31.9	12.4	3.7	3.0	5.1	2.5	
Samish Bay	24.0	26.3	31.9	66.3	16.4	13.2	
Padilla & Fidalgo Bays	47.6	11.0	20.0	21.6	13.3	11.8	
	231.5	139.7	178.2	231.1	85.0	52.8	153.1
Region 2							
N. San Juan Islands	8.4	4.1	6.9	11.7	16.5	2.7	
S. San Juan Islands	78.3	29.4	54.3	30.1	51.1	7.8	
	86.7	33.5	61.2	41.8	67.6	10.5	50.2
Region 3							
Saratoga Passage	275.8	224.6	291.8	372.8	0.3	59.9	
Dungeness Bay	83.4	65.8	89.6	132.2	45.4	74.7	
	359.2	90.4	381.4	505.0	45.7	134.6	252.7
Region 4							
Port Susan	15.2	8.1	19.8	53.8	20.1	20.4	22.9
Region 5							
Admiralty Inlet	111.7	108.6	190.3	242.8	69.6	221.0	
Port Gardner & Useless Bay	85.9	80.2	126.5	140.5	21.5	77.7	
Kingston & Port Madison	95.6	93.5	196.7	118.0	61.6	100.8	
Port Orchard	80.2	50.0	74.9	110.6	39.5	77.4	
Vashon/Commencement Bay	124.2	74.7	101.0	52.5	55.4	110.0	
	497.6	406.8	239.6	664.4	247.6	586.9	440.5
Region 6							
Hood Canal (upper)	162.5	161.7	260.0	80.9	114.2	141.9	
Hood Canal (central)	150.3	125.9	210.1	95.4	122.3	135.5	
Hood Canal (lower)	156.8	109.0	159.2	89.7	138.7	139.3	
	469.6	396.5	628.8	266.0	375.2	416.7	432.9
Region 7							
Nisqually-Fox Islands	21.9	33.1	29.8	25.4	27.2	96.6	
Carr Inlet	55.9	55.9	65.9	36.4	52.5	111.9	
Case Inlet	41.2	41.2	14.0	38.3	29.9	46.5	
Budd, Eld, Totten Inlets	44.5	44.5	34.8	22.5	27.5	47.0	
	163.5	98.2	144.5	122.6	137.1	302.0	121.3
TOTAL:	1823.3	1173.2	1653.5	1884.7	978.3	1523.9	1473.6

Table 5

PHYSICAL, BIOLOGICAL, AND ENVIRONMENTAL PARAMETERS
AFFECTING CLAM AND MUSSEL RESOURCE DISTRIBUTION

Physical Parameters

- Water temperature
- Water salinity
- Water depth
- Dissolved oxygen
- pH
- Water currents
- Waves
- Substrate composition

Biological Parameters

- Reproduction
- Recruitment
- Survival
- Growth
- Competition
- Mortality

Environmental Parameters

- Nutrients
- Food Availability
- General water quality
- Harvesting
- Re-seeding
- Environment enhancement
- Predation
- Disease
- Toxins

Source: OIW, 1981

BIVALVE LIFE HABITS AND HABITATS

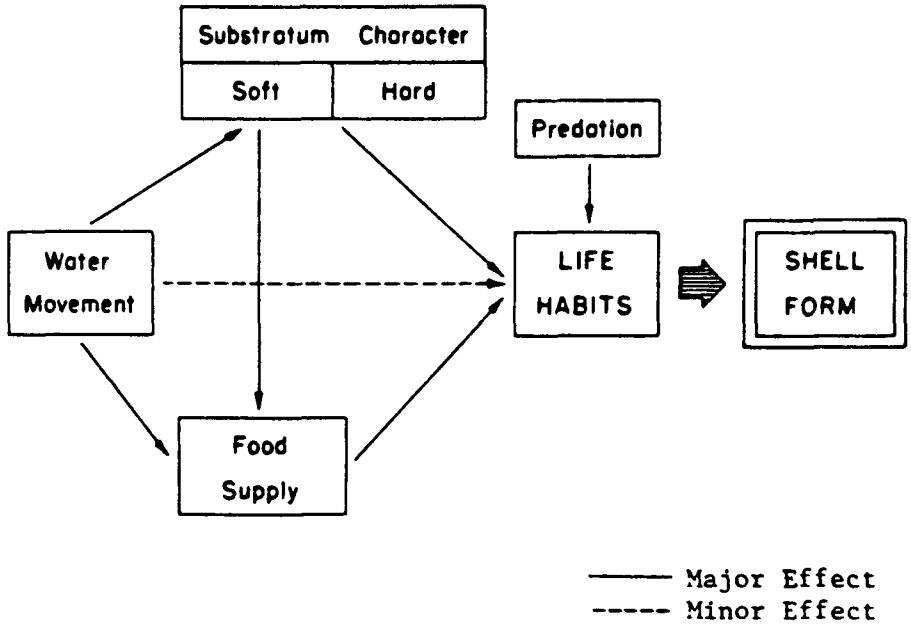


Figure 24

INTERRELATIONSHIPS AMONG ENVIRONMENTAL FACTORS
AND BIVALVE LIFE HABITS
(Stanley, 1973)

2.3.2 Manila Clam (Tapes japonica)

Geographic Range

In North America, Manila clams range from San Francisco Bay north into the Queen Charlotte Islands. In Puget Sound, Manila clams are ubiquitous, but the southern Sound area (Region 7) is the major production area for commercially harvested clams. Because Manila clams occupy the intertidal zone which is primarily privately owned, few data are available regarding local distribution and abundance.

Biology

Manila clams are usually found above the half-tide level on intertidal beaches in substrates of pea gravel with silt, mud, sand and broken shell material. These substrates are typically found along the beaches of inlets, coves, and lagoons. The Manila clam, also known as the Japanese littleneck, is a fast growing and hardy species making it ideal for aquaculture. It can reach commercial size (2 inches) in approximately two years and can grow as large as eight inches. It burrows to a depth of approximately three inches and thus is easily preyed on by gulls, scoters, flatfish, crabs, starfish and moon snails. The shallow burrow also exposes these clams to temperature extremes and many perish during cold winters. Manila clams prefer firm and well-packed gravelly beach sites because these beaches afford better protection from predators.

Spawning occurs in Puget Sound from May through October. Larvae are free swimming for approximately three weeks and feed on phytoplankton. At the end of the larval period, juvenile clams "set" or burrow into the substrate and anchor with a byssal thread to a piece of rock or gravel. This thread anchor may enable a clam to alter its location although its primary function is to protect the clam from currents and wave action.

Manila clams are not native to this area but were introduced with Japanese oyster seed. This introduction, unlike most unwelcome invaders, proved to be beneficial since this clam occupies a niche not generally utilized by native littleneck or butter clams.

Commercial Fisheries/Aquaculture - Present And Potential

Manila clams are chiefly cultivated in the bays of southern Puget Sound. The Manila is commercially seeded and hand harvested after two to four years. Approximately 1.5 million pounds are harvested annually with a value of nearly $600,000 (1979-1983). While the production of Manila clams could probably be increased, the WDF feels its expansion is limited due to the availability of suitable public bed sites.

Recreational Harvest

The harvest of intertidal clams for personal use occurs on public and private tidelands. Hood Canal and selected areas in Central Puget Sound are good recreational sites for digging Manila clams (A. Scholz, WDF, pers. comm.). Solomon and Mills (1983) conservatively estimated the annual recreational harvest of all hardshell clams to be approximately two million pounds valued at $2,275,000, though no data specific to Manila clams are available.

Summary Points - Manila Clams

- Region 7 is the major areas for Manila clam production (Figure 25).
- Five year average (1979-1983) of commercial fishing indicates value to be almost $600,000 for approximately 1.5 million pounds.
- Important contacts and sources of information include:

UW	Ken Chew
WDF	Ron Westley
	Lynn Goodwin
	Eric Hurlburt
	Al Scholz
DOE	Bob Saunders
	Joan Thomas
DNR	Doug Magoon
	Dave Jamison
	Mervin W. Howden
DSHS	Jack Lilja
Other Organizations	NOAA, NMFS
	Oceanographic Institute of Washington
	King Clam, Inc., Tacoma
	Washington Shellfish Advisory Commission
	Pierce and Thurston County Health Departments

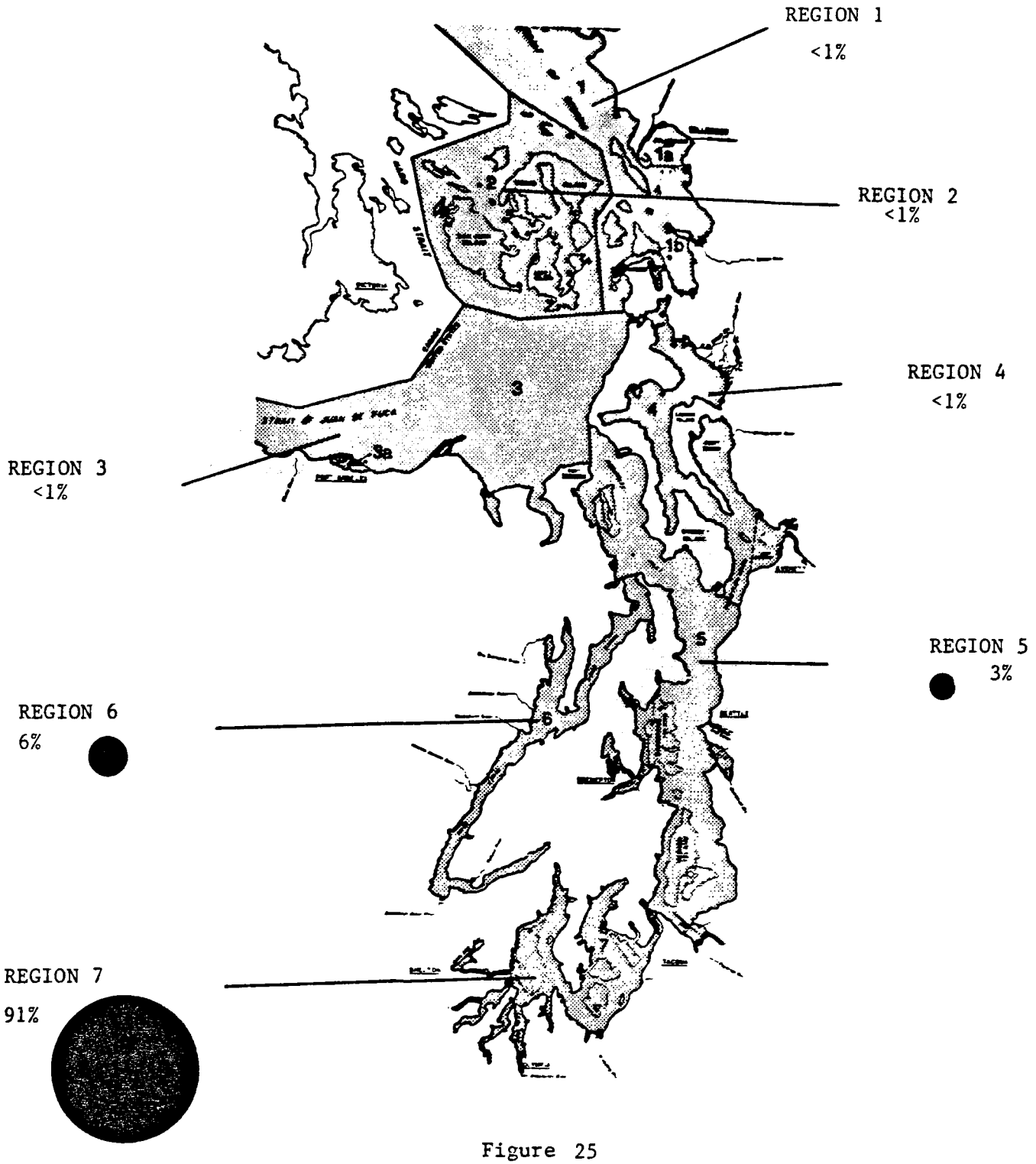


Figure 25

DISTRIBUTION OF MANILA CLAM HARVEST IN PUGET SOUND

(based on WDF statistics)

2.3.3 Butter Clams (Saxidomus giganteus)

Geographic Range

Butter clams range from the Aleutian Islands to Monterey, California. In Puget Sound butter clams are ubiquitous, but the majority of beds surveyed by WDF are located in the Strait of Juan de Fuca (Region 3) central Puget Sound (Regions 4 and 5) and the San Juan Islands (Region 2).

Biology

The butter clam is a large clam (4-6 inches) that occurs chiefly in the lower tidal zone and can extend to water depths of 60 feet. Butter clams are often found with littleneck clams although butter clams are more common in the subtidal areas. Butter clams burrow from 8-12 inches into a substrate of sand, broken shells and pea gravel. They reach commercial size (2-3 inches) in approximately four years. Large beds of butter clams have been known to be completely harvested since beds may consist of only one age class and successive reproductions may not occur.

Spawning occurs in the spring and may extend through the summer. Larvae are free swimming before setting as juvenile clams. The juvenile or "spat" burrows into the substrate and anchors itself to a piece of rock shell or gravel by the byssal thread. This anchor may also assist the clam in relocation.

Known Water Quality Needs or Sensitivities

The butter clam is known to be fairly tolerant to changes in temperature and salinity. The butter clam, like all filter-feeding molluscs, can become toxic from paralytic shellfish poisoning. Unlike most other molluscs that become nontoxic in a few weeks, the butter clam can retain this poison for two or more years. This is because the toxin is accumulated more in the siphon and gill rather than in the body cavity (Quayle and Bourne, 1972).

Commercial Fisheries/Aquaculture - Present And Potential

Annual harvest of butter clams in Puget Sound is approximately 250,000 pounds at a value of $50,000 (1979-1983). Sequim Bay, Admiralty Inlet, Boundary Bay, Agate Pass and Hood Canal (Regions 3, 5 and 6) are important areas for the culturing and harvesting of butter clams.

Recreational Harvest

The harvest of butter clams for personal use occurs on public and private tidelands. Solomon and Mills (1983) conservatively estimated the recreational harvest of all hardshell clams to be approximately two million pounds valued at $2,275,000.

Summary Points - Butter Clams

- Regions 3, 5, and 6 are the major production areas for butter clams (Figure 26).
- Five year (1979-1983) average of commercial fishery indicates value to be almost $50,000 for approximately 250,000 pounds.
- Important contacts and sources of information:

UW	Ken Chew
WDF	Ron Westley
	Eric Hurlburt
	Lyn Goodwin
	Al Scholz
DOE	Bob Saunders
	Joan Thomas
DNR	Doug Magoon
	Mervin W. Howden
	Dave Jamison
DSHS	Jack Lilja
Other Organizations	NOAA, NMFS
	Oceanographic Institute of Washington
	King Clam, Inc., Tacoma
	Washington Shellfish Advisory Commission
	Pierce and Thurston County Health Departments

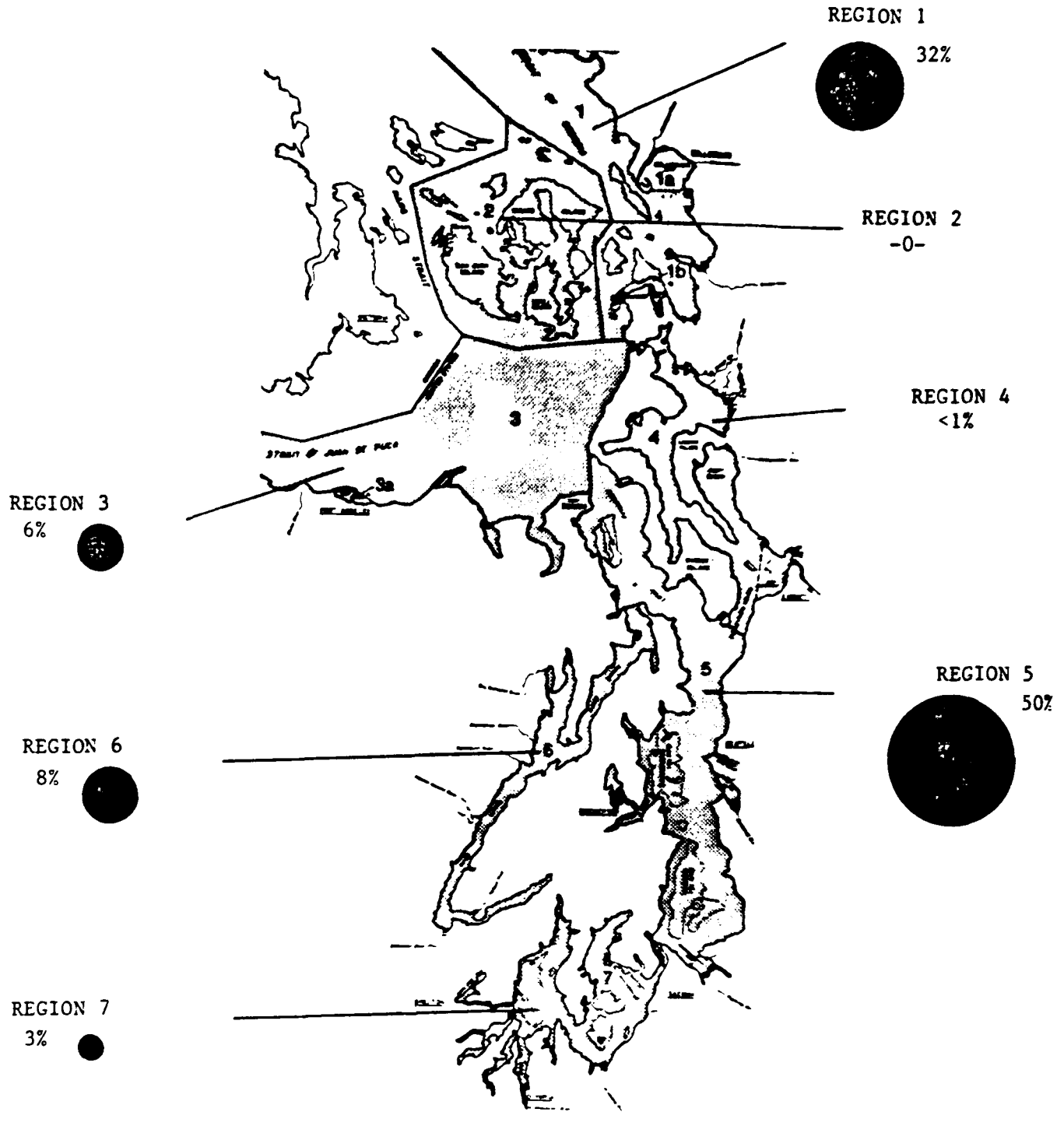


Figure 26

DISTRIBUTION OF BUTTER CLAM HARVEST IN PUGET SOUND

(based on WDF statistics)

2.3.4 Native Littleneck Clam (Protothaca staminea)

Geographic Range

Native littleneck clams range from Baja, California to the Aleutian Islands. Subtidal surveys conducted by WDF found the majority of littleneck clam beds in central Puget Sound (Region 5).

Biology

The native littleneck clam is a medium sized (2.5-3 inch maximum length) clam that occurs from the mid-intertidal beach to the upper subtidal zone. They can occur in deeper waters having been recorded to 60 ft (Goodwin, 1973). Littlenecks prefer a substrate composed of sands and gravel in which they burrow to depths of six to ten inches. They are slow growers, reaching commercial size in as many as six years.

Spawning occurs in the spring. Larvae are free swimming for approximately three weeks. Juvenile clams settle into the substrate and use byssal threads to anchor to the bottom.

Commercial Fisheries/Aquaculture - Present And Potential

Annual harvest from leased subtidal beds are approximately 500,000 pounds at a value of almost $150,000 (1979-1983). Sequim Bay, Admiralty Inlet, Boundary Bay, Agate Pass and Hood Canal (Regions 3, 5 and 6) are important areas for the culturing and harvesting of native littleneck clams.

Recreational Harvest

The harvest of native littleneck clams for personal use occurs on public and private tidelands. Solomon and Mills (1983) conservatively estimated the recreational harvest of all hardshell clams to be approximately two million pounds valued at $2,275,000.

Summary Points - Native Littleneck Clams

- Regions 3, 5, 6, and 7 are the major production areas for native littleneck clams (Figure 27).
- Five year (1979-1983) average of commercial fishery indicates value to be almost $150,000 for approximately 500,000 pounds.

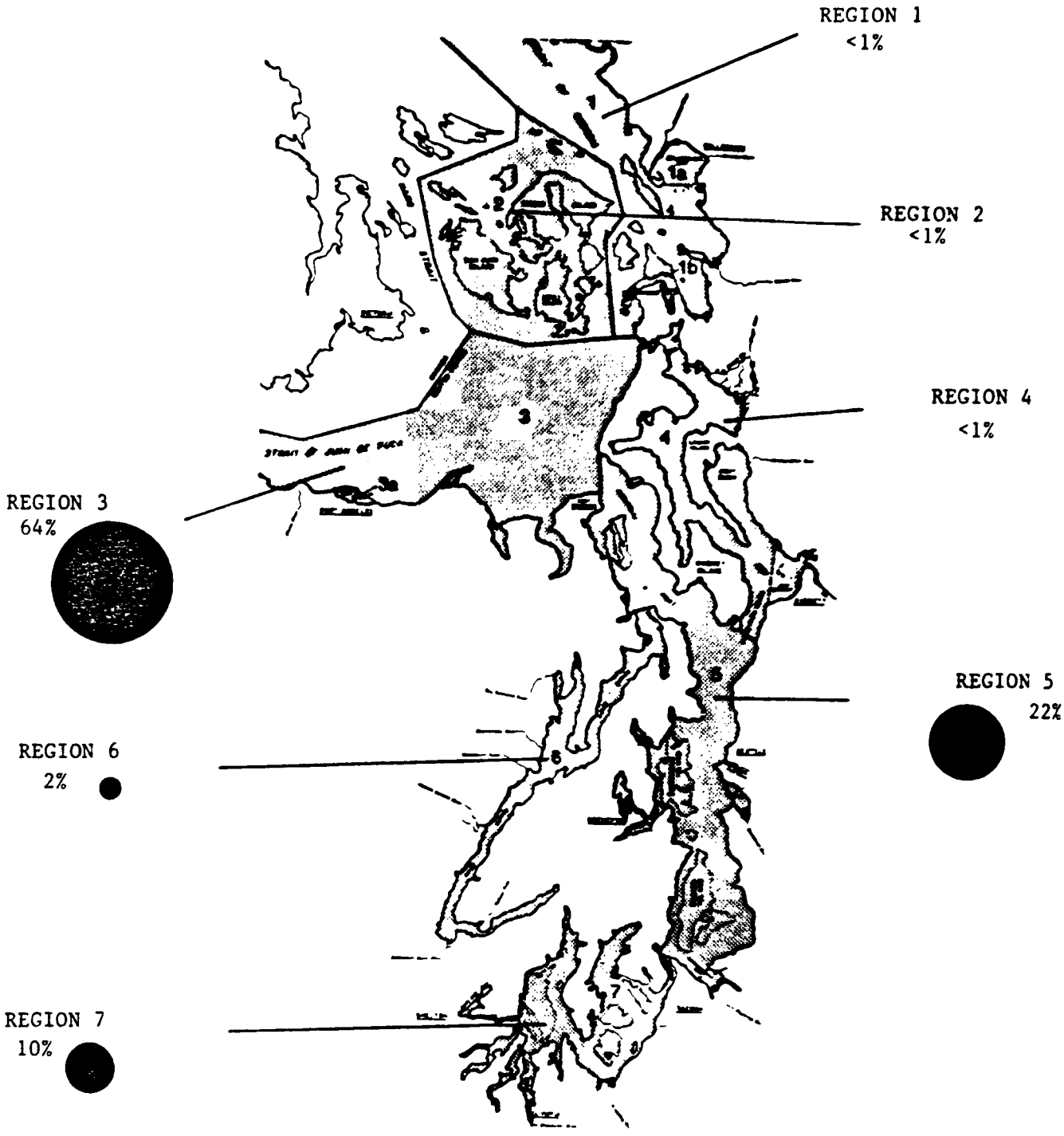


Figure 27

DISTRIBUTION OF NATIVE LITTLENECK CLAM HARVEST IN PUGET SOUND

(based on WDF statistics)

- Important contacts and sources of information include:

UW	Ken Chew
WDF	Ron Westley
	Eric Hurlburt
	Lynn Goodwin
	Al Scholz
DOE	Bob Saunders
	Joan Thomas
DNR	Doug Magoon
	Mervin W. Howden
	Dave Jamison
DSHS	Jack Lilja
Other Organizations	NOAA, NMFS
	Oceanographic Institute of Washington
	King Clam, Inc., Tacoma
	Washington Shellfish Advisory Commission
	Pierce and Thurston County Health Departments

2.3.5 Horse Clam (Tresus capax and T. nuttallii)

Geographic Range

Tresus nuttallii ranges from Washington south to Baja, California. T. capax has a wide range extending from Alaska to Monterey, California (Abbott, 1974). Horse clams can be found throughout Puget Sound, particularly in the subtidal zone.

Biology

Two species of horse clams are found in the lower intertidal and subtidal zones (out to 60 ft) in Puget Sound. Both clams are large (5-8 inches) and are often mistaken for geoducks. Other names for these clams include gaper and Washington clams. T. capax prefers substrates of gravel and shell fragments and are often found with butter and native littleneck clams. As adults and spat, this species is often found in stands of eelgrass (Mottet, 1980). T. nuttallii prefers substrates of sand and occasionally clay. In general, both clams burrow to depths of 12-18 inches. (T. nuttallii is usually the deeper burrower and can be found at depths of 20 inches.) Both clams grow quickly attaining commercial size of 2-4 inches in a few years. T. capax spawns in the spring while T. nuttallii spawns in the summer. Larvae are free swimming. At the end of the larval period, juvenile clams set or burrow into the substrate and anchor with a byssal thread to a piece of rock or gravel. The horse clams possess a characteristic shell that is elongated and permits deep burrowing. Horse clams typically are permanent occupants of their burrows (Stanley, 1973).

Known Water Quality Needs or Sensitivities

Adult horse clams disturbed from their burrow (usually as a result of harvesting) are especially vulnerable to predation because they do not easily reburrow.

Commercial Fisheries/Aquaculture - Present and Potential

Annual harvest of horse clams in Puget Sound is approximately 85,000 pounds at a value of $9,000 (1979-1983). Sequim Bay, Admiralty Inlet, Boundary Bay, Agate Pass and Hood Canal (Regions 3, 5, and 7) are important areas for harvesting of horse clams.

Horse clams are not as popular commercially as butter or native littleneck clams because their shells are often broken during harvesting with forks or shovels causing the meat to rapidly desicate. Furthermore, approximately one-third of its body weight is edible meat while the remainder is the very muscular neck with a skin that is generally removed before consumption (Quayle and Bourne, 1972). Subtidally horse clams are harvested using a hydraulic harvester (Hanks type) and intertidally by hand. Most horse clams are harvested from subtidal beds (OIC, 1981).

Recreational Harvest

The harvest of horse clams for personal use occurs on public and private tidelands. Solomon and Mills (1983) conservatively estimated the recreational harvest of all hardshell clams to be approximately two million pounds valued at $2,275,000.

Summary Points - Horse Clams

- Regions 1 and 5 are the major production areas for horse clams (Figure 28).
- Five year (1979-1983) average of commercial fishery indicates value to be almost $9,000 for approximately 85,000 pounds.
- Important contacts and sources of information include:

UW	Ken Chew
WDF	Ron Westley
	Eric Hurlburt
	Lynn Goodwin
	Al Scholz
DOE	Bob Saunders
	Joan Thomas
DNR	Doug Magoon
	Mervin W. Howden
	Dave Jamison
DSHS	Jack Lilja
Other Organizations	NOAA, NMFS
	Oceanographic Institute of Washington
	King Clam, Inc., Tacoma
	Washington Shellfish Advisory Comm.

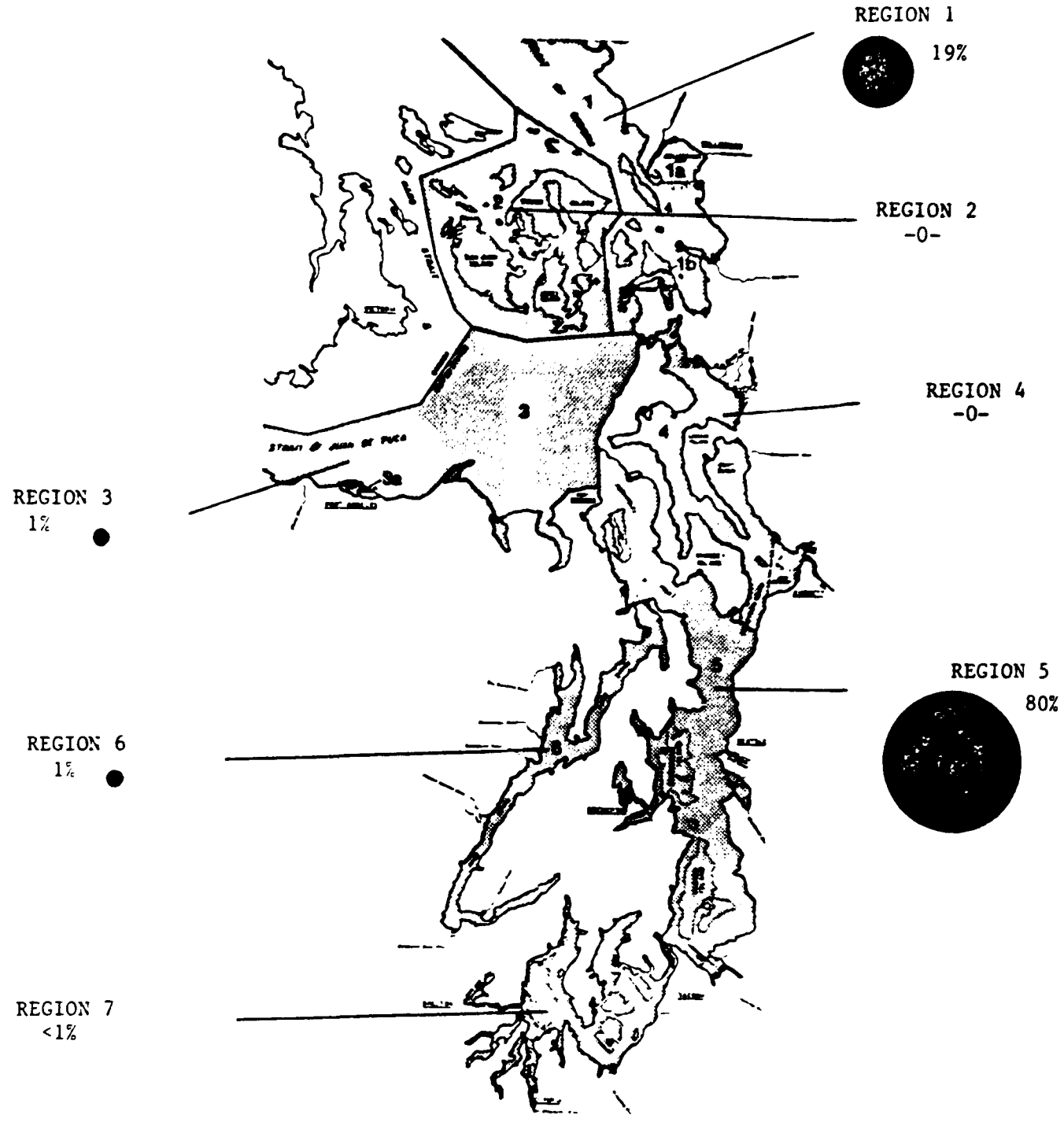


Figure 28

DISTRIBUTION OF HORSE CLAM HARVEST IN PUGET SOUND

(based on WDF statistics)

2.3.6 Geoduck Clam (Panope generosa)

Geographic Range

These clams range from Alaska in the north to as far south as Baja, California with the maximum abundance found in Puget Sound and British Columbia.

Biology

Geoducks are the largest burrowing clams, averaging two pounds in weight but sometimes reaching as much as ten pounds. Recent and ongoing surveys conducted by WDF and DNR indicate that geoducks probably extend from the lower intertidal or subtidal regions to depths beyond (200 feet). While geoducks prefer sand and mud substrates, they have also been found in rock and gravel areas. They burrow two to three feet into the substrate and feed on suspended material.

Geoducks are broadcast spawners and their larvae are planktonic for four to five weeks. Juveniles settle on appropriate substrates and remain in their burrow the remainder of their lives which can be exceedingly long. Some geoducks are estimated to be over 100 years old (WDF, 1983).

Known Water Quality Needs or Sensitivities

No specific water quality sensitivities have been identified, generally, the factors identified under hardshell clams (Table 5 and Figure 24) would pertain to geoducks. The larval stage is a critical period in geoduck development since the success of the larvae to settle on suitable beds is totally dependent upon water currents. Likewise the quality of the water column could also have an effect on the success of larval survival. As adults, geoducks are filter feeders and do not move from their burrow. They are therefore subjected to local water quality conditions and may be a threat to human health if geoducks feeding in contaminated waters are consumed.

Commercial Fishery/Aquaculture - Present And Potential

The geoduck resource is managed by two state agencies: WDF surveys the locations of geoduck beds and selects the beds to lease for harvesting; DNR then leases these beds. Locally, the Washington geoduck fishery has experienced a rapid expansion so that today it is the largest clam fishery on the west coast of North America. The annual harvest of over four million pounds in Puget

Sound is valued at almost $700,000 (1979-1983). This valuable resource has been harvested commercially for less than 20 years, thus it enjoys the benefits from sound management practices that regulate harvests on a maximum sustained yield basis. Unlike other fisheries that were heavily exploited or even depleted, the geoduck fishery should continue to thrive and if artificial plantings of hatchery seed are successful, the fishery production could be doubled. Figure 29a presents the distribution of commercial geoduck beds in Puget Sound based on the seven regions delineated by Jones and Stokes (1983). Surveys conducted by the WDR since 1967 in shallow waters (18-60 ft deep) have revealed abundant beds, particularly in the central and southern Sound regions (Regions 5 and 7). Over 34,000 acres of beds have been identified; the major commercial beds are reported to contain 280 million pounds in 19,545 acres. Current commercial bed statistics (L. Goodwin, WDF, pers. comm.) indicate that over 6,000 acres have been leased or could be leased in the near future. These beds contain 140 million pounds or 77 million geoducks. Another 11,000 acres with an estimated 60 million geoducks are located in waters that are unsuitable for harvest due to pollution and decertification. The decertified beds are located primarily on the eastern shores of central Puget Sound. Figure 29b presents the DNR marine land allocations for geoduck harvest as well as the location of geoduck beds that are decertified.

Each year, approximately 200-500 acres are harvested by divers using hand-held water jets. This harvest represents approximately 1.5-3% of the annual harvestable stock of five million pounds (maximum sustained yield). Recovery of harvested beds can be slow, some as long as 50 years.

Although geoducks grow quickly and can reach a harvestable size in approximately four to 10 years, recruitment to suitable beds is the major factor limiting production potential. Ongoing research by WDF and DNR has been directed towards artificially reseeding beds in order to overcome the variability in recruitment. Successful spawning and larval culture in the Brinnon Lab by WDF has been reported (L. Goodwin, WDF, pers. comm.). Planting 30 million hatchery seed each year could double the commercial fishery by accelerating the average rotation period of beds. WDF intends to begin their plantings in the summer of 1984. Based on the survival of these plantings, they will be able to provide a good assessment of this artificial seeding program and future geoduck harvest potentials.

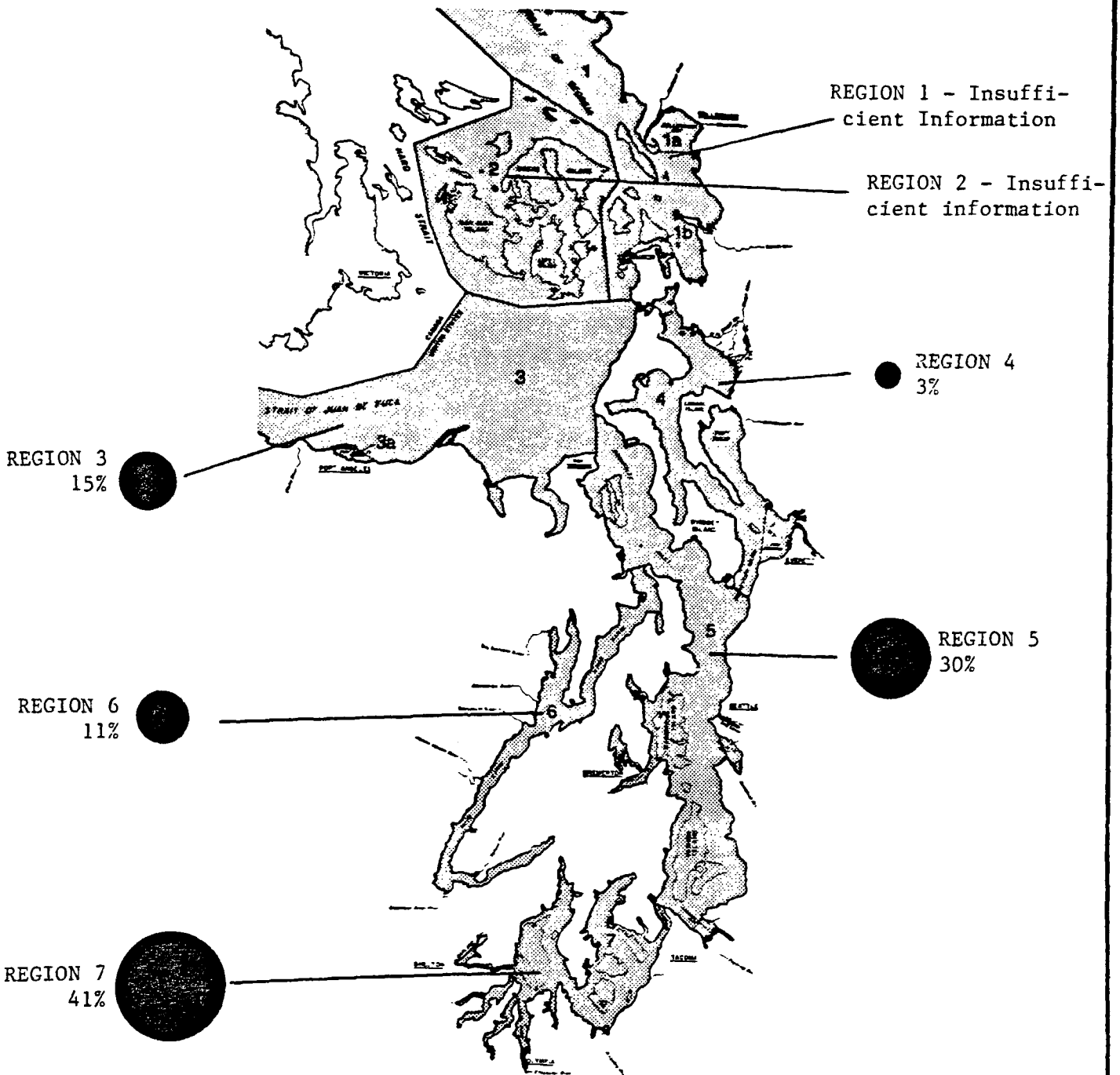
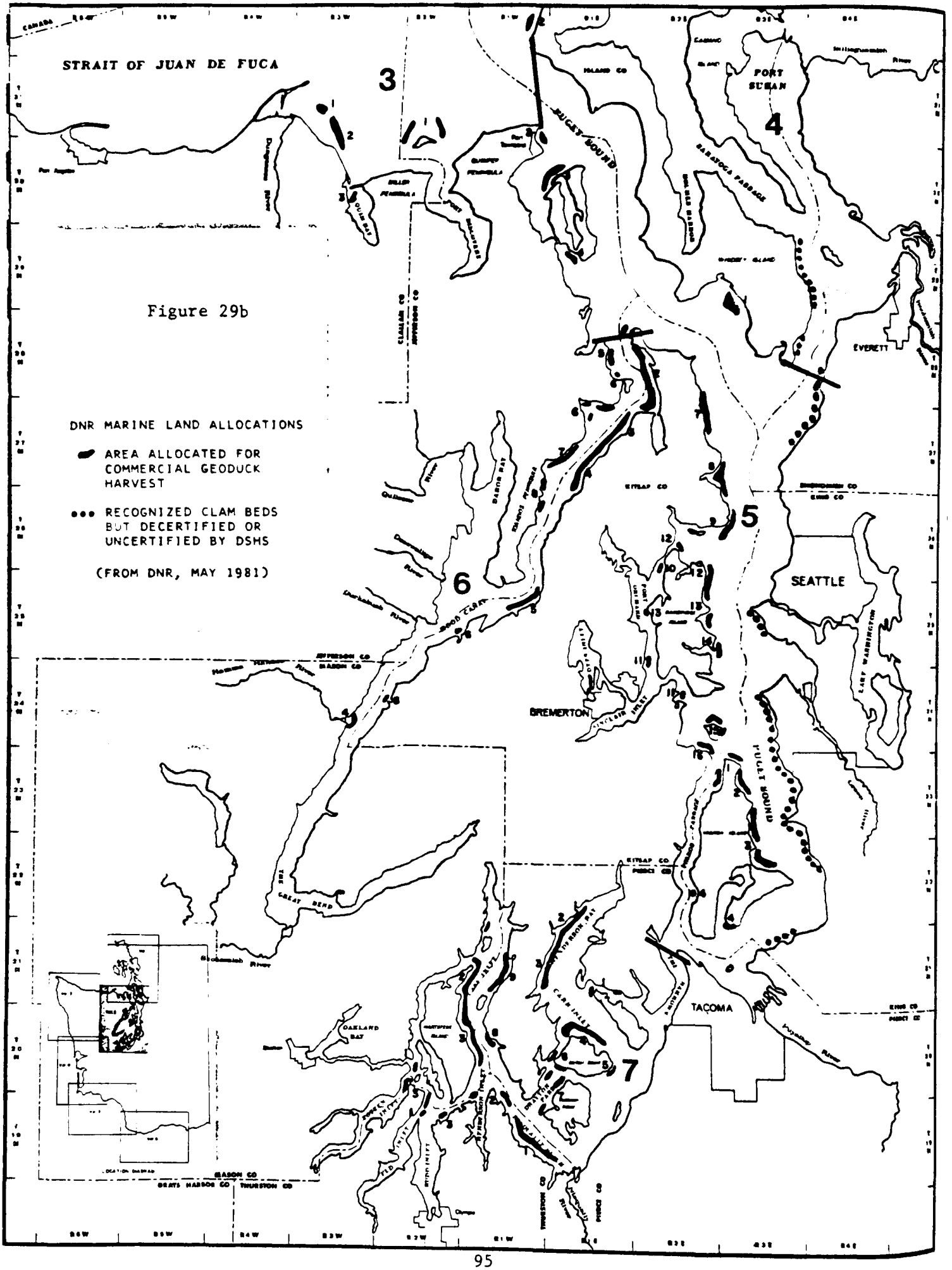


Figure 29a

DISTRIBUTION OF COMMERCIAL GEODUCK BEDS IN PUGET SOUND

(based on WDF statistics)


STRAIT OF JUAN DE FUCA
Figure 29b
DNR MARINE LAND ALLOCATIONS
AREA ALLOCATED FOR COMMERCIAL GEODUCK HARVEST
RECOGNIZED CLAM BEDS BUT DECERTIFIED OR UNCERTIFIED BY DSHS
(FROM DNR, MAY 1981)
PORT SUSAN
EVERETT
SEATTLE
BREMERTON
TACOMA
PUGET SOUND
3
4
5
6
7

Recreational Harvest

The harvest of geoducks for personal use occurs on public and private tidelands. WDF surveys this harvest only in that portion of Puget Sound east of the base of Dungeness Spit. These surveys only occur from April through August. No data is available for the remainder of the year. Tables 4 and 5 present the estimated 1975-1980 personal-use harvest (number of trips and pounds harvested) of hardshell clams in which WDF include geoducks.

Summary Points - Geoducks

- Geoducks are most abundant in the central and southern Sound (Regions 5 and 7) (Figure 29a).
- Critical stage is the planktonic larval stage.
- Five year average of commercial fishing indicates value to be almost $700,000 for over 4,000,000 pounds.
- Important contacts and sources of information include:

WDF	Lynn Goodwin
	Ron Westley
	Eric Hurlburt
DNR	Doug Magoon
	Mervin W. Howden
	Dave Jamison
DSHS	Jack Lilja
Other Organizations	Oceanographic Institute of Washington
	Geoduck Harvest in Tacoma, WA
	Brian Laboratories
	Pierce and Thurston County Health Departments

2.3.7 Softshell Clam (*Mya arenaria*)

Geographic Range

Softshell clams range along the west coast as far north as Alaska (Abbott, 1974). In Puget Sound, the bulk of softshells are found in Port Susan and Skagit Bay (Region 4).

Biology

The eastern softshell clam or steamer clam is a medium to large-sized clam (3-4 inches) found in the intertidal zone in substrates of sand mixed with mud. It prefers lower salinities and hence is more often located in the upper stretches of bays and lagoons that are flushed by rivers and streams. This clam will burrow to depths of 6-14 inches and will attain commercial size (2-3 inches) in three years (OIC, 1981). There is some question as to whether the softshell clam is native to this area although Kozloff (1973) asserts it is an imported species because there are no softshell fragments found in historic Indian shell mounds.

Softshell clams are broadcast spawners and their larvae are free swimming. Juveniles settle by attaching byssel threads to solid objects. Softshell clams that have anchored themselves to floating objects have been observed, usually on pieces of floatsam (Mottet, 1980). The softshell is a slow burrower and it is reported that if they are dislodged they cannot reburrow.

Known Water Quality Needs or Sensitivities

Generally the factors identified under hardshell clams (Table 5 and Figure 24) apply to softshell clams. Because the softshell is primarily adapted to low energy estuarine environments and due to their slow movements, softshells inhabiting open beaches are subject to mortality from storms. Softshells cannot easily clear sand or debris from their siphons (Stanley, 1973).

Softshell clams are however, extremely hardy with regard to temperature and salinity. Mottet (1980) describes an experiment where adult clams revived after being frozen (-4°C) for seven weeks. In another experiment, clams survived a 42 hour exposure to distilled water. This tolerance is probably a function of metabolic rate as smaller clams did not survive in the same experiment.

Commercial Fishery/Aquaculture - Present and Potential

Figure 30 depicts the distribution of softshell clam resources in Puget Sound. Because these clams occupy the intertidal regions, most of which is privately owned, total standing stocks are unknown.

Commercial harvest of intertidal softshell clams has historically been accomplished primarily with a hydraulic harvester. This is no longer the case (OIC, 1980). The operation of mechanical harvesters in estuarine areas is a controversial subject because of the environmental effects of such operations. Hand harvesting of softshell clams has occurred on the Skokomish Indian Reservation (Region 6).

Due to the problems of mechanical harvesting and decertification, production of hardshell clams is low (10,000-20,000 lb annually). If these problems were surmounted, however, the potential for this fishery is extremely high with estimates of over 500,000 pounds annually.

Recreational Harvest

The harvest of softshell clams for personal use occurs on public and private tidelands. There is no data regarding the number of pounds of softshell clams annually harvested because they occur on intertidal beaches most of which are privately owned.

Summary Points - Shoftshell Clams

- Region 4 is the major area for softshell clam production (Figure 30).
- Softshell clams have demonstrated broad tolerance of salinity and temperature.
- Five year average (1979-1983) of commercial fishing indicate value to be almost $4,000 for approximately 10,000 pounds.
- Important contacts and sources of information include:

UW	Ken Chew
WDF	Ron Westley
	Lynn Goodwin
	Eric Hurlburt
	Al Scholz
DOE	Bob Saunders
	Joan Thomas
DNR	Doug Magoon
	Dave Jamison
	Mervin W. Howden

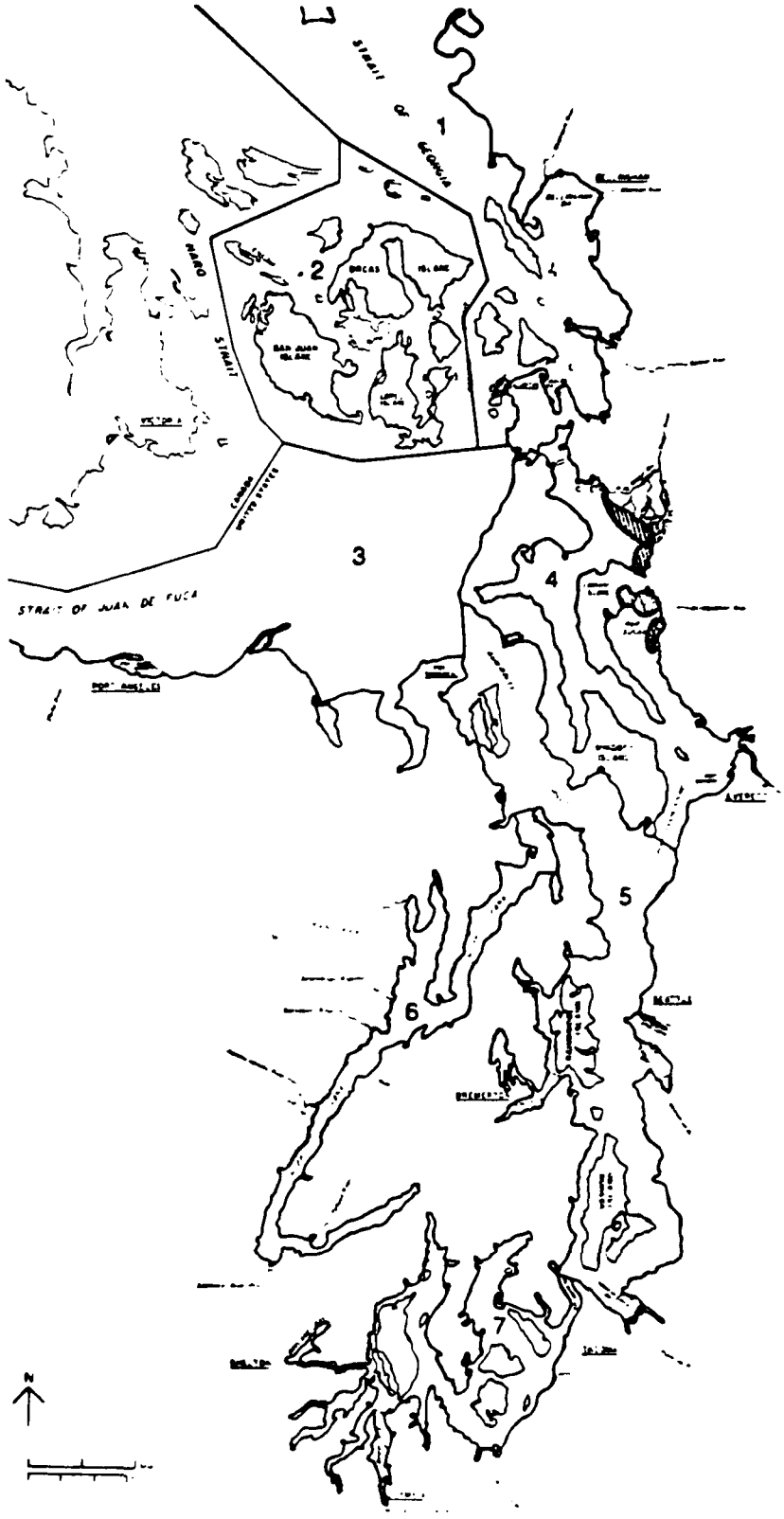


Figure 30

DISTRIBUTION OF SURVEYED SOFTSHELL CLAM
RESOURCES IN PUGET SOUND

(OIC, 1981)

DSHS	Jack Lilja
Other Organizations	Skokomish Indian Tribe
	Oceanographic Institute of WA
	NOAA, NMFS
	King Clam, Inc., Tacoma
	Washington Shellfish Advisory Comm.
	Sea Harvest Corp., Camano Island

2.3.8 Mussels (Mytilus edulis and M. californianus)

Geographic Range

The blue mussel ranges from California to Alaska. The California mussel extends from the Aleutian Islands to Mexico (Abbott, 1974). In Puget Sound the California mussel occurs only in the San Juan Archipelago while the blue is found throughout the Sound (OIC, 1980).

Biology

The blue mussel (Mytilus edulis) is found in intertidal areas particularly in calm estuaries of low salinity. This mussel prefers substrates of sand and mud with large objects for attachment such as rocks and pilings (OIC, 1980). It reaches a commercially harvestable size (2 inches) in about two years. The California mussel (M. californianus) occurs on exposed beaches in the lower intertidal zone. This mussel is not harvested like the blue mussel due to its scarcity in Puget Sound and its propensity for being the most toxic shellfish on the open coast for paralytic shellfish poisoning (Kozloff, 1973).

Mussels are broadcast spawners releasing spawn when water temperatures rise, usually in spring and summer. Larvae are free swimming for as long as 35 days or more depending on water temperature and the ability to find an appropriate settling location. Commonly, many mussels attach themselves close together resulting in large clumps. Successive spat falls will attach to both live and dead animals.

Known Water Quality Needs or Sensitivities

Generally the factors identified under hardshell clams (Table 5 and Figure 24) pertain to mussels. Mussels apear to have tolerances to very low salinities (Morton, 1968) but temperature could be a controlling factor. As long as water temperatures do not fall below 30°F or exceed 77°F they will continue to grow (Magoon and Vining, 1980). Predators such as scoters, perch, starfish and whelks can cause serious losses to commercial mussel aquaculture activities.

Commercial Fishery/Aquaculture - Present and Potential

Surveys of Puget Sound mussel stocks are not available (OIC, 1980). The commercial mussel industry is essentially an aquaculture practice using raft

culture. Commercial harvesting of mussels occurs primarily in Island, San Juan and Mason Counties (Regions 3, 4 and 6). Penn Cove and Holmes Harbor are the most important mussel production areas. The annual harvest of 60,000 pounds in Puget Sound is valued at almost $50,000 (1979-1983). Culturing of mussels have been especially enhanced as a result of research by WDF and the University of Washington. If conflicts related to the public opposition to raft culture are resolved, the potential for increased production of blue mussels in Puget Sound could be significant. Until that time, predictions of harvest or potential income are not practicable. Furthermore, areas suitable for mussel culture must provide moderate temperatures and areas of good natural set. Hood Canal (Region 6) does not appear to be an appropriate site because space conflicts with other shellfish culturing. Attempts to culture mussels on rafts in the southern Sound (Region 7) have not been very successful. The current harvest locations would be potentially the most suitable sites for expansion if public approval is obtained (Jack Lilja, DSHS, pers. comm.).

Recreational Harvest

UNKNOWN

Summary Points - Mussels

- Bulk of commercial harvest is from raft culturing activities primarily in Region 4.
- Critical life stages unknown although mussels appear to be temperature sensitive for seed and spat development. Mussels exhibit tolerance of low salinities.
- Mussels are a food source for wildlife including waterfowl, fish and invertebrates.
- Five year average (1979-1983) of commercial fishing indicates value to be almost $50,000 for approximately 60,000 pounds.
- Important contacts and sources of information:

UW	Ken Chew
WDF	Ron Westley
	Eric Hurlburt
DOE	Doug Magoon
DSHS	Jack Lilja
Other Organizations and individuals	NOAA, NMFS
	Washington Shellfish Advisory Comm.
	Oceanographic Institute of Washington
	James Colby, Bremerton
	Peter Jefferds, Penn Cove
	Ken Pickard, Penn Cove

2.3.9 Oysters

Puget Sound is an important region for the culturing and harvest of oysters. The State of Washington is the largest west coast producer of oysters (Magoon and Vining, 1980). Following Willapa Bay, Puget Sound, particularly the southern Sound (Regions 6 and 7), accounts for almost half of the state's total production (Eric Hurlburt, WDF, pers. comm.). Five species of oysters are grown in Puget Sound: the Pacific oyster (*Crassostrea gigas*), the native Olympia oyster (*Ostrea lurida*), the Kumamoto oyster (*C. gigas* var. *Kumamoto*) the European oyster (*O. edulis*) the eastern oyster (*C. viginica*). Of all of the above, the Pacific oyster is commercially the most important. The following presents a general discussion on oyster. Biology, commercial and recreational sections deal only with the Pacific and the Olympia oyster because they are the most important within Puget Sound.

Geographic Range

In North America, the Pacific oyster ranges from California to British Columbia while the Olympia oyster's original range extended from Baja, California to Alaska. By the beginning of this century, stocks of Olympia oysters were so severely depleted by overharvesting that the resource never recovered. Today, the culturing of Olympia oysters occurs primarily in the southern Puget Sound areas (Regions 6 and 7).

Biology

Figure 31 depicts a generalized scenario of the life and culture cycles of oysters. Pacific oysters are cupped oysters imported from Japan. These oysters do not generally spawn successfully in Puget Sound except in limited areas (Dabob and Quilcene Bays have good natural sets). Therefore commercial growers rely on imported seed from Japan. Generally, local spawning occurs from mid-summer until fall.

The native Olympia oyster spawns during the summer releasing sperm into the water which must enter the female's shell cavity before fertilization can occur. Larvae are free swimming for approximately 2.5 weeks and then settle on a bed usually composed of rocks (in the wild) or oyster shells (cultured).

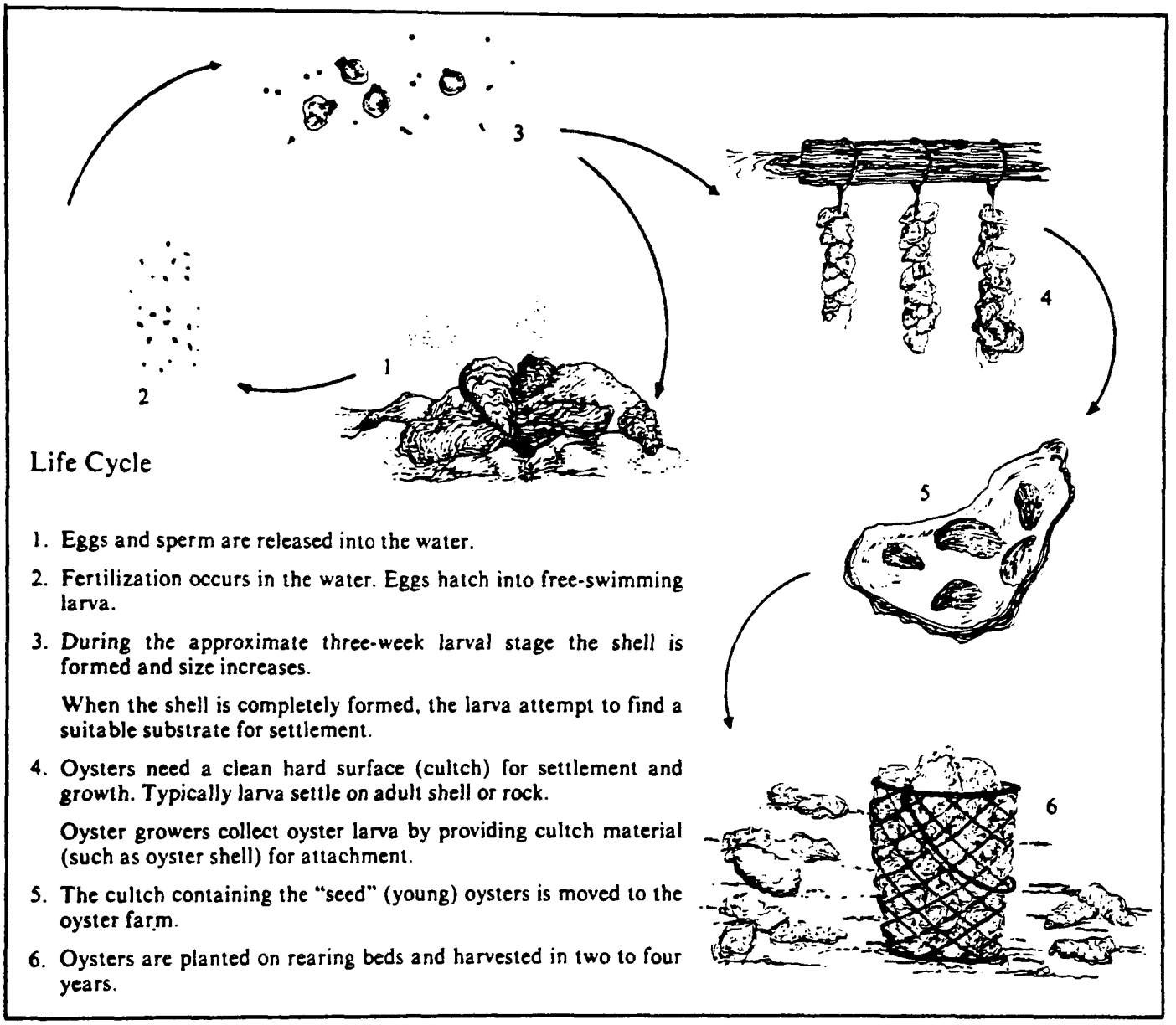


Figure 31

GENERALIZED LIFE CYCLE AND CULTURE CYCLE OF OYSTERS

(Magoon and Vining, 1980)

Pacific oysters are usually cultured on rafts or bottom substrates but they can also be grown on stakes, long lines, suspended trays or variations of these. Olympia oysters are cultured in ponds as they must be constantly covered with water. The Pacific oyster is a fast grower reaching commercial size in two to five years. The Olympia oyster grows slowly and is much smaller than the Pacific.

Known Water Quality Needs or Sensitivities

Generally critical factors discussed under hardshell clams (Table 5 and Figure 24) apply to oysters. The Pacific oyster is extremely hardy and can tolerate extremes in temperatures or tidal fluctuations. The hardiness of the Pacific oyster has made conditions for Olympia oysters difficult since they are much more sensitive and therefore cannot compete easily.

Oysters are victim to predation from starfish, crabs and oyster drills. Moreover competition from other shellfish, sponges and seaweeds can cause stunting or mortality (Magoon and Vining, 1980).

Commercial Fishery/Aquaculture - Present and Potential

Current production of oysters for commercial markets occurs primarily in the southern Sound and Hood Canal regions with some in Bellingham Bay (Eric Hurlburt, WDF, pers. comm.). Most culturing occurs on rafts. The oyster industry in Washington is important in terms of local employment and as a fisheries resource. Over six million pounds are produced annually and nearly one half of this production comes from Puget Sound. The potential for expanding this resource could be extremely high if pollution problems, public opposition to raft culture, and biological constraints are overcome (E. Hurlburt, WDF, pers. comm.). However, private oyster growers believe that the WDF estimates of oyster potential impractical because suitable waters with rich food sources and storm safe bays are finite. They would predict growth much more conservatively (D. MacMillan, Olympia Oyster Company, pers. comm.). Similarly, DSHS (Jack Lilja, pers. comm.) believes that most of the suitable oyster grounds are currently used and does not anticipate a massive increase in production. One fact all these people agreed on was that decertified areas

reduce the oyster production potential. For example, the most productive portions of Port Susan and all of Budd Inlet are closed not only to oysters but other shellfishing or culturing due primarily to nonpoint source pollution.

Recreational Fisheries

Personal harvest of oysters occurs on both public and private tidelands of Hood Canal (Region 6) (Hoines et al., 1983). Table 6 presents the estimated harvest in user trips and in number of pounds from 1972 to 1980.

Summary Points - Oysters

- Pacific and Olympia oysters are the most important species of oysters cultured. Quilcene and Dabob Bays in Region 6 and the southern Sound, Region 7, are the most important oyster producing areas in Puget Sound (Figures 32 and 33).

- Critical stages with cultured oysters are during initial cultch settling. Temperature may effect the larval development and thus make predicting natural spatfall difficult; an important factor to growers of native Olympia oysters.

- Five year average (1979-1983) of commercial fishing indicates values of Pacific oyster to be almost $2,000,000 for over two million pounds. Olympia averages are almost 6,000 pounds valued at approximatley $75,000.

- Important contacts and sources of information include:

DOE	Bob Saunders
	Joan Thomas
WDF	Ron Westley
	Eric Hurlburt
DNR	Dave Jamison
	Doug Magoon
DSHS	Jack Lilja
UW	College of Fisheries
Other Organizations	Washington Shellfish Advisory Comm.
	Olympia Oyster Co., D. MacMillan
	Pete Becker
	Dick Lewis, Pacific Coast Assoc.
	Arnold Woring, Coast Oysters
	Pierce and Thurston County Health Departments

Table 6

ESTIMATED PERSONAL-USE HARVEST OF OYSTERS BY CATCH AREA
1972 to 1980

Area	1972	1973	1974	1975	1976	1977	1978	1979	1980
	User Trips in 1000s								
Upper Hood Canal	96.6	47.5	51.4	51.5	49.1	57.9	25.2	30.5	32.8
Central Hood Canal	21.2	27.3	32.5	34.1	38.2	46.9	26.6	34.1	29.9
Lower Hood Canal	18.1	23.1	31.2	35.6	33.1	35.5	25.0	39.2	31.1
TOTAL	135.9	97.9	115.1	121.2	120.4	140.3	76.8	103.8	93.8
	1000s of Pounds								
Upper Hood Canal	56.1	27.6	29.8	29.9	22.8	26.8	14.6	12.5	15.7
Central Hood Canal	9.6	12.4	18.9	19.8	17.7	21.7	12.1	14.0	14.3
Lower Hood Canal	8.2	10.5	14.2	20.7	15.3	16.4	11.4	16.1	14.9
TOTAL	73.9	50.5	62.9	70.4	55.8	65.0	38.1	42.6	44.9

Source: WDF, 1981

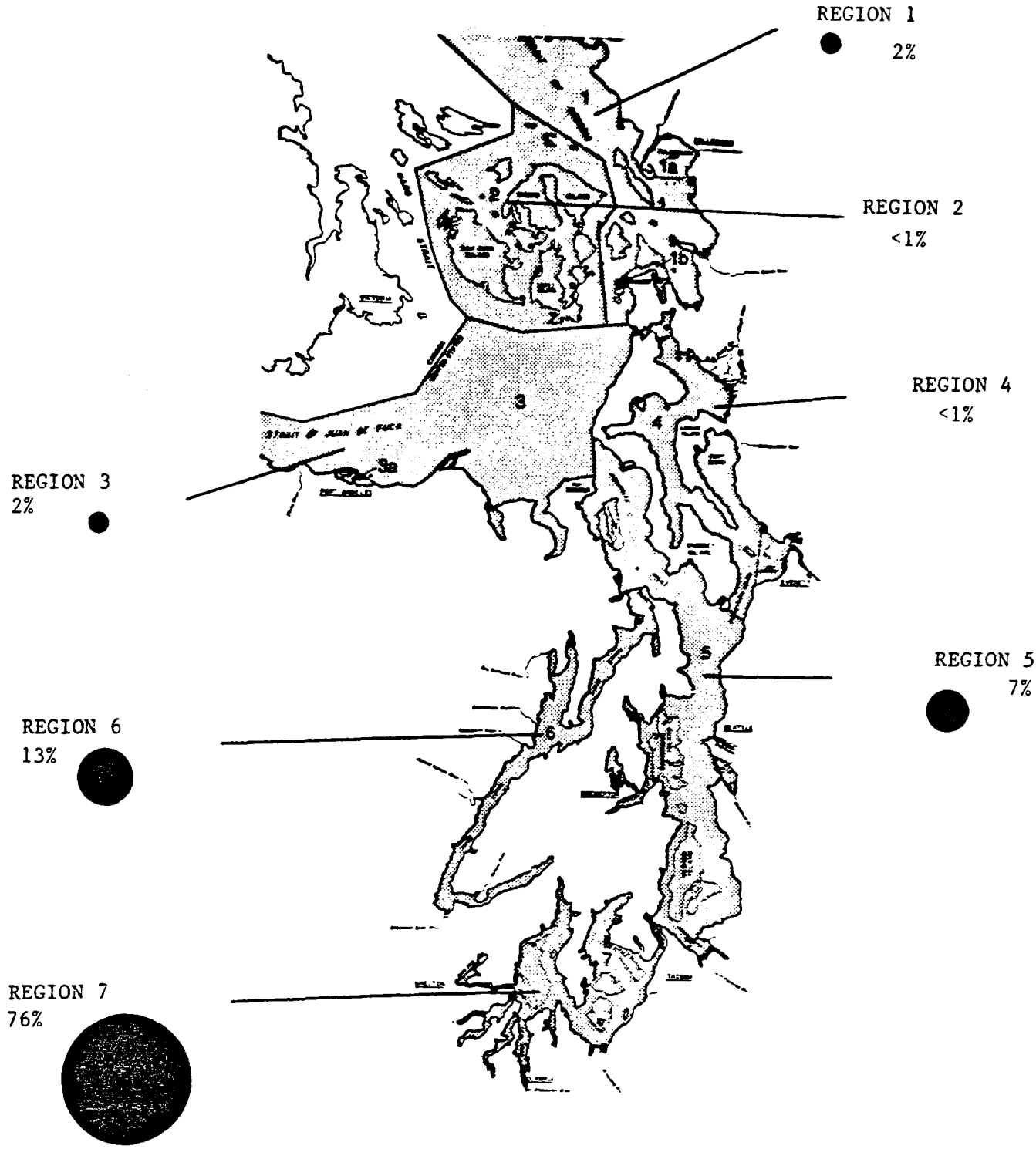


Figure 32

DISTRIBUTION OF PACIFIC OYSTER HARVEST IN PUGET SOUND

(based on WDF statistics)

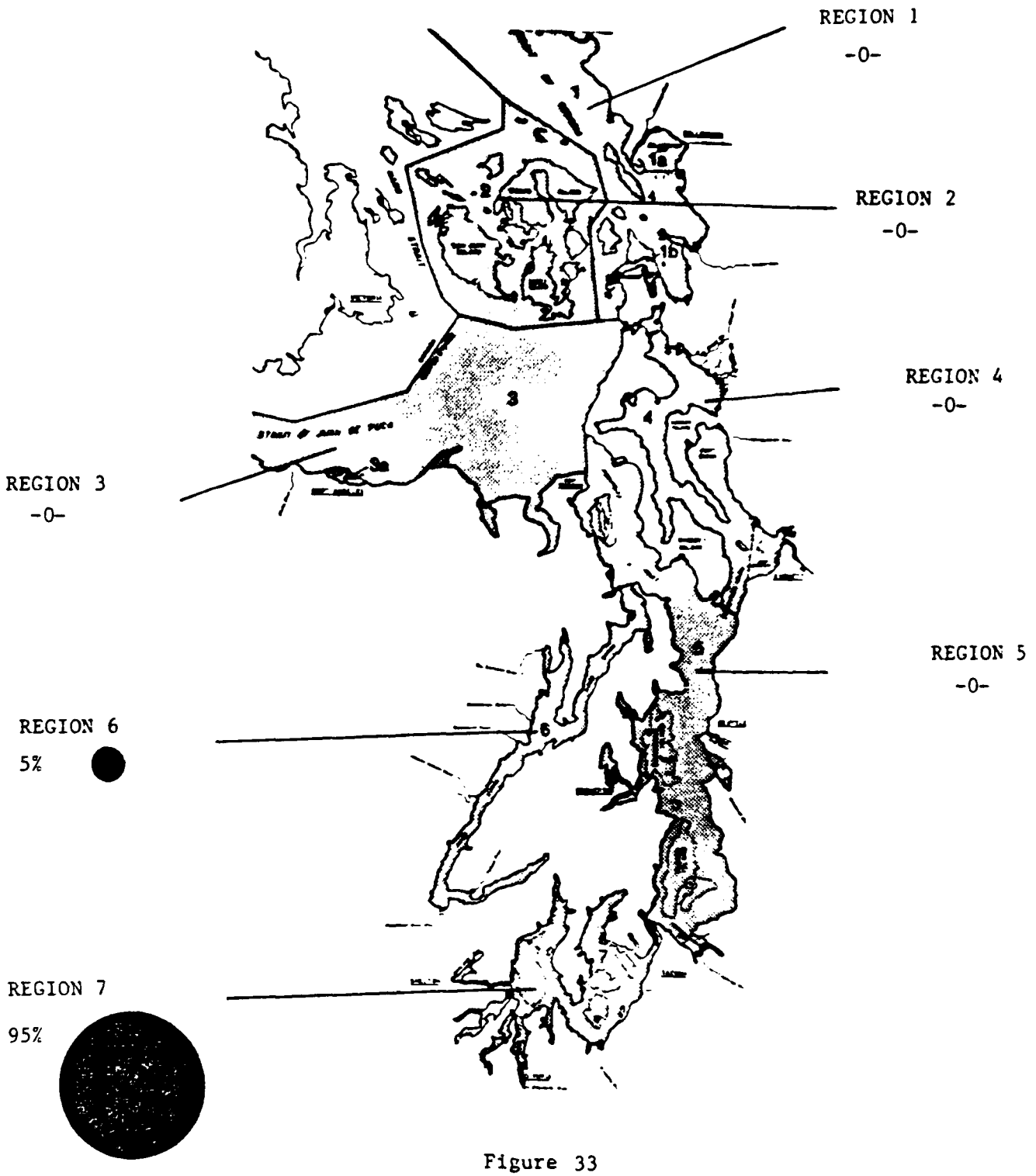


Figure 33

DISTRIBUTION OF OLYMPIA OYSTER HARVEST IN PUGET SOUND

(based on WDF statistics)

2.3.10 Crustaceans

Both crab and shrimp represent significant and lucrative resources to Puget Sound's commercial and recreational fisheries. These resources combined contributed approximatley 25% of the value in dollars to the total Puget Sound commercial shellfish harvest over the past five years. The primary species include Dungeness crab (Cancer magister), spot shrimp (Pandalus platyceras), pink shrimp (P. borealis) and coonstripe shrimp (P. hypsinotus).

2.3.11 Dungeness Crab

Geographic Range

The Dungeness crab is found from Mexico to southwestern Alaska (Shapiro, 1971). In Puget Sound, Bellingham, Padilla and Lummi Bays are important areas due to the occurrence of eelgrass beds.

Biology

Dungeness crabs are found from low water to 50 fathoms in substrates of mud, sand, gravel, stones or shells (Nations, 1975). Adults spend most of their lives in depths of 25 fathoms or less but adults move inshore during the spring to reproduce. Females carry eggs for a time before larvae emerge the first zoeal stage, one of six stages as planktonic organisms. Upon the completion of all zoeal stages the larva become a megalops larva which molt into a bottom dwelling juvenile. Juvenile Dungeness crabs live in intertidal and subtidal waters in beds of algae or eelgrass. In approximately three years, the juvenile crab will mature and move to deeper waters.

Critical Water Quality Needs and Sensitivities

It is generally accepted that juvenile and larval stages of crustaceans are among the most sensitive marine invertebrates. For this reason they are often selected for bioassays, particularly for studies on hydrocarbon toxicity.

Most Dungeness crab mortality is related to predation or disease. Molting crabs are extremely susceptible, particularly once they have lost their protective shell. Migrating crabs instinctively attracted to female pheromones and spawning areas are also susceptible to toxicant exposure, both in terms of toxicity and interference with important reproductive signals.

Commercial Fisheries/Aquaculture - Present and Potential

The Dungeness crab fishery contributes 1.5 million pounds annually to Puget Sound commercial fisheries with a value of $1,500,000. There is little potential for the culture of Dungeness crabs since they are cannabalistic. Consequently, the management of wild stocks is important to maintain a maximum sustained yield equivalent to current levels. The northern Sound including the San Juan Islands (Region 2) and the Straits of Juan de Fuca and Georgia (Region 1 and 3) are important crab resource areas in Puget Sound. Table 7 presents current and potential commercial and recreational harvests of Dungeness crabs in Puget Sound.

Recreational Harvest

Recreational harvesting of Dungeness crabs and rock crabs using crab pots is a popular pastime in Puget Sound, particularly in the San Juan Islands (Region 3), Admiralty Inlet (Region 5), Hood Canal (Region 6) and the Straits of Juan de Fuca and Georgia (Regions 1 and 3). Table 8 presents the 1979 and 1980 summaries of sport crab pot fishing in Puget Sound by number of effort days and crabs.

Summary Points - Dungeness Crabs

- Region 1 is the most important area in Puget Sound for Dungeness Crab production (Figure 34).
- Resource estimates of standing stocks are not available. Commercial landing statistics of crabs are used to predict potential harvest data.
- Critical life stages: larval, juveniles and molts.
- Five year average (1979-1983) is estimated to be $1,500,000 for 1.5 million pounds.
- Important contacts and sources of information include:

WDF	Ron Westley
	Eric Hurlburt
UW	School of Fisheries

Table 7

DUNGENESS CRAB LANDINGS AND VALUES, PUGET SOUND DISTRICT
(rounded off to nearest thousand)

DUNGENESS CRAB LANDINGS (lbs)

Region	Catch Area	Present Harvest			Potential Harvest		
		Commercial	Recreational	Total	Commercial	Recreational	Total
1	Gulf of Georgia	1,447,000	11,000	1,458,000	1,496,000	11,000	1,507,000
1	Bellingham Bay	216,000	88,000	304,000	306,000	88,000	394,000
1	Samish Bay	136,000	32,000	168,000	155,000	32,000	187,000
2	San Juan Islands	89,000	17,000	106,000	139,000	17,000	156,000
1	Padilla & Fidalgo Bays	53,000	32,000	85,000	57,000	32,000	89,000
3	Skagit Bay, Saratoga Pass	65,000	40,000	105,000	65,000	40,000	105,000
4	Port Susan	30,000	22,000	52,000	30,000	22,000	52,000
3	Dungeness Bay	13,000	25,000	38,000	20,000	25,000	45,000
5	Admiralty Inlet	2,000	3,000	5,000	2,000	3,000	5,000
5	Port Gardner, Useless Bay	16,000	7,000	23,000	16,000	7,000	23,000
5	Kingston, Port Madison	2,000	6,000	8,000	2,000	6,000	8,000
6	Hood Canal, Upper	-0-	34,000	34,000	-0-	34,000	34,000
6	Hood Canal, Central	-0-	17,000	17,000	-0-	17,000	17,000
6	Hood Canal, Lower	-0-	48,000	48,000	-0-	48,000	48,000
	TOTAL	2,069,000	382,000	2,451,000	2,288,000	382,000	2,670,000

DUNGENESS CRAB VALUES ($)

1	Gulf of Georgia	949,000	7,000	956,000	981,000	7,000	988,000
1	Bellingham Bay	142,000	58,000	200,000	201,000	58,000	259,000
1	Samish Bay	89,000	21,000	110,000	102,000	21,000	123,000
2	San Juan Islands	58,000	11,000	69,000	91,000	11,000	102,000
1	Padilla & Fidalgo Bays	35,000	21,000	56,000	37,000	21,000	58,000
3	Skagit Bay, Saratoga Pass	43,000	26,000	69,000	43,000	26,000	69,000
4	Port Susan	20,000	14,000	34,000	20,000	14,000	34,000
3	Dungeness Bay	9,000	16,000	25,000	13,000	16,000	29,000
5	Admiralty Inlet	1,000	2,000	3,000	1,000	2,000	3,000
5	Port Gardner, Useless Bay	10,000	4,000	14,000	10,000	4,000	14,000
5	Kingston, Port Madison	1,000	4,000	5,000	1,000	4,000	5,000
6	Hood Canal, Upper	-0-	22,000	22,000	-0-	22,000	22,000
6	Hood Canal, Central	-0-	11,000	11,000	-0-	11,000	11,000
6	Hood Canal, Lower	-0-	31,000	31,000	-0-	31,000	31,000
	TOTAL	1,357,000	248,000	1,605,000	1,500,000	248,000	1,748,000

Source: Solomon and Mills, 1983

Table 8

CRAB AND SHRIMP SPORT FISHERIES[a]
FOR 1979 AND 1980

Region	Area	Sport Crab Pot Gear			Sport Shrimp Pot Gear	
		Effort	Number of Crabs		Effort	Shrimp
	1979	Pot Days	Dungeness	Rock	Pot Days	(lb)
1	Gulf of Georgia	17,419	22,454	1,394		
1	Bellingham Bay	57,353	92,433	4,588		
1	Samish Bay	8,586	22,747	689		
2	South San Juan Islands	24,718	28,656	1,977		
1	Anacortes	13,147	23,737	1,052		
3	Strait of Juan de Fuca	1,097	549	88		
4	Skagit Bay-Saratoga Pass	85,417	120,319	6,833		
4	Port Susan	23,226	63,191	1,858		
3	Dungeness-Discovery	48,559	57,904	3,885		
5	Admiralty Inlet	15,716	18,653	1,257		
5	Useless Bay-Port Gardner	18,675	17,923	1,494		
5	Seattle-Port Madison	11,792	19,226	943		
6	Upper Hood Canal	20,833	35,371	1,667	14,219	15,796
6	Central Hood Canal	11,305	17,853	904	13,839	16,067
6	Lower Hood Canal	29,032	56,297	2,323	20,813	26,768
	Total	386,875	597,313	30,952	48,871	58,631
	1980					
1	Gulf of Georgia	18,643	30,959	1,679		
1	Bellingham Bay	53,475	58,021	4,813		
1	Samish Bay	7,398	17,207	666		
2	South San Juan Islands	24,741	14,504	2,227		
1	Anacortes	14,064	19,970	1,266		
3	Strait of Juan de Fuca	2,870	6,468	258		
4	Skagit Bay-Saratoga Pass	101,129	105,553	9,102		
4	Port Susan	29,824	41,414	2,684		
3	Dungeness-Discovery	42,393	47,604	3,815		
5	Admiralty Inlet	15,749	16,850	1,417		
5	Useless Bay-Port Gardner	20,413	14,874	1,837		
5	Seattle-Port Madison	11,014	13,880	991		
6	Upper Hood Canal	30,655	22,918	2,759	16,661	22,556
6	Central Hood Canal	11,639	12,700	1,048	15,472	30,413
6	Lower Hood Canal	31,417	73,383	2,828	27,373	31,511
	Total	415,424	496,305	37,390	59,506	84,480

[a] in number of days effort and number of crab or pounds of shrimp.

Source: Solomon and Mills, 1983

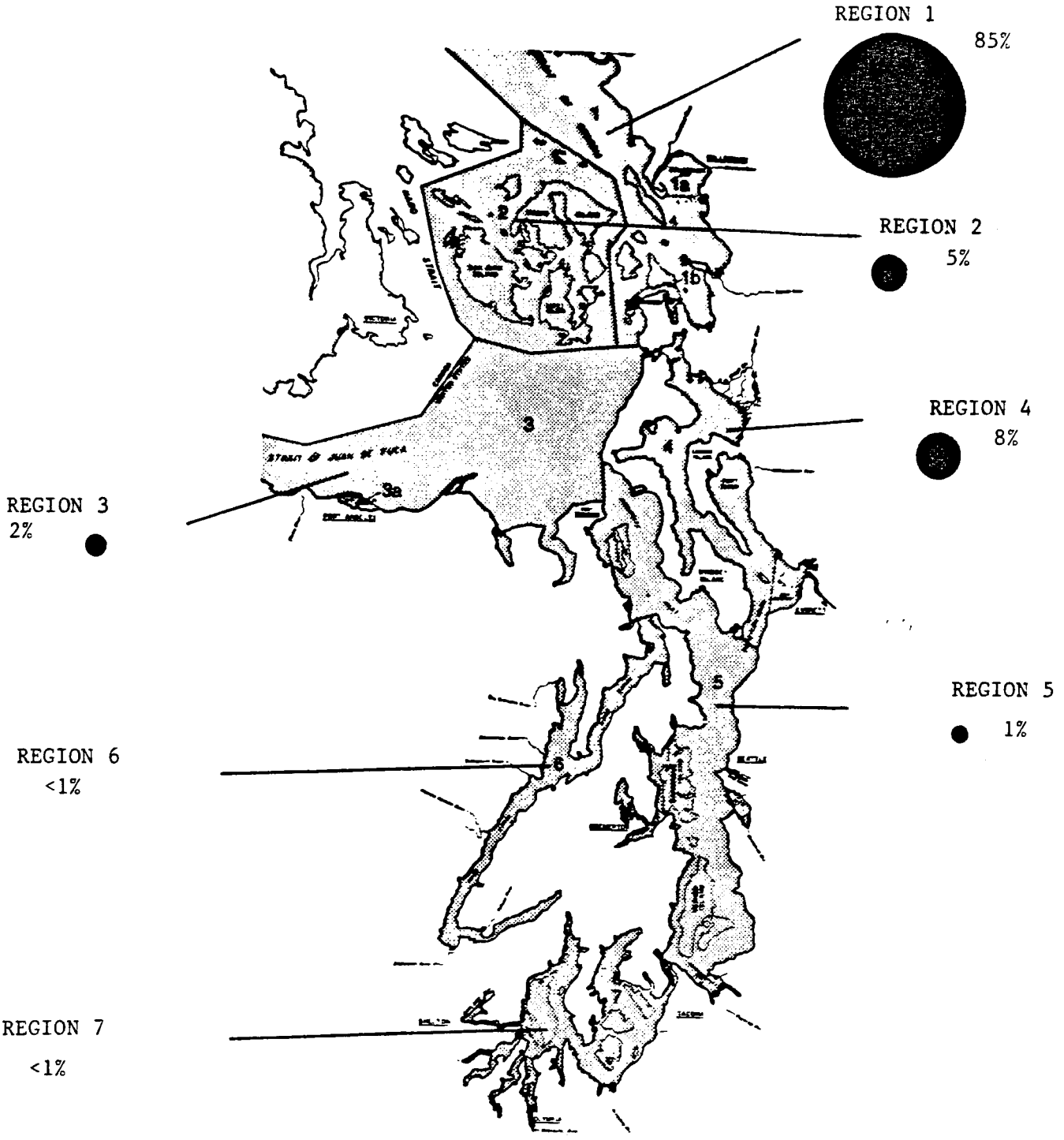


Figure 34

DISTRIBUTION OF DUNGENESS CRAB HARVEST IN PUGET SOUND

(based on WDF statistics)

2.3.12 Shrimp Resource

Geographic Range

The pandalid shrimp found in Puget Sound occur from Alaska to California. Pink and coonstripe shrimp are common in Saratoga Passage and the San Juan Islands (Regions 3 and 4), while spot shrimp are primarily in Hood Canal (Region 6) (Solomon and Mills, 1983).

Biology

Pandalid shrimp are an important facet of Puget Sound's marine resources. Pandalids in Puget Sound can range from shallower waters around rafts and pilings for the coonstripe shrimp to the deeper waters which pink shrimp typically inhabit. Adult pandalids may be found from the intertidal zone to the deepest waters preferring substrates with high organic matter. This is particularly true of the pink shrimp which feeds on infaunal organisms. Adult shrimp seasonally migrate to spawn in shallower bays. After mating, the female releases the eggs, usually in the spring and summer. The larvae are planktonic for two or more months before metamorphosing into the benthic juvenile stage.

Known Water Quality Needs or Sensitivities

It is generally accepted that juvenile and larval stages of crustaceans are among the most sensitive marine invertebrates. While juvenile and postlarval stages are fairly tolerant of salinity changes, cultured pandalid shrimp appear to be more sensitive to sudden chilling (Bardach et al. 1972).

Commercial Fishery/Aquaculture - Present and Potential

Pandalid shrimp are harvested with baited traps. In the last five years, Puget Sound's shrimp fishery has been worth $150,000 annually with an average annual catch of 50,000 pounds. Spot shrimp are commercially cultured by rearing in floating pens. The northern Sound and Hood Canal are the most important areas for or harvesting wild pandalid shrimp (Regions 1, 4 and 6). Table 9 presents current and potential commercial and recreational harvest of shrimp in Puget Sound.

Table 9

PANDALID SHRIMP LANDINGS AND VALUES, PUGET SOUND DISTRICT
(rounded off to nearest thousand)

PANDALID SHRIMP LANDINGS (lbs)

Region	Catch Area	Present Harvest			Potential Harvest		
		Commercial	Recreational	Total	Commercial	Recreational	Total
2	San Juan Islands	36,000	Unavailable	36,000	51,000	Unavailable	51,000
3	Port Angeles Harbor	1,000	Unavailable	1,000	2,000	Unavailable	2,000
4	Saratoga Passage	2,000	Unavailable	2,000	5,000	Unavailable	5,000
4	Port Susan	2,000	Unavailable	2,000	5,000	Unavailable	5,000
6	Hood Canal, Upper	11,000	18,000	29,000	13,000	25,000	38,000
6	Hood Canal, Central	9,000	15,000	24,000	17,000	20,000	37,000
6	Hood Canal, Lower	11,000	24,000	35,000	27,000	33,000	60,000
	TOTAL	72,000	57,000	129,000	120,000	78,000	198,000

PANDALID SHRIMP VALUES ($)

2	San Juan Islands	11,000	-0-	11,000	15,000	-0-	15,000
3	Port Angeles Harbor	3,000	-0-	3,000	4,000	-0-	4,000
4	Saratoga Passage	500	-0-	500	1,000	-0-	1,000
4	Port Susan	500	-0-	500	2,000	-0-	2,000
6	Hood Canal, Upper	26,000	44,000	70,000	32,000	61,000	93,000
6	Hood Canal, Central	23,000	36,000	60,000	42,000	49,000	91,000
6	Hood Canal, Lower	27,000	60,000	87,000	30,000	82,000	112,000
	TOTAL	91,000	140,000	232,000	126,000	192,000	318,000

Source: Solomon and Mills, 1983

Recreational Harvest

Recreational harvesting of shrimp using baited traps, wading and underwater diving is popular in Puget Sound and is reported by WDF only for Hood Canal (Region 6). Table 8 reported the number of days and pounds of shrimp harvested recreationally in this region for 1979 and 1980.

Summary Points - Shrimp

- Regions 3 and 4 are the most important areas for shrimp production in Puget Sound.
- Critical life stages are larvae and juveniles.
- Five year average of commercial fishing indicates value to be $150,000 for approximately 50,000 pounds.
- Important Sources of Information include:

WDF	Ron Westley
	Eric Hurlburt
UW	School of Fisheries

2.3.13 Other Shellfish

Puget Sound is also a source of commercial shellfish that are not heavily exploited but are becoming increasingly important. Harvests of octopus, squid, scallops, sea cucumbers, and sea urchins are worth over $100,000 annually (1979-1983 average). Table 10 presents the comparative annual landings of some of these shellfish as reported by WDF (1982).

The culturing of many of these species promises to greatly increase annual harvests as well as boost local employment and economics. This, of course, is dependent upon the success of culturing techniques, success of adapting these methods to local areas, and public acceptance.

According to WDF, some areas in Puget Sound are particularly suitable for the culturing of shellfish. These include Discovery and Sequim Bays, Killisut Harbor, Penn Cove, Holmes Harbor, Port Susan, Skagit Bay, Dabob and Quilcene Bays, Port Gamble and the San Juan Islands (Solomon and Mills, 1983). These areas can be found in Regions 2, 3, 4, 5 and 6.

The following is a brief description of the commercial fishery and an assessment of its aquacultural potential. This information was provided by Eric Hurlburt, WDF Shellfish Division (pers. comm.).

2.3.14 Scallops

Current commercial harvest of scallops is focused primarily in the northern Sound, San Juan Islands and Hood Canal (Regions 2, 3, and 6). The weathervane and the purple-hinged rock scallop are the major commercial species. Experimental work performed on scallop culture and production by WDF's Shellfish Division appears promising. They believe scallop culture has the potential of producing 5-10,000,000 pounds annually in Puget Sound.

2.3.15 Abalone

Native abalone are found in the northern Sound in the Straits of Juan de Fuca. Commercial harvest of this shellfish occurs along the coast but is exceedingly small. Due to their slow growth and recruitment and limited availability of suitable habitat, the potential for culture or increased wild harvest of this shellfish is low at this time.

Table 10

COMPARATIVE ANNUAL LANDINGS OF SHELLFISH
PUGET SOUND DISTRICT IN NUMBER OF POUNDS

Year	Octopus	Scallops	Sea Cucumbers	Sea Urchins	Shrimp	Squid
1968	12,166	--	--	--	25,080	674
1969	12,127	14,474	--	--	22,990	609
1970	12,780	530	--	--	33,074	453
1971	30,195	--	7,806	1,800	63,025	4,314
1972	17,830	--	6,444	2,500	88,484	172
1973	35,718	485	10,044	14,734	144,093	666
1974	48,546	1,759	--	57,449	115,162	1,352
1975	30,760	1,163	3,485	30,962	83,073	389
1976	10,446	--	14,754	1,544,411	57,649	1,080
1977	10,031	--	63,326	902,591	38,908	513
1978	41,573	--	126,865	1,025,844	66,303	1,699
1989	27,530	--	236,115	1,002,183	89,864	3,972
1980	51,994	2,704	420,754	43,267	79,896	3,592
1981	29,700	69,708	275,615	268,407	101,301	11,533
1982	25,819	4,848	27,089	202,387	112,075	4,291

Source: WDF, 1982

2.3.16 Sea Urchin

Three species of sea urchins are found in Puget Sound: the purple, red, and green. The harvest of purple sea urchins is not permitted currently and the green is not exploited at all. The commercial market is low and demand is not expected to rise in the near future. However, there is the potential for the red sea urchin to support an annual harvest of 1,000,000 pounds and the green have an annual harvest of 2,000,000 pounds. Culturing sea urchins is not likely at this time because of the low demand.

2.3.17 Sea Cucumber

Sea cucumbers are ubiquitous in Puget Sound, particularly in the deeper waters. Current peak harvest is 400,000 pounds annually from Regions 2, 5, 6 and 7 (Figure 35). This however, could potentially be doubled, but market demands are low at this time, and WDF has not intensively studied this issue. Culturing of sea cucumbers is not anticipated at this time. Perhaps a more important issue to sea cucumber harvest is a better understanding of their ecological role which may be more important than their commercial value.

2.3.18 Squid

The squid is a pelagic organism that is usually found in the northern sound, but also occurs in the southern Sound later in the year. This movement is believed to be a spawning migration. At the present, the average annual harvest of squid is approximately 22,000 pounds (1979-1983). Because squid production is too variable from year to year WDF does not anticipate a great increase in its commercial harvest. Culturing of squid is not likely at the present time.

2.3.19 Octopus

The octopus is a territorial bottom dweller and is found primarily in the northern and central Sound. At the present, the average annual harvest of octopus is approximately 29,000 pounds (1979-1983). Because the octopus population size is fairly stable in Puget Sound, there may be some potential for expanding wild harvests though reliable data is not available. Octopus aquaculture appears promising, particularly because of rapid growth rates. However, this culture will have to consider their cannabalistic behavior and this factor may hinder potential culturing efforts.

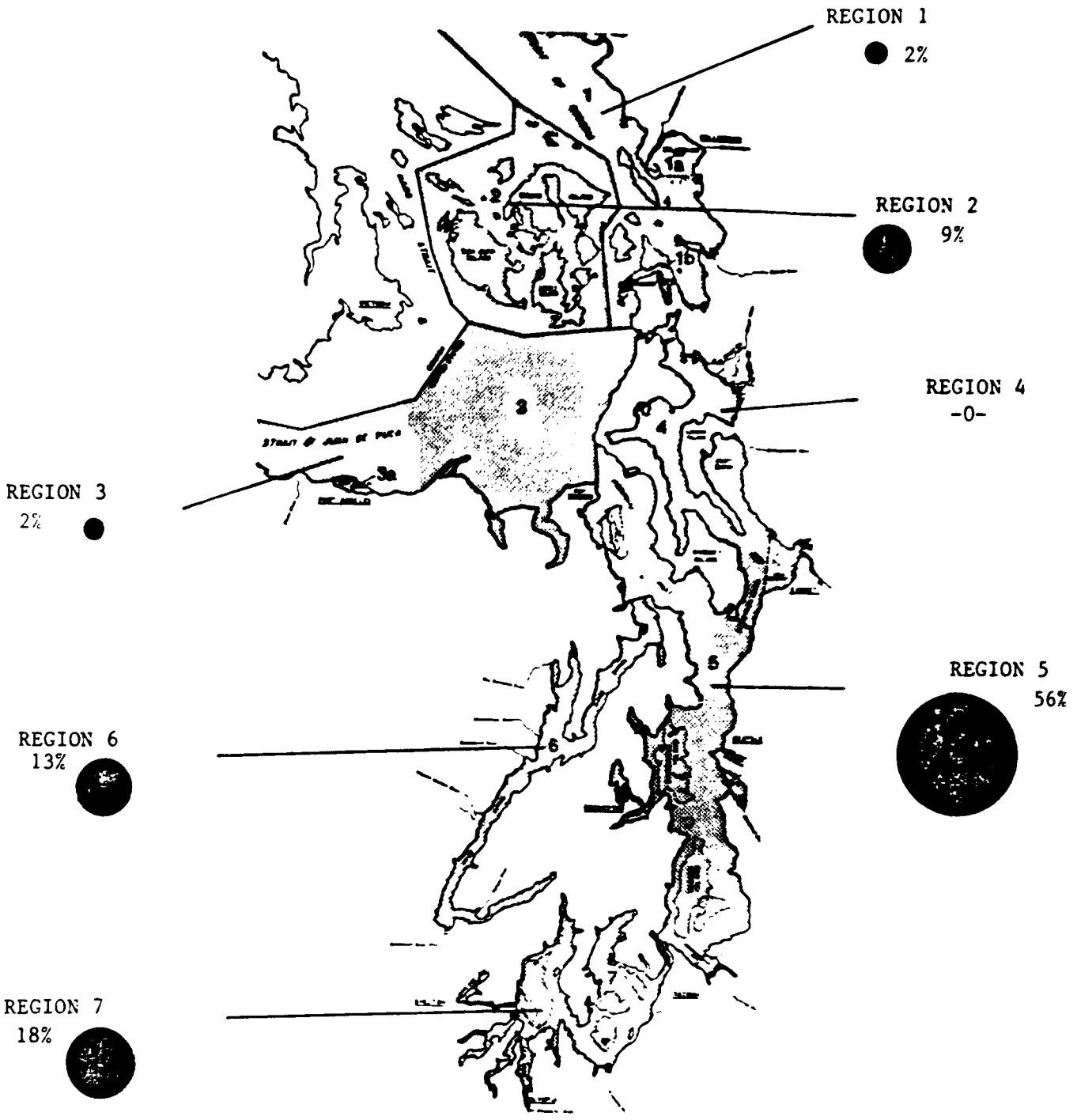


Figure 35

DISTRIBUTION OF SEA CUCUMBER HARVEST IN PUGET SOUND

(based on WDF statistics)

2.4 AQUACULTURE OF MARINE MACROPHYTES

Numerous species of marine macrophytes such as the red, green and brown algaes are used as food, primarily for animals but also for humans. Additional uses of these seaweeds include fertilizers, food additives, and varied industrial processes (Bardach et al., 1972). The culture of Nori or Porphyra, a red algae, holds the highest potential for plant aquaculture in Puget Sound because of its ease of culture and its popularity in many Oriental foods. Nori is nutritious, rich in vitamins A, B, and C and is considered as a valuable food source, particularly in areas of the world with food shortages (DiChiro 1981). Currently, DNR is studying the culturing and production of Nori in Puget Sound. They believe that local production of Nori would supply a large local demand because it is fresher and less costly than the imported product. They also believe that Nori could be grown on small scale sea farms thus expanding the productivity of Puget Sound's marine lands. At the current time, harvesting of seaweeds is limited to the personal harvest of wild stocks. This can be a problem if many plants are improperly harvested as they may not regenerate.

The potential for culturing sea vegetables is very high in Puget Sound. Any bay or shoreline with suitable characteristics including flattened or slightly sloping shelves, shallow water and good flushing will provide an ideal location. Vegetables could be grown at the water's surface usually in nets suspended in the intertidal zone. Currently, the practical limit for sea farming is around 60 feet, however as culturing techniques and market demands increase more remote areas could be used. Because Puget Sound is characterized by relatively protected waters, high nutrients, and overall high water quality, the potential for culturing Nori and other sea vegetables is very high. Some other potential algae for culture include: Laminaria (brown algae), Nereocystis (brown), Grassolaria (red) and Monostroma (green).

The question of whether macrophytes take up heavy metals and other toxicants, particularly from sewage or industrial wastes contamination is of concern. Macroalgae will take up heavy metals but it is believed the metals become irrevocably bound. The potential for human health problems is unknown, although some contend that because humans do not have the proper enzymes to digest plant cell walls where the metal concentrations are believed to accumulate, the potential for human health risks is low (Thomas, 1983).

Summary Points - Plant Aquaculture

- Current harvest is restricted to personal use of wild stocks only.

- Important contacts and sources of information include:

UW	John Merrill
DNR	Tom Mumford
	Giovanna Di Chiro
	Joan Thomas
Other Organizations	American Sea Vegetable Co.
	John Olson
	Luke Lucosky

2.5 PUGET SOUND RECREATION

In assessing recreational activities that are dependent upon good water quality, we limited our evaluation to only those activities which require body contact with the waters of Puget Sound, namely swimming and SCUBA diving. While we recognize that other recreation within the Sound is undoubtedly affected by water quality to some extent, we also recognize that these activities could occur despite the quality of the water. For example, boating itself is not impaired by poorer water quality although we can assume that boating recreation may diminish in grossly contaminated waters.

Consideration of swimming and diving opportunities within the Sound is hampered by the fact that accurate records on swimmer and diver user days is not available. Obtaining this information would essentially require interviewing state, county and local park authorities who are on-site at each location in order to determine the level of effort. Therefore, only the number and locations of all swimming and diving sites within Puget Sound have been included. This information is presented in Table 11 and Figures 36 and 37 for swimming and Table 12 and Figures 38 and 39 for diving.

Table 11

SWIMMING BEACHES IN PUGET SOUND

Region	Site Number	Name	Jurisdictional Authority
1	23	Bayview RA	State Parks
	24	Birch Bay RA	State Parks
	27	Saddle Bag Island RA	State Parks
2	26	Moran State Park	State Parks
	28	Spencer Spit RA	State Parks
	29	Sucia Island State Park	State Parks
	30	Turn Island RA	State Parks
3	16	Dungeness Spit	State Parks/USIWS
	25	Deception Pass State Park	State Parks
4	1	Freeland County Park	Island County
5	2	Richmond Beach County Park	King County
	3	Alki Point Park	Seattle City Parks
	4	Carkeek Park	Seattle City Parks
	5	Dash Point State Park	State Parks
	6	Seahurst Park	King County
	7	Point Defiance	City of Tacoma
	9	Browns Point Lighthouse	Pierce County
	10	Pichic Point	Snohomish County
	15	Ft. Worden State Park	State Parks
	18	S. Whidbey Island RA	State Parks
	20	Saltwater RA	State Parks
6	11	Twanoh RA	State Parks
	14	Potlatch RA	State Parks
	17	Belfair RA	State Parks
	19	Scenic Beach RA	State Parks
	22	Kitsap Memorial RA	State Parks
7	8	Titlow Beach	City of Tacoma
	12	Stretch Point RA	State Parks
	13	Squarin Island RA	State Parks
	21	Penrose Point RA	State Parks

RA = Recreational Area

Percent of Total by Region

1	10%
2	13.3%
3	6.7%
4	3.3%
5	36.7%
6	16.7%
7	13.3%

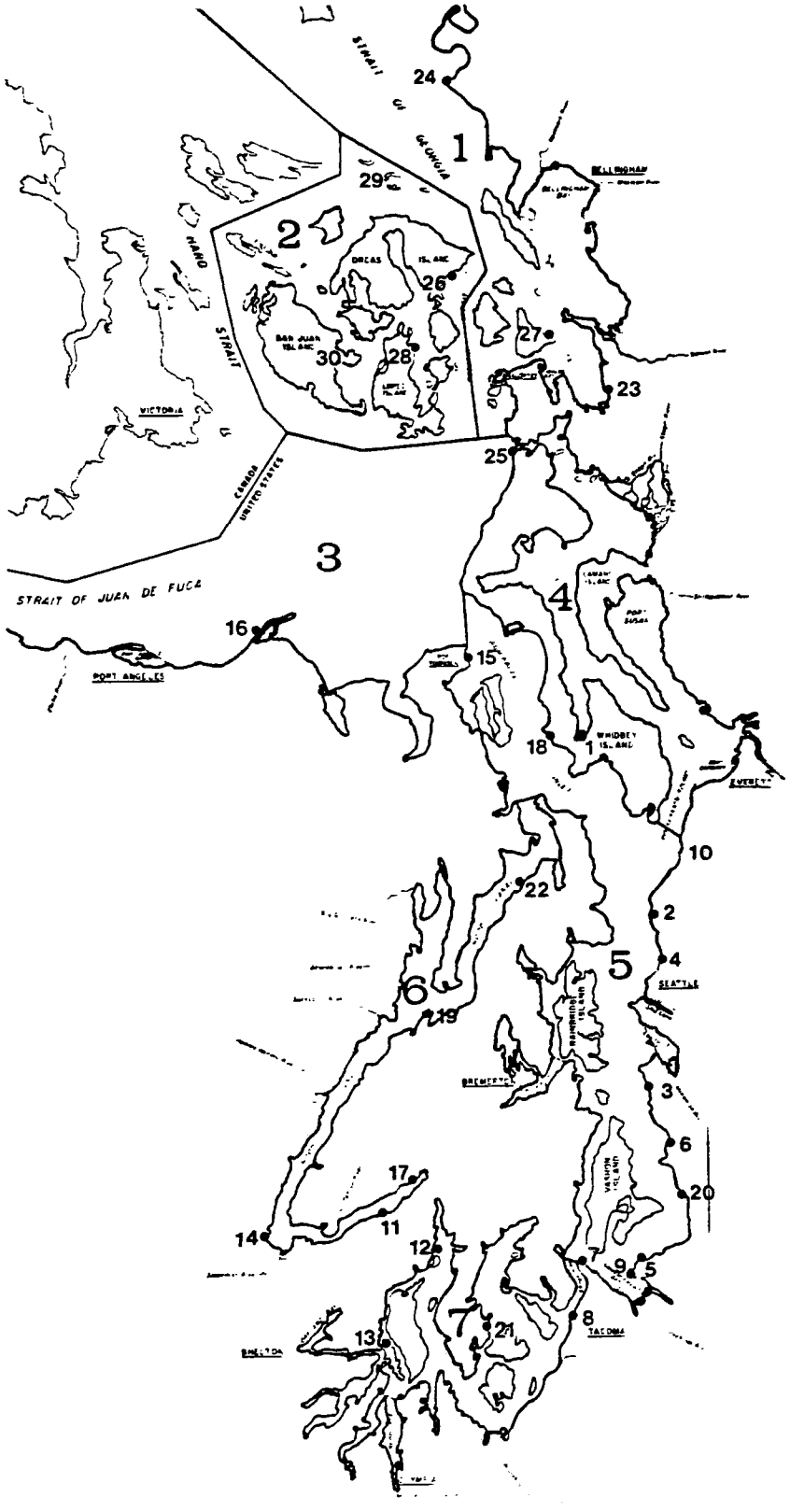


Figure 36

LOCATIONS OF PUBLIC SWIMMING BEACHES IN PUGET SOUND
(see Table 11)

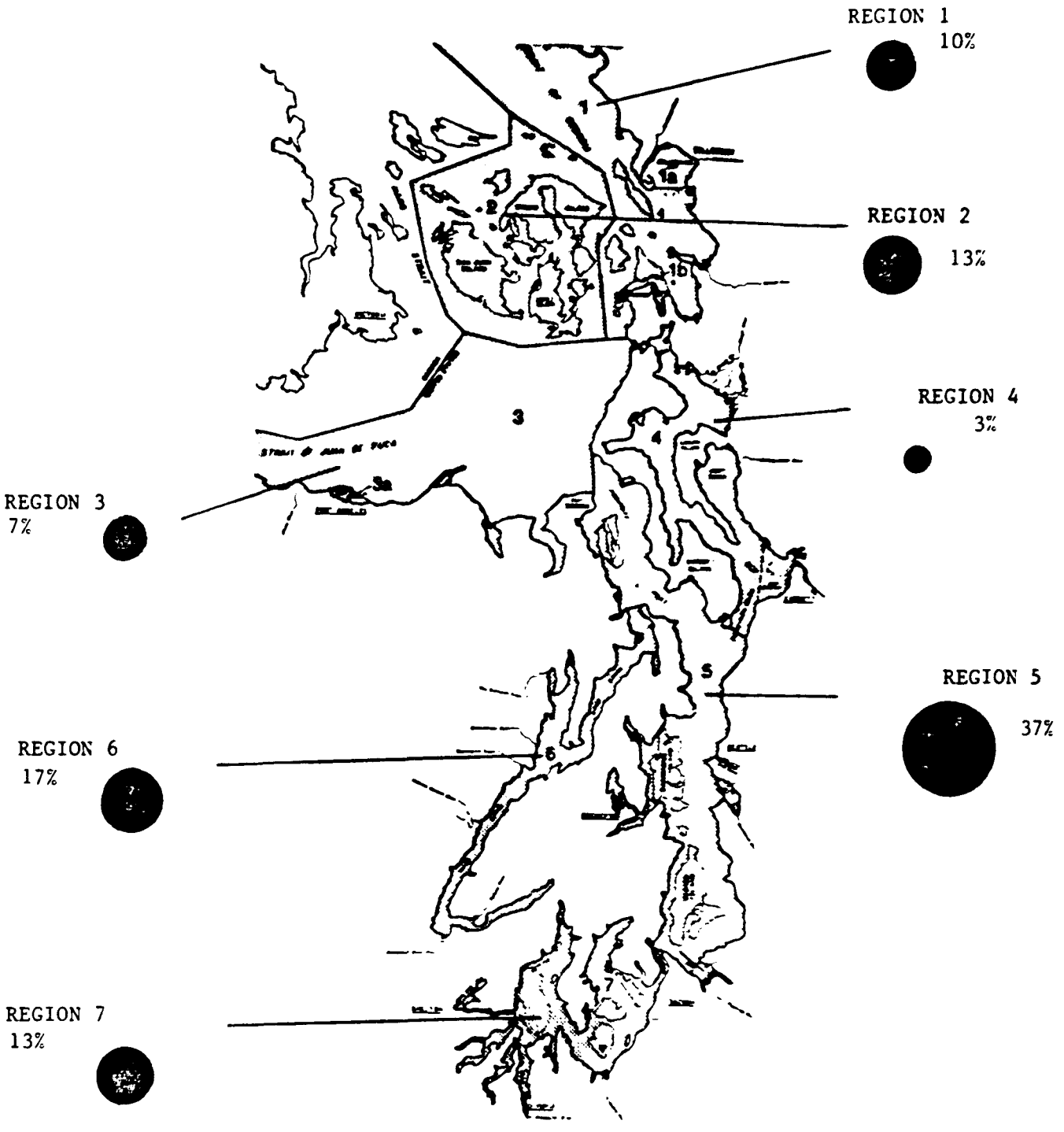


Figure 37

DISTRIBUTION OF PUBLIC BEACHES IN PUGET SOUND

Table 12

SCUBA SITES IN PUGET SOUND

Region	State Inventory Number	Name	Uses[a]	Access[b]
1	64	Birch Bay	S,SH	S
	63	Lummi Island	S,O,P	B
	62	Larrabee State Park	SH	S
	61	Eliza Rock	S,SH	B
	60	Guemis Island	S,SH	B
	59	Sunset Beach	S,O,SH	S
	58	Fidalgo Head	S	B
2	65	Ewing Cove (artif. reef)	P,S,O,H	B
	66	Sucia Island	S,P,O,SH	B
	67	Orcas Island	S	B
	68	White Rock	P,O,S,SH	B
	69	Gossip Island	S,P,O,SH	B
	71	Roche Harbor	S	B,S
	70	Speider Island	S,P,O	B
	72	Lime Kiln Point	S,P,O	B,S
	73	Pile Point	H,S,P,O	B
	74	Eagle Point	S,O,SH	B,S
	75	Reid Rock	S	B
	76	Crane Island	S	B
	77	Bell Island	S	B
	78	Orcas Island Ferry Dock	S	S
	79	Orcas Island Reef	S,O	B
	80	Shag Rock	S,O	B
	81	Spencer Spit	O,S,SH	S,B
	83	Peapod Rocks[c]	P,O,S,SH	B
	82	Doe Island	S	B
	84	Buckeye Shoals	S,P,O	B
3	57	Roaria Beach[c]	S,O,P,SH	S
	56	Deception Pass[c]	H,O,P	S,B
	48	Dungeness Bay	S,SH	S
	49	Ediz Hook (Port Angeles)	S,SH	S
	50	Freshwater Bay	S,P,O,SH	S
	46	Fort Worden[c]	S	S
	47	Discovery Bay	H	S
4	53	Langley	S,SH	S
	52	Columbia Beach	S	S
	51	Mukilteo	S,SH	S
5	55	Fort Casey[c]	O,P	S
	54	Keystone[c]	P,S,O,SH	S
	45	Port Townsend Jetty	P,S,H,O,SH	S
	44	Irondale	H,S,SH	S
	43	Port Townsend Canal	P,S,H	S
	42	Klas Rock	S,P,O,SH	B
	41	Colvos Rock	S,O,SH	B
	39	Port Ludlow	S,P,O	S,B
	40	Foulweather Bluff	S,SH	S
	26	Point No Point	H	S
	25	Edmonds[d]	H,P,O	S
	24	Point Wells	S	S
	23	Richmond Beach	S	S
	22	Agate Pass	S	B
	21	Shilshole Breakwater	S,P,O,SH	S
	20	Blakely Rock	S,P,O,SH	B
	19	Alki Point North (artif. reef)	O	S
	18	Alki Point South	S,O	S
	17	Fort Ward St. Park - Orchard Rocks[c]	O,P,S	S,B
	16	Blake Island[c]	P,H,S,O,SH	B
	15	Vashon Island	S,H	B
	14	Seahurst State Park (artif. reef)	P,O,S	S,B
	13	Saltwater State Park[c]	P,O,S	S,B
	13	Vashon Island Neill Point	S	B
	11	Gig Harbor	H,S	B

Table 12
(cont'd)

Region	State Inventory Number	Name	Uses	Access
6	38	Hood Canal Bridge	S	S
	37	Sisters Rock	S,P,SH	S,B
	36	Gamble Bay	S,H,P,SH	B
	35	Lofall	S,P,O	S
	32	Pulali Point	S,SH	B
	34	Seabeck Dock	S,P,H	S
	31	Pleasant Harbor	H,P,O,SH	S,B
	33	Stavis Bay	P,S,O,SH	S
	30	Triton Cove	S,P,SH	B
	29	Eldon	S,SH,O	S
	28	Lilliwaup	S,SH	S
	27	Hoodsport	P,S,O,SH	S
7	10	Tacoma	S,P,H,SH,O	S,B
	9	Point Fosdick	S,H,P,O	B
	8	Fox Island	S,P,SH	S
	7	Kopachuck[c] (artif. reef)	S,P,O,SH	S,B
	6	Day Island	S,P,SH	S
	5	Fox Island	S	B
	4	Tolivia Shoal	S,O,SH	B
	3	Tolmie State Park[c] (artif. reef)	O,S,SH	S,B
	2	Dana Passage	S,H	B
	1	Steamboat Island	P,O	B

Percent Total by Region

1	8.3%
2	23.8%
3	8.3%
4	3.6%
5	29.8%
6	14.3%
7	11.9%

[a]Use Codes: S - Spear Fishing
SH - Shell Fishing
P - Photography
O - Observation
H - Historical Interest

[b]Access Codes: S - Shore
B - Boat

[c]State Underwater Park

[d]City Underwater Park

Source: Wash. State Parks & Recreation Comm., 1977.

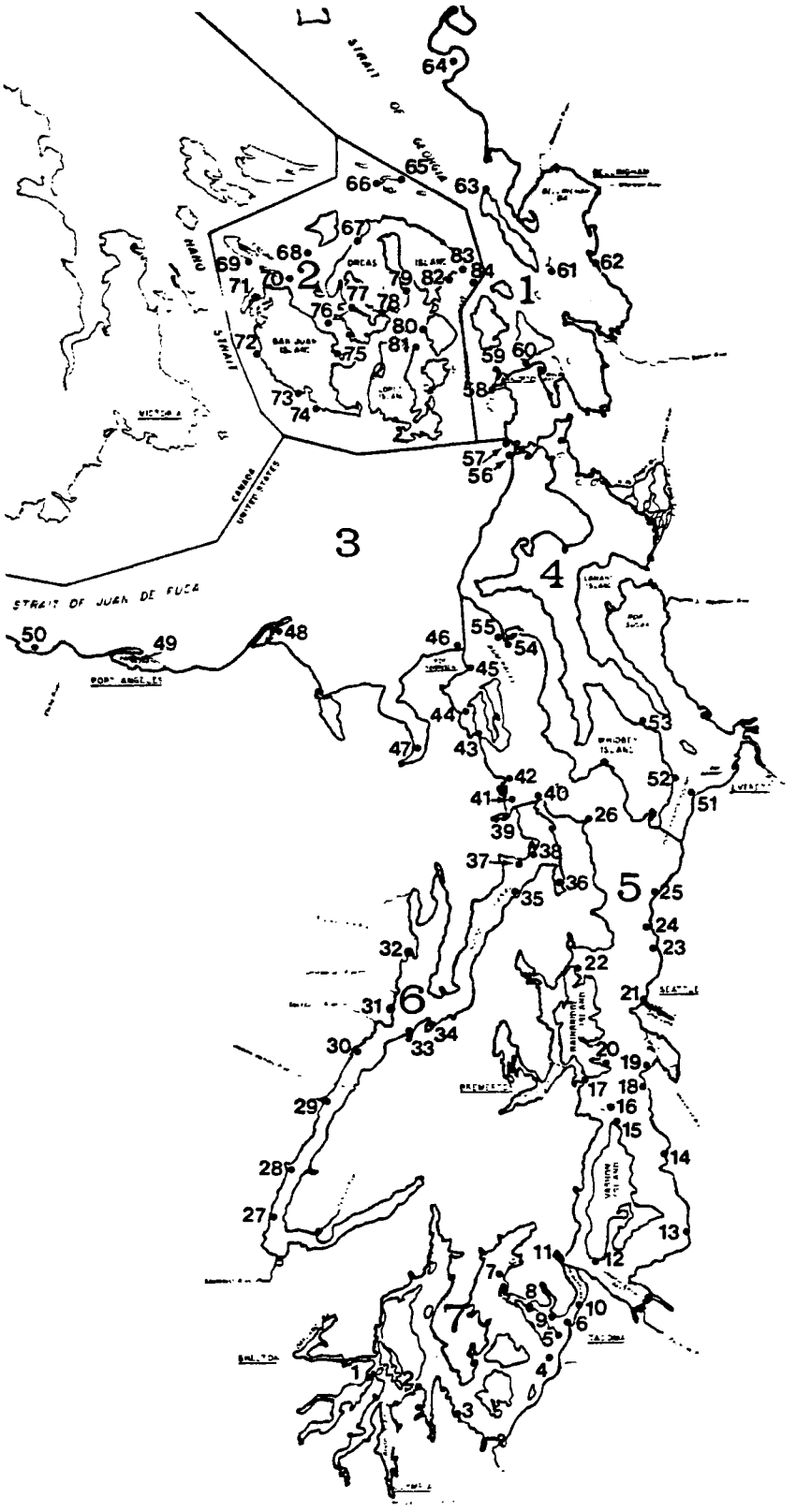


Figure 38

LOCATIONS OF SCUBA SITES WITHIN PUGET SOUND
(see Table 12)

Source: Wash. State Parks & Recreation Comm., 1977.

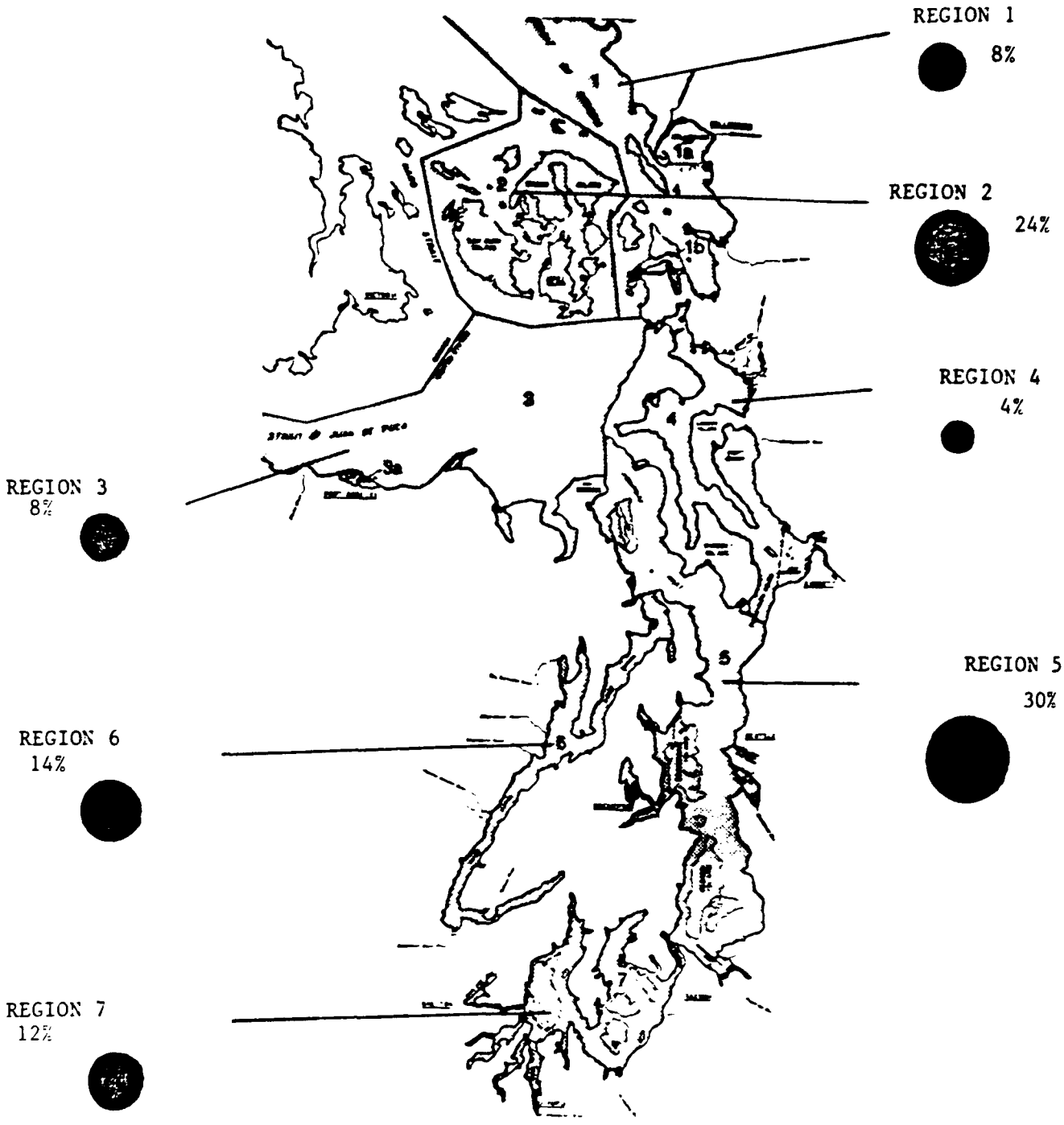


Figure 39

DISTRIBUTION OF SCUBA SITES IN PUGET SOUND

3.0 REGIONAL PROFILES OF FISHERIES RESOURCES

The relative importance of all the fisheries resources identified in Section 2.0 are discussed below within each of the subregions of Puget Sound. Presentation of this data is complicated by the incompatibility of WDF catch reporting areas and the seven subregions of Puget Sound identified by Jones and Stokes (1983). Interpretation of the data is even further complicated by the fact that WDF uses three different divisions of the Sound for catch reporting: one for marine fish and shellfish; a second for salmon; and a third for oysters.

The WDF marine fish and shellfish reporting areas are shown in Figure 40. There are nine major regions of the Sound, each with two to five subregions. In order to present this data in a consistent format, the WDF subregions were grouped in a manner that would most closely approximate the Jones and Stokes subregions. The WDF marine fish and shellfish boundaries used and their relationship to the Jones and Stokes divisions are shown in Figure 41. A similar procedure was followed for salmon (Figures 42 and 43) and oysters (Figures 44 and 45). It is important to note that the WDF statistics are based on landing areas which may not necessarily reflect areas of catch.

The annual commercial catches of marine fish, shellfish and salmon within each of the seven Puget Sound subregions are presented in Appendices A-D. The dollar values of these resources are presented in Appendix E. In order to present this data in a more readable format and to identify those resources of greatest economic importance within each subregion, the data from the appendices are summarized in Figures 46-52. The major resources are identified both in terms of pounds harvested and dollar value. Two criteria were used in selecting major species for inclusion in these figures: 1) the pounds harvested (or dollar value) of the species comprised 1% or more of the total of all fisheries resources harvested in the region; or 2) the regional harvest (or dollar value) of the species comprised over 50% of the total Sound harvest.

Region 1 (Figure 46) - Based on 1979-1983 data, pink salmon is the dominant fisheries resource in terms of pounds harvested, followed by herring and sockeye salmon. The latter two species are of greatest importance in terms of dollar value in the region, followed by chinook salmon and Dungeness crab.

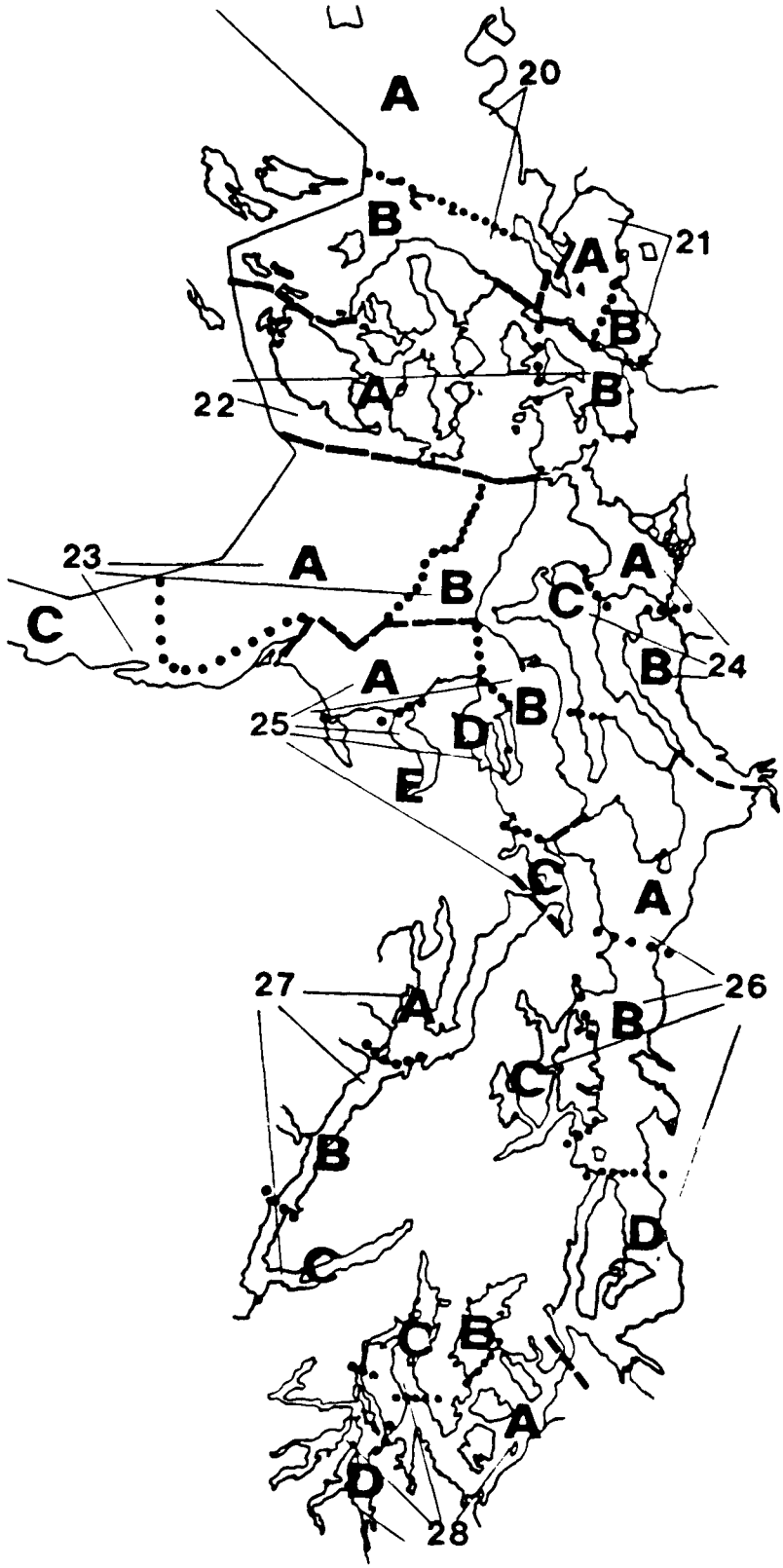
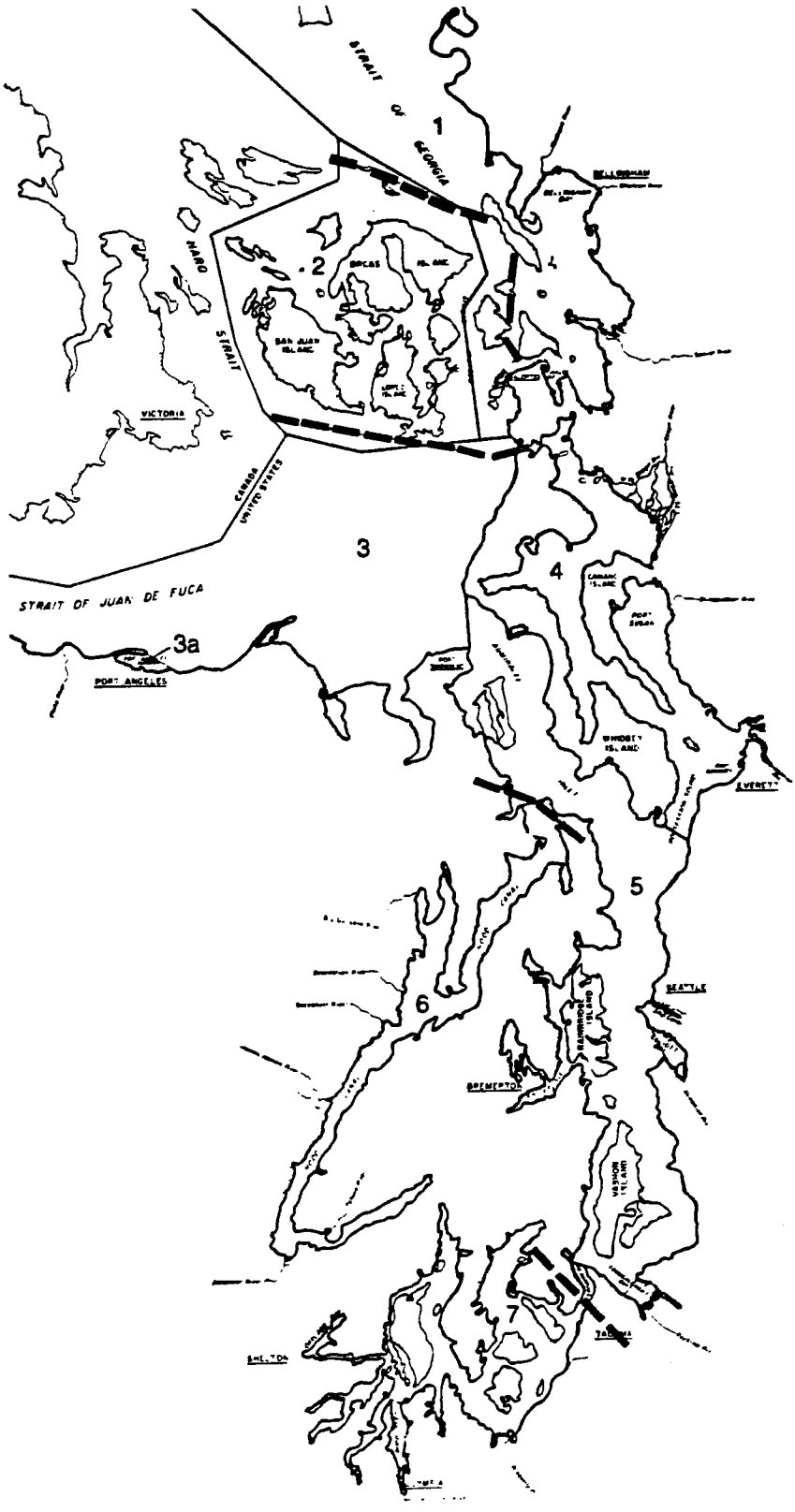


Figure 40

WDF MARINE FISH AND SHELLFISH CATCH REPORT AREAS

---- Regional Boundaries
●●●● Subregional Boundaries



1 - 20A, 21A, 21B, 22B

2 - 20B, 22A

3 - 23A, 23B, 23C, 25A, 25E

4 - 24A, 24B, 24C

5 - 26A, 26B, 26C, 26D, 25B, 25D

6 - 27A, 27B, 27C, 25C

7 - 28A, 28B, 28C, 28D

Figure 41

SUBAREAS OF PUGET SOUND WITH BOUNDARY ADJUSTMENTS
TO INCLUDE WDF MARINE AND SHELLFISH REPORTING AREAS

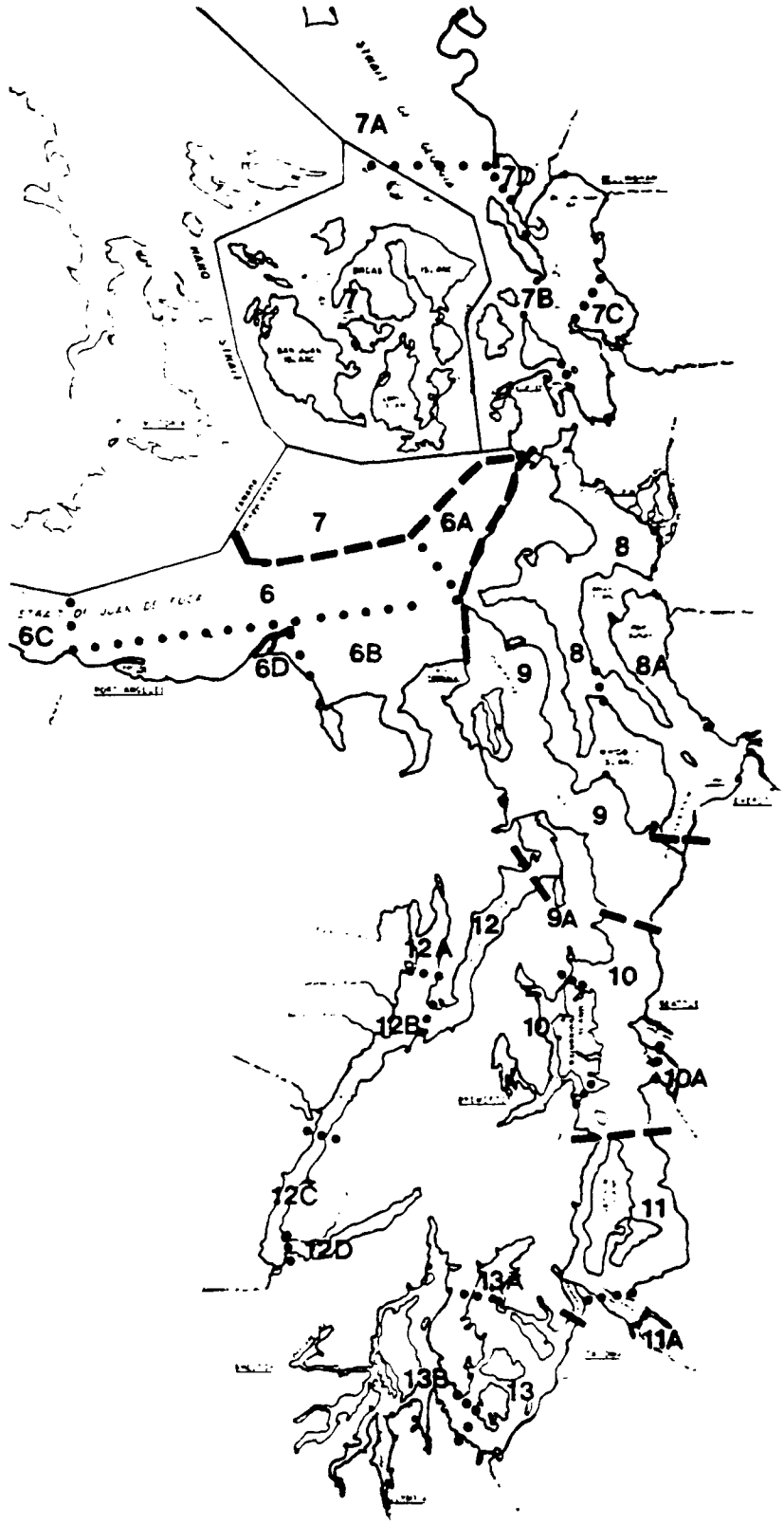
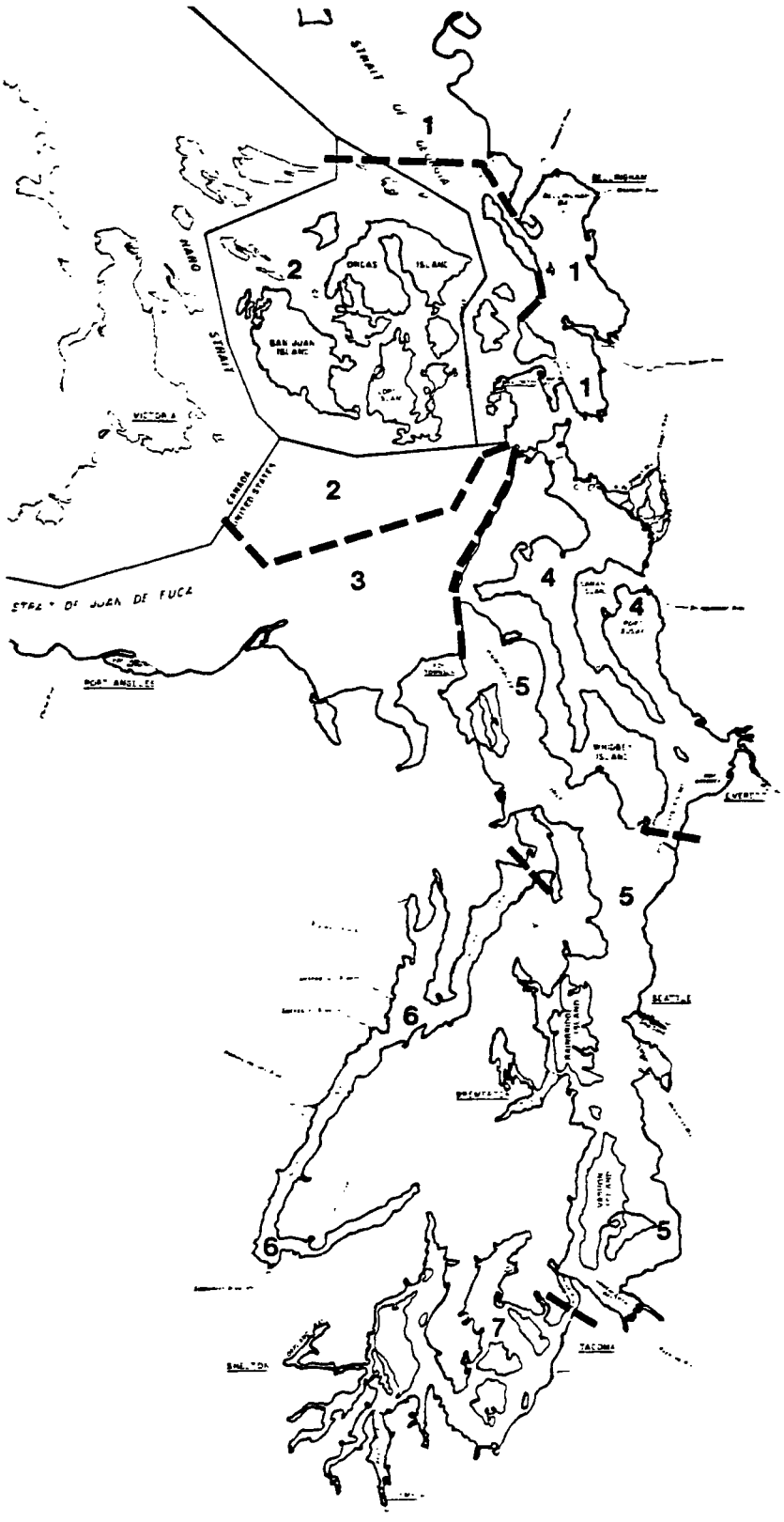


Figure 42

WASHINGTON DEPARTMENT OF FISHERIES SALMON CATCH REPORT AREAS

---- Regional Boundaries
●●●● Subregional Boundaries



Subarea

1 - 7A, 7B, 7C, 7D

2 - 7

3 - 6, 6A, 6B, 6C, 6D

4 - 8, 8A

5 - 9, 9A, 10, 10A, 10E, 11, 11A

6 - 12, 12A, 12B, 12C, 12D

7 - 13, 13A, 13B

Figure 43

SUBAREAS OF PUGET SOUND WITH BOUNDARY ADJUSTMENTS
TO INCLUDE WDF SALMON REPORTING AREAS

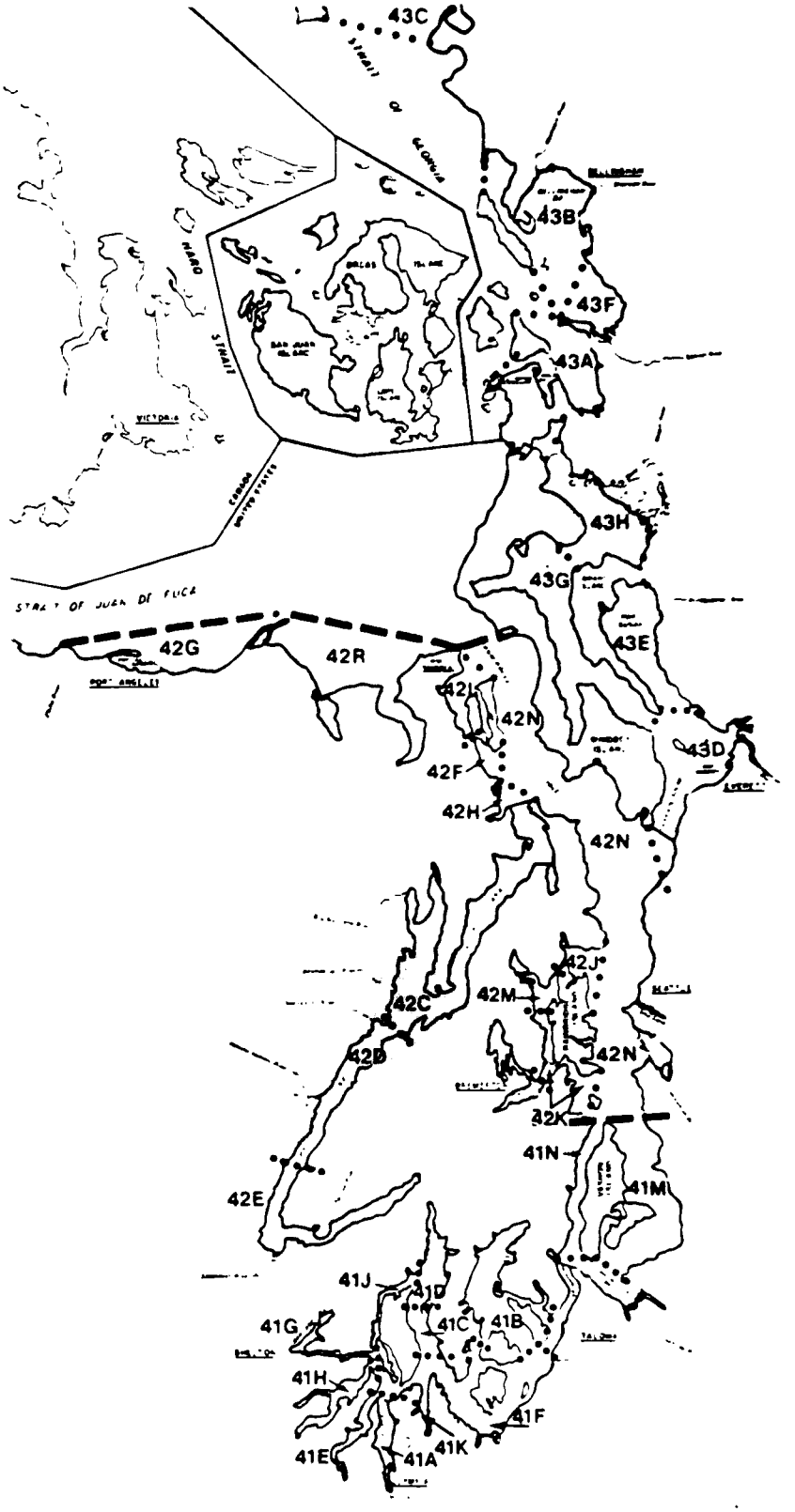
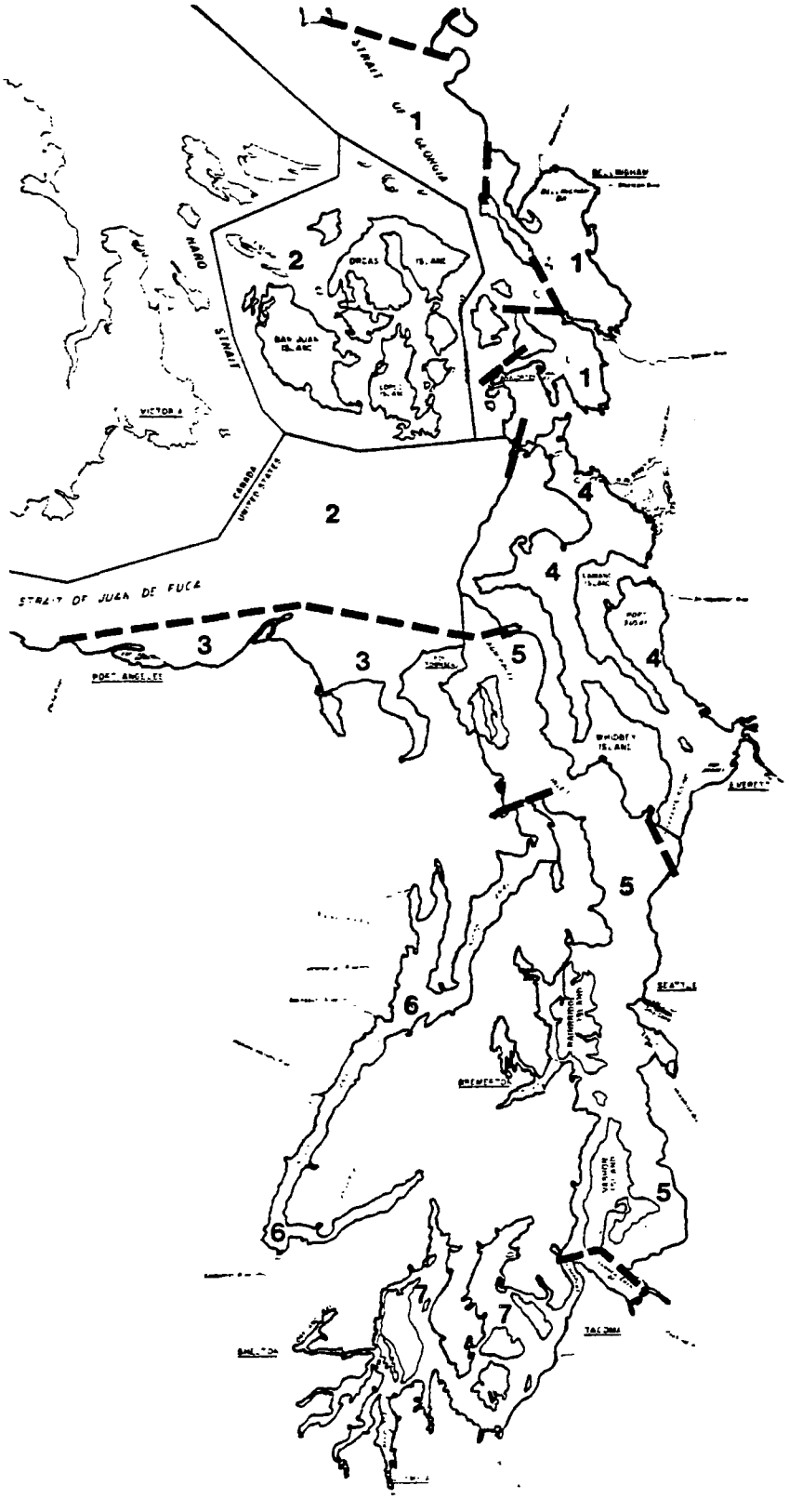


Figure 44

WASHINGTON DEPARTMENT OF FISHERIES OYSTER CATCH REPORT AREAS

---- Regional Boundaries
●●●● Subregional Boundaries



Subarea

1 - 43A, 43B, 43C, 43F

2 - 43J

3 - 42G, 42R

4 - 43D, 43E, 43G, 43H

5 - 41N, 41M, 42F, 42H, 42J, 42K, 42L, 42M, 42N

6 - 42C, 42D, 42E

7 - 41A, 41B, 41D, 41E, 41F 41G, 41H, 41K

Figure 45

SUBAREAS OF PUGET SOUND WITH BOUNDARY ADJUSTMENTS TO INCLUDE WDF OYSTER REPORTING AREAS

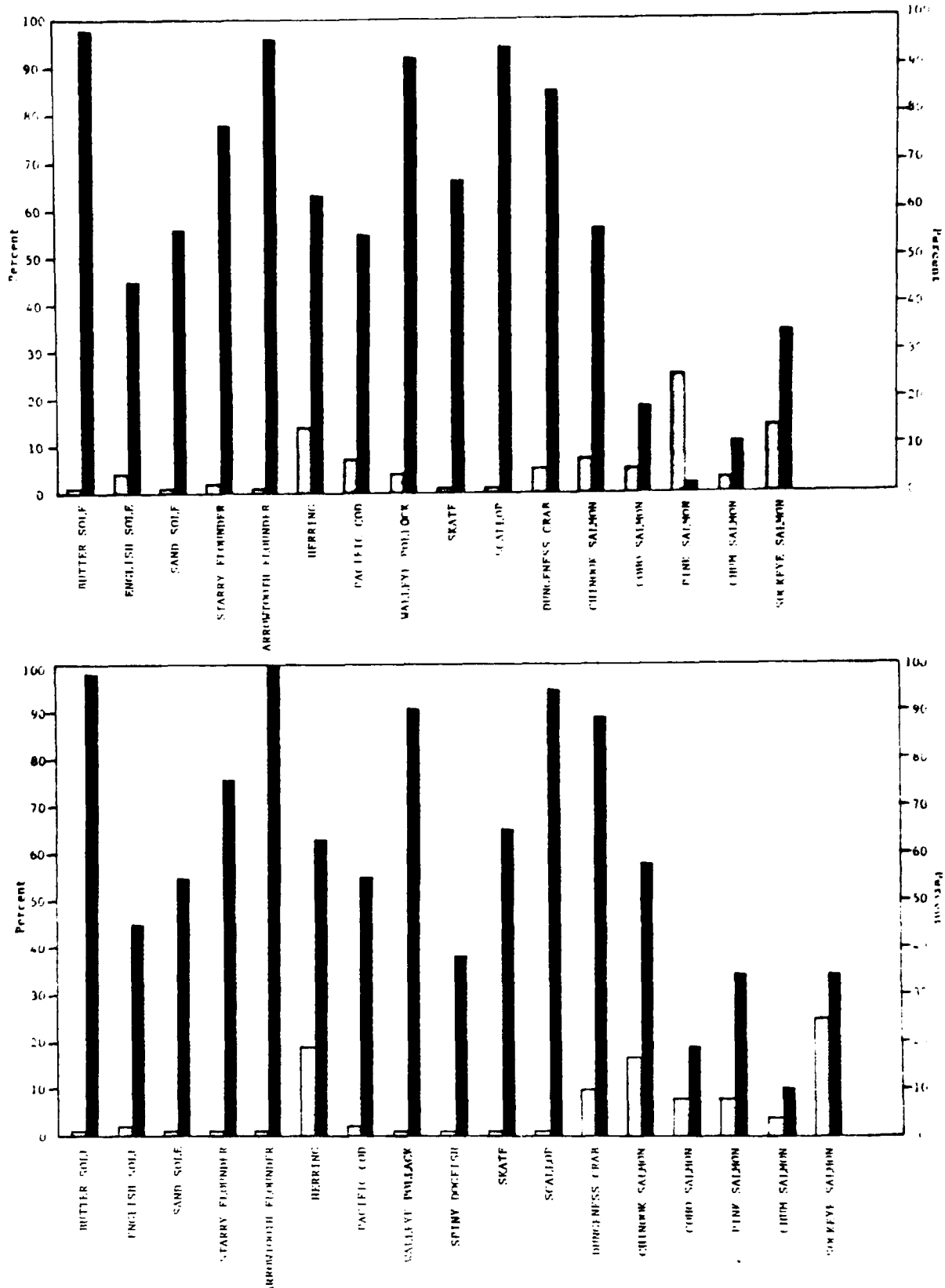
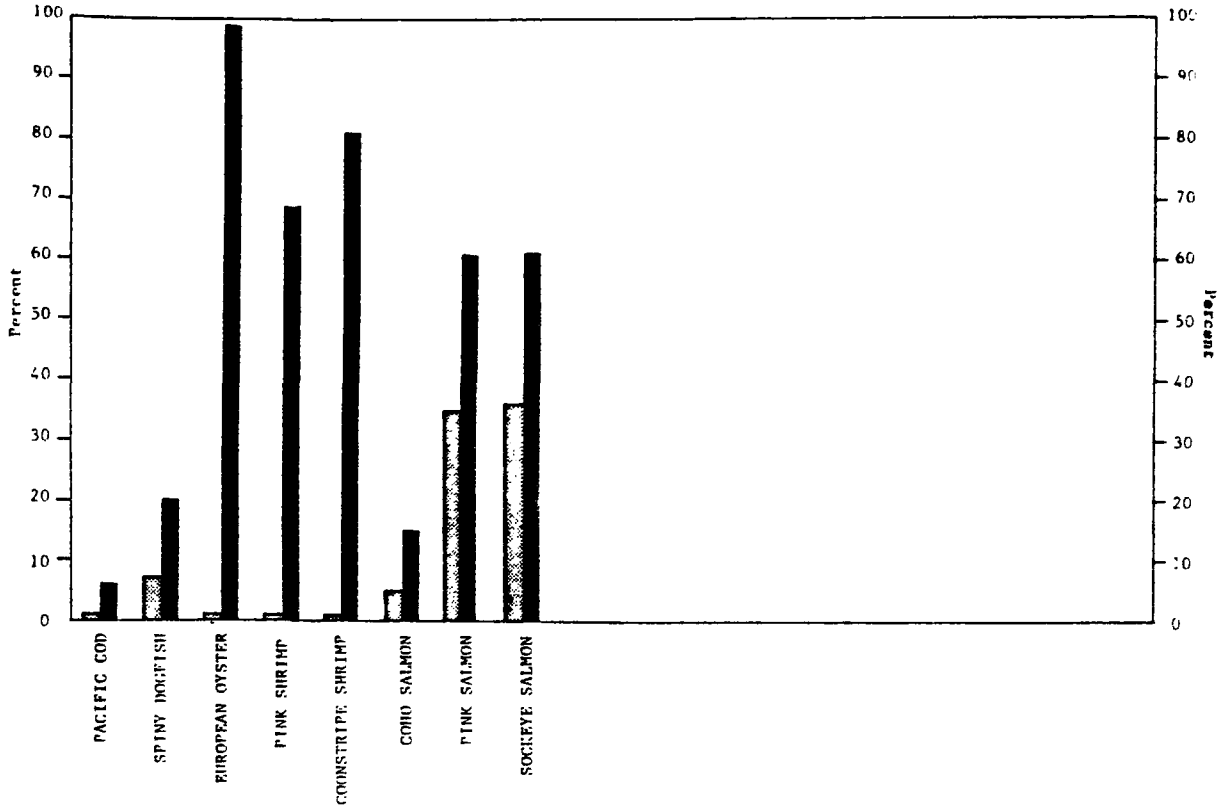


Figure 46

MAJOR FISHERIES RESOURCES OF REGION 1 IN TERMS OF ROUND POUNDS HARVESTED (upper figure) AND DOLLAR VALUE (lower figure)

□ Proportion of that particular species harvest to the total weight or dollar value of all fisheries resources harvested in the region.

■ Proportion of the regional harvest of that species to the total Puget Sound harvest or dollar value for the same species.



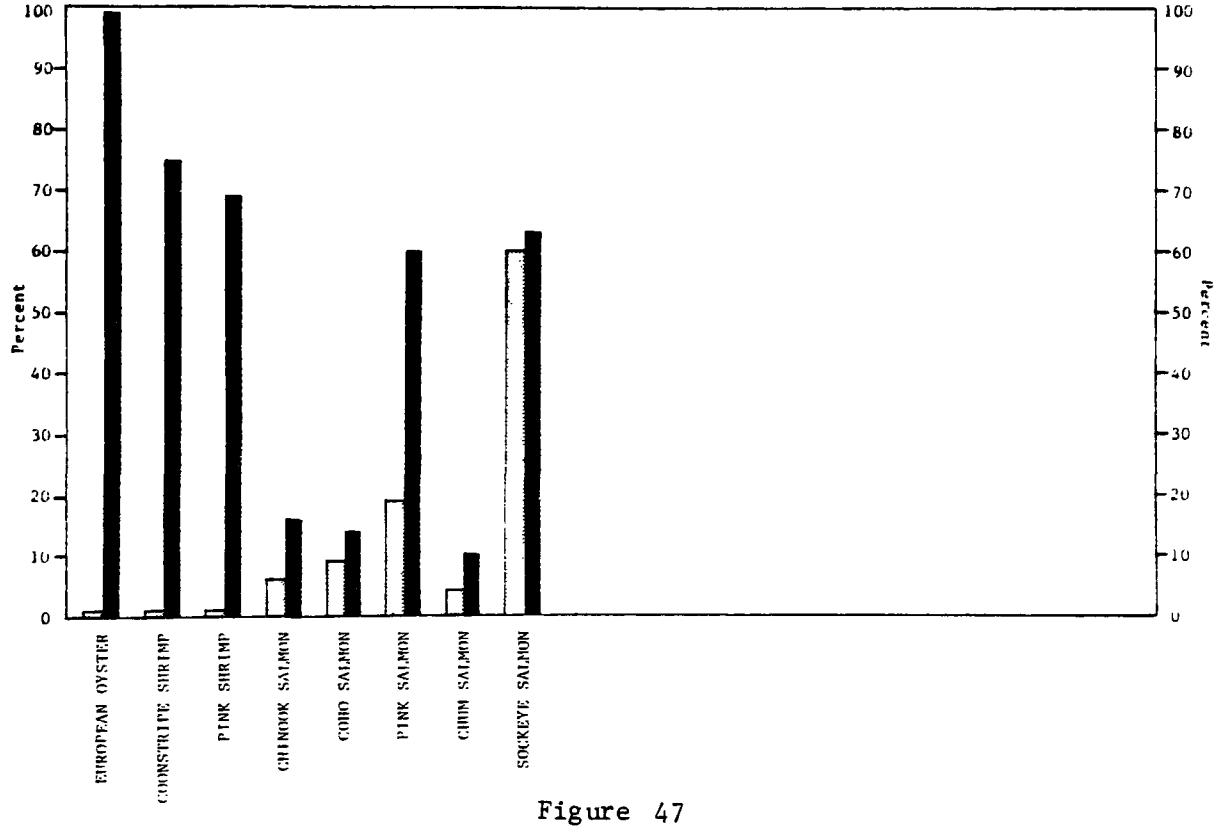


Figure 47

MAJOR FISHERIES RESOURCES OF REGION 2 IN TERMS OF ROUND POUNDS HARVESTED (upper figure) AND DOLLAR VALUE (lower figure)

Proportion of that particular species harvest to the total weight or dollar value of all fisheries resources harvested in the region.

Proportion of the regional harvest of that species to the total Puget Sound harvest or dollar value for the same species.

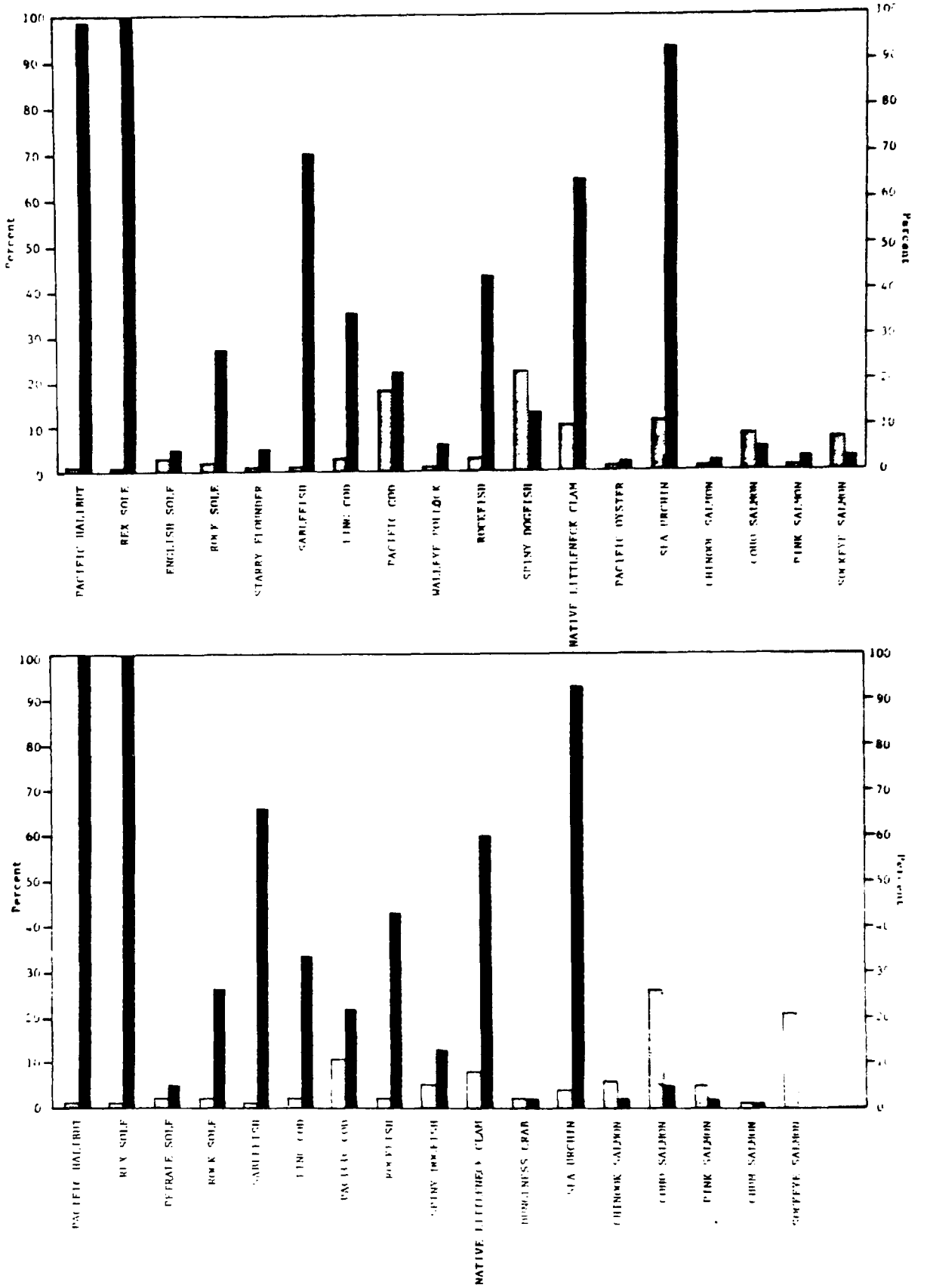


Figure 48

MAJOR FISHERIES RESOURCES OF REGION 3 IN TERMS OF ROUND POUNDS HARVESTED (upper figure) AND DOLLAR VALUE (lower figure)

□ Proportion of that particular species harvest to the total weight or dollar value of all fisheries resources harvested in the region.

■ Proportion of the regional harvest of that species to the total Puget Sound harvest or dollar value for the same species.

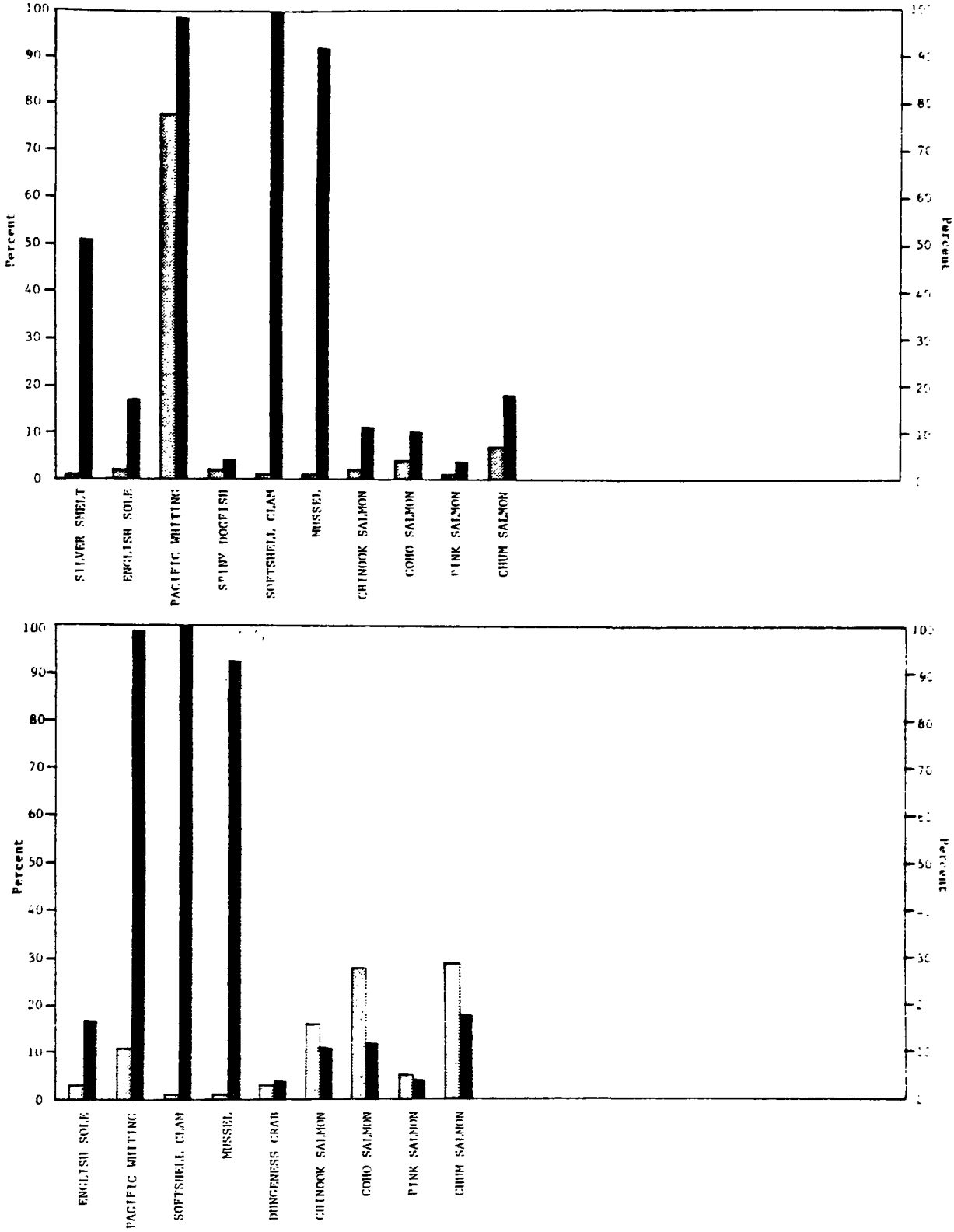
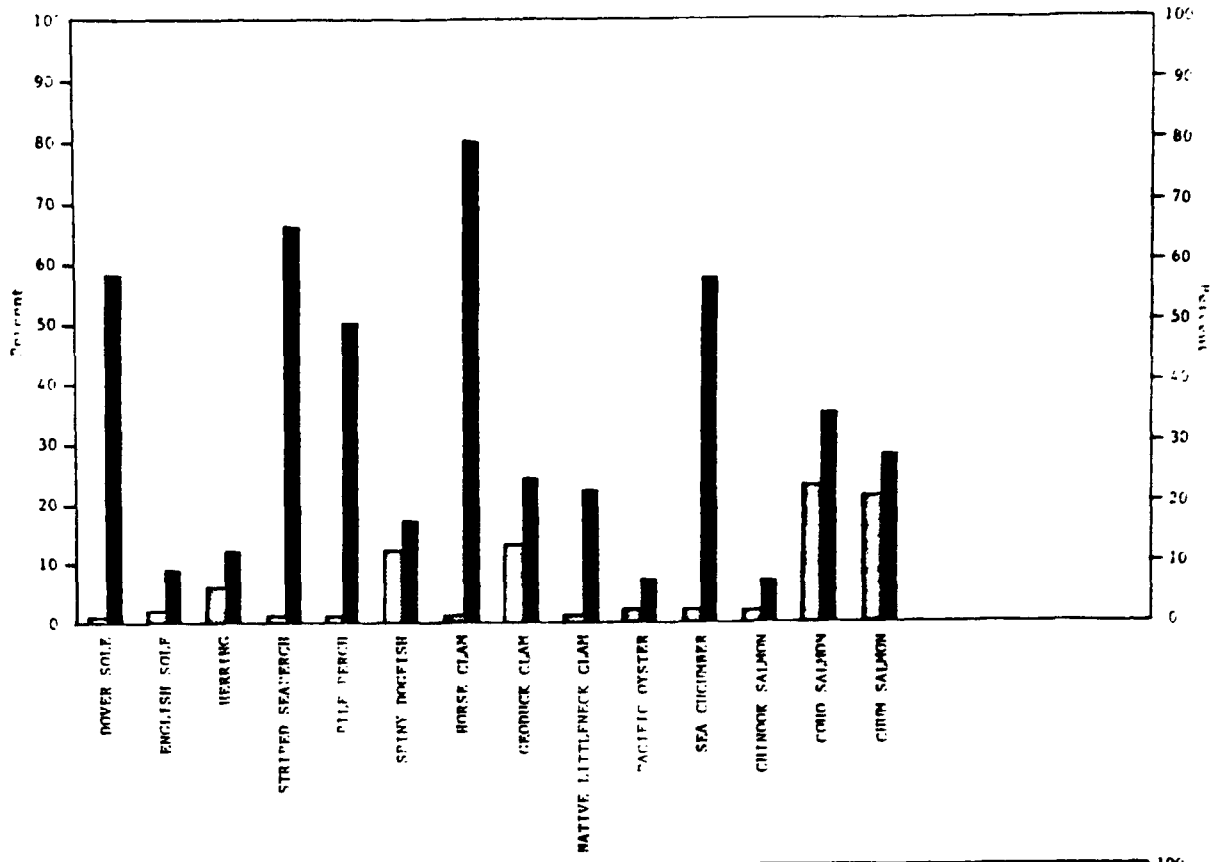


Figure 49

MAJOR FISHERIES RESOURCES OF REGION 4 IN TERMS OF ROUND POUNDS HARVESTED (upper figure) AND DOLLAR VALUE (lower figure)

Proportion of that particular species harvest to the total weight or dollar value of all fisheries resources harvested in the region.

Proportion of the regional harvest of that species to the total Puget Sound harvest or dollar value for the same species.



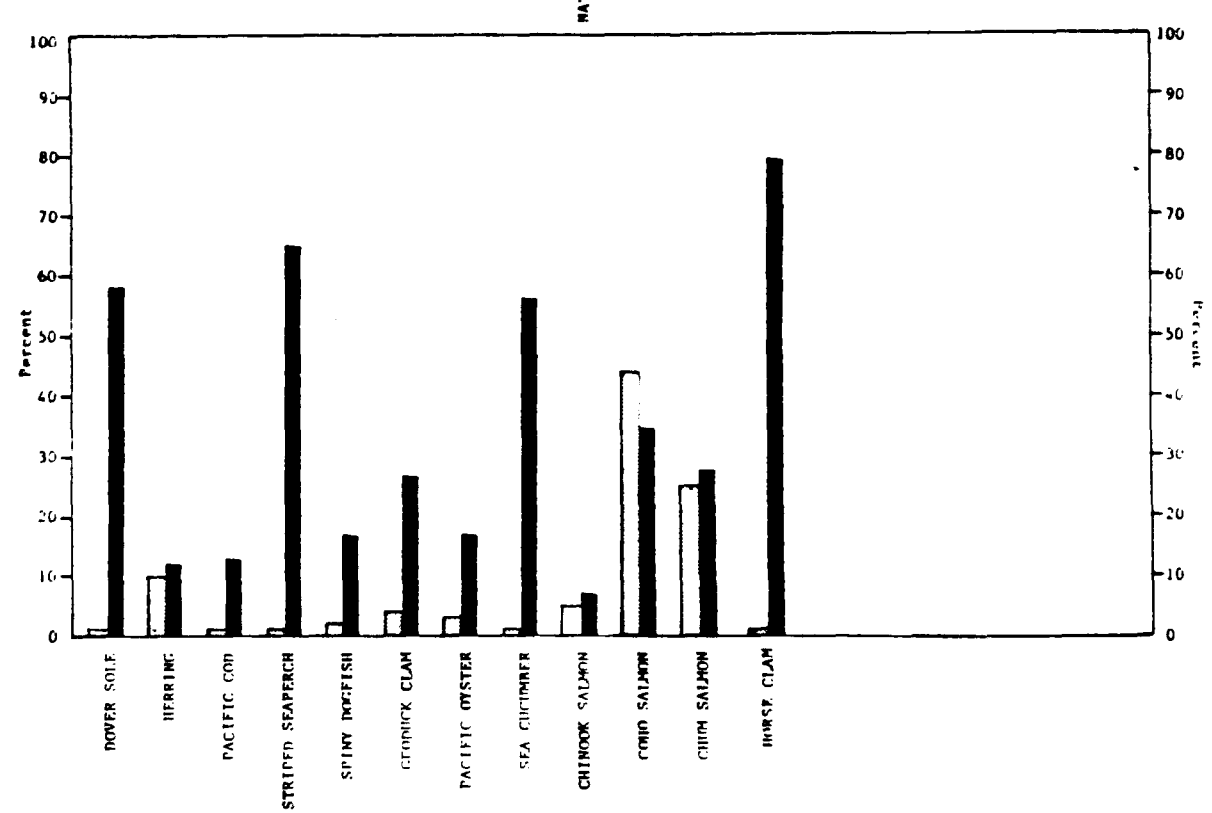


Figure 50

MAJOR FISHERIES RESOURCES OF REGION 5 IN TERMS OF ROUND POUNDS HARVESTED (upper figure) and DOLLAR VALUE (lower figure)

Proportion of that particular species harvest to the total weight or dollar value of all fisheries resources harvested in the region.
Proportion of the regional harvest of that species to the total Puget Sound harvest or dollar value for the same species.

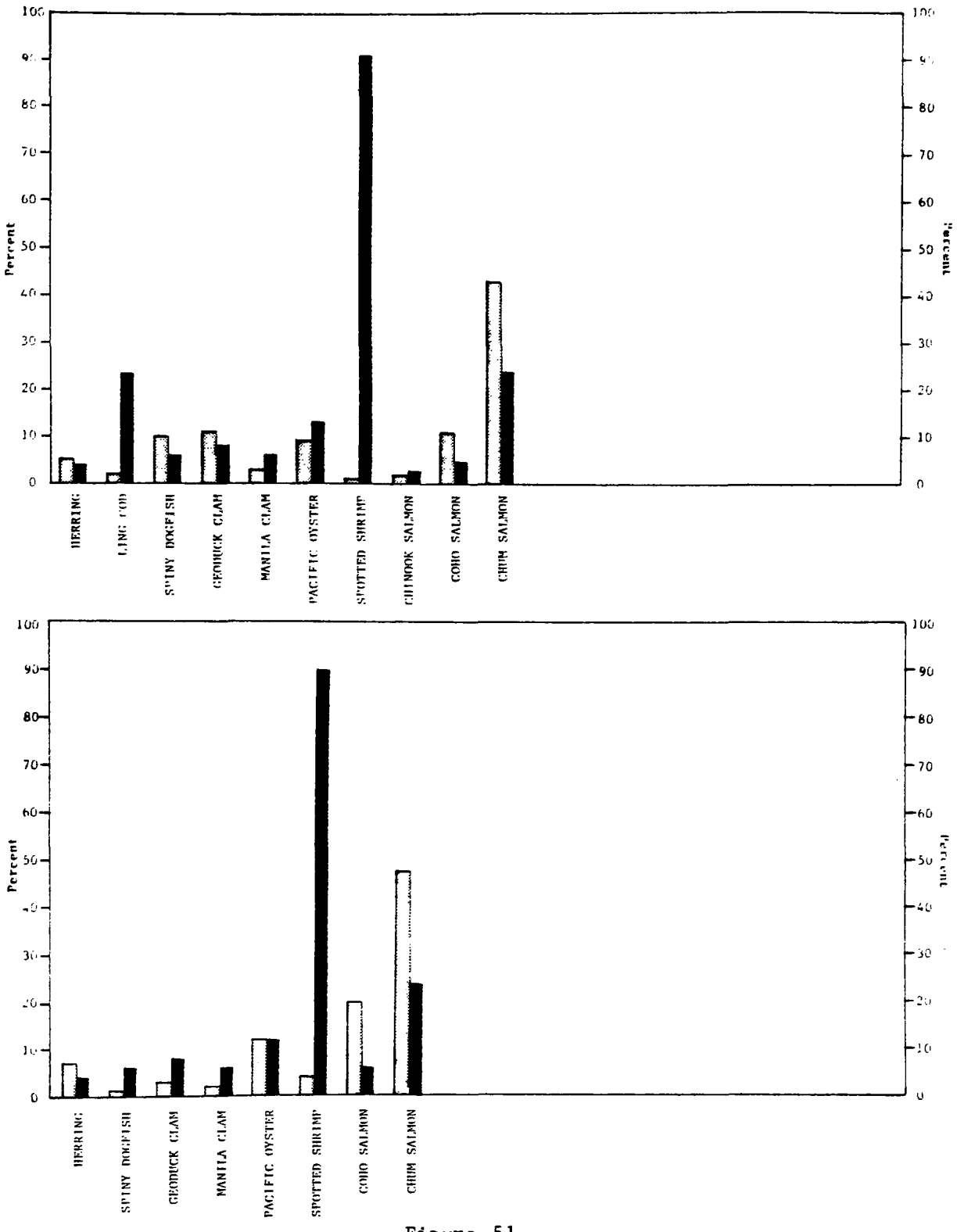


Figure 51

MAJOR FISHERIES RESOURCES OF REGION 6 IN TERMS OF ROUND POUNDS HARVESTED (upper figure) AND DOLLAR VALUE (lower figure)

Proportion of that particular species harvest to the total weight or dollar value of all fisheries resources harvested in the region.

Proportion of the regional harvest of that species to the total Puget Sound harvest or dollar value for the same species.

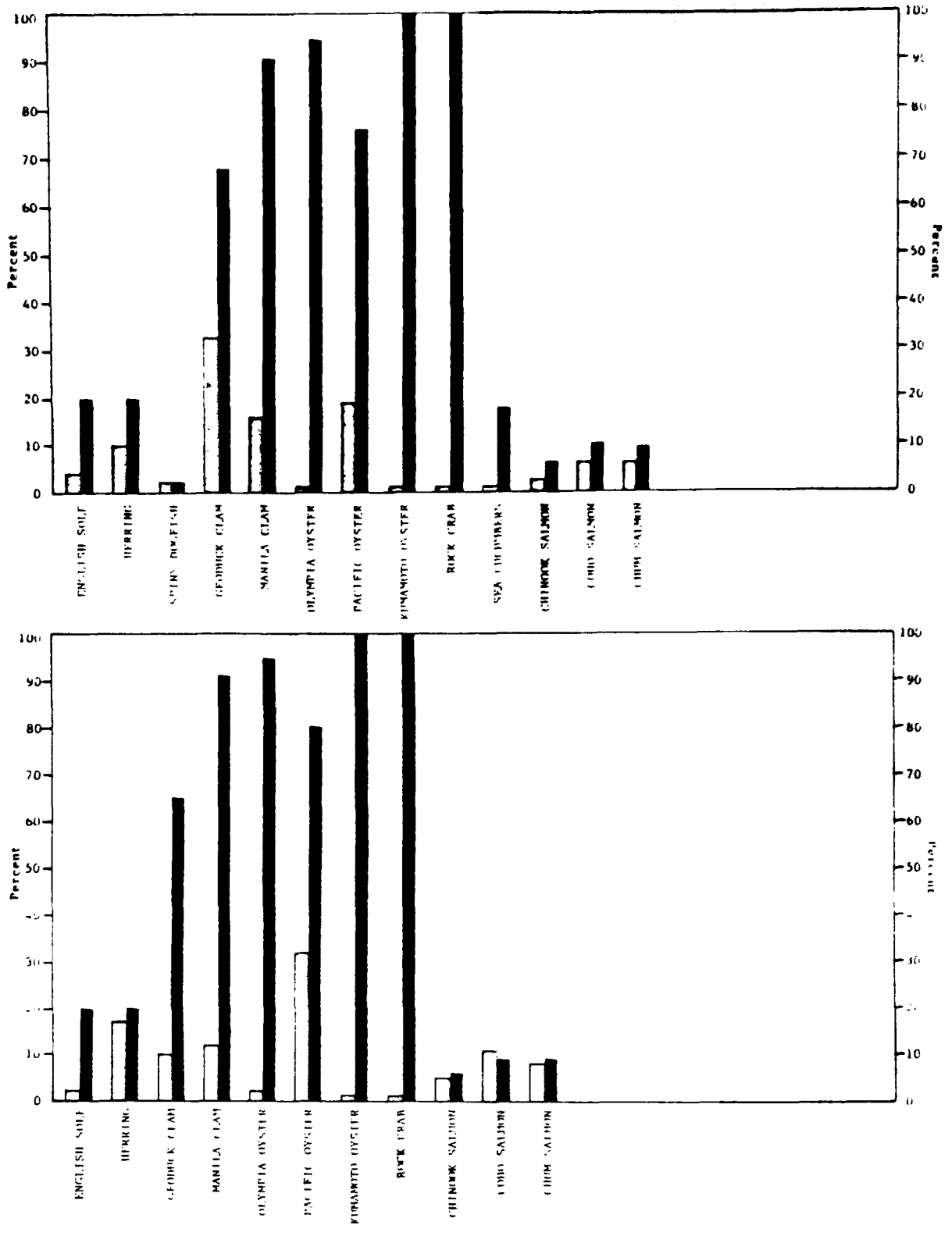


Figure 52

MAJOR FISHERIES RESOURCES OF REGION 7 IN TERMS OF ROUND POUNDS HARVESTED (upper figure) AND DOLLAR VALUE (lower figure)

□ Proportion of that particular species harvest to the total weight or dollar value of all fisheries resources harvested in the region.

■ Proportion of the regional harvest of that species to the total Puget Sound harvest or dollar value for the same species.

Region 1 serves as the principal harvest area for a number of species, most notably butter sole, arrowtooth flounder, walleye pollock, scallop and Dungeness crab.

Region 2 (Figure 47) - Pink salmon and sockeye salmon are the most important harvested resources both in terms of pounds harvested and dollar value. Region 2 harvest of European oyster, coonstripe shrimp and pink shrimp comprise the vast majority of the total harvest of these resources in the Sound.

Region 3 (Figure 48) - Pacific cod and spiny dogfish comprise the major fisheries resources of Region 3 in terms of pounds harvested. However on the basis of dollar value, coho and sockeye are the more valuable resources of the region. Region 3 provides the majority of the total Sound harvest of Pacific halibut, rex sole, sablefish, native littleneck clam and sea urchins.

Region 4 (Figure 49) - Pacific whiting comprise over three-fourths of the fisheries resources of region 4, in terms of pounds harvested. however because of a very low price per pound, this species contributes only 10% of the fisheries dollar value of the region. Coho, chum and chinook salmon are the major species of the region in terms of economic value. The vast majority of Pacific whiting, softshell clam and mussels harvested in the Sound come from Region 4.

Region 5 (Figure 50) - Coho and chum salmon are the major resources of Region 5 both in terms of economic value and pounds harvested. Region 5 is the principal harvest area for Dover sole, striped seaperch and sea cucumber.

Region 6 (Figure 51) - The chum salmon is the major fisheries resource of the region. The spotted shrimp is the only species harvested primarily in Region 6.

Region 7 (Figure 52) - The Pacific oyster is the most economically valuable fisheries resource of Region 7, though both the geoduck clam and Manila clam are also important in terms of pounds harvested. Region 7 is the primary harvesting area for a variety of shellfish including the geoduck and Manila clams, the Olympia, Pacific and Kumamoto oysters, and the rock crab.

4.0 CONCLUSIONS

The information presented within this report identifies many existing and potential water qualty dependent water uses within the seven subregions of Puget Sound. These water uses include commercial and recreational fisheries and recreational activities such as swimming and diving.

Fisheries values, both commercial and recreational, were considered only in terms of their economic worth in landed pounds and dollars and only for the last five years (1979-1983). The report does not reflect standing crop or biomass (except for hardshell clams and geoducks), because in most cases this information is not available.

Whenever possible, critical life stages or habitat requirements were described within each species' account in order to provide an environmental manager the means to understand these important resources and begin to recognize any steps necessary to protect them. Table 13 presents a summary of all critical life stages and habitats or conditions necessary to sustain each species listed within this report. As the table and species accounts indicate, many such critical stages or factors are unknown. In particular, information on the environmental needs of early life stages is not available or is inadequate. Larvae of many Puget Sound fish and shellfish form a part of the marine zooplankton community which is an essential link in the trophic dynamics of the Sound. Fisheries resources are renewable, but their continued survival depends upon sustained recruitment. Early life stages, furthermore, are generally accepted as being more sensitive to environmental perturbations than the adults. Juvenile teleosts and crustaceans are known to be sensitive to pollutants such as heavy metals and hydrocarbons (Hempel, 1979). A lack of understanding of the early life stages of fish and shellfish can result in major gaps in the understanding of the ecological significance of many species or even the environmental condition of a given area.

Therefore it is vital that environmental managers have at their disposal the data necessary to correlate these life stages to water quality conditions that

Table 13

CRITICAL LIFE STAGE AND HABITATS FOR
IMPORTANT PUGET SOUND FISHES AND INVERTEBRATES

Species or Species Group	Critical Life Stage*	Areas and Conditions Necessary for Critical Stage in Life History
All Salmonids	Smolts	Estuarine areas off all major spawning areas (see species accounts for specific Puget Sound areas).
Pacific Whiting (hake)	Larvae (survival of larvae considered most important to success of year class, Bailey and Francis, 1982).	Port Susan, Gulf of Georgia and Carr Inlet are the known spawning areas in Puget Sound (Solomon and Mills, 1983).
Walleye Pollock	Unknown - probably early life stages	Eggs and larvae are pelagic (Pedersen and DiDonato, 1982). Pollock spawn in Gulf of Georgia, Tacoma (Solomon and Mills, 1983).
Pacific Cod	Unknown - probably early life stages	Spawning concentrations occur near Port Angeles, Protection Island, Port Townsend, Port Gamble, Agate Pass, Tacoma, Port of Georgia (Solomon and Mills, 1983). Eggs are semi-pelagic or benthic (Hart, 1973).
Pacific Herring	Unknown - probably early life stages	Major spawning site is the Strait of Georgia. Eggs deposited on marine vegetation. Juveniles and larvae are found in shallow waters along the shoreline (Trumble, 1979).
Starry Flounder	Unknown - probably early life stages	Known spawning sites include Boundary Bay and Bellingham Bay (Solomon and Mills, 1983). Eggs are pelagic (Pedersen and DiDonato, 1982).
Dover Sole	Unknown - probably early life stages	Spawning areas unknown. Eggs and larvae are pelagic and pelagic life may extend several months (Hart, 1973).
English Sole	Unknown - probably early life stages	Known spawning sites include Elliott Bay, Discovery Bay, East Sound, and Gulf of Georgia (Solomon and Mills, 1983). Larvae are pelagic for approximately six to 10 weeks (Hart, 1973). Juveniles occupy shallow intertidal areas (Hart, 1973).
Rock Sole	Unknown - probably early life stages	Killisut Harbor is a known spawning area (Solomon and Mills, 1983). Eggs are demersal and adhesive. Larvae are pelagic and develop in shallow waters (Hart, 1973).
Sand Sole	Unknown - probably early life stages	Bellingham Bay is a known spawning area (Solomon and Mills, 1983). Eggs are pelagic (Hart, 1973; Pedersen and DiDonato, 1982).
Ling Cod	Adult males guarding egg masses in shallow waters are vulnerable to fishing. Likewise, the success of the hatch is dependant on the male's presence (Bargmann, 1982; Pedersen & DiDonato, 1982)	Ling cod spawn on the substrate in rocky crevaces in shallow and intertidal areas (Pedersen and DiDonato, 1982; Hart, 1973). Eggs are adhesive and are guarded by males. Larvae are dispersed by currents and occur in surface waters, especially sandy estuarine areas (Bargmann, 1982; Pedersen and DiDonato, 1982).
Rockfishes	Unknown - probably early life stages	Pelagic embryos released near preferred habitat of rocky areas or kelp growths in 0-500 ft depths (Solomon and Mills, 1983).
Surf Smelt	Spawning period is critical because of the specific habitat requirements for successful egg deposition (sandy-gravel substrate).	Port Orchard and Saratoga Passage important spawning areas (Solomon and Mills, 1983). Eggs are deposited on gravel in upper intertidal zones (Trumble, 1983). Larvae occur in surface waters after hatching.
Surf Perches	Unknown - probably early life stages	Viviparous fish found in shallow waters seldom deeper than 60 ft. (Pedersen and DiDonato, 1982).
Hardshell Clams Geoducks Horse Clams Softshell Clams Oysters	Pelagic larvae which are dependant upon water movement and sedentary adults if their habitat is threatened by water quality changes or physical alterations.	Intertidal to subtidal zones throughout Puget Sound.

Table 13
(cont'd)

Crustaceans	Larvae, molting and breeding adults	Eelgrass beds in intertidal zones to deep water throughout Puget Sound, but especially in Bellingham, Padilla, and Lummi Bays. Intertidal to deep water throughout Puget Sound but especially in Saratoga Passage, Hood Canal, and around the San Juan Islands for pandalid shrimp.
Scallops	Seed scallops most sensitive stage (Magoon and Vining, 1980)	Deep water scallops intolerant of environmental alterations. Larvae must anchor to objects off the bottom to prevent smothering (Magoon and Vining, 1980).
Abalone	Unknown - probably larvae and juvenile stages	Larval stage are planktonic and congregate in surface waters. Post-larvae and adults feeding on seaweeds on rocky headlands, especially along the Strait of Juan de Fuca and the San Juan Islands.

*In many cases a specific critical life stage is unknown for Puget Sound fish. Larval and developmental stages are, however, considered to be sensitive in many fish species and when information concerning this life stage is available, it is included herein.

will be affecting them. The means to do this of course is not readily available at this time, but summaries of fisheries data such as those included within this report are a beginning. Additional research into all life stages as well as the inclusion of known water quality factors such as sensitivities to particular pollutants should be pursued. Furthermore, identification of additional water uses such as wildlife habitat values and aesthetics are also imperative when assessing the impacts of specific or general water quality factors.

The importance of aquaculture and recreational opportunities within Puget Sound cannot be disputed. However, the environmental manager and planner must look beyond the current distribution of such activities. He or she must also consider emerging demands, public acceptance, availability of facilities and proximity to population centers before a complete understanding of these water uses is achieved.

5.0 RECOMMENDATIONS

5.1 RESOURCE ATLAS

The information presented in this report is such that it encompasses many factors about Puget Sound that could be best presented in a graphical or atlas format. All the uses included within this report should be considered as well as important remaining factors such as ecological values, non-harvested species data, and more complete recreational information.

This atlas would encompass all seven subregions of Puget Sound as identified by Jones and Stokes (1983). By utilizing a map scale of 1:50,000, an even finer detail of the Sound could be achieved. This would be particularly useful when incorporating various fisheries statistical data which are much more specific to geographical zones within Puget Sound. Each of the seven subregions would correspond to a subdivision of the atlas. Preceding each subregion would be an overview section with introductory and important factual material that would provide a succinct characterization of that subregion's most important water quality dependent water uses.

These water uses could then be presented on a series of maps. Each map would be accompanied by a facing page that would provide important information regarding each water use. Examples of this format are included in Figures 53 and 54 from the Biological Resource Atlas of Alaska's Beaufort Sea coast which JRB Associates designed. While the intent of the Alaskan document is different from the Puget Sound Water Use project, these figures do illustrate the ease by which biological and site specific data can be mapped and how well this can facilitate management decisions. Each map of Puget Sound would synthesize background environmental data including range, distribution, and seasonality of various species and groups of organisms such as:

1. Fisheries - marine and anadromous
2. Birds - waterfowl and shorebirds
3. Invertebrates - shellfish, zooplankton, etc.
4. Marine mammals

BIRDS

Large concentrations of molting Oldsquaw have been observed north of Howe Island (25).

Brant and Snow Geese nest on Howe Island; this island supports one of the largest Alaskan colonies of Snow Geese (11).

The Sagavanirktok River delta attracts waterfowl and shorebirds, particularly in the spring when major overflows provide early open water (2). In July, the Snow Geese on Howe Island move south into the outer Sagavanirktok delta to traditional brood rearing areas (S. Johnson, pers. comm. 1983).

Black Brant nest on the Niakuk Islands (39).

Shorebirds, particularly phalaropes, are found along the mainland shores in Prudhoe Bay in areas near salt marshes (41).

Glaucous Gulls are commonly associated with the mouth of the Sagavanirktok River delta. Nesting colonies are found on Niakuk Island and west of Howe Island (11,21).

TERRESTRIAL MAMMALS

All the land area is within the summer range of the Central Arctic Caribou Herd. Calving may occur throughout, although most calving occurs west of the Kuparuk River (Maps 43,44) (7,38).

Eastward movements of caribou occur through this area in July. Movement to the south and west occurs in early to mid-August (38,44).

The Prudhoe Bay area (see Maps 47, 48 & 53) is considered highly productive for arctic fox. Up to 200 animals may overwinter there (15). A fox den has been reported on Howe Island (S. Johnson, pers. comm. 1983).

FISH

Extensive surveys have been carried out in this region. Nearshore areas are heavily used by anadromous and marine fishes during the open water period (3,13,15,35,45). Winter sampling indicates arctic cod and snailfish overwinter in offshore waters (40).

Channels in the Sagavanirktok River delta are migratory pathways for arctic char and whitefish. Overwintering areas for grayling, whitefish, burbot and sculpin may occur in deep pools in the river channels (3).

MARINE MAMMALS

Ringed seals may be present in all marine waters during the summer, but are probably excluded from Prudhoe Bay and other shallow waters during the winter due to grounded ice (4,5). Bearded seals may be present in summer months, especially if substantial ice is near the coast (38).

Heald Point contained a confirmed polar bear den in 1974 (34). Other suitable habitat in the delta may be used.

Howe Island contained a confirmed polar bear den in 1974 (34). Lentfer (28) considers that the Sagavanirktok River delta provides suitable denning habitat.

General bird use area

Bird high use area

"

Shorebird symbol may depict gulls, terns, and passerines.

General terrestrial mammal use area

Special terrestrial mammal use area

Caribou movements

Underscore indicates confirmed fox den.

High density fish zone (see General Overview)

Medium density fish zone (see General Overview)

Low density fish zone (see General Overview)

Fish migration

Whale migration

Underscore indicates confirmed polar bear den site.

This information has been compiled from existing sources and is not a product of original research.

Figure 53

EXAMPLE OF CRITICAL HABITAT DESCRIPTIONS AND MAP KEY FROM THE ALASKAN BEAUFORT SEA BIOLOGICAL RESOURCE ATLAS (Source: ACS, 1983)
(Example of corresponding map presented in Figure 54)

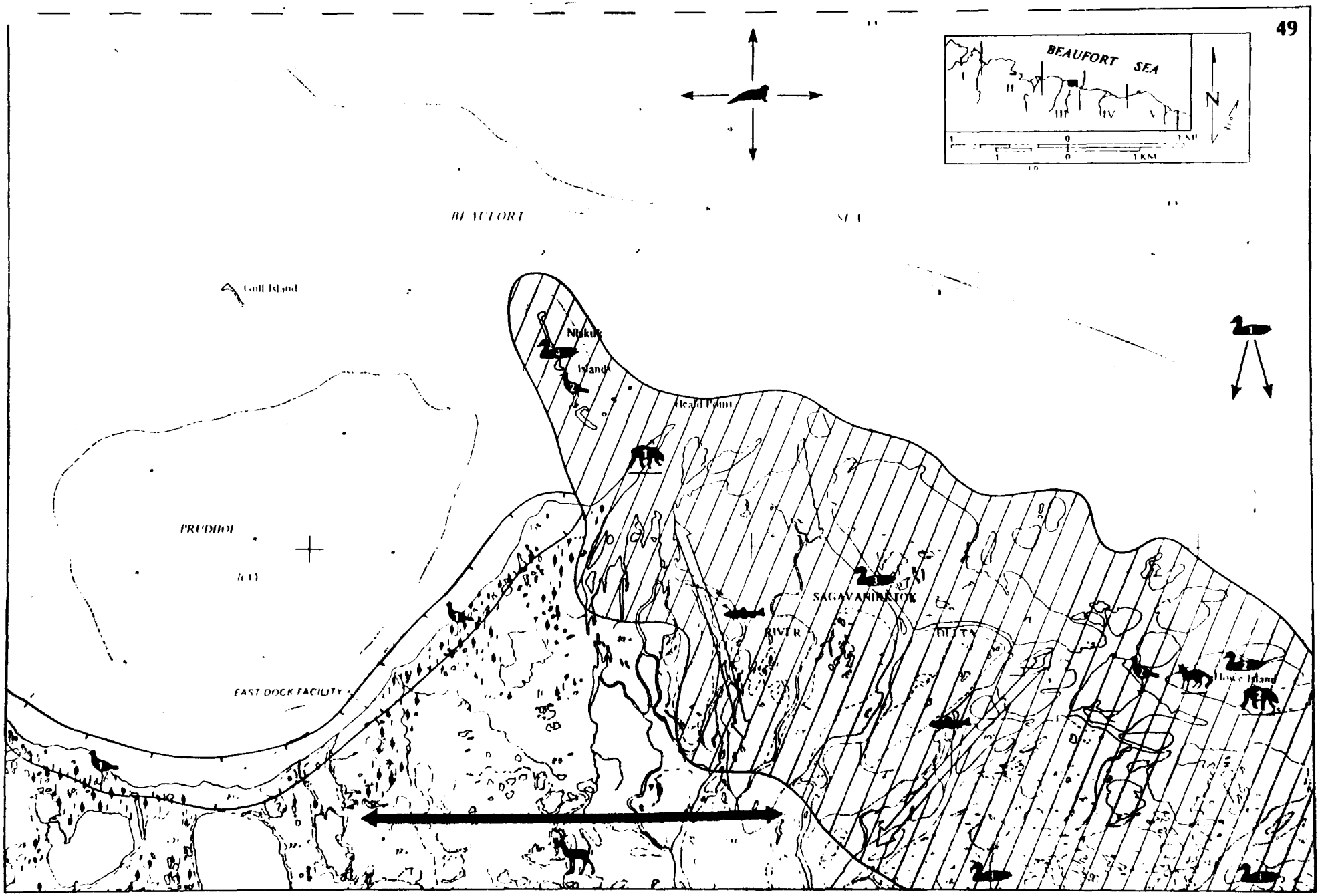


Figure 54

EXAMPLE OF BIOLOGICAL RESOURCE MAP FROM
THE ALASKAN BEAUFORT SEA BIOLOGICAL RESOURCE ATLAS (Source: ACS, 1983)
(Example of corresponding descriptions and map key presented in Figure 53)

Important sites for recreational or commercial exploitation would also be highlighted. The facing page for each map would not only define the extent of these uses, it could also list critical water quality factors corresponding to that use. In addition, important physical characteristics of the Sound such as hydrologic data or geomorphology could be charted and defined. By using this atlas format, possibly employing overlays, the environmental manager would have the advantage of viewing several key characteristics of a particular area simultaneously. The format of this document should be amenable to including any new information as it becomes available. Ancillary information included within the resource atlas should be key contacts or local authorities for resource-related information. Overall, the atlas could assist a planner or manager in assessing the water uses within a specific area of Puget Sound and provide him or her with an important tool to perform sensitivity rankings when faced with a water quality impact potential.

5.2 SPECIES PROFILES

This report has served to identify those resources within each region that are of greatest economic value to that region. The next logical step is to identify the environmental constraints of each resource (species) and the water quality conditions which must be met in order to protect that resource.

Presentation of this information could best be done as a species profile which would provide for each species:

- Habitat requirements
- Life history information
- Fisheries value
- Ecological role
- Environmental requirements
  - Physical - substrate, depth, temperature, turbidity
  - Chemical - dissolved oxygen, salinity, sensitivity to pollutants (heavy metals and organics)

Such information was presented herein, but not in great detail because of the extensive search of the scientific literature which would be required. However, if available, this information would be extremely valuable to resource managers.

The U.S. Fish and Wildlife Service and Army Corp of Engineers are currently supporting efforts to develop species profiles for over forty species of fish and invertebrates of the Pacific Northwest. These profiles are intended to document life histories and environmental requirements (temperature, salinity, dissolved oxygen, etc.) though they do not deal with sensitivity to pollutants. To date only a single species profile for chinook salmon has been released (Beauchamp et al., 1983) and funding cutbacks threaten the continuation of the effort. It is doubtful that more than half of the projected forty profiles will eventually be completed.

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APPENDIX A

WDF HARVEST DATA FOR MARINE FISH (1979-1983) ANNUAL AVERAGE

MARINE FISH IN ROUND POUNDS BY REGION

Region 1--WDF Report Areas 20A, 21A, 21B, 22B

MARINE FISH	1979	1980	1981	1982	1983	MEAN
Mackerel						
Candlefish						
Anchovy						
Silver Smelt	23,500	3,800	5,500	3,200	10,400	9,300
Pacific Halibut						
Butter Sole	55,900	28,800	45,800	14,600	10,400	31,100
C-O Sole						
Dover Sole	20,400	58,900	23,400	16,800	8,300	25,600
Rex Sole		*	*	*		*
English Sole	864,300	783,600	734,600	636,100	595,600	722,800
Petrale Sole	*	300	200	*	1,000	300
Rock Sole	154,900	128,700	141,500	110,700	80,300	123,200
Sand Sole	87,400	86,600	87,800	62,100	64,300	77,600
Sole, General	800	1,800	4,600	400	200	1,600
Starry Flounder	709,100	514,500	262,300	358,400	376,800	444,200
Arrowtooth Flounder	29,500	2,100	6,700	2,600	3,800	9,000
Miscel-laneous	251,500	439,300	7,300	135,000	31,900	173,000
Sablefish	7,100	1,000		*	600	1,700
Herring	5,406,000	5,004,000	1,179,500	1,233,400	576,200	2,679,800
Ling Cod	19,500	48,200	62,900	117,200	102,300	70,000

*Less than 100 pounds.

(CONTINUED NEXT PAGE)

REGION 1—CONTINUED

MARINE FISH	1979	1980	1981	1982	1983	MEAN
Pacific Cod	1,310,300	1,615,700	1,566.800	1,099,100	1,050,500	1,328,700
Pacific Tom Cod						
Walleye Pollock	954,900	731,600	1,468,400	141,000	81,600	675,500
Pacific Whiting	152,900	1,700	26,200	3,800	72,900	51,500
Rockfish	17,500	97,000	53,400	41,300	27,500	47,400
Perch, General						
Striped Seaperch		300	700		*	200
Pile Perch	1,000	3,700	8,600	3,400	600	3,500
White Sea Bass						
Greenling						
Ratfish	340,600	17,800	96.400	14,400	5,800	95,000
Sculpin				100		*
Spiny Dogfish	1,986,300	2,018,000	194,800	3,164,400	2,345,500	1,941,800
Skate	24,300	66,600	81,700	186,200	190,400	109,800
Shark, General						
Sand Dab						

*Less than 100 pounds.

MARINE FISH IN ROUND POUNDS BY REGION

Region 2--WDF Report Areas 20B, 22A

MARINE FISH	1979	1980	1981	1982	1983	MEAN
Mackerel						
Candlefish						
Anchovy						
Silver Smelt	1,200	600	500		300	500
Pacific Halibut		*				*
Butter Sole		*		*		*
C-O Sole						
Dover Sole	*	6,000	3,800	1,300	*	2,200
Rex Sole						
English Sole	15,700	49,400	46,500	21,100	4,800	27,500
Petrale Sole		*	100			*
Rock Sole	11,900	20,200	23,000	25,700	3,200	16,800
Sand Sole	900	1,200	2,700	2,000	500	1,400
Sole, General		200	3,800			800
Starry Flounder	9,800	40,000	9,800	10,400	2,100	14,400
Arrowtooth Flounder	400			*		*
Miscel-laneous		300	3,600	1,700	2,500	1,600
Sablefish	1,800	500	*	300	200	600
Herring	85,100	76,200	32,600	69,500		52,700
Ling Cod	14,500	18,300	34,000	19,500	12,900	19,800

*Less than 100 pounds.

(CONTINUED NEXT PAGE)

REGION 2—CONTINUED

MARINE FISH	1979	1980	1981	1982	1983	MEAN
Pacific Cod	126,500	173,300	257.200	120,600	69,200	149,400
Pacific Tom Cod						
Walleye Pollock	2,600	3,700		1,200		1,500
Pacific Whiting	600					510
Rockfish	17,800	15,800	11,000	9,500	4,400	11,700
Perch, General						
Striped Seaperch						
Pile Perch		*		100	*	*
White Sea Bass						
Greenling						
Ratfish						
Sculpin						
Spiny Dogfish	1,695,400	1,767,500	978,500	284,900	419,800	1,029,200
Skate	1,200	14,000	17,100	7,700	8,300	9,700
Shark, General				100		*
Sand Dab						

*Less than 100 pounds.

MARINE FISH IN ROUND POUNDS BY REGION

Region 3--WDF Report Areas 23A, 23B, 23C, 25A, 25E

MARINE FISH	1979	1980	1981	1982	1983	MEAN
Mackerel	*					*
Candlefish						
Anchovy			*			*
Silver Smelt	300	1,700	1,100	1,500	1,500	1,200
Pacific Halibut	1,700	500	5,600	*	900	1,800
Butter Sole						
C-O Sole						
Dover Sole	14,900	4,800	27,100	200	400	9,500
Rex Sole	1,800	1,300	*	*		600
English Sole	76,600	111,400	143,100	73,900	32,400	87,500
Petrale Sole	700	500	*	*	*	300
Rock Sole	85,000	86,100	80,800	50,500	50,500	70,600
Sand Sole	4,700	7,700	22,300	14,200	5,600	10,900
Sole, General		*	800	400	*	200
Starry Flounder	18,100	37,500	43,700	22,800	16,600	27,700
Arrowtooth Flounder	100	*		*	300	100
Miscel-laneous			800	3,200		800
Sablefish	2,400	1,400	1,000	42,000	100	9,400
Herring	12,800	6,300				3,800
Ling Cod	3,800	84,300	145,300	107,500	21,300	79,300

*Less than 100 pounds.

(CONTINUED NEXT PAGE)

REGION 3—CONTINUED

MARINE FISH	1979	1980	1981	1982	1983	MEAN
Pacific Cod	606,700	983,200	462.200	334,200	309,400	538,800
Pacific Tom Cod		*				*
Walleye Pollock	26,400	77,300	91,000	11,700	*	41,300
Pacific Whiting			*			*
Rockfish	147,000	184,400	63,200	69,200	21,800	97,100
Perch, General						
Striped Seaperch				100	1,600	300
Pile Perch	3,300	100	300	1,600	900	1,200
White Sea Bass					*	*
Greenling					*	*
Ratfish			*			*
Sculpin	600	700		200	*	300
Spiny Dogfish	1,607,600	921,200	288,700	184,500	280,500	656,700
Skate	27,400	13,900	24,900	17,400	11,700	19,000
Shark, General						
Sand Dab					*	*

*Less than 100 pounds.

MARINE FISH IN ROUND POUNDS BY REGION

Region 4--WDF Report Areas 24A, 24B, 24C

MARINE FISH	1979	1980	1981	1982	1983	MEAN
Mackerel						
Candlefish						
Anchovy						
Silver Smelt	30,800	26,200	40,400	24,300	6,600	25,600
Pacific Halibut						
Butter Sole	700	200	700	200	1,200	600
C-O Sole						
Dover Sole	200	9,000	12,800	900	600	4,700
Rex Sole						
English Sole	301,900	396,700	281,700	239,300	174,700	278,900
Petrale Sole	100			*		*
Rock Sole	31,000	31,000	21,000	1,900	20,700	21,100
Sand Sole	7,900	18,800	16,900	13,500	18,500	15,100
Sole, General	900		100		*	200
Starry Flounder	198,900	295,500	290,400	400,200	269,400	290,900
Arrowtooth Flounder						
Miscel-laneous		8,500		17,500	700	5,300
Sablefish		*		*	100	*
Herring			20,200			4,000
Ling Cod	15,200	1,500	500	300		3,500

*Less than 100 pounds.

(CONTINUED NEXT PAGE)

REGION 4—CONTINUED

MARINE FISH	1979	1980	1981	1982	1983	MEAN
Pacific Cod	84,600	77,200	118.800	41,400	32,300	70,900
Pacific Tom Cod		*				*
Walleye Pollock	18,400	20,200	9,300	3,200	4,000	11,000
Pacific Whiting	9,618,100	10,275,800	9.382,100	13,324,200	14,965,700	11,513,200
Rockfish	11,700	11,900	5,900	13,600	13,500	11,300
Perch, General						
Striped Seaperch		400	1,200		300	400
Pile Perch	4,300	2,900	4,100	4,800	6,400	4,500
White Sea Bass						
Greenling						
Ratfish			700			100
Sculpin	*					*
Spiny Dogfish	550,200	156,700	56,400	191,300	169,100	224,700
Skate	300	2,200	11,000	56,400	25,200	19,000
Shark, General						
Sand Dab						

*Less than 100 pounds.

MARINE FISH IN ROUND POUNDS BY REGION

Region 5--WDF Report Areas 25B, 25D, 26A, 26B, 26C, 26D

MARINE FISH	1979	1980	1981	1982	1983	MEAN
Mackerel					100	*
Candlefish		900	200			200
Anchovy						
Silver Smelt	10,900	3,800	1,600	3,300	4,000	4,700
Pacific Halibut	*					*
Butter Sole	400			200	*	100
C-O Sole				300		*
Dover Sole	69,900	25,300	42,600	37,800	121,600	59,400
Rex Sole					*	*
English Sole	132,300	64,000	100,100	146,500	270,500	142,700
Petrale Sole	*	*	*	*	*	*
Rock Sole	28,500	18,100	27,400	27,000	22,600	23,700
Sand Sole	2,300	5,900	9,700	10,900	10,100	7,800
Sole, General	600	900	200	100	200	400
Starry Flounder	6,700	14,200	34,500	51,200	94,800	40,300
Arrowtooth Flounder	*				1,100	200
Miscel-laneous				11,900	200	2,400
Sablefish	500	600	*	600	700	500
Herring	477,100	551,500	615,742	536,600	264,100	489,000
Ling Cod	12,800	2,000	3,200	1,400	300	4,000

*Less than 100 pounds.

(CONTINUED NEXT PAGE)

REGION 5—CONTINUED

MARINE FISH	1979	1980	1981	1982	1983	MEAN
Pacific Cod	515,700	338,500	252.200	211,400	205,200	304,600
Pacific Tom Cod		*				*
Walleye Pollock	7,200	2,400	2,900	6,200	900	3,900
Pacific Whiting		*	6,000	3,300		1,900
Rockfish	22,700	36,000	68,300	20,000	19,800	33,400
Perch, General	*					*
Striped Seaperch	29,300	31,600	20,900	31,900	12,800	25,300
Pile Perch	75,200	62,100	63,700	62,500	49,100	62,500
White Sea Bass						
Greenling						
Ratfish	500			9,000		1,900
Sculpin	300	300	200	800	*	300
Spiny Dogfish	1,749,100	1,183,800	497,600	584,500	432,600	889,500
Skate	800	3,700	8,100	15,500	6,000	6,800
Shark, General						
Sand Dab						

*Less than 100 pounds.

MARINE FISH IN ROUND POUNDS BY REGION

Region 6--WDF Report Areas 25C, 27A, 27B, 27C

MARINE FISH	1979	1980	1981	1982	1983	MEAN
Mackerel						
Candlefish			*			*
Anchovy			300			*
Silver Smelt	9,500	7,400	7,500	200	1,400	5,200
Pacific Halibut						
Butter Sole					*	*
C-O Sole						
Dover Sole	*	*				*
Rex Sole						
English Sole	31,800	1,300	3,100	10,700	15,100	12,400
Petrale Sole	*	*			500	100
Rock Sole	3,600	1,800	2,900	4,300	3,500	3,200
Sand Sole			*	500	400	200
Sole, General						
Starry Flounder	400	600	500	600	1,400	700
Arrowtooth Flounder		*				*
Miscel-laneous						
Sablefish	*	300		300		100
Herring	199,000	329,600	173,400	104,000		161,200
Ling Cod	*	100			263,800	52,800

*less than 100 pounds.

(CONTINUED NEXT PAGE)

REGION 6—CONTINUED

MARINE FISH	1979	1980	1981	1982	1983	MEAN
Pacific Cod	12,400	6,700	6.300	7,400	3,300	7,200
Pacific Tom Cod		*				*
Walleye Pollock		100		200		*
Pacific Whiting		*				*
Rockfish	1,900	6,300	500	700	1,800	2,300
Perch, General						
Striped Seaperch	10,100	2,800	2,600	1,200	3,100	4,000
Pile Perch	29,700	15,600	16,600	7,000	20,500	17,900
White Sea Bass						
Greenling						
Ratfish						
Sculpin	*	*				*
Spiny Dogfish	608,100	495,100	122,600	73,300	195,700	298,900
Skate		700		800	900	500
Shark, General						
Sand Dab					*	*

*Less than 100 pounds.

MARINE FISH IN ROUND POUNDS BY REGION

Region 7--WDF Report Areas 28A, 28B, 28C, 28D

MARINE FISH	1979	1980	1981	1982	1983	MEAN
Mackerel						
Candlefish						
Anchovy						
Silver Smelt	1,300	4,700	2,700	600	9,500	3,800
Pacific Halibut						
Butter Sole						
C-O Sole			*			*
Dover Sole	200		*	700	500	300
Rex Sole				200		*
English Sole	183,800	280,400	49,900	468,900	633,800	323,400
Petrale Sole			*			*
Rock Sole	4,600	2,300	5,200	8,500	9,000	5,900
Sand Sole	32,900	26,800	16,400	27,100	19,600	24,600
Sole, General					200	*
Starry Flounder	17,200	40,400	9,000	23,300	36,800	25,400
Arrowtooth Flounder						
Miscel-laneous	4,600					900
Sablefish					5,000	1,000
Herring	1,566,600	800,200	543,600	514,500	775,600	840,100
Ling Cod	*		*		*	*

*Less than 100 pounds.

(CONTINUED NEXT PAGE)

REGION 7—CONTINUED

MARINE FISH	1979	1980	1981	1982	1983	MEAN
Pacific Cod	21,000	14,100	9.000	12,100	14,200	14,100
Pacific Tom Cod						
Walleye Pollock	11,500	200	*		200	2,400
Pacific Whiting	100					*
Rockfish	31,700	23,800	14,100	19,000	21,800	22,100
Perch, General						
Striped Seaperch	17,100	12,000	4,000	4,900	4,100	8,400
Pile Perch	45,100	53,000	29,700	26,900	29,300	36,800
White Sea Bass						
Greenling						
Ratfish						
Sculpin	*		*			*
Spiny Dogfish	391,100	109,800	105,600	18,200	5,700	126,100
Skate	1,890	1,100	3,500	4,800	1,500	2,600
Shark, General						
Sand Dab						

*Less than 100 pounds.

APPENDIX B

WDF HARVEST DATA FOR SHELLFISH (1979-1983) ANNUAL AVERAGE

SHELLFISH IN ROUND POUNDS BY REGION

Region 1--WDF Report Areas 20A, 21A, 21B, 22B

SHELLFISH	1979	1980	1981	1982	1983	MEAN
Butter Clams	5,500	258,600	126,800	4,700	700	79,300
Horse Clams	500	18,500	52,600	600	*	14,400
Geoduck Clams			1,100			200
Native Littleneck Clams	400	2,000	2,700	600	4,400	2,000
Manila Clams	3,500	300	5,200	3,200	3,300	3,100
Softshell Clams						
Mussels					*	*
Scallops		2,400	67,300	4,500	700	15,000
Octopus	7,000	19,600	12,800	10,100	13,800	12,600
Squid		3,600	3,300	500	*	1,500
Dungeness Crab	1,603,200	1,583,100	1,280,600	1,075,100	1,276,400	1,363,700
Rock Crab						
Coonstripe Shrimp				6,700	11,600	3,700
Spotted Shrimp				200	200	*
Pink Shrimp	3,600		1,000	3,400	12,100	4,000
Sea Cucumbers		14,300	9,100			4,700
Sea Urchins			1,400			300

*Less than 100 pounds.

Region 2--WDF Report Areas 20B, 22A

SHELLFISH	1979	1980	1981	1982	1983	MEAN
Butter Clams						
Horse Clams						
Geoduck Clams						
Native Littleneck Clams			5,800	6,600	600	2,600
Manila Clams			4,700	8,100	1,800	2,900
Softshell Clams						
Mussels				2,400	1,600	800
Scallops			1,300	300	100	400
Octopus	*	8,400	900	900	200	2,100
Squid			100	200	400	100
Dungeness Crab	53,700	35,500	106,100	45,900	24,300	53,100
Rock Crab						
Coonstripe Shrimp	31,600	16,300	5,600	10,300	3,300	13,400
Spotted Shrimp	2,200		300		200	500
Pink Shrimp	19,300	9,900	35,900	36,100	21,900	24,600
Sea Cucumbers		10,400	107,100			23,500
Sea Urchins	123,900		6,100		600	26,100

*Less than 100 pounds.

Region 3--WDF Report Areas 23A, 23B, 23C, 25A, 25E.

SHELLFISH	1979	1980	1981	1982	1983	MEAN
Butter Clams	11,700	25,800	17,200	14,900	6,400	15,000
Horse Clams	1,000	1,100	1,500	400		800
Geoduck Clams	31,300	2,900	15,800			10,000
Native Littleneck Clams	148,400	342,500	364,900	308,200	313,500	295,600
Manila Clams				600		100
Softshell Clams						
Mussels						
Scallops						
Octopus	4,600	15,800	13,000	8,000	4,400	9,200
Squid	2,300		*	200	42,400	9,000
Dungeness Crab	3,300	29,200	26,300	32,000	32,500	24,700
Rock Crab						
Coonstripe Shrimp	*	1,100	*	100	*	300
Spotted Shrimp	800	2,700	1,500	1,700	1,100	1,600
Pink Shrimp		1,100	2,300	800	1,100	1,200
Sea Cucumbers				2,800	24,600	5,500
Sea Urchins	878,300	43,300	260,900	202,400	319,000	340,800

*Less than 100 pounds.

Region 4--WDF Report Areas 24A, 24B, 24C

SHELLFISH	1979	1980	1981	1982	1983	MEAN
Butter Clams			*			*
Horse Clams						
Geoduck Clams			1,400			300
Native Littleneck Clams	2,000	300		200	200	500
Manila Clams				300		*
Softshell Clams	15,200	8,500		12,200	16,300	10,400
Mussels	30,100	39,800	88,200	97,400	34,300	58,000
Scallops						
Octopus	2,300	1,300	600	300	700	1,000
Squid						
Dungeness Crab	133,200	78,400	83,900	30,600	32,100	71,600
Rock Crab						
Coonstripe Shrimp		1,100	*	300	500	400
Spotted Shrimp		3,200	700	600	500	1,000
Pink Shrimp		15,300	4,500	3,100	5,700	5,700
Sea Cucumbers		400				*
Sea Urchins						

*Less than 100 pounds.

Region 5--WDF Report Areas 25B, 25D, 26A, 26B, 26C, 26D

SHELLFISH	1979	1980	1981	1982	1983	MEAN
Butter Clams	71,600	83,000	92,700	159,500	224,600	126,300
Horse Clams	46,800	41,300	46,000	61,000	157,000	70,400
Geoduck Clams	2,126,700	1,030,100	347,800	1,971,300	343,900	1,164,000
Native Littleneck Clams	184,500	152,200	143,500	62,800	138,000	136,200
Manila Clams	600	10,00	126,900	69,000	9,000	43,200
Softshell Clams						
Mussels			5,900			1,200
Scallops		300	1,100			300
Octopus	3,400	5,900	2,200	5,400	2,900	4,000
Squid	*	*	1,100	1,600	38,400	8,200
Dungeness Crab	23,800	11,000	4,700	17,700	7,100	12,900
Rock Crab						
Coonstripe Shrimp						
Spotted Shrimp		*	200	*		*
Pink Shrimp					*	*
Sea Cucumbers	192,000	207,600	114,600	22,700	212,200	149,900
Sea Urchins						

*Less than 100 pounds.

Region 6--WDF Report Areas 21A, 21B, 21C

SHELLFISH	1979	1980	1981	1982	1983	MEAN
Butter Clams	17,700	38,400	3,100		42,300	20,300
Horse Clams					2,200	400
Geoduck Clams	1,132,700	355,000	147,900			327,100
Native Littleneck Clams	500	14,700	22,800	2,900	14,200	11,000
Manila Clams	900	178,100	157,600	36,600	44,600	83,600
Softshell Clams						
Mussels						
Scallops						
Octopus		*	*			*
Squid			1,000			200
Dungeness Crab		*	400		3,100	700
Rock Crab						
Coonstripe Shrimp		*			600	100
Spotted Shrimp	32,400	28,100	49,200	31,800	18,500	32,000
Pink Shrimp		300			*	*
Sea Cucumbers		2,100			25,000	5,400
Sea Urchins					*	*

*Less than 100 pounds.

Region 7--WDF Report Areas 28A, 28B, 28C, 28D

SHELLFISH	1979	1980	1981	1982	1983	MEAN
Butter Clams	700	300	10,400	9,200	22,000	8,500
Horse Clams			200			*
Geoduck Clams	1,328,700	2,522,800	3,776,100	3,331,800	3,173,400	2,826,600
Native Littleneck Clams	12,500	4,600	85,200	37,700	85,800	45,100
Manila Clams	1,434,400	1,240,200	1,176,800	1,336,300	1,501,400	1,337,800
Softshell Clams						
Mussels			200	2,700	11,900	3,000
Scallops						
Octopus	1,000	1,000	200	1,200	1,100	900
Squid	1,700		6,000	1,700	1,100	2,100
Dungeness Crab		200	800			200
Rock Crab				500		100
Coonstripe Shrimp						
Spotted Shrimp						
Pink Shrimp						
Sea Cucumbers		185,900	44,800	1,500	9,500	48,400
Sea Urchins						

*Less than 100 pounds.

APPENDIX C

WDF HARVEST DATA FOR SALMON (1979-1983) ANNUAL AVERAGE

SALMON IN ROUND POUNDS BY REGION

Region 1--WDF Report Areas 7A, 7B, 7C, 7D

SALMON	1979	1980	1981	1982	1983	MEAN
Chinook	1,342,400	1,898,400	1,302,400	1,513,700	849,600	1,381,300
Chum	57,500	1,639,200	203,100	963,300	288,700	630,400
Pink	5,303,500	400	5,265,000	*	3,368,100	2,787,400
Coho	974,300	1,212,800	579,300	952,400	761,600	896,100
Sockeye	3,921,200	1,046,400	2,066,700	5,641,900	725,500	2,680,400

Region 2--WDF Report Area 7

SALMON	1979	1980	1981	1982	1983	MEAN
Chinook	374,260	418,500	460,400	358,800	213,900	365,200
Chum	26,900	2,159,000	88,100	460,100	12,000	549,200
Pink	12,772,900	400	12,433,000	*	4,176,800	4,897,200
Coho	467,800	1,835,000	601,500	643,400	202,000	749,900
Sockeye	5,938,000	1,272,900	4,784,800	11,806,400	118,800	4,998,000

Region 3--WDF Report Areas 6, 6A, 6B, 6C, 6D

SALMON	1979	1980	1981	1982	1983	MEAN
Chinook	53,700	32,000	34,800	76,200	16,600	42,700
Chum	2,700	61,700	12,400	5,300	2,900	17,000
Pink	548,700	100	132,300		25,400	141,300
Coho	232,000	187,200	193,200	287,100	341,100	248,100
Sockeye	354,500	81,400	288,800	263,700	13,600	200,400

*Less than 100 pounds.

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Region 4--WDF Report Areas 8, 8A

SALMON	1979	1980	1981	1982	1983	MEAN
Chinook	270,500	336,600	295,300	223,600	152,900	255,800
Chum	143,300	1,022,600	970,900	2,534,700	221,600	978,600
Pink	902,600	*	360,500	*	212,500	295,100
Coho	407,500	1,222,900	554,200	436,700	313,600	587,000
Sockeye	2,300	1,400	1,000	1,700	400	1,300

Region 5--WDF Report Areas 9, 9A, 10, 10A, 10E, 11, 11A

SALMON	1979	1980	1981	1982	1983	MEAN
Chinook	82,300	122,000	162,400	162,900	272,400	160,400
Chum	71,500	1,743,500	1,556,400	3,196,500	1,347,500	1,583,100
Pink	74,700	400	22,300	*	41,300	27,800
Coho	1,276,900	2,068,700	1,068,400	2,207,900	2,016,900	1,727,800
Sockeye	3,400	37,700	100	1,300	1,900	8,900

Region 6--WDF Report Areas 12, 12A, 12B, 12C, 12D

SALMON	1979	1980	1981	1982	1983	MEAN
Chinook	79,700	77,100	94,600	59,200	45,600	71,200
Chum	556,100	1,472,600	1,446,500	1,788,500	1,281,500	1,309,000
Pink	6,800		4,000		2,000	2,500
Coho	220,500	656,700	141,200	421,400	269,900	342,000
Sockeye	900	600	*	100	200	400

*Less than 100 pounds.

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Region 7--WDF Report Areas 13, 13A, 13B

SALMON	1979	1980	1981	1982	1983	MEAN
Chinook	124,100	164,700	180,800	66,300	144,900	136,200
Chum	48,300	896,300	455,200	680,200	324,700	480,900
Pink	2,500		4,500		1,600	1,700
Coho	346,000	601,000	326,900	861,600	407,500	508,600
Sockeye	1,200		200	*	200	300

APPENDIX D

WDF HARVEST DATA FOR OYSTERS (1979-1983) ANNUAL AVERAGE

OYSTERS IN ROUND POUNDS BY REGION

Region 1--WDF Report Areas 43A, 43B, 43C, 43F

OYSTERS	1979	1980	1981	1982	1983	MEAN
Olympia					*	
Pacific	321,800	273,600	247,200	190,400	191,700	244,900
Kumamoto				1,600		300
European						
Eastern						

Region 2--WDF Report Area 43J

OYSTERS	1979	1980	1981	1982	1983	MEAN
Olympia						
Pacific			16,700	6,000	1,800	4,900
Kumamoto			300			*
European				1,200	3,400	900
Eastern			2.100			400

Region 3--WDF Report Areas 42G, 42R

OYSTERS	1979	1980	1981	1982	1983	MEAN
Olympia						
Pacific			44,800	94,600	21,400	32,200
Kumamoto						
European						
Eastern						

*Less than 100 pounds.

Region 4--WDF Report Areas 43D, 43E, 43G, 43H

OYSTERS	1979	1980	1981	1982	1983	MEAN
Olympia						
Pacific	200	11,700		5,600	8,900	5,300
Kumamoto						
European						
Eastern						

Region 5--WDF Report Areas 41M, 41N, 42F, 42H, 42J, 42K, 42L, 42M, 42N

OYSTERS	1979	1980	1981	1982	1983	MEAN
Olympia						
Pacific	419,300	49,500	35,500	133,800	105,000	148,600
Kumamoto						*
European						
Eastern						

Region 6--WDF Report Areas 42C, 42D, 42E

OYSTERS	1979	1980	1981	1982	1983	MEAN
Olympia		*			1,400	300
Pacific	308,900	164,400	186,100	304,500	354,800	263,700
Kumamoto						
European						
Eastern						

*Less than 100 pounds.

Region 7--WDF Report Areas 41A, 41B, 41C, 41D, 41E, 41F, 41G, 41H, 41J, 41K

OYSTERS	1979	1980	1981	1982	1983	MEAN
Olympia	4,800	5,500	3,000	2,700	10,900	5,400
Pacific	1,608,200	1,836,500	1,376,800	1,526,000	1,621,800	1,593,900
Kumamoto					25,900	5,200
European				*	*	*
Eastern						

APPENDIX E

DOLLAR VALUE OF PUGET SOUND
MARINE FISH, SHELLFISH, AND SALMON BY REGION

DOLLAR VALUE* OF PUGET SOUND MARINE FISH, SHELLFISH, AND SALMON

BY REGION

SPECIES	I	II	III	IV	V	VI	VII	TOTAL
Mackerel								
Candlefish								
Anchovy								
Silver Smelt	3,300	200	400	9,100	1,700	1,900	1,300	17,900
Pacific Halibut			3,400					3,400
Butter Sole	3,900			100				4,000
C-O Sole								
Dover Sole	5,500	500	2,000	1,000	12,800		100	21,900
Rex Sole			100					100
English Sole	199,000	7,600	24,000	76,700	39,200	3,400	88,900	438,800
Petrale Sole	200		100			100		400
Rock Sole	36,400	5,000	20,800	6,200	7,300	1,000	1,700	78,400
Sand Sole	28,700	500	4,000	5,600	2,900	100	9,100	50,900
Sole, General	400	200	100		100			800
Starry Flounder	82,200	2,700	5,100	53,800	7,400	100	4,700	156,000
Arrowtooth Flounder	900							900
Miscel-laneous**	90,000	900	400	2,800	1,300		500	95,900
Sablefish	600	200	3,300		500		400	5,000

*Mean of years 1979 and 1983, rounded out to nearest $100.
**Represents 1983 prices only.

Source: Washington Department of Fisheries

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DOLLAR VALUE—CONTINUED*

SPECIES	I	II	III	IV	V	VI	VII	TOTAL
Herring	2,438,700	48,000	3,500	3,700	445,000	146,700	764,500	3,850,100
Ling Cod	17,200	4,900	19,400	900	1,000	13,000		56,400
Pacific Cod	299,000	33,600	121,200	16,000	68,500	1,700	3,200	543,200
Pacific Tom Cod								
Sand Dab								
Walleye Pollock	71,000	200	4,300	1,200	400		200	77,300
Pacific Whiting	100			287,900				288,000
Rockfish	10,400	2,600	21,400	2,500	7,300	500	4,900	49,600
Perch, General								
Striped Seaperch	100		100	100	7,100	1,100	2,400	10,900
Pile Perch	800		300	1,100	15,000	4,300	8,800	30,300
White Sea Bass								
Greenling								
Ratfish								
Sculpin			100		100			200
Spiny Dogfish	184,500	97,800	62,400	21,300	84,500	28,400	12,000	490,900
Skate	5,500	500	1,000	1,000	300		100	8,400
Shark, General								

*Mean of years 1979 and 1983, rounded out to nearest $100.

Source: Washington Department of Fisheries

(CONTINUED NEXT PAGE)

DOLLAR VALUE—CONTINUED*

SPECIES	I	II	III	IV	V	VI	VII	TOTAL
Butter Clam	13,900		2,600		22,100	3,600	1,500	43,700
Horse Clam	1,500		100		7,400			9,000
Geoduck Clam			1,600		186,200	52,300	452,200	692,300
Native Littleneck Clam	600	700	85,700	200	39,500	3,200	13,100	143,000
Manila Clam	1,300	1,200			17,500	33,800	541,800	595,600
Softshell Clam				3,800				3,800
Mussels		600		44,000	500		2,300	47,400
Scallop**	3,800	100			100			4,000
Octopus	3,600	600	2,600	300	1,100		300	8,500
Squid	500		3,000		2,700	200	700	7,100
Dungeness Crab	1,329,600	51,800	24,000	69,900	12,500	700	200	1,488,700
Rock Crab**							100	100
Coonstripe Shrimp	2,900	10,700	200	300		100		14,200
Spot Shrimp	200	1,400	4,200	2,700	100	86,000		94,600
Pink Shrimp	2,200	13,800	700	3,200				19,900
Sea Cucumber	700	3,800	900		24,000	5,400	7,700	42,500
Sea Urchin**		3,400	44,300					47,700
Olympia Oyster	200					4,000	73,600	77,800
Pacific Oyster	22,000	4,400	2,900	4,800	133,800	237,400	1,434,500	1,839,800
Kumamoto Oyster							18,000	18,000
European Oyster**		13,600					200	13,800
Eastern Oyster								

*Mean of years 1979 and 1983, rounded out to nearest $100.
**Represents 1983 prices only.

Source: Washington Department of Fisheries

(CONTINUED NEXT PAGE)

DOLLAR VALUE—CONTINUED[a]

SPECIES	I	II	III	IV	V	VI	VII	TOTAL
SALMON:								
Chinook	2,168,600	573,300	67,000	401,600	251,800	11,200	213,800	3,687,300
Chum	466,500	406,400	12,600	724,200	1,171,500	968,700	355,900	4,105,800
Pink	1,073,100	1,885,400	54,400	113,600	10,700	1,000	700	3,138,900
Coho	1,057,400	884,900	292,800	692,700	2,038,800	403,500	508,600	5,878,700
Sockeye	3,216,400	5,997,600	240,500	1,600	10,700	400	400	9,467,600

APPENDIX F

SUPPLEMENTARY SOURCES OF PUGET SOUND COMMERCIAL & RECREATIONAL FISHERIES

Oysters-Wholesale

Blau Oyster Co Inc
919A N Beach Rd Bow 766-6171
Ellisen Oyster Company
2620 NW Madrona Beach Rd
Olympia 866-7551
Olympia Oyster Co
1042 Bloomfield Rd Shelton 426-3354
Rockpoint Oyster Company
239 Chuckanut Dr Blanchard 766-6002
Simmons Oyster Co
3022 NW Simmons Rd Olympia ... 866-9021

Fish Brokers

Beaumont-Hunter Inc
300 120th NE Bellevue 454-7959
Cole Robert O (Washington) Inc
5950 S 6th Seattle 762-2205
Comex International
600 1st Av Seattle 622-6364
Decatur Seafoods Inc
1519 Dexter Av N Seattle 285-9110
Esveldt Geo Inc
Smith Tower Seattle 622-3013
Euro-Pacific International Corporation
1200 Westlake N Seattle 284-3651
Evergreen Brokerage Co
4110 NE 165th Seattle 363-3911
Federspiel G E Company
3625 1st S Seattle 623-6906
Great Pacific Seafoods Inc
3623 6th S Seattle 623-0052
Hamlin E H Associates
Lowman Bg Seattle 682-9180
Intersea Fisheries Ltd
4225 23rd Av W Seattle 285-5630
Isaco Trading Company Inc
PO Box 16329 Seattle 767-9510
Kachemak International Sales Inc
100 Valley Seattle 282-7245
Kelley Clarke Company
2460 S 6th Seattle 622-2581
M/V Alaskan
2700 Roeder Bellingham 671-9356
Marine Resources Co
192 Nickerson Seattle 285-6424
Marco Intertrade Inc
4044 23rd Av W Seattle 282-5655
Mutual Fish Co
2335 S Rainier Seattle 322-4368
Northern Products Corp
705 Terminal Sales Bldg Seattle . 622-6677
Northland Sea Products Inc
3600 15th Av W Seattle 285-0781
Northwestern Traders Inc
10245 Des Moines Wy S Seattle.. 762-1580
Pesca Inc
8221 44th Av W Everett 745-6022
Prelude Foods International Inc
200 SW Michigan Seattle 762-0260
Sea-West Industries Inc
Squalicum Fill Bellingham 734-8900
Seafood Merchant Inc The
4502 NW 14th Seattle 789-4015
SEAPORT SEAFOODS INC
If It Swims-We Try For It
6923 SE 36th Mercer Island 232-6963
Seven Seas Inc Pier 24 Seattle ... 622-2520
Swiftsure Fisheries Inc
200 W Thomas Seattle 284-9860
Transalaska Fisheries
1515 Dexter Ave Seattle 281-5352
Universal Mercantile Corp
1818 Westlake N Seattle 282-0568
Vanguard Fisheries
18411 9th Av Alderwood Manor.. 771-3667
Wendt International
180 Nickerson Seattle 284-9907

Fish By-Products

Mayco Fish Products Inc
2535 Jefferson Tacoma 572-3070
Puget Sound Salmon Egg Co Inc
1440 S Jackson Seattle 323-5550

Fish Nets

SEATTLE MARINE & FISHING SUPPLY CO
Trawl Seine Gill Net
2121 W Commodore Wy Seattle . 285-5010
SEINERS ASSOCIATION
Specializing In Commercial
Gear & Equipment
1111 NW 45th Seattle 783-7733

Fish Packers

COOK INLET PROCESSING INC
FROZEN SALMON
Box 8163 NRB Kenai AK99611
1035 W Northern Lights
Blvd 776-8832

Fish Packers Equipment

BURTON-PACIFIC SAW CORP & INDUSTRIAL SUPPLY
12880 NE Bellevue-Redmond Rd
Bellevue 454-7627
Seattle Tele No 824-5384
CAMFORD SEAFOODS INC
New Innovations In Processing Seafood
Behind Airport Texaco
Homer AK 907 235-7755
FLOHR METAL FABRICATORS INC
3920 6th Av NW Seattle 633-2222
Scan Marine Inc
5416½ NW 20th Seattle 789-2790
Seattle Knife Supply
Pike Place Public Market
Seattle 682-4563

Fish & Seafood-Wholesale

Alaska Packers Association Inc
1200 112th Bellevue 455-1745
Alaska-Shell Inc
4241 21st Av W Seattle 285-3350
ALL ALASKAN SEAFOODS INC
Herring-Salmon-King Crab
2009 Minor E Seattle 322-3730
Allied Fisheries Inc
Squalicum Way Bellingham 676-1069
Am Can Trading Co Inc
2815 Federal Everett 259-9117
Anacortes Seafoods Inc
2302 Commercial Anacortes 293-7526
Associated Meat & Seafoods Distr Inc
2228 Occidental S Seattle 622-5395
Bakerview International Inc
2211 E Bakerview Rd
Bellingham 671-5507
Bell Bros Inc
11206 Chenault Beach Rd
Everett 347-2626
Booth Fisheries
Terminal 25 Seattle 622-2942
C & D Trading Inc
3600 15th Ave W Seattle 285-2326
Camford Seafoods Inc
Behind Airport Texaco
Homer AK 907 235-7755
Cee & Dee Meats & Seafods
517 Rainier Snohomish 382-0750
Codfather The
Edward Antonelli Sez Ey-Eata You Fish
157 Yesler Seattle 682-3150
Consolidated Fish Co
1 Squalicum Flll Bellingham 734-9906
Corinthian Fish Co
Dakota & Oakes Av Anacortes ... 293-3159
Cossack Caviar Inc
101 S Dakota Seattle 624-2995
Dahl Fish Co Inc
601 W Chestnut Bellingham 733-3940
Eagle Island Seafoods Inc
2304 Jefferson Tacoma 272-7986
Fisherman's Market
514 W Holly Bellingham 733-3200
Fresh Fish Northwest Inc
Lynnwood 775-0936
Glacier Seafoods Inc
1112 E 54th Ave Tacoma 922-7970
High Seas Fish Co
1800 W Emerson Seattle 283-3366
Interocean Seafood Co
200 SW Michigan Seattle 767-6390
Island Fish Market
3 W North Camano Dr
Camano Island 387-9891
Jessie's Ilwaco Fish Company
12727 Northup Wy NE Bellevue . 883-8383

Fish & Seafood-Wholesale — (Cont'd)

Johnny's Sea Food Co
S 15th & Rock Tacoma 627-2158
Jonah Incorporated
10629 NE 8th Bellevue 455-4664
K & N Meats 2900 4th S Seattle.. 628-4811
Kitsap Bait Sales
1595 SW State Highway 160
Port Orchard 876-1189
LaConner Fish & Crab Co
115 N 1st La Conner 466-4166
Lummi Indian Tribal Enterprise
2612 Kwina Rd Bellingham 734-1030
Mackerel Jack's
3995 SE Bethel Rd Port Orchard.. 876-6511
New Venture Fisheries Inc
200 SW Michigan Seattle 763-9168
Northern Fish Products Inc
3911 S 56th Tacom 475-3858
Northwest Waters Seafood Co Inc
20001 Iowa Bellingham 671-8894
Pacific Fish Co
814 6th Av S Seattle 623-1011
Pacific Pearl Seafoods
1450 114th SE Bellevue 453-4600
Pacific Salmon Co Inc
Pier 66 Seattle 622-9368
Pacific Seafoods Inc
14040 NE 8th Bellevue 746-6886
Pacific Seafoods Inc 671-2233
Pacific Western Seafoods Inc
444 NE Ravenna Blvd Seattle 522-9411
Pan-Alaska Fisheries Inc
Fisherman Terminal Seattle 284-0900
Peles Sales Co
653 NE Northlake Wy Seattle 632-9000
Pesca Inc
8221 44th Av W Everett 355-2010
Pete's Seafood
3612 Colby Everett 259-2654
Provide Seafood Corp
Logan Bg Seattle 622-1320
PUGET SOUND SEAFOODS
8404 Bowdoin Wy Edmonds 778-2996
22627 Bothell-Everett Hwy SE Bothell
..... 481-5503
Sea Ram Seafoods Ltd
3818 Westlake N Seattle 282-7800
Seattle Seafoods Inc
Pier 24 Seattle 682-2150
Shafer-Haggart Ltd
4660 E Marginal Wy S Seattle ... 767-5331
Shellfish Of North America Inc
401 Alexander Tacoma 838-2052
Shellfish Of North America The
401 Alexander Tacoma 272-4916
Skokomish Indian Tribal Enterprises
Seafood Division
Rt 5 Hoodsport 877-9246
Specialty Seafoods
1719 13th Anacortes 293-4661
Stewart Seafoods
1520 Norton Everett 258-2546
Stewart Seafoods
1520 Norton Everett 743-5202
Svornich D E
Foot Of K Av Anacortes 293-6989
Swinomish Indian Fish Co
955 Moorage Rd La Conner 466-3179
Tamura America Inc
3637 56th SW Seattle 932-3112
Trident Seafoods Corp
653 NW 41st St Seattle 783-3818
Union Wharf
10 Taylor Port Townsend 385-0954
University Seafood & Poultry Co
1317 NE 47th Seattle 632-3900
Ursin Seafoods Inc
1414 Dexter N Seattle 284-8720
Valhalla Hi-Fi Marketers
444 NE Ravenna Blvd Seattle 522-9411
Variamos Brothers
4268 N Aurora Seattle 632-9548
Verone Sausage Co Inc
12557 SE Green Valley Rd
Auburn 838-6440
Western Fish & Oyster
1137 Dock Tacoma 838-9491
WESTERN FISH & OYSTER CO INC
Imitational - Fresh & Frozen Seafood
Weekly Deliveries to Puget Sound Area
1137 Dock Tacoma ... 383-1668
Seattle 838-9491
Yankee Fish Co
Squalicumwater Wy Bellingham.. 733-1657

Fishermen-Commercial

SEINERS ASSOCIATION
Specializing In Commercial
Gear & Equipment
1111 NW 45th Seattle 783-7733

Fishermen's Supplies

ALA-PAC INC
9407 E Marginal Wy S Seattle .. 762-6782
Aqua Dyne Enterprises
19909 144th Av NE Woodinville 483-8488
Cumberland Grocery
31302 SE 354th Enumclaw 886-2745
Ellis Highliner Fishing Gear
11555 27th NE N Seattle 365-8387
Fishermen's Metal Products
3950 6th NW Seattle 633-4886
King Neptune Co
5425 16th W Seattle 282-3111
KOLSTRAND SUPPLY CO
4714 Ballard NW Seattle..... 789-1886
LUMMI FISHERIES SUPPLY INC
International Paints
851 Coho Wy Bellingham 734-2386
Mam Yang Fishing Net Ind Co Ltd
16943 NE 16th Pl Bellevue 746-9547
Marsol 1304 80th St SW Everett.. 347-4080
Marsol Inc
1304 80th St SW Everett 743-4428
Pacific King Inc
219 E Main Mrro 743-6411
Polyform US Ltd
6830 S 224th Kent 872-0308
Seafood Preservative Inc
515 116th Bellevue 454-4551
Seattle Marine & Fishing Supply Co
2121 W Commodore Wy Seattle.. 285-5018
Seiners Association
1111 NW 45th Seattle 783-7733
Shakey Enterprises
327A Blackburn Mount Vernon ... 336-3485
SUNSET MARINE SUPPLY
4749 Ballard Av NW Seattle 789-4388
Temco Inc
13451 SE 27th Pl Bellevue 747-1550
Western Anglers 255-7528
White Metal Fabricating Inc
4259 22nd Av W Seattle 284-6133

Fishery Consultants

Frederiksen Kamme & Associates Inc
116 Lee St SE Tumwater 352-0640
Pacific Fisheries Research
509 E 12th Olympia 754-4895

Fishing Tackle-Wholesale & Mfrs

Bailey Jud & Co Inc
22805 Pacific Hwy S Seattle 824-5490
Big Al's Tackle
1122 S Woodlawn Tacoma 565-3398
GOLD STAR PRODUCTS INC
7116 220th SW
Mountlake Terrace 774-7388
JMF Marine
450 Admiral Wy Edmonds 776-9824
Jensen Lure & Sons Inc
2817 Pacific Av Tacoma 272-3064
Kasabell Industries Inc
113 E Holly Bellingham 734-9990
Kingfisher Salmon Leaders & Tackle
415 N 61st Seattle 784-2782
Martin Tackle & Manufacturing Co
512 N Minor Seattle 622-7540
Metzler Marine & Mfg
11200 SW 15th S Seattle 242-4200
Mittet Line Co
4218 W 23rd Seattle 282-8411
Morrison Gladys Fishing Supplies
20910 63rd W Lynnwood 778-2640
Nordby Supply Co
2600 W Commodore Wy Seattle.. 284-4000
Sports Service Inc
2911 S Chandler Tacoma 272-6133

Source: GTE Business-to-Business Commercial Directory, Seattle-Puget Sound Edition, 1981/1982.

DOLLAR VALUE—CONTINUED*

SPECIES	I	II	III	IV	V	VI	VII	TOTAL
Butter Clam	13,900		2,600		22,100	3,600	1,500	43,700
Horse Clam	1,500		100		7,400			9,000
Geoduck Clam			1,600		186,200	52,300	452,200	692,300
Native Littleneck Clam	600	700	85,700	200	39,500	3,200	13,100	143,000
Manila Clam	1,300	1,200			17,500	33,800	541,800	595,600
Softshell Clam				3,800				3,800
Mussels		600		44,000	500		2,300	47,400
Scallop**	3,800	100			100			4,000
Octopus	3,600	600	2,600	300	1,100		300	8,500
Squid	500		3,000		2,700	200	700	7,100
Dungeness Crab	1,329,600	51,800	24,000	69,900	12,500	700	200	1,488,700
Rock Crab**							100	100
Coonstripe Shrimp	2,900	10,700	200	300		100		14,200
Spot Shrimp	200	1,400	4,200	2,700	100	86,000		94,600
Pink Shrimp	2,200	13,800	700	3,200				19,900
Sea Cucumber	700	3,800	900		24,000	5,400	7,700	42,500
Sea Urchin**		3,400	44,300					47,700
Olympia Oyster	200					4,000	73,600	77,800
Pacific Oyster	22,000	4,400	2,900	4,800	133,800	237,400	1,434,500	1,839,800
Kumamoto Oyster							18,000	18,000
European Oyster**		13,600					200	13,800
Eastern Oyster								

*Mean of years 1979 and 1983, rounded out to nearest $100.
**Represents 1983 prices only.

$5,211,500

Source: Washington Department of Fisheries

(CONTINUED NEXT PAGE)

DOLLAR VALUE—CONTINUED*

SPECIES	I	II	III	IV	V	VI	VII	TOTAL
Herring	2,438,700	48,000	3,500	3,700	445,000	146,700	764,500	3,850,100
Ling Cod	17,200	4,900	19,400	900	1,000	13,000		56,400
Pacific Cod	299,000	33,600	121,200	16,000	68,500	1,700	3,200	543,200
Pacific Tom Cod								
Sand Dab								
Walleye Pollock	71,000	200	4,300	1,200	400		200	77,300
Pacific Whiting	100			287,900				288,000
Rockfish	10,400	2,600	21,400	2,500	7,300	500	4,900	49,600
Perch, General								
Striped Seaperch	100		100	100	7,100	1,100	2,400	10,900
Pile Perch	800		300	1,100	15,000	4,300	8,800	30,300
White Sea Bass								
Greenling								
Ratfish								
Sculpin			100		100			200
Spiny Dogfish	184,500	97,800	62,400	21,300	84,500	28,400	12,000	490,900
Skate	5,500	500	1,000	1,000	300		100	8,400
Shark, General								

*Mean of years 1979 and 1983, rounded out to nearest $100.

Source: Washington Department of Fisheries

$5,785,300
+ 874,400
$6,279,700

(CONTINUED NEXT PAGE)

Oysters-Whol

Blau Oyster Co Inc
9194 N Beach Rd Bow 766-6171
Ellrsen Oyster Company
2620 NW Madrona Beach Rd
Olympia 866-7551
Olympia Oyster Co
1042 Bloomfield Rd Shelton 426-3354
Rockpoint Oyster Company
239 Chuckanut Dr Blanchard 766-6002
Simmons Oyster Co
3022 NW Simmons Rd Olympia ... 866-9021

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Comco International
600 1st Av Seattle 622-6364
Decatur Seafoods Inc
1515 Dexter Av N Seattle 285-9110
Everett Gee Inc
504th Tower Seattle 622-3013
Euro-Pacific International Corporation
1200 Westlake N Seattle 284-3651
Evergreen Brokerage Co
4110 NE 145th Seattle 363-3911
Federspiel G E Company
3625 1st S Seattle 623-6906
Great Pacific Seafoods Inc
3623 6th S Seattle 623-0052
Hamlin E H Associates
Lowman Bg Seattle 682-9180
Intersea Fisheries Ltd
4225 23rd Av W Seattle 285-5430
Isaco Trading Company Inc
PO Box 34329 Seattle 767-9510
Kachemak International Sales Inc
100 Valley Seattle 282-7245
Kelley Clarke Company
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2700 Roeder Bellingham 671-9356
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Mutual Fish Co
2395 S Rasmer Seattle 322-4368
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Northland Sea Products Inc
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Northwestern Traders Inc
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Pesca Inc
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Prelude Foods International Inc
200 SW Michigan Seattle 762-0260
Sea-West Industries Inc
Squalicum Fill Bellingham 734-8900
Seafood Merchant Inc The
4502 NW 14th Seattle 789-4015
SEAPORT SEAFOODS INC
If It Swims-We Try For It
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Seven Seas Inc Pier 24 Seattle ... 622-2520
Swiftsure Fisheries Inc
200 W Thomas Seattle 284-9860
Transalaska Fisheries
1515 Dexter Ave Seattle 281-5352
Universal Mercantile Corp
1818 Westlake N Seattle 282-0568
Vanguard Fisheries
18411 9th Av Alderwood Manor .. 771-3667
Wendt International
180 Nickerson Seattle 284-9907

Fish By-Products

Magee Fish Products Inc
2535 Jefferson Tacoma 572-5070
Puget Sound Salmon Egg Co Inc
1440 S Jackson Seattle 323-9550

Fish Nets

SEATTLE MARINE & FISHING SUPPLY CO
Trawl Seine Gill Net
2121 W Commodore Wy Seattle . 285-5010
SEINERS ASSOCIATION
Specializing In Commercial
Gear & Equipment
1111 NW 45th Seattle 783-7733

Fish Packers

COOK INLET PROCESSING INC
FROZEN SALMON
Box 8163 NRB Kenai AK99611
1035 W Northern Lights
Blvd 776-8832

Fish Packers Equipment

BURTON-PACIFIC SAW CORP & INDUSTRIAL SUPPLY
12880 NE Bellevue-Redmond Rd
Bellevue 454-7827
Seattle Tele No 824-5384
CRAWFORD SEAFOODS INC
New Innovations In Processing Seafood
Behind Airport Texaco
Homer AK 907 235-7755
FLOOR METAL FABRICATORS INC
3920 6th Av NW Seattle 633-2222
Scan Marine Inc
5416½ NW 20th Seattle 789-2790
Seattle Knife Supply
Pike Place Public Market
Seattle 682-4563

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Alaska-Shell Inc
4241 21st Av W Seattle 285-3350
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Squalicum Way Bellingham 676-1069
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2302 Commercial Anacortes 293-7526
Associated Meat & Seafoods Distr Inc
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2211 E Bakerview Rd
Bellingham 671-5507
Ball Bros Inc
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Everett 347-2626
Booth Fisheries
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Cranford Seafoods Inc
Behind Airport Texaco
Homer AK 907 235-7755
Coe & Doe Meats & Seafods
517 Rasmer Snohomish 382-0750
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Cossack Caviar Inc
101 S Dakota Seattle 624-2995
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Eagle Island Seafoods Inc
2304 Jefferson Tacoma 272-7986
Fisherman's Market
514 W Holly Bellingham 733-3200
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Lynnwood 775-0936
Glacier Seafoods Inc
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High Seas Fish Co
1800 W Emerson Seattle 283-3366
Intercean Seafood Co
200 SW Michigan Seattle 767-6390
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Jessie's Ilwaco Fish Company
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Jonah Incorporated
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1595 SW State Highway 160
Port Orchard 876-1189
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115 N 1st La Conner 466-4166
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Mackerel Jack's
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Northern Fish Products Inc
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Pacific Seafoods Inc 671-2233
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Pesca Inc
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3612 Colby Everett 259-2634
Provide Seafood Corp
Logan Bg Seattle 622-1320
PUGET SOUND SEAFOODS
8404 Bowdoin Wy Edmonds 778-2996
22627 Bothell-Everett Hwy SE Bothell 481-5503
Sea Ram Seafoods Ltd
8818 Westlake N Seattle 282-7800
Seattle Seafoods Inc
Pier 24 Seattle 682-2150
Shafer-Haggart Ltd
4660 E Marginal Wy S Seattle ... 767-5331
Shellfish Of North America Inc
401 Alexander Tacoma 838-2052
Shellfish Of North America The
401 Alexander Tacoma 272-4916
Skokomish Indian Tribal Enterprises
Seafood Division
Rt 5 Hoodsport 877-9246
Specialty Seafoods
1719 15th Anacortes 293-4661
Stewart Seafoods
1520 Norton Everett 258-2546
Stewart Seafoods
1520 Norton Everett 743-5202
Seaweed D E
Foot Of K Av Anacortes 293-6989
Swinomish Indian Fish Co
955 Moorage Rd La Conner 466-3179
Tampa America Inc
3657 36th SW Seattle 932-3112
Trident Seafoods Corp
453 NW 41st St Seattle 783-3818
Union Wharf
10 Taylor Port Townsend 385-0954
University Seafood & Poultry Co
1317 NE 47th Seattle 632-3900
Ursin Seafoods Inc
1414 Dexter N Seattle 284-8720
Valhalla Hi-Fi Marketers
444 NE Ravenna Blvd Seattle 522-9411
Variamos Brothers
4268 N Aurora Seattle 632-9548
Vernor Sausage Co Inc
12557 SE Green Valley Rd
Auburn 838-6440
Western Fish & Oyster
1137 Dock Tacoma 838-9491
WESTERN FISH & OYSTER CO INC
Institutional - Fresh & Frozen Seafood
Weekly Deliveries to Puget Sound Area
1137 Dock Tacoma 383-1668
Seattle 838-9491
Yankee Fish Co
Squalicumwater Wy Bellingham .. 733-1657

Fishermen-Commercial

SEINERS ASSOCIATION
Specializing In Commercial
Gear & Equipment
1111 NW 45th Seattle 783-7733

Fishermen's Supplies

ALA-PAC INC
9407 E Marginal Wy S Seattle .. 762-6700
Aqua Dyne Enterprises
19909 144th Av NE Woodinville 483-0400
Cumberland Grocery
31302 SE 354th Enumclaw 886-2745
Elin Nightner Fishing Gear
11555 27th NE N Seattle 365-8307
Fishermen's Metal Products
3950 6th NW Seattle 633-4000
King Neptune Co
3425 16th W Seattle 282-3111
KOLSTRAND SUPPLY CO
4724 Ballard NW Seattle 789-1900
LUMMI FISHERIES SUPPLY INC
International Paints
851 Coho Wy Bellingham 734-2301
Nam Yang Fishing Net Ind Co Ltd
16943 NE 16th Pl Bellevue 746-9547
Norsel 1304 80th St SW Everett .. 347-4000
Norsel Inc
1304 80th St SW Everett 743-4428
Pacific Kreg Inc
219 E Main Mare 743-6411
Polyform US Ltd
6830 S 224th Kent 872-0300
Seafood Preservative Inc
515 116th Bellevue 454-4561
Seattle Marine & Fishing Supply Co
2121 W Commodore Wy Seattle .. 285-5010
Seiners Association
1111 NW 45th Seattle 783-7733
Shakey Enterprises
327A Blackburn Mount Vernon ... 336-3488
SUNSET MARINE SUPPLY
4749 Ballard Av NW Seattle 789-4300
Temco Inc
13451 SE 27th Pl Bellevue 747-1550
Western Anglers 255-7538
White Metal Fabricating Inc
4259 22nd Av W Seattle 284-6133

Fishery Consultants

Frederikson Kamone & Associates Inc
116 Lee St SE Tumwater 352-0640
Pacific Fisheries Research
509 E 12th Olympia 754-4895

Fishing Tackle-Whol & Mfrs

Bailey Jud & Co Inc
22805 Pacific Hwy S Seattle 824-5498
Big Al's Tackle
1122 S Woodlawn Tacoma 565-3598
GOLD STAR PRODUCTS INC
7116 220th SW
Mountlake Terrace 774-7388
JMF Marine
450 Admiral Wy Edmonds 776-9824
Jensen Lehr & Sons Inc
2817 Pacific Av Tacoma 272-3064
Kasabell Industries Inc
113 E Holly Bellingham 734-9990
Kingfisher Salmon Leaders & Tackle
4158 61st Seattle 784-2782
Martin Tackle & Manufacturing Co
512 N Mover Seattle 622-7540
Metzler Marine & Mfg
11200 SW 15th S Seattle 242-4200
Mettel Line Co
4218 W 23rd Seattle 282-8411
Morrison Gladys Fishing Supplies
20910 63rd W Lynnwood 778-2640
Nordby Supply Co
2600 W Commodore Wy Seattle .. 284-4000
Sports Service Inc
2911 S Chandler Tacoma 272-6133

Source: GTE Business-to-Business Commercial Directory, Seattle-Puget Sound Edition, 1981/1982.