AN ABSTRACT OF THE THESIS OF

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Title: Development of the Fisheries of the Eastern North Pacific: A Natural-Cultural Systems Perspective

Abstract approved: Redacted for Privacy

William J. Liss

The eastern margin of the Eastern North Pacific Ocean was classified into physiographic regions based on a suite of physical characteristics. Information on cultural and biological characteristics of this area was meshed with this classification. The result was a classification of the Eastern North Pacific into natural-cultural systems whose boundaries coincide with those of physiographic regions. Development of commercial fisheries was examined in three selected natural-cultural systems over a span of 88 years in order to identify developmental patterns unique to each and similar in all systems. Life history patterns of selected species were also examined within the context of characteristics of natural and cultural systems of the Eastern North Pacific.

Species life history patterns have developed within, and therefore may tend to correlate with, general patterns in

physical environment as they occur in different areas in the Eastern North Pacific. Yet life history patterns are also affected by cultural factors like exploitation and habitat destruction. Like life history patterns, fisheries also have developed differently in each natural-cultural system in the Eastern North Pacific due to differences in many interacting physical, cultural, and biological characteristics. Differences in fishery development between systems include management and exploitation techniques and technology, but also include characteristics of catch such as taxonomic composition and trophic composition, and distance from shore from which the majority of the catch came. Yet there were also similarities in patterns of fishery development between different natural-cultural systems. A 'fishing up' process occurred in each natural-cultural system examined, along with declines in catch of most species that maintained a high value. Shifts in trophic structure of the catch occurred, with movement toward proportionally greater landing weights of species of lower trophic groups.

Implications of such generalized patterns of exploitation and of fishery development for species life histories and for fish communities are discussed, and several management measures are suggested.

Development of the Fisheries of the Eastern North Pacific: A Natural-Cultural Systems Perspective

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INTRODUCTION

Fishery managers have traditionally managed species and stocks individually. Such single unit management has apparently assumed that the unit operates relatively independently of the many factors that exist in its surrounding environment. Yet, any fishery tends to be quite complex. Most fisheries are multi-species and multi-stock fisheries, but effects of harvest on population dynamics, population structure, and life history structure are likely to be different for each species and life history type involved.

Several studies have presented evidence for change in life histories of fish species and stocks in response to exploitation. In general, growth rates of exploited species increase, and ages or sizes at maturity decrease (Bowering 1987; Schaffer and Elson 1975) though this will depend on the nature of exploitation, that is, on sizes and age classes removed from the fishery (Ricker 1981; Beverton 1963). Exploitation generally tends to decrease the number of age classes in a population (Bowering, 1987; Leaman and Beamish 1984; Regier and Loftus, 1972; Murphy 1968), and to select against larger individuals (Ricker 1981). Exploitation also has potential to alter community structure. It may select against species at higher trophic levels (Sherman et al. 1981). However, fish communities and life histories change not only because of exploitation, but for a host of interacting and interrelated reasons: other cultural factors such as habitat destruction and pollution, biological interactions, and components of the physical environment, especially those that regulate productivity and survival.

Regardless of the particular communities involved, catch and catch patterns have changed within many areas where commercial exploitation has occurred over a relatively long time period (Regier and Loftus 1972; Christie 1974). Catch patterns, like community and life history structure, are a result of many interacting factors. Changes in catch patterns are reflective of changing cultural conditions such as management policies, fishing technology, and fishery economics, but changes in catch are also reflective of changing physical and biological parameters which create varying levels of abundance of particular species.

A theory of natural-cultural systems should encompass the concept that many factors interact to affect biological systems and patterns of fishery exploitation. A natural-cultural system is composed of a physical habitat, a biological community, and cultural influences (Warren and Liss 1983). It is viewed as having a particular capacity, a performance, and an environment. Environment here is used in a very general sense as a set of possibilities provided to and constraints imposed on a system by another system at a larger scale or at a higher level of organization. Therefore, any system has some more encompassing set of factors within which it functions. Any environment can change over time, and the natural-cultural system within its environment must develop in response to this change.

Fisheries develop over time, but they do so within the context of, and as an interconnected part of, change in the natural-cultural system. Fishery development is viewed partially as changes over time in various aspects of catch, but also as changes in fishery management techniques, in fishing technology, and as changes in political, social, and economic conditions as they relate to fisheries.

The purpose of this thesis is to classify physiographic regions within the Eastern North Pacific. Through incorporation of cultural and biological information, these physiographic regions will be viewed as natural-cultural systems. Aspects of fishery development are examined within the context of interacting components of selected natural-cultural systems. Aspects of catch (one component of fishery development) examined over time are taxonomic composition, trophic composition, distance from shore from which the majority of the catch was landed, number of taxa composing the catch, and landed weights of particular taxa. Life history strategies of several species are examined for patterns that correspond to variables of the physical environment in different regions. Implications of exploitation (as it occurs within the context of other constraints within the natural-cultural system) on life history patterns are discussed. This thesis will demonstrate that fisheries in different natural-cultural systems develop differently. Yet there are also patterns of fishery development that these systems have in common.

GENERAL SYSTEMS THEORY

A natural-cultural system may be divided into interacting and interpenetrating physical (climate, water, and substrate), biological, and cultural subsystems (Figure 1a). Each natural-cultural system has an environment, the network of natural-cultural systems, within which it operates (Figure 1b). This is a more encompassing level of organization that provides possibilities and imposes constraints on the systems within it. Any organismic system (such as a natural-cultural system) develops within such an environment. 'Organismic system' here is used in an abstract sense: an organismic system could be a life history type, a species, a community, a natural-cultural system, etc. Any such system has some potential capacity (Figure 2). This capacity, theoretically, is a set of all potentially available developmental patterns.

Over time, a system acquires realized capacities which are determined by the interaction of potential capacity with the encompassing environment (Figure 2). The realized capacity of an organismic system is determined by its potential capacity and by effects imposed by the particular encompassing environment within which it developed. At different stages in its development, a system has different realized capacities. Theoretically, development is change in realized capacity, but is seen as change in performance, that is, as change in structure and organization through

Figure 1. a) Natural-cultural system encompassing subsystems of climate (Cli), water (H_2O), substrate (Sub), biota (Bio), and Culture (Cul). b) Network of natural-cultural systems forming the environment of a natural-cultural system of interest. From Warren and Liss 1983.

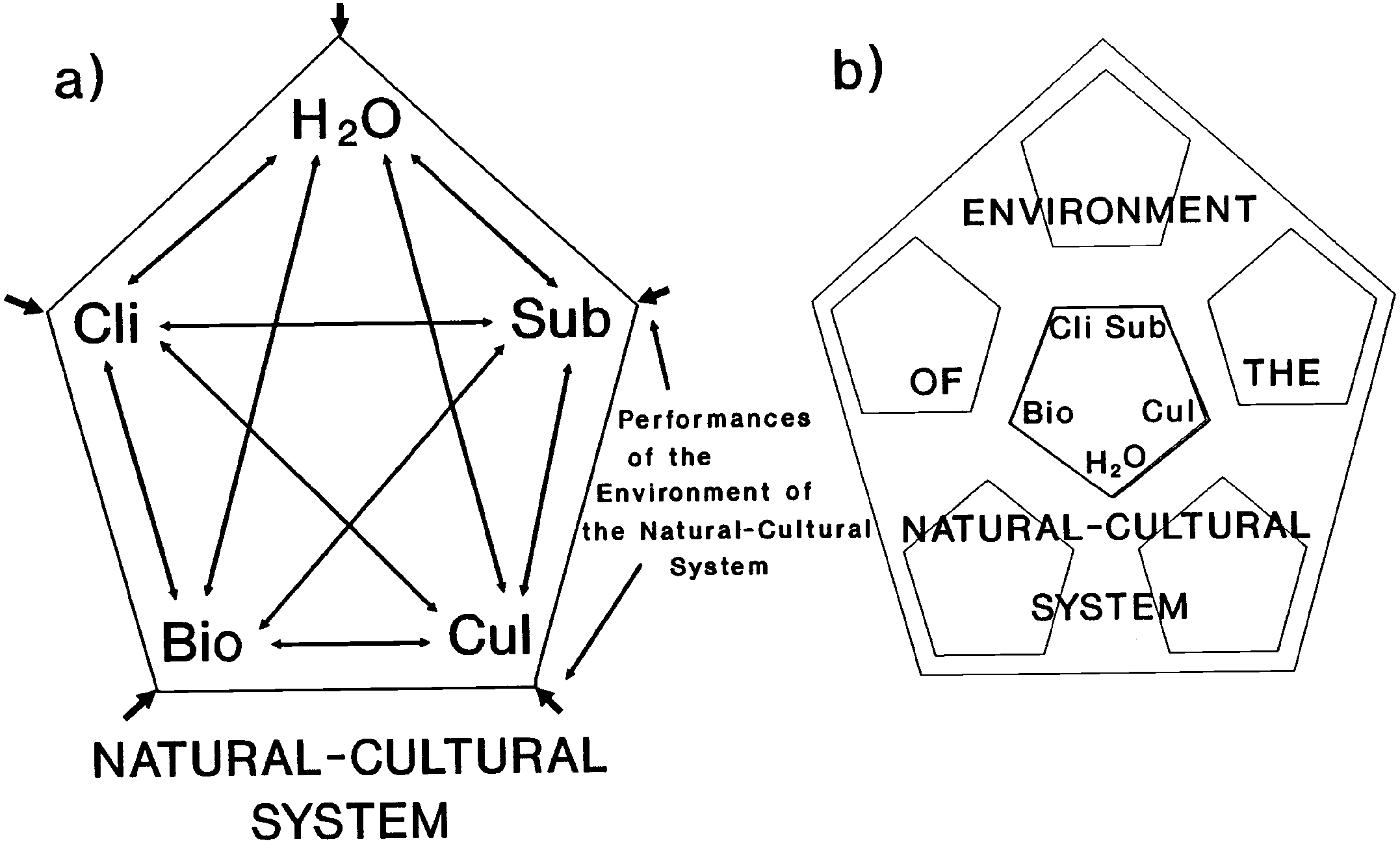

a)
H2O
Cli
Sub
Bio
Cul
NATURAL-CULTURAL SYSTEM
Performances of the Environment of the Natural-Cultural System
b)
ENVIRONMENT
OF
THE
NATURAL-CULTURAL
SYSTEM
Cli Sub
Bio Cul
H2O

Figure 1.

Figure 2. The capacity of an organismic system. Each organismic system possesses a potential capacity to behave in certain ways. The interaction of system capacity with the encompassing environmental system determines realized capacity which, in turn, displays some performance (such as the structure or organization of the organismic system). From Warren et al. 1979.

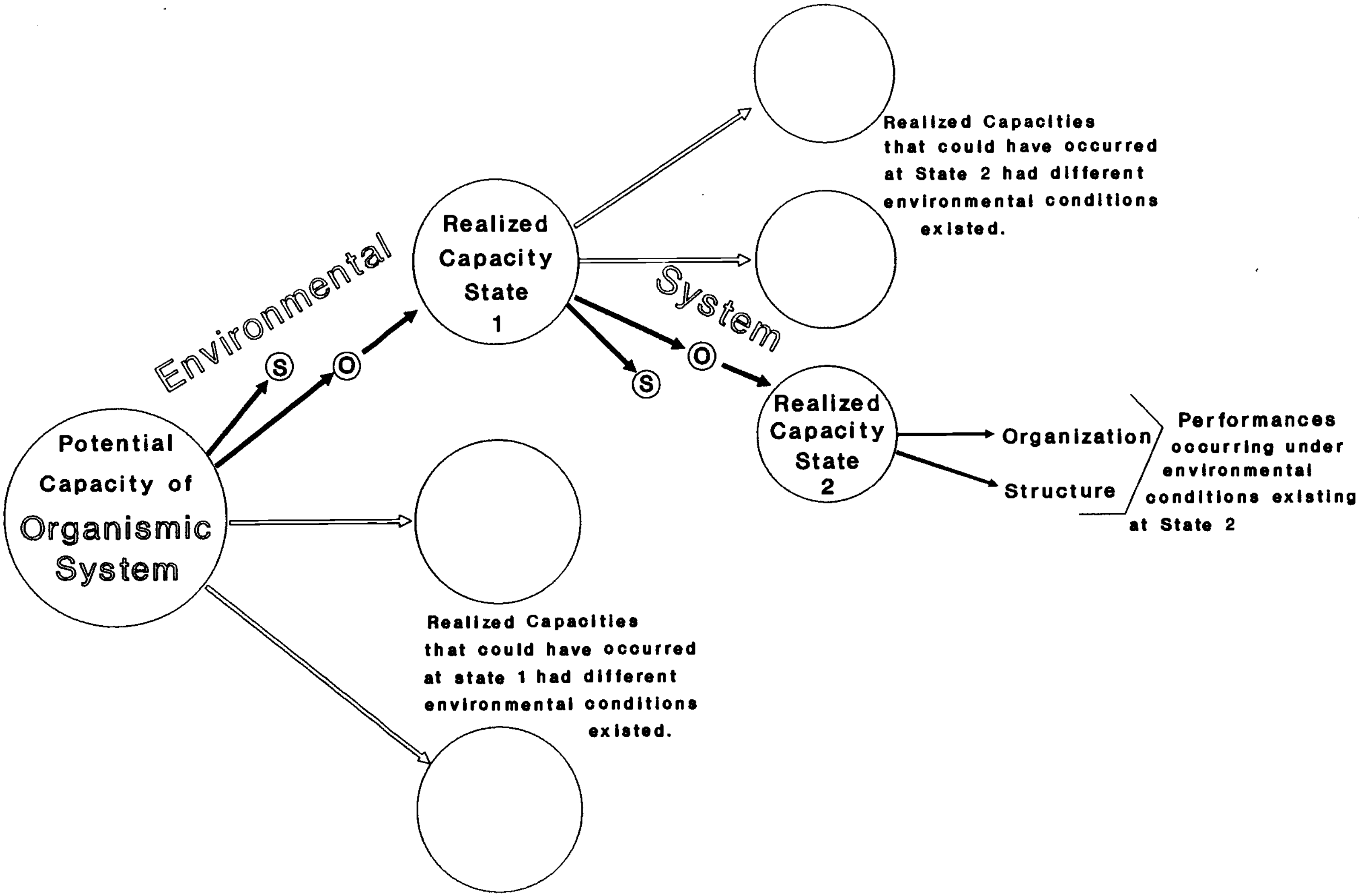

Potential Capacity of Organismic System
Environmental
S
O
Realized Capacity State 1
System
S
O
Realized Capacity State 2
Organization
Structure
Performances occurring under environmental conditions existing at State 2
Realized Capacities that could have occurred at State 2 had different environmental conditions existed.
Realized Capacities that could have occurred at state 1 had different environmental conditions existed.

Figure 2.

time (Warren et al. 1979). Organization is conceptualized as including interrelationships between subsystems; in a natural-cultural system then, organization includes interrelationships between physical, biological, and cultural components. Organization also includes incorporation of these subsystems (or components) into the unified whole (Liss et al. 1986).

Development is changing realized capacity, structure, and organization of the organismic system and its subsystems. It occurs in concordance with the changing capacity and performances of the environmental system (Figure 2). The environmental system then serves as a framework or template within which the organismic system develops. Because of interconnection and co-development of subsystems, the organismic system as a whole, and its environment, the behavior or performance of any subsystem can occur only within the context of the whole system and its environment.

The concept of capacity is a highly theoretical one, and as such is very abstract. Performance, a term that still maintains enough abstraction to be fairly general, provides definition by implying visible or measurable results of interaction of environmental system and organismic system capacity (Figure 3). Different natural-cultural systems differ in potential and realized capacities, in encompassing environments, and in resulting

Figure 3. Interaction of environmental and organismic system capacities. a) shows that, based on some capacity, a performance of an organismic system is determined by the state of its environmental system. b) shows that environmental states or performances are based on some environmental capacity. c) shows a graphical relationship between organismic and environmental performances. The performance of an organism is dependent on both its own capacity and that of its encompassing environment. From Warren and Liss 1983.

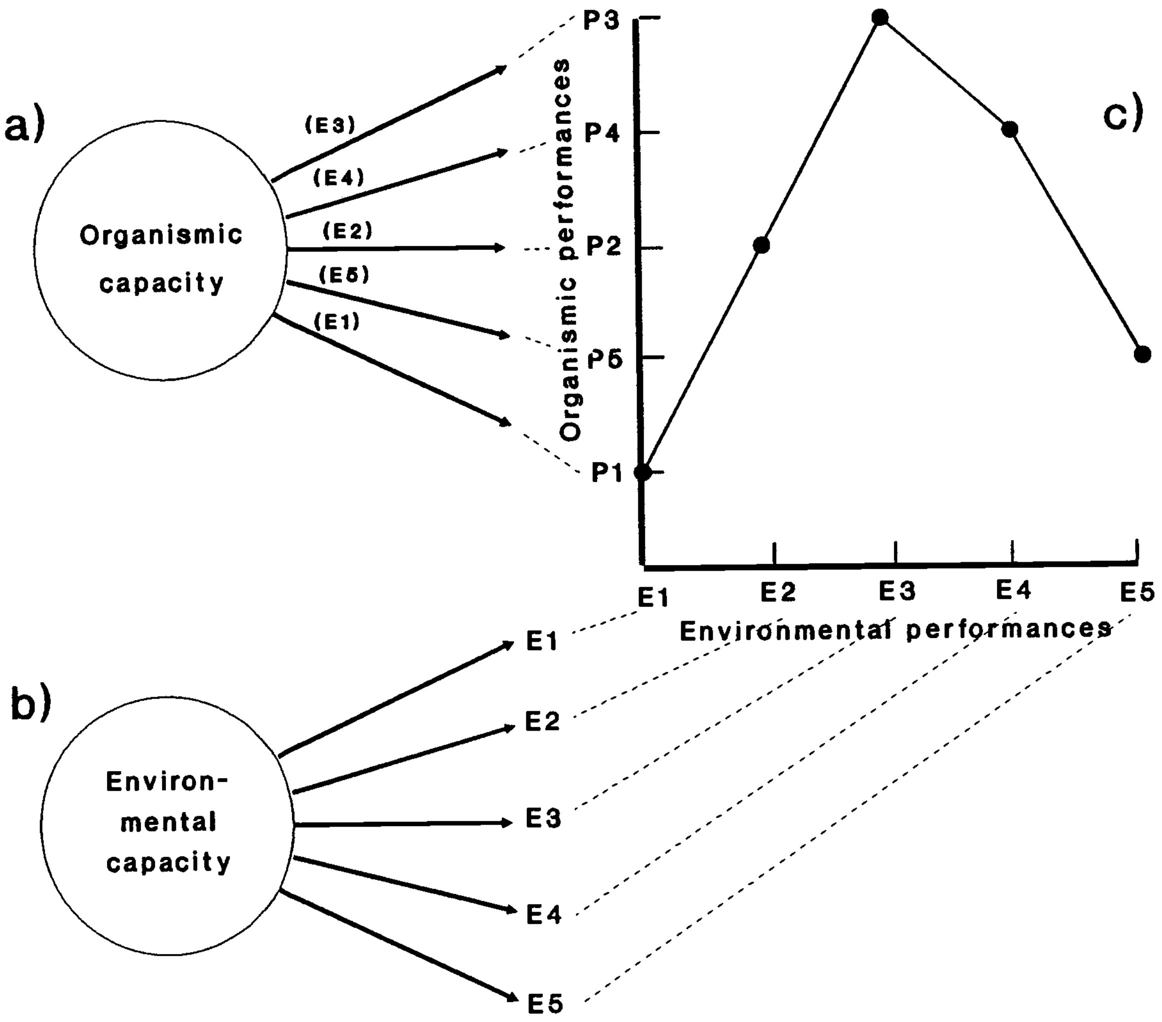

a)
Organismic capacity
(E3)
(E4)
(E2)
(E5)
(E1)
P3
P4
P2
P5
P1
Organismic performances
c)
E1
E2
E3
E4
E5
Environmental performances
b)
Environ- mental capacity
E1
E2
E3
E4
E5

Figure 3.

performances. They therefore differ in structure, organization, and development, all of which are performances of the natural-cultural system.

Interpenetration of subsystems demands that cultural subsystems, biological subsystems, and physical subsystems do not develop independently. However, development (a performance based on capacity) of one subsystem must be seen in relation to capacity (for change) of the others. If change in physical or cultural subsystems is too great for the capacity of the biological system, the performance of the latter may be de-stabilizing change or extinction. Subsystem performance, then, is also a performance of the system as a whole.

The region of the Eastern North Pacific from the Gulf of Alaska to Baja California forms a network of interconnected and interpenetrating natural-cultural systems. This area can be classified into natural-cultural systems with different capacities, environments, and performances. Ideally, systems should be classified according to their potential capacities and the capacities of their environments (Warren et al. 1979). However, capacities cannot be directly and completely observed. Such a classification system must be based on performances, which are proxies for capacity. These performances must be relatively intransitory (at least on a human time scale: about 10^2 years) and highly determining of other more transitory performances. For this reason, classification of the Eastern North Pacific is based on physical characteristics of general patterns of climate, water (oceanography), and substrate (geomorphology) rather than on characteristics of biological or cultural subsystems. The result of this classification is a series of physiographic regions. Relationships between natural-cultural systems defined by these physiographic regions can then be examined.

Such a classification scheme of the physical environment must recognize interconnection and interpenetration between natural-cultural systems, making boundaries between systems only relative. Nevertheless, a classification scheme is instructive for comparing performances (such as patterns of development) between systems on relatively large scales of time and space.

The biological subsystem within the natural-cultural system includes the community whose organization is based on the species pool (the communities in other natural-cultural systems that provide colonizing species to a developing community) and on the encompassing environment of the community, that is, on the physical and cultural subsystems which develop and interpenetrate with the community (Warren et al. 1979; Warren and Liss 1983). The biological subsystem also includes, on a different dimension, species life histories which are implicit components of community organization.

Components of the cultural subsystem examined here include legal and political factors, management schemes, fishing technology and methods, markets, and human population and its corresponding environmental pressures. Development within the cultural subsystem includes patterns of change in these parameters over time. Catch is a performance of the natural-cultural system which is highly integrated with development, capacity, and performance not only of the cultural subsystem, but also of the physical and biological subsystems. Therefore, catch is a performance of the natural-cultural system as a whole.

Generalizations about natural-cultural systems are:

1) Natural-cultural systems have different capacities, environments, and performances. The latter of these includes system development, which is change in structure and organization over time.

2) Co-development and concordance occurs between environmental and organismic systems and subsystems.

3) Due to co-development, concordance, and interconnection, performances of any subsystem are also performances of the system as a whole.

More specific generalizations, illustrated in this thesis, include:

1) Physical subsystems are climate, water (oceanography), and substrate (geomorphology); differences

between natural-cultural systems are manifested in part by differences in performance of these components.

2) Performances of the cultural subsystem include management and exploitation techniques and technology; the development of these is a performance not only of the cultural subsystem, but also of the natural-cultural system as a whole. Natural-cultural systems will differ in these performances.

3) Fish catch is a performance which arises from interaction and interpenetration of all subsystems (biological, cultural, and physical); it is a performance of the system as a whole. Aspects of catch will differ between natural-cultural systems.

4) Community structure, including trophic structure, is a performance of communities, and population dynamics and life history strategies are performances of species and populations. Differences in natural-cultural systems will be manifested as differences in community structure, species population dynamics, and species or population life history strategies.

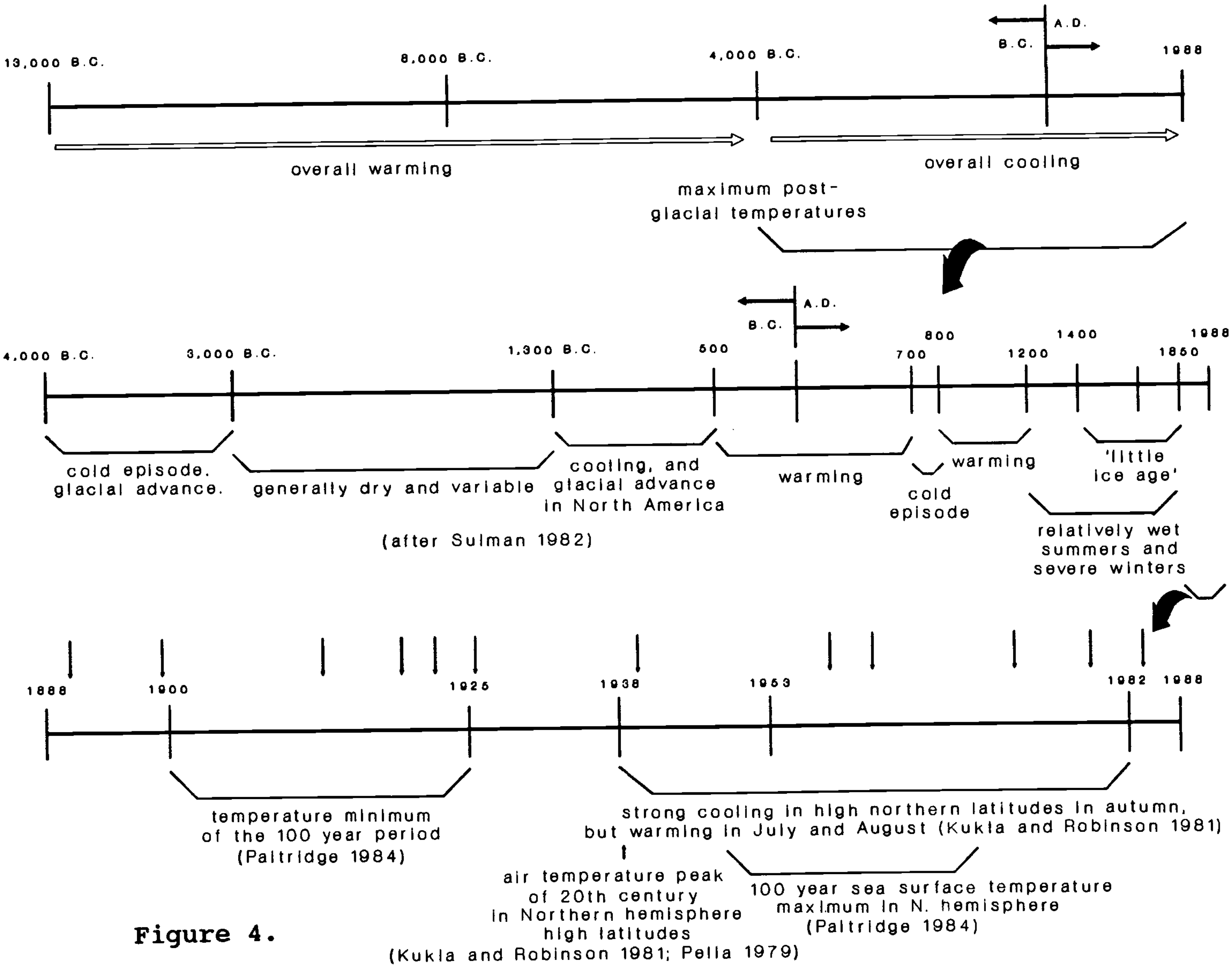
5) There are overriding aspects within the network of natural-cultural systems of the Eastern North Pacific which cause similarities in pattern of development in all natural-cultural systems within the Eastern North Pacific.

CLASSIFICATION OF THE PHYSICAL ENVIRONMENT

Many scales exist, in space and time, on which a classification of the physical environment can be based. Yet, classification systems are useful for understanding only if the characteristics of the objects classified are relatively invariant. Climatic episodes that would have affected ocean temperature, salinity, and sea level can be defined on several spatio-temporal scales (Figure 4). However, climatic variability operates within constraints imposed by global ocean circulation and ocean-atmosphere systems.

On one spatio-temporal scale, there is a great deal of variation in the physical environment of the North Pacific. El Nino events, and the anomalous oceanographic conditions connected with them, recur within the range of 2 to 7 years (Mysak 1986; Quinn et al. 1978). The recurrence interval may be regulated by oscillations in the ocean-atmosphere system of the Pacific basin (Mysak 1986). According to Berggren and Hollister (1977), global sea level glaciation, sea ice, and the cold deep-water regime of the oceans began about 38 million years ago. Repeated southward transgression and regression of polar water in the North Pacific have occurred during at least the last 1.2 million years. However, within this time period, general large-scale patterns and ranges of variability in surface circulation have been essentially the same in the North

Figure 4. Various scales of climatic variation. Top: 13,000 B.C. to the present. Middle: 4,000 B.C. to present. Bottom: 1888 to present.



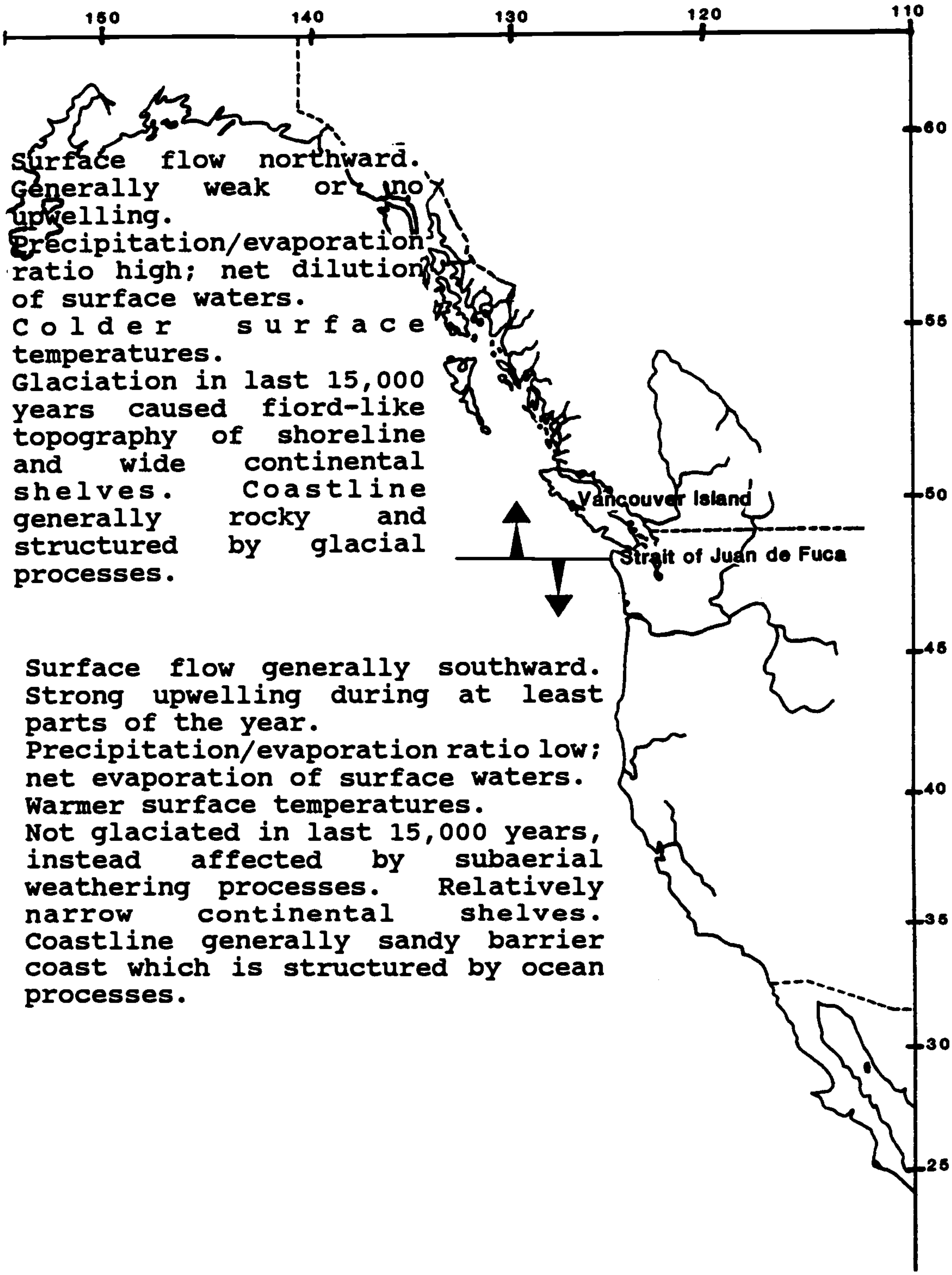
13,000 B.C.
8,000 B.C.
4,000 B.C.
B.C.
A.D.
1988
overall warming
overall cooling
maximum post-glacial temperatures
4,000 B.C.
3,000 B.C.
1,300 B.C.
500
B.C.
A.D.
700
800
1200
1400
1850
1988
cold episode, glacial advance.
generally dry and variable
cooling, and glacial advance in North America
warming
cold episode
warming
'little ice age'
relatively wet summers and severe winters
(after Sulman 1982)
1888
1900
1925
1938
1953
1982
1988
temperature minimum of the 100 year period (Paltridge 1984)
strong cooling in high northern latitudes in autumn, but warming in July and August (Kukla and Robinson 1981)
air temperature peak of 20th century in Northern hemisphere high latitudes (Kukla and Robinson 1981; Pella 1979)
100 year sea surface temperature maximum in N. hemisphere (Paltridge 1984)

Figure 4.

Pacific. Physiographic regions are therefore unified by common patterns of climate change and by a dynamic and tightly interconnected oceanic-atmospheric circulation system (Newell 1981; Mysak 1986). They are also unified by common patterns of tectonic movement which contribute to the structure and sediment characteristics of the continental margin and to the shape of the coastline.

On a coarse scale of resolution, the eastern margin of the Eastern North Pacific can be divided into two distinct regions based on parameters likely to affect the marine biological communities within the regions. These include morphology of the continental margin and shoreline, patterns of ocean surface circulation, climatology, and patterns of upwelling and downwelling, temperature, and salinity (Figure 5).

Pleistocene glacial periods shaped continental margins and shorelines. These periods created considerable changes in sea level. Indirect effects of glacial ages appear in submarine and coastal morphology and sediment patterns. Most of the present continental shelf areas of the west coast (along with those of most of the rest of the world) have been repeatedly exposed to subaerial weathering processes within the last 150,000 years (Shepard 1973), and topographic patterns and sediment characteristics of the continental margins reflect this. Margins south of the Strait of Juan de Fuca strongly reflect subaerial weathering



Surface flow northward. Generally weak or no upwelling. Precipitation/evaporation ratio high; net dilution of surface waters. Colder surface temperatures. Glaciation in last 15,000 years caused fiord-like topography of shoreline and wide continental shelves. Coastline generally rocky and structured by glacial processes.

Surface flow generally southward. Strong upwelling during at least parts of the year. Precipitation/evaporation ratio low; net evaporation of surface waters. Warmer surface temperatures. Not glaciated in last 15,000 years, instead affected by subaerial weathering processes. Relatively narrow continental shelves. Coastline generally sandy barrier coast which is structured by ocean processes.

Figure 5. Coarse-scale classification of the Eastern North Pacific.

processes, and coastlines in this area are generally structured by ocean processes; they tend to be sandy barrier coasts (Shepard and Wanless 1971).

Direct effects of the most recent glacial period (the Wisconsin) are seen in areas north of and including the Strait of Juan de Fuca (Figure 5). These areas were covered with ice sheets during the most recent glacial period. As a result, they have been heavily scoured by glaciers, resulting in a generally rocky coastline, deep, steep-walled straits, deeply incised coastlines, and many rugged offshore islands, glacial moraines, and outwash plains. Massive quantities of glacial outwash have, over vast spans of time, partially filled some basins and fjords, and helped create wide continental shelves.

Width and morphology of the continental margin (both shelf and slope) are largely a result of land-based sedimentation and tectonic processes. Representative profiles of the continental margin are shown in Figure 6. In general, from southern California (Figure 6a) to Kodiak Island Alaska (Figure 6j), the continental shelf increases in width in a northward direction with a relatively distinct change occurring at the southernmost terminus of Wisconsin glacial activity, the Strait of Juan de Fuca (Figure 5,6g). The continental slope has a northward trend of decreasing width and increasing steepness. These topographic factors partially structure available habitat for marine

Figure 6. Representative profiles of the continental margin of the Eastern North Pacific. The continental shelf is generally considered to be that region extending from the shoreline to a depth of between 110 and 200 meters (average 120 meters). The continental slope continues from the shelf break, much more steeply, down to the abyssal plain (generally 3,000 meters or more). The inshore ravine in profile g is what remains of a glacially cut trough.

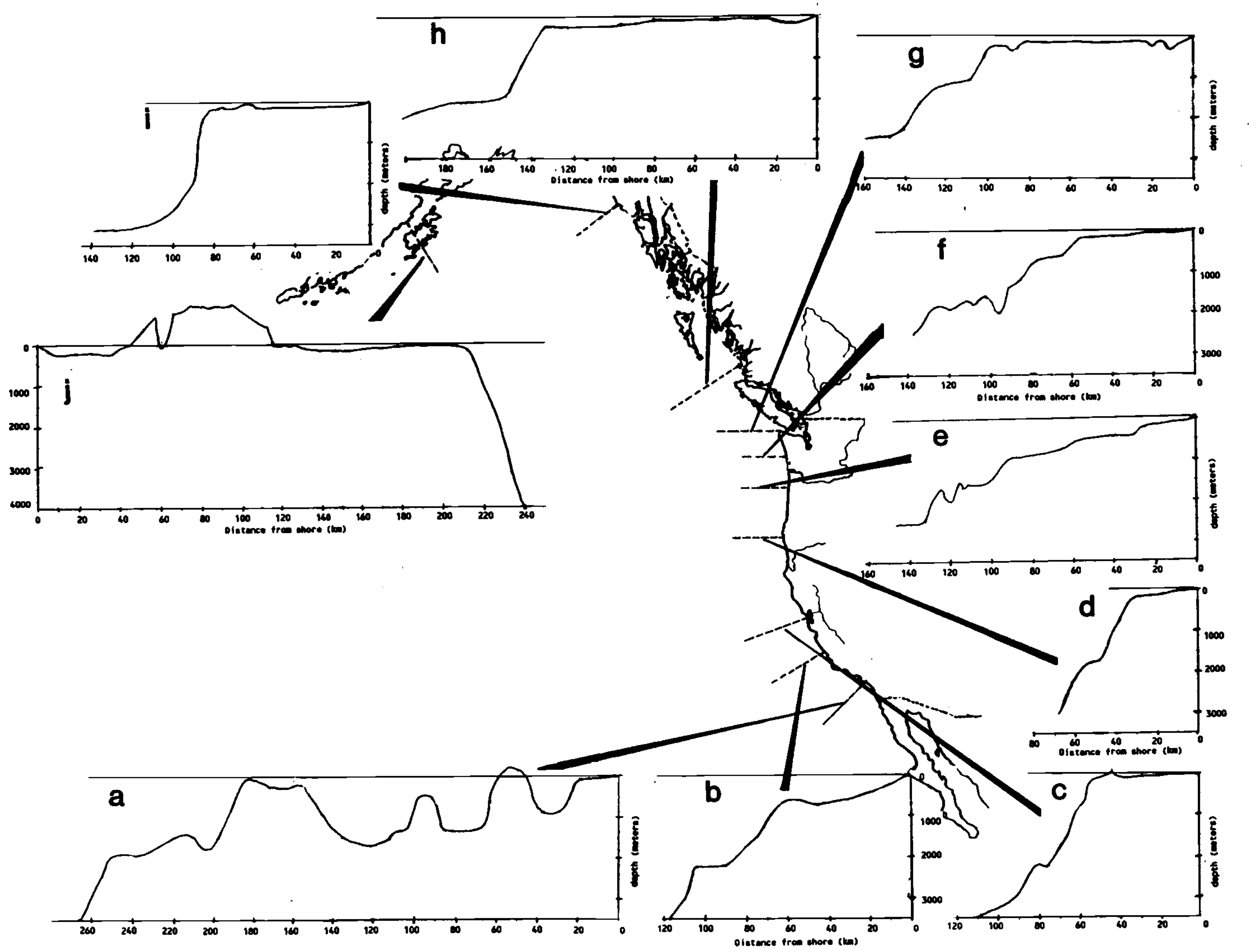

a
b
c
d
e
f
g
h
i
j
depth (meters)
Distance from shore (km)
0
1000
2000
3000
4000
260
240
220
200
180
160
140
120
100
80
60
40
20

Figure 6.

communities. General patterns of ocean surface circulation in the Eastern Pacific also allow characterization of the region into two sections. Again the boundary between regions falls at about Vancouver Island and the Strait of Juan de Fuca. The largest portion of the Subarctic North Pacific current turns to the south off Vancouver Island and continues its flow as the California current (Figure 7). North from Vancouver Island, the flow is to the north and counterclockwise as the Alaska gyre. Such patterns are significant structuring forces for the biological communities by themselves (through transport processes) and when linked with general climatology.

The combination of surface circulation and prevailing wind patterns determine patterns of upwelling or downwelling, significant as regulators of productivity and energy cycling. Figure 8 illustrates general patterns of atmospheric pressure, wind stress, geostrophic flow, and resulting Ekman transport which is linked to upwelling and downwelling patterns. In general, little or no upwelling occurs north of Vancouver Island at any time during the year (Sharma 1979; Bakun 1973). South of there, relatively strong upwelling occurs at least at some time during the year (Parrish et al. 1981; Bakun 1973).

Other climatic factors that may be used to characterize regions are temperature and salinity, though gradients in both of these occur as a north-south continuum. Temperature

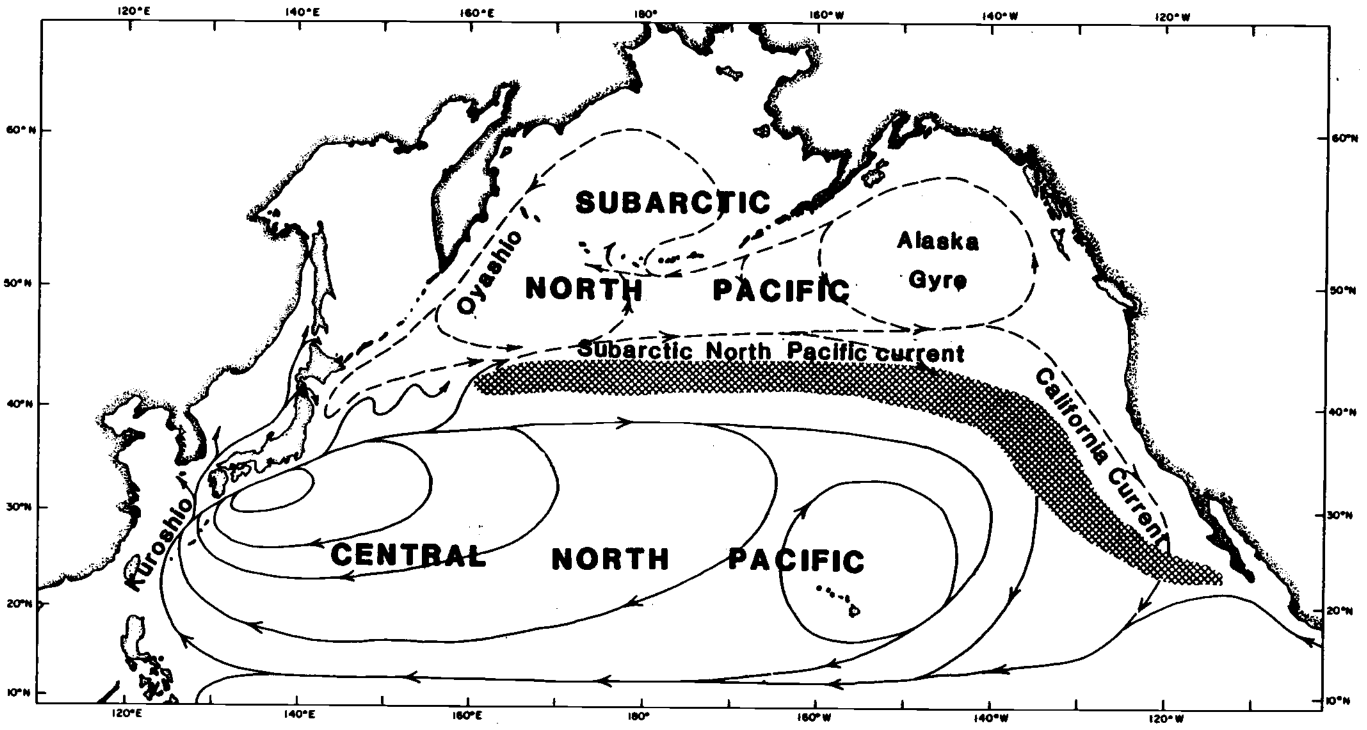


Figure 7. Large-scale generalized patterns of ocean surface circulation in the North Pacific Ocean. Hatched area is intermediate water between the Subarctic North and the Central North Pacific. Modified from Kasahara 1961. Also: Dodimead et al. 1963.

Figure 8. Patterns of atmospheric pressure (HIGH/LOW), wind stress (long thin arrows), geostrophic flow (short thin arrows), and Ekman transport (short thick arrows) for summer (left) and winter (right) over the Eastern North Pacific. Strength of Ekman transport is roughly indicated by size of short thick arrows. Offshore Ekman transport leads to upwelling, while onshore transport leads to downwelling. After: Bakun 1973, Van Loon 1984, Parrish et al. 1981, Sharma 1979, and others.

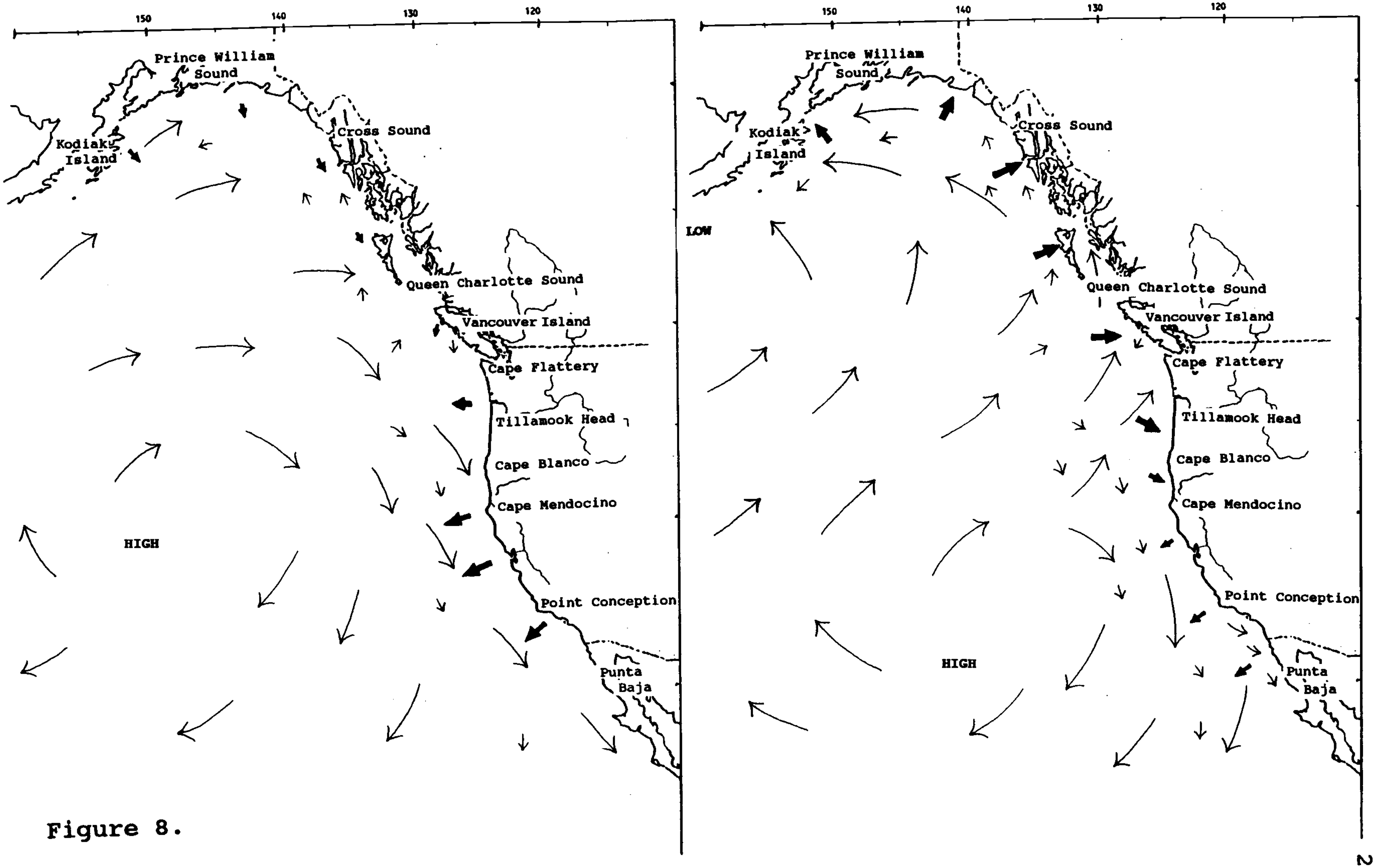

150
140
130
120
Prince William Sound
Kodiak Island
Cross Sound
Queen Charlotte Sound
Vancouver Island
Cape Flattery
Tillamook Head
Cape Blanco
Cape Mendocino
HIGH
Point Conception
Punta Baja
150
140
130
120
Prince William Sound
Kodiak Island
Cross Sound
LOW
Queen Charlotte Sound
Vancouver Island
Cape Flattery
Tillamook Head
Cape Blanco
Cape Mendocino
Point Conception
HIGH
Punta Baja

Figure 8.

and salinity partially dictate survival, growth, and reproductive rates of species. In general, mean annual temperature of surface waters increases in a southward direction. Because of coastal currents though, warm temperature isotherms bend to the north along the coast of Canada and Alaska, and because of coastal currents and upwelling, cool isotherms bend far to the south off the Pacific Northwest and California. This latter phenomenon is most pronounced in summer (Robinson and Bauer 1976). In deeper waters, annual (and latitudinal) temperature ranges are smaller (Dodimead et al. 1963).

The Subarctic North Pacific is a region of overall net dilution of surface water; the precipitation/evaporation ratio is highest in the northern end of the range, and decreases radically to the south (Figure 5). Mean annual surface salinities are lower (by as much as 4.5 ppt) in the Gulf of Alaska than in Southern California (Robinson and Bauer 1976).

Definition of physiographic regions

On a finer scale of resolution, physiographic regions can be defined. These regions and their geomorphic, oceanographic, and climatic characteristics are shown in Figure 9 and are further characterized below.

Geology and geomorphology of coastline and margins

Punta Baja to Point Conception

The continental margin from Punta Baja to Point

Figure 9. Physiographic regions resulting from a classification of the eastern margin of the Eastern North Pacific.

A = 'Continental borderland' basin and range topography. Margin affected by faults. Upwelling year-round, but quite weak in winter, strong in summer. Closed gyral surface circulation near coast.

B = Narrow continental shelves. Many submarine canyons. Rugged mountainous fault coast characterized by granitic and volcanic promontories, and the San Andreas fault. Upwelling strong in summer, weaker in winter. Downwelling may occur during winter storm events.

C = Shelves relatively narrow. Slope gradual. Continental margin ends in subduction zone. Very narrow coastal plain. Strong summer upwelling; weak winter downwelling.

D = Shelves relatively wider (to ca. 30 km). Margins end in subduction zone. Barrier coast; soft sedimentary rocks interspersed with hard volcanics. Moderate summer upwelling, winter downwelling. No submarine canyons.

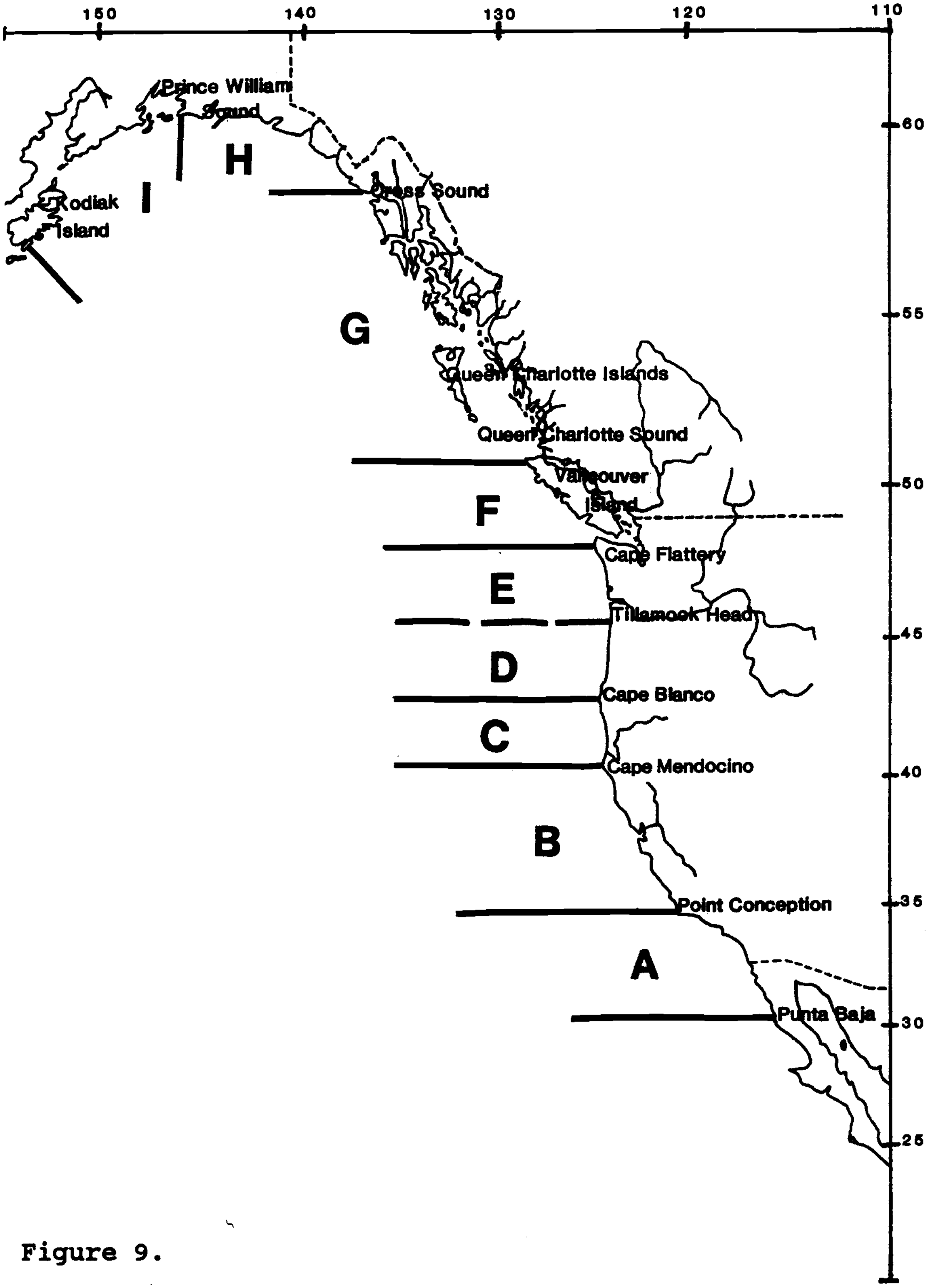
E = Same as below except submarine canyons exist. 'Glacial margin' geology.

F = 'Glacial scour' topography. Shelves relatively wide (to ca. 80 km). Very weak summer upwelling, winter downwelling. Surface currents transitional: generally southward nearshore, northward offshore.

G = 'Glacial scour' topography. Shelves very wide (to 100+ km). Geology affected by Queen Charlotte fault. Strong winter downwelling; non-existent or very weak summer upwelling. Currents disrupted locally by islands and uneven shoreline.

H = Coastal plain actively glaciated to sea level. Geology affected by active faults. Strong winter downwelling. Weak summer upwelling.

I = Mountainous fault coast. Glaciers deteriorate to the south. Continental margin ends in deep Aleutian trench. Strong winter downwelling, summer upwelling.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Prince William Sound
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Kodiak Island
Cross Sound
G
Queen Charlotte Islands
Queen Charlotte Sound
Vancouver Island
F
Cape Flattery
E
Tillamook Head
D
Cape Blanco
C
Cape Mendocino
B
Point Conception
A
Punta Baja

Figure 9.

Conception is known as the 'continental borderland.' This region, considered to be part of the continental slope (rather than the shelf), is a continuation of the basin and range topography that characterizes the adjacent land area (Figure 6a). For example, the set of channel islands off Santa Barbara (San Miguel, Santa Rosa, Santa Cruz) is thought to be a continuation of the Santa Monica mountains north of Los Angeles (Shepard and Wanless 1971).

The continental shelf in this region is quite narrow; it may be 10 to 25 km wide at the larger bays, but at some points, submarine canyons reach a head within 1 km of the shoreline. Basins in the continental borderland become progressively deeper with distance offshore. These basins are separated by islands, island ridges, and banks. High levels of tectonic activity are indicated by numerous escarpments. The continental slope terminates to the southwestward with the Patton escarpment which drops steeply to the abyssal plain (1500 m in 7 km). Continental borderland topography stops in a line south of Point Conception.

The coastline is largely protected from heavy ocean pounding by the Channel Islands, but straight wave-cut cliffs and wave-cut terraces do occur. Deltaic plains built out from the mountains are indicative of the vast amounts of sediment carried by the occasional but characteristic heavy floods. Several of the major cities in the region are built on these plains, including Los Angeles and Santa Barbara.

Point Conception to Cape Mendocino

The San Andreas fault in this region occurs very close to the coastline (Figure 10), resulting in very high levels of generally horizontal tectonic activity; east-west displacement of topographic features is common. The coast is mostly very mountainous, in some places consisting of fault cliff faces as high as 300 meters which are sliced off mountain ranges. Prominent points and capes are granitic or volcanic ridges, and sometimes are extensions of coastal mountain ranges. Coastal terraces also occur.

The region is characterized by a very narrow continental shelf (Figure 6b): south of San Francisco Bay, the shelf at its widest is less than 15 km, but the slope is wide, gradual, and smooth, the base occurring 60 to 120 km from shore. North of San Francisco Bay, the shelf at its widest is 30 km, but the continental slope is much steeper. Submarine canyons come to a head right at the coastline, though north of the bay it is more common to find them coming to a head at the shelf break.

San Francisco Bay appears to be the only area of subsidence in a region otherwise characterized by uplift. It is thought to be a fault-formed bay that receives most of the drainage of California through the Sacramento and San Joaquin rivers. Both southern and central California

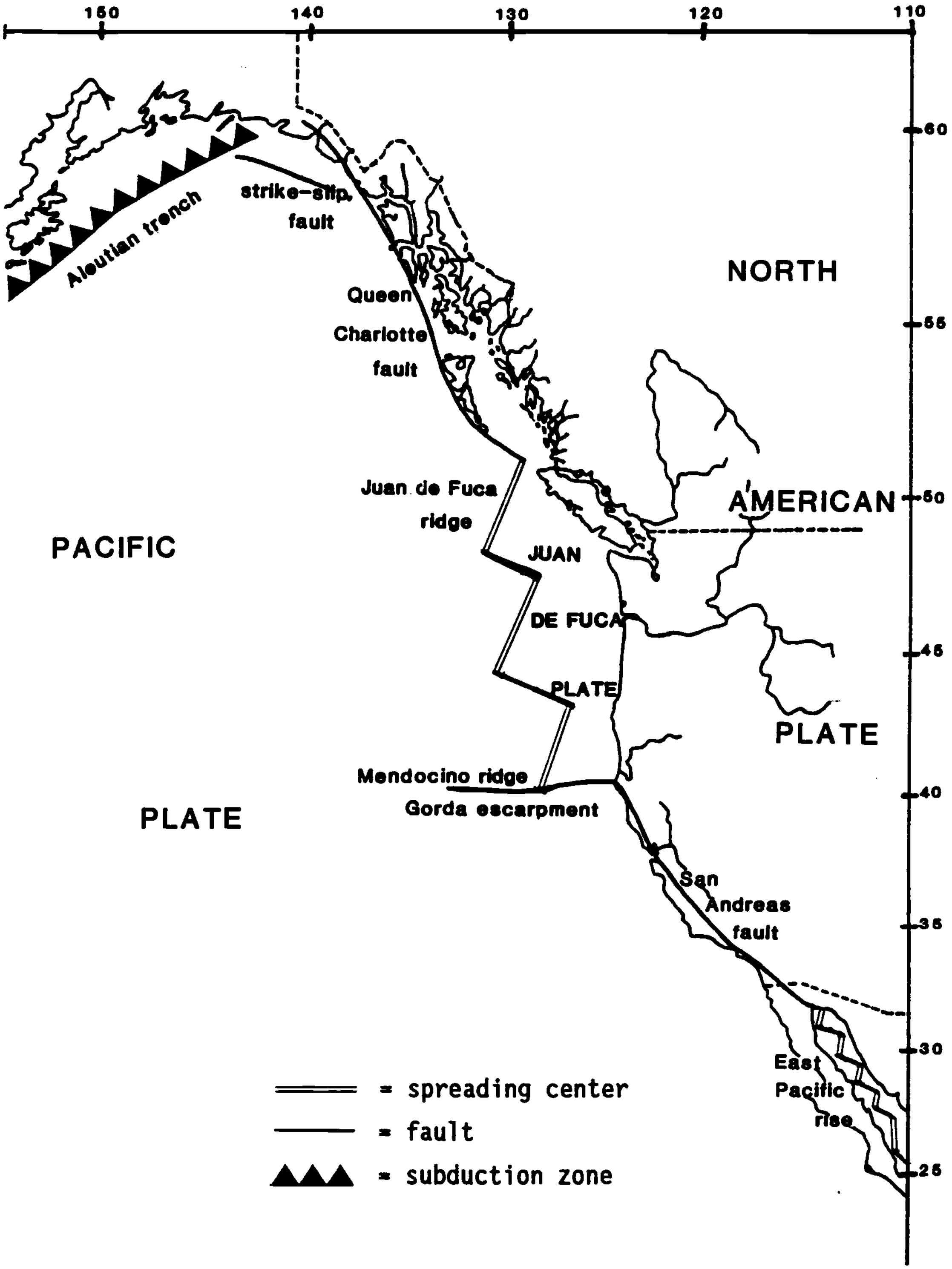


Figure 10. Major tectonic features of the eastern margin of the Eastern North Pacific.

are subject to occasional severe flooding. These events, occurring on otherwise very arid land, carry a large load of silt and sediment. A testimony to the quantity of sediment carried during these floods is the depth of San Francisco Bay; the majority of it (80%), despite relatively recent subsidence, has remained shallower than 10 meters (Shepard and Wanless 1971). A second testimony is the relative shallowness of the Gulf of the Farallons, a shelf basin which extends seaward of the Golden Gate Narrows to the Farallon Islands about 50 km offshore (Figure 6c). This gulf is generally less than 100 meters deep and is the widest area of shelf in the region. Seaward of the Islands, the Farallon escarpment drops relatively rapidly to abyssal depths (2,850 m in 25 km).

The northern end of this region is the Mendocino ridge-Gorda escarpment (Figure 10) which is the westward continuation of the San Andreas fault. This ridge represents the northern termination of the mountainous fault coast.

Cape Mendocino to Cape Blanco

The Mendocino Ridge is the location of the southern terminus of the Juan de Fuca spreading center which runs as far north as Queen Charlotte Sound (Figure 10). From Cape Mendocino north into Canada, volcanic activity is prevalent due to the subduction zone present; the Juan de Fuca plate is sliding under the continental crust. From Cape Mendocino northward to Cape Flattery, the coastline is a 'barrier coast'; many areas are structured by beach depositional processes. Coastal rocks are soft sedimentaries interspersed with more resistant volcanics which form points and headlands, and the coast alternates between sandy beaches and dunes and basaltic cliffs.

The Cape Mendocino-Cape Blanco area is distinguished from the region to the north by its extremely narrow coastal plain. Though also a barrier coast (like the coast to the north of it), coastal mountains rise abruptly, and the shoreline is still quite uneven.

Cape Blanco to Tillamook Head

The continental shelf in this region continues its northward widening, increasing from 12 to 33 km (Figure 6d,e). Significant bank areas occur on the slope at a distance of 30 to 60 km from shore. No major submarine canyons exist in the entire region. The coastline is very straight; the only significant interruption of the straight line is the drowned river mouths which form bays and estuaries. As an area included in the barrier coast region, great quantities of sand are transported along the coast (Shepard and Wanless 1971), and sand spits and barriers have formed at mouths of most rivers in the region.

Columbia River and the Washington coast

Only the northernmost portion of the Washington coast was covered by ice sheets during the last glacial age. The southern Washington coast is characterized by deeply incised and drowned river valleys (Columbia River, Willapa Bay, Grays Harbor, all associated with large submarine canyons). These were thought to be formed by meltwater cutting through a region that, at the margin of the glacier, bulged more strongly upward than it does today. In the northern portion of the Washington coast (the Olympic peninsula), glaciers ran through the river valleys, but the rivers here do not have drowned mouths. The southern portion of the Washington coast therefore appears to be a post-glacial subsidence coast, while the northern portion is not (Shepard and Wanless 1971). Partially as a result of glacially transported sediments, the continental shelf here is quite wide (Figure 6f,g).

Aside from river valleys, the Washington coastline is relatively straight, and as a barrier coast, much sand is transported northward from the Columbia river creating spits across river mouths.

Cape Flattery to Cross Sound

Northward of the Strait of Juan de Fuca, ice sheets directly affected the coastline. Straits, sounds, and river valleys were glacially scoured, and therefore have steep sides. The coast is a fiordland with outlying rugged islands: Vancouver and the Queen Charlotte Islands to the south, and a 100-mile-wide band of the Alexander Archipelago to the north. Much of the region is characterized by a lack of topsoil or flat land. The shortage of flat land is revealed in the location of many towns in the Alaska panhandle which are built on river fan-deltas (areas which tend to be highly unstable during earthquakes). Glaciers exist today in mountainous areas, but in general do not approach sea level south of Cross Sound.

The continental shelves from Queen Charlotte Sound northward are very broad - up to 100 km wide - partially because of the massive amounts of silt and debris deposited from glacial melt-waters (Figure 6h,i). Deep troughs were cut across the shelves by glaciers, and remnants of these still remain [for example, the trough seaward of the Strait of Juan de Fuca (Figure 6g)], though many of these troughs have been significantly filled with sediment by retreating glaciers.

The northernmost reach of the Pacific spreading center (in this region known as the Juan de Fuca ridge) approaches the base of the continental slope off Queen Charlotte Sound (Figure 10). From this point northward, to about Yakutat Bay, the coastal region is believed to be a transform fault known as the Queen Charlotte fault (Circum-Pacific Map Project 1984; Ingmanson and Wallace 1985; Isacks and Oliver 1968) though there is some debate on this question (Dewey 1972; Thurman 1987). While tectonic movement in southern California is mostly horizontal, the Alaska coast, virtually in its entirety, is characterized by vertical movement (Shepard and Wanless 1971), and earthquakes and rockslides are very common.

Cross Sound to eastern Prince William Sound

North of Cross Sound, glacial activity still plays an important role in shaping the landscape. Glaciers reach the sea, and the streams entering the sea are often milky with silt-laden runoff. The coastline is a lowland coastal plain at the base of the high coastal mountains. The Aleutian trench and Queen Charlotte fault meet in the area (Figure 10), and tectonic activity of the continental margin may be affected by these and by a prominent strike-slip fault that occurs off the shelf along the entire area. The shelf is quite wide and the slope very steep (Figure 6i).

Eastern Prince William Sound to southern Kodiak Island

Kodiak Island represents the southwest end of the coastal mountain system which also forms the Kenai peninsula and the Chugach mountain range (Figure 10). This region also experiences much tectonic activity; an area of subsidence running from Kodiak Island across much of the Kenai peninsula and Cook Inlet is bordered on both sides by areas of uplift (Shepard 1973). Here also, most of the only flat land is river deltas or glacial outwash plains which, during earthquakes, have been known to slump into the steep fjords on which they are built. The cities of Anchorage and Seward are built in such areas. Glaciers reach the sea in the northern portion of this region, but become much less prominent to the south. No glaciers occur on Kodiak Island.

The continental shelf in this region is very wide (Figure 6j), and the slope is very steep, dropping into the deep Aleutian trench (to 6500 m), a zone of subduction of oceanic crust.

Oceanography/Climatology

Upwelling indices for the west coast, from Baja north to the Kenai Peninsula, are shown in Figure 11. Anomalous oceanographic events like El Nino occurrences not only have temporal, but spatial significance since their effect varies between regions. In areas where upwelling generally occurs, there is a reduction or lack of upwelling in warm El Nino-like years coupled with increased ocean temperatures (Mysak 1986; Enfield and Allan 1988). Shifts in oceanographic patterns then potentially have greatest effects in regions of general year-round upwelling.

Upwelling indices and classification schemes based on them are therefore subject to considerable variation. However, as factors structuring the biological systems in the regions, mean annual patterns are potentially of as much interest as is variability.

Punta Baja to Point Conception

Parrish et al. (1981) classified several areas within the California current based on ocean-atmosphere conditions: the southern California Bight, Cape Blanco to Point Conception, and the Pacific Northwest (and a southern Baja, California region which is out of the range of this

Figure 11. Upwelling indices from various regions of the Eastern North Pacific. Indices are m^3 sec^{-1} per 100 meters and are averages calculated over 25 years. Letters at the top (J through D) axis correspond to months of the year, so indices are for 1 year. From Bakun 1973.

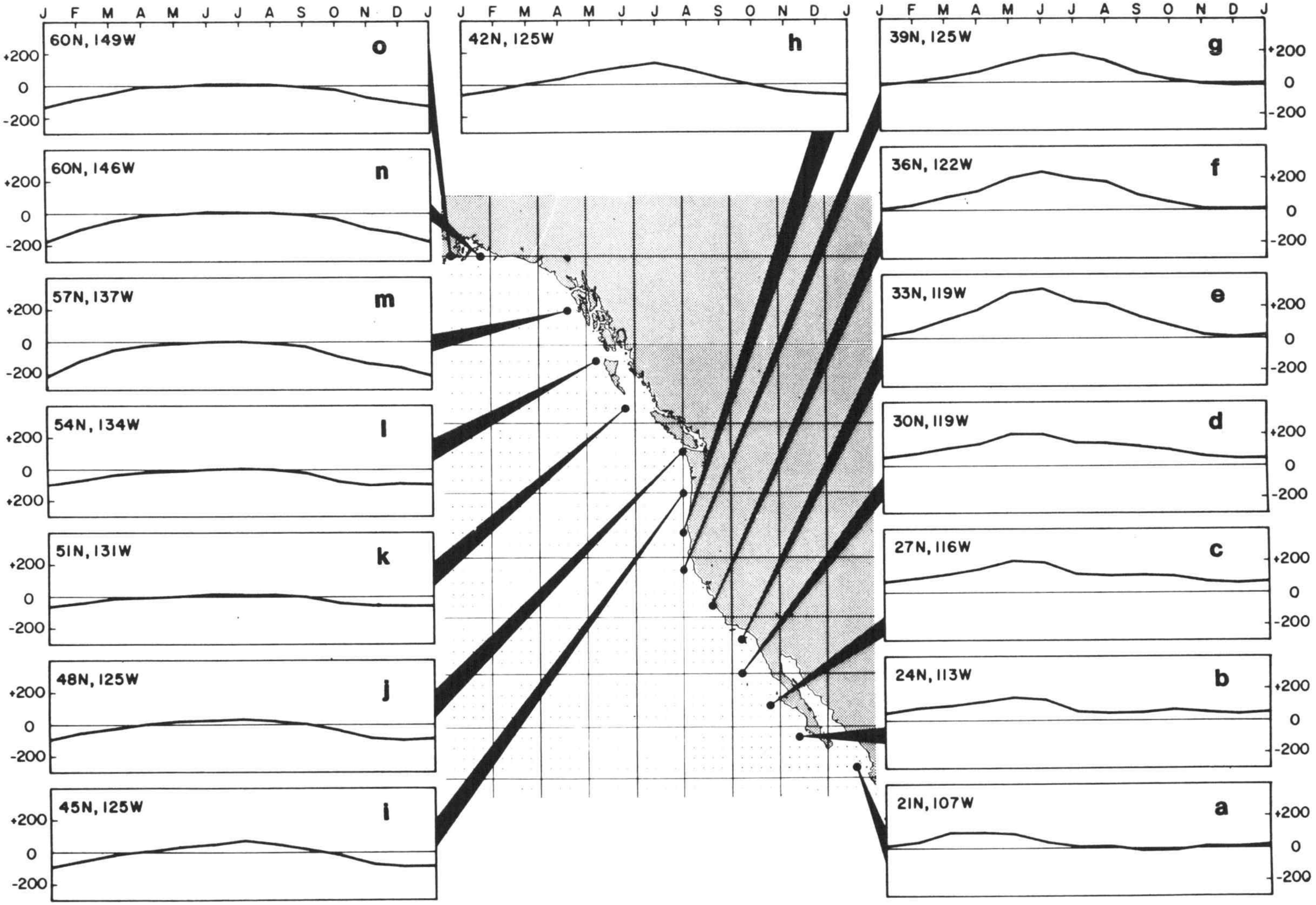

J F M A M J J A S O N D J
60N, 149W o
60N, 146W n
57N, 137W m
54N, 134W l
51N, 131W k
48N, 125W j
45N, 125W i
42N, 125W h
39N, 125W g
36N, 122W f
33N, 119W e
30N, 119W d
27N, 116W c
24N, 113W b
21N, 107W a
+200
0
-200

Figure 11.

study). In the region between Punta Baja and Point Conception (the southern California Bight), winds come from the northwest year round. Ekman transport is offshore (Figure 8, short, thick arrows), and upwelling occurs year round (Figure 11d,e), though it is weaker in winter than in summer. Geostrophic flow tends eastward to southeastward (Figure 8, short, thin arrows), creating a gyral which tends, at least near shore, to somewhat counteract offshore Ekman transport.

Point Conception to Cape Mendocino

Between Point Conception and Cape Mendocino, predominant winds blow from the northwest year round, though stronger in summer (Figure 8). Since geostrophic flow is also in this direction, Ekman transport, and therefore upwelling, is offshore year round, and is very strong in summer, and somewhat weaker in winter (Figure 11f,g).

Cape Mendocino to Cape Blanco

This region is somewhat of a transition area between its two bordering regions. As in the regions to the south, strong summer upwelling occurs, while in winter, as in the region to the north, downwelling occurs, though weakly (Figure 11h).

Cape Blanco to Vancouver Island

Cape Blanco to northern Vancouver Island is an area of non-uniform geostrophic flow. Though near the coast in the vicinity of the Columbia River the flow is northward, in general it is a southward flow. Seasonal winds create alternating patterns of Ekman transport (Figure 8; short, thick arrows). In summer, predominant wind direction is dictated by the California subtropical high pressure system and therefore is from the northwest. This creates offshore Ekman transport and consequent weak summer upwelling (Figure 11i,j). In winter, the influence of the Aleutian low pressure system creates winds that blow predominantly from the southwest, and Ekman transport is onshore, leading to downwelling. During frequent winter storms however, wind direction is reversed and pulses of upwelling occur (Parrish et al. 1981).

Vancouver Island to Kodiak Island

The region from Vancouver Island to Kodiak Island experiences relatively uniform (within the region) conditions. Geostrophic flow is around the Gulf of Alaska in a counterclockwise direction (Figure 8, short, thin arrows), but direction of wind stress is reversed between winter and summer (Figure 8, long, thin arrows). In winter, wind flows generally with the surface current, a situation that leads to very strong onshore Ekman transport and downwelling (Figure 11k-o). In summer, wind flows generally against the geostrophic current. Weak upwelling during this period does occur in the western Gulf of Alaska (Sharma 1979), but generally does not occur in the eastern Gulf of Alaska (Bakun 1973).

An apparent break in this relatively uniform picture may occur because of large coastal islands which create blocks to uniform flow, and tend to cause turbulence and local upwelling. Therefore, nearshore currents are likely to be largely influenced by island structure and location, and tidal flushing from sounds and fjords.

The Prince William Sound to Kodiak Island region is distinguished from the eastern Gulf of Alaska by the occurrence of weak summer upwelling (Figure 8).

DEVELOPMENT OF NATURAL-CULTURAL SYSTEMS

In general, the rate of development of cultural subsystems within natural-cultural systems of the Eastern North Pacific has been too great to readily permit a spatial classification that is relevant over a hundred year period. Interpenetration between regions is created by exchange of information and technology between fishermen and between managers, and this exchange occurs quite rapidly. In a historic view, the pattern of development, rather than specific static traits, become the most apparent performance of cultural subsystems. Differences in cultural patterns are reflected in catch patterns over time. The historical context of exploitation is used here as a tool for understanding catch patterns.

Historical context of fishery exploitation

1850 - 1900

During this period, intense economic development in America was being encouraged. There was a great push to expand the economy even at the expense of seemingly needless destruction of natural resources. Gold mining, logging, and milling all depended heavily on streams, and all these activities severely degraded fish habitat. Private assets were the key to effective legal action, and the social costs of economic development remained unaddressed. Though the U.S. Fish Commission was established in 1871 to study declines in coastal fish stocks, the Commission was not legally capable of regulating all of the economic activities that degraded fishery habitat, and it was not until almost 1900 that the first court challenges were won in favor of commons resources (McEvoy 1986). It was in California where impacts of these activities were most heavily felt in the early years of the fisheries (Collins 1889; McEvoy 1986). Salmon stocks in many areas were depleted due both to heavy, uncontrolled fishing effort, and to destruction of spawning habitat. During the 1880's and 1890's, the legal and social structure in this country not only was largely unfavorable for challenging the destruction of habitat, but also promised few means for enforcement of regulations that limited exploitation.

The management response to resource crises occurring with anadromous fish was to promote artificial propagation of fish through hatchery programs, and through stocking rivers with non-native species that promised increased production levels. The immediate response of salmon stocks to hatchery production seemed to be favorable, though a change in conditions of climate could also have been the cause of increased production (McEvoy 1986), and the biological and genetic consequences of these plantings were never studied (Regier and Applegate 1972). However, the effective cultural result of the management 'solution' was a reinforcement of habitat destruction, since fishery managers "seemed to fulfill the promise . . . that applied science could revive and sustain the productivity of a ravaged environment without requiring any fundamental changes in the ways in which people used it" (McEvoy 1986).

<u>1880 - 1915</u>

This period was characterized by increased movement of fishers away from their home ports due to the beginnings of mechanization; steam tugs, then gasoline engines replaced sail power. More different kinds of fishing gear were put to use: besides gill nets, beach seines, and fish wheels, purse seines, paranzella nets (trawls towed between 2 boats), and salmon traps came into use by 1870. Troll gear came into use by the 1880's (Browning 1974). Markets for fish products were expanded due to the beginnings of train transport of fresh iced salmon and halibut in the 1890's (Browning 1974; Hart 1973), and to improvements in product preparation. Market factors were also improved during World War I which had the effect of triggering a 'liberalization' of fisheries; restrictions were removed or loosened to provide protein and fishery by-products for the country (Regier and Applegate 1972; McEvoy 1986).

The U.S. Fish Commission responded to this situation by encouraging development and expansion of unutilized or 'under-utilized' fishery resources. Fishers generally responded quite readily to this encouragement. State fishery agencies during this time were somewhat more habitat oriented; they were concentrating on pollution controls, and on building fishways around dams (McEvoy 1986).

It was also in the early 1900's that studies of population dynamics evolved as management tools; concepts such as maximum sustainable yield (MSY), catch per unit effort (CPUE), stock overfishing, and growth overfishing, were developed. However, the fishers responded to controls far less favorably than they did to expansion and diversification.

Mid- 1920's

It was northward and seaward expansionism that caused the first international fishery conflicts; these occurred with Canada over halibut stocks. This conflict triggered a push for greater research - especially on those species which crossed international boundaries. The International Pacific Halibut Commission was established primarily as a research organization, but had some limited regulatory powers, using MSY as a base for harvest levels. However, the main conflict resolution technique used by management to deal with international and user group conflicts relied on inefficiency measures: specifically, season restrictions (in the halibut fishery), gear restrictions (in the Columbia River salmon fishery), and vessel restrictions (epitomized by the 'Alaska limit' boat where vessel size was limited [Browning 1974]).

The fishers responded to the imposition of inefficiency measures by developing new fishing methods that would increase efficiency, but in ways not specifically prohibited by regulations. In other words, imposition of inefficiency measures required of fishers the same flexibility and the same skills that were necessary for them to make a living in a changing environment; they adapted old tools and methods in new ways to meet the demands of new situations. Development of already existing and more efficient gears were used in various new fisheries; for example, 1925 marked the very early beginnings of the trawl fishery on the west coast (Browning 1974), as well as the use of purse seines to catch sardines (McEvoy 1986).

Mid 30's - mid 40's

Depletion of salmon stocks continued during this period. Stocks which were utilized by competing groups of fishers - such as Fraser River sockeye utilized by the U.S. and Canada - and affected by dam building were especially impacted. This period also marked the beginning of the seemingly abrupt end of the sardine fishery. These problems were occurring while ecological studies were showing no clear evidence to support the conclusion that hatcheries were doing any good (McEvoy 1986; Regier and Applegate 1972), and while very serious conflict was occurring between state and federal fishery management agencies especially with regard to sardine management (McEvoy 1986).

The management response to depletion of Fraser River sockeye was to provide a very specific solution similar to that proffered by the formation of the Halibut Commission; the International Pacific Salmon Fisheries Commission was established in 1937 between the U.S. and Canada to assure maximum production and an equal share of Fraser River stocks (Kasahara and Burke 1973). In response to state-federal power struggles, the states of California, Oregon, and Washington formed their own fishery research organization - the Pacific Marine Fisheries Commission - and the state of California made an attempt to regulate the sardine harvest indirectly by imposing product restrictions where limits were placed on the quantity of sardines that could be used for reduction.

The fishing industry used the internal management conflicts to its temporary advantage; it sided with the less restrictive federal agency by simply putting sardine reduction plants onto ships which they moved 3 miles offshore (Ahlstrom and Radovich 1970). The state had no jurisdiction outside the territorial sea (3 miles), and in 1945 temporarily lost jurisdiction of even that region since the Truman Proclamations, partly a move to develop an offshore oil industry, effectively handed management of fisheries of the territorial seas over to the federal agencies.

Advancements in technology (as the otter trawl came into common use) and seaward expansion of the resource base (ocean trolling for albacore expanded) continued during this period. The World War II years had the apparent effect of altering patterns of exploitation. Pressure on some species was relieved, while it was increased on other previously underexploited species; for example, a dogfish shark (Squalus spp.) fishery took place only during this time, since shark livers were used for production of vitamin A and fish oils (McEvoy 1986; Browning 1974; Anonymous 1987).

Mid-40's to mid-50's

In the 1945 Truman Proclamations the U.S., as a world naval power with an interest in maintaining 'freedom of the high seas,' laid claim to only a 3-mile territorial sea. This occurred in contrast with much of the rest of the world, where 12-mile territorial seas were becoming common (Jacobson 1983). And in the case of the Santiago Proclamation (1947) involving Chili, Peru, and later Ecuador, a claim was made asserting sovereignty over 200 miles. Because of the limited nature of U.S. control over its adjoining seas, large trawlers from the great distant-water fishing countries of Japan and the Soviet Union began to fish off the U.S. coasts, and they fished legally, and without limits.

U.S. fleets were at the same time rapidly increasing their efficiency; it was during the late 1940's that artificial fibers began to be used in net manufacture, thereby increasing efficiency by a factor of two or three (Regier and Applegate 1972). In the early 50's the power block and net drum came into use with the consequent capability of hauling purse seines and other nets aboard more rapidly and with much smaller crews (Browning 1974). The result of these increases in efficiency was increased fishing pressure which tended to mask declines in many stocks (Regier and Applegate 1972) as well as to increase conflict with foreign fleets.

A major management crisis came to a head during this time with the disappearance of Pacific sardine stocks. In 1953, Congress attempted to calm state-federal management agency struggles by ceding control of the territorial sea back to the states through the Submerged Lands Act, though this was too late for the sardine fishery. The second major resource crisis appearing at this time - conflict with foreign fishers over salmon and halibut - intensified in proportion to technological advancements made in the U.S. fleet. Management again adopted very specific measures; the U.S., Japan, and Canada entered into an agreement by establishing the International North Pacific Fisheries Commission (INPFC) in 1951. Here Japan agreed to several principles of abstention: namely, it would refrain from fishing for salmon of U.S. origin east of 175 degrees west longitude (Kasahara and Burke 1973). It would also abstain from fishing for halibut and herring off U.S. coasts. In retrospect, the success of this treaty was marginal, since the Soviets, non-members of the INPFC, continued to fish legally in the same areas and for some of the same species that the Japanese had given up, and since many salmon from U.S. rivers travelled west of the longitude specified in the international treaty (Kasahara and Burke 1973).

Conflicts were also arising with Latin American countries bordering the eastern tropical Pacific since the majority of American tuna catches were made south of U.S. coastal regions (McEvoy 1986). Threats to the American fleet's tuna supply were dealt with in two ways: the Inter-American Tropical Tuna Commission was established in 1949 between the U.S. and Costa Rica (with later additions of Panama, Ecuador, and Columbia) with the specified intent of the "gathering...of factual information to facilitate maintaining. . . populations of yellowfin and skipjack tuna. . . in the Eastern Pacific Ocean" (Inter-American Tropical Tuna Comm. 1952). In 1953, intense conflict over tuna resources and international disagreement over control of fishing zones prompted the U.S. Congress to adopt the Fisherman's Protective Act which reimbursed "owners of U.S. vessels seized for fishing in what the United States considered international waters" that is, in waters more than three miles off any coast (McEvoy 1986). It was within the context of these fishery conflicts that proceedings of the United Nations Conference on the Law of the Sea began in 1958.

Control of the increasingly efficient domestic fleet still depended on inefficiency measures, especially gear restrictions and quotas. MSY became the predominant 'doctrine' for managing fishery resources at this time, though in a fishery that is rapidly expanding technologically, this concept has major shortcomings (Larkin 1977).

The response of fishers to these political and managerial arenas might be briefly summarized by saying that domestic fishers readily blamed foreigners for declines in catch of some species, while these same fishers were quick to expand their operations and efficiency and to resist controls on their activities.

60's & 70's

There were two major aspects to fishery resource crises of the 60's and early 70's. Foreign fishing continued more strongly than ever. The Soviets had not signed the U.N. Law of the Sea (UNCLOS I & II) agreements, and a third series of UNCLOS proceedings were just beginning, so they continued to fish in waters currently held sovereign by the U.S. By the mid-1960's they had developed very effective mid-water trawls resulting in severe depletion of Pacific ocean perch and overfishing of some other species. It was because of the ineffectiveness of removing the Soviets from these fisheries that Japan was removed from its abstention status for halibut fishing - the strategy which had been agreed to in the INPFC treaty (Kasahara and Burke 1973). This problem, coupled with domestic problems of overfishing and environmental degradation of streams, rivers, estuaries, and nearshore environments (for example, the 1969 Santa Barbara oil blowout), created a growing list of overfished and depleted species (Niblock et al. 1977).

The growing awareness of environmental degradation promoted a spate of environmental legislation in the 70's, including the Clean Water Act, National Environmental Policy Act (NEPA), and Marine Protection, Research, and Sanctuaries Act (MPRSA). In response to increasing pressure from the fishing industry, Congress first adopted a 12-mile exclusive fishing zone (1966), then in 1976 adopted the Magnuson Fishery Conservation and Management Act. This act established a 200-mile zone of exclusive U.S. fishery jurisdiction, but excluded 'highly migratory species' from the treaty, an exception made to circumvent jurisdictional claims by Latin American countries who wanted to control American tuna fishers off their coasts (Hildreth and Johnson 1983). The Magnuson Act also attempted to resolve state-federal management conflicts by setting up regional councils for the purpose of developing management plans.

In the management realm, the 'MSY doctrine' was giving way to the somewhat more encompassing, but much more vague 'optimum yield' (Larkin 1977). Though optimum yield (OY) is an attempt to incorporate economic, social, and ecological factors into management strategies, the harvest levels that it specifies are based on extremely subjective, judgmental decisions (Niblock et al. 1977), and the proportion of biological information that it incorporates is unclear.

Since Magnuson

In spite of environmental legislation, pollution and habitat degradation of marine and riverine systems are still a problem. Construction of dams for hydroelectric power has created very large losses of spawning habitat for salmon and steelhead, especially in California and the Pacific Northwest (Anonymous 1988).

Since the implementation of the Magnuson Act, the U.S. industry has largely taken over catches that were once exclusively or largely made by foreign fishers. Most marketable resources are being exploited, and improvements in fishing technology (especially electronics) continue. Overexploitation remains a problem because of overcapitalization in the industry; harvesting capacity far outstrips the productive capacity of the resource (Anonymous 1987). Groundfish landings have increased tremendously during this time. Overcapitalization is in many cases causing economic instability, especially in the face of environmental variability, a factor which became especially apparent during the last El Nino years ('82-'83).

Domestic management practices are even now restricted to ever tighter controls through inefficiencies. There is some talk of limiting entry, at least in groundfish fisheries, and limited entry programs have been started in some cases, but this largely remains a politically volatile alternative. There are also the tenuous beginnings of a more integrated approach to the management of fisheries. The fishing community is beginning to realize the problems with unlimited access and overexploitation, but that community is still characterized by an attitude of strong independence, while it continues to invest ever more money into fishing equipment (Anonymous 1987).

METHODS OF COMPILATION AND ANALYSIS OF CATCH DATA

Catch data was compiled from commercial fishery statistics. A goal was to cover approximately a 100-year period of the commercial fishery in order to be able to examine and analyze patterns of fishery development. The following sets of years within this period were chosen for analysis: 1888, 1922-28 (referred to as the 1920's), 1942-51 (referred to as the 1940's), and 1967-76 (referred to as the 1970's). It was intended that time periods examined be spaced relatively evenly, but these particular sets of years were chosen on the basis of consistency of methods of data collection within a group of years without any prior knowledge of fishery activity during that period. Regions for which catch data was compiled are shown in Figure 12. These regions correspond to management areas defined by other agencies in the following manner: Southeast Alaska is the region designated as such by the state of Alaska and runs from the Canadian border to Point Suckling, just east of the Copper River delta. This corresponds roughly to the International North Pacific Fisheries Commission (INPFC) statistical areas of Southeastern (Alaska) and Yakutat combined (International North Pacific Fish. Comm. 1976). It also corresponds to a combination of contiguous parts of two of the previously defined physiographic regions: northern Vancouver Island to Cross Sound, and Cross Sound to Eastern Prince William Sound (Figure 9). This region is

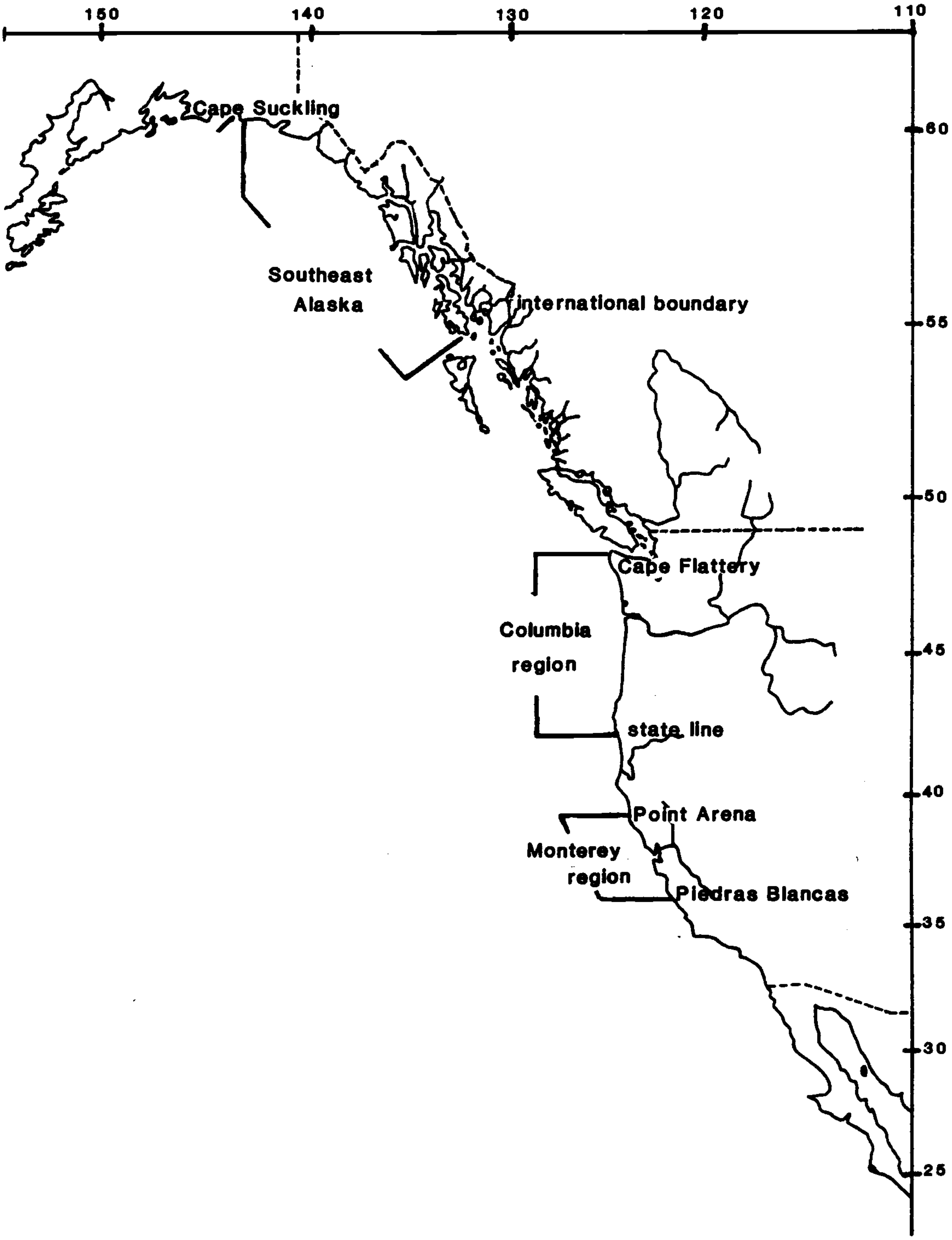


Figure 12. Regions for which landing data was compiled in this study.

characterized by strong winter downwelling, weak or non-existent summer upwelling, glacially structured coastlines, and very wide continental shelves.

The Columbia region of this study includes all landing data from the states of Oregon and Washington except Puget Sound. This corresponds roughly to the INPFC statistical area 'Columbia' except that the latter does not include regions south of Cape Blanco. It includes the previously defined physiographic regions from Cape Blanco to Cape Flattery (Figure 9), and is characterized by continental shelves of intermediate width, barrier coastlines, moderate summer upwelling, and winter downwelling. The Monterey region here includes landing data from the state of California's districts of San Francisco and Monterey combined (as these appear in federal statistical digests). This includes the area from Point Arena to Piedras Blancas. This region corresponds roughly to the INPFC statistical area 'Monterey', though it is considerably smaller. It is included within the physiographic region that stretches from Point Conception to Cape Mendocino (Figure 9) which is characterized by year-round upwelling (especially strong in summer), and narrow continental shelves with the exception of the San Francisco Bay - Farallon Island area.

Catch data includes landings of finfish (no shellfish) from all commercial marine fisheries and "commercial fisheries [for anadromous species]. . . of the coastal rivers as far inland as commercial fishing is important" (Statistical Survey Procedures 1944). Within these regions, weights of all commercially landed species were gathered by year from the list of sources given in Appendix I.

Long-term catch data can be used to describe the characteristics and process of exploitation as it occurs over a relatively long period. However, due to the long-term nature of this data, some inconsistency in methods of data collection and compilation were inevitable. Inconsistencies are briefly addressed here and are discussed in more detail in Appendix II.

Total weights used for this summary include both foreign and domestic commercial landings in these areas, but do not include sport catches. Weights also represent landed catch weights, not total catch. This means that any culling that is done at sea or on land would be weight of the actual catch that goes unrecorded. Also, landed weights in statistical summaries were registered as catch weight in the area in which they were brought to port regardless of the actual 'area of origin' (area in which those fish were actually caught). This appears to present a problem in only a few cases; these are discussed below. For 1888 and the 1920's, weights represent 'fishery product' weight. Because of uncertainty over what this meant in terms of whole fish, no attempt was made to convert weights from this time period into whole round weight, and catch weights will be under-represented. During the 1940's and 1970's periods, round weight is used.

Briefly summarized, all data for Alaska appear to be quite reliable. Landing data for the Columbia region appears reliable with the exception of 1970's data for species not covered by statistics of the International North Pacific Fisheries Commission. Landing data for the Monterey region appears to be least reliable. It should be noted that different agencies put quite different boundaries around the area called the Monterey district or region. However, some of the unreliability may also be indicative of a relatively greater amount of movement of vessels between fishing grounds and landing area. Tables listing mean annual landing weights for each taxa by period and region is listed in Table A.III.

In order to analyze the nature of fishing exploitation as well as fish community changes over time, taxa were grouped according to general trophic level, oceanographic region (anadromous, shelf, slope, etc.), and oceanographic depth (epipelagic, mesopelagic, or demersal) occupied by adults of the species. Tables I and II list this information as well as references used to acquire it. Where adults fed on a wide range of food items, the trophic level assigned represents, as best as possible, the middle of that range. The oceanographic region assigned is generally the region where commercial fishing first occurred on that taxa.

Very often, this is the portion of the adult's range which is closest to shore. Flatfish and rockfish species were left out of trophic level and depth analysis since these species were lumped into 'flatfish' and 'rockfish' groups rather than listed as individual species in all but the most recent statistical survey records.

Table I. Codes and descriptions used in Table II.

CODES FOR TROPHIC LEVELS:

Trophic Status	Description of prey	Trophic Code	Trophic Number
piscivore	medium to large fishes, squid, large crustaceans.	pisc	1
macronektivore	large crustaceans, mollusks, medium-sized fishes (anchovy, small hake and mackerel).	macn	2
omnivore - macronektivore	euphausids, small fishes, macronekton and anything else above.	omn-macn	3
omnivore - micronektivore	euphausids, small squids, jellyfish, combjellies, zooplankton, and anything else below.	omn-micn	4
micronektivore/ zoobenthivore	small invertebrates: jellyfish medusae, crustaceans including euphausiids, small zoobenthos (worms, small mollusks, amphipods). Juvenile or small fishes including melamphids.	micn	5
zooplanktivore	crustacean plankton, invertebrate larvae, fish larvae.	zoop	6
phytoplanktivore	diatoms and other algae	phtp	7

Table I (continued).

CODES FOR OCEANOGRAPHIC REGION:

Region	Description	Region Code
anadromous	spawning in rivers	anad
littoral/coastal	surf zone & tidelands to ca 50 meters	coast
inner shelf	50 to ca 100 meters	inslf
outer shelf	ca 100 - 200 meters	outslf
upper - mid slope	ca 200 to 1000 meters	slp
oceanic	lower slope and deep ocean basin	ocnc

CODES FOR OCEANOGRAPHIC DEPTH:

Zone	Description	Depth Code
epipelagic	surface to 200 meters	epip
mesopelagic	200 to 1000 meters	mesop
demersal	in close assiciation with the sea floor	demsl

CODES FOR REFERENCES:

Number	Title	Number	Title
1	Gabriel 1982	12	King and Bateman 1985
2	Rexstad and Pikitch 1986	13	Gunderson 1977
3	Hart 1973	14	Alverson et al. 1964
4	Moyle and Cech 1982	15	Quast 1986
5	Love et al. 1984	16	Pinkas 1966
6	Pearcy et al. 1984	17	Walford 1932
7	Livingston 1983	18	Roedel 1953
8	Clausen 1981	19	Ripley 1946
9	Beacham 1986	20	Walford 1974
10	Miller and Lea 1972	21	Anon. 1949
11	Baxter 1967	22	Horn 1970

Table II. Species, trophic status, distance from shore generally fished, and habitat associations for all species in database.

Common Name	Scientific Name	Trophic Status (Code)	Trophic Number	Reference Numbers	Oceanog. Region (Code)	Reference Numbers	Oceanog. Depth (Code)	Reference Numbers
anchovies	Engraulidae	micn/zoop	5.5	3	coast	3,11	epip	3,11
barracuda	Sphyraena spp.	pisc	1	3,16	coast/inslf	3,16,20	epip	10,20
bonito	Sarda chiliensis	pisc	1	3,20	coast	20,21	epip	3,20
cabezone	Scorpaenichthys marmoratus	macn	2	3	coast/inslf	3	demsl	
cod	Gadus macrocephalus	omn-macn	3	3	slp	3	demsl	3
croaker, white	Genyonumus lineatus	omn-macn/omn-mic	3.5	3,4,5	coast/inslf	5,10	demsl	4,10
dogfish	Squalus (and Mustelus) spp.	macn	2	3	outslf	3,14	epip/mesop	3
eulachon	Thaleichthys pacificus	micn/zoop	5.5	3	anad	3,4	epip	3
flatfish	Pleuronectidae and Bothidae	-	-		-		demsl	
hake	Merluccius productus	omn-macn	3	2,3,7	outslf/slp	1,7,14	mesop	1,14
halibut, California	Paralichthys californicus	pisc	1	21	inslf	10	demsl	
halibut, Pacific	Hippoglossus stenolepis	pisc	1	3	inslf/outslf	3,14	demsl	3
herring	Clupea harengus pallasi	micn/zoop	5.5	3	coast	3,15	epip	3
jack mackerel	Trachurus symmetricus	omn-micn	4	3	inslf	18	epip	10,18

Table II (continued).

Common Name	Scientific Name	Trophic Status (Code)	Trophic Number	Reference Numbers	Oceanog. Region (Code)	Reference Numbers	Oceanog. Depth (Code)	Reference Numbers
kingfish	Menticirrhus spp.	micn	5	18	coast	10	demsl	
lingcod	Ophiodon elongatus	pisc	1	3	coast/inslf	3	demsl	3
mackerel (true) spp.	Scomber and Scomberomorus spp.	macn	2	3,20	coast	20	epip	3,20
pacific ocean perch	Sebastes alutus	micn	5	4	slp	4,13,14	mesop	3
pollack	Theragra chalcogramma	omn-micn	4	3,8	outslf/slp	8,14	epip/mesop	3
pompano	Peprilus simillimus	micn	5	22	coast	10	epip	21
rockfish	Sebastes spp.	-	-		-		demsl	
sablefish	Anoplopoma fimbria	micn	5	3	slp	1,14	demsl	1
salmon, chinook	Oncorhynchus tshawytscha	pisc	1	3	anad		epip	3
salmon, chum	Oncorhynchus keta	omn-macn/omn-mic	3.5	3,6	anad		epip	3
salmon, coho	Oncorhynchus kisutch	macn	2	3,6,9	anad		epip	3
salmon, pink	Oncorhynchus gorbuscha	omn-macn/omn-mic	3.5	3,6	anad		epip	3
salmon, sockeye	Oncorhynchus nerka	omn-micn	4	3,6	anad		epip	3
sardines	Sardinops caerulea (+Etrumeus)	zoop/phtp	6.5	3	coast	3	epip	10
sea bass, black	Stereolepis gigas	pisc	1	10,20	coast	20	demsl	20
sea bass, white	Cynoscion nobilis	pisc	1	3	coast/inslf	5,10	demsl	10

Table II (continued).

Common Name	Scientific Name	Trophic Status (Code)	Trophic Number	Reference Numbers	Oceanog. Region (Code)	Reference Numbers	Oceanog. Depth (Code)	Reference Numbers
shad	Alosa sapidissima	zoop	6	3	anad	3	epip	3
shark (not soupfin)	Hexanchiformes & Squaliformes	pisc	1	3	-	3	epip	10
shark, soupfin	Galeorhinus zyopterus	pisc	1	3	inslf	19	epip	10,19
skates	Rajiformes	omn-macn	3	3	outslf/slp	3	demsl	
smelt	Osmeridae	micn/zoop	5.5	3,4	coast	3,4	epip	3
steelhead	Salmo gairdneri	micn	5	3	anad	3	epip	3
striped bass	Morone saxatilis	pisc	1	3	anad	3	epip	
sturgeon	Acipenser spp.	pisc	1	3	anad	3	demsl	
surfperch	Embiotocidae	micn	5	3	coast	3,10	epip	
tomcod	Microgadus proximus	omn-macn/omn-mic	3.5	3	coast	3,10	demsl	
tuna, albacore	Thunnus alalunga	macn	2	3,20	ocnc	3,12,20	epip	3,10,20
tuna, bluefin	Thunnus thynnus	pisc	1	20	ocnc	12,16	epip	10
tuna, skipjack	Euthynnus lineatus (pelamis)	macn/omn-macn	2.5	20	ocnc	12,21	epip	10,12
tuna, yellowfin	Thunnus albacares	pisc/macn	1.5	20	ocnc	12,21	epip	10,12

Where a '-' exists, data for this taxon was not used for analysis/summary.

FISHERY DEVELOPMENT

Regier and Loftus (1972) have described for the Laurentian Great Lakes what they term the 'fishing up' sequence. A simplified version of this sequence can be described as it occurred in the Eastern North Pacific. Fishing up includes seaward expansion and diversification of fisheries, greater mobility of fishers, and increases in total landings. There was seaward expansion of the Eastern North Pacific fishery over time. This is illustrated by a time series of catch weights for each oceanographic region (Figure 13). In the beginning of the exploitation process (1888), the overwhelming majority of the total catch came from anadromous and coastal species. Over time, exploitation pressure spread out over the continental shelf and slope and open ocean, until the majority of the total catch (Monterey and Columbia regions) or at least a significant portion (Southeast Alaska) came from offshore. Either Pacific hake, Pacific ocean perch, or albacore (outer shelf and slope, slope, and oceanic species respectively) made up a significant portion of the catch in each region by the 1970's, though anadromous and coastal fisheries still made up a large share of the catch in Southeast Alaska. In general, fisheries also expanded by diversifying; that is, a greater number of species were exploited over time (Figure 14). The number of species (or species groups) exploited by the commercial fishery increased in each

Figure 13. Regional catches (in thousands of metric tons) by oceanographic region (distance from shore). X-axis values represent general oceanographic region of adults of species in the catch. Left column: Monterey region catch over time. Middle column: Columbia region. Right column: Southeast Alaska. Flatfish and rockfish were excluded from this summary (see methods section).

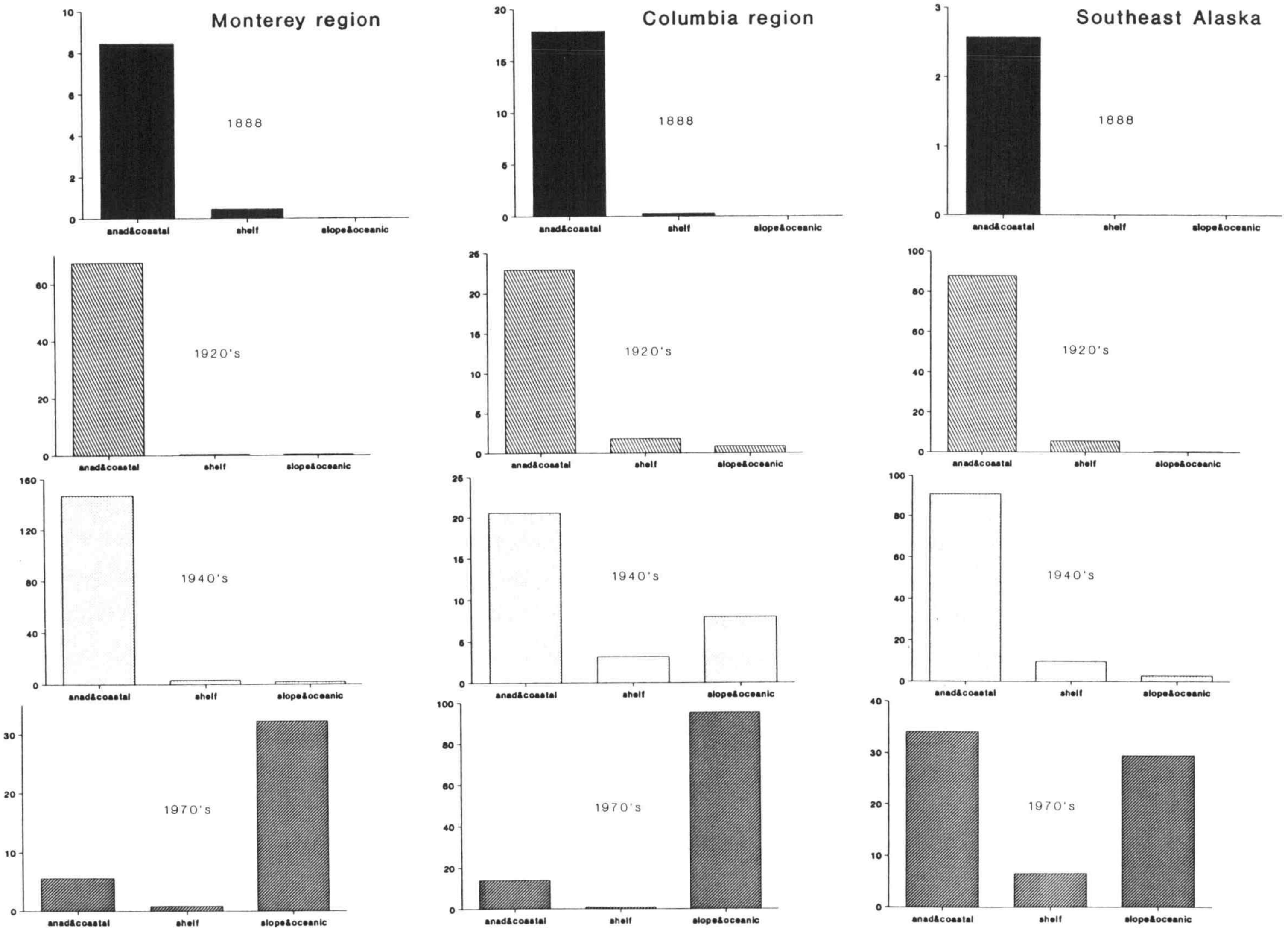

Monterey region
Columbia region
Southeast Alaska
1888
1888
1888
1920's
1920's
1920's
1940's
1940's
1940's
1970's
1970's
1970's
0
2
4
6
8
10
0
5
10
15
20
0
1
2
3
0
20
40
60
0
5
10
15
20
25
0
20
40
60
80
100
0
40
80
120
160
0
5
10
15
20
25
0
20
40
60
80
100
0
10
20
30
0
20
40
60
80
100
0
10
20
30
40
anad&coastal
shelf
slope&oceanic

Figure 13.

Figure 14. Number of species (or species groups) exploited by the commercial fishery (by region and time period). All rockfish are lumped into a species group (see Table A.III) as are all flatfish and all true mackerel species. Species (or species groups) that appear in this table had mean annual landing weights greater than or equal to 10 mt. Numbers in parentheses are cumulative number of species (or species groups) that were excluded from the commercial fishery. Species considered excluded are those for which mean annual landing weights fall below and remain below 10 mt through 1976.

	1888	1920's	1940's	1970's
SE ALASKA	1	9	13	16(3)
COLUMBIA	5	14(1)	27(1)	25(6)
MONTEREY	18	20(2)	24(3)	20(11)

Figure 14.

region, though by the 1970's, number of taxa utilized by the commercial fishery had begun to decline in both the Monterey and Columbia regions. Along with this general increase in diversification came an increase in the number of species that were permanently excluded from the commercial fishery (Figure 14).

Size of fishing vessels also changed over time (Figure 15). Between 1888 and the 1920's, heavy wood sailing vessels were replaced with lighter steel-hulled gas and diesel engines. Therefore, vessel weights decreased through this period. Later, between the 1940's and 1970's, vessel size began to increase again, especially in California. Vessel size trend is determined by several things. It may be a response to nearshore depletion of particular species coupled with a cultural system that highly prizes economic growth. Larger vessels increase economic commitment (greater cost per vessel) and therefore spur even further depletion of the fish community. Larger vessels pull larger nets, generally move faster, process larger catches, and may be more mobile since both horsepower and safety tend to increase with vessel size. Greater mobility allows travel further to sea and further from home ports.

Another trend that became apparent in both Southeast Alaska and the Monterey region was an increase in mean annual landing weights of the total catch (all taxa combined) through the post-war 1940's, but a significant

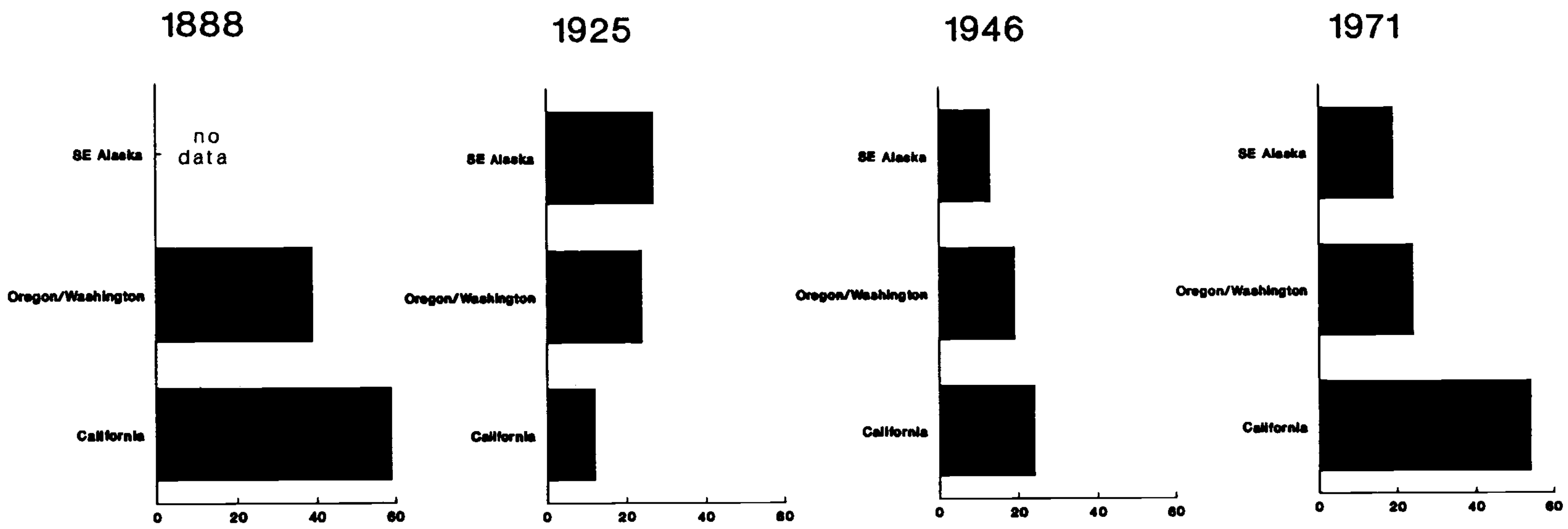


Figure 15. Mean vessel size (tons per vessel) by area and year. Source statistics: Fisheries Statistics of the United States.

decrease by the 1970's (up to 1976) in the Monterey region and Southeast Alaska in spite of diversification of the fishery (Figure 16). In the Columbia region, total landing weights increased through the 1970's. In all three regions, pelagic species (salmon, sardines, herring, perch, albacore, hake) made up the majority of the catch. The portion of the catch made up of demersal species was never much more than 1/4 of total landing weights.

In spite of similarities between regions, each region also had a unique developmental history. Of the three regions studied, commercial fisheries began first in the south in the San Francisco and Monterey area, later moving north to the Columbia River, more remote areas off the coast of Oregon and Washington, and then into Canada and Alaska. For instance, the first salmon cannery was opened on the Sacramento River in 1864, while canneries began to appear on the Columbia River in 1866, and in Southeast Alaska in the late 1870's (Browning 1974). Thus, developmental patterns began later in more northern regions.

Development of the commercial fishery in each region is illustrated in Figure 16. Fisheries have tended to be dominated by a few taxa, though these were different in each region. In Southeast Alaska, chinook salmon dominated the catch in 1888. In the 1920's and 1940's, pink and other salmon species comprised the majority of the total catch. By the 1970's, Pacific ocean perch and demersal species such

Figure 16. Development of the commercial fishery by region (rows) and time period (columns). Represented are mean annual landings (for all taxa) for each time period split by individual taxa or by general oceanographic depth which adults of groups of taxa occupy. Totals listed below each pie chart are mean annual (for that time period) landing weights for all taxa combined.

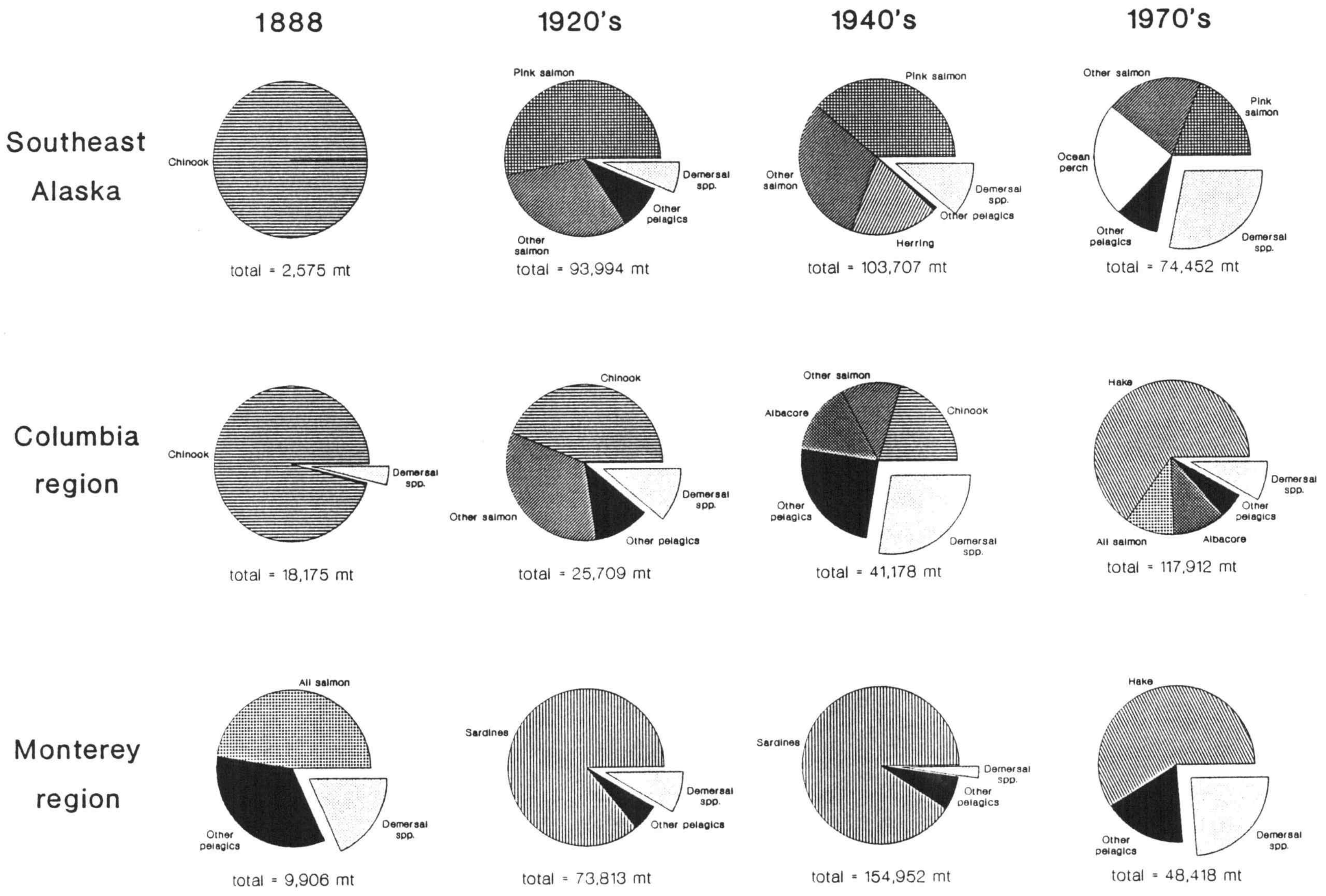

1888
1920's
1940's
1970's
Southeast Alaska
Chinook
total = 2,575 mt
Pink salmon
Demersal spp.
Other pelagics
Other salmon
total = 93,994 mt
Pink salmon
Other salmon
Demersal spp.
Other pelagics
Herring
total = 103,707 mt
Other salmon
Pink salmon
Ocean perch
Other pelagics
Demersal spp.
total = 74,452 mt
Columbia region
Chinook
Demersal spp.
total = 18,175 mt
Chinook
Demersal spp.
Other salmon
Other pelagics
total = 25,709 mt
Other salmon
Albacore
Chinook
Other pelagics
Demersal spp.
total = 41,178 mt
Hake
Demersal spp.
Other pelagics
All salmon
Albacore
total = 117,912 mt
Monterey region
All salmon
Other pelagics
Demersal spp.
total = 9,906 mt
Sardines
Demersal spp.
Other pelagics
total = 73,813 mt
Sardines
Demersal spp.
Other pelagics
total = 154,952 mt
Hake
Other pelagics
Demersal spp.
total = 48,418 mt

Figure 16.

as sablefish, halibut, rockfish and flatfish were also significant portions of landings. In the Columbia region, salmon made up most of the catch until after the 1920's when diversification to other pelagic species such as albacore tuna and sardines, and to demersal species like flatfish and rockfish occurred. By the 1970's, immense quantities of Pacific hake were added to the catch. In the Monterey region, salmon comprised a large portion of the catch in 1888. The overwhelming majority of catch by weight within the 20th century however came primarily from sardines and Pacific hake.

Commercial quantities of Pacific hake could only be landed with midwater trawls which were not developed until the late 1960's. Landings of such magnitude however also required a certain political climate: a lack of agreement among fishing nations concerning jurisdiction over natural resources.

Ryther (1969) observed that upwelling regions of the world, in comparison to coastal and oceanic regions, were characterized by utilizable fish production which came from taxa at lower trophic levels. Taxa from lower trophic groups have made up a larger portion of the catch by weight in the Monterey region (compared with regions to the north) where upwelling occurs strongly year-round (Figure 17a,b). The greatest proportion of the total catch by weight in the Monterey region came from sardines which are planktivores.

Figure 17. Pie charts representing mean annual landings for all taxa combined and for all years of data used in this study (28 years of data). a) Regional catches split according to taxa or general oceanographic depth of adults in the catch. b. Regional catches split according to trophic group of adults of taxa in the catch. Numbers correspond to trophic code designations (as in Tables I and II) where 1 is piscivores, and 6 is zooplanktivores.

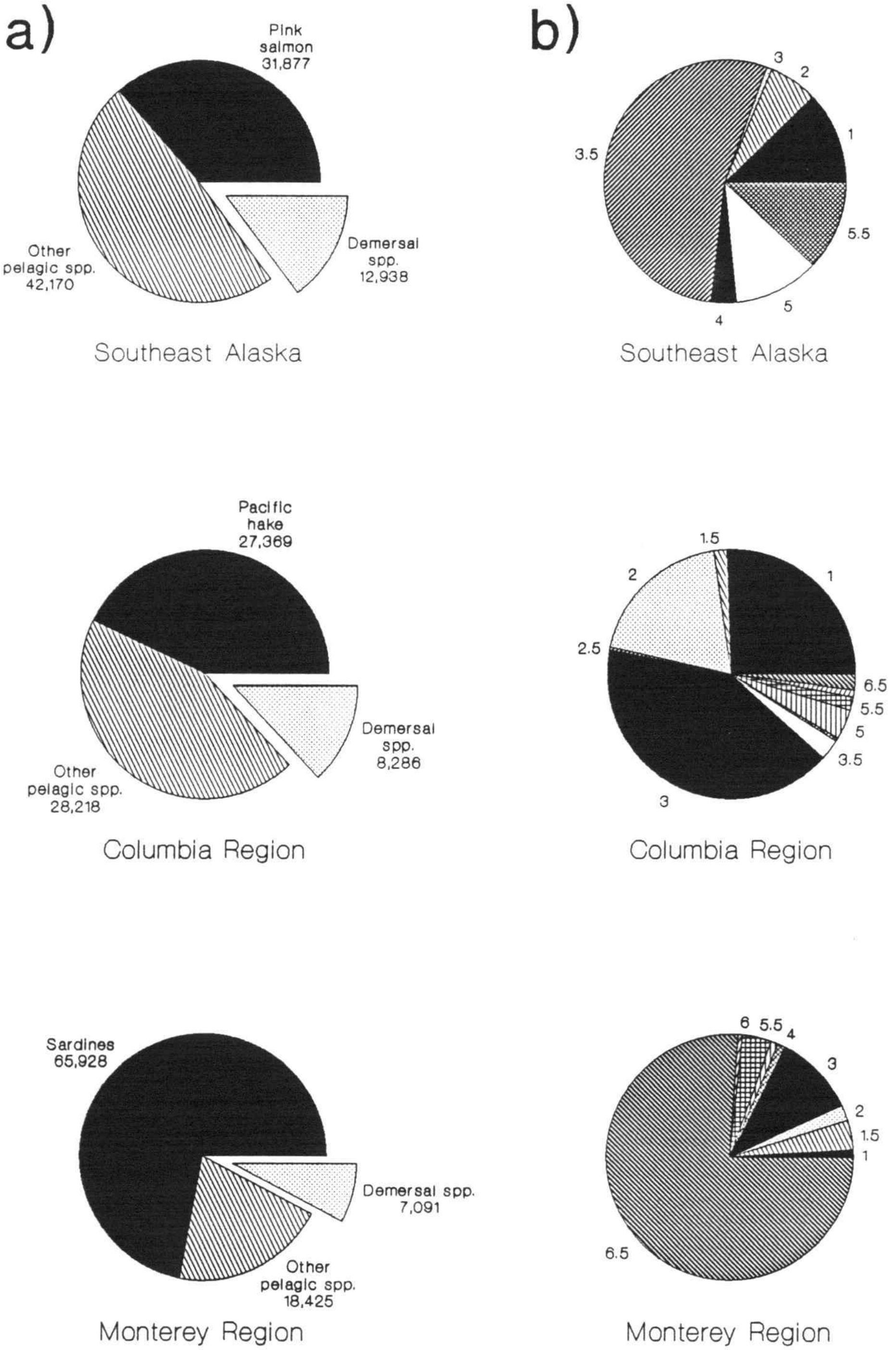

a)
Pink salmon 31,877
Other pelagic spp. 42,170
Demersal spp. 12,938
Southeast Alaska
b)
3
2
1
3.5
5.5
5
4
Southeast Alaska
Pacific hake 27,369
Other pelagic spp. 28,218
Demersal spp. 8,286
Columbia Region
1.5
2
1
2.5
6.5
5.5
5
3.5
3
Columbia Region
Sardines 65,928
Demersal spp. 7,091
Other pelagic spp. 18,425
Monterey Region
6
5.5
4
3
2
1.5
1
6.5
Monterey Region

Figure 17.

In the Columbia region and Southeast Alaska, where upwelling occurs seasonally or generally does not occur, the greatest proportion of catches were made up of species at higher trophic levels. In the Columbia region, trophic structure of the catch has been quite diverse, with significant proportions of piscivores, macronektivores, and omnivore-macronektivores (Figure 17b). Catches in Southeast Alaska, dominated by pink salmon, were characterized by a trophic composition which was heavily weighted toward omnivores.

Since 1888, shifts have occurred in each region in trophic composition of the catch. Figure 18 shows these changes over time for catches of the Columbia region. In 1888, the position of the peak in landings was far to the left indicating high catch weights of piscivores (in this case chinook salmon). By the 1920's, a considerable diversification of trophic groups composing the catch had taken place, yet piscivores still made up a larger portion of the landings than any other single trophic group. By the 1940's, landings of piscivores and macronektivores (code 2) were essentially equal. By the 1970's, landings of omnivore-macronektivores (dashed line; code 3) and macronektivores (code 2) had far outstripped landings of any other group, while species at the highest trophic levels had declined in terms of absolute weight landed (from 18 to 6 thousand metric tons).

A similar situation occurred in Southeast Alaska

Figure 18. Changes in trophic composition of catch over time for the Columbia region. Data plotted is mean annual landings (for that time period) in thousands of metric tons. Landings are split according to trophic level of adults of each taxa in the catch. Numbers on the x-axis represent trophic level from piscivore (1) to zooplanktivore (6). Dashed line corresponds to catches of Pacific hake which overwhelmed catches of other species or trophic groups.

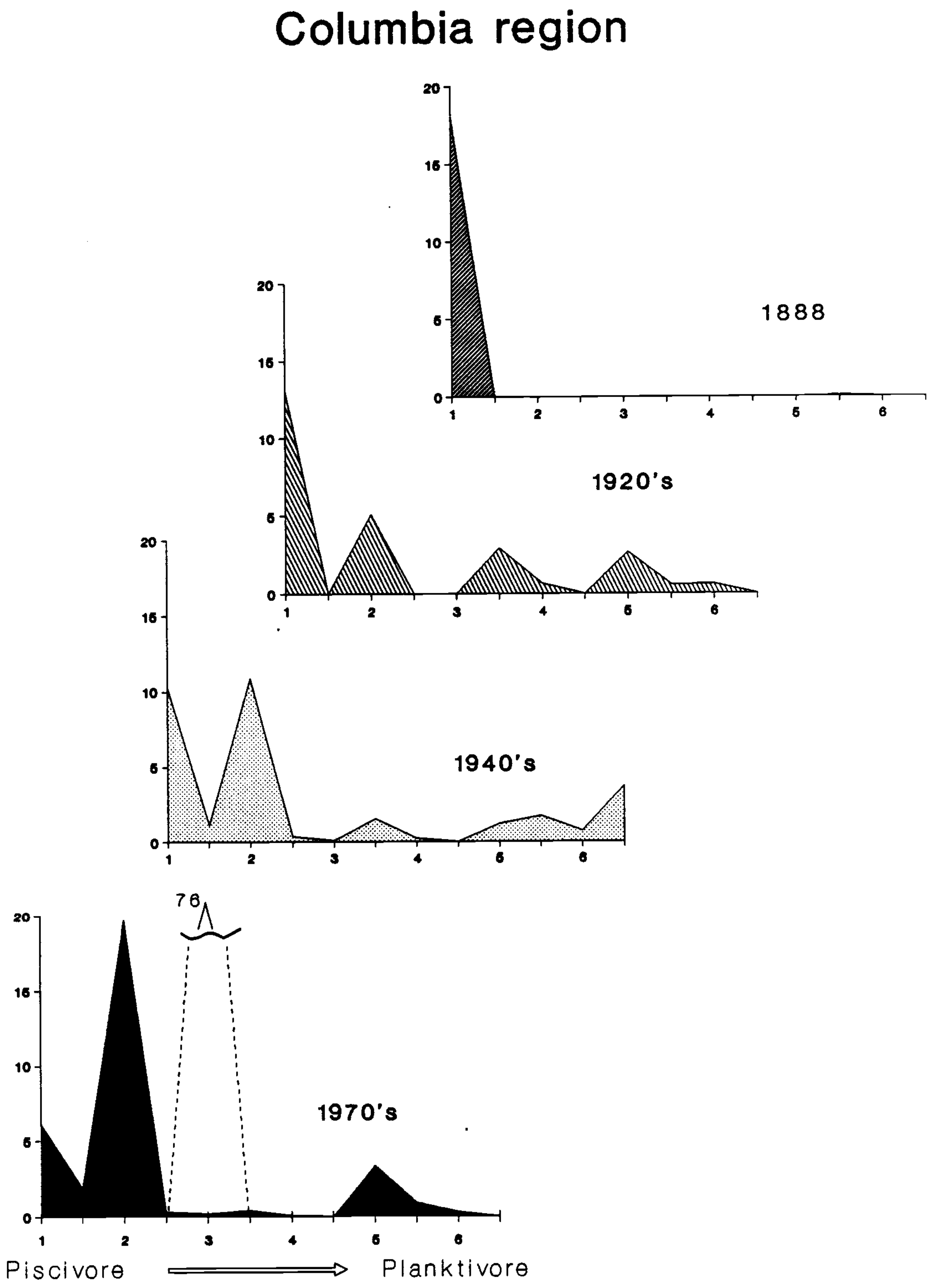

Columbia region
1888
1920's
1940's
1970's
76
20
15
10
5
0
1
2
3
4
5
6
Piscivore
Planktivore

Figure 18.

landings (Figure 19). Though commercial exploitation began much later in this region, the trend toward diversification and toward change in predominant trophic group in the catch was even more pronounced. By the 1970's, micronektivores, principally Pacific ocean perch, were the major trophic group being harvested.

By 1888, fisheries of the Monterey region (Figure 20) were quite advanced in the sense that the salmon fishery had already gone into a strong decline and the fishery was more diverse than in the Columbia region or Southeast Alaska at this time. Sardine (planktivores) and later hake (omnivore-macronektivore) fisheries from the 1920's through the 1970's were extremely productive (dashed lines). These dwarf landings of other species. Therefore, trends toward diversification of the fishery and change in predominant trophic group in the catch only become apparent if these two fisheries are excluded from analysis. When these latter two are excluded, the pattern, though weak, is similar to patterns in the other two regions; a reduction occurred in landings of piscivores (code 1), while there was a corresponding increase in landings of species at lower trophic levels (codes 4 through 5.5).

Patterns of exploitation were revealed in catch histories of individual species. Since 1888, significant declines have occurred in mean landings, in at least part of the species range, of almost all species that have had

Figure 19. Changes in trophic composition of catch over time for Southeast Alaska. Graph is similar to Figure 18, but dashed lines correspond to catches of pink salmon.

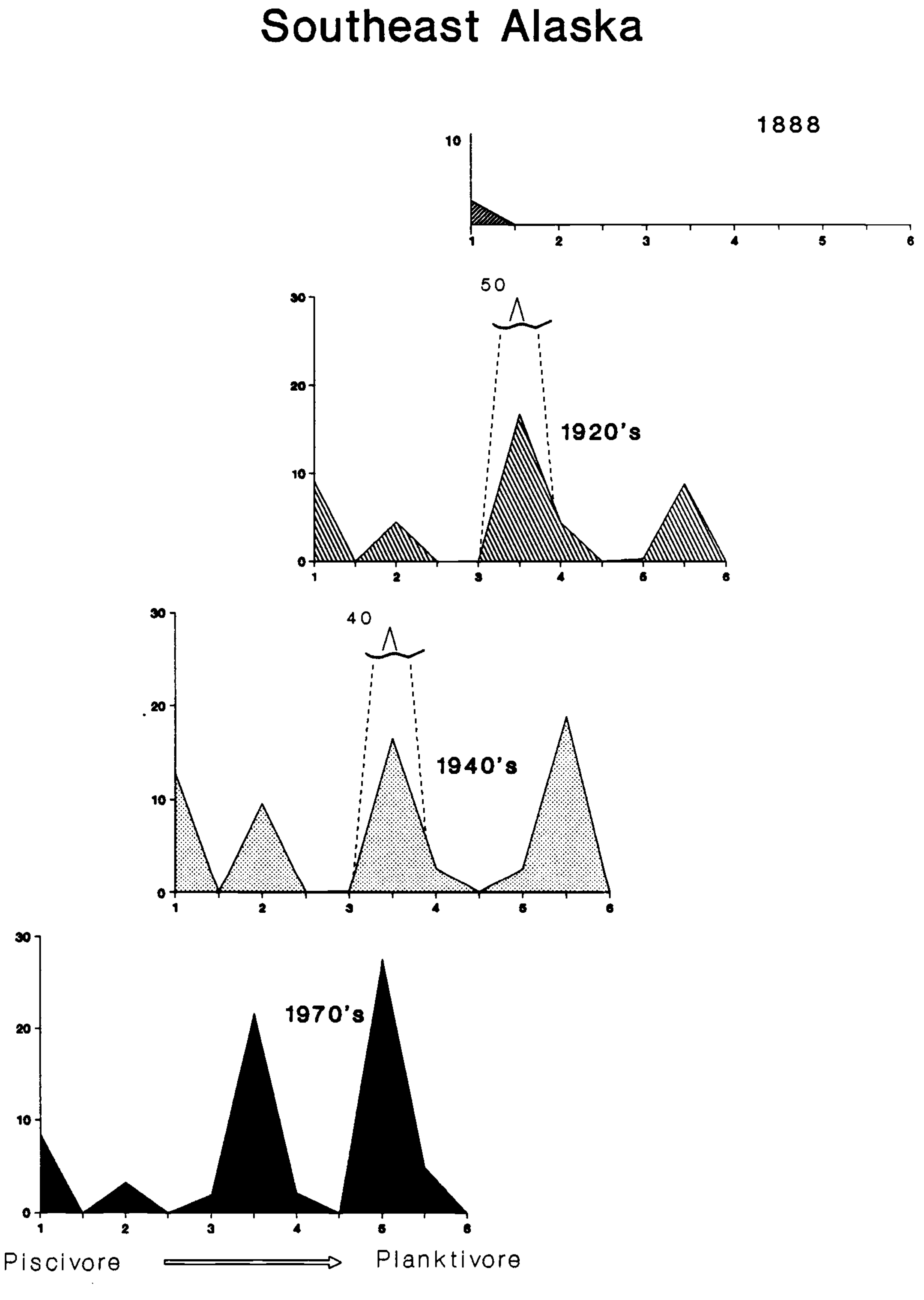

Southeast Alaska
1888
10
1 2 3 4 5 6
50
30
20
10
0
1920's
1 2 3 4 5 6
40
30
20
10
0
1940's
1 2 3 4 5 6
30
20
10
0
1970's
1 2 3 4 5 6
Piscivore
Planktivore

Figure 19.

Figure 20. Changes in trophic composition of catch over time for the Monterey region. Graph is similar to Figure 18, but dashed lines corresponds to catches of sardines (1920's and 1940's) or Pacific hake (1970's).

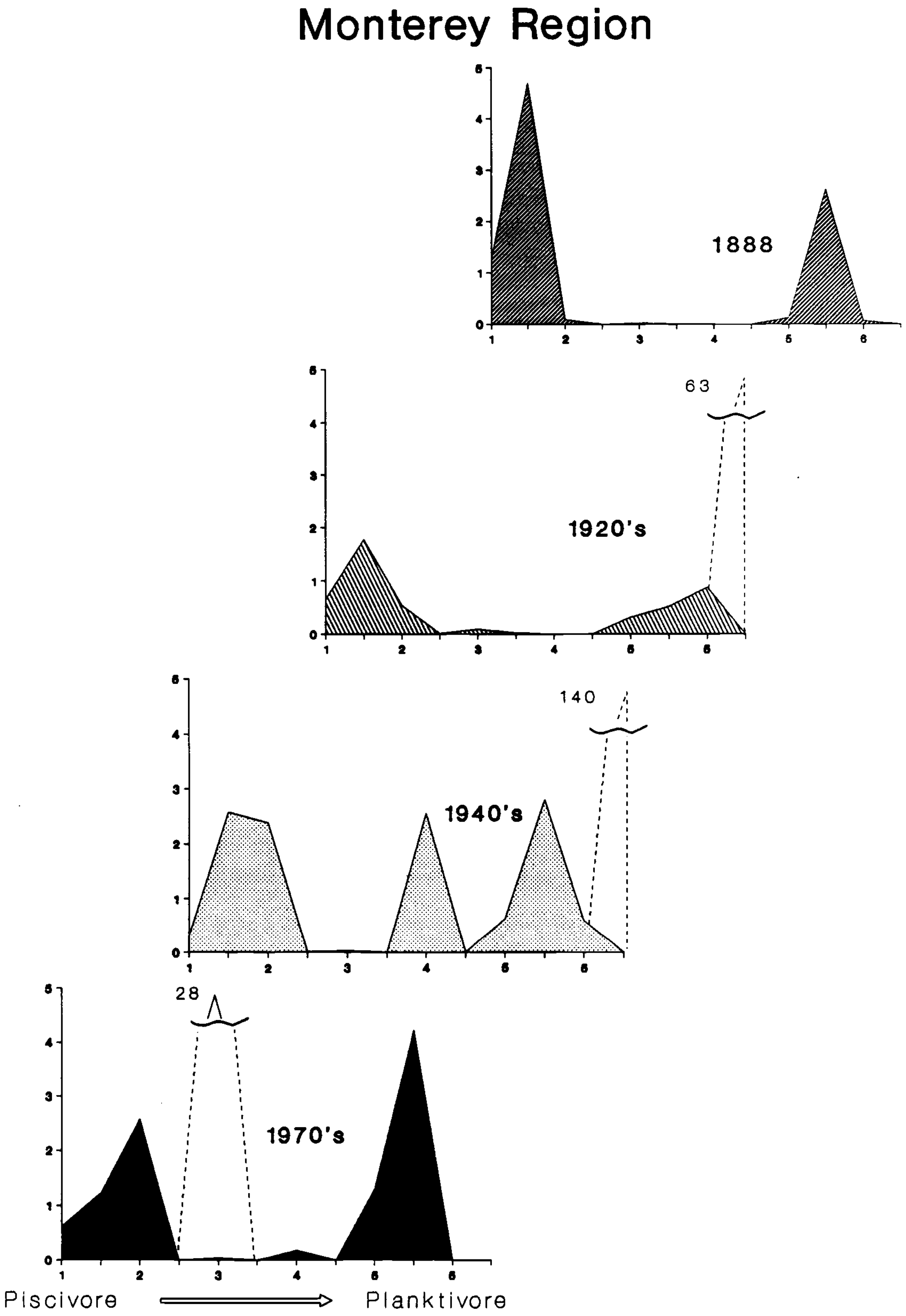
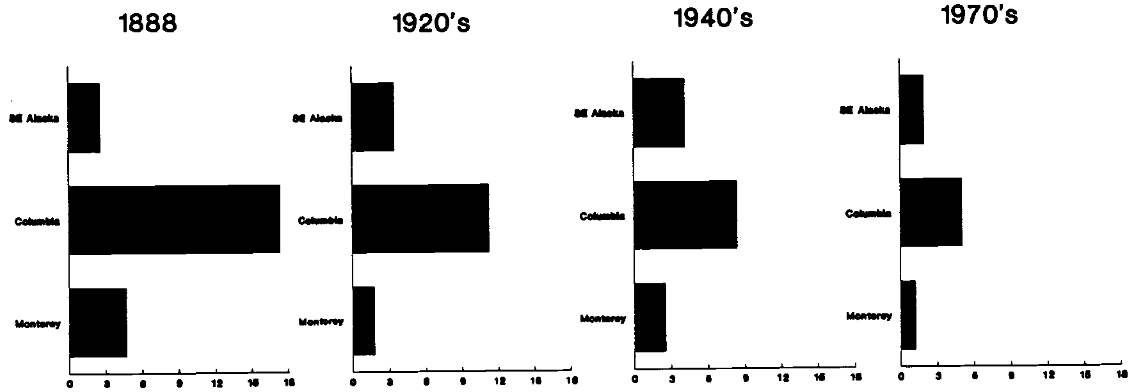

Monterey Region
1888
1920's
63
1940's
140
1970's
28
0
1
2
3
4
5
1
2
3
4
5
6
Piscivore
Planktivore

Figure 20.

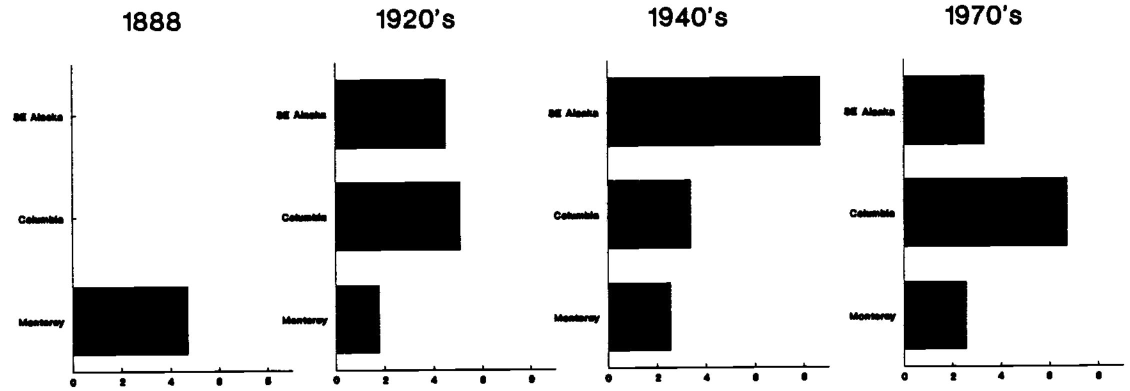
a long and relatively intense exploitation history. These include all salmon species, steelhead, halibut, sturgeon, true mackerels, sardines, and barracuda (Figure 21a-k). This trend may be explained by the general pattern of fishery development, where each technological improvement enhanced fishing efficiency which served to increase catches on already heavily exploited stocks or species. Once a species became a part of the commercial fishery, it seems in general to have been very difficult to remove it, though species were removed from the catch through fishing politics (species were relegated to the sport fishery), economics (market demand declined or disappeared), or biology (stock declines and lack of recovery). In general, depleted stocks left behind by fishers looking for richer resources often continued to be exploited by fishers whose outlays of capital expenditure were generally smaller and who had less mobility. Figure 14 gives the number of species in each region permanently excluded from the commercial fishery at each time period. Though any of the above three factors may be involved in these exclusions, it is interesting to note that the highest number of exclusions is associated with the region with the longest history of commercial exploitation: the Monterey region.

There are unique catch patterns for individual species within different physiographic regions. In some regions, species may be more resilient to harvesting effects than in

a) Chinook salmon



b) Coho salmon



c) Chum salmon

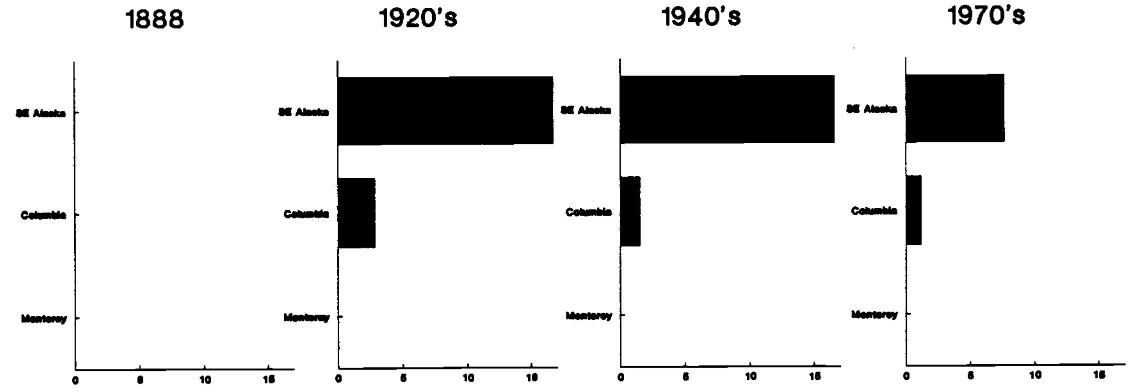
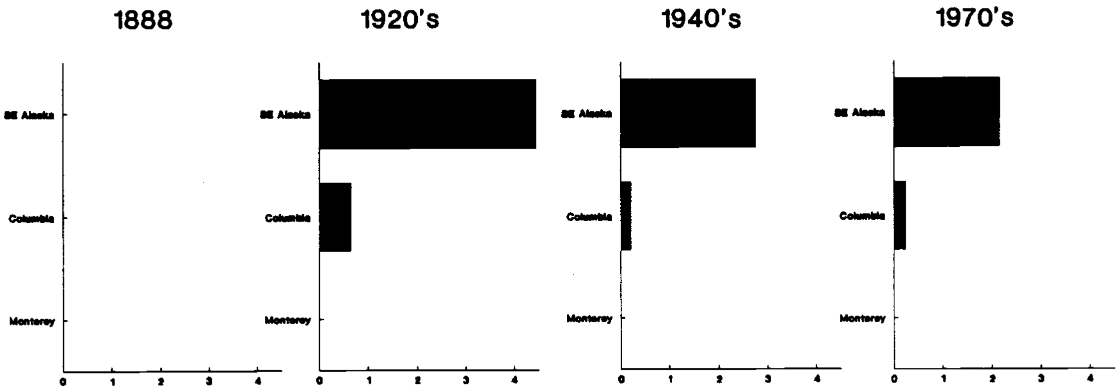
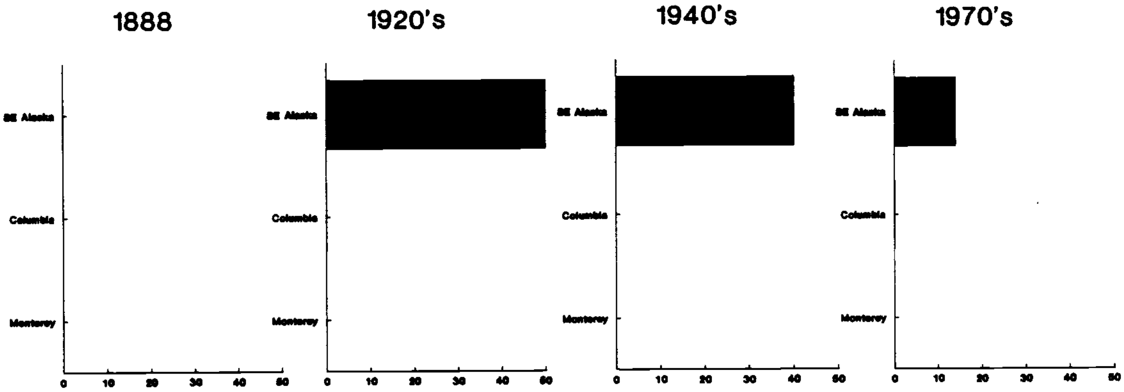


Figure 21. Mean annual landings (in thousands of metric tons) of individual taxa for each region (horizontal) and time period (vertical).

d) Sockeye salmon



e) Pink salmon



f) Pacific Halibut

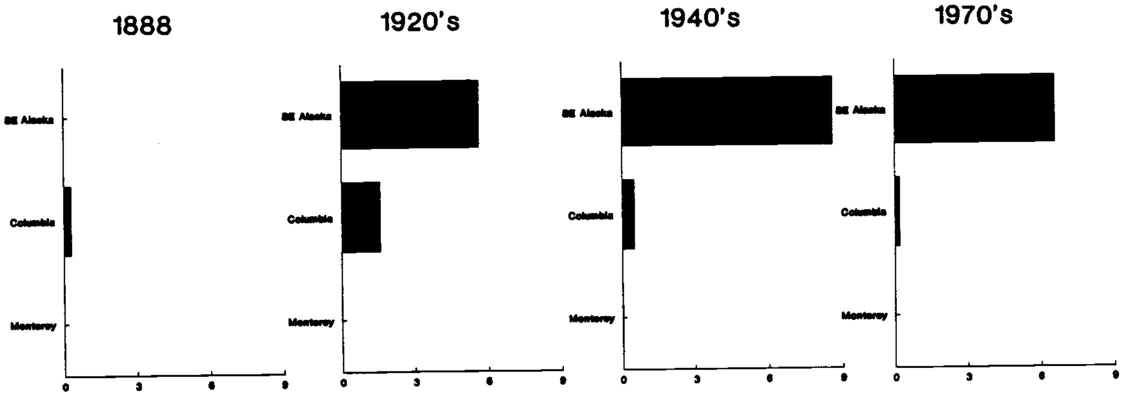
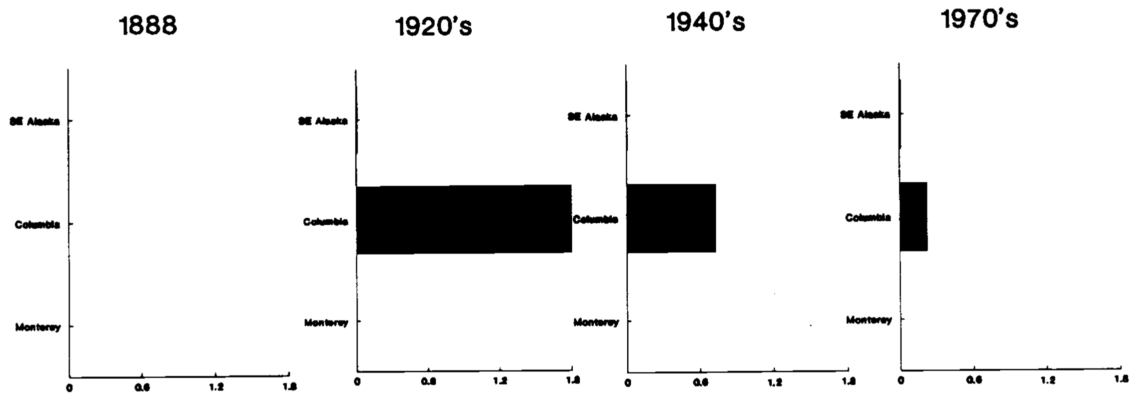
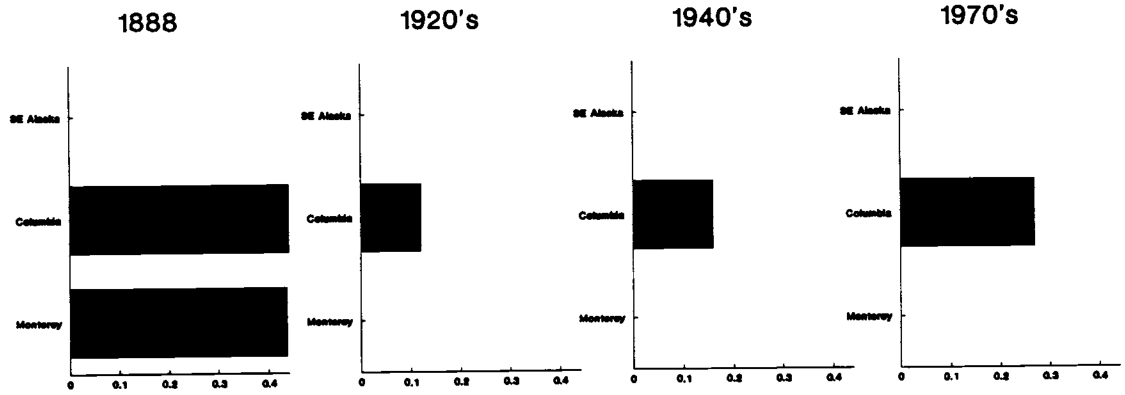


Figure 21 (continued). Mean annual landings (in thousands of metric tons) of individual taxa for each region (horizontal) and time period (vertical).

g) Steelhead



h) Sturgeon



i) Barracuda

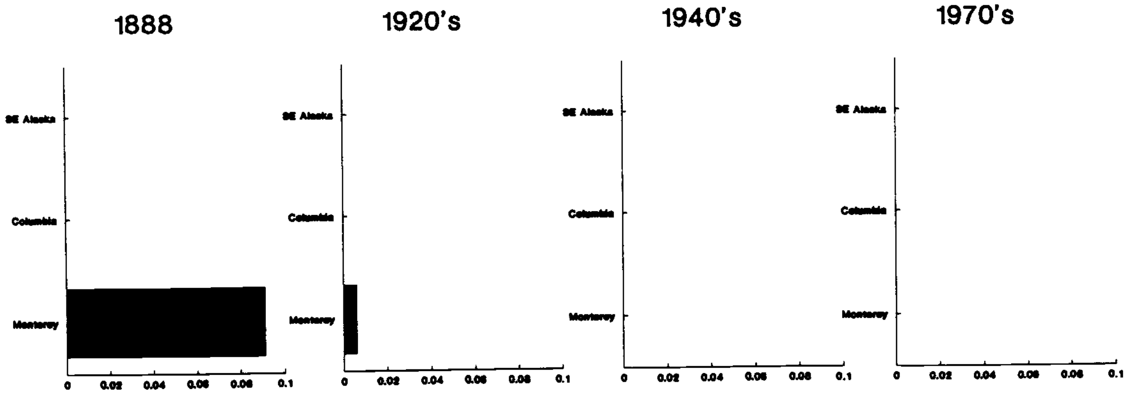
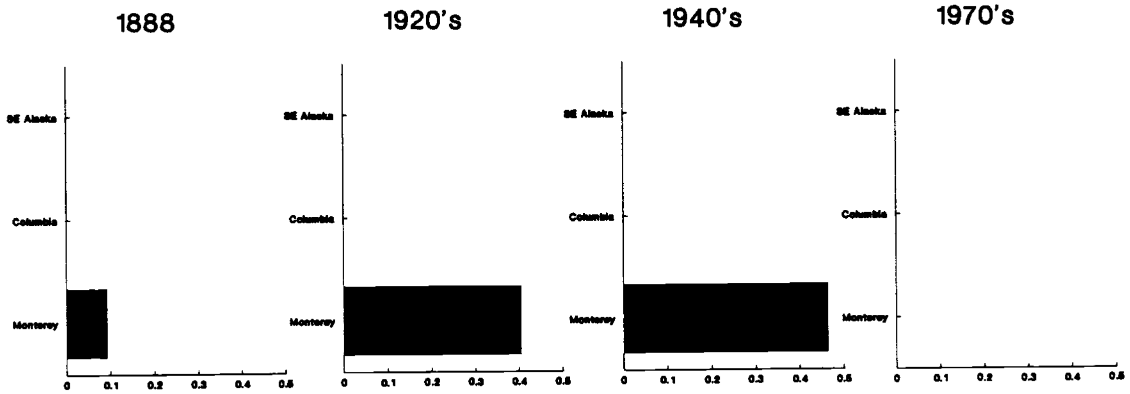


Figure 21 (continued). Mean annual landings (in thousands of metric tons) of individual taxa for each region (horizontal) and time period (vertical).

j) True mackerel

all species combined



k) Sardines

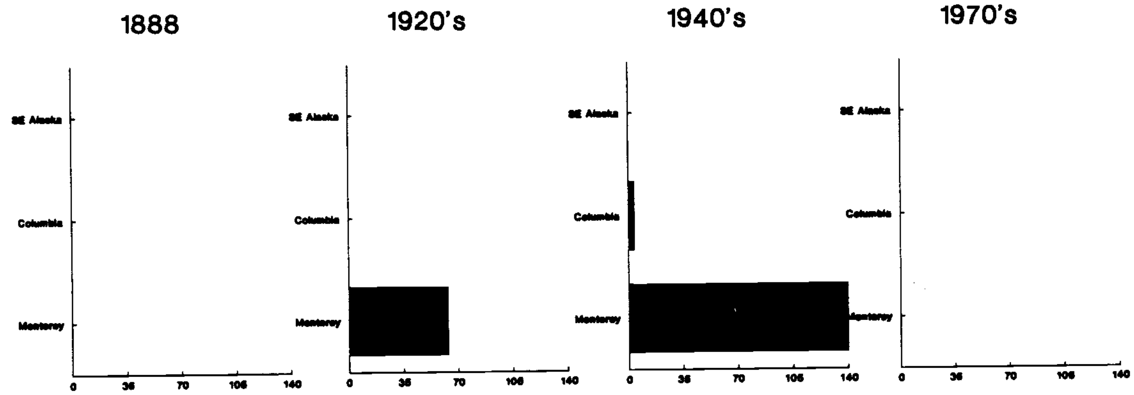


Figure 21 (continued). Mean annual landings (in thousands of metric tons) of individual taxa for each region (horizontal) and time period (vertical).

others. Sturgeon disappeared from commercial catches in the Monterey region (Figure 21h) before the 1920's while continuing to be caught in the Columbia region through the 1970's. Relative catch between regions may be related closely to species distributions. The majority of the catch weights of barracuda (Figure 21i), sardines (Figure 21k), and true mackerels (Figure 21j) came from the southern fisheries, and the majority of catch weights of chum (Figure 21c), sockeye (Figure 21d), and pink salmon (Figure 21e) as well as Pacific halibut (Figure 21f) came from the northern fisheries. The Columbia region was distinguished by proportionally higher catch weights of chinook salmon (Figure 21a) and steelhead (Figure 21g).

SPECIES LIFE HISTORY PERFORMANCE AND ENVIRONMENT

The natural-cultural system structures not only communities and species, but also species life histories. Life history patterns develop in concordance with development of the physical and biological environments. Adaptive significance of life history traits can only be inferred. However, to the extent that the current environment is similar to that of the relatively recent past (in geological time), evidence of the codevelopment of species with their coextensive physical and biological environment might be indicated in the concordance between current life history strategies and biological and physical environmental characteristics.

Two species have made up a major portion of the total landings (by weight) from California to Washington: Pacific sardines and hake. These species show many similarities in life history patterns. Adults of both species primarily inhabit pelagic waters (Alverson et al. 1964; Miller and Lea 1972). Though different stocks do exist, the major portion of the U.S. fishery is thought to be formed by one (for hake) or two (for sardines) large stocks (Stauffer 1985; Marr 1960; Murphy 1968). Both species spawn from Point Conception southward through the 'continental borderland' area (Figure 9); stocks that contribute to U.S. fisheries spawn as far south as central to southern Baja. Spawning also occurs over a great range from east to west with large concentrations of eggs occurring quite far from shore (Ahlstrom 1954; Stauffer 1985). Individuals of both species migrate north in summer for feeding, and south in winter for spawning.

Most sardine larvae occur above 55 m in depth (Ahlstrom 1954). While spawning is spread throughout the year, peaks occur from March to June (Ahlstrom 1954). Hake spawn from December to April, with the peak occurring in January and February. Eggs and larvae occur in the lower mixed layer, from 40 to 100 m in depth, somewhat above the depth of spawning (Stauffer 1985). With an estimated maximum age of 23 years (Leaman & Beamish 1984), hake are longer lived than sardines which have a maximum age of 13 years (Beverton 1963).

These life history patterns closely correspond to patterns within the biological and physical environments. Parrish et al. (1981) have suggested that species spawning in the Southern California Bight may minimize oceanward dispersal of eggs and larvae because of the closed gyral pattern of geostrophic flow that occurs south of Point Conception, and because of minimized offshore Ekman transport in this region. Upwelling is tremendously important for the stimulation of production of plankton on which larvae feed; however, if it occurs after spawning, larval survival may plummet due to being transported too far offshore. The key for a pelagic species may be to adopt a life history strategy in which the benefits of upwelling (high production) can be balanced against the liabilities (low survival) during egg and larval stages.

There is however a tremendous amount of variability in the California Current (Mysak 1986; Bakun 1973; Parrish et al. 1981). There is intra-annual variation in temperature and upwelling patterns. Hake spawn in winter during periods of weak upwelling. This would provide one method to avoid offshore transport of reproductive products. The depth at which hake eggs and larvae occur, the lower mixed layer, is also the lower end of the portion of the water column that is affected by offshore Ekman transport. Sardines, on the other hand, have adopted a different strategy. Peak spawning occurs after upwelling and offshore Ekman transport have already begun. Perhaps in compensation for this, sardines tend to spawn somewhat nearer to shore (less than about 280 km from shore; Ahlstrom 1954) than hake (less than about 400 km from shore; Stauffer 1985), though they may still be considered to have a 'riskier' spawning strategy. That is, eggs and larvae still have a greater chance of being swept too far offshore.

There is also much interannual variation in the Eastern North Pacific. All cold years in this region are characterized by a strong southward flow, and strong upwelling and offshore transport. In warm years, both the intensity of the southward flow of the California Current and the intensity of upwelling are reduced, while the northward flowing Davidson current and the eddy of the California Bight are intensified (Bailey and Francis 1985; Marr 1960). Both sardines and hake exhibit huge fluctuations in year-class size, affected by climate and oceanography, with cold years resulting in poor year-classes for both sardines and hake. Though not all warm years result in strong year-classes, strong year-classes in both species appear only in conjunction with warm years (Stauffer 1985; Marr 1960). It is likely that strong year classes of both species require a relatively rare combination of events in the timing or magnitude of warm, low intensity upwelling (minimum offshore transport), and cool, high intensity upwelling (high plankton productivity) phenomena. There is some evidence that long life span has evolved as a strategy to ensure "evolutionary persistence under reproductive uncertainty" (Leaman and Beamish 1984). Long life span may then provide an adaptive advantage in an environment where conditions which produce strong year classes rarely occur (Murphy 1968; Leaman and Beamish 1984). Greater dependence on warm years and relatively shorter life span may be one reason for the seemingly more inconsistent occurrence of sardines than of hake in the California current region over the last 2000 years (Soutar and Isaacs 1969).

Two demersal species which predominate in the commercial catch are halibut and sablefish. They have had quite different histories of exploitation, though they are caught with the same gear. The two species share many common life history characteristics. Adults of both species range from southern California to the Gulf of Alaska, into the Bering Sea and south to Japan (Sasaki 1984; Hart 1973), but distribution of eggs, larvae, and juveniles is much more limited. The center of abundance for these two species is the Gulf of Alaska (Sasaki 1984; Bell 1981), though halibut are also very abundant off the coast of British Columbia.

Both species experience large ontogenetic niche shifts. Spawning occurs mostly along the continental slope, and eggs and larvae of both species are distributed over the slope, occurring at depths greater than 100 meters, with the vast majority occurring deeper than 300 meters. Post-larvae (4 to 6 months) move into surface waters, and are pushed inshore by surface currents. Juveniles occur in nearshore and inside waters either at the surface (sablefish) or on the bottom (both halibut and sablefish) and move offshore as they age (Bell 1981; Mason et al. 1983; Sasaki 1984). In both species, the entire eastern North Pacific population appears to be either a single stock or at least well-mixed stocks since both juveniles and adults commonly make extensive migrations, sometimes over the majority of the species' range (Bell 1981; Sasaki 1984).

Unlike halibut, sablefish do not appear to have specific spawning grounds, spawning instead all along the continental slope (Mason et al. 1983). However, eggs and larvae of both sablefish and halibut are dispersed in a wide band. Due to the great depth at which they occur, it is not surface water movements which affect eggs and larvae. Rather, the California undercurrent and deep Alaska current carry eggs and larvae northward and counterclockwise around the Gulf of Alaska. The time of spawning (both species are winter spawners peaking in February) and the pattern of moving up in the water column during the post-larval stage serve to take advantage of onshore surface transport in the Gulf of Alaska which carries post-larvae to nursery grounds. By the time larvae metamorphose into juveniles, they would then have been passively positioned over nursery grounds either inshore or in the relatively shallow Bering Sea (Sasaki 1984; Bell 1981). At later stages, both species may possibly exhibit eastward movement, at least out of the Bering Sea, to compensate for westward movement of early pelagic phases (Bell 1981; Bracken 1983).

As juveniles, both species appear to make heavy use of areas where surface currents are disrupted by islands; such current disruption may create localized upwelling and high productivity. A primary nursery area for juvenile sablefish appears to be southeast Alaska and British Columbia (Sasaki 1984; McFarlane and Beamish 1983), and a large number of juvenile halibut are associated with the Aleutian Island chain (Bell 1981). Both species are quite long-lived;

maximum age of halibut is 60 years (Bell 1981), and that for sablefish is 53 (Leaman and Beamish 1984). Both species exhibit large fluctuations in year-class size. The strategy of longevity then may apply to any species with pelagic eggs and larvae which are dependent on an uncertain favorable combination of ocean currents and Ekman transport events for strong year-class occurrence.

Degree of seasonal movement at the adult stage may be coupled to temperature range of adult habitat. Adult sablefish are typically associated with the continental slope where temperature varies little seasonally, while adult halibut are associated with both shelf and slope (migrating into deeper water for spawning). Adult sablefish appear, in general, to migrate much less than juveniles which occupy shallower more variable regions and which migrate long distances (Dark 1983). Adult halibut on the other hand, which are found in greatest abundance on the shelf (Alverson et al. 1964) where temperature ranges and flow patterns may be more variable, appear to make extensive seasonal migrations both horizontally and vertically (Bell 1981).

DISCUSSION

Differences between general areas of the Eastern North Pacific are revealed in part by differences in climate, oceanography, and geomorphology and geology of the continental margin and coastline. Classification of these differences resulted in a series of interpenetrating physiographic regions. When meshed with biological and cultural information, these physiographic regions were viewed as natural-cultural systems. Such a classification scheme could provide a logical basis for placement of statistical area boundaries such as those used by the International North Pacific Fisheries Commission (International North Pacific Fish. Comm. 1976). With this basis, biological characteristics (such as productivity or life history patterns) of fish species or communities could be compared between regions within an appropriate context of specific environmental features.

An integrated approach for viewing fisheries development is useful because catch and catch patterns can only be understood in the context of their encompassing framework of cultural, biological, and physical factors. Such a framework was provided with a classification of the Eastern North Pacific using units of natural-cultural systems. This classification then provided a means to identify characteristics unique to each natural-cultural system and its fisheries. It also provided a method for comparing patterns of fishery development between systems so that characteristics common to all systems studied could be identified.

Each natural-cultural system has different capacities and performances as it develops over time. Performances of these systems include management and exploitation techniques and technology. The history of management was somewhat different in each natural-cultural system studied, partially because of differences in magnitude and timing of fishing pressure, but also because of differences in composition of the fish communities in each system. However, for the time period studied, management agencies throughout the Eastern North Pacific expressed a common characteristic; they showed a reliance over time on inefficiency measures. This occurred in spite of continuous improvements in fishery technology which tended to perpetually improve efficiency. There has also been a history of divided management authority, especially between state and federal agencies, and a lack of means to resolve conflict between those authorities.

Another performance of natural-cultural systems is catch and catch patterns. Differences between natural-cultural systems were revealed through differences in catch between regions. Catch in the Monterey region has been dominated by species at relatively low trophic levels. This may be due to the nature of the physical environment;

upwelling regions may be characterized by shorter community trophic chains. Salmon were exploited and depleted relatively early in the Monterey region due to a host of interacting factors which include relatively early onset of commercial fishing and of conflicting land use activities that degraded fishery habitat. Hake, a schooling deep-water pelagic species, became an important component in the catch only after technological development made midwater trawls possible. Even then, such immense catch quantities only occurred within the context of a certain political framework.

The Columbia region is characterized by a relatively large number of species harvested, and by relatively high trophic diversity of the catch. This may be a reflection of this region's physical location as an intermediate or overlap area between colder water communities or faunal provinces to the north and warmer water ones to the south (Alverson et al. 1964; Hedgpeth 1957), therefore containing species from both.

In Southeast Alaska, chinook salmon were a significant component of the catch only in the early fishery. Pinks and other salmon became much more important as fishing pressure increased. Non-salmonids formed large portions of the catch much later in Southeast Alaska than in the other two regions. This pattern again is likely a result of many interacting factors. One of these may include continued high abundance of salmonids since Southeast Alaska is relatively closer to the center of near-shore distribution of pink, chum, and sockeye salmon (Hart 1973). Human population has also remained significantly sparser in this region. Therefore, fewer land and water use conflicts have occurred in this region than in regions to the south. For example, as recently as 1981, Alaskan rivers were obstructed by only 19 dams large enough to produce hydroelectric power. Washington rivers had 50 such dams, Oregon rivers had 58, and California rivers had 66 (U.S., Army Corps of Engineers 1981). Such dams can represent large losses of spawning habitat for anadromous species (Anonymous 1988).

In spite of differences between natural-cultural systems, similarities in patterns of catch (and of fishery development) existed. The 'fishing up' process occurred in each region, beginning relatively earlier in the Monterey region, and relatively later in Southeast Alaska. This process was partially expressed through movement of fishers to areas further offshore, through changes in vessel size, and through number of species exploited. Other patterns common to each region were declines in catch of many commercially important species (especially salmon), and changes (first increases, then decreases by the 1970's in two systems) in mean annual landing weights of the total catch. Shifts occurred in trophic composition of the catch toward proportionally greater harvest of species at lower trophic levels.

Because these patterns of catch are common to each natural-cultural system studied, it is felt that they are likely to be characteristic of catch patterns in the entire Eastern North Pacific. Such patterns, along with factors of management and cultural history that are common to the entire Eastern North Pacific, have certain implications for species life history patterns and population dynamics, and for fish communities.

Life history strategies are integrated performances of species and populations. These performances may vary between regions since evolution and development of life history patterns must occur in interaction with environmental constraints. Though each species exhibits unique life history strategies, unrelated species inhabiting similar oceanographic regions may exhibit similar characteristics. Such similarities imply codevelopment of organismic systems and physical/biological systems.

Exploitation is an intense selection pressure which may impose different pressures from those imposed by the physical and biological environments. Species life history performances must change in response to exploitation. However, species which have evolved primarily in response to particular characteristics of the physical and biological environment do not have a guarantee of survival when cultural conditions radically change the characteristics of their selective environment. By reducing the lifespan of species, exploitation may significantly reduce spreading of reproductive risk (den Bohr 1968). In the context of high variability in the physical environment, continued ecological success of a species may require a long life span and many reproductive year-classes (Leaman and Beamish 1984). If these life history traits are required to spread the risk of reproductive failure over many years (thereby diminishing the risk), the population may not be able to survive selection pressure exerted by fishing exploitation which tends to result in a reduced number of year classes. It is noteworthy that a large number of species which are present in the fisheries of the Eastern North Pacific are very long lived (Leaman and Beamish 1984) and therefore may be highly sensitive to heavy harvesting. These fisheries also tend to be heavily dependent on the occurrence of strong year classes.

Over relatively long time spans (decades), declines in catch of many economically valuable fish species have occurred in the Eastern North Pacific. Regional trends in catch may be crudely reflective of changes in relative abundance of species that have had a high market demand after landings reached a peak (a 'fully developed' fishery) and then began to decline. This is likely to occur because of the difficulty involved in removing from the commercial catch (or radically restricting harvest of) traditionally fished and valuable species. Such management strategies have tended to succeed only when fishers actually perceived declines in abundance.

Very great declines in abundance may cause economic destruction (Anderson 1977). That is, though it may be very difficult to drive a marine fish species to extinction, it is possible for that species to reach a point where it is no longer economically feasible to fish for it. However, implications of declines in abundance of species extend far beyond problems of economic destruction. Large changes in relative abundance of species may translate to the community level as shifts in structure. Large changes in abundance of particular life stages may change the ecological role of a species. For example, sardines may have been ecologically replaced by anchovies (Murphy 1966), perhaps because of competition at the larval stage (Marr 1960).

Large changes in relative abundance may also create shifts in trophic composition of the community. This possibility is suggested by Carpenter's concept of cascading trophic interactions (1985). This theory provides a mechanism for change at higher trophic levels cascading down through lower trophic levels within the community. Shifts in species appear to have occurred in various aquatic systems because of human effects (Murphy 1966; Sherman et al. 1981; Christie 1974; Smith 1972). Many unexploited communities appear to be dominated by large old individuals of species (Regier and Loftus 1972; Odum 1969) which may be high on the trophic chain (Johnson 1972; Terbough 1988). Exploitation has been implicated in reductions of these less productive populations because it reduces their abundance, therefore possibly favoring increases in small, rapidly growing opportunistic fish species (Overholtz and Tyler 1985; Regier and Loftus 1972; Sherman et al. 1981). Trophic structure within the community would then be rearranged.

Changes in trophic composition of catch in the systems studied may indicate that some species at higher trophic levels are being selected against, and therefore that smaller more productive species are favored by exploitation. However, as illustrated by sardine fisheries, species and communities are not regulated only by cultural pressures for high production and high efficiency of energy use. Whether even smaller more productive species (like sardines) survive is dependent on the rate of exploitation combined with other constraints imposed by the natural-cultural system.

CONCLUSION

The view of Eastern North Pacific fisheries as developing systems encompasses evolutionary theory, implying that systems are not static, but are changing through geological time and through human life-span time. This view also encompasses the concept that an organismic system, whether species, community, or natural-cultural system, responds to and evolves within a multitude of environmental factors within physical, biological, and cultural subsystems. In an environment where all components develop and change at different magnitudes and at different rates in response to each other, production-oriented exploitation cannot be viewed either as a neutral selective process or as reversible or predictable.

This problem is interconnected with current ongoing management problems. Harvest has been, and largely continues to be, regulated principally by inefficiency measures because of a social system that does not promote either self-regulation or allow a larger scale of regulatory control. In a historical sense, management agencies addressed some components of resource crises (technological solutions, reactive management approaches, production- and extraction-oriented economics), while not addressing other critical components including cultural solutions to resource problems, proactive management approaches, uncertainty of supply of stocks, or natural (cyclic or renewable) economics[1]. There is still no clear framework of plans and procedures for resolving conflict (national or international) between management agencies or between fishers and managers. While control over foreign fishers has largely been achieved, serious problems continue to plague the domestic industry. These include severe overcapitalization of the industry, and a lack of regulatory enforcement measures. These problems stem from a lack of means to limit entry coupled with an overriding world view that predominates in the U.S. which may be inconsistent with sound management of open access 'commons' resources. This world view tends to emphasize individualism and materialism and de-emphasize community or global values. Utilitarianist goals have also been adopted over preservationist goals.

It is because of these problems and within the context of these interconnected factors within the natural-cultural system that the following management suggestions are made. Management tools must no longer be restricted to inefficiency measures related to curbing continually improving technology. An appropriate framework for proactive management and conflict resolution should be developed. Such a framework should take into account both the interagency and international nature of fisheries

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[1] Jim Lickatowich, speech given at the Oregon Chapter American Fisheries Society, February, 1989.

exploitation. All fishery agencies should work with and support progress on United Nations Law of the Sea conferences as they relate to fisheries management. Since reactive management does not appear to be very effective, management agencies need to become more multidisciplinary, innovative, and pro-active, serving as community organizers and educators; that is, managers must recognize that they manage people as well as fish.

Economic stabilization of the fishing industry is very desirable, but depends, I feel, on several things. Uncertainty of supply of various fisheries must be addressed. Given fluctuations in environmental conditions and the fact that fisheries are capable of developing so rapidly that little time is available for collection of biological information, it may be desirable to adopt 'safety factors' used to account for limitations of analytical information (Bella 1979). Economic stabilization is also very likely to depend on ceasing federal subsidization programs that promote fishery development, and on developing economic incentives (or disincentives) for maintaining sustainable harvests. This is likely to require some reconciliation with limited entry programs.

REFERENCES

Ahlstrom, E.H. 1954. Distribution and abundance of egg and larval populations of the Pacific sardine. Fish. Bull., U.S. 93:83-140.

Ahlstrom, E.H., and J. Radovich. 1970. Management of the Pacific sardine. In: Benson, N.G., ed. A Century of Fisheries in North America. Am. Fish. Soc. Spec. Pub. 7. Washington, D.C.: Am. Fish. Soc.

Alverson, D.L., A.T. Pruter, and L.L. Ronholt. 1964. A Study of Demersal Fishes and Fisheries of the Northeastern Pacific Ocean. Vancouver, B.C.: Univ. of British Columbia.

Anderson, L.G. 1977. The Economics of Fisheries Management. Baltimore: Johns Hopkins Univ. Press.

Anonymous. 1988. Pacific salmon and steelhead management. Portland, OR: Western Region U.S. Fish and Wildlife Service.

Anonymous. 1987. Oregon's commercial fishing industry: its importance to Oregon's economy. Portland, OR: West Coast Fisheries Development Foundation.

Anonymous. 1949. The commercial fish catch of California for the year 1947 with an historical review 1916-1947. Calif. Dept. Fish and Game, Fish Bull. 74.

Bailey, K.M., and R.C. Francis. 1985. Recruitment of Pacific whiting, Merluccius productus, and the ocean environment. Mar. Fish. Rev. 47(2): 8-15.

Bakun, A. 1973. Coastal upwelling indices, west coast of North America, 1946-71. U.S. Dept. Commer., NOAA Tech. Rpt. NMFS SSRF-671.

Baxter, J.L. 1967. Summary of biological information on the northern anchovy, Engraulis mordax (Girard). Calif. Coop. Oc. Fish. Invest. Rpt., Vol. 11.

Beacham, T.D. 1986. Type, quantity, and size of food of Pacific salmon (Oncorhynchus) in the Strait of Juan de Fuca, British Columbia. Fish. Bull., U.S. 84(1): 77-89.

Bell, F.H. 1981. The Pacific Halibut: The Resource and the Fishery. Anchorage: Ak Northwest Pub. Co.

Bell, F.H, H.A. Dunlop, and N.L. Freeman. 1952. Pacific coast halibut landings 1888 to 1950 and catch according to area of origin. Int. Fish. Comm. Rpt. 17.

Bella, D.A. 1979. An inquiry into the rationale and use of environmental safety factors. Available from author at: Dept. of Civil Engineering, Oregon State University, Corvallis, OR.

Berggren, W.A., and C.D. Hollister. 1977. Plate tectonics and paleocirculation - commotion in the ocean. Tectonophysics 38: 11-48.

Beverton, R.J.H. 1963. Maturation, growth and mortality of clupeid and engraulid stocks in relation to fishing. Rapp. Proces. Verbaux Reun. Cons. Perm. Int. Explor. Mer. 154:44-67.

Bowering, W.R. 1987. Distribution of witch flounder, Glyptocephalus cynoglossus, in the southern Labrador and eastern Newfoundland area and changes in certain biological parameters after 20 years of exploitation. Fish. Bull., U.S. 85(3):611-629.

Bracken, B.E. 1983. Sablefish migration in the Gulf of Alaska based on tag recoveries. In: Melteff, B.R., ed. Proceedings of the International Sablefish Symposium. Fairbanks: Alaska Sea Grant College Program.

Browning, R.J. 1974. Fisheries of the North Pacific: History, Species, Gear, and Processes. Anchorage: Alaska Northwest Pub. Co.

Carpenter, S.R., J.F. Kitchell, and J.R. Hodgson. 1985. Cascading trophic interactions and lake productivity. BioSci. 35(10): 634-639.

Chase, T.E., H.W. Menard, and J. Mammerickx. 1971. Topography of the North Pacific. Inst. of Mar. Res. Tech. Rpt. Ser., TR-17. La Jolla, CA: Scripps.

Christie, W.J. 1974. Changes in the fish species composition of the Great Lakes. J. Fish. Res. Board Can. 31: 827-854.

Circum-Pacific Map Project. 1984. Circum-Pacific Council for Energy and Mineral Resources. Plate-tectonic Map of the Circum-Pacific Region: Pacific basin sheet. Tulsa, OK: Am. Assoc. of Petrol. Geologists.

Clausen, D.M. 1981. Summer food of Pacific cod, Gadus macrocephalus, in coastal waters of southeastern Alaska. Fish. Bull., U.S. 78(4): 968-973.

Collins, J.W. 1889. Report on the fisheries of the Pacific coast of the U.S. In: Annual Report of the U.S. Commissioner of Fisheries, 1889. U.S., Dept. of Commerce, Bureau of Fisheries.

Dark, T.A. 1983. Movement of tagged sablefish released at abundance index sites off Southeastern Alaska, Washington, Oregon, and California during 1978-81. In: Melteff, B.R., ed. Proceedings of the International Sablefish Symposium. Fairbanks: Alaska Sea Grant College Program.

den Boer, P.J., 1968. Spreading of risk and stabilization of animal numbers. Acta Biotheor. 18: 165-194.

Dewey, J.F. 1972. Plate tectonics. In: Continents adrift and continents aground. San Francisco: Freeman and Co.

Dodimead, A.J., F. Favorite, and T. Hirano. 1963. Review of oceanography of the subarctic Pacific region. Int. North Pacific Fish. Comm. Bull. 13.

Enfield, D.B., and J.S. Allen. 1980. On the structure and dynamics of monthly mean sea level anomalies along the Pacific coast of North and South America. J. Phys. Oceanogr. 10: 557-578.

Fleming, R.H. 1955. Review of the oceanography of the Northern Pacific. Int. North Pacific Fish. Comm. Bull. 2.

Forrester, C.R., R.G. Bakkala, K. Okada, and J.E. Smith. 1983. Groundfish, shrimp, and herring fisheries in the Bering Sea and Northeast Pacific - historical catch statistics, 1971 - 1976. Int. North Pacific Fish. Comm. Bull. 41.

Forrester, C.R., A.J. Beardsley, and Y. Takahashi. 1978. Groundfish, shrimp, and herring fisheries in the Bering Sea and Northeast Pacific - historical catch statistics through 1970. Int. North Pacific Fish. Comm. Bull. 37.

Gabriel, W.L. 1982. Structure and Dynamics of Northeastern Pacific Demersal Fish Assemblages. PhD thesis, College of Oceanography, Corvallis: Oregon State Univ.; Dissertation.

Gunderson, D.R. 1977. Population biology of Pacific Ocean perch, Sebastes alutus, stocks in the Washington-Queen Charlotte Sound region, and their response to fishing. Fish. Bull., U.S. 75(2): 369-403.

Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Board Canada, Bull. 180.

Hedgpeth, J.W. 1957. Marine biogeography. Geol. Soc. of Am. Memoir 67, Vol. 1: pp. 359-382.

Hildreth, R.G., and R.W. Johnson. 1983. Living resource management. In: Hildreth, R.G., and R.W. Johnson, eds. Ocean and Coastal Law. Englewood Cliffs, NJ: Prentice-Hall.

Horn, M.H. 1970. Systematics and biology of the stromateid fishes of the genus Peprilus. Bull. Mus. Comp. Zoo. 140(5): 165-262.

Ingmanson, D.E. and W.J. Wallace. 1985. Oceanography: An Introduction (3rd edition). Belmont, CA: Wadsworth Inc.

Inter-American Tropical Tuna Comm. 1952. Annual report for the years 1950 and 1951.

International North Pacific Fish. Comm. 1976. Statistical summary, 1976. In: Forrester, C.R., ed. Int. North Pacific Fish. Comm. Statistical Yearbook, 1976.

Isacks, B., and J. Oliver. 1968. Seismology and the new global plate tectonics. J. of Geophys. Res. 73(18): 5855-5899.

Johnson, L. 1972. Keller Lake: characteristics of a culturally unstressed salmonid community. J. Fish. Res. Board Canada 29: 731-740.

Kasahara, H. 1961. Fisheries Resources of the North Pacific Ocean. Part 1. Vancouver, B.C.: Univ. British Columbia.

Kasahara, H., and W. Burke. 1973. North Pacific fisheries management. Program of Int. Studies of Fish. Arrangements, paper 2.

Keleher, J.J. 1972. Great Slave Lake: effects of exploitation on the salmonid community. J. Fish. Res. Board Canada 29: 741-753.

King, D.M. and H.A. Bateman. 1985. The economic impact of recent changes in the U.S. tuna industry. Cal. Sea Grant College Program working paper no. P-T-47.

Kukla, G.L., and D.A. Robinson. 1981. Temperature changes in the last 100 years. In: Berger, A., ed. Climatic Variations and Variability: Facts and Theories. Boston: Reidel.

Larkin, P.A. 1977. An epitaph for the concept of maximum sustained yield. Trans. Am. Fish. Soc. 106:1-11.

Leaman, B.M., and R.J. Beamish. 1984. Ecological and management implications of longevity in some Northeast Pacific groundfishes. Int. North Pacific Fish. Comm. Bull. 42.

Liss, W.J., L.J. Gut, P.H. Westigard, and C.E. Warren. 1986. Perspectives on arthropod community structure, organization, and development in agricultural crops. Ann. Rev. Entomol. 31: 455-478.

Livingston, P.A. 1983. Food habits of Pacific whiting, Merluccius productus, off the west coast of North America, 1967 and 1980. Fish. Bull., U.S. 81(3): 629-636.

Love, M.S., G.E. McGowen, W. Westphal, R.J. Lavenberg, and L. Martin. 1984. Aspects of the life history and fishery of the white croacker, Genyonemus lineatus (Sciaenidae), off California. Fish. Bull., U.S. 82(1): 179-198.

Marr, J.C. 1960. The causes of major variations in the catch of the Pacific sardine. In: Rosa, H.Jr., and G. Murphy, eds. Proceedings of the World Scientific Meeting on the Biology of Sardines and Related Species, Vol. 3. Rome: Food and Ag. Organization (UN).

May, R.M., J.R. Beddington, C.W. Clark, S.J. Holt, and R.M. Laws. 1979. Management of multispecies fisheries. Science 205: 267-277.

Mason, J.C., R.J. Beamish, and G.A. McFarlane. 1983. Sexual maturity, fecundity, spawning, and early life history of sablefish (Anoplopoma fimbria) in waters off the Pacific coast of Canada. In: Melteff, B.R., ed. Proceedings of the International Sablefish Symposium. Fairbanks: Alaska Sea Grant College Program.

McEvoy, A.F. 1986. The Fisherman's Problem: Ecology and Law in the California Fisheries, 1850 - 1980. Cambridge, Mass.: Cambridge Univ. Press.

McFarlane, G.A., and R.J. Beamish. 1983. Preliminary observations on the juvenile biology of sablefish (Anoplopoma fimbria) in waters off the west coast of Canada. In: Melteff, B.R., ed. Proceedings of the International Sablefish Symposium. Fairbanks: Alaska Sea Grant College Program.

Miller, D.J. and R.N. Lea. 1972. Guide to the coastal marine fishes of California. Calif. Dept. Fish and Game, Fish Bull. 157.

Moyle, P.B., and J.C. Cech, Jr. 1982. Coastal habitats. In: Fishes: An Introduction to Ichthyology. Englewood Cliffs, NJ: Prentice-Hall.

Murphy, G.I. 1966. Population biology of the Pacific sardine (Sardinops caerulea). Proc. Cal. Acad. Sci. 34(1):1-84.
Murphy, G.I. 1968. Pattern in life history and the environment. Am. Nat. 102:391-407.

Myhre, R.J., G.J. Peltonen, G. St-Pierre, B.E. Skud, and R.E. Walden. 1977. The Pacific halibut fishery: catch, effort, and CPUE, 1929-1975. Int. Pacific Halibut Comm. Tech. Rpt. 14.

Mysak, L.A. 1986. El Nino, interannual variability and fisheries in the Northeast Pacific Ocean. Can. J. Fish. Aquat. Sci. 43: 464-497.

Newell, R.E. 1981. Climate and the ocean. In: Skinner, B.J., ed. Climates Past and Present. Los Altos, CA: Kaufman.

Niblock, R.W., P.A. Johnson, P.S. Adler, K.A. Beil, T.A. Cotton, R.M. Crawford, E.L. Govan, R.C. Raymond, J.M Roales, and B.L. Silverstein. 1977. Establishing a 200-Mile fisheries zone. U.S., Congress, Off. Tech. Assess., Oceans Program.

Odum, E.P. 1969. The strategy of ecosystem development. Science 164: 262-270.

Overholtz, W.J. and A.V. Tyler. 1985. Long-term responses of the demersal fish assemblages of Georges Bank. Fish. Bull., U.S. 83(4): 507-520.

Paltridge, G.W. 1984. Latitudinal variation in the change of sea surface temperature from 1880 to 1977. Monthly Weather Rev. 112: 1093-1095.

Parrish, R.H., C.S. Nelson, A. Bakun. 1981. Transport mechanisms and reproductive success of fishes in the California Current. Biol. Oc. 1(2):175-203.

Pearcy, W., T. Nishiyama, T. Fujii, and K. Matsuda. 1984. Diel variations in the feeding habits of Pacific salmon caught in gill nets during a 24-hour period in the Gulf of Alaska. Fish. Bull., U.S. 82(2): 391-399.

Pella, J.J. 1979. Climate trends and fisheries. In: Clepper, H., ed. Predator-prey Systems in Fisheries Management. Wash., D.C.: Sport Fishing Inst.

Pinkas, L. 1966. A management study of the California barracuda, Sphyraena argentea (Girard). Calif. Dept. Fish and Game, Fish Bull. 134: 5-11.

Quast, J.C. 1986. Annual production of eviscerated body weight, fat, and gonads by Pacific herring, Clupea harengus pallasi, near Auke Bay, Southeastern Alaska. Fish. Bull., U.S. 84: 705-721.

Quinn, W.H., D.O. Zopf, K.S. Short, and R.W.K Yang. 1978. Historical trends and statistics of the Southern Oscillation, El Nino, and Indonesian droughts. Fish. Bull., U.S. 76: 663-678.

Regier, H.A. and V. C. Applegate. 1972. Historical review of the management approach to exploitation and introduction in SCOL lakes. J. Fish. Res. Board Canada 29: 683-692.

Regier, H.A., and K.H. Loftus. 1972. Effects of fisheries exploitation on salmonid communities in oligotrophic lakes. J. Fish. Res. Board Canada 29: 959-968.

Rexstad, E.A., and E.K. Pikitch. 1986. Stomach contents and food consumption estimates of Pacific hake, Merluccius productus. Fish. Bull., U.S. 84(4): 947-956.

Ricker, W.E. 1981. Changes in the average size and average age of Pacific salmon. Can. J. Fish. Aquat. Sci. 38: 1636-1656.

Ripley, W.E. 1946. The soupfin shark and the fishery. In: The biology of the soupfin, Galeorhinus zyopterus, and biochemical studies of the liver. Calif. Dept. Fish and Game, Fish Bull. 64: 7-19.

Robinson, M.K. and R.A. Bauer. 1976. Atlas of North Pacific Ocean Monthly Mean Temperatures and Mean Salinities of the Surface Layer. Washington: U.S., Naval Oceanographic Office.

Roedel, P. M. 1953. The jack mackerel, Trachurus symmetricus: a review of the California fishery and of current biological knowledge. Calif. Dept. Fish and Game, Fish Bull. 39(1): 45-68.

Ryder, R. A., S.R. Kerr, W.W. Taylor, and P.A. Larkin. 1981. Community consequences of fish stock diversity. Can. J. Fish. Aquat. Sci. 38: 1856-1866.

Ryther, J.H. 1969. Photosynthesis and fish production in the sea. Science 166: 72-77.

Sasaki, T. 1984. Studies on the sablefish resources of the North Pacific Ocean. Bull. of the Far Seas Fish. Research Lab. 232: 1-108.

Schaffer, W.M., and P.F. Elson. 1975. The adaptive significance of variations in life history among local populations of Atlantic salmon in North America. Ecology 56: 577-590.

Sharma, G.D. 1979. The Alaskan Shelf: Hydrographic, Sedimentary, and Geochemical Environment. New York: Springer-Verlag.

Shepard, F.P. 1973. Submarine Geology. New York: Harper.

Shepard, F.P, and H.R. Wanless. 1971. Our Changing Coastlines. New York: McGraw-Hill.

Sherman, K., C. Jones, L. Sullivan, W. Smith, P. Berrien, and L. Ejsymont. 1981. Congruent shifts in sand eel abundance in western and eastern North Atlantic ecosystems. Nature 291(5815): 486-489.

Smith, S.H. 1972. Factors of ecologic succession in oligotrophic fish communities of the Laurentian Great Lakes. J. Fish. Res. Board Canada 29: 717-730.

Soutar, A., and J.D. Isaacs. 1969. History of fish populations inferred from fish scales in anaerobic sediments off California. Calif. Coop. Oc. Fish. Invest. Rpt. 13:63-70.

Statistical Survey Procedures, 1944. In: Fisheries Statistics of the U.S., 1944. U.S., Dept. of the Interior, Fish and Wildlife Service.

Stauffer, G.D. 1985. Biology and life history of the coastal stock of Pacific whiting, <u>Merluccius productus</u>. Mar. Fish. Rev. 47(2):2-7.

Sulman, F.G. 1982. Short- and long-term changes in climate, Vol. 2. Boca Raton, Fl: CRC Press.

Sverdrup, H.U., M.W. Johnson, R.H. Fleming. 1942. The Oceans: Their Physics, Chemistry, and General Biology. Englewood Cliffs, NJ: Prentice Hall.

Terborgh, J. 1988. The big things that run the world - a sequel to E.O. Wilson. Conservation. Biol. 2(4):402-403.

Thurman, H.V. 1987. Essentials of Oceanography. Columbus: Merrill.

U.S., Army Corps of Engineers. 1981. Hydropower Analysis Techniques and National Resources Summary. In: National Hydroelectric Power Resources Study, Vol. 12.

U.S., Dept. of Commerce, Bureau of Fisheries. Annual Report of the U.S. Commissioner of Fisheries, 1889. Also: same for 1925 through 1929.

U.S., Dept. of Commerce, National Marine Fisheries Service. Fisheries Statistics of the United States, 1967. Also: same for 1968 through 1976.

U.S., Dept. of the Interior, Fish and Wildlife Service. Fisheries Statistics of the United States, 1942. Also: same for 1943 through 1953.

Van Loon, H. 1984. Climates of the oceans. In: Van Loon, H., ed. World Survey of Climatology, Vol. 15. New York: Elseveir.

Walford, L.A. 1974. Marine game fishes of the Pacific coast from Alaska to the equator. Neptune, NJ: T.F.H. Publication.

Walford, L.A. 1932. The California barracuda (Sphyraena argentea). Calif. Dept. Fish and Game, Fish Bull. 37.

Warren, C.E, M. Allen, J.W. Haefner. 1979. Conceptual frameworks and the philosophical foundations of general living systems theory. Behavioral Sci. 24:296-310.

Warren, C.E., and W.J. Liss. 1983. Systems classification and modeling of watersheds and streams. Available from: W.J. Liss, Dept. of Fisheries and Wildlife, Oregon State University, Corvallis, OR.

Warren, C.E., and W.J. Liss. 1980. Adaptation to aquatic environments. In: Lackey, R.T., and C.A. Nielsen, eds. Fisheries Management. New York: Halstead Press.

Werner, E.E. 1986. Species interactions in freshwater fish communities. In: Diamond, J., and T.J. Case, eds. Community Ecology. New York: Harper and Row.

APPENDICES

APPENDIX I. Sources of fishery data by year.

Year	Year	General Fishery Statistics	Foreign Catches	Halibut	Groundfish & Herring
1888	1888	Rept. of the U.S. Comm. of Fisheries		Bell 1952	
1922	1922	Rept. of the U.S. Comm. of Fisheries		Bell 1952	
1923	1923	Rept. of the U.S. Comm. of Fisheries		Bell 1952	
1924	1924	Rept. of the U.S. Comm. of Fisheries		Bell 1952	
1925	1925	Rept. of the U.S. Comm. of Fisheries		Bell 1952	
1926	1926	Rept. of the U.S. Comm. of Fisheries		Bell 1952	
1927	1927	Rept. of the U.S. Comm. of Fisheries		Bell 1952	
1928	1928	Rept. of the U.S. Comm. of Fisheries		Bell 1952	
1942	1942	USFWS Stat. Digest		Myhre et al. 1977	
1943	1943	USFWS Stat. Digest		Myhre et al. 1977	
1944	1944	USFWS Stat. Digest		Myhre et al. 1977	
1945	1945	USFWS Stat. Digest		Myhre et al. 1977	
1946	1946	USFWS Stat. Digest		Myhre et al. 1977	
1947	1947	USFWS Stat. Digest		Myhre et al. 1977	
1948	1948	USFWS Stat. Digest		Myhre et al. 1977	
1949	1949	USFWS Stat. Digest		Myhre et al. 1977	
1950	1950	USFWS Stat. Digest		Myhre et al. 1977	
1951	1951	USFWS Stat. Digest		Myhre et al. 1977	
1967	1967	U.S. NMFS Stat. Digest	Forrester et al. 1978	Myhre et al. 1977	INPFC Stat. Yearbook, 1976
1968	1968	U.S. NMFS Stat. Digest	Forrester et al. 1978	Myhre et al. 1977	INPFC Stat. Yearbook, 1976
1969	1969	U.S. NMFS Stat. Digest	Forrester et al. 1978	Myhre et al. 1977	INPFC Stat. Yearbook, 1976
1970	1970	U.S. NMFS Stat. Digest	Forrester et al. 1978	Myhre et al. 1977	INPFC Stat. Yearbook, 1976
1971	1971	U.S. NMFS Stat. Digest	Forrester et al. 1983	Myhre et al. 1977	INPFC Stat. Yearbook, 1976
1972	1972	U.S. NMFS Stat. Digest	Forrester et al. 1983	Myhre et al. 1977	INPFC Stat. Yearbook, 1976
1973	1973	U.S. NMFS Stat. Digest	Forrester et al. 1983	Myhre et al. 1977	INPFC Stat. Yearbook, 1976
1974	1974	U.S. NMFS Stat. Digest	Forrester et al. 1983	Myhre et al. 1977	INPFC Stat. Yearbook, 1976
1975	1975	U.S. NMFS Stat. Digest	Forrester et al. 1983	Myhre et al. 1977	INPFC Stat. Yearbook, 1976
1976	1976	U.S. NMFS Stat. Digest	Forrester et al. 1983	Myhre et al. 1977	INPFC Stat. Yearbook, 1976

APPENDIX II. Inconsistencies in the data.

In statistical surveys made before 1942, the entire catch of a vessel was attributed to that vessel's "principle port of landing, regardless of the actual point of landing" (Statistical Survey Procedure, 1944). In other words, if a vessel traveled much within a year, many of its catches could have been recorded in incorrect areas. However, for the early years of the fisheries (1880's and 1920's) this does not seem problematic for the following reasons:

1) Vessel fisheries (those likely to be conducted far from home ports) were tremendously outnumbered by shore and boat fisheries with the exceptions of a cod fleet based in San Francisco, and the halibut fleet of Seattle. In these early years, cod were caught almost exclusively in waters of the Bering Sea and Aleutian Islands, and were dry-salted at sea. Dry-salted cod were recorded as such in catch information, and could therefore be excluded from catches of the Monterey region. In regions other than Monterey, only landed weights of fresh cod were used. This would have the effect of minimizing the possibility that fish could have been transported a great distance from their region of capture before being landed. For the 1920's, Seattle-based halibut fleet catch weights were listed by fishing grounds, so the weight of species caught by these vessels (halibut, rockfish, sablefish, lingcod, sturgeon) could be attributed to their regions of origin.

2) Anadromous species, flatfish, many rockfish species,

and nearshore species were primarily caught by the shore and boat fishery which was unlikely to travel far from the area where fish were caught.

Problems caused by movement of vessels were therefore minimized.

Qualifications of specific periods

1888

All reported weights for this period (and for the 1920's) are 'product' weights. Salmon weights in southeast Alaska are estimated from the number of cases packed. Added to canned weights are products weights of other methods of preparation of salmon, including fresh, pickled, dried and salted, etc.

From the Monterey region, partial records came from the San Francisco fresh fish trade. Species sold in this trade are listed in a qualitative fashion, and therefore some interesting information about particular species of flatfish, rockfish, and mackerel are provided (Collins 1888), but catch of all species within these groups are lumped into their respective group. Jack mackerel (Trachurus symmetricus), which in the 1920's was separated from true mackerel, was lumped with true mackerel in 1888, but landings in 1888 were likely to be low.

1922-1928

Catch of halibut, rockfish, sablefish, and lingcod made by the Seattle halibut fleet is listed by fishing ground for this period in the Annual Reports of the U.S. Commissioner of Fisheries, so landing weights for the Columbia region are quite accurate.

In southeast Alaska, a halibut fleet was just being created in the 1920's. Catches were made by this fleet in both British Columbia and Southeast Alaska, but in federal records, the catches from both these regions were assigned to Southeast Alaska. Records of halibut catch therefore came from International Pacific Halibut Commission Records where catch was recorded according to area of origin (Bell, 1952), but species caught incidentally with halibut (sablefish, lingcod, rockfish) would be over-represented in federal records. Therefore, if halibut landings for Southeast Alaska reported in federal records were not within 15% of weights reported by the Halibut Commission, it was assumed that the halibut fleet spent much time outside Alaskan waters. Catch records for sablefish, lingcod, and rockfish for these years were subsequently deleted from mean period weights. While this left only three of the seven years of data available, all landing weights for these species were so low that differences in means of three and seven years of data was, in all cases, less than 100 mt (Table A.II.1, Southeast Alaska).

1942-1951

In statistical surveys made after and including 1942, 'the catch of fish...is credited to the port where it is landed' (Statistical Survey Procedure, 1944), and catch weights are round weight. In southeast Alaska, the same

Table A.II.1. Comparisons between catch weight data (in mt) provided by different sources.

SOUTHEAST ALASKA:

1920's:	Stat. Digest	other*	Absolute Difference	Percent Difference	1940's: Stat. Digest	other**	Absolute Difference	Percent Difference	1970's: Stat. Digest	other***	Absolute Difference	Percent Difference
Lingcod	3	5	2	38%	94	11	82	88%	26	7	19	73%
Rockfish	6	4	1	26%	201	117	84	42%	2,332	2,286	47	2%
Sablefish	294	195	99	34%	2,687	2,870	182	6%	10,616	10,018	598	6%
Cod									189	167	22	11%
Flatfish									2,015	2,019	4	0%
Herring									4,899	4,939	40	1%
Ocean perch									17,377	17,495	119	1%

Stat. Digests are compiled by the U.S. Fish Commission, U.S. Fish & Wildlife Service, or National Marine Fish. Service.

*Weights are averages of 3 years of data where wt. of halibut from digest records corresponded well with Halibut Commission records.

**Weights come from 'products as prepared for market' (Alaska landings only) for 1942 & 1943.

***Weights are INPFC catch weights for the corresponding area.

COLUMBIA REGION:

1970's:	Stat. Digest	other*	Absolute Difference	Percent Difference
Cod	361	183	178	49%
Flatfish	7,060	5,451	1,609	23%
Hake	76,886	76,616	270	0%
Herring	26	0	26	*
Lingcod	924	607	317	34%
Ocean perch	2,685	2,469	217	8%
Rockfish	3,235	2,306	928	29%
Sablefish	950	703	247	26%

*Weights are INPFC catch weights for the corresponding area.

MONTEREY REGION:

1970's:	Stat. Digest	other*	Absolute Difference	Percent Difference
Flatfish	2,948	5,386	2,438	45%
Hake	28,459	28,455	4	0%
Herring	753	20	733	97%
Lingcod	355	493	138	28%
Rockfish	3,810	4,380	569	13%
Sablefish	1,656	1,037	619	37%

*Weights are INPFC catch weights for the corresponding area.

problem occurs with federal records of halibut fleet landings as occurred in the 1920's, so halibut landings were again taken from IPHC records (Myhre et al. 1977). For two years (1942 and 1943), only Alaska landings of sablefish, lingcod, and rockfish occurred in a section of federal records called 'products as prepared for market.' These product weights were converted to round weight and an average taken. When these means were compared with means of landings of all years from federal records, absolute differences in those means were less than 200 mt (Table A.II.1). Therefore, means from landings in the federal records were used.

Columbia region landings do not include landings made by the Seattle halibut fleet since these could not be divided according to fishing ground. Therefore, the reported catch weights of sablefish, lingcod, and rockfish are likely to be an underestimate of actual landings according to area of origin. I could find no means of comparing these weights with landing weights according to area of origin.

1967-1976

Southeast Alaska data from Statistical Digests (federal records) has the same qualifications as it did for the 1940's. However, for this time period, the International North Pacific Fisheries Commission (INPFC) gathered data on 'catch' weights (landings according to area of origin). Therefore, INPFC weights were used. However, in order to get some idea of accuracy of landings of species reported by federal records, but not by INPFC records (non-groundfish), comparisons were made between means of INPFC catch data and means of Statistical Digest landings data. Results of these comparisons appear in Table A.II.1. For Southeast Alaska, if the difference in absolute means was >100 mt, then the % difference was <10%. Percent difference in mean weights for the Columbia region are within 30% with one exception: Pacific cod, and here the difference is less than 200 mt. The Monterey region displays the greatest discrepancy between federally-reported landing weights and INPFC-reported catch weights. A significant note here is that the difference in area between INPFC statistical areas and the federal statisical regions is greatest in the Monterey region. This may be part of the reason for the greater discrepancy. Other reasons however may relate to the fact discussed in this paper that mean vessel size in Monterey is much greater than that in the other two regions and has been so since before the 1940's. Therefore, it is likely that Monterey region fishermen consistently travel farther from areas of landing than other fishermen.

Foreign catches appear in this database only for the years 1967 through 1976, and come from Forrester et al. (1978). Foreign fishing in U.S. waters was restricted to the Bering Sea and western Alaska before the mid-1950's (Alverson et al. 1964), and therefore was insignificant in the regions studied during other time periods.

Halibut

Halibut catch weights are taken from International Pacific Halibut Commission (earlier title: International Fisheries Commission) records, and represent landings according to area of origin (Bell et al. 1952; Myhre et al. 1977). However, the Halibut Commission lumped all catches south of Cape Blanco, Oregon into one statistical area since landings in this region were commercially insignificant. Therefore, for this study, landings of halibut in the Monterey region are taken from Fisheries Commission Reports and Statistical Digests in the same manner as all other species. For Southeast Alaska, catch weights in Halibut Commission statistical areas 14 through 20 were totaled, and catch in statistical areas 00 through 05 were totaled for the Columbia region. In order to maintain consistency with other data, weights preceding and including 1928 are product weights (headed/gutted fish), and following and including 1942 are round weight (converted from headed/gutted weight by multiplying by 1.5).

Cod

Landings weights of pacific cod also present some difficulty, since Seattle vessels (for which landing data was not included) are likely to have fished for cod off British Columbia and Alaska as well as off Washington. For example, total weight of cod landed in Washington for 1922 was 33 mt. Only 2 mt of this was landed in the coastal region. The origin of the Seattle landings (the remainder) is impossible to determine, and therefore was not added to

Columbia region landings. Cod landings then are likely an underestimate of catch made in the Columbia region, but again total landings are quite low.

Table A.III. Means of landings by time period and region.

SOUTHEAST ALASKA:

	1888	1920'S	1940'S	1970'S
COD	0	11	16	167
DOGFISH (& other sharks)	0	0	910	0
FLATFISH (all but halibut)	0	3	8	2,019
HAKE	0	0	0	772
HALIBUT	0	5,651	8,600	6,539
HERRING	0	8,827	18,897	4,939
LINGCOD	0	5	94	7
OCEAN PERCH	0	0	0	17,495
POLLACK	0	0	0	1,036
ROCKFISH	0	6	201	2,286
SABLEFISH	0	294	2,687	10,018
SALMON, CHINOOK	2,575	3,457	4,173	1,960
SALMON, CHUM	0	16,712	16,560	7,571
SALMON, COHO	0	4,503	8,665	3,304
SALMON, PINK	0	50,068	40,078	14,130
SALMON, SOCKEYE	0	4,444	2,753	2,161
SKATES	0	0	61	0
SMELT	0	6	1	39
STEELHEAD	0	7	4	10

Table A.III (continued).

COLUMBIA REGION:

	1888	1920'S	1940'S	1970'S
ANCHOVIES	0	0	0	63
COD	0	0	64	183
DOGFISH	0	0	1,431	8
FLATFISH (all but halibut)	0	1	5,278	5,451
HAKE	0	0	16	76,616
HALIBUT	295	1,599	501	197
HERRING	0	10	34	0
LINGCOD	0	208	813	607
OCEAN PERCH	0	0	0	2,469
POLLACK	0	0	0	0
ROCKFISH	0	104	4,138	2,306
SABLEFISH	0	854	411	703
SALMON, CHINOOK	17,338	11,196	8,367	5,018
SALMON, CHUM	0	2,822	1,512	275
SALMON, COHO	0	5,091	3,382	6,709
SALMON, PINK	0	93	3	158
SALMON, SOCKEYE	0	647	209	100
SARDINES	0	0	3,736	0
SHAD	5	603	709	305
SHARK (excluding dogfish & soupfin)	0	0	18	0
SHARK, SOUPFIN	0	0	432	0
SKATES	0	0	19	56
SMELT, EULACHON	82	558	1,332	801
SMELT, SURF	0	0	323	56
STEELHEAD	0	1,799	733	221
STRIPED BASS	0	1	43	16
STURGEON	440	121	160	268
SURFPERCH	1	2	26	1
TOMCOD	14	0	2	1
TUNA, ALBACORE	0	0	6,073	12,993
TUNA, BLUFN	0	0	0	12
TUNA, SKIPJACK	0	0	317	344
TUNA, YLWFN	0	0	1,095	1,971

Table A.III (continued).

MONTEREY REGION:

	1888	1920'S	1940'S	1970'S
ANCHOVIES	142	102	1,622	4,167
BARRACUDA	91	6	0	0
BONITO	37	5	0	10
CABEZONE	0	0	4	2
DOGFISH (& other sharks)	0	95	365	55
FLATFISH (all but halibut & Cal. halibut)	344	4,530	1,957	5,386
HAKE	0	31	4	28,455
HALIBUT, CALIFORNIA	0	10	42	65
HALIBUT, PACIFIC	0	3	17	0
HERRING	1,871	295	814	20
JACK MACKEREL	0	2	2,563	173
KINGFISH	29	63	103	70
LINGCOD	133	245	208	493
MACKEREL (true) SPP.	91	404	463	0
OCEAN PERCH	0	0	0	171
POMPANO	2	0	25	11
ROCKFISH	615	1,083	882	4,380
SABLEFISH	0	212	454	1,037
SALMON (all spp.)	4,701	1,781	2,552	1,238
SARDINES	29	63,395	140,218	0
SEA BASS, BLACK	0	0	0	53
SEA BASS, WHITE	250	57	30	8
SHAD	75	874	599	0
SKATES	18	91	35	40
SMELT	608	118	369	36
STRIPED BASS	328	322	0	0
STURGEON	437	0	0	0
SURFPERCH	101	37	43	21
TOMCOD	4	9	0	0
TUNA, ALBACORE	0	38	1,547	2,527
TUNA, BLUEFIN	0	0	13	0
TUNA, SKIPJACK	0	4	13	0
TUNA, YELLOWFIN	0	0	25	0