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DISTRIBUTIONAL ANALYSIS OF NEARSHORE AND DEMERSAL FISH
SPECIES GROUPS AND NEARSHORE FISH HABITAT
ASSOCIATIONS IN PUGET SOUND

by

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INTRODUCTION

The ecology of nearshore and demersal fishes in Puget Sound has become the subject of increasing study during recent years. In spite of a growing awareness of the importance of these fishes, neither an analysis of nearshore fish assemblages and habitat associations, nor an analysis of the geographical distribution of demersal fish assemblages has yet been conducted. The absence of such information is unfortunate since it is these nearshore and demersal fish assemblages that are most susceptible to the stresses of various forms of pollution. It is important, therefore, that we intensify our efforts to better understand these assemblages and habitat associations, and then subsequently apply that knowledge to problems of environmental monitoring and impact assessment.

Puget Sound is a complex system of basins, channels, bays, and islands formed by glacial activity during the Pleistocene. The variety of habitat types, bottom sediments, and nearshore vegetation provides an extremely varied environment for marine fishes. According to DeLacy, et al. (1972), 211 species of marine fish have been reported from various areas of Puget Sound (e.g., central Puget Sound, south Puget Sound, etc.). An examination of the available distributional data suggests that many species exhibit uneven distributions throughout Puget Sound, and in some instances occur more frequently in particular geographical regions. Because of the varied character of Puget Sound, it seems probable that nearshore and demersal fish assemblages have become either habitat associated or restricted to specific geographic areas. The recent compilation of data on the geographical distributions of individual fish species in Puget Sound (Miller and

Borton 1974) should now permit a detailed and thorough analysis of this question.

MATERIALS AND METHODS

Data Composition

The two types of catch data utilized in this study were obtained by beach seine (nearshore fish analysis) and otter trawl (demersal fish analysis) gear. The analysis of beach seine data was restricted to data collected with the 37-m sinking beach seine gear employed in previous DOE and METRO investigations. A total of 235 collections from 27 sites in several different areas of Puget Sound (Table 1) served as the data base for the analysis of nearshore fish assemblages. Abundance data for 80 species of fishes were obtained for each of these 27 sites (Table 2). The majority of sites were located in northern Puget Sound, and were part of the Nearshore Fish Survey conducted for DOE by FRI. Additional data, however, were taken from METRO and MESA studies, in central Puget Sound and the Strait of Juan de Fuca, respectively.

The principal sources of distributional and abundance data for demersal fishes were University of Washington research projects and the logbook of the R.V. COMMANDO. University research projects included detailed investigations from Port Gardner, Port Susan, Saratoga Passage, Skagit Bay, central Puget Sound, portions of Hood Canal, and south Puget Sound. In addition, catch data from numerous locations in northern Puget Sound were obtained from UW Department of Oceanography logbooks.

Otter trawl data used in this study were confined to data collected by a 3-m beam trawl used by the UW Department of Oceanography, a 5-m shrimp trawl used by FRI, and the commercial otter trawl gear used

Table 1. Sites used in the analysis of nearshore fish species groups (beach seine data only) and their habitat affinities.

Site	Habitat type	Season			
		Spring	Summer	Autumn	Winter
Alki Point	Sand/eelgrass	x	x	x	x
Point Pully	Sand/eelgrass	x	x	x	x
West Point	Sand	x	x	x	x
South Beach	Cobble	x	x	x	x
Guemes South	Gravel	x	x	x	x
Cherry Pt.	Cobble	x	x	x	x
Legoe Bay	Gravel	x	x	x	x
Deadman Bay	Gravel	x	x	x	x
Beckett Point	Sand/eelgrass	x	x	x	x
Birch Bay	Sand/eelgrass	x	x	x	x
Guemes North	Sand/eelgrass		x	x	
Westcott Bay	Mud/eelgrass	x	x	x	x
Fidalgo Bay	Mud/eelgrass	x	x	x	x
Eagle Cove	Sand/eelgrass	x	x	x	x
Alexander's Beach	Sand/cobble	x		x	
West Beach	Sand/gravel	x	x	x	
Twin Rivers	Sand/eelgrass	x	x	x	x
Dungeness Spit	Sand/gravel	x	x	x	x
Morse Creek	Sand/cobble	x	x		x
False Bay	Sand/eelgrass		x		
Jamestown	Mud/eelgrass	x	x		
Burrows Bay	Sand/eelgrass		x		
Nisqually	Gravel/cobble	x	x		x
Kydaka Beach	Sand	x			x
Cattle Point	Sand/eelgrass				
Golden Gardens	Sand	x			
Dumas Bay	Sand	x			

Table 2. List of species utilized in the analysis of nearshore and demersal fish species groups.

Species	Nearshore fish analysis (beach seine)	Demersal fish analysis (otter trawl)
Brown cat shark		x
Dogfish	x	x
Big skate	x	x
Longnose skate		x
Ratfish	x	x
Pacific herring	x	x
Northern anchovy		x
Chum salmon	x	
Pink salmon	x	
Coho salmon	x	
Chinook salmon	x	
Surf smelt	x	x
Longfin smelt	x	x
Midshipman	x	x
Pacific cod	x	x
Pacific hake		x
Tomcod	x	x
Walleye pollock	x	x
Red brotula		x
Shortfin eelpout	x	x
Black eelpout		x
Wattled eelpout	x	x
Blackbelly eelpout	x	x
Tubesnout	x	x
Stickleback	x	x
Bay pipefish	x	x
Redtail surtperch	x	
Kelp perch	x	
Shiner perch	x	x
Striped perch	x	x
Pile perch	x	x
Pacific sandfish	x	
Northern ronquil		x
High cockscomb	x	
Snake prickleback	x	x
Bluebarred prickleback		x
Penpoint gunnel	x	x
Crescent gunnel	x	x
Saddleback gunnel	x	x
Sandlance	x	x
Arrow goby	x	x
Bay goby	x	x
Brown rockfish	x	x
Copper rockfish	x	x
Greenstriped rockfish		x

Table 2, cont'd

Species	Nearshore fish analysis (beach seine)	Demersal fish analysis (otter trawl)
Yellowtail rockfish	x	x
Quillback rockfish	x	x
Black rockfish	x	x
Redstripe rockfish		x
Sharpchin rockfish		x
Sablefish		x
Kelp greenling	x	x
Whitespotted greenling	x	x
Painted greeling		x
Longspine combfish		x
Padded sculpin	x	x
Scalyhead sculpin	x	
Smoothhead sculpin	x	
Rosylip sculpin	x	
Silverspotted sculpin	x	x
Roughback sculpin	x	x
Sharpnose sculpin	x	
Spinyhead sculpin		x
Buffalo sculpin	x	x
Soft sculpin	x	x
Red Irish lord	x	x
Northern sculpin		x
Spotfin sculpin		x
Pacific staghorn sculpin	x	x
Blackfin sculpin		x
Great sculpin	x	x
Sailfin sculpin	x	x
Tidepool sculpin	x	
Warty poacher	x	
Tadpole sculpin	x	x
Slim sculpin		x
Cabezon	x	x
Manacled sculpin	x	
Spearnose poacher	x	x
Sturgeon poacher	x	x
Smooth alligatorfish	x	
Gray starsnout		x
Spinycheek starsnout		x
Pygmy poacher		x
Tube-nose poacher	x	x
Blacktip poacher		x
Bluespotted poacher		x
Spiny lump-sucker	x	x

Table 2, cont'd

Species	Nearshore fish analysis (beach seine)	Demersal fish analysis (otter trawl)
Spotted snailfish	x	
Ribbon snailfish	x	x
Kingtail snailfish	x	
Tidepool snailfish	x	
Showy snailfish	x	x
Pacific sanddab	x	x
Speckled sanddab	x	x
Arrowtooth flounder		x
Petrale sole		x
Rex sole		x
Flathead sole		x
Butter sole	x	x
Rock sole	x	x
Slender sole	x	x
Dover sole	x	x
English sole	x	x
Starry flounder	x	x
C-0 sole	x	x
Sand sole	x	x
Blackfin poacher		x
Pallid eelpout		x
Whitebarred prickleback		x
Total number species	80	91

by the COMMANDO. Abundance data for 91 species (Table 2) from numerous sites and stations in Puget Sound (Tables 3, 4, 5, 6) served as the data base for the analysis of demersal fish assemblages.

The terms defined below are used consistently throughout this report in reference to catch data or the locations from which the data were obtained.

Catch per unit effort (CPUE): CPUE is the standard method of determining the relative abundance of species captured by various types of sampling gear. In this study, a 10-min tow served as the unit of effort for trawl data, and a single set with the beach seine gear served as the unit of effort for beach seine data. For example, if 100 individuals of species A were captured in five 10-min tows, then the CPUE would be 20 fish/tow.

Collection: Refers to the catch data from a set of samples, where the abundance of each species in the collection is given by its catch per unit of effort.

Site: Refers to a location in Puget Sound from which collections were obtained. The number and location of sites used in the analyses changed slightly with each season.

Station: Each otter trawl site generally consisted of several stations, each station being at a different depth.

Analysis

Ecological Analysis Package (EAP)

The ecological analysis package (EAP) developed by Dr. Robert Smith, formerly at the University of Southern California, was employed extensively in this study. The EAP consists of five major program

packages (Appendix 1) written in the PL/1 program language and linked together by IBM job control language. These five programs allow the user to: (1) construct and manipulate large and small data sets (i.e., matrices), (2) print out and plot various kinds of data or the results of data analyses, and (3) perform numerical classification, discriminant analysis, and several other types of multivariate analyses.

The EAP makes readily convenient the most complete and easiest to use set of programs currently available for the types of analyses employed in this study. Computer analysis is generally necessary in most instances with these methods because of the size of the data sets involved and the complexity of the calculations. At present, the major difficulty associated with the EAP is its restriction to IBM computers because of the PL/1 language in which it was written. Thus, the EAP is incompatible with the University of Washington computer system and must be utilized at facilities having IBM equipment.

Numerical Classification

General Applications in Ecological Studies. The most complete reviews of this methodology and its general use in ecological studies are provided by Clifford and Stephenson (1975) and Smith (1976). According to Clifford and Stephenson, numerical classification has three general usages in ecological studies. The first of these is to detect and describe discrete groups of species based on their patterns of co-occurrence and abundance in a set of collections. Generally, this is possible since more than one species in a given area or habitat usually responds to similar environmental factors, gradients, or discontinuities. This seems a more realistic approach to describing fish communities, since individual species do not live in ecological

vacuums independent of one another. Furthermore, in order to study interactions between different species, it seems important to determine which species are consistently found together.

The second major use of classification in ecological studies is in determining the faunal similarity (i.e., the similarity in species composition and abundance) of a set of biological collections. For example, if the collections have been obtained from several different geographic areas, then one can determine the faunal similarity between these areas. Alternatively, if the collections have been obtained from stations located at different depths, then one can determine patterns of depth zonation.

The third major use of numerical classification is in determining the distribution of species groups among a set of biological collections, which can be readily accomplished by using two-way coincidence tables.

Definitions and General Methodology. Numerical classification refers to the mathematical procedure by which a set of either species or biological collections is organized into a series of groups. In general, this technique is a means of organizing complex data sets into a form which readily displays any pattern existing in the data. The general methodology of classification (Appendix 2) will be discussed below. First, however, a series of terms used in the description of the methodology and throughout the remainder of this text will be defined.

Definitions.

Entity: The units, either species or collections, that are grouped in a classification analysis.

Attributes: The characteristics (e.g., species abundances) of the entities that are used in comparing and then grouping the entities in a

classification analysis.

Transformation: A preliminary mathematical operation (e.g., a square root transformation) that is applied to each element in a body of raw data prior to classification in order to control the scale (or range) of the data values.

Standardization: A preliminary mathematical operation that is applied to a body of transformed data, prior to the classification, to adjust either the scale or the distributional qualities of the data values. Examples are the species maximum and species mean standardizations.

Inter-entity distance: The distance between two entities is a measure of their similarity, based on a comparison of their respective attributes. Several different measures of similarity or distance are available; however, in this study the Bray-Curtis index was used in all analyses.

Numerical classification: The mathematical process by which entities (either species or collections) are grouped together. Several methods are available for grouping entities; however, in this study the flexible sorting strategy was used in all analyses.

Dendrogram: A diagram that displays the two-dimensional relationships between groups of species or collections (i.e., entities).

Normal classification: A classification in which the entities are collections and the attributes are the species.

Inverse classification: A classification in which the species are the entities and the collections are the attributes.

Two-way coincidence table: A rearranged original data matrix in which both the collections and the species are reordered according to the groups which were formed in earlier normal and inverse classifications.

General methodology. The process of numerical classification always begins with a raw data matrix. In this study, the raw data consisted of species abundances (i.e., catch per unit of effort for each species) in a set of collections from different locations and times. Before any analysis, the raw data are usually transformed and standardized in some manner to meet assumptions or minimize certain problems with the data. In this study a square root transformation (Appendix 3) was applied to each raw data value before standardization. This operation modified the range (or scale) of the data values and resulted in decreasing the difference between large and small data values. After the data transformation, two separate data standardizations are applied: A species maximum standardization (Appendix 3) is applied to transformed data used in inverse (i.e., species) classifications, and a species mean standardization (Appendix 3) is applied to transformed data used in normal (i.e., collection) classifications. The species maximum standardization is used to scale the abundance values of each individual species to a maximum of 1.0 to equalize the contribution of each species in the inverse analysis. In contrast, the species mean standardization is used, before the normal analysis, to scale the abundance of each individual species by its average abundance over the entire set of collections being examined.

After the raw data have been transformed and standardized, the next step is to compute a measure of similarity (termed, distance) between all pairs of species or collections, depending on the type of classification to be performed. In this study, the Bray-Curtis distance measure (Appendix 3) was used for this purpose in all analyses. After all Bray-Curtis distance values have been computed, they are then

placed in a matrix, termed an inter-entity distance matrix (Appendix 4).

The actual process of classification and formation of a dendrogram is called a clustering strategy or sorting strategy. In all cases, the input to a clustering strategy is the distance matrix described above. In this study, the flexible sorting strategy, as recommended by Smith (1976), was used in all analyses. An example of how a sorting strategy uses a distance matrix to construct a dendrogram is shown in Appendix 4.

After both the normal and the inverse analyses have been performed on the same body of data, a two-way coincidence table can be constructed by simply rearranging the sequence of rows and columns in the original data matrix to correspond to the results of the classification analyses (Appendix 5). These tables are especially useful in determining the distribution of individual species groups by geographic area, habitat, or depth.

To illustrate the distribution of individual species groups a series of distributional maps have been employed in this report. Each map shows the location of sampling sites used in the analysis by a series of labeled circles. The sites at which a particular group occurred are indicated by filled circles. In contrast, the open circles indicate sites at which that group did not occur.

RESULTS

Nearshore Fishes

Overall Classification of Beach Seine Collections

Based on the relative abundance of 80 species (Table 2), the 232 nearshore (i.e., beach seine) fish collections utilized in this analysis clustered into six (I-VI) major groups (Fig. 1). At the highest level of the dendrogram, there was a clear separation of collections (site group A) taken at sand/eelgrass sites in central Puget Sound (CPS) from all remaining collections. At a somewhat lower level of the dendrogram the remaining collections separated into five groups, primarily on the basis of the habitat type from which they were obtained (gravel, cobble, sand/eelgrass, etc.), and secondarily on the basis of geographic location. In general, mud/eelgrass collections were the most distinct in terms of species composition and abundance. Sand/eelgrass collections from northern Puget Sound (NPS) and the Strait of Juan de Fuca (SJF), in addition to collections from sand/cobble or sand/gravel sites on the SJF, generally grouped together as well, but exhibited some geographical separation from other areas. Collections from cobble and gravel sites in NPS tended to be less distinctive, and more similar to one another than to collections from other habitat types or areas. The composition of each major group of collections, in terms of site and habitat representation, and geographic location, is considered below.

Group A. Group A (Table 7) comprised 35 collections all originating from CPS sand/eelgrass sites (Alki Point, West Point, and Point Pully), which could be divided into two primary subgroups, A1 and A2. Subgroup A1 consisted largely of collections taken in spring and summer

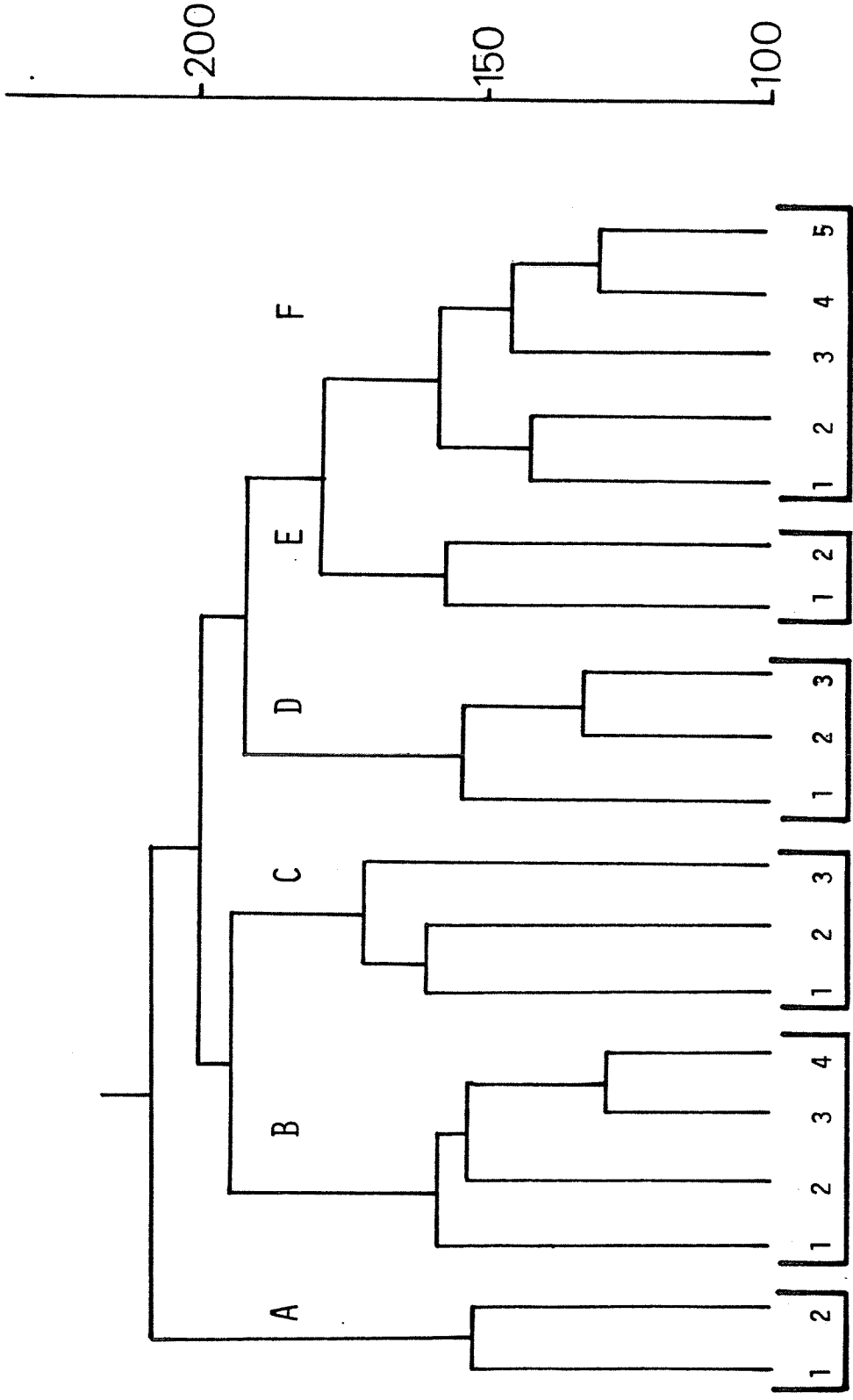


Fig.1. Overall normal classification of the 235 beach seine collections used in the analysis of nearshore fishes.

Table 7. Composition of the six major groups of beach seine collections (A-F), based on a normal classification.

Site group	No. of collections	Geographic area	Habitat	Seasons
A	1	CPS ¹	Sand/eelgrass	Spring, summer
	2	"	"	Fall, winter
B	1	NPS ²	Gravel	Spring, summer
	2	"	"	Fall, winter
	3	"	"	Spring, summer
	4	"	Gravel, cobble	Fall
C	1	NPS, SPS ³ , SJF ⁴	Sand, cobble, gravel	Spring
	2	NPS	Sand/eelgrass	Spring, summer
	3	"	Cobble	All
D	1	NPS	Mud/eelgrass	Winter, fall
	2	"	"	Spring, summer
	3	"	"	"
E	1	SJF	Sand/eelgrass; sand, cobble, gravel	Winter, spring
	2	SJF, NPS, WI ⁵	Sand/eelgrass; sand, cobble, gravel	Spring, summer
F	1	NPS	Sand/eelgrass; mud/eelgrass	All
	2	"	Sand/eelgrass; mud/eelgrass	Winter, spring
	3	CPS, SJF	Sand/eelgrass	Spring
	4	NPS	Sand/eelgrass; mud/eelgrass	"
	5	"	Sand/eelgrass	"

¹Central Puget Sound

²Northern Puget Sound

³South Puget Sound

⁴Strait of Juan de Fuca

⁵Whidbey Island

(April-September), and subgroup A2 consisted of fall and winter (October-March) collections only. Within each subgroup, collections from Alki Point and Point Pully usually grouped separately from collections obtained at West Point.

Group B. Group B (Table 7) comprised 46 collections which could be separated into four main subgroups (B1-B4). Except for three collections taken from Beckett Point in SJF, all collections in this group were obtained from sites in NPS. Although collections from gravel, cobble, and sand/eelgrass habitats occurred in group B, the majority of collections (41/46) were taken from either gravel or cobble sites. Furthermore, of these 46 collections, more than 70% (33) were obtained from gravel habitat sites (Deadman Bay, Legoe Bay, Guemes South) in NPS. The remaining five collections all came from sand/eelgrass sites, primarily from Beckett Point.

The four subgroups in group B generally consisted of either spring-summer or winter-fall collections. Subgroups B1 and B3 included collections taken largely in spring and summer; however, Deadman Bay collections dominated B1, whereas Legoe Bay and Guemes South collections dominated B3. A similar pattern was apparent in the fall-winter subgroups (B2 and B4), the Deadman Bay and Legoe Bay collections most often occurring in B2 and the Guemes South collections primarily occurring in B4.

Group C. Group C, comprising 44 collections taken in NPS and SJF could be divided into three principal subgroups (C1-C3). In addition, several collections in this group were taken from the Nisqually River site in south Puget Sound (SPS). All major habitat types were represented in group C; however, the majority (35/44) of collections

were made at cobble and gravel sites in NPS, or at non-vegetated sites (i.e., gravel, cobble and sand sediment mixtures) in SJF or SPS. The remaining nine collections were taken at either sand/eelgrass or mud/eelgrass sites in NPS.

Subgroup C1 comprised 15 collections taken in spring from widely disparate localities in NPS, SPS, and SJF, representing cobble, gravel, or other non-vegetated habitat types. In contrast, subgroup C2 was more heterogeneous in composition, comprising eight collections from sand/eelgrass and mud/eelgrass sites and nine collections from cobble and gravel sites. All 17 collections in C2 were obtained from sites in SJF or NPS in spring and early summer. The majority of sand/eelgrass or mud/eelgrass collections originated from sites along SJF or along the southwest coast of San Juan Island. Subgroup C3 consisted almost entirely of collections (11/12) taken throughout the year from the South Beach (cobble habitat) site on San Juan Island.

Group D. The fourth major group (D) comprised 29 collections, mostly from mud/eelgrass sites, in particular Westcott Bay on San Juan Island. In addition, two collections from Birch Bay, a sand/eelgrass site, also occurred in group D. Group D could be divided into three main subgroups (D1-D3), subgroup D1 comprising winter and fall collections and subgroups D2 and D3 comprising spring and summer collections. The majority of collections were taken at Westcott Bay; however, additional mud/eelgrass collections obtained from Jamestown in SJF, and from Fidalgo Bay, north of Bellingham, also occurred in this group.

Group E. Group E consisted of two major subgroups (E1 and E2), and 31 collections. A majority of the collections (18/31) came from either sand/eelgrass sites or sites with sand, cobble, and gravel

sediment mixtures (i.e., nonvegetated substrates) located along SJF or on the northwest coast of Whidbey Island. The remaining 13 collections, except one from CPS (West Point), were all taken from sand/eelgrass sites (Eagle Cove and Birch Bay) in NPS.

Collections in subgroup E1 were taken mostly during winter and/or spring, and originated primarily from sites on SJF. In contrast, subgroup E2 comprised collections that were obtained in summer and/or fall from sand/eelgrass sites in NPS (primarily Eagle Cove), or from sand/cobble sites on Whidbey Island (West Beach and Alexander's Beach).

Group F. The final major site group (F), comprised 47 collections and could be divided into five primary subgroups (F1-F5). More than 80% of the collections were taken in winter or spring from sand/eelgrass or mud/eelgrass sites located in NPS (31/47) and CPS (12/47). In addition, three collections from the Nisqually River site and one from the Alexander's Beach site on Whidbey Island occurred in F. Subgroups F1 and F2 consisted of collections taken during all seasons; however, the majority were taken during winter and spring from either sand/eelgrass or mud/eelgrass sites in NPS. In contrast, the remaining collections, from subgroups F3-F5, were taken in spring. Subgroup F3 consisted entirely of collections from sand/eelgrass sites in CPS, whereas subgroups F4 and F5 included a mixture of sand-mud/eelgrass collections taken primarily from NPS.

Seasonal Classifications of Beach Seine Collections

Using all available data from winter (January-March), spring (April-June), summer (July-September), and fall (October-December), individual classifications were performed on a seasonal basis. This

analysis indicated that the relationship between site-summarized (i.e., the CPUE for each species taken at that site within any given season) collections remained very stable during spring, summer, and fall (Fig. 2). During each of these seasons, sites from CPS, representing sand/eelgrass habitats, and sites from NPS, representing mud/eelgrass, sand/eelgrass, gravel, and cobble habitats, generally clustered together. A separate group was formed by collections taken from SJF, Whidbey Island, and San Juan Island (Eagle Cove site). Within the NPS subgroup, collections usually segregated on the basis of gravel-cobble, sand/eelgrass, and mud/eelgrass habitat types. In winter, however, the relationship between site-summarized collections changed, particularly in NPS. Gravel, cobble, sand/eelgrass, and mud/eelgrass collections from NPS clustered in separate groups rather than grouping together. The gravel and cobble collections occurred in one group with CPS and SJF sand/eelgrass collections, whereas the remaining NPS collections clustered with collections from nonvegetated sites along SFJ.

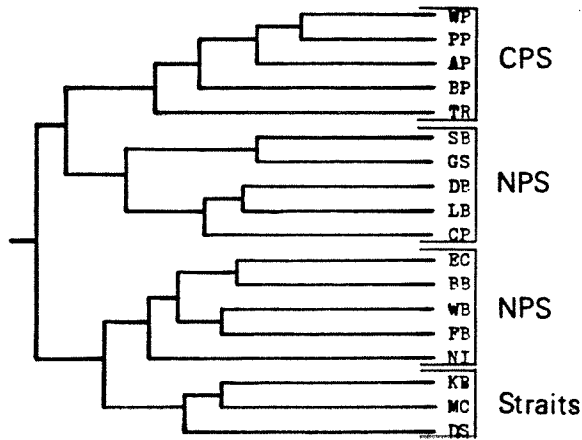
Overall Species Classification

Overall, 58 of the 80 species utilized in the analysis of nearshore fishes could be grouped together into 12 (I-XII) distinct species groupings or assemblages (Fig. 3, Table 8). In general, species groups I-III occurred predominantly in CPS, whereas groups IV-XII occurred predominantly in NPS and SJF.

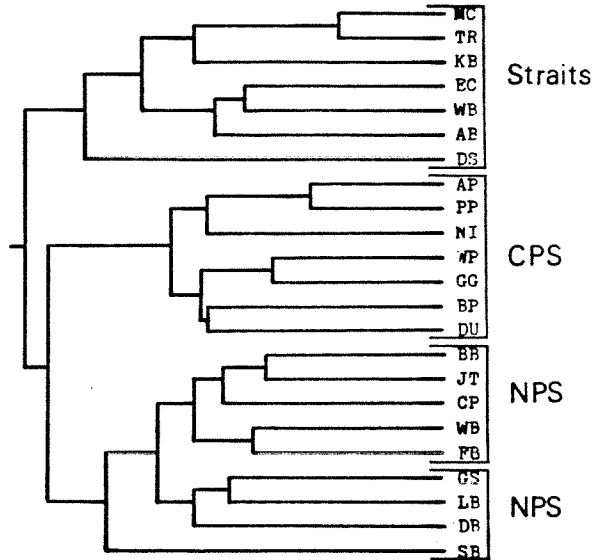
Composition and Distribution of Nearshore Species Groups

The 12 species groups identified on the basis of the 80-species inverse classification (Fig. 3, Table 8) consisted of 3-7 species. Certain groups were restricted to specific geographic areas, habitats, or sites, whereas others had extremely broad patterns of distribution (Tables 9-12).

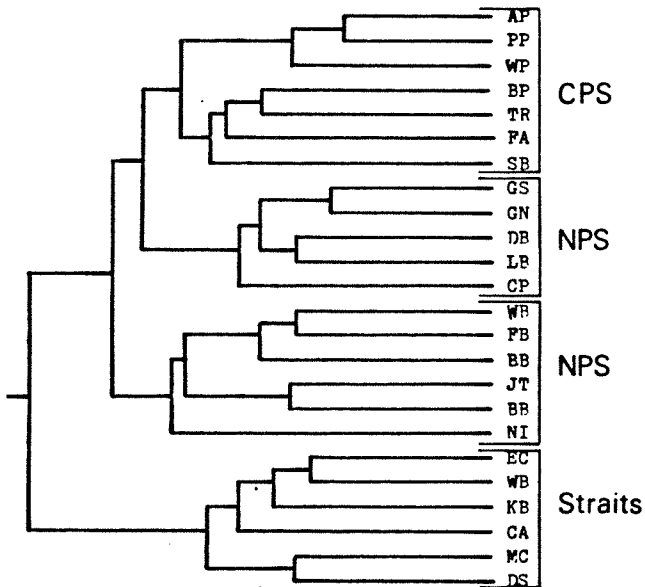
WINTER



SPRING



SUMMER



FALL

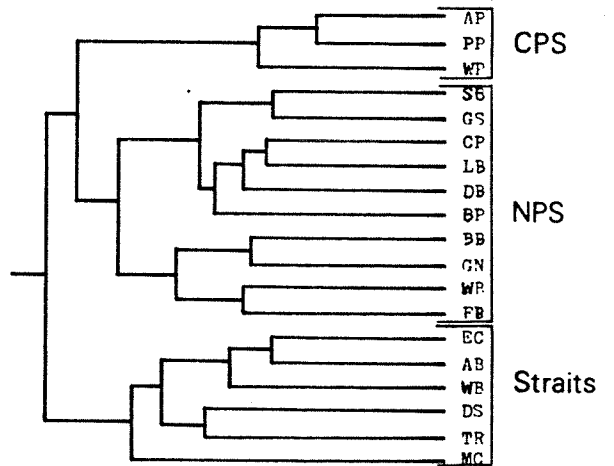


Fig. 2. Winter, spring, summer and fall classifications of beach seine sites used in the determination of near-shore fish species groups.

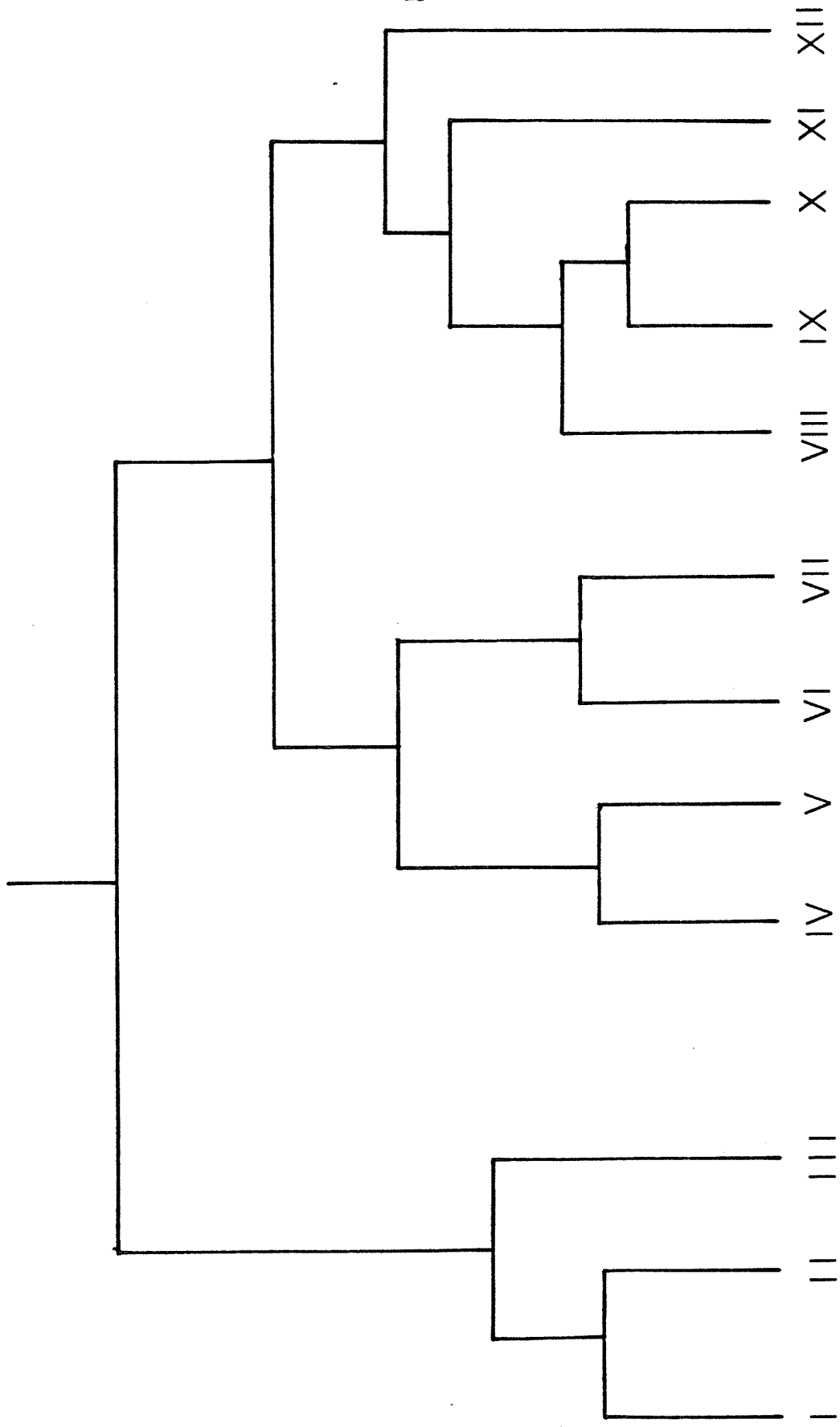


Fig. 3. Overall species classification of 80 nearshore fishes based on 235 beach seine collections from Puget Sound.

Table 8. Composition of nearshore fish species groups found in Puget Sound.

Species group	No. of occurrences	Member species
I	15	rock sole, C-0 sole, English sole, shiner perch, striped perch, pile perch
II	4	tomcod, sturgeon poacher, roughback sculpin, slender sole, sailfin sculpin
III	2	brown rockfish, Dover sole, speckled sanddab, spearnose poacher, Pacific sanddab
IV	10	staghorn sculpin, starry flounder, surf smelt, threespine stickleback, tidepool sculpin, [Pacific herring, snake prickleback]
V	1	big skate, shortfin eelpout, wattled eelpout, ribbon snailfish, tidepool snailfish
VI	1	sand sole, redbtail surfperch, longfin smelt, saddleback gunnel, rosylip sculpin
VII	4	sandlance, chum salmon, coho salmon
VIII	10	penpoint gunnel, crescent gunnel, silverspotted sculpin, whitespotted greenling, tubenose poacher
IX	20	padded sculpin, buffalo sculpin, great sculpin, sharpnose sculpin
X	9	tubesnout, bay pipefish, cabezon
XI	3	copper rockfish, kelp greenling, smoothhead sculpin, manacled sculpin, spotted snailfish
XII	3	walleye pollock, spiny lumpsucker, spiny dogfish, ratfish

Table 10. Seasonal occurrence of nearshore fish species assemblages I-XII at mud/eelgrass habitat sites.

Site	Season	Species assemblages											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Westcott Bay	Winter												
	Spring				X								
	Summer				X						X		
	Autumn				X	X				X			
Fidalgo Bay	Winter									X			
	Spring				X								
	Summer				X								
	Autumn												
Jamestown	Winter												
	Spring								X				
	Summer												
	Autumn									X			

Table 11. Seasonal occurrence of nearshore fish species assemblages I-XII at cobble and gravel habitat sites.

Site	Season	Species assemblages											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
South Beach (cobble)	Winter												
	Spring												
	Summer							X		X			X
	Autumn									X			X
Cherry Point (cobble)	Winter												
	Spring												
	Summer												
	Autumn									X	X		
Guemes So. (gravel)	Winter									X			
	Spring									X			
	Summer								X				
	Autumn								X	X			X
Deadman Bay (gravel)	Winter									X			
	Spring								X	X		X	
	Summer	X			X			X	X	X		X	
	Autumn	X							X		X	X	
Legoe Bay (gravel)	Winter									X			
	Spring									X			
	Summer				X				X	X	X		
	Autumn									X			

Table 12. Seasonal occurrence of nearshore fish species assemblages I-XII at sites lacking vegetation and characterized by various mixtures of mud, sand, cobble, and gravel sediments.

Site	Season	Species assemblages											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Nisqually	Winter												
	Spring												
	Summer												
	Autumn												
Dungeness Spit	Winter												
	Spring												
	Summer												
	Autumn												
Morse Creek	Winter												
	Spring												
	Summer												
	Autumn												
Kydaka Beach	Winter												
	Spring												
	Summer												
	Autumn												
West Beach	Winter												
	Spring												
	Summer										X		
	Autumn												
Alexander's Beach	Winter												
	Spring												
	Summer												
	Autumn										X		

Species group I consisted of six species, including the rock sole, C-0 sole, English sole, shiner perch, striped perch, and pile perch (Table 8). This group occurred primarily at sand/eelgrass sites in CPS during most of year, but was also found at Beckett Point (spring, winter) along the Strait of Juan de Fuca, and at Deadman Bay (summer, fall).

Species groups II (tomcod, sturgeon poacher, roughback sculpin, slender sole, and sailfin sculpin) and III (brown rockfish, Dover sole, speckled sanddab, spearnose poacher, and Pacific sanddab) occurred exclusively at sites in central Puget Sound. Group II occurred at Alki Point, West Point, and Point Pully, whereas group III was found only at Point Pully. Both groups were found only in late summer and fall, periods when beach seine sampling was conducted at night.

The fourth primary species group (IV) was composed of five core species (staghorn sculpin, starry flounder, surf smelt, threespine stickleback, and tidepool sculpin) and two associated species (snake prickleback and herring). This group was found primarily in NPS at mud/eelgrass sites (i.e., Fidalgo Bay, Westcott Bay), but also occurred at gravel and sand/eelgrass sites in summer. At the mud/eelgrass sites, group IV predominated in spring and summer. In addition, group IV was also found at Beckett Point, a protected sand/eelgrass site along the Strait of Juan de Fuca, in spring.

Groups V and VI (Table 8) each consisted of five species which occurred only infrequently. Both had a restricted distribution, group V being found only at Westcott Bay (mud/eelgrass habitat) in the fall, and group VI only at Twin Rivers (sand/eelgrass) in the summer.

Group VII (Table 8) consisted of three pelagic or semipelagic nearshore fish species: Sandlance, chum salmon, and coho salmon. This group occurred exclusively in northern Puget Sound and in a variety of habitats (Tables 9-12). The majority of occurrences were during summer at sites located on the southwest side of San Juan Island (i.e., Deadman Bay, South Beach, Eagle Cove, and Cattle Point).

Species group VIII (Table 8) consisted of five species (penpoint gunnel, crescent gunnel, silverspotted sculpin, whitespotted greenling, and tubenose poacher) which typically occur in association with eelgrass. This group was found occasionally at mud/eelgrass and sand/eelgrass sites along the Strait of Juan de Fuca (Jamestown and Beckett Point) and on San Juan Island; however, most often the assemblage occurred at gravel habitat sites in NPS in summer and fall (Table 11).

Species group IX (Table 8) consisted of four species of sculpin--padded sculpin, buffalo sculpin, great sculpin, and sharpnose sculpin. This particular group was the most widely distributed (Tables 9-12) and the least habitat-specific of all species groups which were described. Group IX was restricted primarily to sites in northern Puget Sound, although it occasionally was found in CPS (Alki Point) and along the Strait of Juan de Fuca (Beckett Point, Jamestown) at sand/eelgrass and mud/eelgrass habitats.

Species group X (Table 8), consisting of tubesnout, bay pipefish, and cabezon, occurred much less frequently than group IX, but in many respects had a similar pattern of distribution (Tables 9-12). In general, this group was found primarily at Alki Point and Point Pully (both sand/eelgrass) in CPS, and at gravel habitat sites in NPS. In addition, group X also occurred at Beckett Point in the SJF and Cherry Point in NPS.

Species groups XI (copper rockfish, kelp greenling, smoothhead sculpin, manacled sculpin, and spotted snailfish) and XII (walleye pollock, spiny lumpsucker, spiny dogfish, and ratfish) both occurred infrequently (Tables 9-12) and only in gravel or cobble habitats. Group XI occurred only at Deadman Bay on San Juan Island, but occurred much of the year (spring to fall). Group XII in contrast was found in both cobble and gravel habitats in summer (South Beach) and fall (South Beach and Guemes South).

Demersal Fishes

Winter

Classification of Winter Collections. The 121 site-summarized collections available from the winter sampling period (Table 3) clustered into six (A-F) major groups (Fig. 4). Each of these major groups was characterized primarily by the depth at which the collections were made (e.g., 5-20 m, 20-40 m), and secondarily by the geographical location of the collection stations. Generally, the collections fell into four depth intervals: 5-20m, 20-40 m, 60-80 m, and 70-120 m. Within each of the three shallowest intervals, collections from CPS and SPS usually clustered together separately in one group, while collections from Whidbey Basin (WB) typically occurred in a distinctly separate group. Collections from the deepest depth interval, however, exhibited a different pattern. One group from this deep zone (E) consisted of collections from CPS and WB, while the other group (F) was composed of collections taken only at deepwater stations (100-150 m) in WB.

Species Group Composition and Distribution. A total of 18 distinct species groups (I-XVIII) was identified from the winter otter trawl collections

WINTER

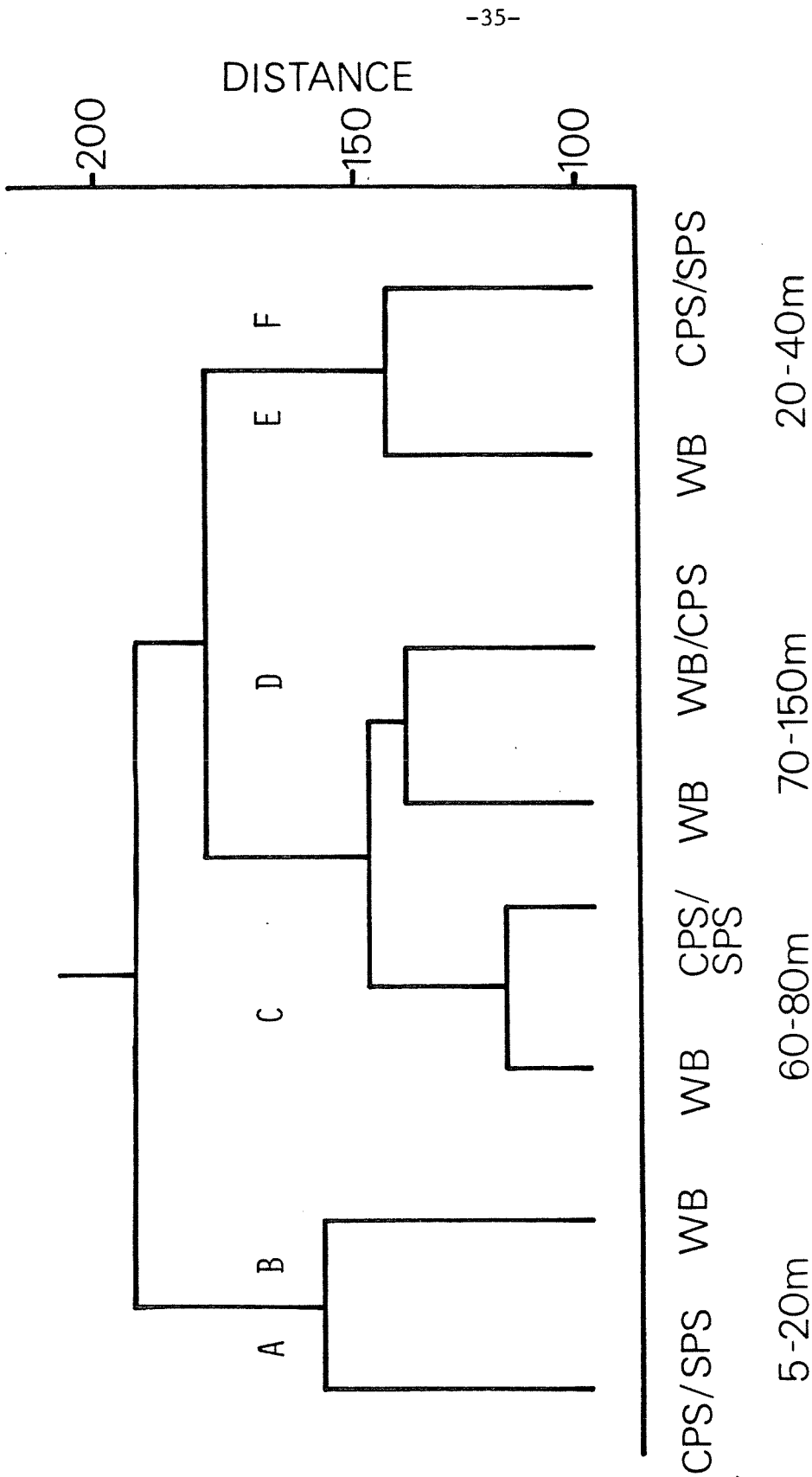


Fig. 4. Classification of winter otter trawl collections from Puget Sound.

(Table 13). These groups consisted of 3-5 species and occurred at 1-16 different sites (Table 14). Although most groups had a partially restricted distribution in terms of geographic area and/or depth, the most frequently occurring groups tended to be more widespread.

The most frequently occurring species groups included groups X, XI (a), XIV (a) and XV (Table 13). Each of these groups exhibited a broad distribution, but tended to be restricted to discrete depth intervals (Table 14). The most frequently occurring species group, XI (a) , consisted of three species: staghorn sculpin, English sole and sand sole. This group typically occurred at depths of 5-30 m at most sites in WB, CPS, and SPS (Fig. 5). Group X, which consisted of four species (roughback sculpin, speckled sanddab, rock sole, and C-0 sole), also occurred frequently. Although this group occurred in all geographic areas, it was clearly more frequent in CPS and SPS (Fig. 6). Over most of its distribution, species group X occurred at depths of 20-45 m ; however, at CPS sites the group also occurred in shallower (5-20 m) water (Table 14). Group XIV(a) was composed of four species which included the blackbelly eelpout, slender sole, blacktip poacher and midshipman. This group was predominantly found at depths of 40-80 m throughout Puget Sound; however, it tended to be somewhat sporadic in occurrence (Figure 7). Species group XV (ratfish, rex sole and Dover sole) occurred exclusively in deep water (70-120 m), through much of Puget Sound; however, the group seemed most dominant in central Puget Sound (Fig. 8).

Several additional groups (IV, III, XIII, XII and XVII) exhibited restricted geographic distributions, often in addition to a restricted depth distribution. Groups IV (spinyhead sculpin, whitebound prickleback and longnose skate) and III (black eelpout, pallid eelpout and blackfin poacher), for example, occurred only in Whidbey Basin (Figs. 9, 10). Group IV was distributed primarily

Table 13. Composition of demersal fish species groups found during the winter

Species group	No. of site occurrences	Member species
I	1	tubenose poacher, showy snailfish, red Irish lord, wattled eelpout
II	3	Pacific cod, Pacific herring, copper rockfish, sablefish
III	3	black eelpout, pallid eelpout, blackfin poacher
IV	3	spinyhead sculpin, whitebarred prickleback, longnose skate
V(a)	2	dogfish, tomcod, brown cat shark
V(b)	2	shortfin eelpout, bluebarred prickleback
VI	1	longfin smelt, spinycheek starsnout, butter sole
VII	1	penpoint gunnel, great sculpin, striped perch, bay pipefish
VIII	4	buffalo sculpin, starry flounder, painted greenling
IX	2	tubesnout, silverspotted sculpin
X	13	roughback sculpin, speckled sanddab, rock sole, C-O sole
XI(a)	16	staghorn sculpin, English sole, sand sole
XI(b)	10	shiner perch, pile perch
XII	6	sailfin sculpin, sturgeon poacher, spearnose poacher, padded sculpin, pygmy poacher
XIII	2	snake prickleback, bay goby, longspine combfish

Table 13, cont'd

Species group	No. of site occurrences	Member species
XIV(a)	10	blackbelly eelpout, slender sole, blacktip poacher, midshipman
XIV(b)	6	Pacific hake, walleye pollock
XV	9	ratfish, rex sole, Dover sole
XVI	2	brown rockfish, quillback rockfish, arrowtooth flounder
XVII	5	redstripe rockfish, bluespotted poacher, slim sculpin, northern ronquil
XVIII	2	spotfin sculpin, Pacific sanddab, northern sculpin

WINTER

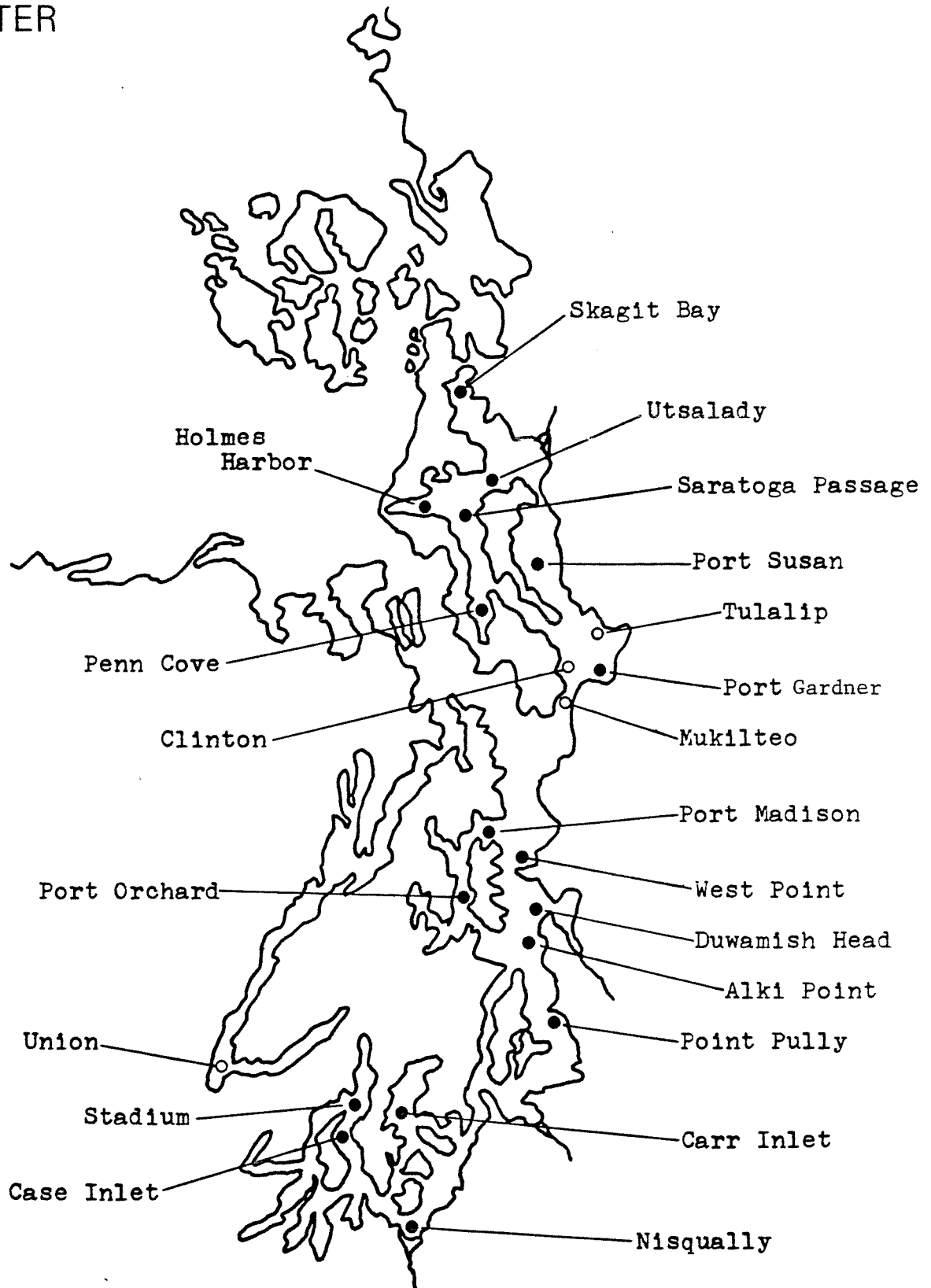


Fig. 5. Geographical distribution of species group XI(a), staghorn sculpin, English sole, and sand sole, in Puget Sound during the winter.

WINTER

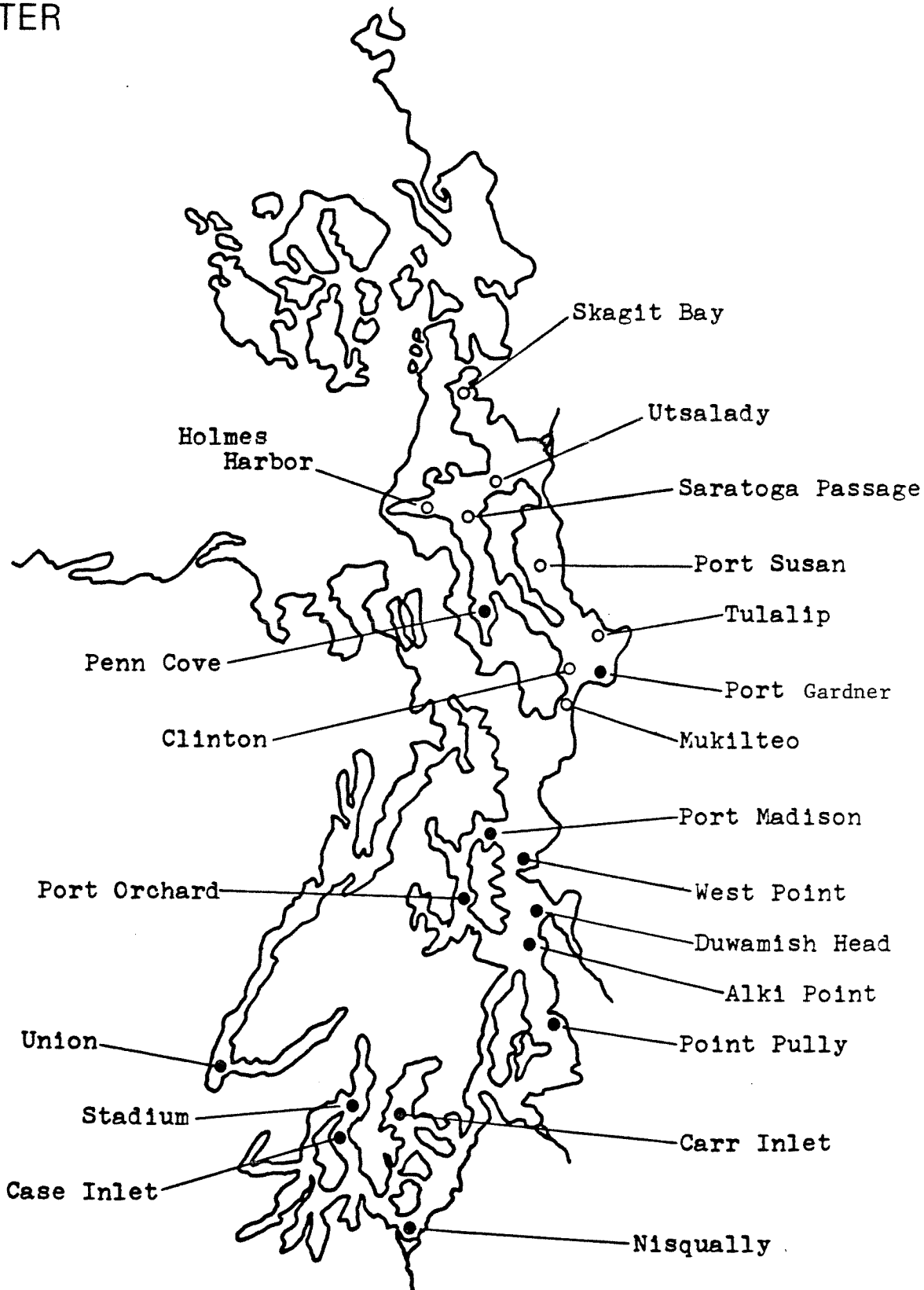


Fig. 6. Geographical distribution of species group X (roughback sculpin, speckled sanddab, rock sole and C-O sole) in Puget Sound during the winter.

WINTER

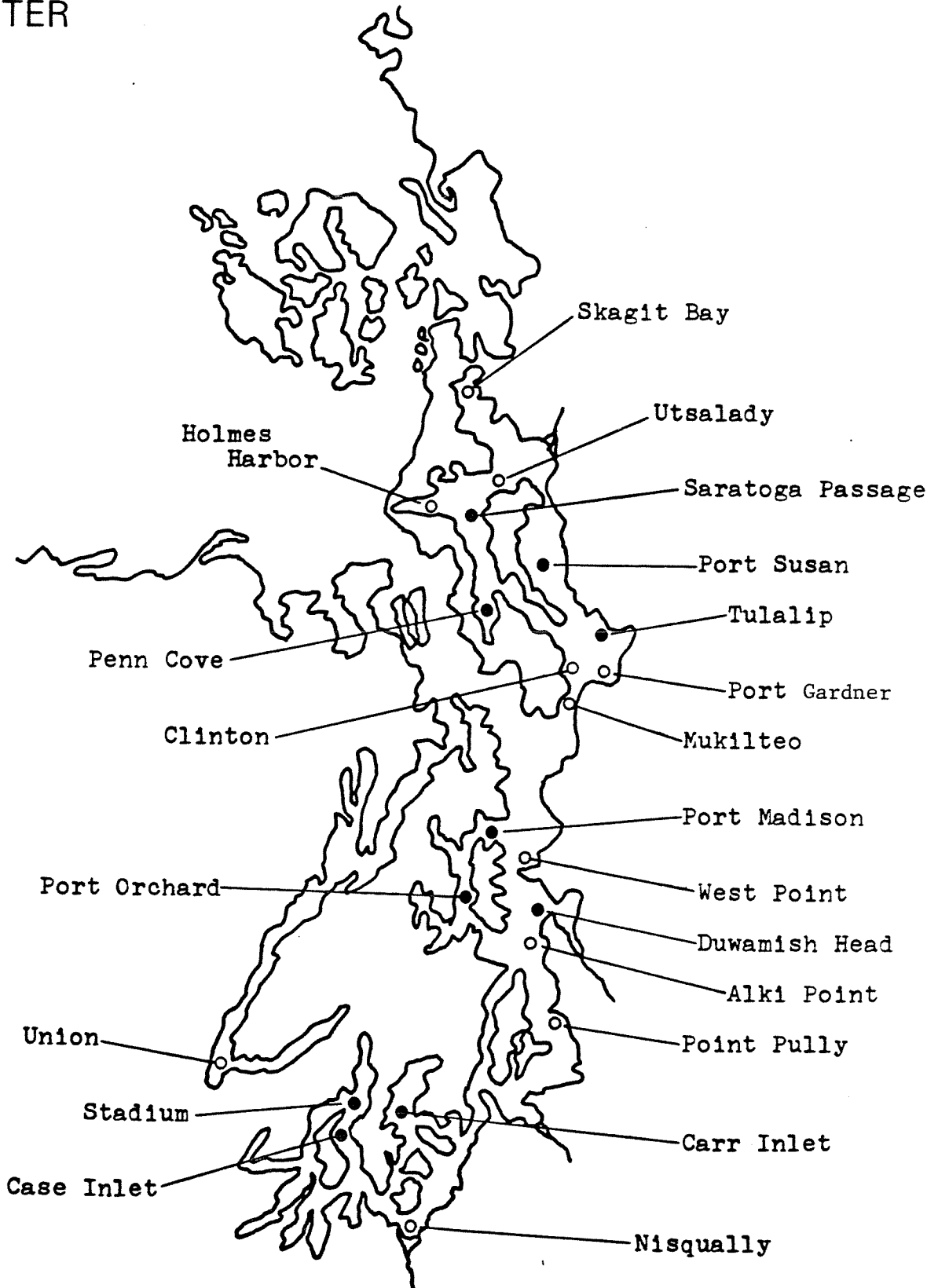


Fig. 7. Geographical distribution of species group XIV (black-belly eelpout, slender sole, blacktip poacher and mid-shipman) in Puget Sound during the winter.

WINTER

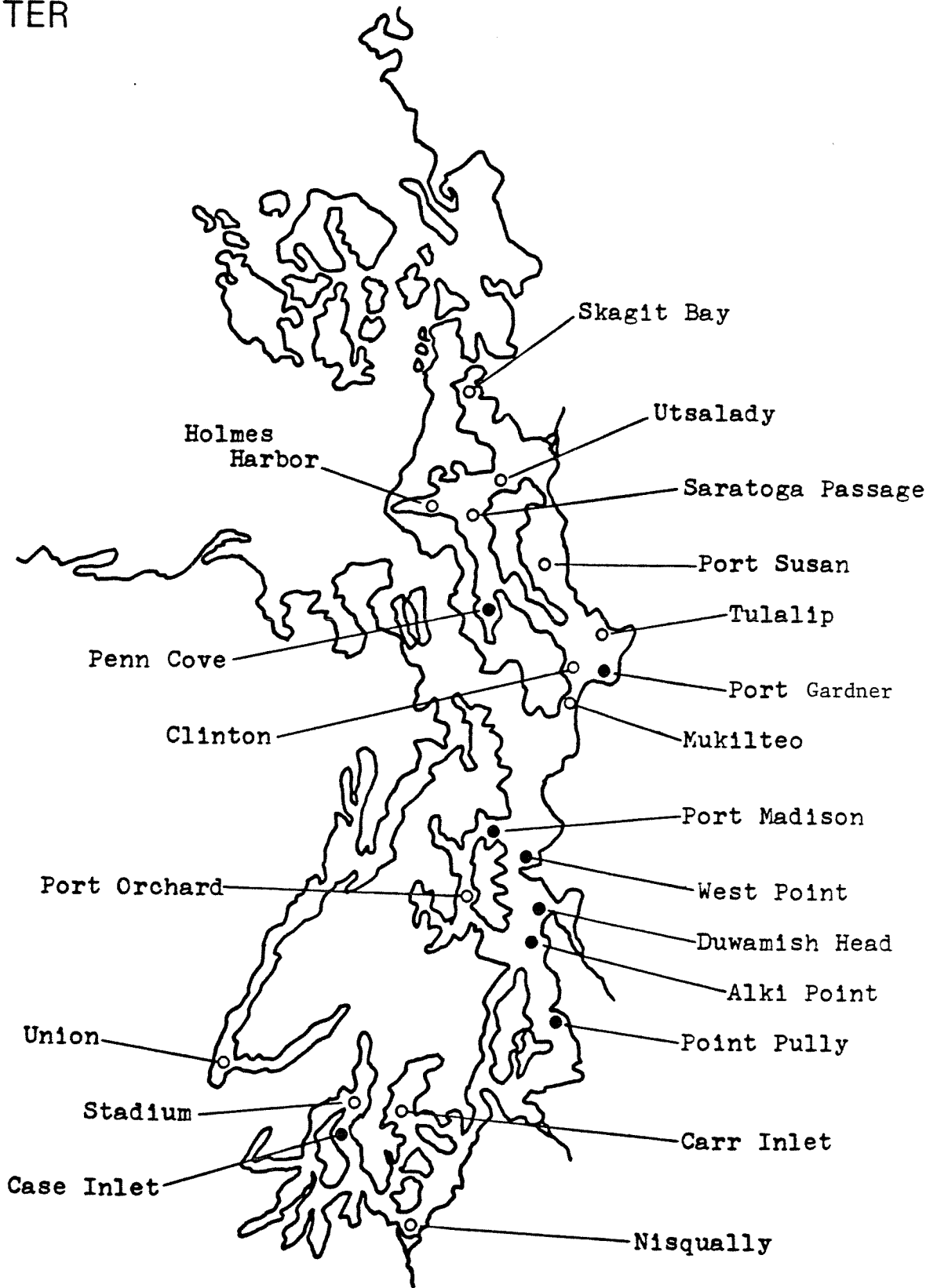


Fig. 8. Geographical distribution of species group XV (ratfish, rex sole and Dover sole) in Puget Sound during the winter.

WINTER

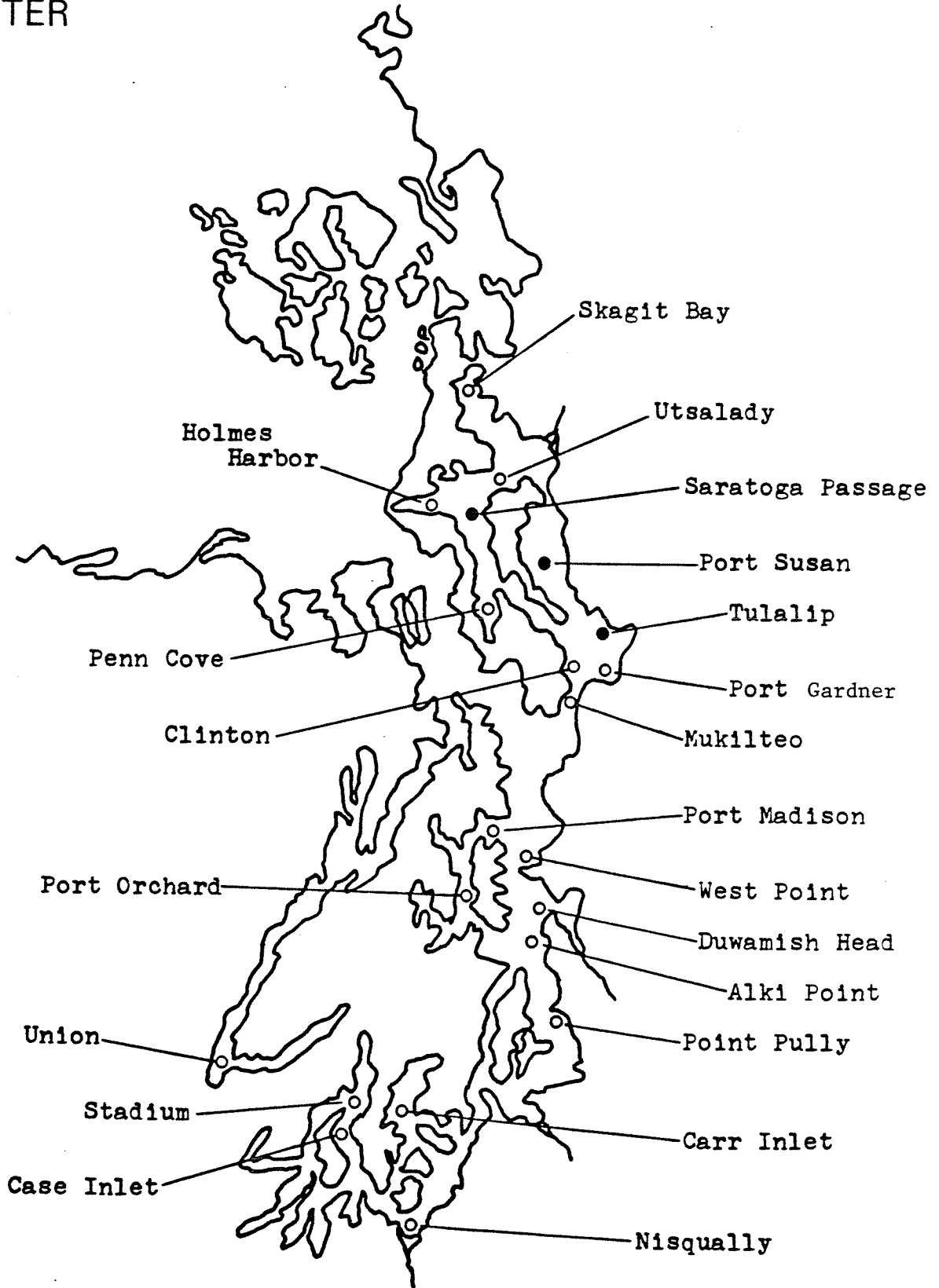


Fig. 9. Geographical distribution of species group IV (spinyhead sculpin, whitebarred prickleback and longnose skate) in Puget Sound during the winter.

WINTER

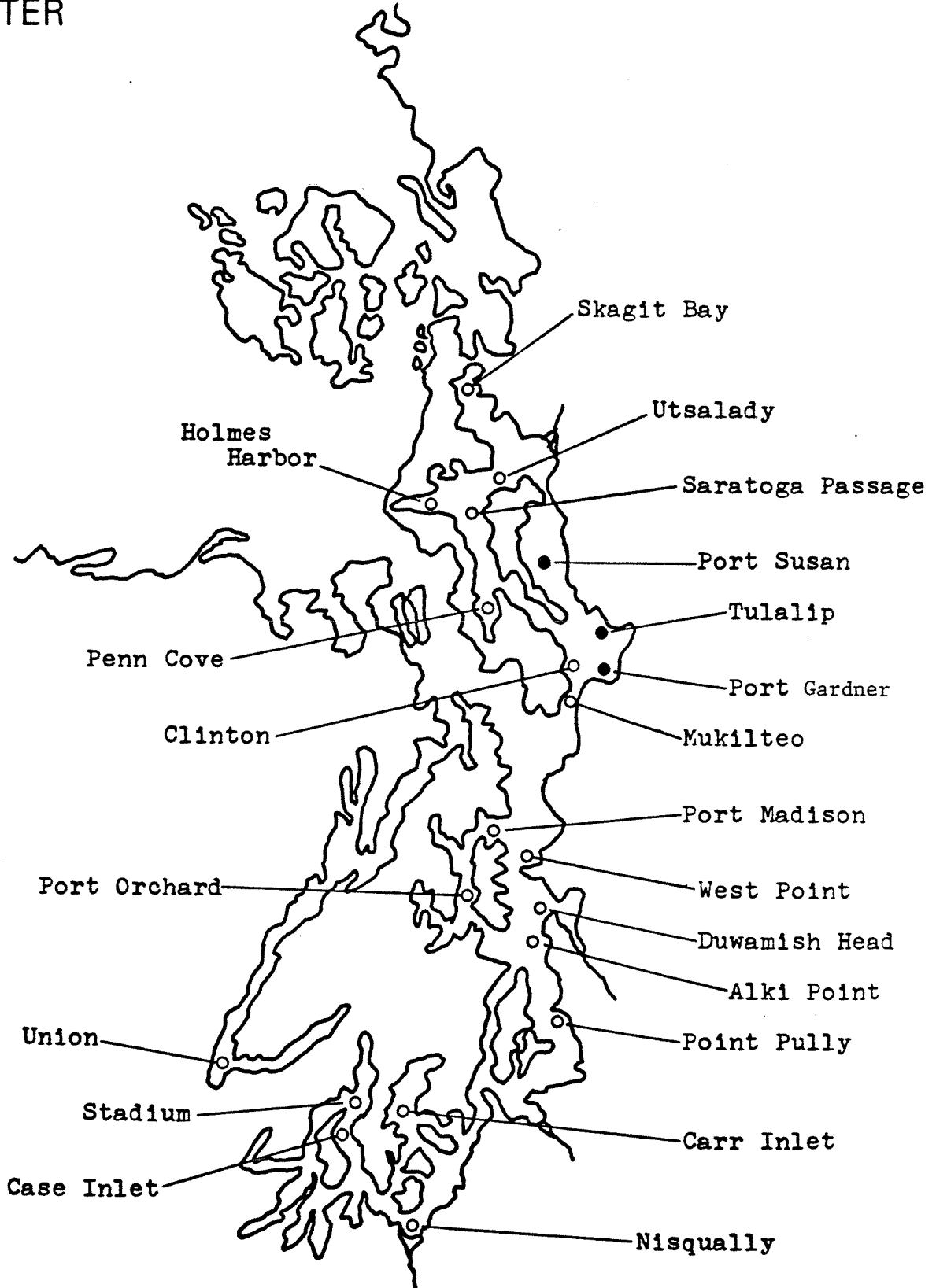


Fig. 10. Geographical distribution of species group III (black eelpout, pallid eelpout and blackfin poacher) in Puget Sound during the winter.

at depths of 30-80 m, while group III was found only at great depths (100-150 m) in the vicinity of Port Gardner. In contrast, species groups XII (sailfin sculpin, sturgeon poacher, spearnose poacher, padded sculpin and pygmy poacher) and XVII (redstripe rockfish, bluespotted poacher, shiner sculpin and northern ronquil) were found only in CPS and SPS (Figs. 11, 12). Group XII, however, occurred primarily at depths of 30-45 m, while XVII occurred at 40-90 m. Finally, species group XIII, composed of the snake prickleback, bay goby, and longspine combfish, was found only in South Puget Sound, principally at depths of 30-40 m (Fig. 13).

Spring

Classification of Spring Collections. The 132 site summarized collections used in the spring analysis (Table 4) clustered into five (A-E) primary groups (Fig. 14). Groups A and E consisted mainly of shallow-water collections taken at depths of 5-30 m. Group A consisted largely of collections from north Puget Sound (NPS) and Whidbey Basin (WB), whereas group E was composed of WB and NPS collections as well as additional collections from CPS and SPS. Groups C and D were composed primarily of collections taken at intermediate depths of 30-80 m. Group D collections originated largely from CPS and SPS, whereas the collections in group C were obtained from SPS, Hood Canal (HC), and WB. The final major group (B) consisted of two subgroups, and included mostly deep water (70-150 m) collections from WB and CPS. One subgroup included collections taken only in WB (near Port Gardner), whereas the other subgroup consisted of both WB and CPS collections.

WINTER

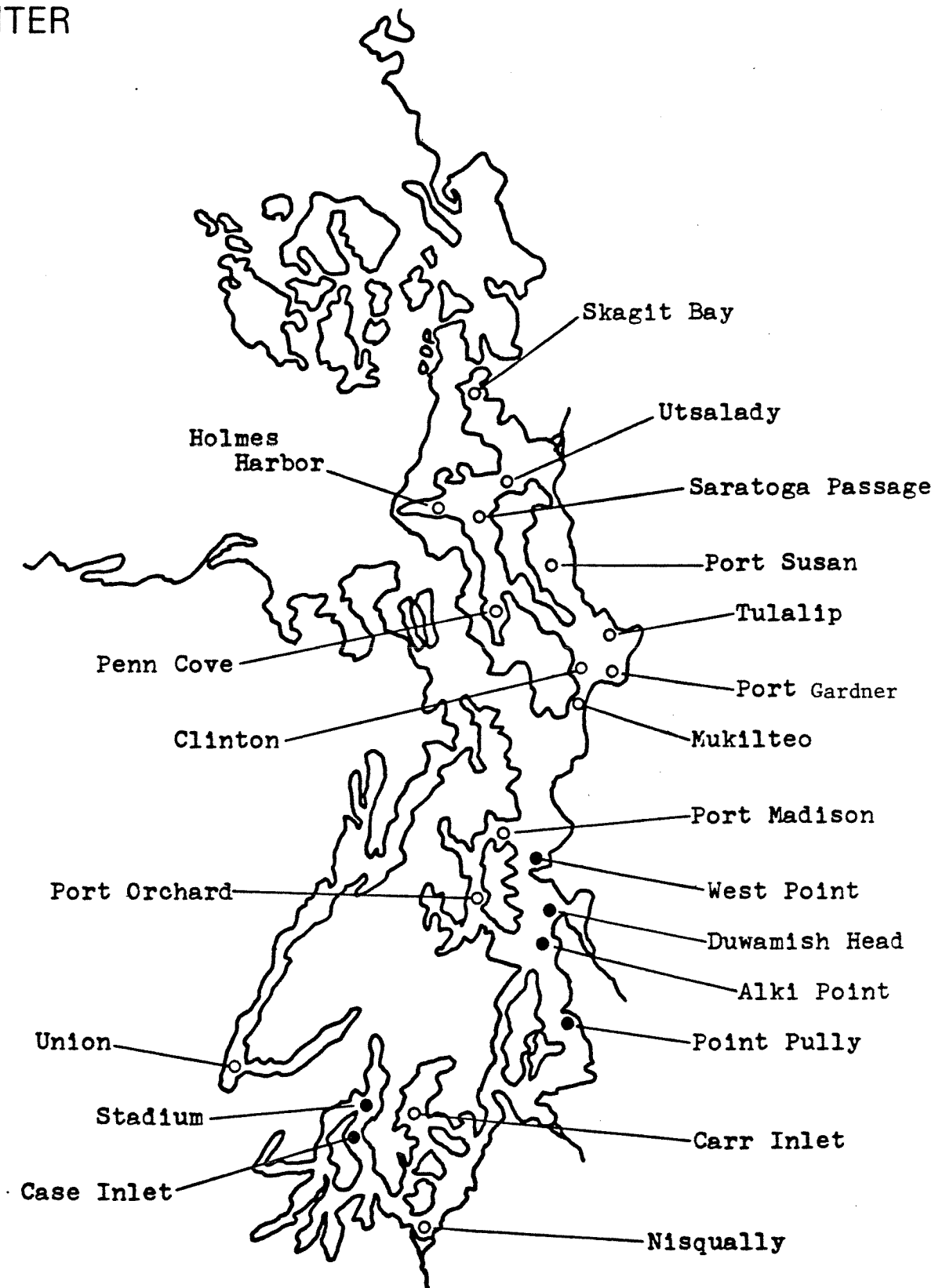


Fig.11. Geographical distribution of species group XII (sailfin sculpin, sturgeon poacher, spearnose poacher, padded sculpin and pygmy poacher) in Puget Sound during the winter.

WINTER

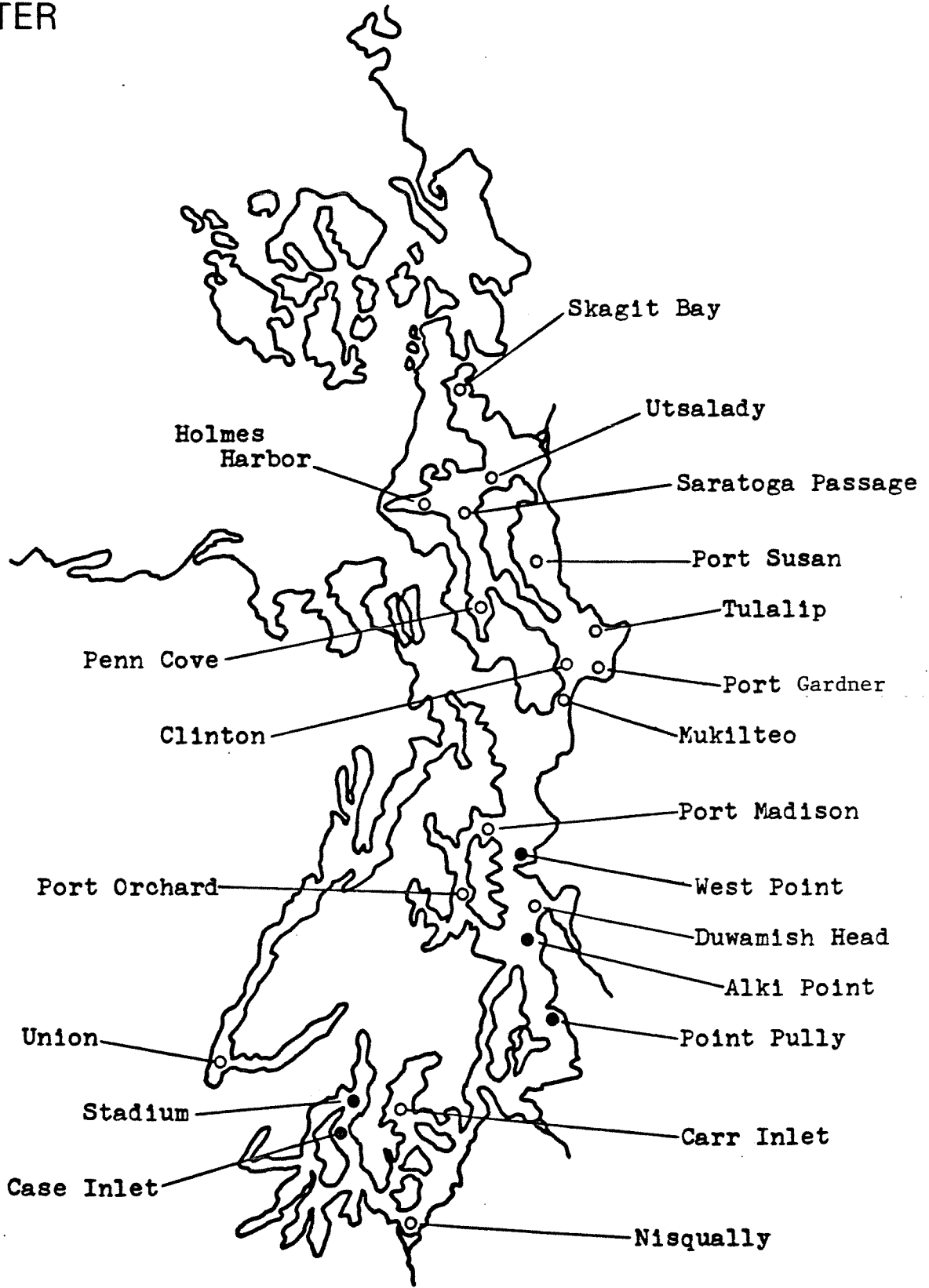


Fig. 12. Geographical distribution of species group XVII (redstripe rockfish, bluespotted poacher, slim sculpin and northern sculpin) during the winter in Puget Sound.

WINTER

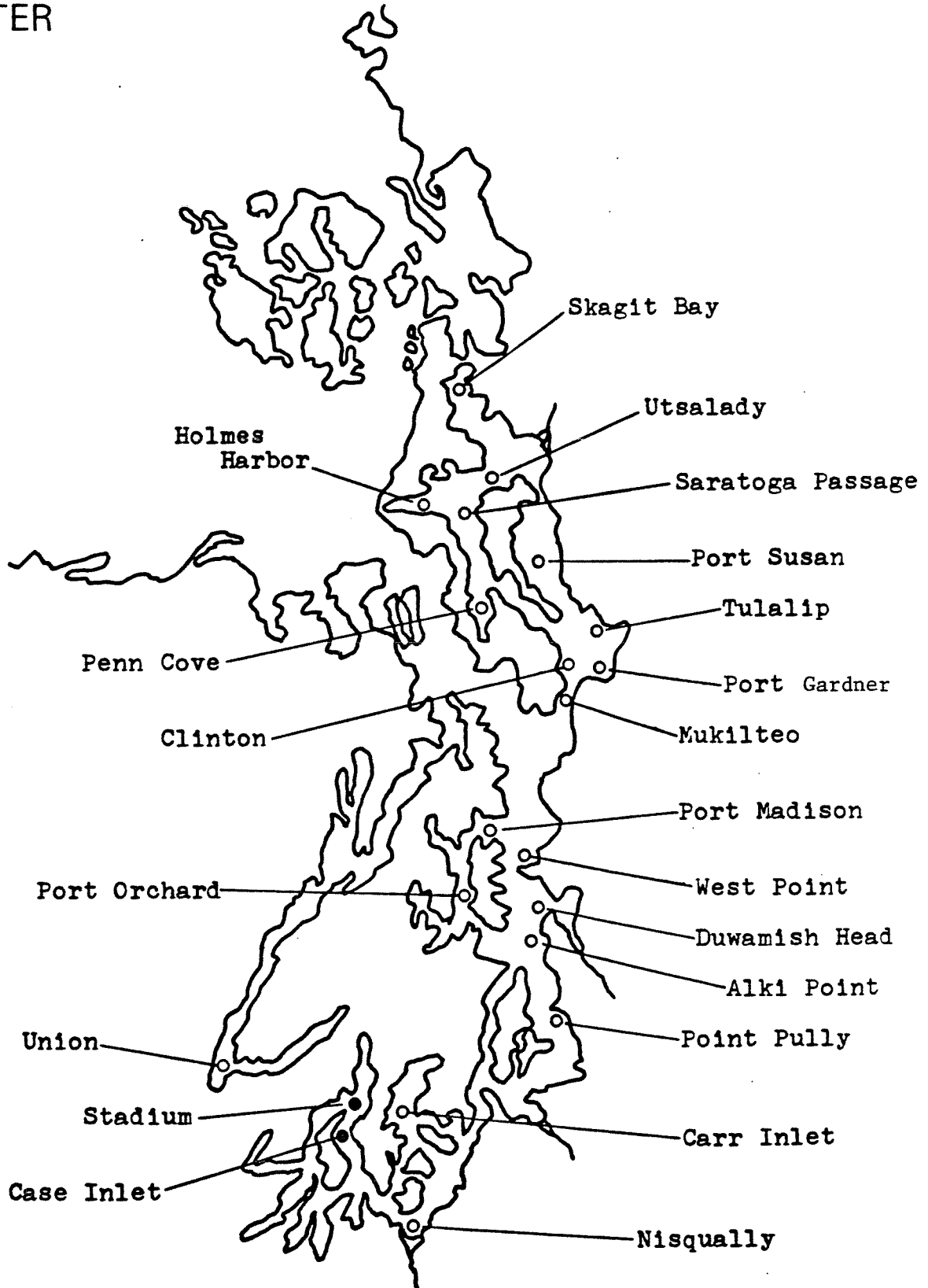


Fig. 13. Geographical distribution of species group XIII, snake prickleback, bay goby, and longspine combfish, from Puget Sound during the Winter.

Species Group Composition and Distribution. A total of 17 distinct species groups was identified from the spring otter trawl collections (Table 15). These groups were composed of 2-5 species and occurred at 1-21 different sites in Puget Sound (Table 16). The most frequently occurring species groups (XII, XV, and XVI) all exhibited broad geographic distributions; however, the majority of groups occurred few times and were more restricted in distribution.

The most frequently occurring group (XII, 17 occasions) consisted of the rock sole, English sole, speckled sanddab, C-0 sole, and roughback sculpin. Generally, this group was restricted to depths of less than 30 m, although in CPS the group tended to occur in deeper water (to 60 m) also. Group XII exhibited an extremely broad distribution, occurring throughout SPS, CPS, WB, and Hood Canal (Fig. 15). Group XII, however, consisted of two subgroups (a,b), each exhibiting somewhat different distributions. In particular, subgroup (a), which consisted of rock sole, English sole, and roughback sculpin, occurred at over 20 sites, and exhibited a more extensive distribution than subgroup (b).

Species group XV consisted of four species, blackbelly eelpout, slender sole, midshipman, and slim sculpin. This group occurred throughout Puget Sound (Fig. 16), and was found over a broad depth range (30-120 m). Group XV occurred at depths of 30-80 m in WB, SPS, and Hood Canal; however, in CPS the group was found over a wider depth range (40-120 m). Species group XVI (ratfish, Dover sole, rex sole) also occurred at intermediate-to-deep water (60-120 m) through much of Puget Sound (Fig. 17); however, the group predominated in central Puget Sound.

Table 15. Composition of demersal fish species groups found during the spring

Species group	No. of site occurrences	Member species
I	4	buffalo sculpin, bay pipefish, crescent gunnel
II	2	dogfish, Pacific herring, big skate
III	3	spinyhead sculpin, whitebarred prickleback, bluebarred prickleback
IV	1	black eelpout, red brotula, Pacific hake
V	3	blackfin poacher, pallid eelpout, brown cat shark
VI	4	striped perch, tubesnout
VII	1	great sculpin, cabezon, saddleback gunnel
VIII(a)	3	northern ronquil, northern sculpin, spearnose poacher
VIII(b)	3	redstripe rockfish, bluespotted poacher
IX	7	shiner perch, pile perch, Pacific tomcod
X	7	snake prickleback, sand sole, butter sole, starry flounder, staghorn sculpin
XI	10	flathead sole, longfin smelt
XII(a)	21	rock sole, English sole, roughback sculpin
XII(b)	16	speckled sanddab, C-0 sole
XIII	4	padded sculpin, pygmy poacher
XIV	2	longspine combfish, sturgeon poacher, sailfin sculpin, bay goby

Table 15, cont'd

Species group	No. of site occurrences	Member species
XV	13	blackbelly eelpout, slender sole, midshipman, slim sculpin
XVI	13	ratfish, rex sole, Dover sole
XVII	4	walleye pollock, brown rockfish, quillback rockfish

SPRING

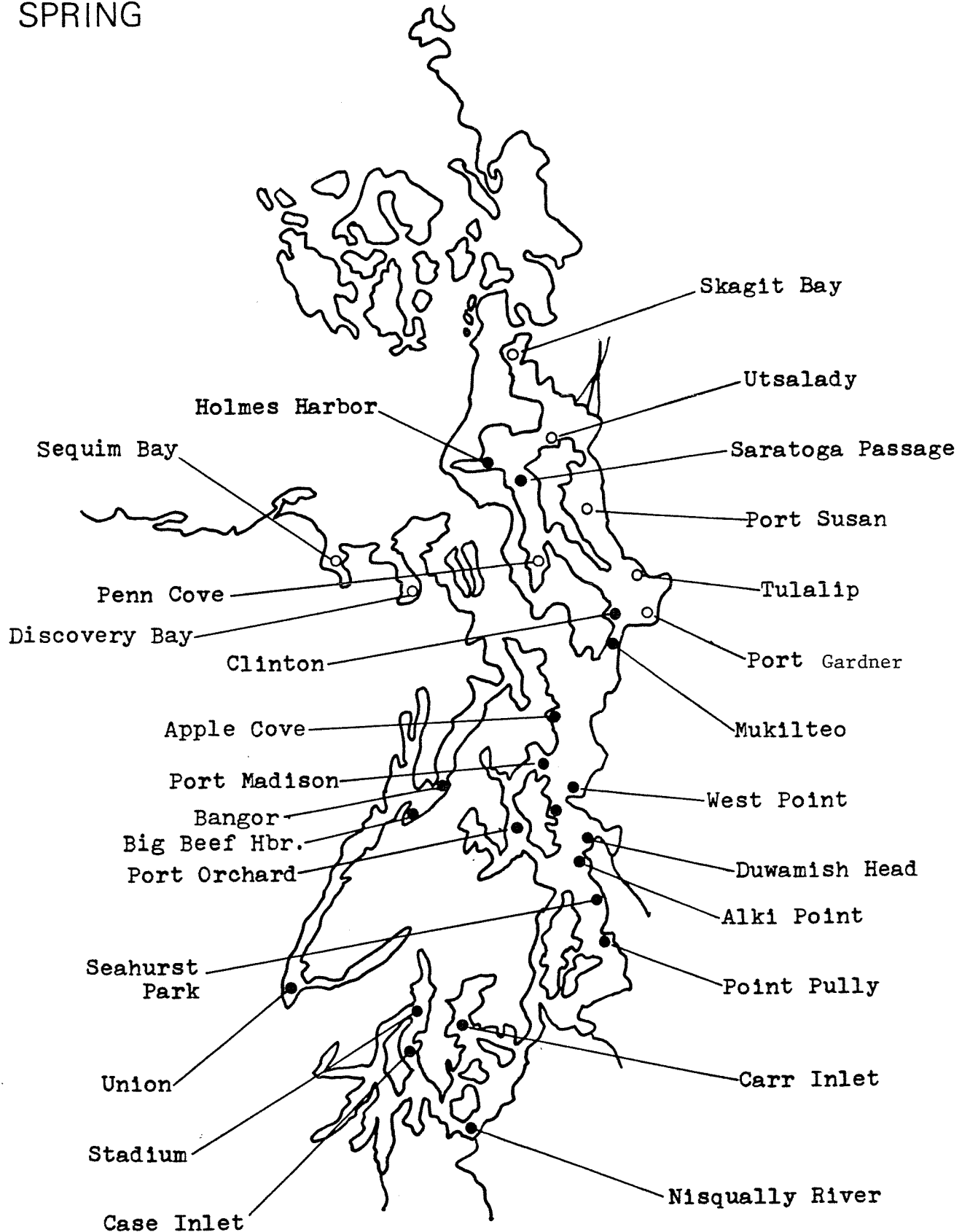


Fig.15. Geographical distribution of species group XII (rock sole, English sole, roughback sculpin, speckled sanddab and C-0 sole) in Puget Sound during the spring.

SPRING

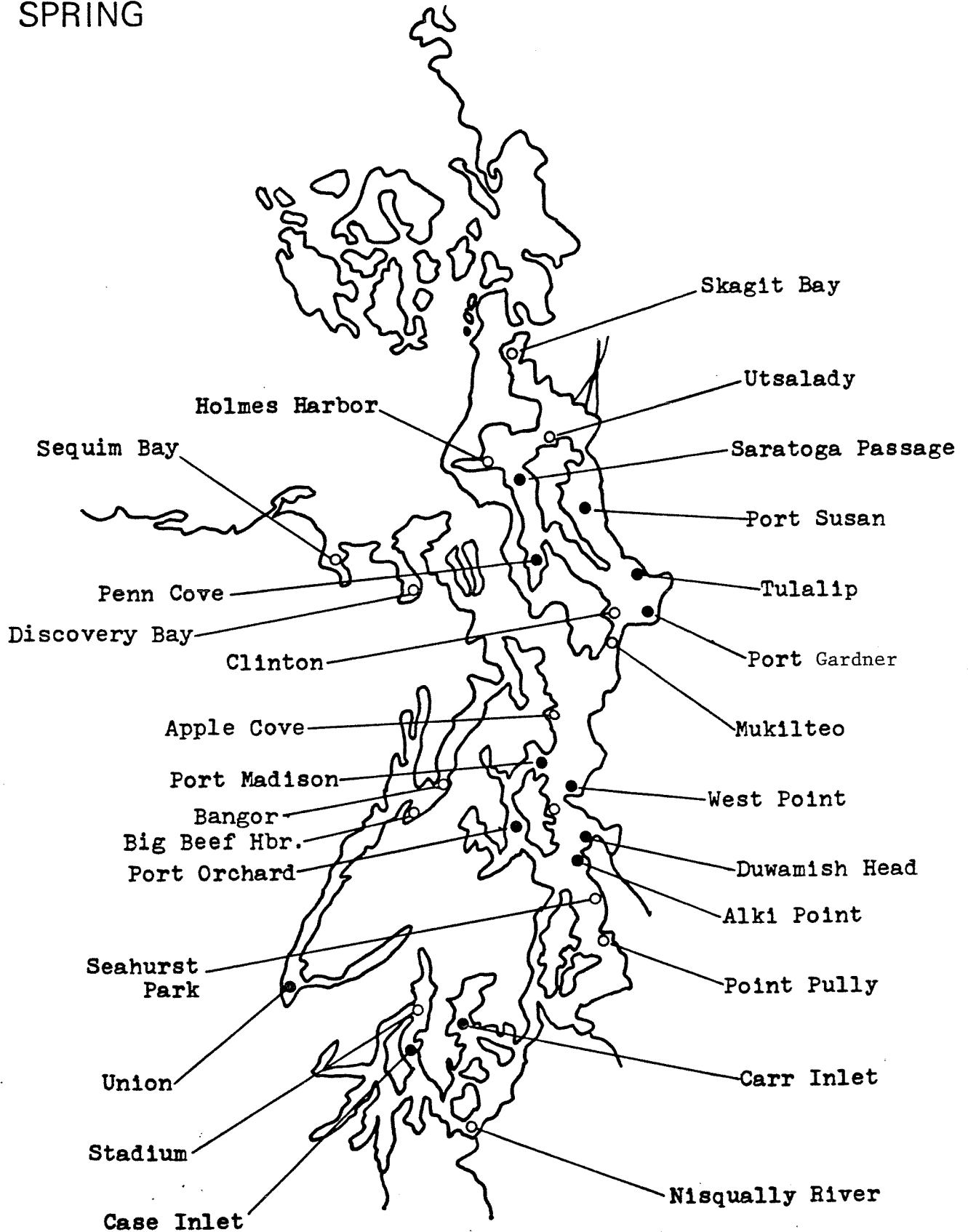


Fig. 16. Geographical distribution of species group XV (blackbelly eelpout, slender sole, midshipman, and slim sculpin) in Puget Sound during the spring.

SPRING

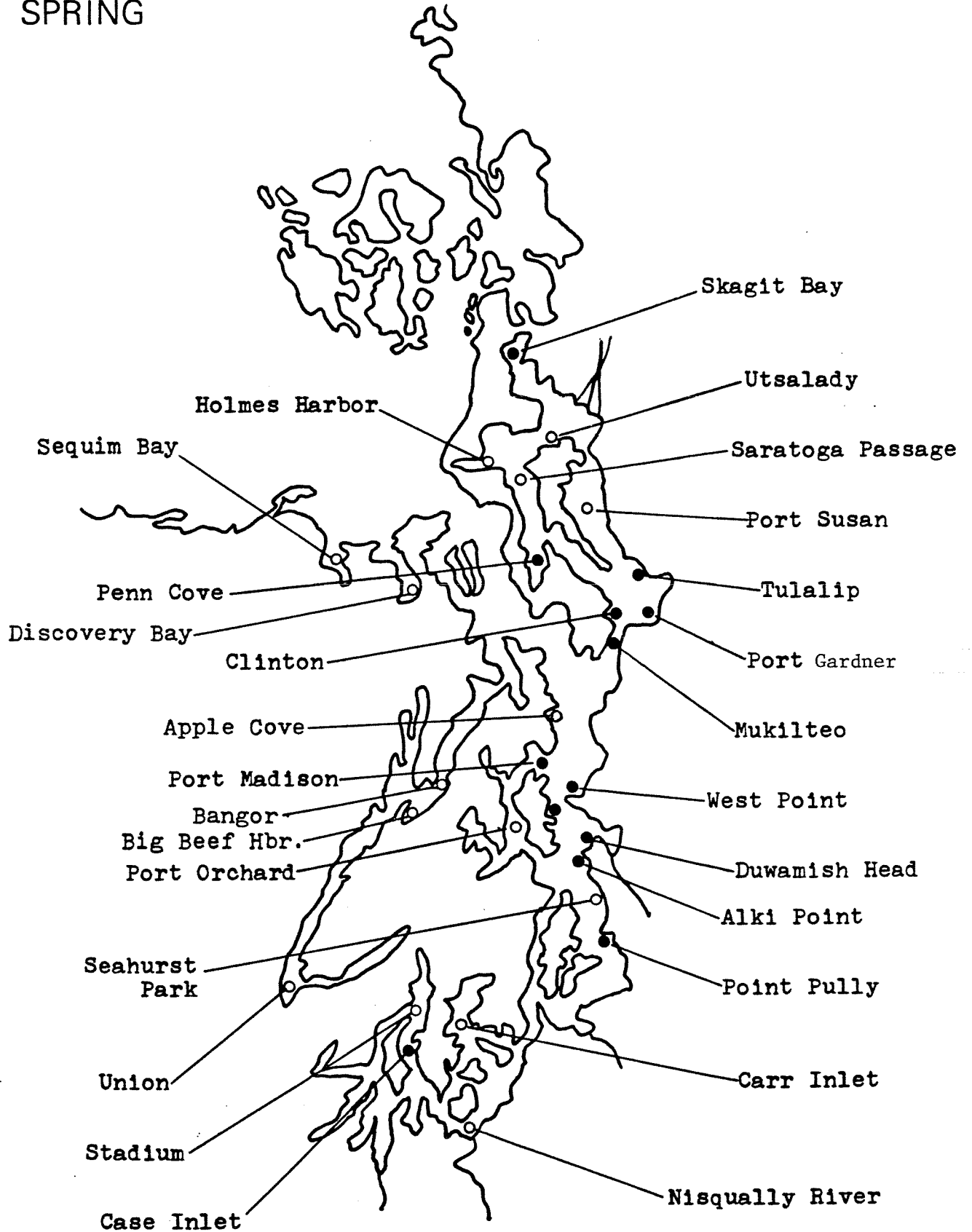


Fig. 17. Geographical distribution of species group XVI (ratfish, rex sole and Dover sole) in Puget Sound during the spring.

Several other species groups only occurred in restricted geographical areas or within restricted depth ranges. The most important of these were groups III, X, XI, and XIV. The first three groups were found primarily in the WB or in both WB and NPS at shallow-to-intermediate depths (Figs. 18, 19, 20). In contrast, group XIV occurred only at intermediate depths (40-50 m) in SPS (Fig. 21).

Summer

Classification of Summer Collections. The relationship between 143 site-summarized collections obtained in summer is presented in Fig. 22. These summer collections clustered into four (A-D) primary groups, and each of these in turn could be further divided into several subgroups. Each major grouping consisted primarily of collections taken from relatively narrow depth intervals. For example, group A was composed predominantly of deep (70-120+ m) water collections, while group B and groups C and D consisted of intermediate (30-80 m) and shallow (5-30 m) water collections, respectively.

Within each primary group, individual subgroups generally were composed of collections from different geographic areas. In shallow water subgroups, collections from WB either clustered separately or with collections from SPS. Collections from CPS, however, grouped with collections from SPS. Similarly, the intermediate depth subgroups consisted either of WB, WB-CPS or SPS collections in most instances. Deep water collections, in contrast, exhibited less segregation by geographic area.

Species Group Composition & Distribution. Based on otter trawl collections taken from throughout Puget Sound, a total of eighteen (I-XVII) distinct species groups were identified during the summer (Table 17). These 18 species groups consisted of from 2-5 species and occurred at 1-21 different sites (Table 18) in Puget Sound.

SPRING

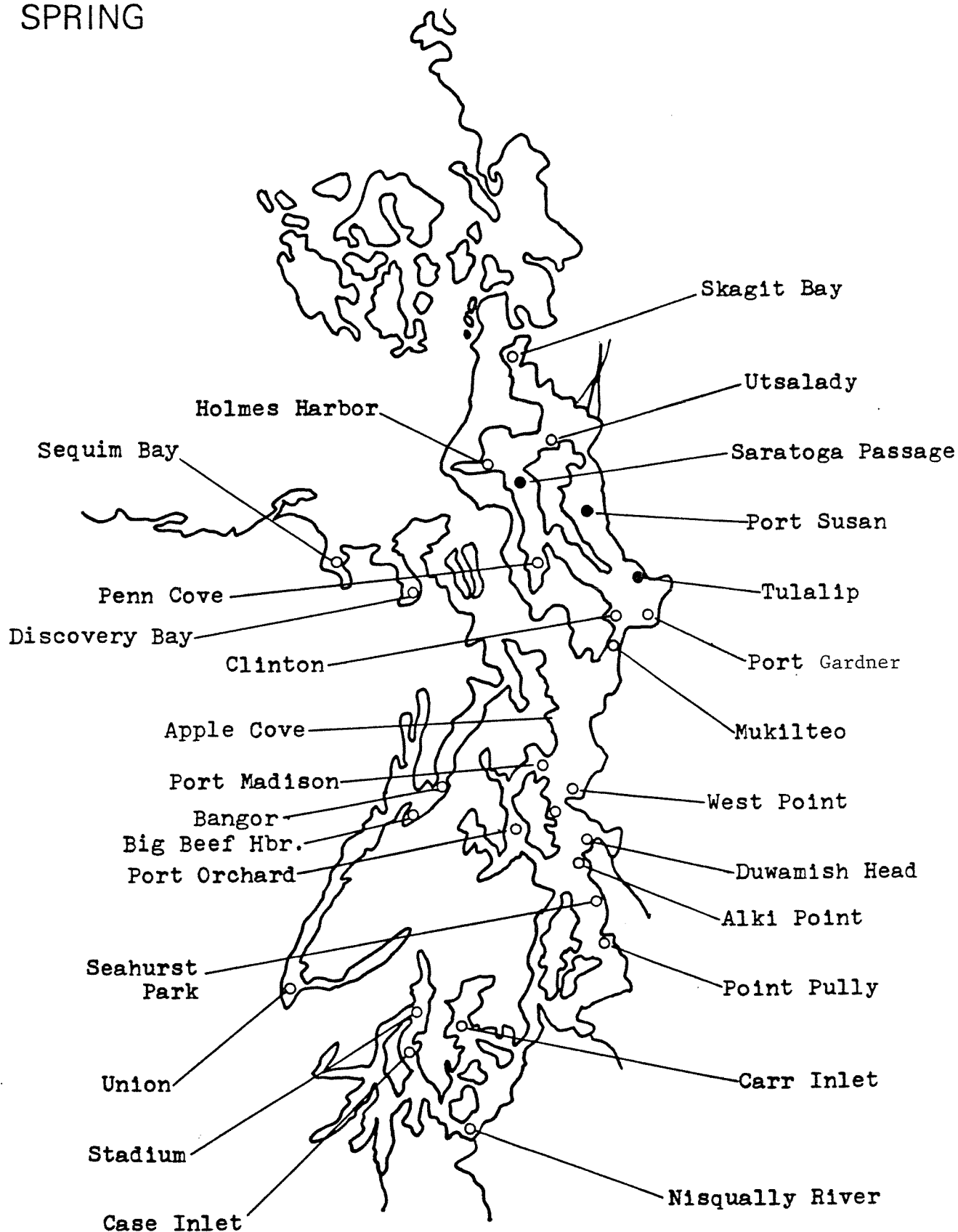


Fig.18. Geographical distribution of species group III (spinyhead sculpin, whitebarred prickleback and bluebarred prickleback) in Puget Sound during the spring.

SPRING

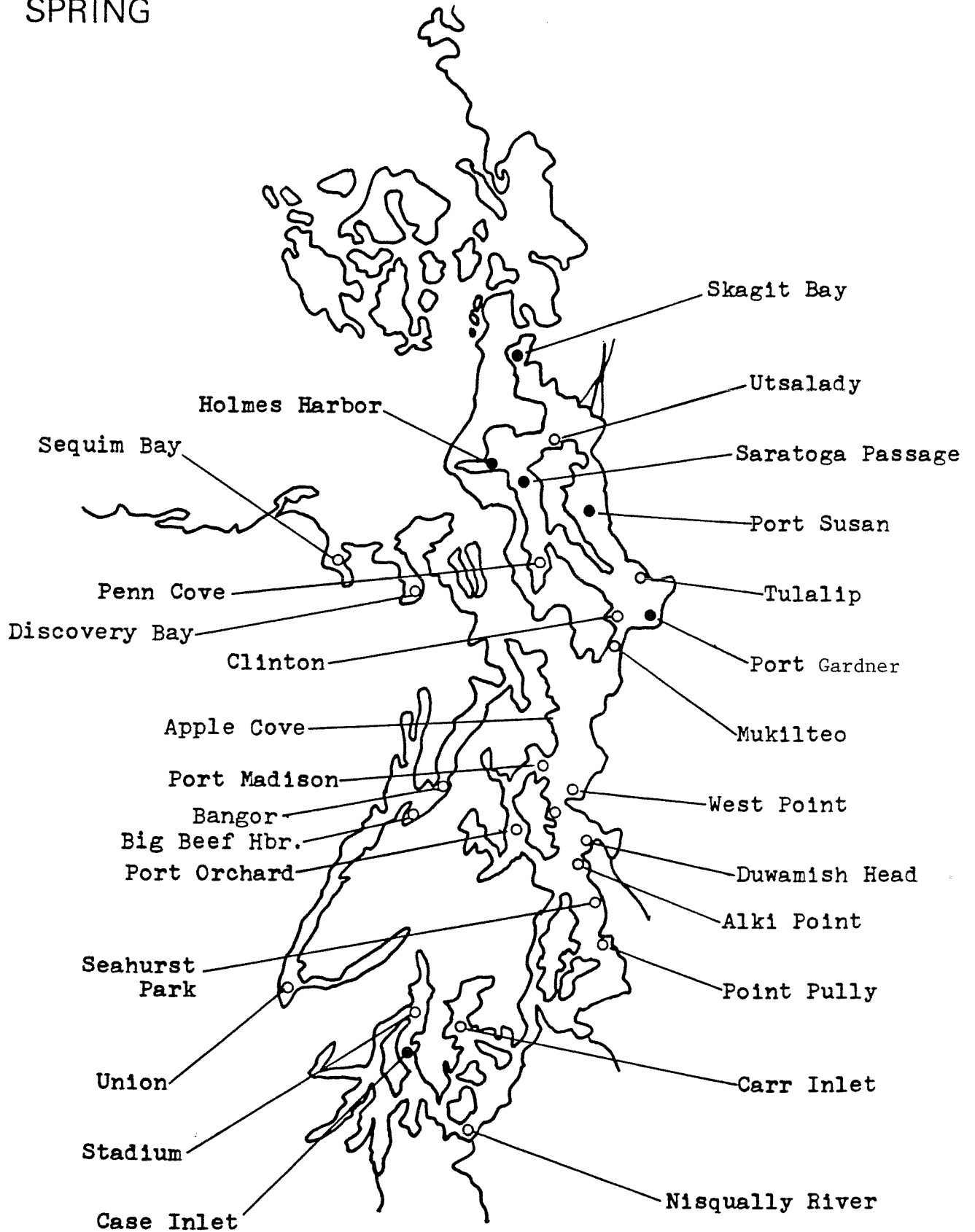


Fig.19. Geographical distribution of species group X (snake prickle-back, sand sole, butter sole, starry flounder and stag-horn sculpin) during the spring in Puget Sound.

SPRING

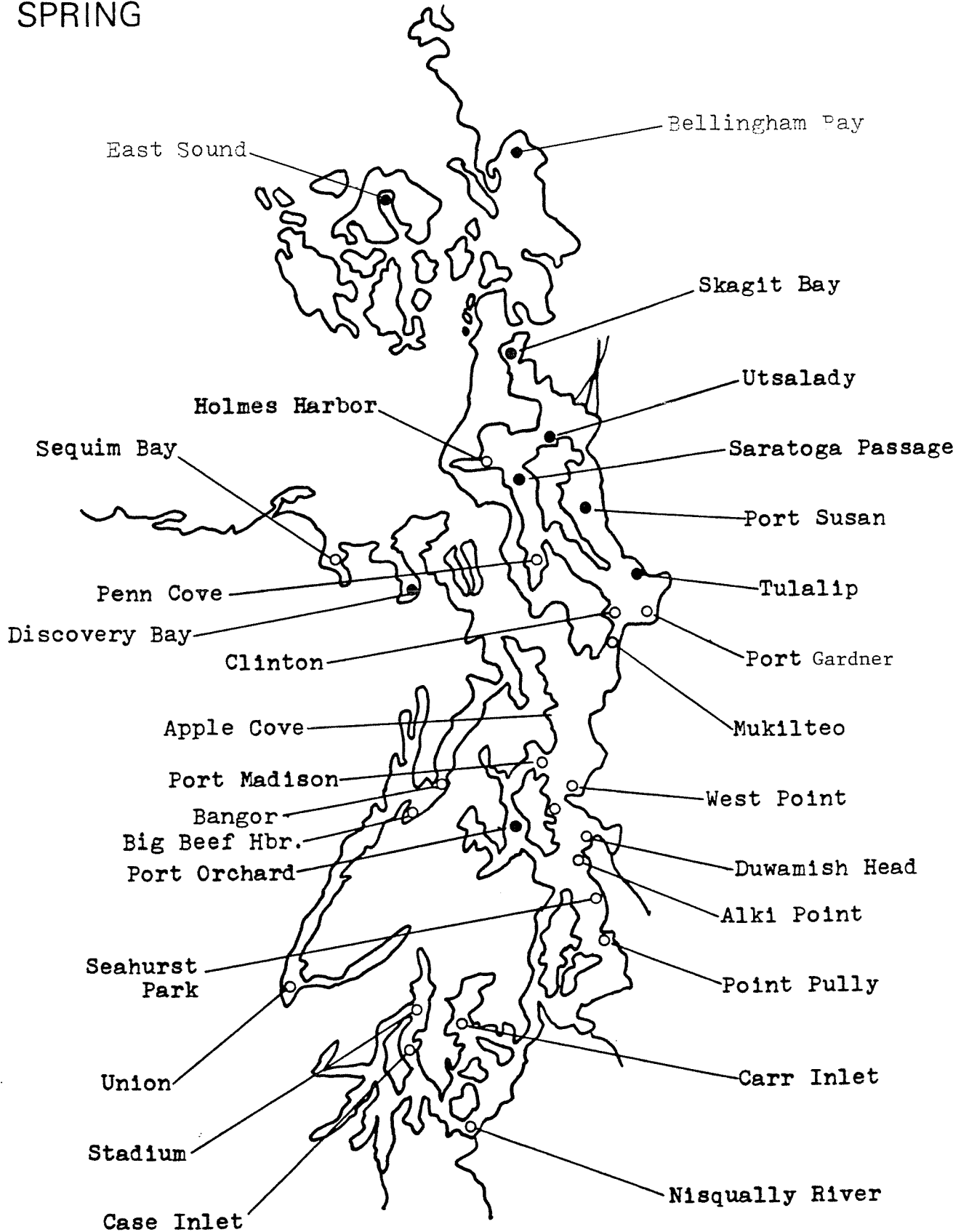


Fig. 20. Geographical distribution of species group XI (flathead sole and longfin smelt) in Puget Sound during the spring.

SPRING

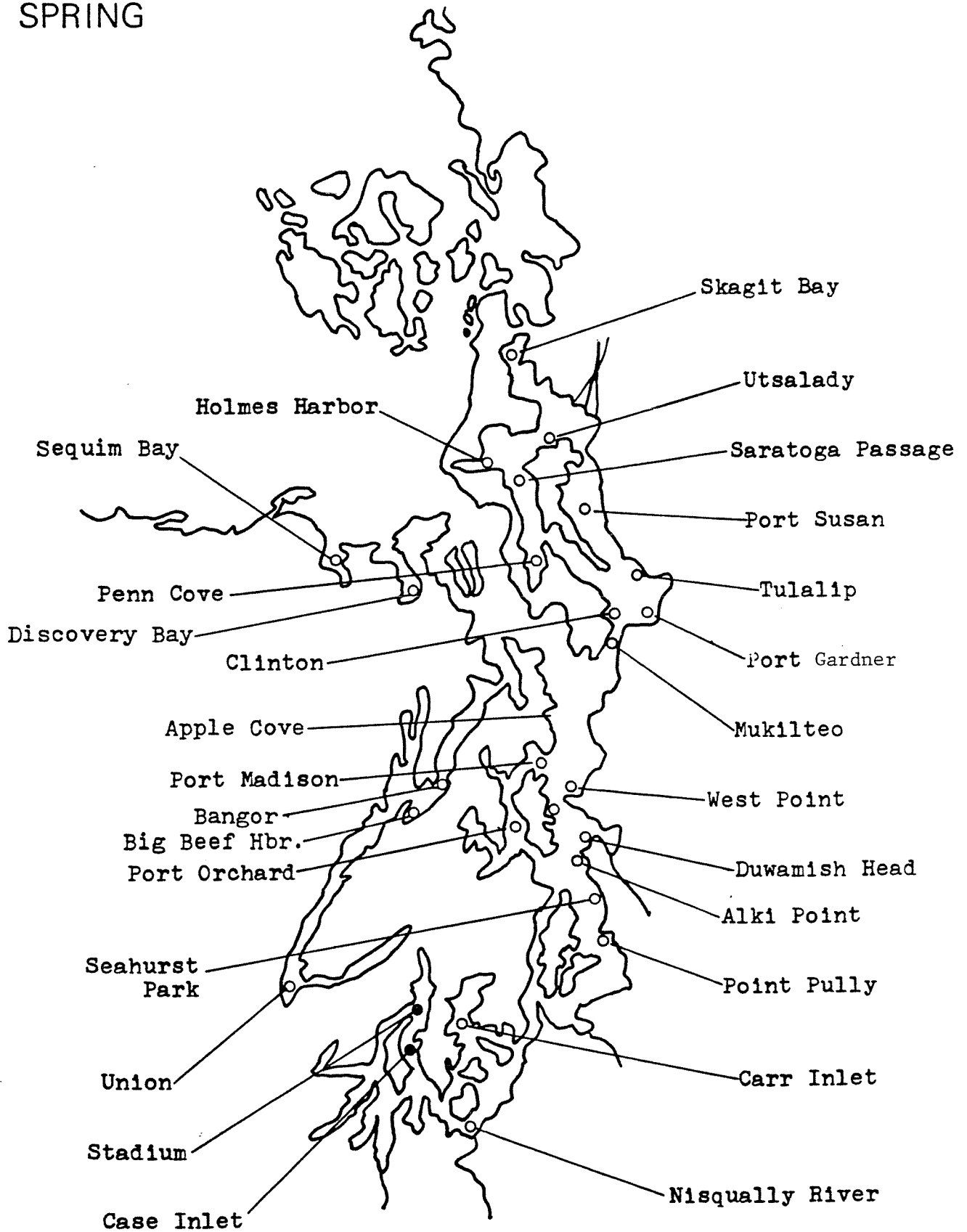


Fig.21. Geographical distribution of species group XIV(longspine combfish, sturgeon poacher, sailfin sculpin and bay goby) in Puget Sound during the spring.

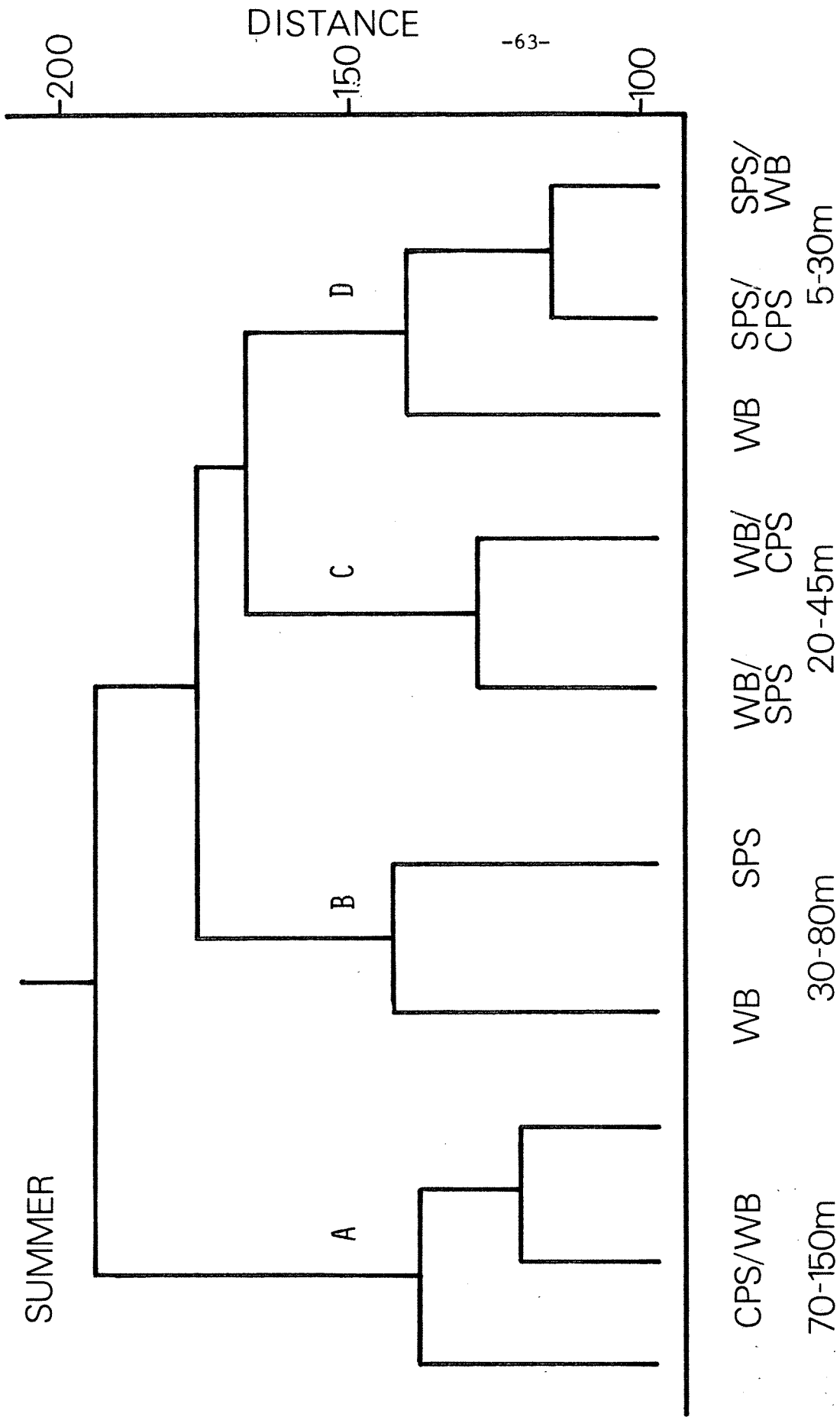


Fig. 22. Classification of summer otter trawl collections from Puget Sound.

Table 17. Composition of demersal fish groups during the summer.

Species group	No. of site occurrences	Member species
I	2	northern sculpin, spotfin sculpin, redstripe rockfish
II	1	crescent gunnel, bay pipefish, saddleback gunnel, threespine stickleback
III	2	striped perch, pile perch, tubesnout, padded sculpin, buffalo sculpin
IV	1	penpoint gunnel, silverspotted sculpin, red Irish lord
V	3	spinyhead sculpin, bluebarred prickleback, whitebarred prickleback
VI	12	blackbelly eelpout, slender sole, blacklip poacher, slim sculpin
VII	1	blackfin sculpin, showy snailfish
VIII(a)	10	ratfish, Dover sole, rex sole
VIII(b)	5	quillback rockfish, Pacific sanddab
IX	2	tadpole sculpin, pallid eelpout, blackfin poacher
X	1	big skate, Pacific herring, surf smelt, shortfin eelpout, black eelpout
XI	1	copper rockfish, Pacific cod, flathead sole, sablefish
XII	6	dogfish, walleye pollock, Pacific hake
XIII	21	rock sole, English sole, speckled sanddab
XIV	8	roughback sculpin, sturgeon poacher, midshipman, brown rockfish

Table 17, cont'd

Species group	No. of site occurrences	Member species
XV(a)	6	northern ronquil, pygmy poacher
XV(b)	3	spearnose poacher, longspine combfish
XVI	5	tomcod, shiner perch, bay goby, sailfin sculpin
XVII	8	snake prickleback, staghorn sculpin, sand sole
XVIII	3	butter sole, starry flounder, longfin smelt

Three groups including XIII, VIII (a), and VI were especially widespread (Table 18) and frequently occurring. Group XIII, which consisted of the rock sole, English sole and speckled sanddab occurred at 21 of the summer sampling sites (Fig. 23) at depths of 5-40 m. These 21 sites included all locations sampled in CPS and SPS, and most from WB. Species group VI (black belly eelpout, slender sole, blacktip poacher and slim sculpin) occurred in all major geographical areas, including Hood Canal (Fig. 24), but was typically confined to an intermediate depth zone (30-60 m). In deeper water (60-120 m) species group VIIIa (ratfish, Dover sole, rex sole) occurred throughout all major areas of Puget Sound (Fig. 25); however, it tended to be more dominant in the CPS basin.

Three additional species groups (XVII, XII and V) from the summer analysis occurred primarily in the WB region; generally in the shallow intermediate (5-70 m) depth range. Group XVII, consisting of the snake pricklyback, staghorn sculpin and sand sole, occurred predominantly in WB, but also occurred in HC, SPS (Case Inlet), and CPS (Duwamish Head) (Fig. 26). Typically, this group was found at depths less than 40 m. Species group XII (dogfish, hake and walleye pollack) consisted of semipelagic species that were taken together almost exclusively in WB over a wide range of depths (20-120 m). Species group V, comprised of the spinyhead sculpin, whitebarred pricklyback and bluebarred pricklyback, was found only in WB as well, and generally was found at depths of 30-60 m (Fig. 27).

Another common distributional pattern was for species groups to be restricted to sites in CPS and SPS. Two examples of this pattern were species groups XVI and XIV (Table 16). With the exception of the Case Inlet site, both species groups tended to be primarily found at shallow water depths (5-30 m) at most sites in both CPS and SPS (Figs. 28, 29).

SUMMER

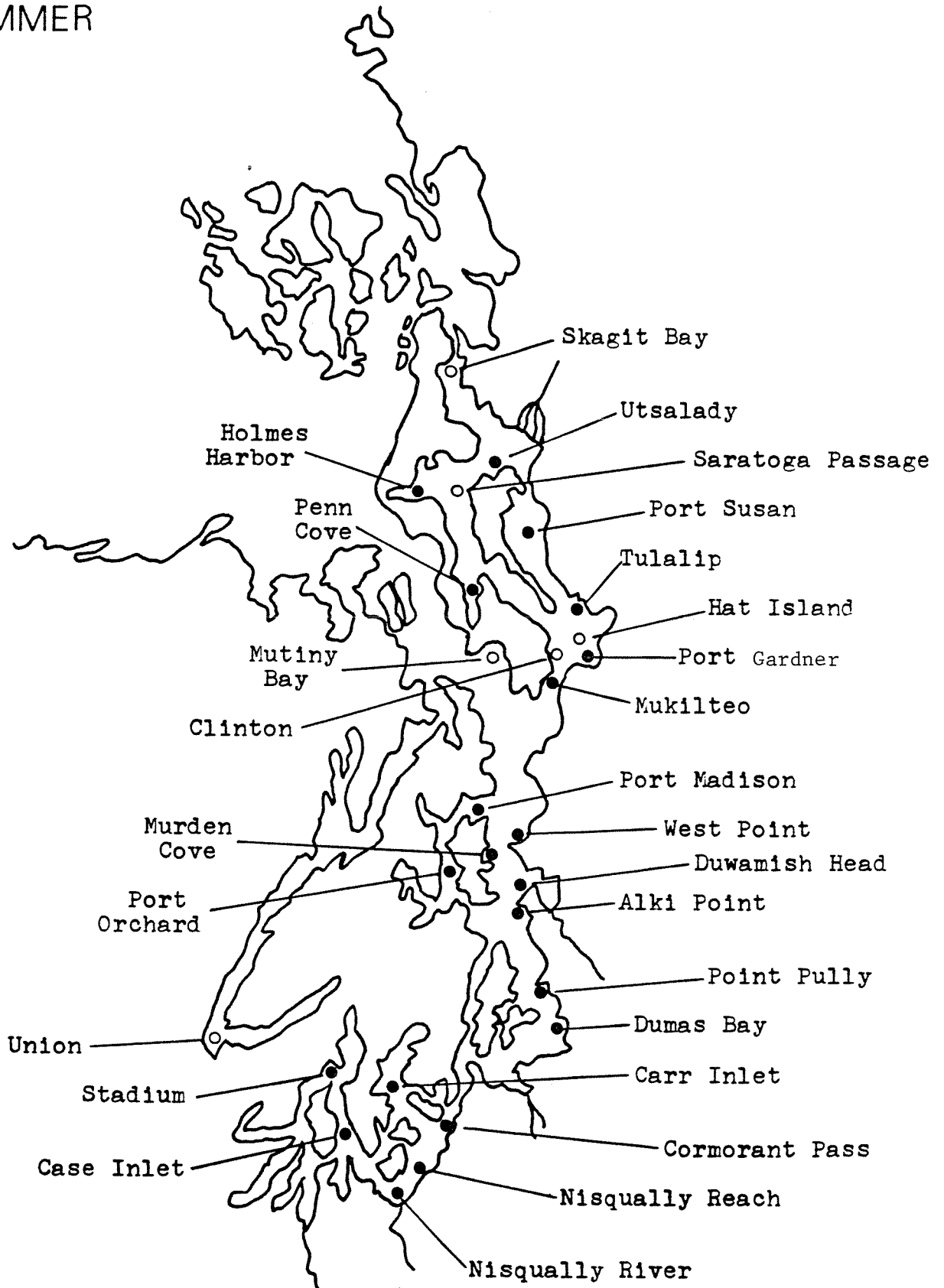


Fig. 23. Geographical distribution of species group XIII (rock sole, English sole and speckled sanddab) in Puget Sound during the summer.

SUMMER

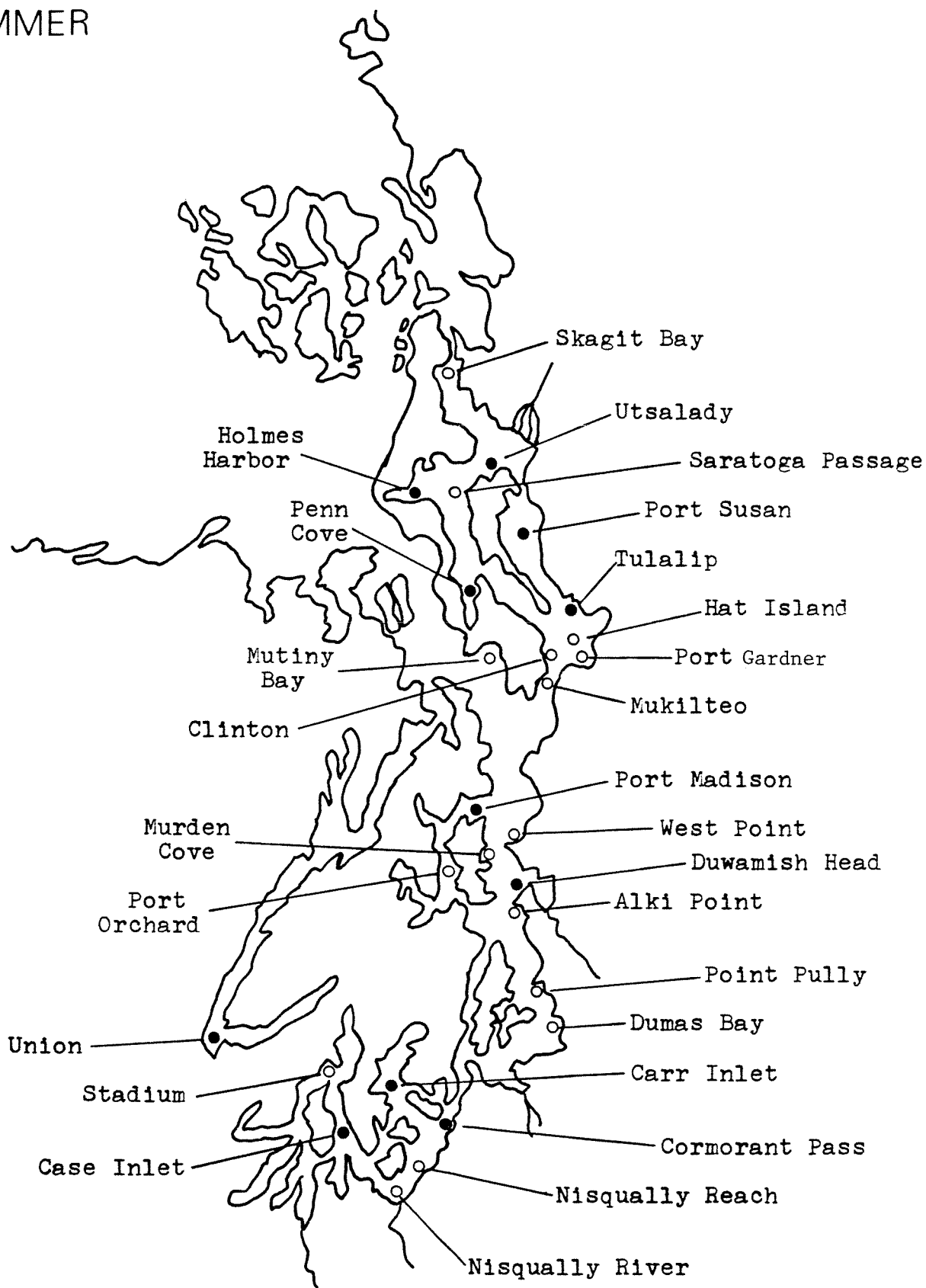


Fig.24. Geographical distribution of species group VI (Blackbelly eelpout, slender sole, blacktip poacher and slim poacher) in Puget Sound during the summer.

SUMMER

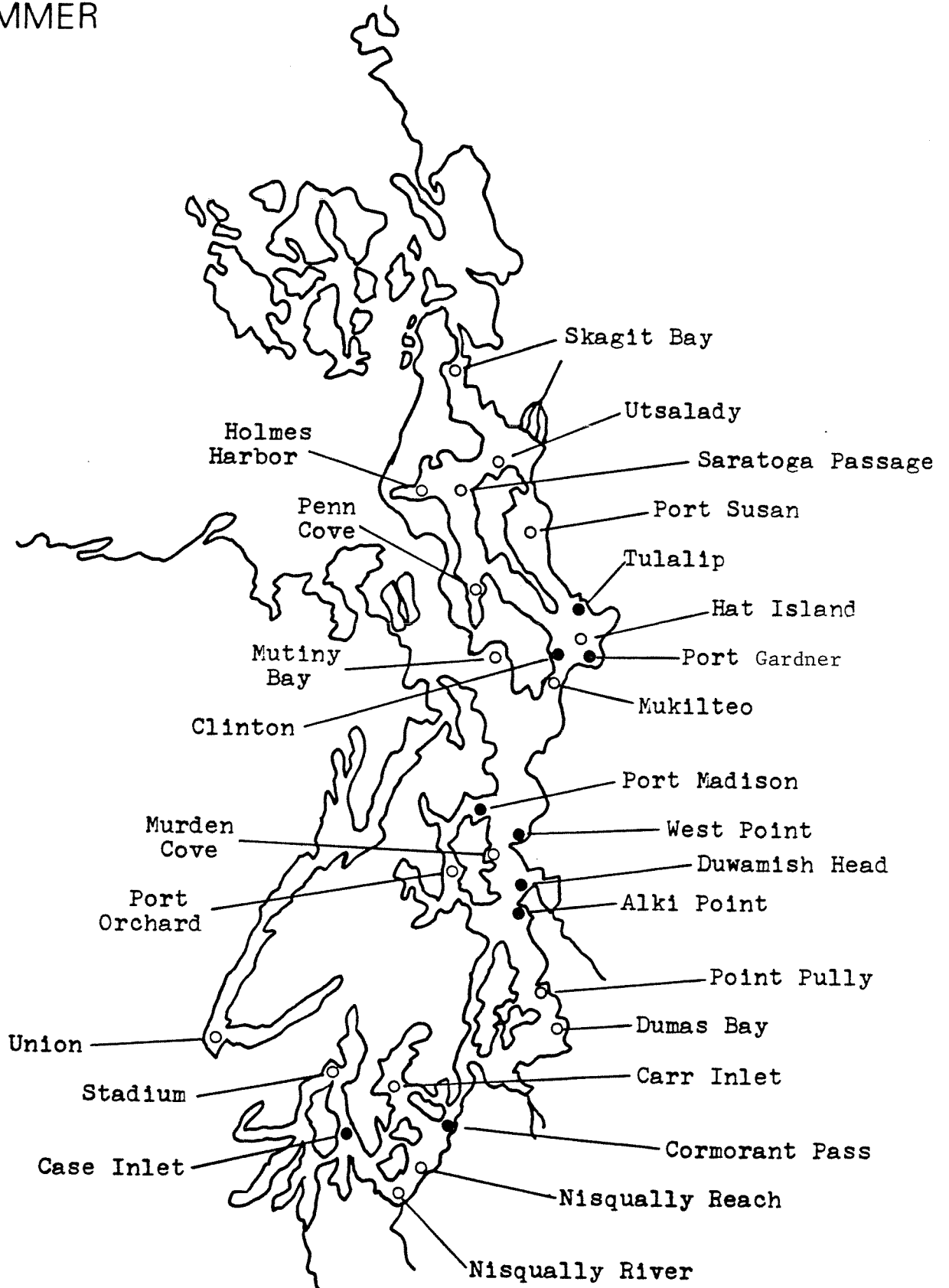


Fig. 25. Geographical distribution of species group VIIIa (ratfish, Dover sole and rex sole) in Puget Sound during the summer.

SUMMER

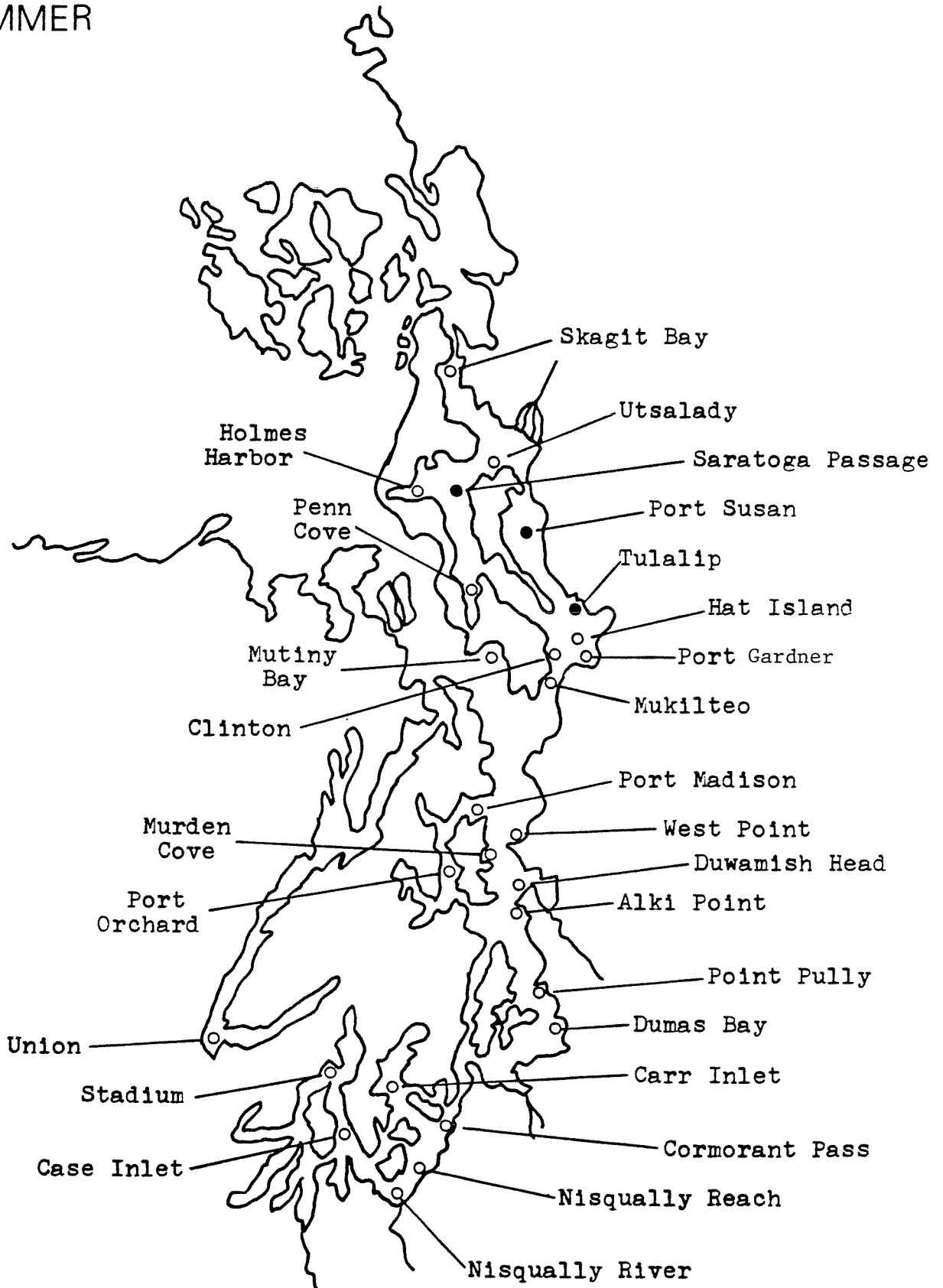


Fig. 27. Geographical distribution of species group V (spinyhead sculpin, bluebarred prickleback and whitebarred prickleback) in Puget Sound during the summer.

SUMMER

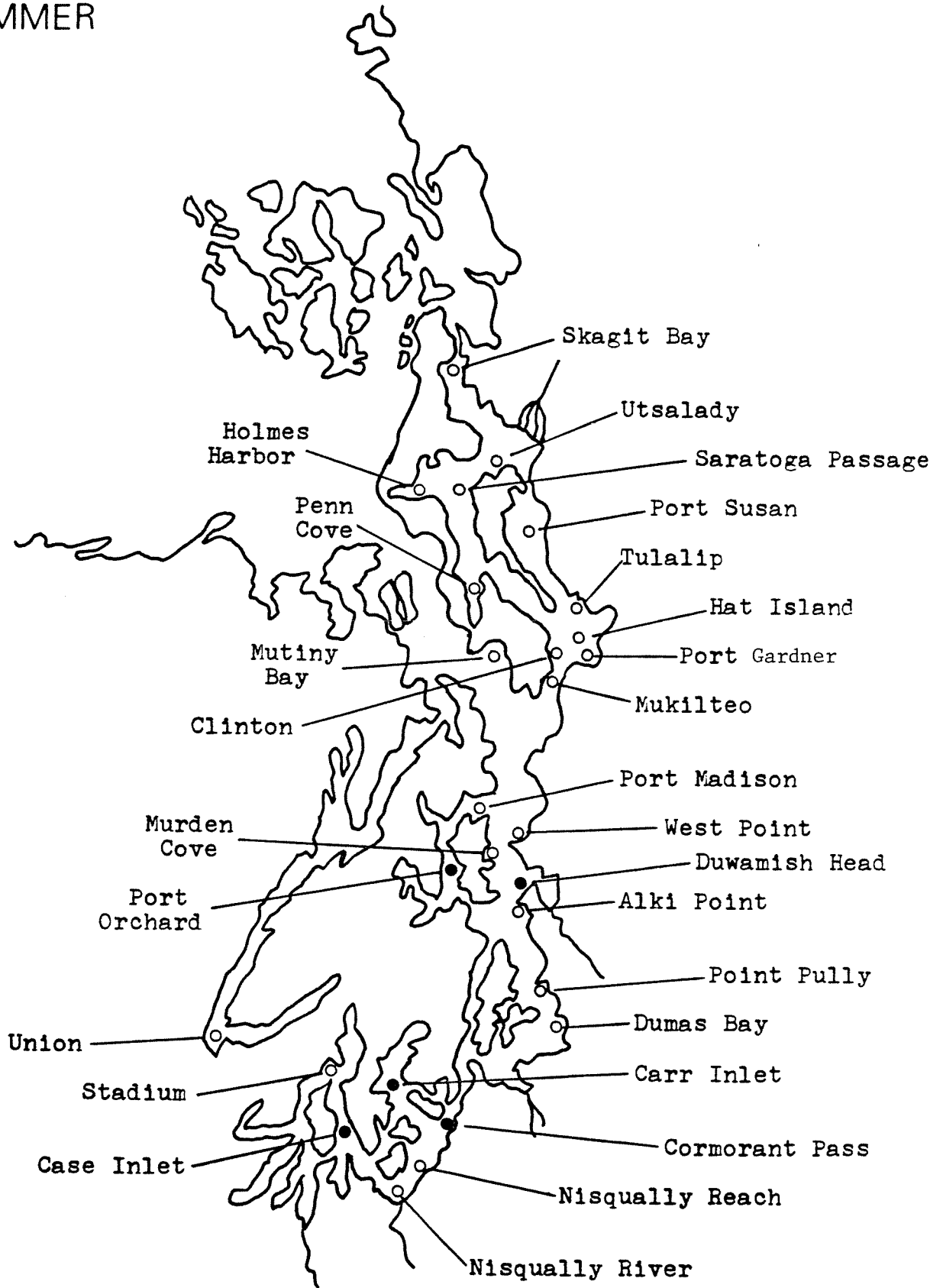


Fig. 28. Geographical distribution of species group XVI (sailfin sculpin, bay goby, tomcod and shiner perch) in Puget Sound during the summer.

SUMMER

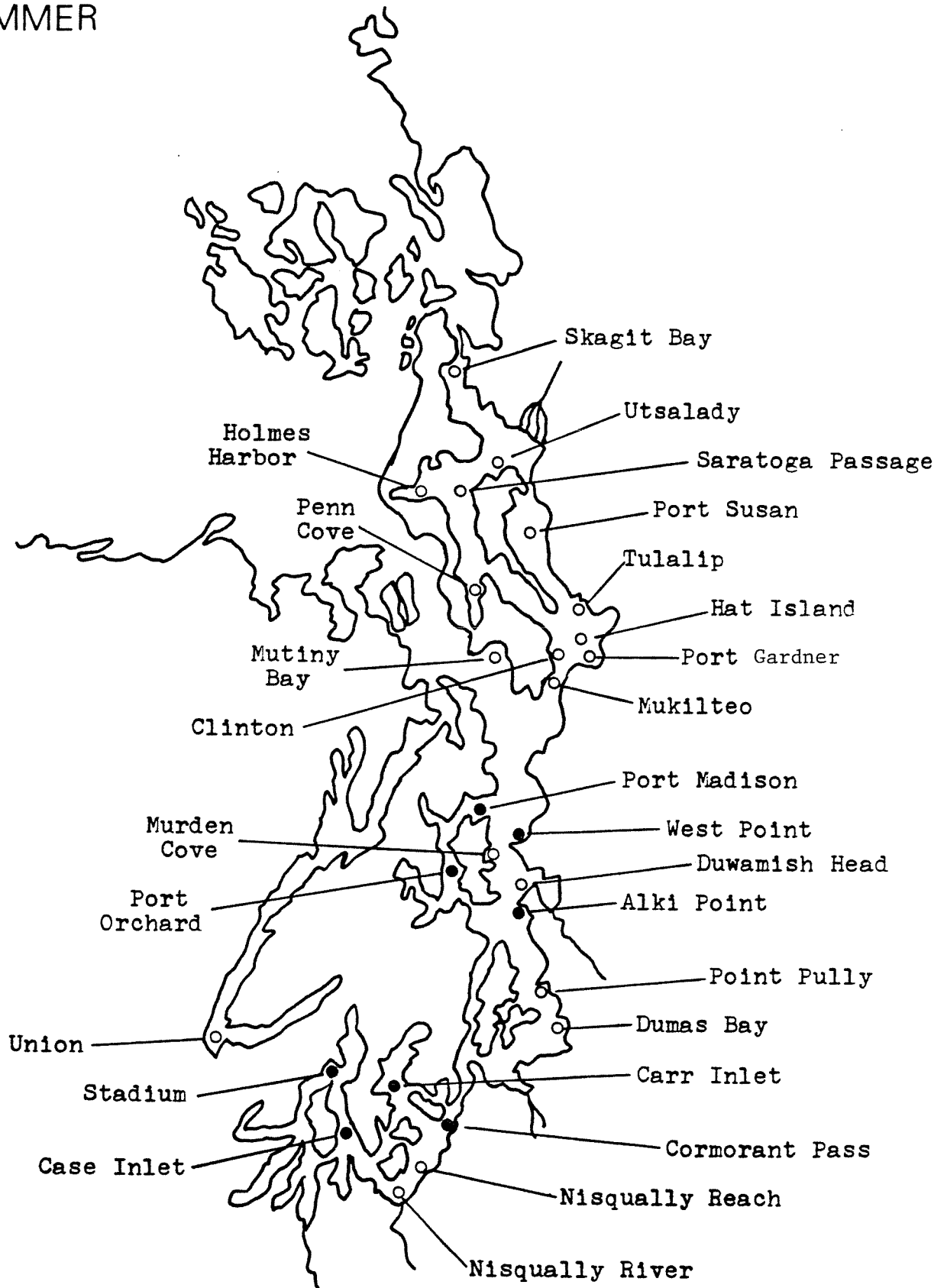


Fig.29. Geographical distribution of species group XIV (roughback sculpin, sturgeon poacher, midshipman and brown rockfish) in Puget Sound during the summer.

Fall

Classification of Fall Collections. As in each previous seasonal analysis, the 129 site-summarized fall collections (Table 6) clustered primarily on the basis of depth and secondarily on the basis of geographic area (Fig. 30). Site groups A and B corresponded to collections taken at deepwater (70-150 m) and intermediate-depth (40-90 m) stations. Within group A, WB collections grouped either with CPS collections or separately. In group B (intermediate-depth collections), there were two major subgroups, one consisting primarily of SPS collections and the other of WB collections. Groups D-E, in general, consisted of collections from shallow-water stations (less than 45 m). Generally, SPS and CPS collections clustered together, whereas WB collections clustered separately or with NPS collections.

Composition and Distribution of Species Groups. A total of 17 (I-XVII) different species groups was identified on the basis of the available fall otter trawl collections (Table 19). All frequently occurring species groups were widespread in the areas sampled (e.g., WB, NPS, CPS, SPS); however, most of the less frequently occurring groups were restricted in geographic distribution (Table 20). In general, all species groups were restricted to specific depth zones, usually < 30-40 m, 30-70 m, and > 70 m.

The most frequently occurring and widespread species groups were X, IX, and VIII. Group VIII, consisting of three species, roughback sculpin, speckled sanddab, and rock sole, occurred at 15 sites in all geographic areas (Fig. 31). In WB, this group was restricted to depths of 5-10 m; however, in other areas the group occurred as deep as 60 m. Group X was composed of three species which primarily occupy the water column rather than the

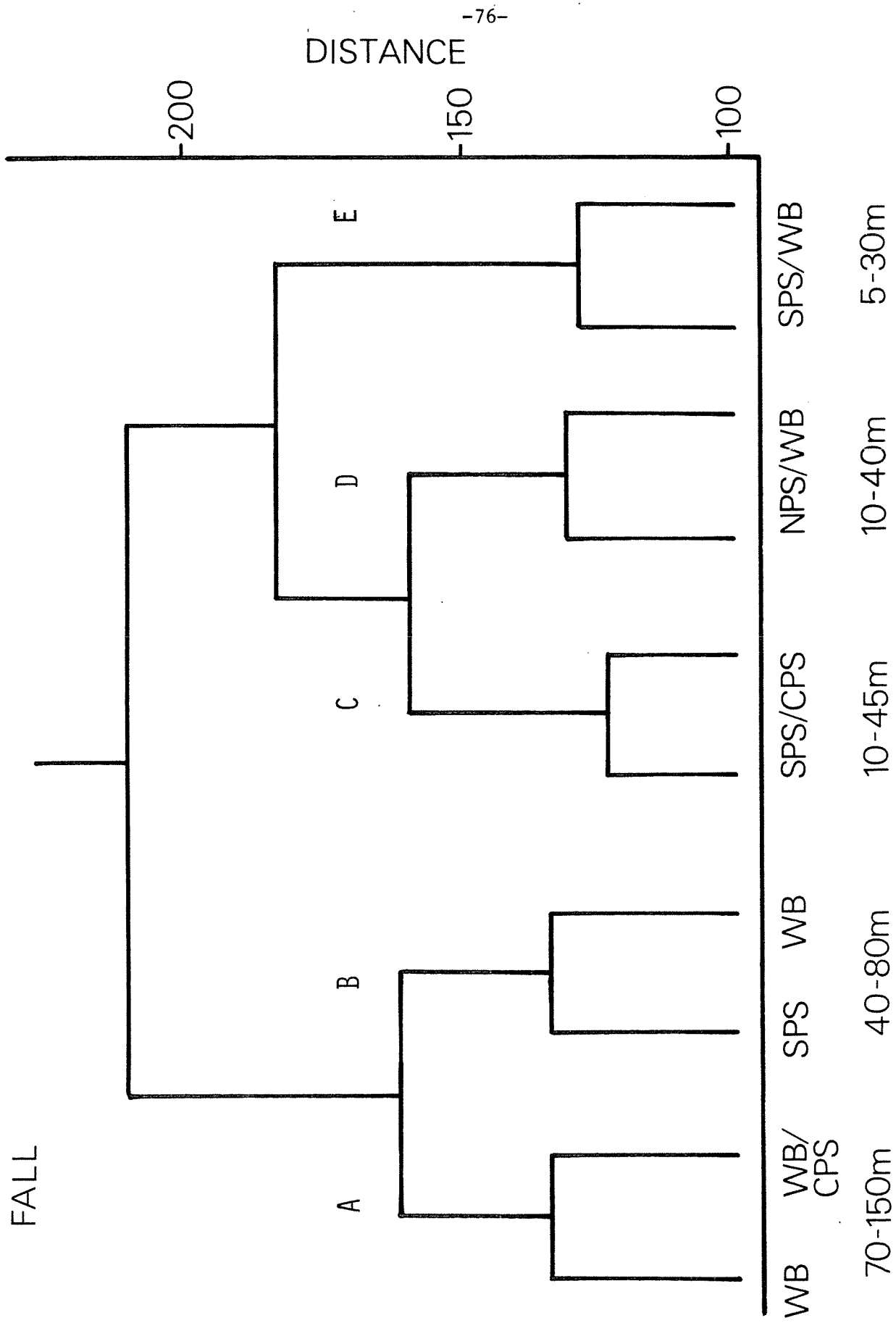


Fig. 30. Classification of fall otter trawl collections in Puget Sound.

Table 19. Composition of demersal fish species groups found during fall.

Species group	No. of site occurrences	Member species
I	2	Pacific herring, longfin smelt, shortfin eelpout
II	3	snake prickleback, flathead sole, bay goby
III	1	big skate, surf smelt, Pacific cod
IV	1	threespine stickleback, penpoint gunnel, bay pipefish, striped perch, padded sculpin
V	2	sturgeon poacher, sailfin sculpin, longspine combfish
VI	6	starry flounder, butter sole
VII	1	great sculpin, tubesnout, whitespotted greenling
VIII	15	roughback sculpin, speckled sanddab, rock sole
IX	19	staghorn sculpin, English sole, sand sole
X	11	tomcod, shiner perch, pile perch
XI	2	redstripe rockfish, sharpchin rockfish, northern sculpin, bluespotted poacher
XII(a)	3	northern ronquil, spearnose poacher, spotfin sculpin, Pacific sanddab
XII(b)	7	slim sculpin, pygmy poacher
XIII	7	slender sole, midshipman, blackbelly eelpout, blacktip poacher
XIV	2	spinyhead sculpin, whitebarred prickleback, bluebarred prickleback
XV	2	pallid eelpout, black eelpout, blackfin poacher

Table 19, cont'd

Species group	No. of site occurrences	Member species
XVI	6	rex sole, Dover sole, quillback rockfish
XVII	8	ratfish, dogfish, walleye pollock

Fall

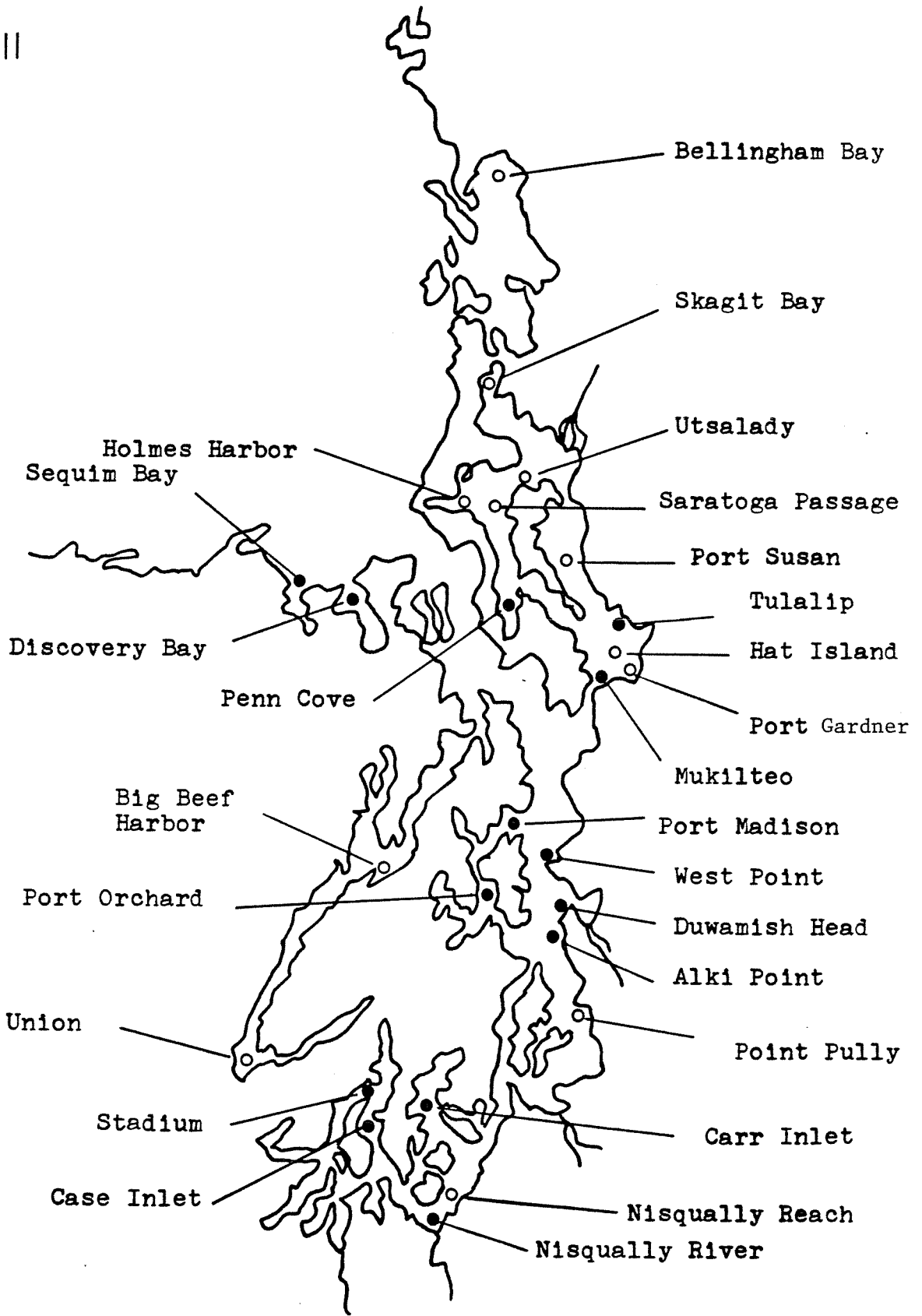


Fig. 31. Geographical distribution of species group VIII (rough-back sculpin, speckled sanddab and rock sole) in Puget Sound during the fall.

benthic habitat (tomcod, shiner perch, and pile perch). Although this group occurred through much of Puget Sound, it tended to occur more consistently in CPS & SPS (Fig. 32). Group X generally was found at depths of 5-40, but unlike other species groups, ranged as deep as 80 m in SPS. The most common species group (IX), consisted of English sole, staghorn sculpin and sand sole (Table 19). This group occurred throughout Puget Sound at shallow and intermediate depths (Fig. 33). Group IX generally occurred at depths of 5-40 m in WB, HC, NPS, SPS and CPS, but also occurred in deeper water (40-60 m) in WB and SPS.

Several species groups, including XV, IV, XIV and XVII occurred primarily or entirely in Whidbey Basin (Table 20). At intermediate depths (40-60 m), group XIV (spinyhead sculpin, whitebarred prickleback, blue-barred prickleback) was a dominant species group near Tulalip and Port Susan. In deeper water (80-120 m), group XV (pallid eelpout, black eelpout and blackfin poacher) occurred only in the vicinity of Port Gardner and Tulalip.

Species group XIII (blackbelly eelpout, blacktip poacher, midshipman and slender sole) occurred throughout Puget Sound (Fig. 34) at depths of 20-80 m, but was most prominent in WB and SPS. The only species group restricted to SPS was group V, which consisted of the sailfin sculpin, longspine combfish and sturgeon poacher (Fig. 35).

Fall

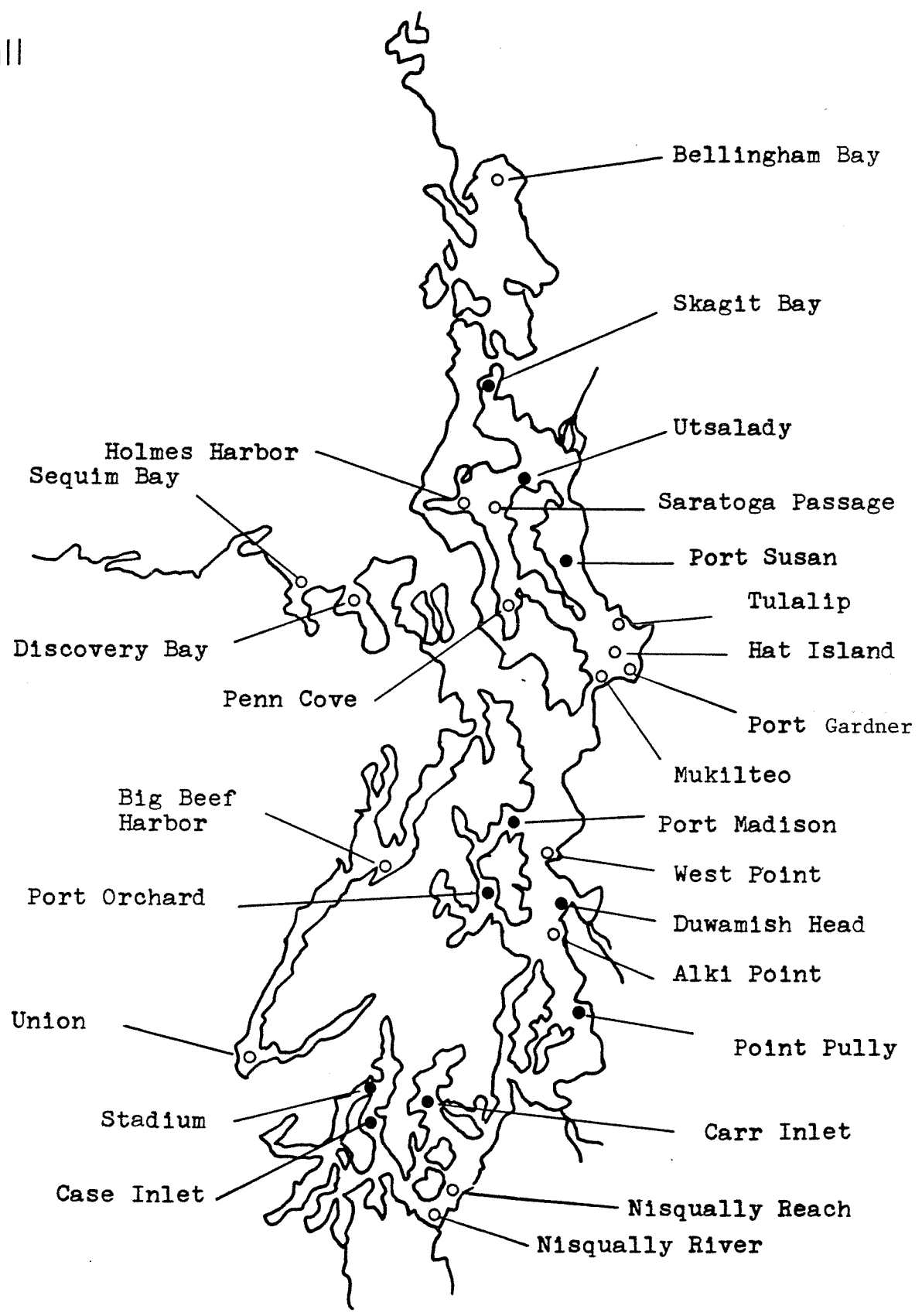


Fig. 32. Geographical distribution of species group X (tomcod, shiner perch and pile perch) in Puget Sound during the fall.

Fall

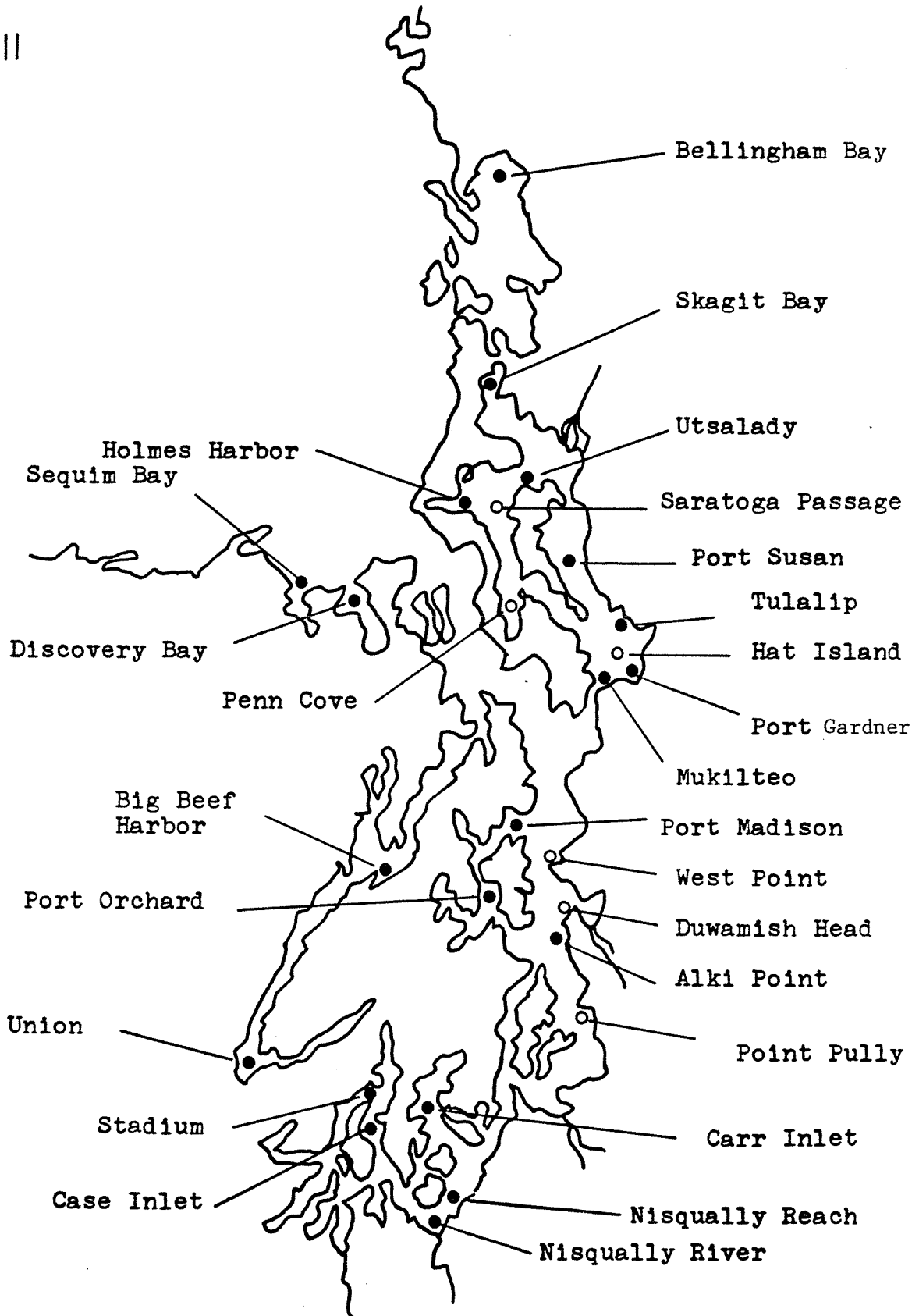


Fig. 33. Geographical distribution of species group IX (staghorn sculpin, English sole and sand sole) in Puget Sound during the fall.

Fall

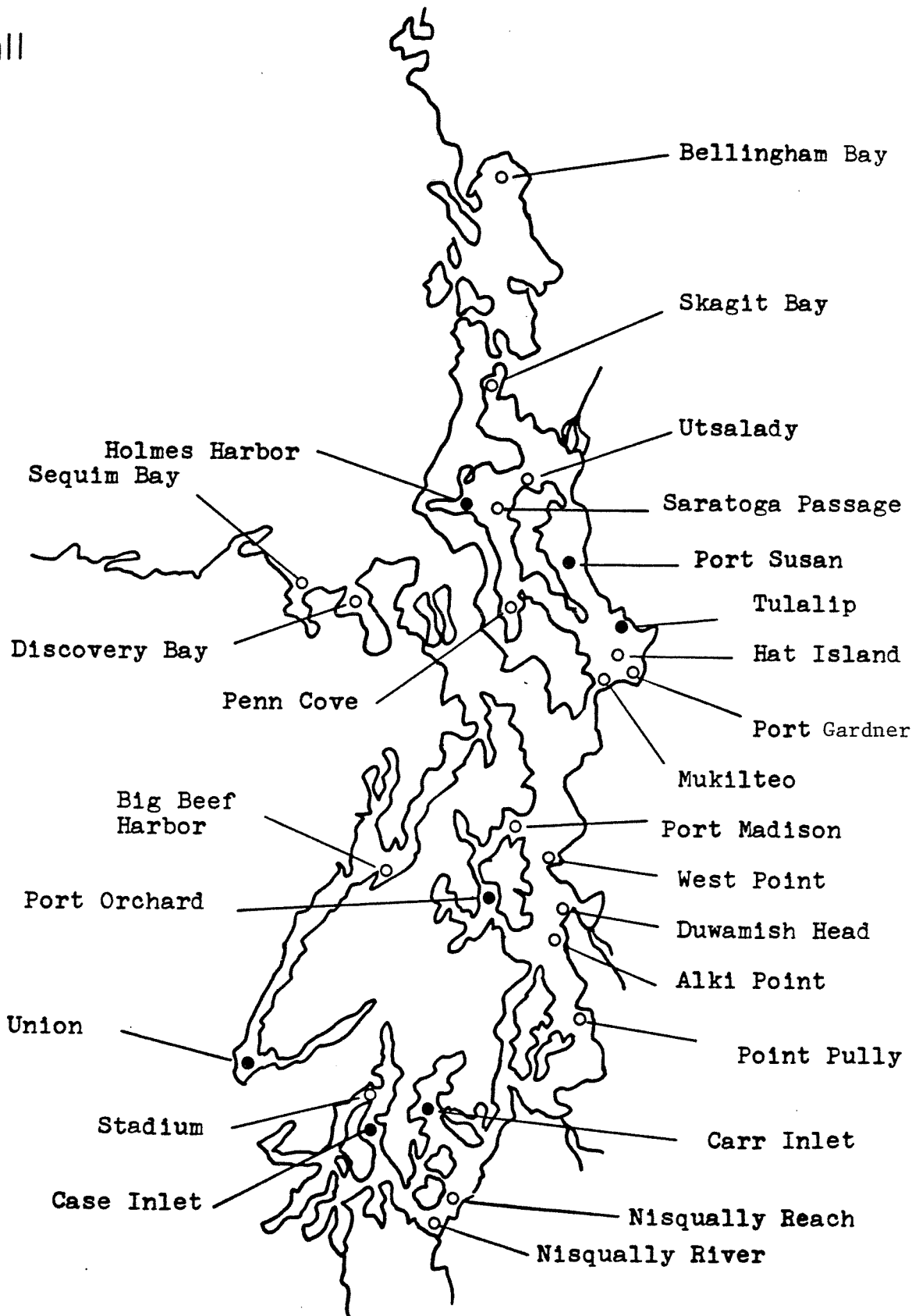


Fig. 34. Geographical distribution of species group XIII (slender sole, midshipman, blackbelly eelpout and blacktip poacher) in Puget Sound during the fall.

Fall

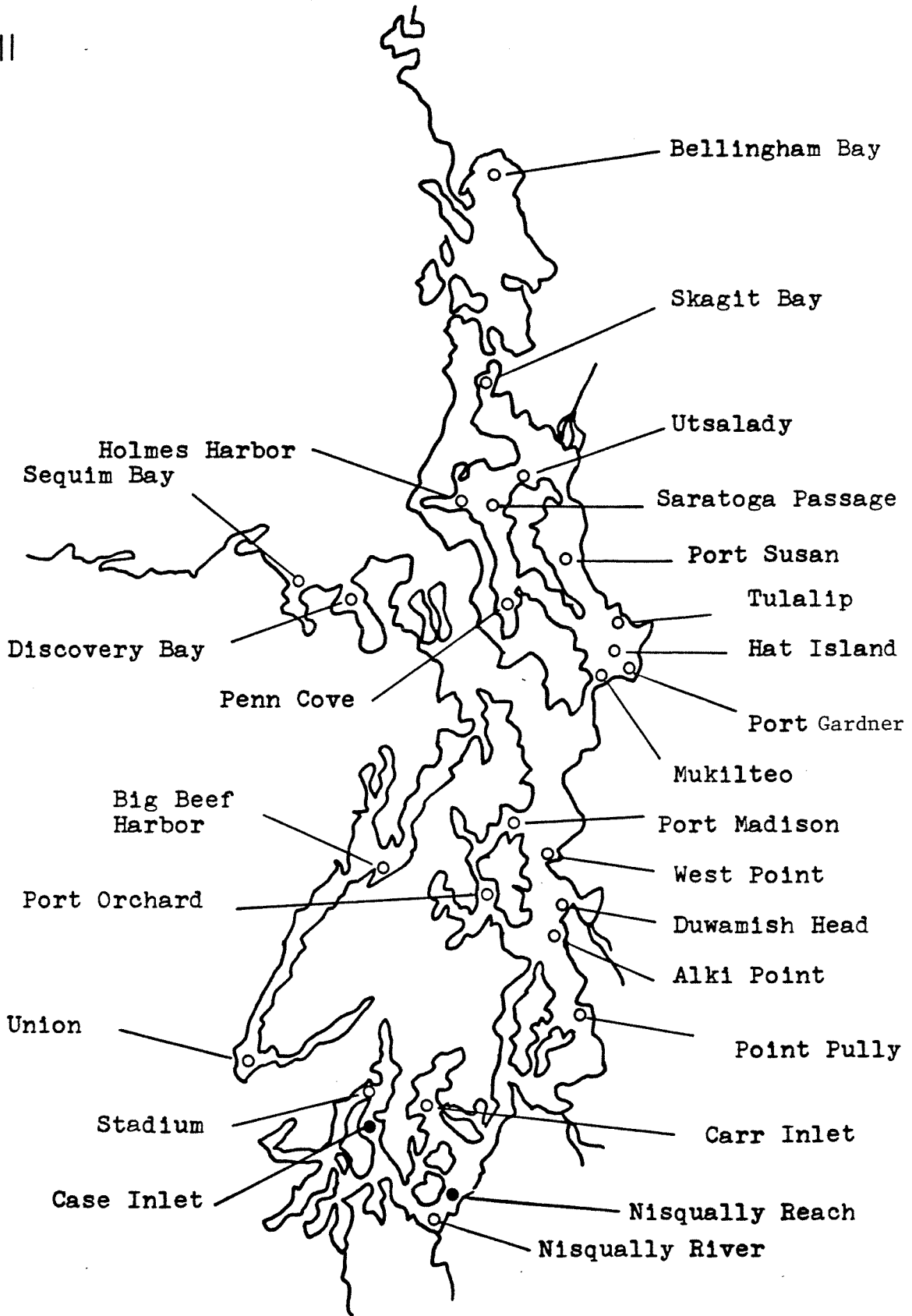


Fig.35. Geographical distribution of species group V (sturgeon poacher, longspine combfish and sailfin sculpin) in Puget Sound during the fall.

DISCUSSION

Nearshore Fishes

Faunal Similarity of Geographic Areas

Based on the results of the four seasonal site classifications presented earlier, it is apparent that sites from NPS and CPS generally exhibited a high level of faunal similarity (i.e., overlap) during most seasons. Similarly, sites at SJF and at Whidbey Island (WI) were usually highly overlapping in terms of species composition and abundance during most seasons. This relationship between sites prevailed in spring, summer, and fall, but not in winter. In winter, gravel and cobble sites from NPS clustered with sites from CPS, whereas sand/eelgrass and mud/eelgrass sites from NPS grouped with sites from SJF.

Two notable exceptions to this general pattern involved the sand/eelgrass (Beckett Point) and mud/eelgrass (Jamestown) sites from SJF. For example, during any season, the Beckett Point site never grouped with other sites from SJF. Instead, Beckett Point clustered with sites from CPS in winter and spring, and with sites from NPS in summer and fall. Collection data from the Jamestown site were only available in spring and summer, yet in both seasons the Jamestown site grouped with the sand/eelgrass and mud/eelgrass sites from NPS.

The Twin Rivers site, a sand-cobble beach with adjacent kelp habitat, also exhibited seasonal variability in its geographic affinities. In summer and winter, the Twin Rivers site clustered with CPS sites, whereas in spring and fall it grouped with other sites from the SJF.

Sites from NPS generally showed a strong tendency to cluster together through the entire year. The primary exception to this pattern, however, was the consistent grouping of the Eagle Cove site (sand/eelgrass habitat) with sites from the SJF. In all season but winter, the Eagle Cove site grouped with sites from the SJF and WI. Similarly, the Cattle Point site (a sand/eelgrass habitat located on San Juan Island), which was only sampled during the summer, clustered with the SJF and WI group of sites.

Relationships Between Habitat Types

Although the sites used in the analysis of nearshore fish species groups generally clustered according to geographic area, they clustered more strongly on the basis of descriptive habitat type. This phenomenon was evident from the overall classification of 235 collections; however, it was even more apparent from the individual seasonal analyses.

Sand/eelgrass sites from CPS, for example, always grouped together throughout the year. In winter and spring, the Beckett Point site, which was also a sand/eelgrass habitat, grouped together with the CPS sites. Within the NPS site group, there was also a clear separation of sites on the basis habitat. Typically, gravel and cobble sites and mud/eelgrass and sand/eelgrass sites grouped together separately. Generally, the gravel and cobble sites did not distinctly segregate during the year, whereas the mud/eelgrass and sand/eelgrass sites clearly separated during winter and fall.

Composition of Species Groups

Twelve distinct nearshore fish species groups were identified using all 235 collections in an inverse (i.e., species) classification. Although some of these species groups appear to be predictable

nearshore assemblages, others are artifacts, either due to sampling bias or because of the microhabitat heterogeneity at certain sampling sites.

Species group I, for example, consisted of six species (English sole, rock sole, C-0 sole, shiner perch, striped seaperch, and pile perch) and was found primarily at sand/eelgrass sites in CPS. Previous studies of nearshore fishes associated with sand and eelgrass habitats, however, have shown that the three flatfish species are most closely associated with sand, while the three species of perch are most closely associated with the eelgrass microhabitat.

Species groups II and III, which occurred only in CPS, consisted exclusively of species which normally occurred in deeper water, but which are also known to migrate onshore at night. These groups occurred only in fall and winter when sampling was conducted at night (because of low tides), and thus may represent artifacts because of the difference in time of sampling. Alternatively, they may be thought of as true species groups which simply exploit the nearshore environment at a different time of day. Group XII, which occurred only at South Beach (cobble habitat) in NPS in fall and winter, is another example of the same phenomenon.

Two of the 12 species groups (V and VI) were found on only a single occasion at one site, and therefore may represent artifact groups due to the simultaneous capture of several infrequently occurring species. This explanation may account for species group V; however, group VI may also represent a group of species which were captured together simply because of adjacent microhabitats. At Twin Rivers, for example, where group VI occurred, the sand sole and surf smelt are associated with

the moderately exposed sand-cobble beach, whereas the redbelt surfperch and remaining two species are most likely associated with the adjacent kelp beds and subtidal/intertidal cobble, respectively. Species group XI, which occurred only at Deadman Bay (gravel habitat), may also be explained in this fashion. Copper rockfish and the two species of sculpin may actually be associated with the gravel habitat; however, the spotted snailfish and kelp greenling are most likely associated with the adjacent intertidal cobble and rock-kelp bed habitats.

Two additional nearshore fish species groups (VII and IV) were composed, in part or entirely, of species which are actually neritic (i.e., occupy the nearshore water column) or semi-pelagic, rather than benthic. Group VII (sandlance, chum salmon, and coho salmon) for example consisted entirely of neritic species. An analysis of townet collections from NPS clearly showed that this group of species occupied the neritic environment, and was not closely associated with any particular habitat type. In general, then, it seems that this group is more neritic in character, and more broadly distributed in NPS, than indicated by the treatment of nearshore fish (i.e., beach seine) data alone. Similarly, three species from group IV (surf smelt, threespine stickleback, and Pacific herring) are primarily neritic in habitat, and thus were probably taken only incidentally to the capture of the other group members which are benthic.

The remaining species groups (VIII, IX, and X) all occurred frequently in NPS and CPS. With the exception of whitespotted greenling in group VIII, all species in these three groups can be considered benthic in habitat. From the results of a study which compared the occurrence and abundance of nearshore fishes on adjacent sand and eelgrass habitats

in CPS, it is evident that most of the species in these three groups are primarily eelgrass-associated. Because these groups occur widely and often in CPS and NPS, they represent, in addition to groups I and IV, the clearest examples of true nearshore fish species groups.

Habitat/Geographic Area Affinities of Species Groups

In general, the most frequently occurring and widespread nearshore fish species groups (I, IV, VIII, IX, and X) (Table 8) did not exhibit a strong tendency to be associated with any specific habitat type or geographic area (Table 21). The major exception to this pattern was the occurrence of species group I (English sole, rock sole, C-0 sole, shiner perch, striped perch, and pile perch) primarily at sand/eelgrass sites in CPS. Although the other commonly occurring species groups usually were found at most habitat types, they were conspicuously absent, except groups VII and IV, from the sand-gravel-cobble sediment dominated sites (i.e., sites lacking vegetation) along SJF and WI.

Species groups IV (staghorn sculpin, starry flounder, surf smelt, threespine stickleback, tidepool sculpin, Pacific herring, and snake prickleback) and VIII (penpoint gunnel, crescent gunnel, silverspotted sculpin, whitespotted greenling, and tubenose poacher) generally occurred at sand/eelgrass, mud/eelgrass, and gravel sites; however, both were absent from the cobble sites in NPS. Except for the occurrence of group IV at Beckett Point and group VIII at Jamestown (both in SJF), these groups were confined to NPS. Species groups IX (padded sculpin, buffalo sculpin, great sculpin, and sharpnose sculpin) and X (tubesnout, bay pipefish, and cabezon), in contrast, were found at all habitat types and in all major geographic areas (CPS, NPS, and SJF).

Table 21. The occurrence of nearshore fish species groups in Puget Sound by habitat type.

Habitat	Species groups											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Gravel	x			x			x	x	x	x	x	x
Cobble							x		x	x		x
Sand/eelgrass	x	x	x	x		x		x	x	x		
Mud/eelgrass				x				x	x	x		
Non-vegetated (sand, gravel, cobble substrate mixture)							x					x

An examination of the habitat associations for the five most frequently occurring species groups (I, IV, VIII, IX, and X) indicated that each occurred at sand/eelgrass sites in some area of Puget Sound. This fact, combined with the knowledge that most of the species in these five groups (particularly groups I, VIII, IX, and X) are eelgrass-associated (Miller, et al., 1977), leads to several conclusions. First, the most frequently occurring nearshore species groups in Puget Sound are probably associated with eelgrass. Second, eelgrass may be one of the most important factors influencing the distribution of nearshore species groups. Finally, the descriptive habitat classification approach previously used by DOE (i.e., sand/eelgrass, mud/eelgrass, gravel, cobble, and rocky/kelp bed habitat designations) is very likely too coarse. In general, it seems a finer-scale approach is necessary to better understand the distribution of both individual species and species groups in Puget Sound. In particular, further study of the importance of eelgrass beds in the ecology of Puget Sound fishes seems warranted.

Demersal Fishes

Faunal similarity of geographic areas

The degree of faunal similarity or overlap between different geographic areas (i.e. CPS, SPS, WB) in Puget Sound varied considerably depending on depth and time of year. In general, the pattern of faunal overlap was reflected in the geographic patterns of distribution for individual species groups.

During all seasons, stations in shallow water (<30 m) from CPS and SPS were generally more similar to one another, in terms of species composition, than to stations from any other area. In contrast, stations from WB either

grouped separately, or with stations from NPS. In general, then, there seemed to be a clear separation between WB-NPS stations and CPS-SPS stations in shallow water. In deep water (70-150 m), the general tendency was for stations from WB and CPS, at depths of 80-100 m, to group together, and for stations from deeper water in WB (100-150 m) to group separately. Stations at intermediate depths (30-80 m); however, normally exhibited greater variability in faunal similarity or overlap. In winter and spring, for instance, stations from CPS and SPS exhibited a high degree of overlap. In the summer and fall, however, this relationship did not occur. Conversely, stations from WB and SPS in the summer, fall and winter showed relatively little faunal similarity with other areas. During the spring, stations from SPS and WB strongly overlapped in faunal composition, whereas during the summer stations from WB and CPS were most similar.

Depth Zonation

A striking feature of each seasonal analysis was that individual stations clustered primarily on the basis of depth, and only secondarily on the basis of geographic area. In general, based on the available collection data, Puget Sound can be divided into three broad depth zones: 5-30 m, 30-70 m, and 70-150 m. This zonation pattern prevailed during all seasons, and was found in each of the three major geographic areas examined (SPS, CPS, and WB). Typically, individual species groups occurred within either one or two of the three depth zones, but never all three.

Seasonal Variation in Composition of Demersal Fish Species Groups

In general, the composition of the dominant demersal fish species groups changed with the seasons. In the shallow-water zone (5-30 m),

speckled sanddab and rock sole were consistent (i.e., core) members of one dominant species group that occurred during all seasons (Table 22). In winter and spring, C-0 sole and roughback sculpin were also associated with these two core species. In addition, English sole was found to be associated with rock sole and speckled sanddab in spring and summer.

At shallow to intermediate depths (5-50 m), in all areas of Puget Sound, staghorn sculpin and sand sole were consistent members of a second dominant species group (Table 22). In winter and fall, English sole occurred together with these two species, whereas in spring and summer, they were associated with starry flounder and snake prickleback. Comparing the composition of these two shallow-intermediate depth species groups, it is apparent that English sole undergo a seasonal shift in bathymetric distribution, thereby also changing its species group affinities.

In the intermediate and deep-water zones, blackbelly eelpout and slender sole constituted the core species of another dominant species group (Table 23). The midshipman was a member of this group in all seasons except summer, and blacktip poacher was a member in all seasons except spring. In general, then, the same species group occurred in fall and winter, but changed composition in spring and summer. During this period, slim sculpin also occurred together with blackbelly eelpout and slender sole.

In the deep-water zone (greater than 70 m), the predominant species group during all seasons except fall consisted of ratfish, Dover sole, and rex sole (Table 23). In fall, rex sole and Dover sole were both associated with quillback rockfish, while ratfish was associated with spiny dogfish and walleye pollock.

Table 22. Seasonal variation in the composition of shallow and intermediate water demersal species groups in Puget Sound.

Depth zone	Group	Species	Autumn	Winter	Spring	Summer
Shallow (5-30 m)	I	Roughback sculpin	x	x	x	
		*Speckled sanddab	x	x	x	x
		*Rock sole	x	x	x	x
		C-0 sole		x	x	
		English sole			x	x
Shallow- intermediate (5-45 m)	II	*Staghorn sculpin	x	x	x	x
		English sole	x	x		
		*Sand sole	x	x	x	x
		Starry flounder			x	x
		Butter sole			x	x
		Snake prickleback			x	x

*Core species

Table 23. Seasonal variation in the composition of intermediate and deep water demersal species groups in Puget Sound.

Depth zone	Group	Species	Autumn	Winter	Spring	Summer
Intermediate (30-80 m)	III	*Blackbelly eelpout	x	x	x	x
		*Slender sole	x	x	x	x
		Blacktip poacher	x	x		x
		Plainfin midshipman	x	x	x	
		Slim sculpin			x	x
Deep (70-150 m)	IV	*Ratfish	x	x	x	x
		*Rex sole	x	x	x	x
		*Dover sole	x	x	x	x
		Quillback rockfish	x			
		Spiny dogfish	x			

*Core species

Regional Variation in Community Structure

Winter. In winter the most frequently occurring species groups were found in all major geographic areas of Puget Sound. In shallow water (less than 30 m), the two major species groups were X (roughback sculpin, speckled sanddab, rock sole, and C-0 sole) and XI(a) (staghorn sculpin, English sole, and sand sole). At intermediate depths, group XIV(a), consisting of blackbelly eelpout, slender sole, blacktip poacher, and midshipman, dominated in all geographic areas. Similarly, group XV (ratfish, rex sole, Dover sole) was found in the deep-water zones (over 80 m) of all major geographic areas in Puget Sound.

The primary differences between areas, in terms of community structure, occurred in Whidbey Basin (WB) and SPS. For example, species group III (black eelpout, pallid eelpout, and blackfin poacher) and IX (spinyhead sculpin, longnose skate, and whitebarred prickleback) were consistently found in both the intermediate and the deep zones of WB, but in no other geographic area. Similarly, group XIII (snake prickleback, bay goby, and longspine combfish) occurred only in SPS. No species groups were restricted to CPS; however, two groups (XII and XVII) were found to occur in both CPS and SPS.

Spring. Four different species groups dominated all major geographic areas of Puget Sound during the spring. Two of these groups were restricted to the shallow water, and two were found only at intermediate depths. In general, few species groups occurred in deeper water at this time of year.

The two dominant, shallow water species groups were groups XII (roughback sculpin, English sole, rock sole, speckled sanddab and C-0 sole) and X (snake prickleback, sand sole, butter sole, starry flounder and staghorn sculpin). Generally, species group XII occurred frequently in all geographic areas, whereas group X was predominantly found in the WB area.

In deeper water, species groups XV (blackbelly eelpout, slender sole, slim sculpin and midshipman) and XVI (ratfish, rex sole and Dover sole) predominated in all areas of Puget Sound. During most of the year, group XVI occurred exclusively in the intermediate depth; however, in the winter the group was distributed over a broader depth range. Species group XV exhibited greater variability in depth distribution between geographic areas. In WB, for example, this group was found at depths less than 80 m, whereas in CPS and SPS the group occurred in both the intermediate and deep water zones.

Although the dominant demersal species groups occurred in all areas of Puget Sound during the spring, several other species groups were restricted to specific geographic areas. For example, groups III (spinyhead sculpin, white-barred prickleback and blue barred prickleback) and V (blackfin poacher, pallid eelpout and brown cat shark) were found to occur only in WB, although in different depth zones. Species group III was narrowly confined to the intermediate depth zone, whereas group V occurred only in deep water (> 120 m).

Species group VIII (northern ronquil, northern sculpin, spearnose poacher, redstripe rockfish, and bluespotted poacher), which occurred in both the shallow and the intermediate depth zones, was the only species group found to be restricted to CPS. The only species group restricted to SPS was group XIV (sturgeon poacher, sailfin sculpin, bay goby, and longspine combfish), which was consistently found at intermediate depths.

Summer. In summer three groups of species (VI, VIII(a), XIII) were found in each major geographic area of Puget Sound. Species group XIII (English sole, rock sole, and speckled sanddab) was the dominant species group in the shallow-water zone, as well as the shallow part of the intermediate-depth zone. Group VIII(a) (ratfish, Dover sole, and rex

sole) was found to occur in both the intermediate and the deep-water zones in each geographic area. In contrast, species group VI (blackbelly eelpout, slender sole, blacktip poacher, and slim sculpin) was restricted to the intermediate-depth zone in all areas where it occurred.

Four additional species groups (V, IV, XVII, and XVIII), found in summer, were found only in WB. Each was restricted to a relatively narrow depth range. Group XVII (snake prickleback, sand sole, and staghorn sculpin) and group XVIII (butter sole, starry flounder, and longfin smelt) were closely associated with each other and occurred only in shallow water less than 30 m. Species groups V (spinyhead sculpin, bluebarred prickleback, and whitebarred prickleback) and IV (tadpole sculpin, pallid eelpout, and blackfin poacher), however, were found in deeper water; group V was restricted to the intermediate-depth zone and group IX was restricted to the deep-water zone. No species groups were restricted to SPS, and only group I (northern sculpin, spotfin sculpin, and redstripe rockfish) was restricted to CPS, primarily at intermediate depths. Two other species groups, XV (northern ronquil, pygmy poacher, tomcod, shiner perch, bay goby, and longspine combfish) and XIV (roughback sculpin, sturgeon poacher, midshipman, and brown rockfish), were widespread throughout CPS and SPS but absent from WB.

Fall. As with the other seasons, several species groups (VIII, IX, XII, and XIII) occurred in all areas. Groups VIII and IX were restricted to the shallow-water zone and groups XII and XIII were found primarily at intermediate depths. Two other groups of species (II and XVII) occurred in both WB and SPS, but were not found in CPS. Group II (snake prickleback, flathead sole, and bay goby) was generally confined to shallow water less than 30 m, whereas group XVII (ratfish, spiny dogfish,

and walleye pollock) was found in both the deeper intermediate and the deep-water zones. Similarly, species group XVI was found to occur only in WB and CPS.

Three additional species groups (VI, XIV, and XV) were restricted to WB in fall, and each in turn was confined to a narrow depth range. Group VI (starry flounder and butter sole), for example, was found only in the shallow-water zone (less than 30 m), whereas groups XIV (spinyhead sculpin, whitebarred prickleback, and bluebarred prickleback) and XV (pallid eelpout, black eelpout, and blackfin poacher) occurred in the intermediate and deep-water zones, respectively.

No species groups were found only in CPS in fall, and only one group (V) was found only in SPS. Group V (sturgeon poacher, sailfin sculpin, and longspine combfish) was typically restricted to the intermediate-depth zone (30-80 m).

CONCLUSIONS

Nearshore Fishes

1. The 235 beach seine collections used in the nearshore fish analysis clustered primarily on the basis of habitat type (gravel, cobble, etc.), and secondarily, in the case of sand/eelgrass collections, by geographic area.
2. Generally, collections from central Puget Sound, north Puget Sound, the Strait of Juan de Fuca, and Whidbey Island grouped separately, although there was some seasonal variation.
3. Collections from the mud/eelgrass sites were typically most distinct in terms of species composition, and were generally more similar in composition to collections from sand/eelgrass sites than other habitats.

4. Collections from the cobble and gravel habitats in north Puget Sound were generally more similar in composition to one another than to collections from other habitat types.

5. A total of 12 distinct nearshore species groups was described, comprising 3-7 species.

6. Five of these 12 groups occurred frequently; however, the majority occurred only occasionally and were considered to be artifacts due to either sampling variability or microhabitat complexity.

7. In general, the most frequently occurring and widespread species groups did not exhibit strong associations with any particular habitat type or geographical area.

8. Although the frequently occurring species groups generally occurred in most habitats, they were often conspicuously absent from the cobble habitat in north Puget Sound and the sand/cobble/gravel sites located along the Strait of Juan de Fuca and Whidbey Island.

9. Because all frequently occurring species groups occurred in the sand/eelgrass habitat, and most of the species in these groups are known to be eelgrass-associated, it was suggested that eelgrass is an important factor in determining the distribution of nearshore fish species groups throughout Puget Sound.

Demersal Fishes

1. Seasonal analysis of otter trawl collections indicated that there are at least three different depth zones in Puget Sound: less than 30 m (shallow), 30-70 m (intermediate), and 70-120 m (deep), each characterized by a different faunal composition.

2. Generally, collections from central Puget Sound and south Puget Sound exhibited greater similarity to one another in terms of species

composition and abundance than to collections from Whidbey Basin.

3. During each season, 15-20 distinct demersal fish species groups were identified in Puget Sound. The majority of these groups were restricted in distribution by both depth and geographic area.

4. In each major depth zone of Puget Sound, dominant species groups were identified which consisted, in part, of year-round "core" species.

5. A comparison of regional variations in community structure in Puget Sound indicated that all major areas (south Puget Sound, central Puget Sound, and Whidbey Basin) were largely similar in structure, except for several unique species groups found only in south Puget Sound and Whidbey Basin.

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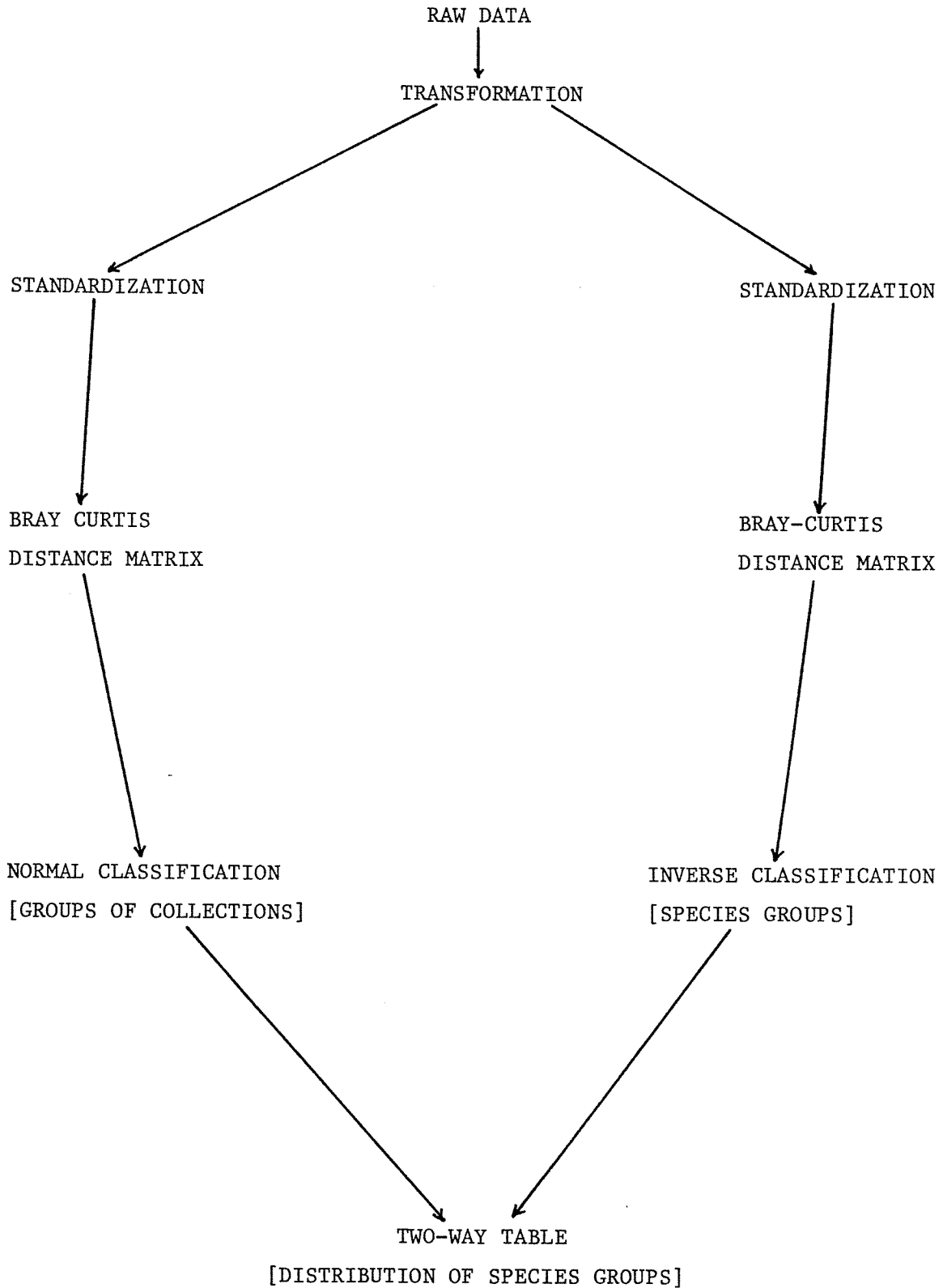
APPENDICES

Appendix 1. Numerical analysis package developed by R.W. Smith at the University of Southern California.

- I. Hierarchical, agglomerative classification
 - A. Distance indices
 1. Bray Curtis
 2. Canberra metric
 3. Euclidean distance
 4. Jaccard
 5. Czekanowski
 - B. Sorting strategies
 1. Group average
 2. Flexible
 - C. Print-out of dendrograms and output for line plotter
 - D. Special distance calculations for classification of variables
- II. Ordination
 - A. Principal components analysis--modifications for mixed data
 - B. Varimax rotation (factor analysis)
 - C. Principal coordinates analysis--same distance indices as in the classification program
 - D. In preparation--Reciprocal Averaging
- III. Correlation and regression
 - A. Correlation coefficients
 1. Rank
 2. Parametric
 3. Partial
 4. Multiple
 - B. Regression
 1. Linear
 2. Curvilinear
 3. Multiple--option for ridge regression
- IV. Discriminant analysis
 - A. Two-group
 - B. Multiple--option for weighted discriminant analysis
- V. Time-series analysis
 - A. Runs test
 - B. Curve smoothing
 - C. Auto correlation
 - D. Cross correlation
- VI. Species diversity
 - A. Information (Shannon-Weaver)
 - B. Evenness component
 - C. Gleason index
 - D. Hulbert rarification
 - E. In preparation--Brillouin index

- VII. Niche parameters
 - A. Niche breadth
 - 1. Simple index, weighted or unweighted
 - 2. Information theory index, weighted or unweighted
 - B. Niche overlap between species
 - 1. Simple index, weighted or unweighted
 - 2. Information theory index, weighted or unweighted
 - 3. Morisita's index
 - C. Measurement of aggregation
 - 1. Morisita's index
 - 2. Mean crowding
- VIII. Univariate sample comparisons
 - A. T-test
 - B. U-test (non-parametric)
 - C. One-way analysis of variance
 - 1. Parametric
 - 2. Non-parametric
- IX. Data display
 - A. Plotting
 - 1. Histograms
 - 2. Bar graphs
 - 3. Two-dimensional
 - B. Two-way coincidence tables
 - C. Matrix print-out
- X. Calculation and ranking of population parameters
 - A. Number of occurrences
 - B. Number per occurrence
 - C. Number per sample
 - D. Total number
 - E. Maximum number
- XI. Data transformation and standardization--30 transformations and standardizations
- XII. Matrix manipulation
 - A. Editing
 - B. Summations
 - C. Reduction
 - D. Catenation
- XIII. Miscellaneous
 - A. Coefficient of variation
 - B. Species distance contributions
 - C. Two-way table summaries
 - D. Weighted-average scores
 - E. Zero adjustments in species data
 - F. Symbol generation for plots

Appendix 2. Flow chart indicating the general sequence of steps in numerical classification.



Appendix 3. Square root transformation, species maximum and mean standardizations, and the Bray-Curtis distance measure used in classification.

a. Square root transformation

$$X_{ij} = \sqrt{X_{ij}}$$

where X_{ij} = the abundance of species i in collection j.

b. Species maximum standardization

$$X_{ij}^{\max} = \frac{X_{ij}}{\left[\begin{array}{l} \text{maximum abundance of species } i \\ \text{in a set of collections} \end{array} \right]}$$

where X_{ij}^{\max} = species maximum standardization

X_{ij} = the abundance of species i in collection j

c. Species mean standardization

$$X_{ij}^{\text{mean}} = \frac{X_{ij}}{\sum_{k=1}^m X_{ik} / T}$$

where X_{ij} = the abundance of species i in collection j

m = total number of collections

T = number of collections with species i

X_{ik} = the count of species i in collection k

d. Bray-Curtis distance measure

$$D_{ij} = \frac{\sum_{k=1}^n (X_{ki} - X_{kj})}{\sum_{k=1}^n (X_{ki} + X_{kj})}$$

where D_{ij} = the distance between entities i and j

X_{ki} = the value of attribute k in entity i

Appendix 3, cont'd

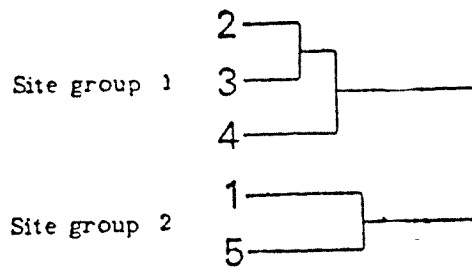
X_{kj} = the value of attribute k in entity j

n = the number of attributes

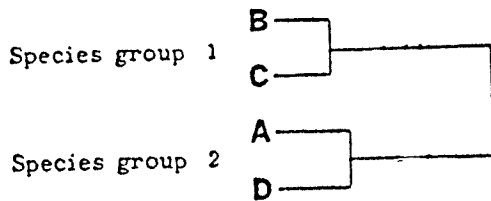
Appendix 5. The process of constructing a two-way table based on the results of classification.

		Sites				
		1	2	3	4	5
Species	A	3	0	1	0	2
	B	0	2	3	1	0
	C	1	3	3	2	0
	D	2	0	0	0	3

c. Hypothetical data matrix



a. Site classification



b. Species classification

		Sites				
		2	3	4	1	5
Species	B	2	3	1	0	0
	C	3	3	2	1	0
	A	0	1	0	3	2
	D	0	0	0	2	3

d. Two-way table