ECOLOGICAL (BIOPHYSICAL) COASTAL CLASSIFICATION OF PACIFIC RIM NATIONAL PARK

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PREFACE

This report is the culmination of five years of work in Pacific Rim National Park. It is not meant to stand alone, but rather to be considered in conjunction with Fisheries Research Board of Canada Manuscript Report 1389 and Fisheries and Marine Service Manuscript Reports 1436, 1467 and 1514 (Lee and Bourne 1976, 1977, 1978 and 1979). These four reports contain detailed descriptions of the intertidal and subtidal marine flora and fauna at selected locations throughout Pacific Rim National Park, and particulars of the various species-specific research projects undertaken. This detailed work is the basis for the map unit descriptions and biophysical maps presented in this report.

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ABSTRACT

Lee, J.C., B.L. Yoshida and N. Bourne. 1981. Ecological (biophysical) coastal classification of Pacific Rim National Park.

The 1979-80 study was the final year of a five-year program to provide information on marine organisms and their associated habitats for park planning, interpretation and management. Data from habitat type and fauna and flora surveys of the previous four years were used to construct an ecological (biophysical) classification system for the coastal areas of Pacific Rim National Park. Coastal systems and coastal types are mapped at a scale of 1:25 000 for the Long Beach and West Coast Trail Sections, and at 1:12 500 for the Broken Group Islands Section.

Key Words: marine park, British Columbia, ecological (biophysical) classification, coastal classification, coastal systems, coastal types.

INTRODUCTION

The marine biophysical study, begun in 1975 in Pacific Rim National Park (Lee and Bourne 1976, 1977, 1978 and 1979), was completed in 1979-80 on behalf of Parks Canada, Western Region, by J.C. Lee and Associates Ltd. in affiliation with the Pacific Biological Station (Nanaimo), Fisheries and Marine Service, Department of Fisheries and Oceans. The 1979-80 study was the final year of a five-year program designed to provide information on marine communities for park planning, interpretation and management.

In the present year, major emphasis was placed on developing an ecological (biophysical) coastal classification system for the marine environment of Pacific Rim National Park.

As Lacate's (1969) hierarchical land classification is the basis for the biophysical land classification systems utilized by Parks Canada, Western Region, it was felt that a coastal classification system for Pacific Rim National Park similar to Lacate's would facilitate the comparison of definitions, terminology and scales of mapping between land and water classification systems. The classification system utilized in this project is based on the four-level hierarchical coastal classification by Warren and Anderson (1975a, 1975b), adapted from Lacate (1969). The four levels, from highest to lowest, include Coastal Region, Coastal District, Coastal System and Coastal Type.

Data from field surveys (1975-79) and literature reviews were combined in the development and definition of the four levels of the hierarchy. Information collected through literature reviews is presented in the "General description of area" and was utilized to define the extent of the coastal region and coastal districts. Data from field surveys were combined to define the extent of the coastal systems and coastal types. Coastal systems and coastal types are mapped at a scale of 1:25 000 for the Long Beach and West Coast Trail Sections and 1:12 500 for the Broken Group Islands.

Terminology used in the annual reports (Lee and Bourne 1976, 1977, 1978 and 1979) have been retained except for the following:

1) Exposure to wave action
   - exposed changed to high energy
   - semi-exposed changed to moderate energy
   - sheltered changed to low energy
2) Intertidal area changed to beach
   Subtidal area changed to nearshore

Following the main body of the report a glossary of technical terms is presented. Words defined in this glossary are underlined where they first appear in the text.

Terms of reference for the development of the coastal classification are given in Appendix 6.

GENERAL DESCRIPTION OF AREA

LOCATION

Pacific Rim National Park established in April 1970, is located on the west coast of Vancouver Island between latitudes 48°30'N and 49°05'N (Fig. 1). The park extends approximately 112 km along the coast and is comprised of three distinct sections. Long Beach is the most northerly section located between the villages of Tofino and Ucluelet; Broken Group Islands are situated in the middle of Barkley Sound; and West Coast Trail, the most southerly section, is located between the village of Bamfield and Port San Juan (Fig. 2).

PHYSIOGRAPHY

Pacific Rim National Park lies within the Vancouver Island Mountains of the Outer Mountain Area of the Canadian Cordilleran Region (Fig. 3). Two physiographic divisions of the Vancouver Island Mountains are found within the park boundaries - Estevan Coastal Plain, a very narrow strip of coastal plain along the western and southwestern coast, and Vancouver Island Ranges, the predominantly mountainous part of Vancouver Island (Holland 1976).

The Estevan Coastal Plain within Pacific Rim National Park is 1.5 to 3 km wide, extends from Tofino to Cullite Cove, 13 km southeast of Carmanah Point (Fig. 4). The majority of the Plain is less than 46 m above sea level, although it is interrupted by irregular hills and isolated knolls which are seldom more than 76 m high (Fig. 5).

During recent geological time, erosion of the coastal plain where it is underlain by relatively soft sediments has resulted in a flat almost featureless surface. However, insufficient time has elapsed for erosion of adjacent harder rocks causing a more uneven surface.

Gently dipping sandstones (relatively soft deposits) are the predominant rock types northwest of Cullite Cove. Southeast of Cullite Cove, sedimentary rocks are almost absent, with only a few remnants remaining in protected bays.

Only the southwest coastal portion of the Vancouver Island Ranges is located within Pacific Rim National Park. The Ranges extend to the coast between Cullite Cove and Gordon River (Fig. 4).

Vancouver Island Ranges are composed of heterogeneous sedimentary and volcanic rocks, folded about northwesterly tending axes and intruded by numerous granitic batholiths. The mountains are the result of uplift and dissection of a Tertiary erosion surface which produced an extremely rugged topography (Holland 1976). This topography was further modified by glaciation. The highest peaks of the Vancouver Island Ranges are in the central part of Vancouver Island with summit elevations diminishing to the northwest and southeast. Although there are no mountain peaks of this range included in Pacific Rim National Park, the rugged topography is most evident between Owen Point and Gordon River where the terrain is much steeper than in any other area of the park.

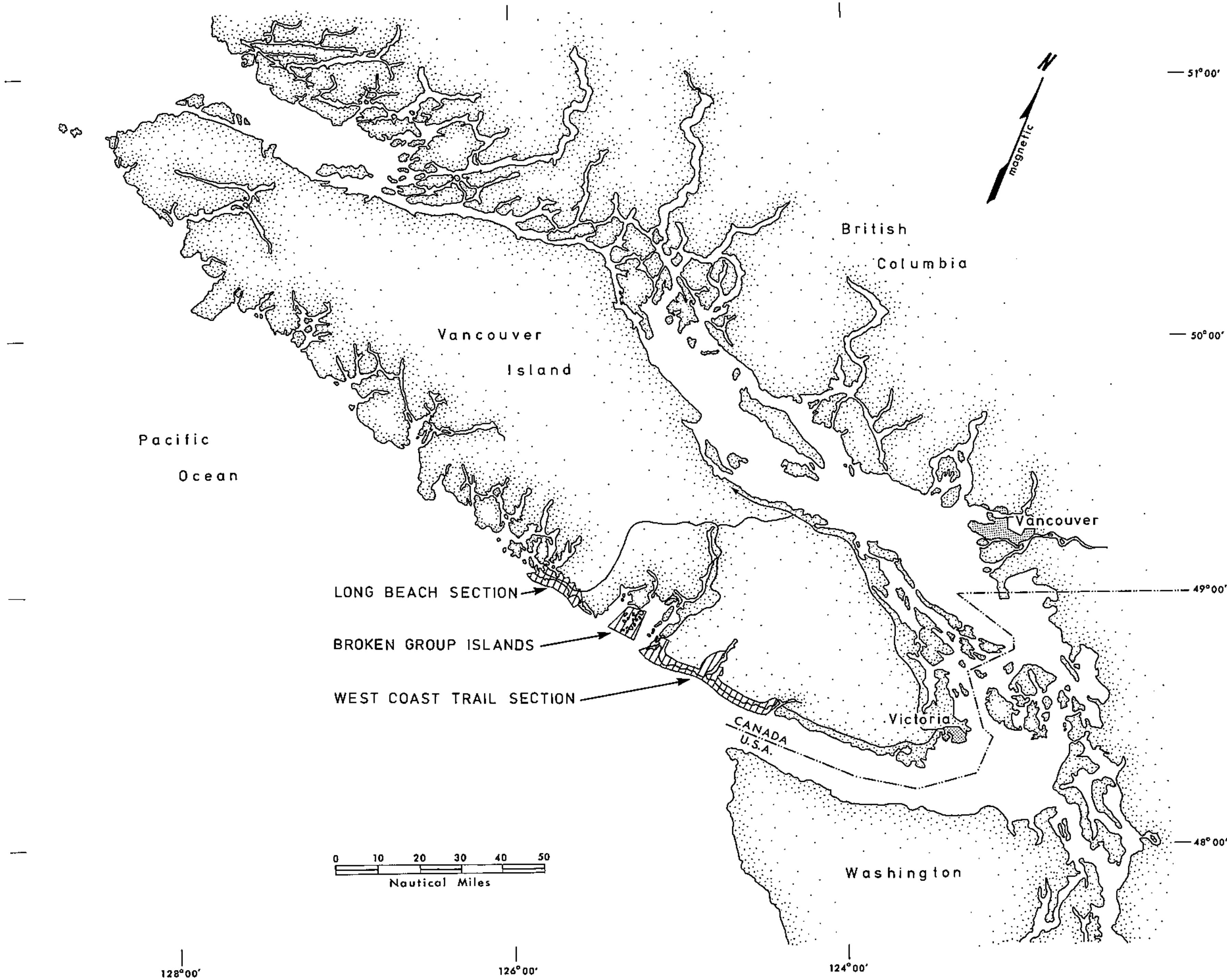


Fig. 1. Geographic location of Pacific Rim National Park.

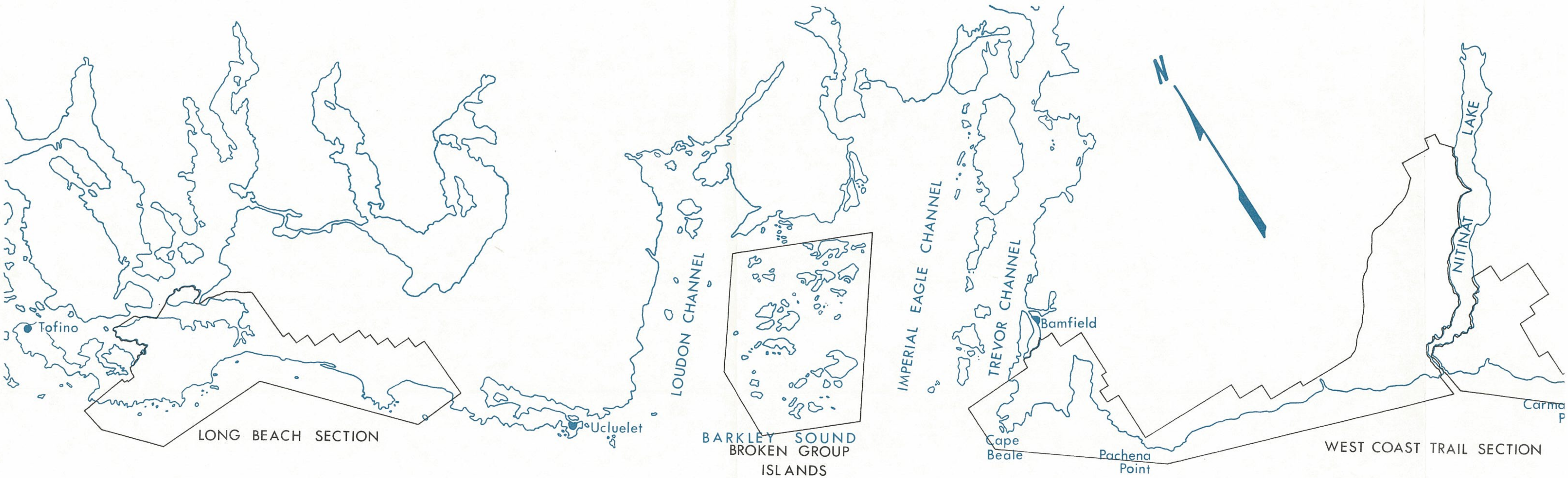
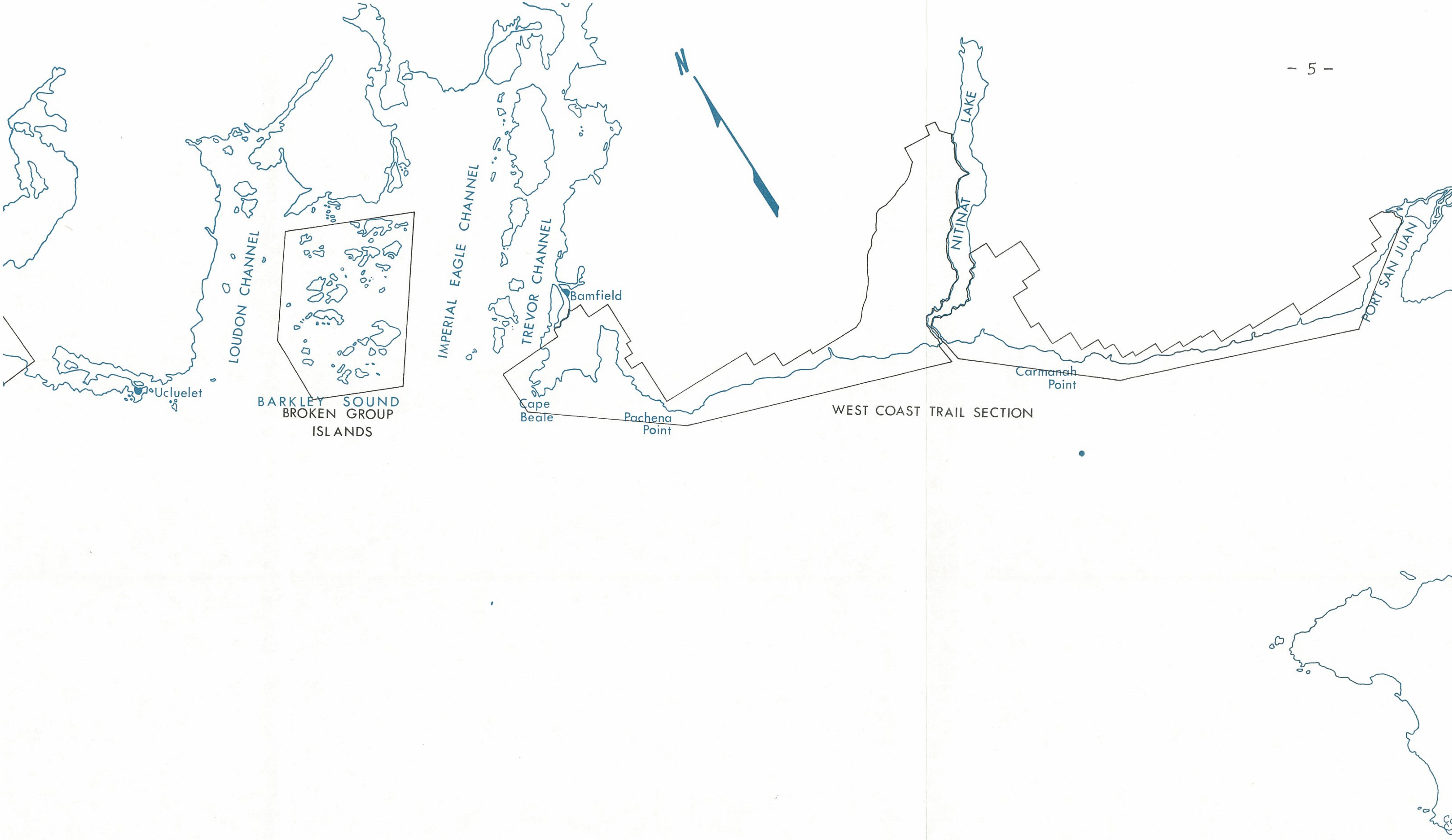


FIGURE 2. PARK BOUNDARIES


N
LOUDON CHANNEL
IMPERIAL EAGLE CHANNEL
TREVOR CHANNEL
Bamfield
Ucluelet
BARKLEY SOUND
BROKEN GROUP
ISLANDS
Cape
Beale
Pachena
Point
NITINAT
LAKE
Carmanah
Point
PORT SAN JUAN
WEST COAST TRAIL SECTION

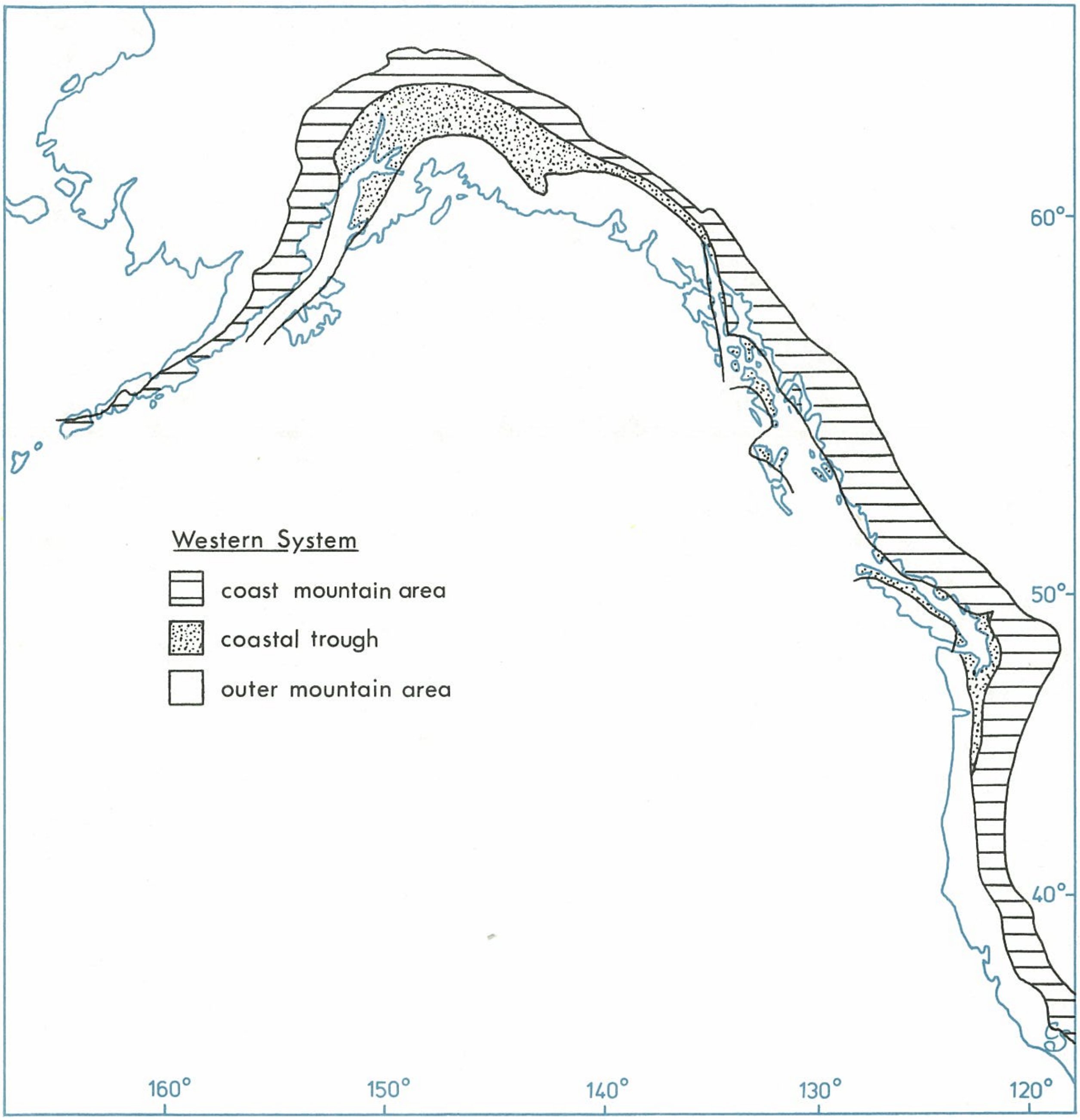


Fig. 3. Major physiographic divisions of western North America (Fenneman and Johnson 1946; Holland 1976; Wahrhaftig 1965)

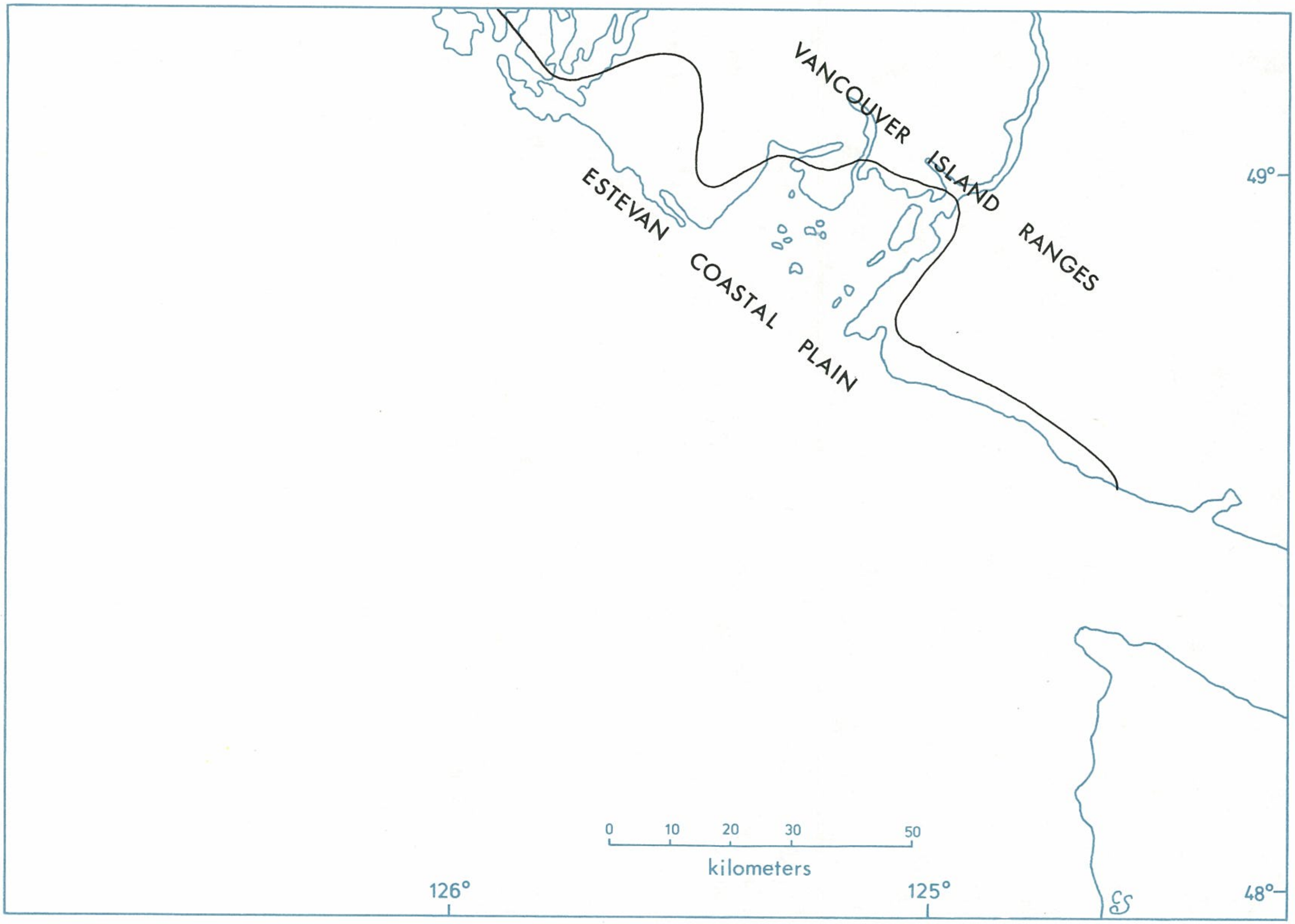


Fig. 4. Physiographic divisions of southwestern Vancouver Island (Holland 1976)

Fig. 5. Estevan Coastal Plain, looking southwest from Esperanza Inlet (B.C. Air Photo Library)

Literature

Reference 107 provides detailed physiographic information on British Columbia. Accounts of the physiographic divisions of the mainland United States and Alaska are found in references 70, 112 and 210. Background geology information is included in reference 167.

GEOLOGY

A general discussion of the geology of Pacific Rim National Park is presented, based primarily on the studies of Muller (1974).

Bedrock geology

The geological formations exposed on rocky shores and underlying sandy beaches of Pacific Rim National Park are described as the "Pacific Rim". The coast of the Long Beach Section is underlain by highly deformed sedimentary and minor volcanic rocks of the probable Jurassic and Cretaceous age (late Mesozoic), the Pacific Rim Complex; the inland part mainly by the early Mesozoic or late Paleozoic Westcoast Crystalline Complex. The Broken Group Island Section is mainly underlain by the same crystalline complex. The West Coast Trail Section is underlain by the Westcoast Crystalline Complex at the west end, and by Leech River Schist at the east end, but most of the West Coast Trail Section is Tertiary sandstone of the Carmanah Formation (Fig. 6) (Muller 1974).

The rock formation of the outer coast of the Long Beach Section, bounded to northeast by the Pacific Rim Fault Zone, is a unique formation not known elsewhere on the Canadian Pacific Coast. Muller (1974) called this formation the Pacific Rim Complex. In this formation the rocks show an intense degree of deformation. Faulting is pervasive and all continuity of layering sequence has been destroyed. A minimal amount of layering has been preserved in the more resistant greywackes and cherts, but in many places the rocks have been ground into a tectonic breccia or a melange.

Two rock assemblages are present in the Pacific Rim Complex: volcanic-sedimentary assemblage and greywacke-argillite assemblage. The volcanic-sedimentary assemblage contains many rock types and is found on the north and south ends of Long Beach and from Florencia Bay south along the coast of the Ucluth Penninsula. In parts of this assemblage, chert is almost the only component as seen on Box Island. The greywacke-argillite assemblage is present mainly along the coast of Schooner Cove and on Quisitis Point.

The Westcoast Crystalline Complex is the foundation of the rock sequence that underlies Vancouver Island. This complex is a good example of a migmatite complex, an assemblage of rocks of partly metamorphic and partly igneous character (eg. amphibolite, quartz diorite and granodiorite). In the Long Beach Section it is present on the islets on the north shore of Grice Bay, the south shore of Tsapee Narrows and on Indian Island. It is separated from the Pacific Rim Complex by the Pacific Rim Fault Zone. The Broken Group

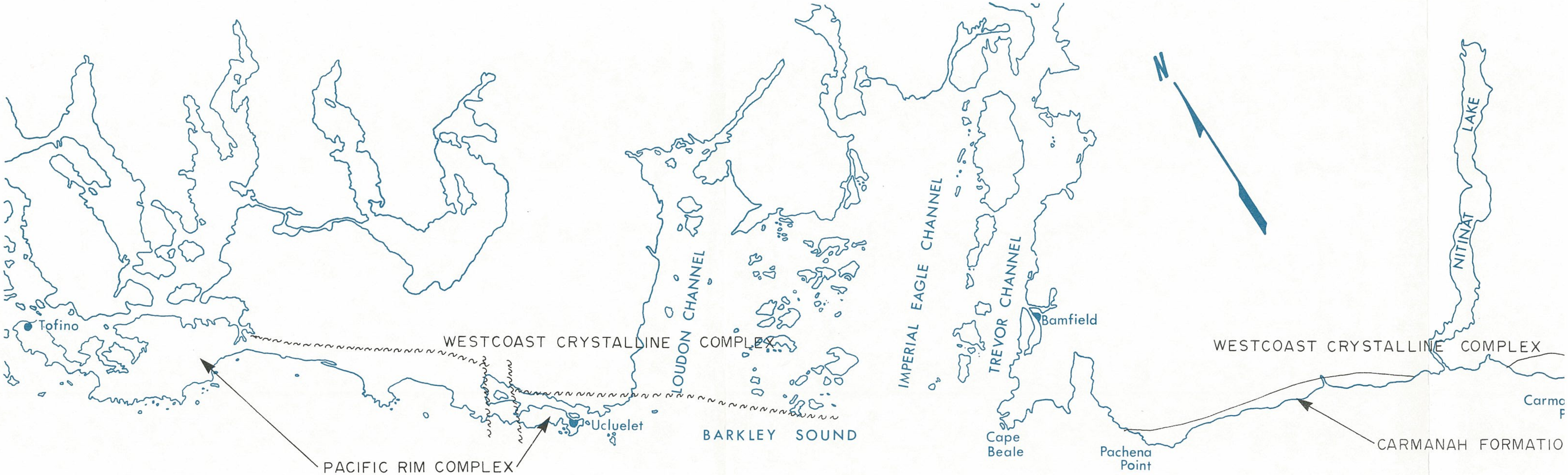
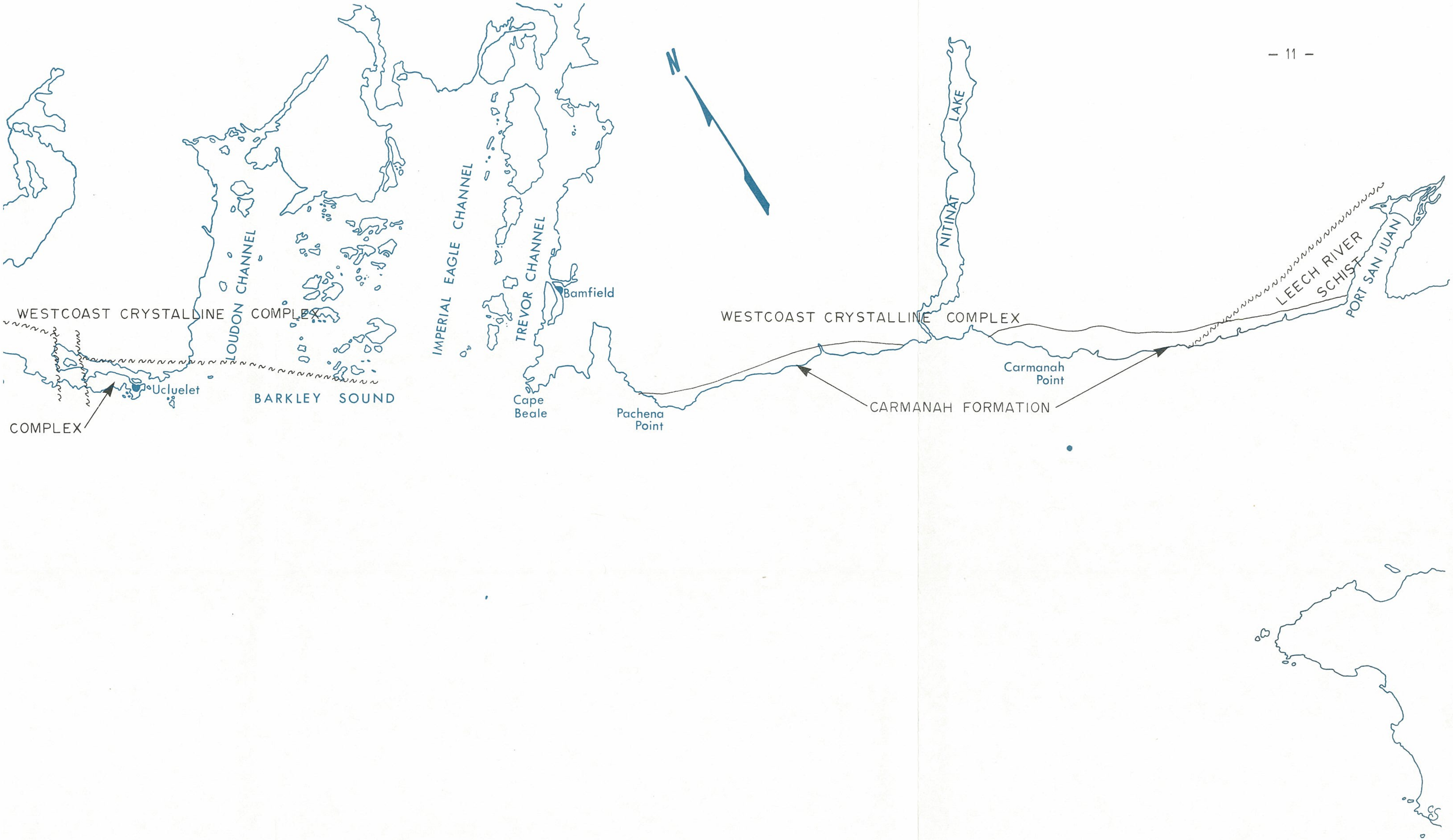


FIGURE 6. GEOLOGICAL FORMATIONS

LEGEND
~~ fault lines

(Muller, 1974)


N
WESTCOAST CRYSTALLINE COMPLEX
LOUDON CHANNEL
IMPERIAL EAGLE CHANNEL
TREVOR CHANNEL
Bamfield
Ucluelet
BARKLEY SOUND
COMPLEX
Cape Beale
Pachena Point
NITINAT LAKE
WESTCOAST CRYSTALLINE COMPLEX
LEECH RIVER SCHIST
PORT SAN JUAN
Carmanah Point
CARMANAH FORMATION

Islands Section is underlain by this complex and in the West Coast Trail Section, it is present as the base under Tertiary sedimentary rocks.

The Carmanah Formation, present along the west coast between Pachena Bay and Port Renfrew, consists of Tertiary sedimentary rock. Between Pachena Bay and Clo-oose, a rough rocky coast of crystalline rocks (of Westcoast Crystalline Complex) alternates with a smooth shoreline of flat wide shelves of sandstone and siltstone. Between Clo-oose and Camper Creek, the crystalline rocks are covered by a succession of sediments such as greywacke-sandstone, conglomerate, siltstone and shale as well as the debris of older volcanic, granitic and sedimentary rocks and their components.

The Leech River Schist consists of sedimentary rocks similar to those of the Pacific Rim Complex but have been subjected to even greater stresses and higher temperatures and have been converted to schist and slate. This rock formation is present along the West Coast Trail east of Camper Creek.

Two other geological formations found along the coast of Pacific Rim National Park but on a much smaller scale are Parson Bay Formation and Paleozoic limestone. Parson Bay Formation consists of sequences of thin-bedded limestone alternating with beds of calcareous argillite, siltstone and greywacke. Only metamorphosed equivalents of this formation are found on Cree, Howell, Benson and Clarke Islands of the Broken Group Islands Section.

Paleozoic limestone is found in the West Coast Trail Section on both sides of Nitinat Lake, near the mouth of the Klanawa River and farther upstream on Walbran River. The limestone is either massive and recrystallized to form medium to coarse-grained marble or is thinly interbedded with siliceous layers.

Unconsolidated material

Sand, gravel and stony clay now covering large portions of Pacific Rim National Park were deposited in shallow sea-water during glacial times. Distribution of these unconsolidated sediments in Pacific Rim National Park is outlined in Figure 7. These sediments are largely restricted to the Long Beach Section.

Sand and gravel, called Quadra Sediments, are exposed in sea cliffs, road cuts and gravel pits in many places on Vancouver Island. Although no radiocarbon dates are available for Pacific Rim National Park sediments, it is probable that the sand exposed in the Tofino municipal gravel pit and the gravel along the road to Radar Hill are Quadra Sediments (Muller 1974).

Stony clay sediments in the cliffs of Florencia Bay probably represent the Fraser Glaciation. Stony clay is also uncovered in the Tofino gravel pit, where it overlies the sand and gravel tentatively correlated with the Quadra Sediments (Muller 1974).

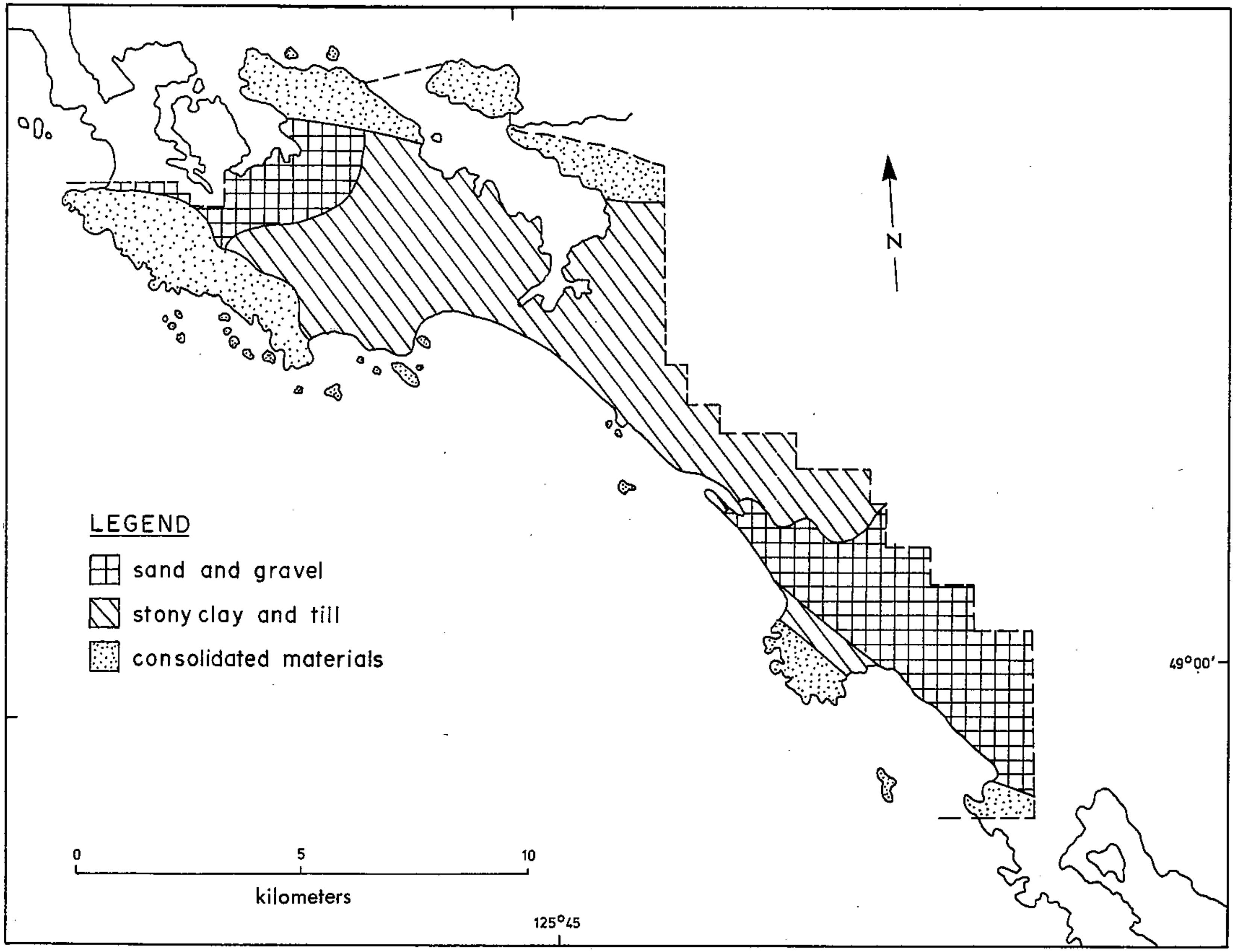


Fig. 7. Unconsolidated material in the Long Beach Section (Muller 1974)

Literature

The most detailed geological information of Pacific Rim National Park is available from reference 148. References 143 and 167 give background information.

SHORELINE FEATURES

The general lack of shoreline features of marine origin has resulted from the recent emergence of the present coastline from beneath the glaciers (less than 11 000 years ago). Beaches in British Columbia are generally scarce because bedrock along most shorelines is resistant to the little erosion that has taken place in geologically recent years. However, extensive beaches have developed along stretches of shallow depth where unconsolidated glacial materials and easily eroded sedimentary rocks have accumulated. Elsewhere, steeply plunging submarine slopes have precluded beach formation.

Shoreline features of Pacific Rim National Park are both unique and representative. Three broad types of geological formations may be distinguished: 1) poorly consolidated Pleistocene sediments; 2) soft rocks, including the less well consolidated Tertiary sediments; and 3) hard rocks, including granitic, volcanic and well-indurated sedimentary rocks.

Pacific Rim National Park encompasses one of the few areas in British Columbia where extensive beaches have accumulated. These beaches are generally associated with areas of Tertiary sediments or with occurrences of unconsolidated fluvioglacial material (Muller 1974, Holland 1976). These sediments are not resistant to erosion. Oceanic waves constantly erode the sea cliffs of unconsolidated material providing sand and coarse materials which accumulate along the shallow shoreline. The largest sandy beaches of this nature in Pacific Rim National Park are Long Beach in Wickaninnish Bay and "Wreck Beach" in Florencia Bay (Fig. 8).

Soft or Tertiary sedimentary rocks form the flat benches of the West Coast Trail Section. They form a straight coast consisting of a vertical cliff and a flat sandstone shelf which slopes down gradually from the highest tide level (Fig. 9). On this gradual, even surfaced, foreshore slope the Pacific swell builds up into high, wide and straight-fronted breakers that are more forceful than those surging against the unevenly indented hard rock coast (Muller 1974).

Hard rocks are most resistant to erosion and form the dominant shoreline features of headlands, islands and reefs. Differences in hardness within the hard rocks are further emphasized by erosion. Headlands are intricately indented with small bays and channels. Harder parts of the rock, like chert layers, pebbles in conglomerate or calcareous concretions in siltstone may weather out and stand in relief on the rock surface (Fig. 10).

Sea cliffs, caves and surge channels are predominant shoreline features along the west coast of Vancouver Island. In Pacific Rim National Park, sea cliffs occur where softer sediments between more resistant rock have been eroded or where resistant sandstone and conglomerate rock of the coastal plain is eroded, producing low cliffs. Faults or soft layers in

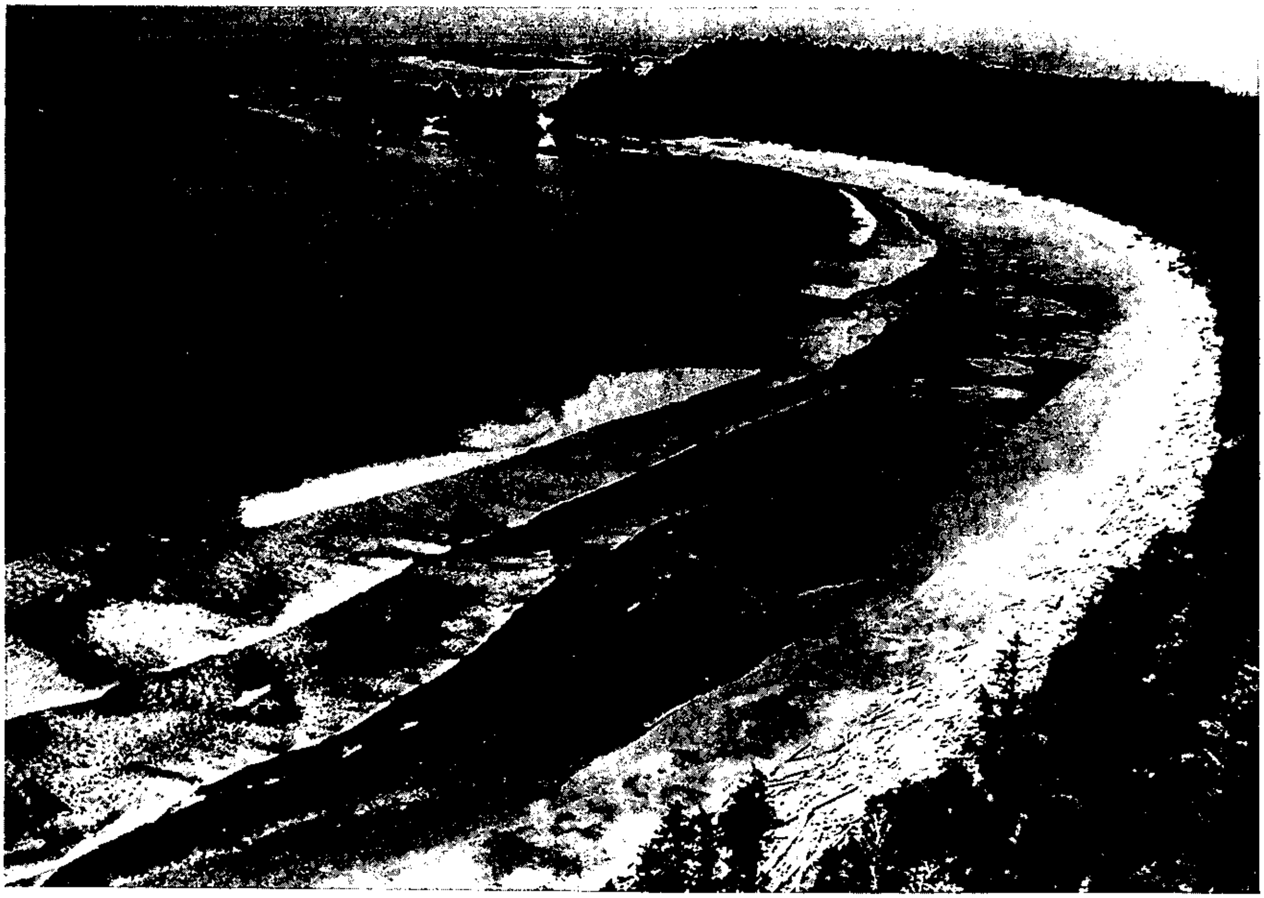


Fig. 8. Florencia Bay, Long Beach Section (Barry Campbell, photo)

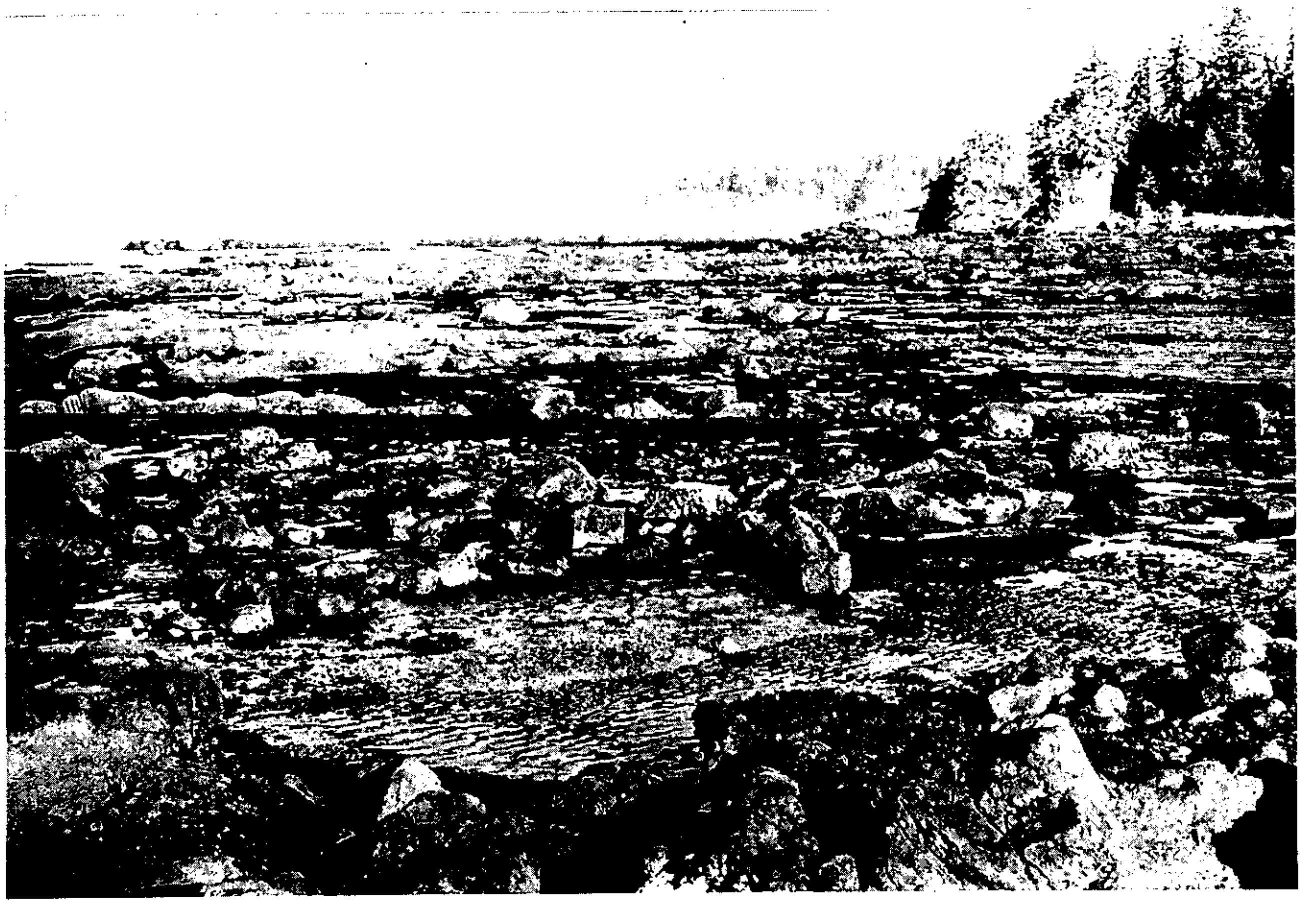


Fig. 9. Sandstone bench, a common shoreline feature of the West Coast Trail Section

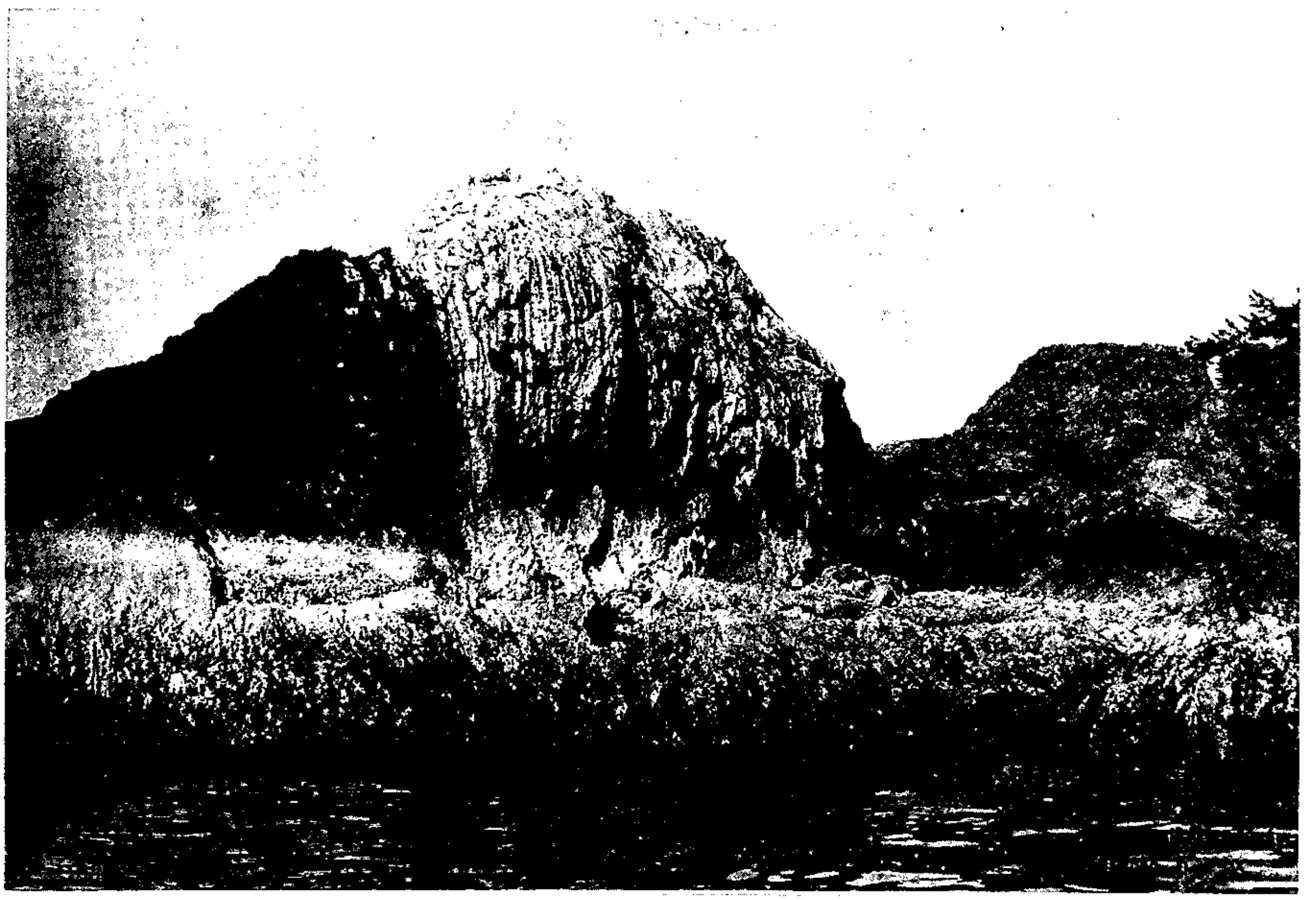


Fig. 10. Harder layers of rock standing out in relief, Broken Group Islands

sedimentary or volcanic rocks eroded by surf, form sea caves and blow holes (eg. Tsuquardra and Tsusiat Points and "Hole in the Wall", West Coast Trail Section). Fault zones are commonly filled with a softer rock which is eroded away to leave surge channels (Fig. 11).

Fiord inlets are outstanding features of the west coast of Vancouver Island. These fiords have steep glaciated sides and U-shaped cross profiles. Shoaling near their mouths is produced by a threshold of bedrock or unconsolidated material with a basin on the inner side of depths usually greater than 90 m.

Although there are no fiords included within the boundaries of Pacific Rim National Park, two fiord systems lie adjacent to the park. The first is a group of narrow inlets on the northeast shore of Barkley Sound which extends seaward as the three main channels of Barkley Sound (Carter 1973). The Broken Group Islands therefore lie between the extensions of two fiord inlets: Loudon Channel to the northwest is the continuation of Pipestem Inlet and Toquart Bay, and Imperial Eagle Channel to the southeast is the seaward extension of Effingham Inlet. The largest fiord inlet entering Barkley Sound is Alberni Inlet which continues seaward as Trevor Channel. A shallow sill of this fiord inlet system extends across the mouth of Barkley Sound.

The other fiord inlet is Nitinat Lake (Northcote, Wilson and Hurn 1964) which divides the West Coast Trail into two nearly equal parts. Nitinat Lake is unique among the fiord inlets of British Columbia in that all water below 30 m is strongly deoxygenated. The deoxygenated bottom water may remain stagnant for several decades with little or no circulation. However, a complete exchange or turnover can occur during winter or early spring when surface waters are cool, contain little fresh water and are exposed to strong offshore winds. The deoxygenated bottom water, high in hydrogen sulphide, is brought to the surface and causes widespread mortality of fauna in the upper water layers. Such an event occurred in 1970 when large numbers of salmon, other fish species and invertebrates were killed due to repiratory poisoning by hydrogen sulphide (Bell and Hoskins 1971).

Literature

Reference 107 gives physiographic information for British Columbia, while references 14, 25, 36, 148 and 150 provide data on shoreline features within Pacific Rim National Park.

Fig. 11. Surge channel, Radar Beaches, Long Beach Section

CLIMATE

The climate of the Pacific Rim National Park area is classed as a humid, mesothermal, oceanic climate (Koppen's classification in Byrne 1973). It is characterized by heavy winter rainfall, mild temperatures and moderately strong winds.

The mean annual precipitation at Tofino is 306 cm while Pachena Point receives 299 cm. Precipitation occurs mainly in winter months (Fig. 12) and less than 2% of it falls as snow. Even in the driest months (May to August) rain can be expected on at least one third of the days. The Tofino precipitation graph (Fig. 12) is representative of conditions throughout most of the park although the extreme southern end of the West Coast Trail lies partially within the rain shadow of the Olympic Peninsula and receives somewhat less rain (Department of the Environment 1973).

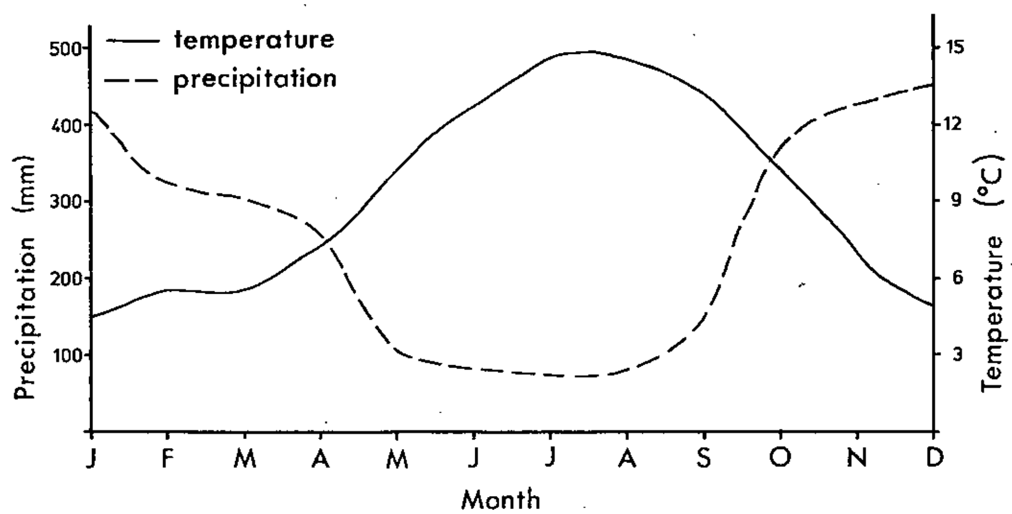


Fig. 12. Mean monthly temperature and precipitation at Tofino - 1941 to 1970 (Department of the Environment 1973)

Temperatures in the park are mild in the winter and summer. Tofino's mean daily temperature in January is 4.4°C and in August is 14.6°C (Fig. 12) (Department of the Environment 1973). These moderate temperatures are largely due to the modifying influence of the ocean and insulating effect of winter clouds and summer fog. Fog is discussed further in the Oceanography section of this report.

Winds are predominantly from the east to southeast in the winter and west to northwest in the summer. Annual average wind speed is about 13 km/h with winter winds averaging closer to 22 km/h (Department of the Environment 1973). A detailed description of wind schemes in Pacific Rim National Park is given in the Oceanography section of this report.

The climate of Pacific Rim National Park promotes luxurious growth of the temperat rain forests. This dense vegetation is one of the major attractions of the park and provides a wide range of interpretive possibilities.

Literature

Detailed records of temperature and precipitation are available in reference 53, while reference 28 gives a general description of the climate of Pacific Rim National Park.

OCEANOGRAPHY

A general discussion of the physical oceanography of the eastern subarctic Pacific Ocean is presented under headings: bathymetry, marine sediments, currents, winds and temperature and salinity. Each topic is expanded to give a more detailed account of the conditions which prevail in the coastal area near Pacific Rim National Park. Finally, short sections on fog, ice, tides and water clarity complete the oceanography information.

Bathymetry

The continental shelf west of Vancouver Island is gently sloping and generally less than 200 m deep; at the shelf edge the slope increases sharply, and the ocean floor drops abruptly to over 2 000 m (Fig. 13). Adjacent to Long Beach the shelf is about 50 km wide and gradually increases in width to almost 80 km opposite Carmanah Point. From there an extension of the Juan de Fuca Strait more than 200 m deep cuts across the continental shelf in a southwesterly direction. The strait itself is a steep-sided, glacially-eroded channel and therefore from Carmanah Point south the coastal sea floor slopes sharply downward to depths exceeding 200 m (Fig. 14).

The outer continental shelf west of Pacific Rim National Park and the inner shelf near Long Beach display gently rolling topography where glaciation was absent or less severe than in the inner shelf areas adjacent to Barkley Sound and West Coast Trail.

The strong glacial influence on the inner continental shelf near Barkley Sound and West Coast Trail is characterized by shallow banks, deep basins and troughs. There are three prominent banks west of Pacific Rim National Park: Amphitrite Bank, La Perouse Bank and Swiftsure Bank (Fig. 14). Extensions of the three main channels of Barkley Sound form two glacially-eroded basins with depths exceeding 200 m between Barkley Sound and La Perouse Bank (Carter 1973). The Juan de Fuca Canyon, a major transverse trough more than 200 m deep, cuts across the continental shelf in a southwesterly direction from the Strait of Juan de Fuca (Fig. 14). There are also several minor troughs which run either parallel or transversely to the coast of Pacific Rim National Park.

The continental shelf is a significant feature of the coastal area off Pacific Rim National Park. In geological time, the shallow gently sloping shelf between Tofino and Ucluelet allowed the accumulation of material to form Long Beach. Today's fishing industry in British Columbia is partially dependent upon the bathymetry of the continental shelf. Many of the best fishing grounds, especially those for groundfish, are in the shallow productive water over-lying banks. And in the future, the continental shelf may be a source of mineral resources (Shepard 1963, Press and Siever 1974).

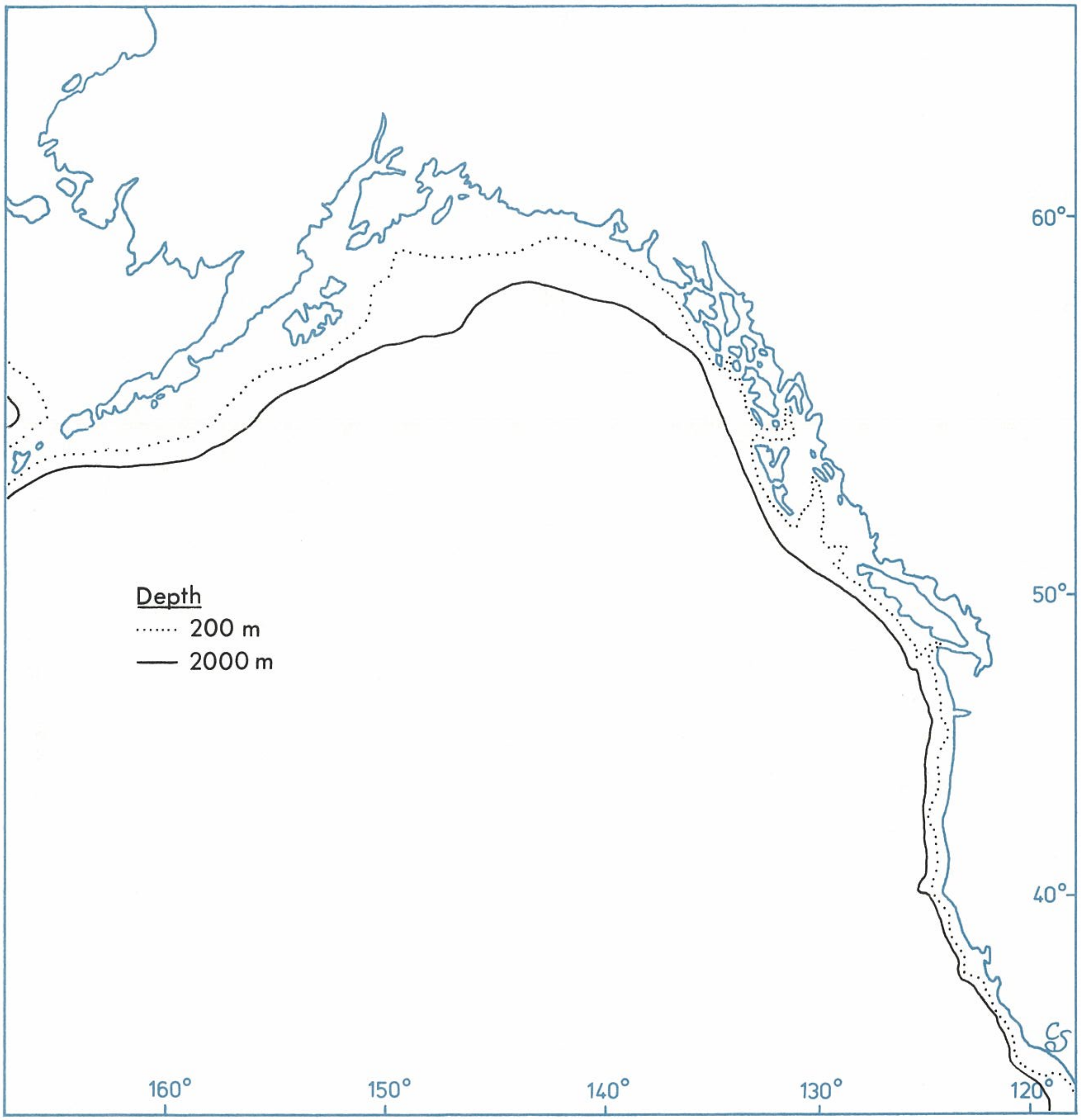


Fig. 13. Approximate position of the outer edge of the continental shelf (200 m), and bottom of the continental slope (2 000 m)

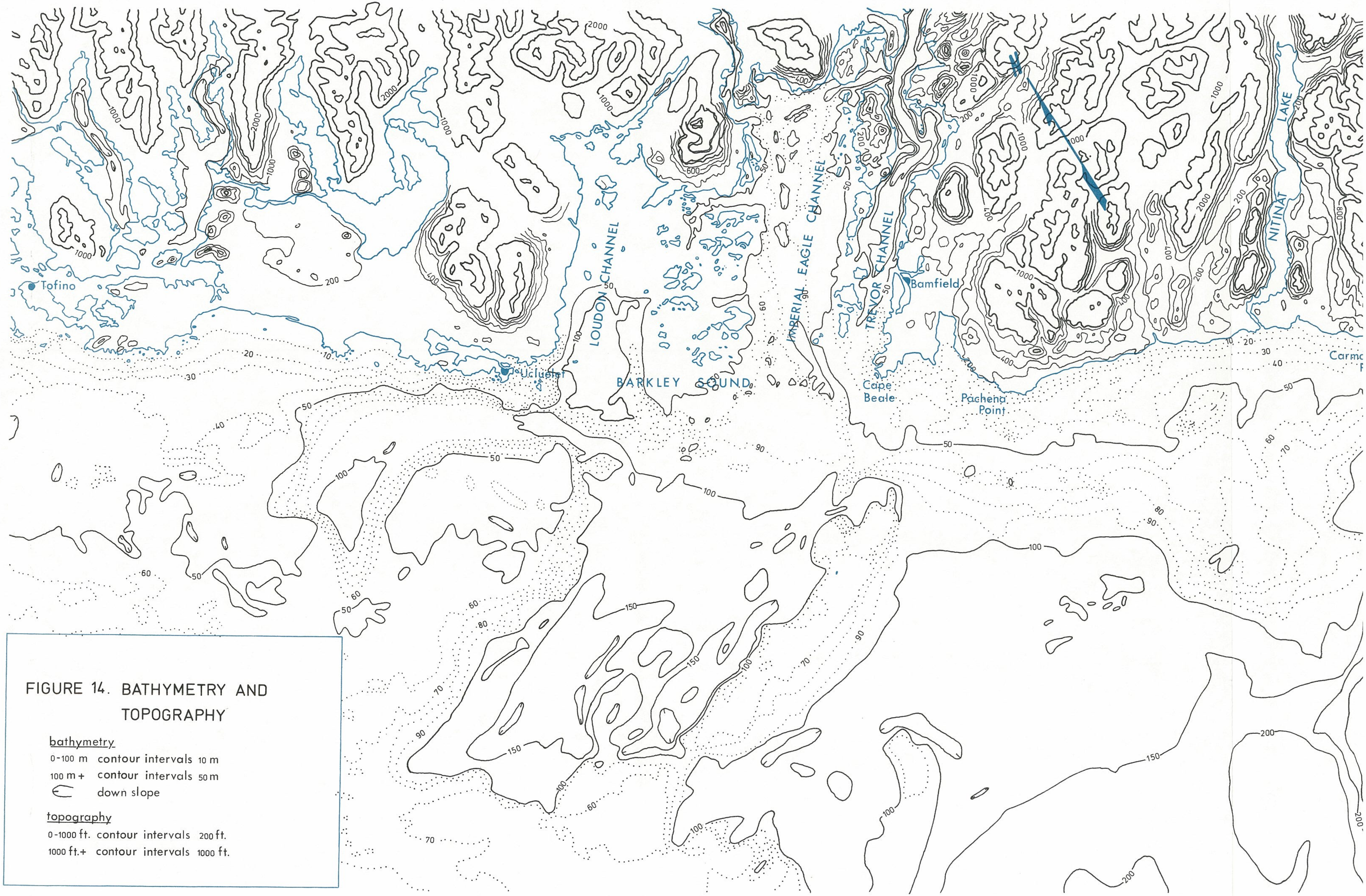
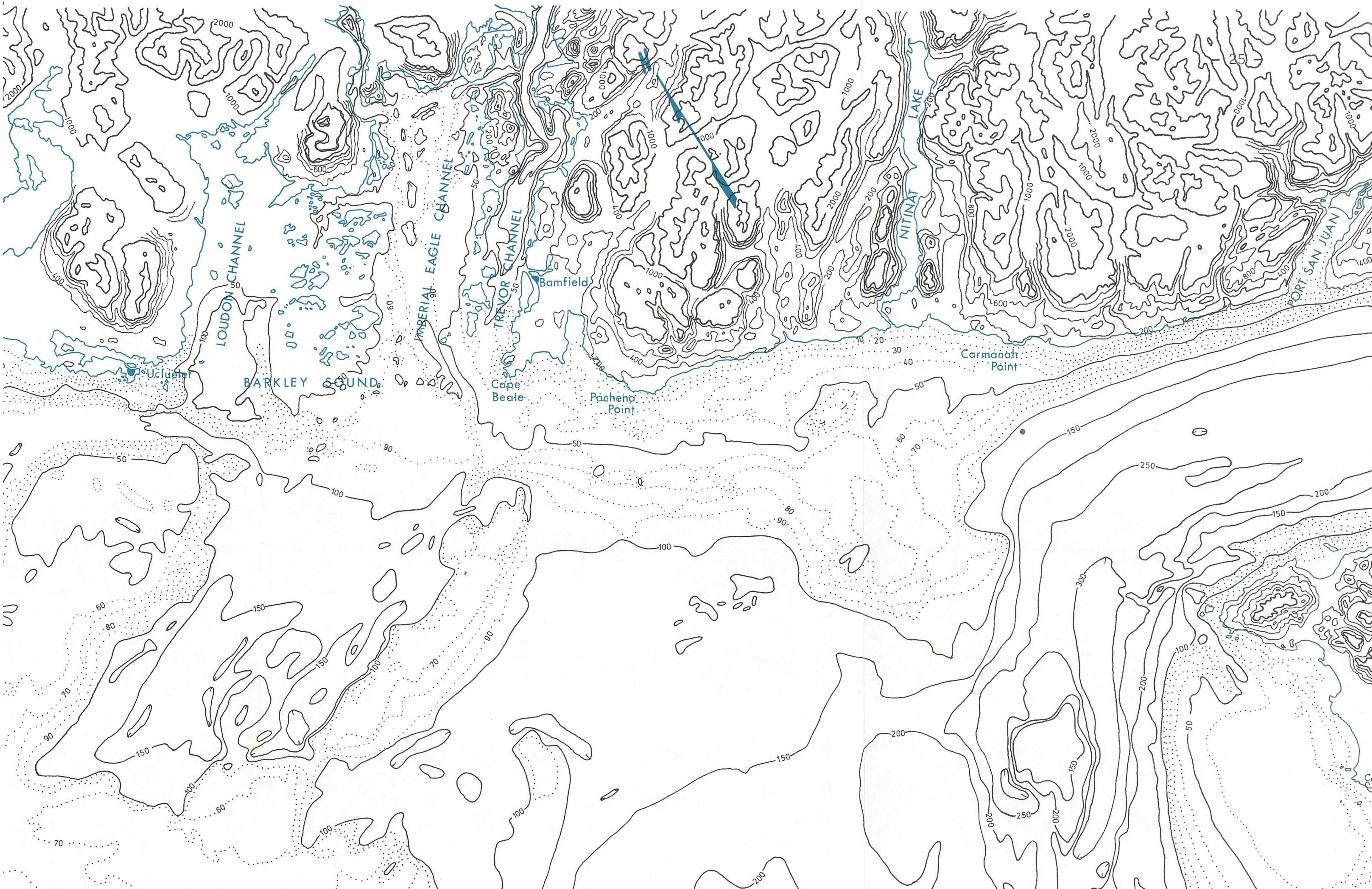


FIGURE 14. BATHYMETRY AND TOPOGRAPHY



LOUDON CHANNEL
IMPERIAL EAGLE CHANNEL
TREVOR CHANNEL
NITINAT LAKE
PORT SAN JUAN
Bamfield
Ucluelet
BARKLEY SOUND
Cape Beale
Pachena Point
Carmanah Point

Marine sediments

Sediments covering the continental shelf west of Vancouver Island are almost entirely terriginous in origin (Shepard 1963). The sediment distribution (Fig. 15) is a reflection of glacial patterns and present-day ocean currents. Glacial action results in the deposition of poorly sorted or heterogeneous sediments while currents sort sediments into various size fractions.

The shelf near Pacific Rim National Park can be divided into three sedimentation areas: the near shore, where modern sand and gravel accumulate; the depressions, which catch silt and clay; and the banks and outer shelf, which are covered with modern and relict sediments (Carter 1973). The sandy sediment off Long Beach and Cape Beale is of modern deposition. This material has been eroded from the coastline and transported to its present position by wave and current action. Bottom currents transport fine sand northwest along the inner shelf at depths to 40 m or greater (Carter 1973). The even finer suspended sediments carried in the same direction by the Davidson Current are trapped by basins and troughs. As a result these deep areas have predominantly muddy sediments. The sills, banks and outer shelf are mantled with sand and gravels having a wide range of size and sorting values. Gravels and coarse sands are relict, and fluvial or glacial, but the ocean currents and storm surges are reworking the fine sand and finer sediments causing them to lose part of their relict character.

Currents

The oceanic circulation of the northern Pacific Ocean is generally a single major gyre. Water takes from four to six years to make a complete counterclockwise curcuit. A major current, the Subarctic Current System, flows eastward across the Pacific Ocean toward coastal British Columbia (Fig. 16). Over the continental shelf between 47°N and 53°N it divides to form the California Current System flowing south and the Alaska Current System flowing north. A small remnant of the Subarctic Current continues eastward towards the coast of Vancouver Island before it turns southward to join the California Current System.

In addition to these major ocean current systems there are smaller coastal and seasonal currents which affect the waters of Pacific Rim National Park. In summer the California Undercurrent flows north at depths below 200 m off the coasts of Oregon, Washington and British Columbia. In winter the Davidson Current, a narrow, nearshore surface current which is part of the California Undercurrent often appears off Vancouver Island. Other more variable coastal currents are generated by tides, local runoff and wind (Bourke, Glenne and Adams 1971).

Tides can create very localized tide rips and currents as occurs along Long Beach proper. In the West Coast Trail Section a notable tidal current empties Nitinat Lake. North of Carmanah Point tidal streams tending toward the land are accentuated during strong southeast to southwest winds, while the flood tidal stream from the entrance of Juan de Fuca Strait south also has a considerable set toward Vancouver Island (Marine Science Directorate 1976) (Fig. 17).

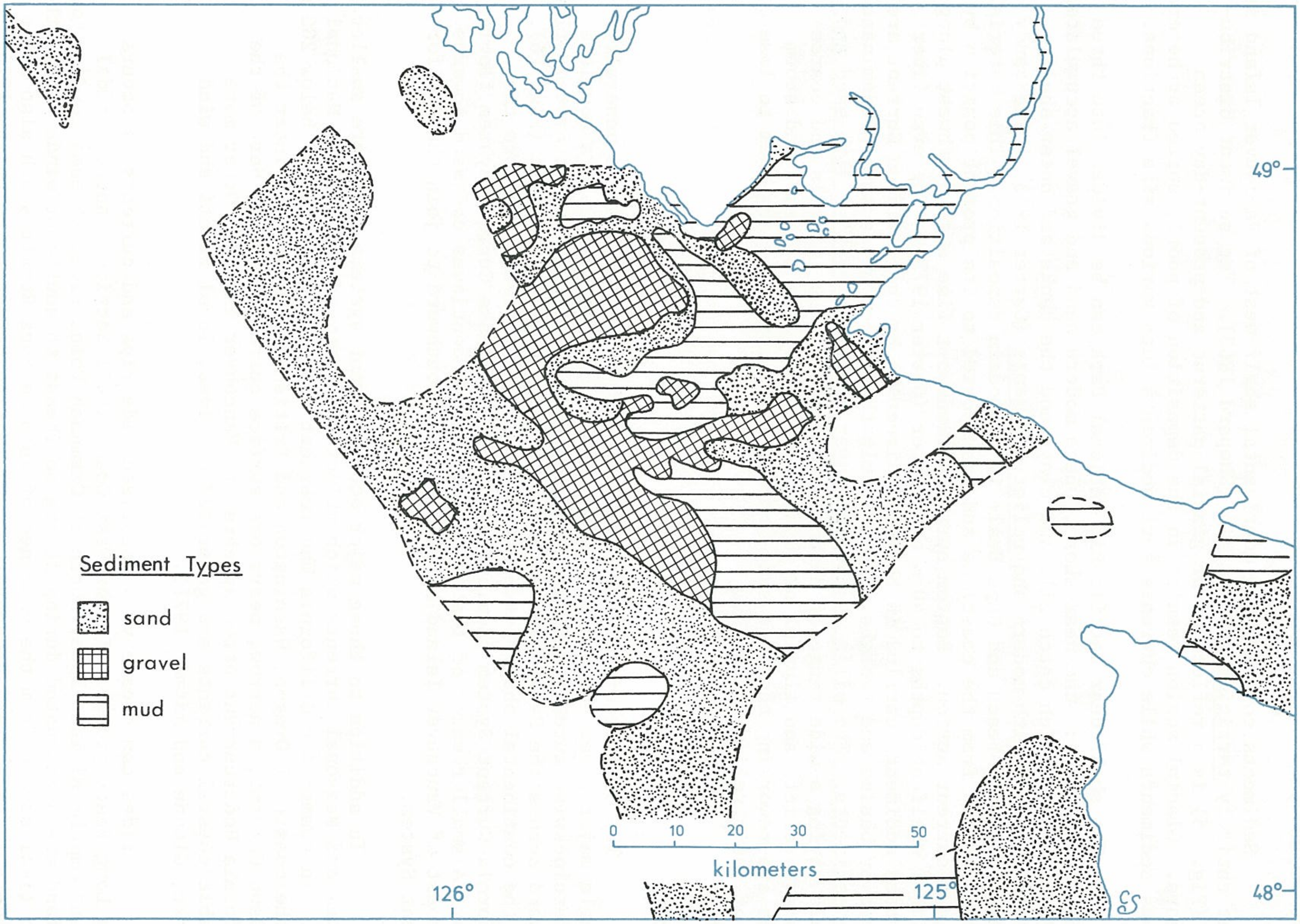


Fig. 15. Distribution of marine surficial sediments (Carter 1973; Cockbain 1963; Gross, McManus and Ling 1967; Luternauer 1976)

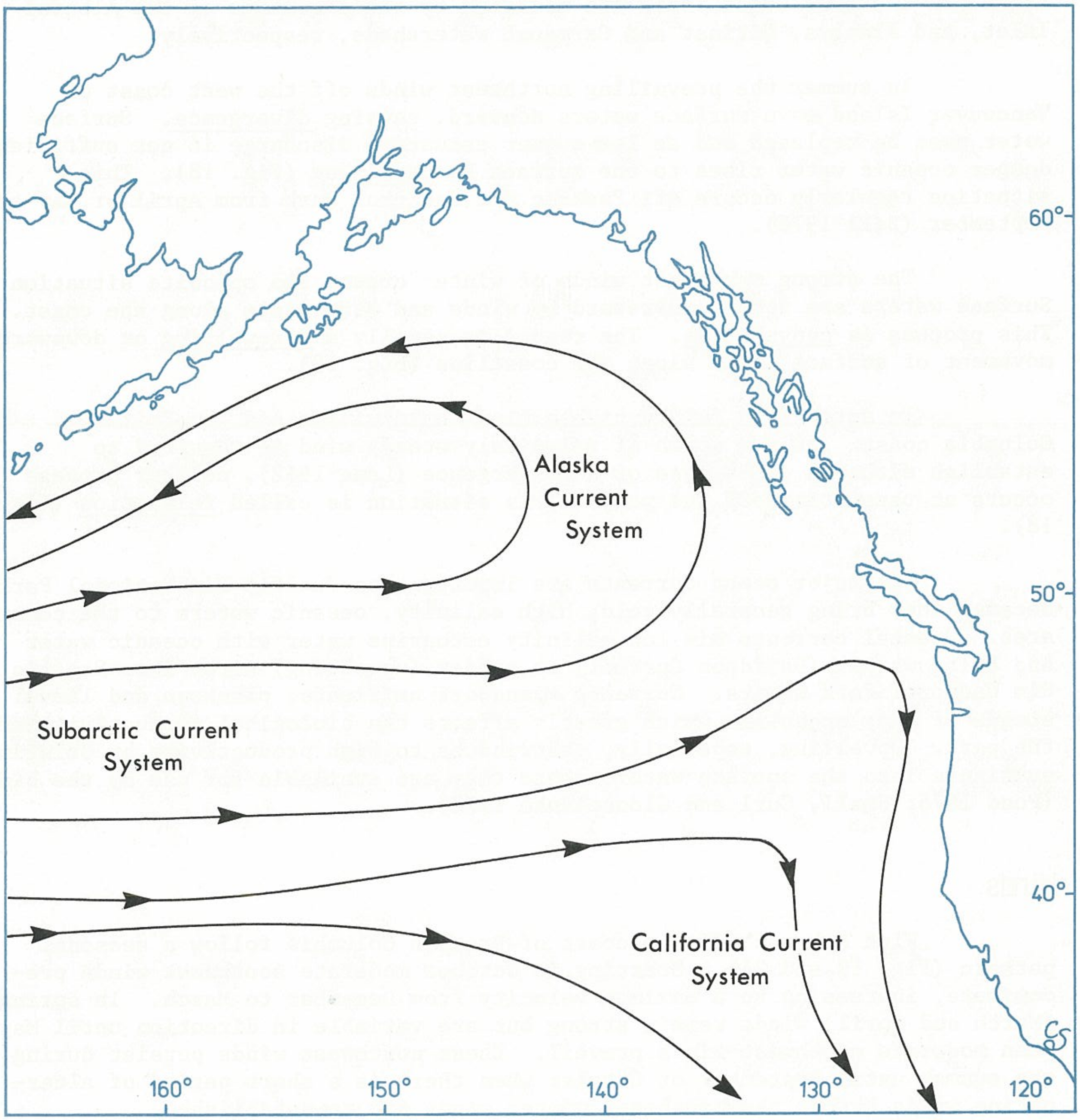


Fig. 16. Schematic diagram of surface circulation of the eastern subarctic Pacific Ocean (revised from Dodimead, Favourite and Hirano 1963)

High winter runoff from local rivers can result in shallow surface currents moving seaward when the lighter freshwater river discharge flows over the heavier saline coastal water. The oceanic water of Barkley Sound and some areas off the West Coast Trail are modified by the discharge of the Alberni Inlet, and Klanawa, Nitinat and Carmanah watersheds, respectively.

In summer the prevailing northwest winds off the west coast of Vancouver Island move surface waters seaward, causing divergence. Surface water must be replaced and as low summer estuarine discharge is not sufficient, deeper oceanic water rises to the surface by upwelling (Fig. 18). This situation regularly occurs off Pacific Rim National Park from April or May to September (Bell 1976).

The strong southeast winds of winter create the opposite situation. Surface waters are forced shoreward by winds and accumulate along the coast. This process is convergence. The result is usually a downwelling or downward movement of surface water along the coastline (Fig. 18).

In spring and fall variable winds predominate off the British Columbia coast. As one month of relatively steady wind is required to establish either a divergence or a convergence (Lane 1962), neither process occurs at these times of the year. This situation is called relaxation (Fig. 18).

The major ocean currents are important to Pacific Rim National Park because they bring generally cold, high salinity, oceanic waters to the coastal area. Coastal currents mix low salinity estuarine water with oceanic water and bring warmer (Davidson Current) or colder (upwelling) water into Pacific Rim National Park waters. Currents transport nutrients, plankton and larval stages of many organisms which greatly affects the biological productivity of the park. Upwelling, especially, contributes to high productivity by bringing nutrients into the surface waters where they are available for use by the biota (Pond 1976; Small, Curl and Glooschenko 1972).

Winds

Wind schemes off the coast of British Columbia follow a seasonal pattern (Fig. 19 and 21). Starting in October moderate southeast winds predominate, increasing to a maximum velocity from December to March. In spring (March and April) winds remain strong but are variable in direction until May when moderate northwest winds prevail. These northwest winds persist during the summer until September or October when there is a short period of alternating winds before the southeast winter winds are re-established.

These seasonal patterns of wind direction and velocity are dependent upon the prevalent pressure systems of the northern Pacific Ocean. In winter the Aleutian Low causes the southeast wind scheme; and the North Pacific High of summer produces prevailing northwest winds of that season (Fig. 19, 20, 21 and 22). The unsettled pressure distribution of spring and fall is reflected in alternating winds.

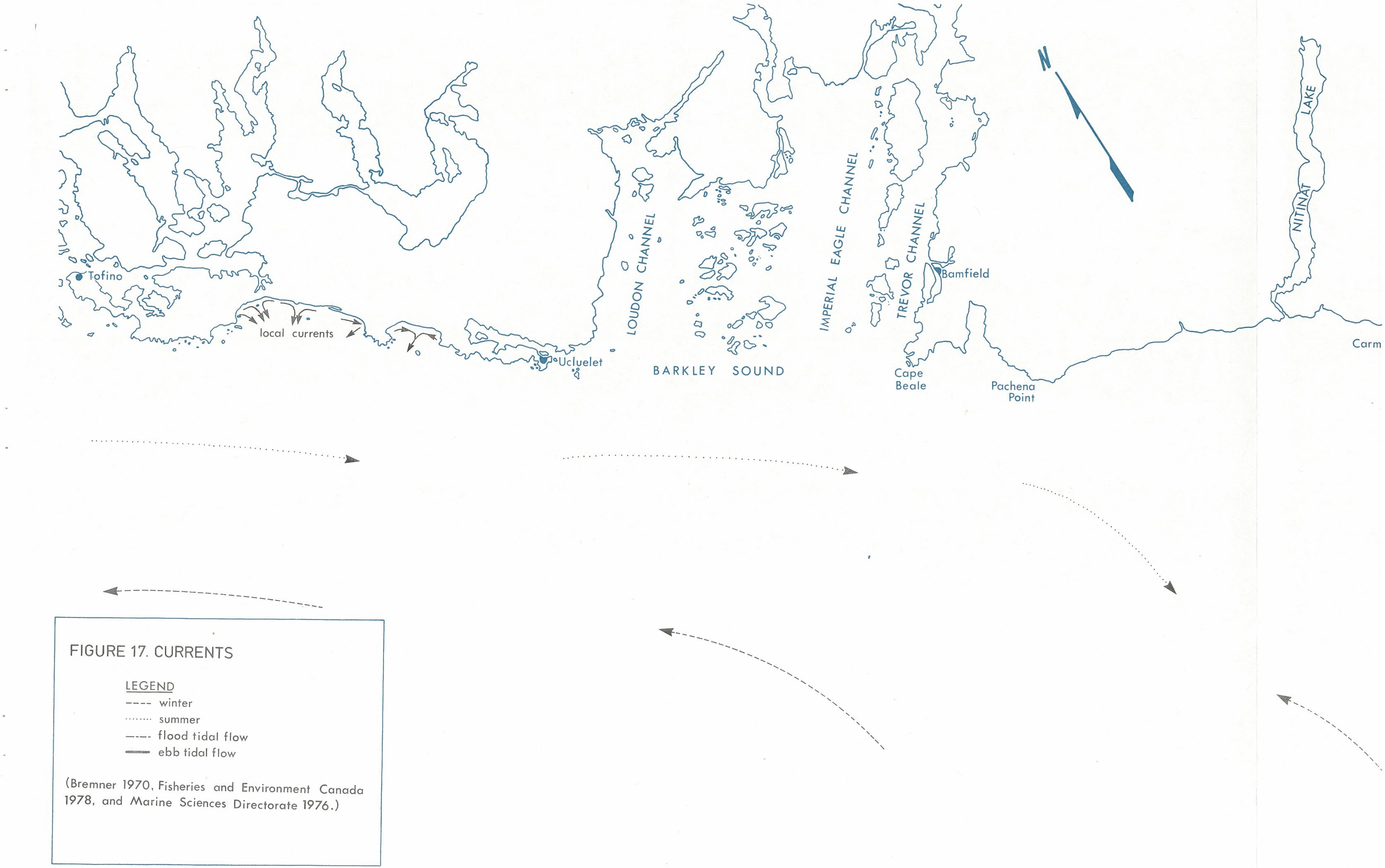
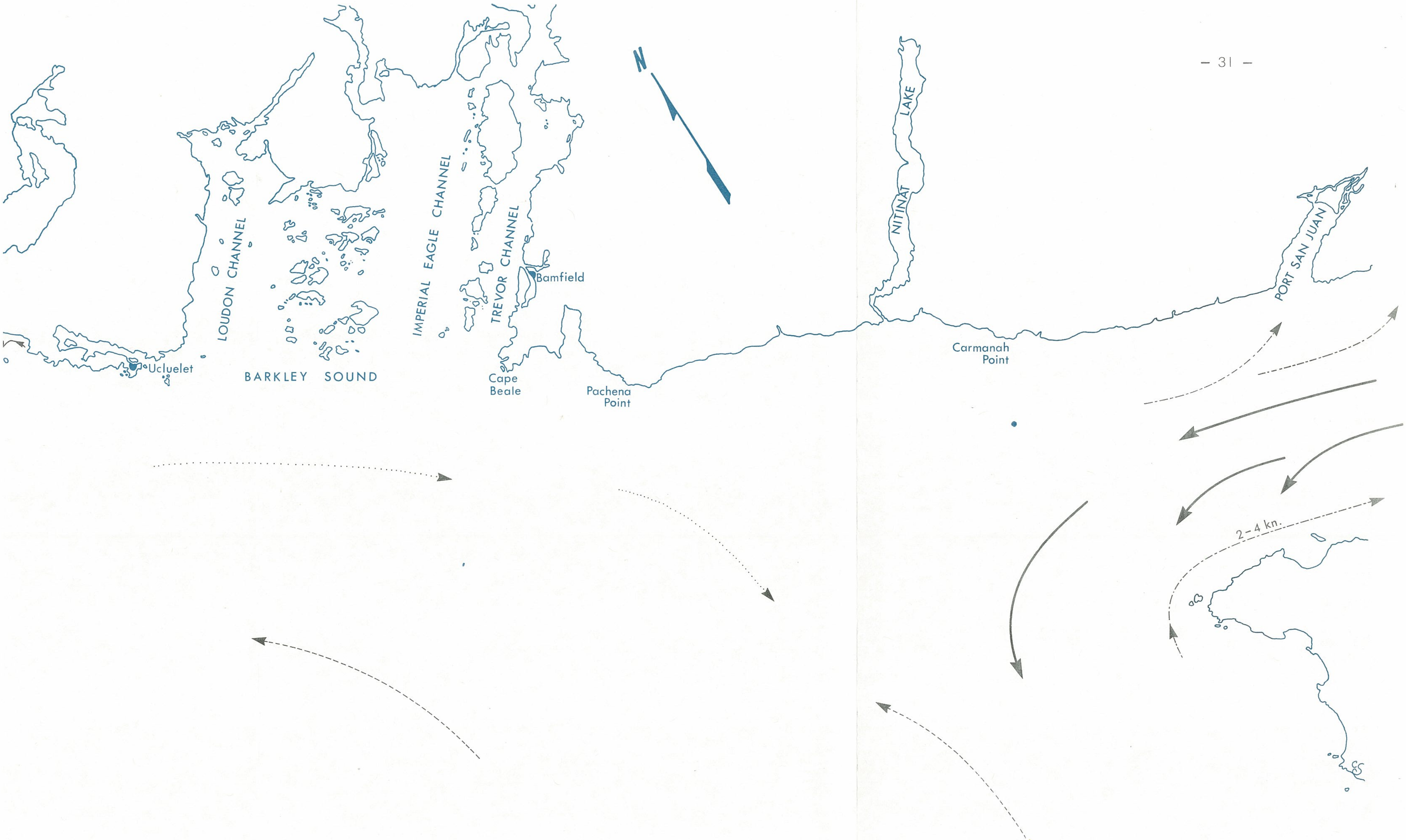


FIGURE 17. CURRENTS

(Bremner 1970, Fisheries and Environment Canada 1978, and Marine Sciences Directorate 1976.)


N
LOUDON CHANNEL
IMPERIAL EAGLE CHANNEL
TREVOR CHANNEL
Bamfield
Ucluelet
BARKLEY SOUND
Cape
Beale
Pachena
Point
NITINAT
LAKE
Carmanah
Point
PORT SAN JUAN
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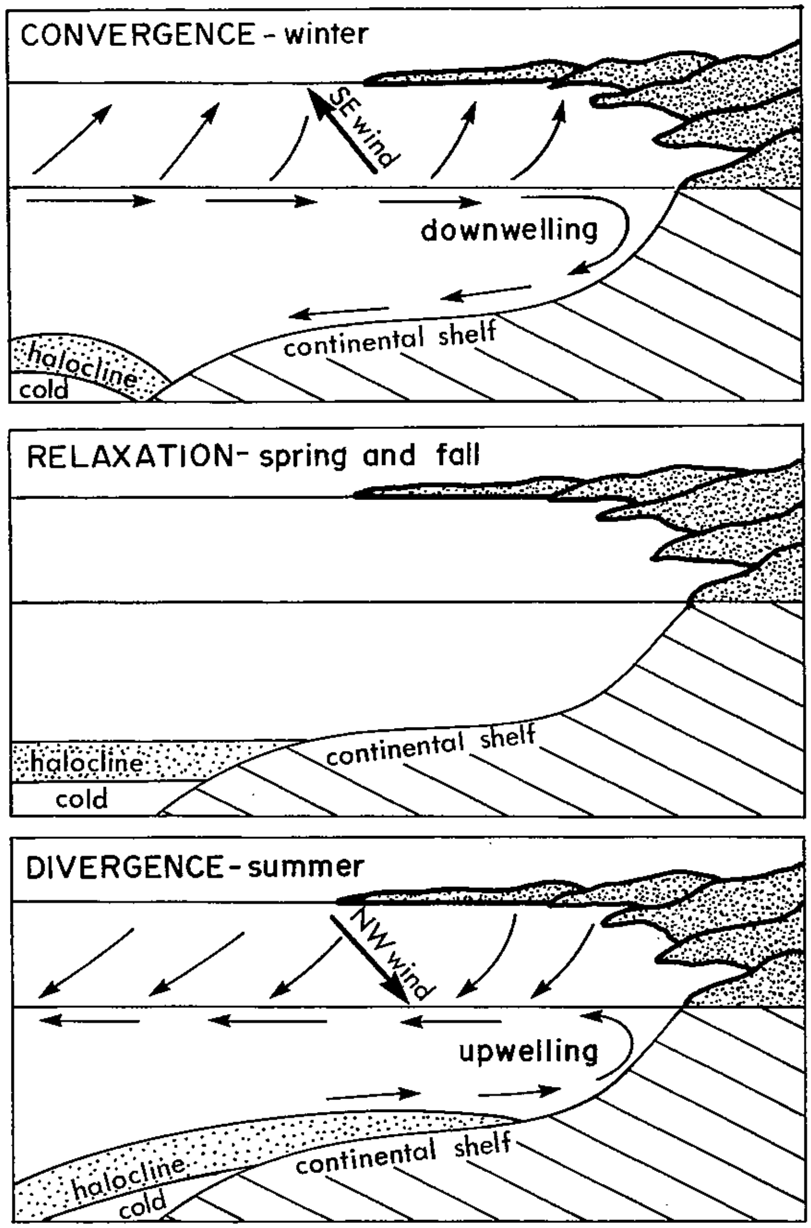


Fig. 18. Schematic diagrams of convergence, relaxation and divergence situations off the west coast of Vancouver Island (revised from Dodimead and Pickard 1967)

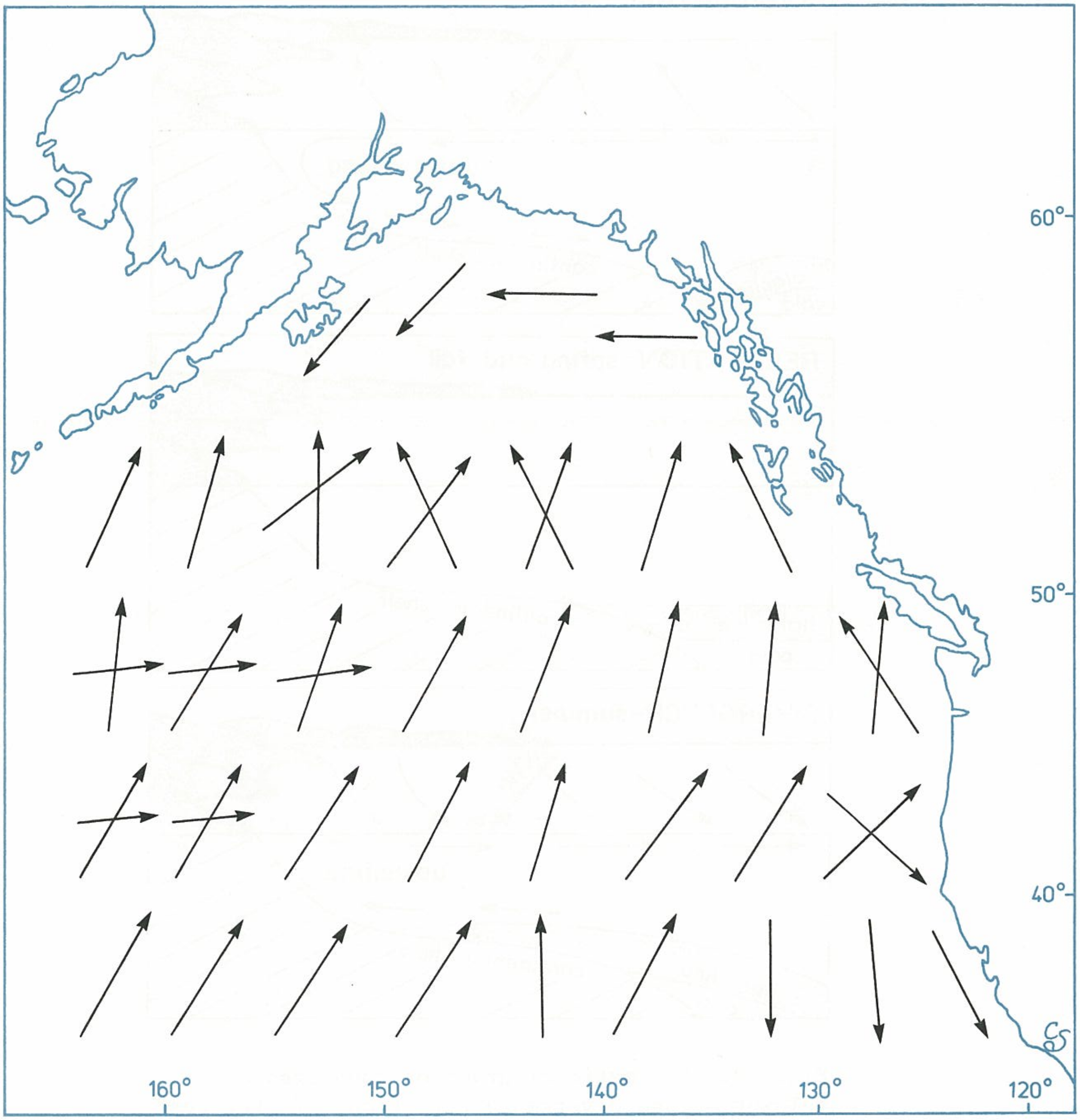


Fig. 19. Prevailing winter surface winds in the eastern subarctic Pacific Ocean (revised from Dodimead, Favourite and Hirano 1963)

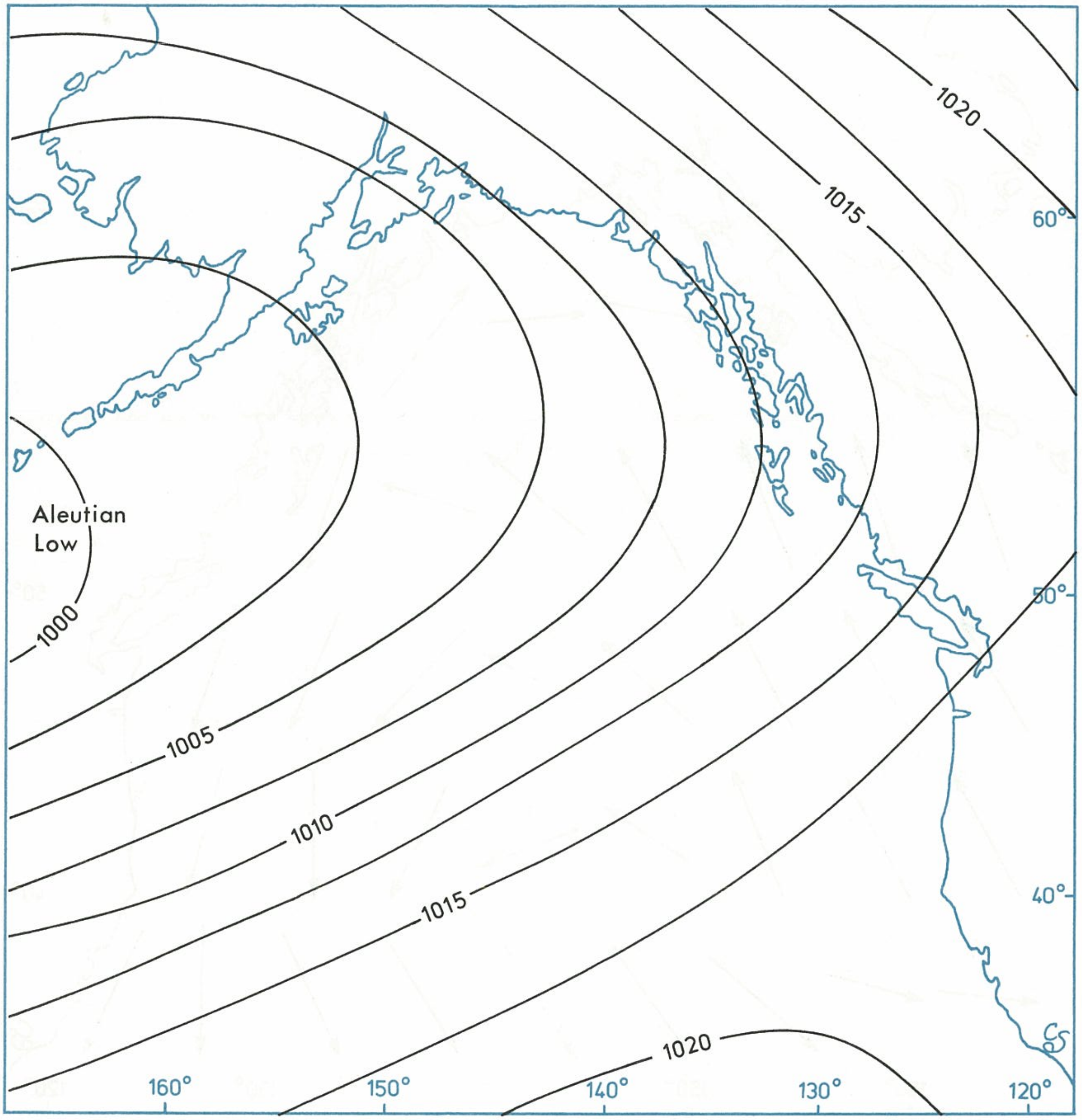


Fig. 20. Mean winter sea level pressure (millibars) in the eastern subarctic Pacific Ocean (Dodimead, Favourite and Hirano 1963)

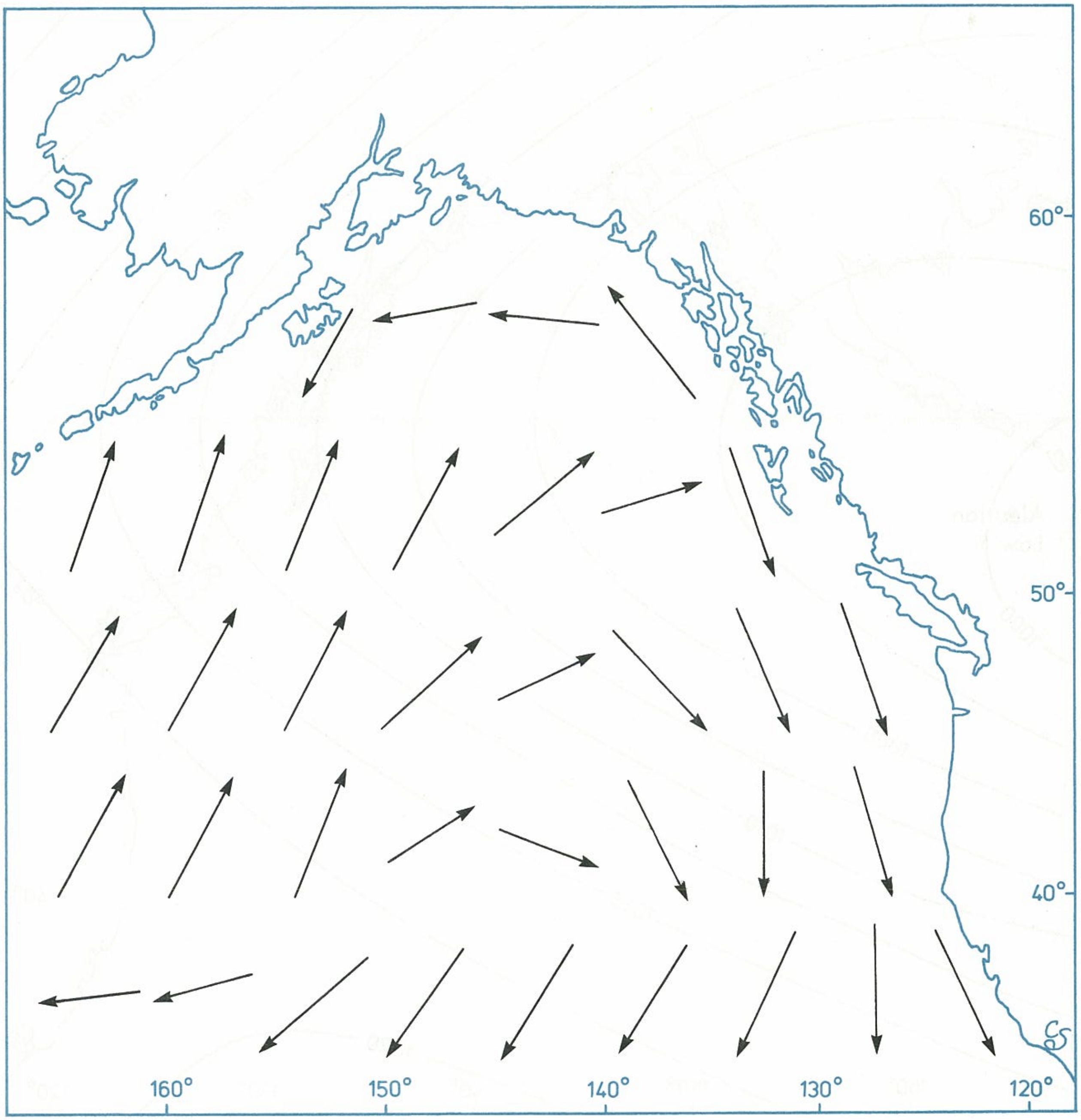


Fig. 21. Prevailing summer surface winds in the eastern subarctic Pacific Ocean (revised from Dodimead, Favourite and Hirano 1963)

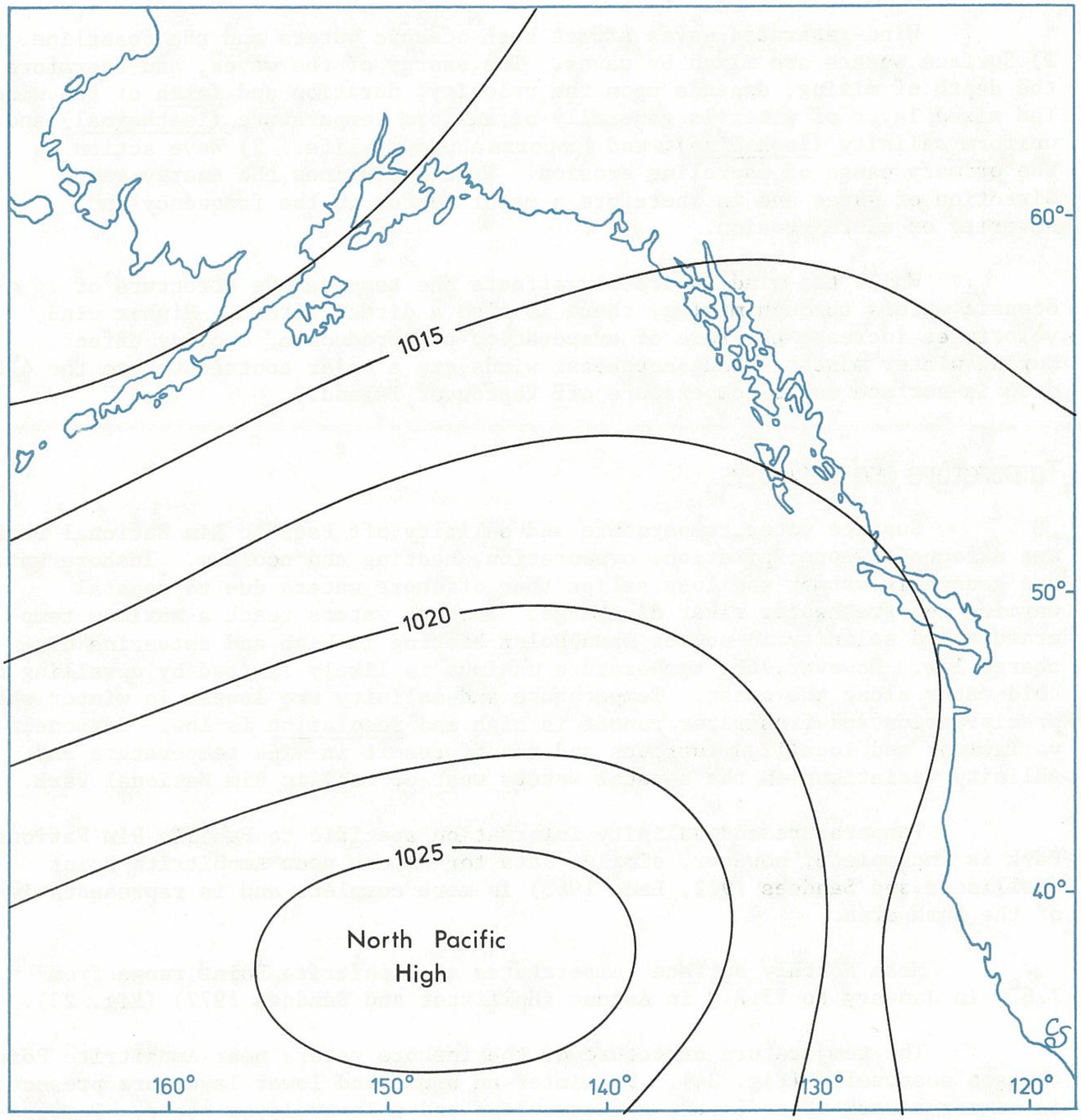


Fig. 22. Mean summer sea level pressure (millibars) in the eastern subarctic Pacific Ocean (Dodimead, Favourite and Hirano 1963)

Wind transport of surface water is responsible for the summer divergence and winter convergence along the outer coast of Vancouver Island as well as localized effects.

Wind-generated waves affect both oceanic waters and the coastline. 1) Surface waters are mixed by waves. The energy of the waves, and therefore the depth of mixing, depends upon the velocity, duration and fetch of the wind. The mixed layer of water is generally of uniform temperature (isothermal) and uniform salinity (isohaline), and supports abundant life. 2) Wave action is the primary cause of shoreline erosion. Wind determines the energy and direction of waves and is therefore a major factor in the frequency and severity of shore erosion.

While the wind indirectly affects the temperature structure of oceanic waters through mixing, there is also a direct effect. Higher wind velocities increase the rate of evaporation and produce a cooling effect. During winter months strong southeast winds are a major contributor to the 4°C drop in surface water temperature off Vancouver Island.

Temperature and salinity

Surface water temperature and salinity off Pacific Rim National Park are affected by precipitation, evaporation, heating and cooling. Inshore waters are generally warmer and less saline than offshore waters due to coastal warming and freshwater river discharge. Inshore waters reach a maximum temperature and salinity in summer when solar heating is high and estuarine discharge low. However, the temperature maximum is likely limited by upwelling of cold water along the coast. Temperature and salinity are lowest in winter when precipitation and freshwater runoff is high and insolation is low. Seasonal variations and localized currents and runoff result in wide temperature and salinity variations in the coastal waters west of Pacific Rim National Park.

Temperature and salinity information specific to Pacific Rim National Park is incomplete; however, similar data for waters near Amphitrite Point (Hollister and Sandnes 1972, Lane 1963) is more complete and is representative of the park area.

Mean monthly surface temperatures at Amphitrite Point range from 7.6°C in January to 13.2°C in August (Hollister and Sandnes 1972) (Fig. 23).

The temperature structure of the inshore waters near Amphitrite Point changes seasonally (Fig. 24). In winter an upper and lower layer are present; in summer a warm upper layer, a thermocline and a lower layer occur. Temperatures of the upper layer generally range from 7°C to 10°C in winter and from 11°C to 15°C in summer. The lower layer temperature is fairly consistent throughout the year, ranging from 8°C to 10°C. The thermocline, when present, has a temperature of 9°C to 11°C (Lane 1963).

Mean monthly surface salinities at Amphitrite Point range from 28.4°/oo in December to 31.0°/oo in August (Hollister and Sandnes 1972) (Fig. 23).

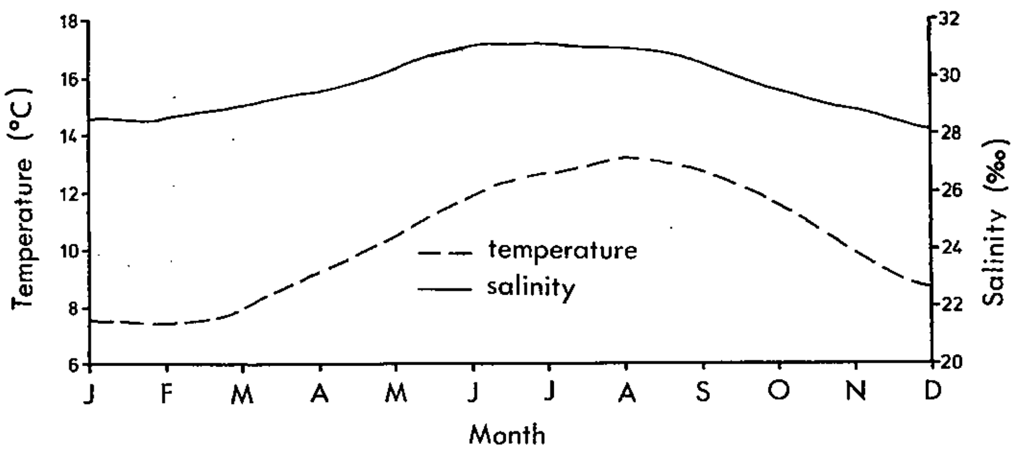


Fig. 23. Mean monthly surface temperature and salinity at Amphitrite Point - 1934 to 1970 (Hollister and Sandnes 1972)

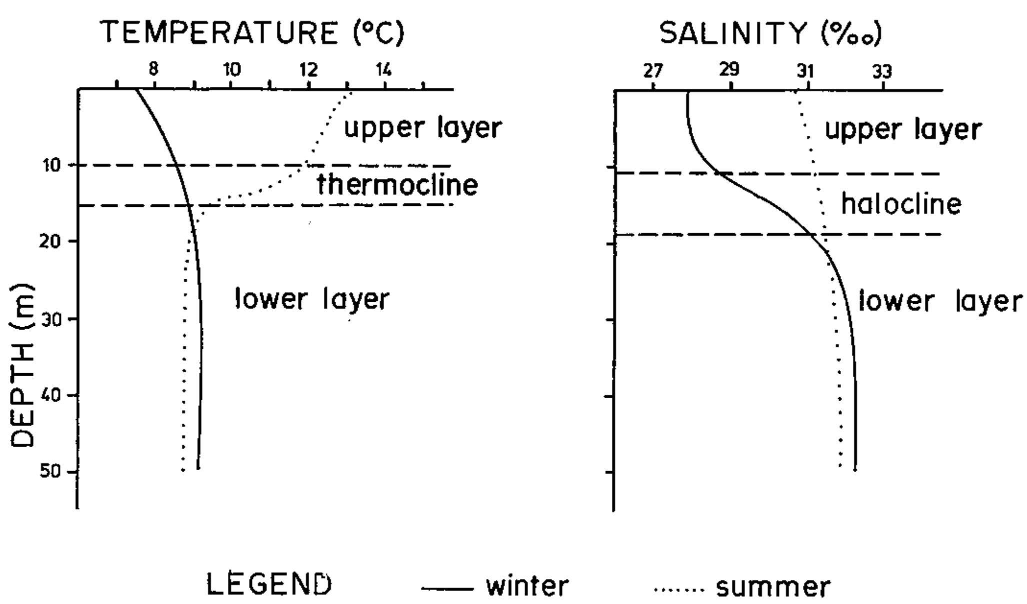


Fig. 24. Schematic graphs of temperature and salinity structure of inshore waters west of Amphitrite Point (from data presented in Lane 1963)

The salinity structure of the inshore waters near Amphitrite Point generally consists of a shallow isohaline upper layer and a lower layer which usually extends to the ocean floor (Fig. 24). In winter the low salinity upper layer is separated from the high salinity lower layer by a halocline. In summer the halocline weakens and the division between the two layers is less distinct. Upper layer salinities generally range from 27°/oo to 31°/oo in winter and from 30°/oo to 31.5°/oo in summer. Lower layer salinities range from 29°/oo at the halocline to 32.6°/oo near the ocean floor.

Water temperature and salinity are important factors affecting marine organisms. Changing temperature regimes by altering current or tidal patterns can have serious effects on the biological population. Low salinity surface water is considered one of the factors determining the upper distribution limit of organisms inhabiting the intertidal area. In the presence of brackish water larvae of some intertidal animals do not stay at the surface, but settle lower in the water column and may never come in contact with the upper intertidal areas. Thus in habitats with a deep, persistent brackish surface layer of water these organisms do not become established in the intertidal area and faunal assemblages remain impoverished (Carefoot 1977).

Tides

In Pacific Rim National Park waters there are two, unequal tide cycles each day, which together are called a mixed, semi-diurnal tide (Fig. 25). The lowest winter tides are in the evening while in summer the lowest tides occur in the morning. Tides in the park increase in amplitude from south to north and range 2.4 to 2.7 m on a mean tide or 3.6 to 4.2 m on a large tide (Fisheries and Oceans Canada 1979b). The shoreline configuration, substrate material, winds and barometric pressure may affect the timing and amplitude of tides within the park.

Water clarity

In the marine environment the amount and quality of light is largely determined by the light transmitting properties of water. Water transmits light poorly and not all wavelengths penetrate to the same depth (Fig. 26). The depth of the photosynthetic plants is limited by light penetration to approximately 30 m. This depth varies with changes in water clarity; most notably, seasonal plankton blooms reduce the light penetration.

The waters of Pacific Rim National Park are relatively clear in the winter but visibility is much reduced during the plankton blooms of the summer months. From March to August, increased light intensity, number of daylight hours and temperature result in increased phytoplankton production and growth. This in turn provides food for an increased number of zooplankton. In addition, many invertebrates spawn at this time, contributing to the plankton density and further reducing water clarity (Adkins 1977).

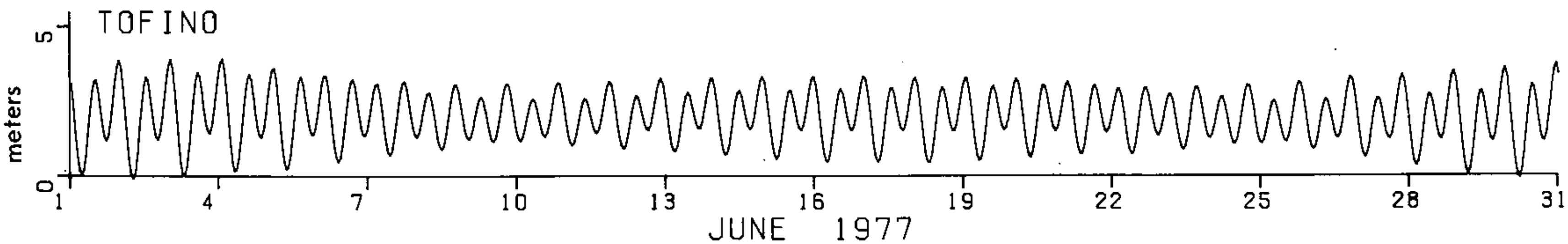


Fig. 25. Mixed, mainly semi-diurnal tidal curve, Tofino (June 1977) (Hydrographic Chart Distribution Office)

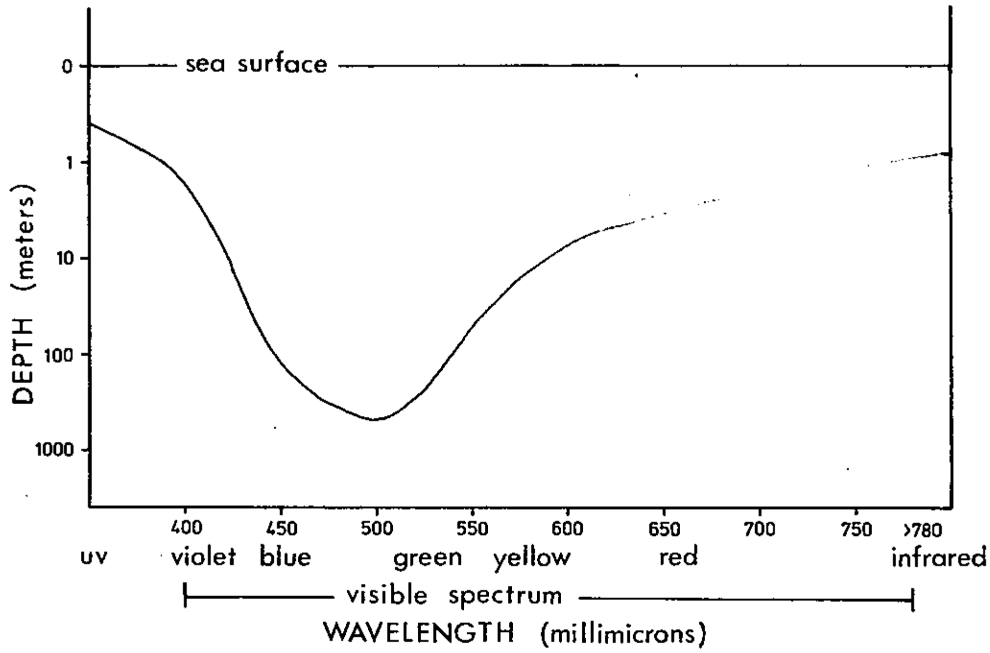


Fig. 26. Penetration of sunlight into clear oceanic water (revised from Carefoot 1977)

Fog

Sea fog occurs most frequently during the summer months and can persist day and night even in moderate winds (Fig. 27). Tofino, just north of Pacific Rim National Park, has visibility reduced to less than one kilometer by fog on an average of 96 days a year, Pachena Point has an average of 58 days of fog and the Port Renfrew area averages 55 days in the year (Marine Science Directorate 1976). The persistence and duration of fog is one of the major navigation hazards on the west coast of Vancouver Island.

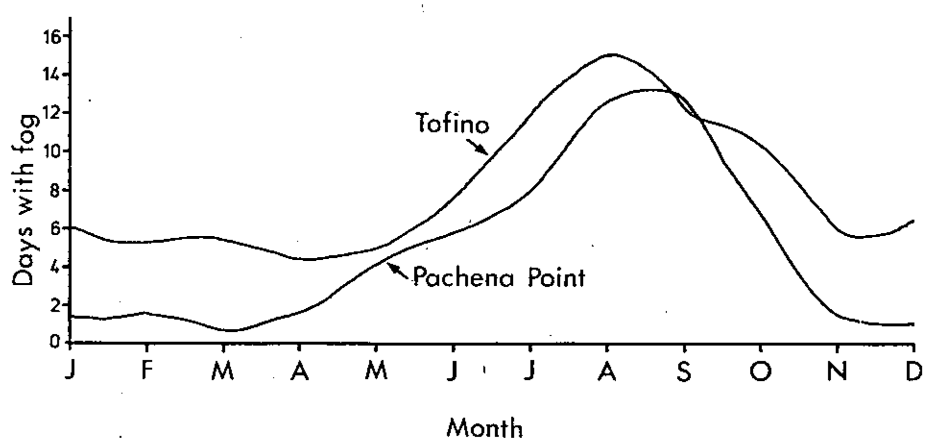


Fig. 27. Mean monthly days of fog (visibility reduced to less than 1 km) at Tofino (elevation 24.4 m) and Pachena Point (elevation 45.6 m). (graph drawn from data presented in Marine Science Directorate 1976)

Ice

There is little sea ice formed within Pacific Rim National Park.

Literature

Information on bathymetry can be found in references 9, 35, 36, 105, 167 and 183. Detailed information on surficial sediments is contained in references 35, 36, 40, 90, 133, 134 and 145. Aspects of ocean and nearshore currents are described in references 16, 20, 54, 55, 56, 57, 58, 63, 68, 69, 83, 89, 104, 139, 156, 161, 165, 187, 199 and 235. Wind information is included in references 54, 55, 56, 63, 68 and 139. References 20, 55, 56, 58, 68, 83, 86, 88, 104, 109, 121, 122, 156, 160, 161, 198 and 205 provide salinity and temperature information. Tidal data in reference 79, water clarity data in reference 1, 32 and 159, and fog information in reference 139 are also available.

ZONATION OF MARINE FAUNA AND FLORA

Discussion of the flora and fauna of the beach and nearshore areas is based on the zonation shown by the more conspicuous organisms. The limits of distribution of these species are determined by physical and biological parameters acting upon the natural tolerances of the organisms.

In this study, the beach is divided into four biotic zones: the splash zone, which is affected only by the highest tides and is often wetted only by spray or rain; the high intertidal zone, usually characterized by the rockweed *Fucus distichus*; the mid intertidal zone or mussel *(Mytilus sp.)* zone; and the low intertidal zone, which is predominately laminarians and exposed only during very low tides. These intertidal zones correspond to Zones 1 to 4 in Ricketts and Calvin (1968) and all previous Pacific Rim National Park reports by Lee and Bourne. The number of nearshore zones varies depending upon survey depth and the biological and physical environment; in this study, one to four zones may occur.

In the beach area upper distribution limits are set by desiccation, temperature and light. The upper beach area is exposed for long periods of time each day; organisms living in this area are adapted to minimize drying (snails, mussels, chitons) or tolerate large losses of water (several seaweed species). While exposed to air, intertidal organisms are also exposed to extreme temperatures. The brown alga, *Fucus sp.*, in the high intertidal zone, tolerates long periods of freezing (Kanwisher 1957). California mussels *(Mytilus californianus)* in the mid intertidal zone have withstood recorded internal temperatures of 27°C without apparent ill effects (Carefoot 1977). Seaweeds in the low intertidal zone are submerged for significant periods of time and therefore receive less sunlight than algae in the mid or high intertidal zones. This gradient of available light is thought to influence seaweed distribution on the beach.

Lower distribution limits in the intertidal zones are primarily set by competition, predation and herbivory. The competition is largely concerned with food and living space. Predation by ochre seastars *(Pisaster ochraceus)* is thought to set the lower distribution limit of California mussels. Grazing of finger limpets *(Collisella digitalis)* and other herbivores is considered a primary factor in determining the lower distribution limits of several algae.

Zonation of nearshore biota is influenced by similar factors. Desiccation is not significant but predation, herbivory, competition and especially light are important. Algal growth is limited by light penetration in seawater to a depth of approximately 30 m. Brown algae usually occur no deeper than 10 m while red algae, which utilize more of the light spectrum for photosynthesis, often occur deeper. Purple sea urchins *(Strongylocentrotus purpuratus)* are dominant herbivores in some locations on the open coast. Their grazing appears to limit the lower distribution limits of their favoured algae (pers. comm. P. Breen), thereby significantly changing the order of dominance of the community. The nearshore zones described in this report are limited to a depth of 12 m.

The width, tidal position and biological composition of marine beach and nearshore zones are further influenced by substrate, slope and wave exposure.

The width of the horizontal biotic bands or zones is primarily determined by slope and exposure of the location. Heavy wave action and gentler slopes widen the zones while calmer waters and steep slopes tend to result in narrower zonation patterns.

High energy waves can expand the upper distribution limits of intertidal organisms thus displacing the whole zone to higher position on the shore (Fig. 28).

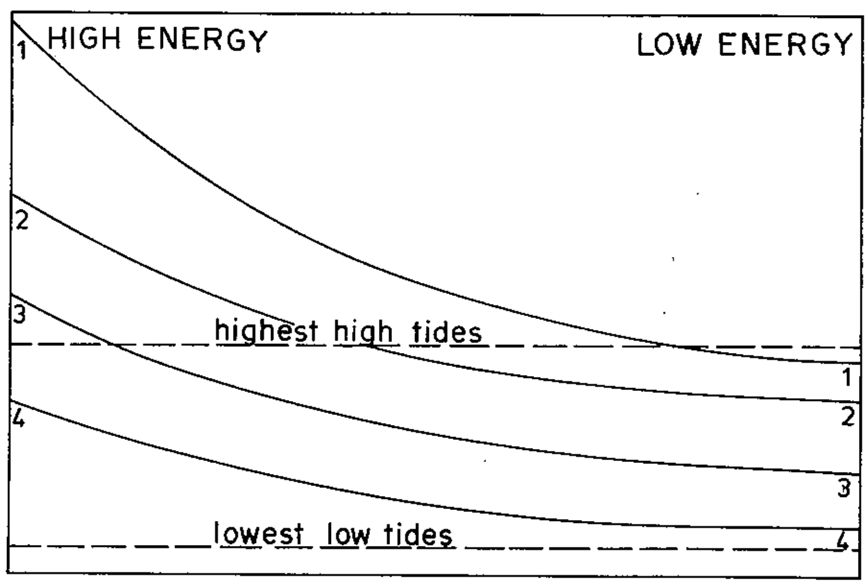


Fig. 28. Schematic diagram of upward displacement of biotic zones as one proceeds toward the higher energy part of the coast (1 = splash zone, 2 = high intertidal zone, 3 = mid intertidal zone, 4 = low intertidal zone) (revised from Ricketts and Calvin 1968)

The biological composition of the beach and nearshore zones is dependant upon substrate type and slope, energy exposure and various biological factors. The energy level of the beach is usually directly related to wave exposure but the nearshore may be additionally influenced by currents. Localized, nearshore currents may increase the energy level of the subtidal portion of an otherwise low energy location. The slope of the shore has two effects, modifying wave impact on the intertidal area and reflecting the amount of substrate movement. Gently sloping beaches tend to dissipate the energy of breaking waves providing a less harsh environment than the steeper shore exposed to the same wave climate. Steeply sloping unconsolidated material is inherently unstable so incoming waves set the substrate in motion. In this situation little macroscopic flora or fauna can become established. Gently sloping shores of unconsolidated material tend to be more stable and often support significant infaunal and algal populations.

Literature

References 118 and 172 provide general explanations and descriptions of zonation; details of specific aspects of zonation are contained in references 32, 44, 86, 116, 123, 124, 125, 126, 127, 128, 129, 141, 195 and 208.

SEABIRDS

Birds occurring within Pacific Rim National Park which spend at least part of the year closely associated with the ocean or shore are listed on Table 1. Some birds generally considered to be freshwater species are included when they occur in marine areas during certain times of the day or year.

Seabird information was drawn from a variety of sources. A British Columbia Provincial Museum map of the seabird nesting colonies of Pacific Rim National Park (Campbell 1976) along with Godfrey (1966); Hatler, Campbell and Dorst (1978), and Martin and Myres (1969) were the most useful references. Nomenclature used in the table follows Hatler, Campbell and Dorst (1978) which includes the American Ornithologists' Union recommended changes to 1976.

Seabirds regularly seen in and around the park can be placed in one of five catagories. There are resident species which nest in the area and can be seen year round, breeding non-residents which nest locally but winter elsewhere, non-breeding residents, migrants and birds which winter in the Pacific Rim National Park area. Non-breeding residents may be seen within the park at any time of the year, but the summer residents are usually juveniles or unpaired birds. In some species the males return to the coast from the nesting area soon after the eggs are laid. Migrant species are seen only in spring and fall but are often present in large flocks. Grice Bay and sheltered areas near the park are important resting and feeding locations for migrating birds.

Seabirds often nest on rocky points and islands. When the same areas are used year after year they become recognized as nesting colonies (Fig. 29). During summer months thousands of pairs of nesting birds occupy the colonies in and near Pacific Rim National Park (Table 2).

Literature

More detailed information on seabirds can be found in references 29, 30, 34, 50, 87, 91, 92, 93, 94, 101, 102, 142 and 181.

Table 1. Seabirds of Pacific Rim National Park (Campbell 1976; Godfrey 1966; Martin and Myres 1969; Sealy and Nelson 1973; Hatler, Campbell and Dorst 1978).

NAME OF BIRD	NESTING	SUMMER	WINTER	MIGRATION	REMARKS
Order Gaviformes					
Family Faviidae					
Yellow-billed loon *Gavia adamsii*	-	-	rare	-	
Arctic loon *G. arctica*	-	-	common	May-Jun Oct	
Common loon *G. immer*	X	X	X	-	-common resident
Red-throated loon *G. stellata*	X	X	X	spring fall	-resident
Order Podicipediformes					
Family Podicipedidae					
Western grebe *Aechmophorus occidentalis*	-	-	Sep-Mar	Mar-Apr fall	-nests in freshwater
Horned grebe *Podiceps auritus*	-	-	X	Apr-May Sep-Oct	-migrates inland for winter
Eared grebe *P. nigricollis*	-	-	X	Apr-May Sep-Oct	-migrates to interior nesting lakes
Red-necked grebe *P. grisegen*	-	-	common	Mar-May Sep	-migrates north for summer
Pied-billed grebe *Podilymbus podiceps*	-	-	X	-	-nests and summers on freshwater lakes in Pacific Rim National Park
Order Procellariiformes					
Family Diomedeidae					
Short-tailed albatross *Diomedea albatrus*	-	-	-	-	-formerly common in Juan de Fuca St. and off British Columbia coast
Laysan albatross *D. immutabilis*	-	-	rare	-	-common well off British Columbia coast

Table 1. cont'd

NAME OF BIRD	NESTING	SUMMER	WINTER	MIGRATION	REMARKS
Blackfooted albatross *D. nigripes*	-	Mar-Sep	-	-	-well off British Columbia coast
Family Procellariidae					
Northern fulmar *Fulmarus glacialis*	-	-	X	-	-spends fall, winter and early spring along the B.C. coast or at sea
New Zealand shearwater *Puffinus bulleri*	-	rare Aug-Oct	-	-	-returns to New Zealand in Sept. to breed
Flesh-footed shearwater *P. carneipes*	-	May-Sep	-	-	-returns to Australia to breed
Pink-footed shearwater *P. creatopus*	-	Apr-Sep	-	-	-seems to migrate north in summer and fall
Sooty shearwater *P. griseus*	-	common Mar-Oct	-	-	-non-breeding visitant, seen at sea
Manx shearwater *P. puffinus*	-	-	Sep-Mar rare	Feb-Apr Aug-Sep	-migrates north in fall, south in spring
Short-tailed shearwater *P. tenuirostris*	-	May-Aug rare	-	-	
Family Hydrobatidae					
Forked-tailed storm-petrel *Oceanodroma furcata*	X	May-Sep rare	-	-	-nests on Seabird Rocks and adjacent areas
Leach's storm-petrel *O. leucorhoa*	X	Jun-Sep	-	-	-nests on Seabird Rocks
Scaled petrel *Pterodroma inexpectata*	-	-	-	-	-1 recorded B.C. sighting
Order Pelecaniformes Family Pelecanidae					
Brown pelican *Pelecanus occidentalis*	-	-	-	-	-rare visitant

Table 1. cont'd

NAME OF BIRD	NESTING	SUMMER	WINTER	MIGRATION	REMARKS
Family Phalacrocoracidae					
Double-crested cormorant *Phalacrocorax auritus*	X	X	X	-	-rare resident, non-migratory population
Pelagic cormorant *P. pelagicus*	X	X	X	-	-common resident, non-migratory population
Brandt cormorant *P. penicillatus*	X	X	X	-	-common resident -breeds on islets between Tofino and Ucluelet
Order Ciconiiformes					
Family Ardeidae					
Great blue heron *Ardea herodias fannini*	X	X	X	-	-common resident
American bittern *Botaurus lentiginosus*	-	-	X	-	
Green heron *Butorides striatus*	-	-	-	-	-sight records only in B.C.
Order Anseriformes					
Family Anatidae					
Subfamily Cygninae					
Trumpeter swan *Olor buccinator*	-	-	Oct-May	-	-about 25% of the world's population winters on Vancouver Is. (Davies 1978)
Whistling swan *O. columbianus*	-	-	-	Mar-May Nov	-occasional flocks migrate along the B.C. coast
Subfamily Anserinae					
White-fronted goose *Anser albifrons*	-	-	-	Mar-May Aug-Nov	-common migrant along the B.C. coast
Brant *Branta bernicla nigricans*	-	-	X	spring fall	-non-breeding birds are resident -migrate offshore
Canada goose *B. canadensis*	X	X	X	-	-year-round resident on west coast of Vancouver Is.

Table 1. cont'd

NAME OF BIRD	NESTING	SUMMER	WINTER	MIGRATION	REMARKS
Snow goose *Chen caerulescens*	-	-	-	Apr Sep-Dec	-often feed on west coast of Vancouver Is.
Emperor goose *Philacte canagica*	-	-	rare	-	-winter visitant
Subfamily Anatinae					
Pintail *Anas acuta*	-	-	X	Mar-Apr Aug-Oct	-winter in B.C. in small numbers, majority migrate through
American wigeon *A. americana*	-	-	Sep-Apr common	-	-feed on eelgrass
Northern shoveler *A. clypeata*	-	-	X	spring fall	-prefer freshwater
Green-winged teal *A. crecca*	-	-	common	-	
Cinnamon teal *A. cyanoptera*	-	-	-	May Aug	-primarily a freshwater bird
Blue-winged teal *A. discors discors*	X	-	-	-	-rarely occurs in salt or brackish water
European wigeon *A. penelope*	-	-	Oct-Nov	-	-rare winter visitant
Mallard *A. platyrhynchos*	X	-	X	-	-frequent coastal saltwater in winter
Gadwall *A. strepera*	-	-	-	May Sep-Dec	-rare migrant
Wood duck *Aix sponsa*	X	X	-	-	-woodland bird -seen on Turtle Is.
Subfamily Aythyinae					
Lesser scaup *Aythya affinis*	-	-	X	spring fall	-found in bays and estuaries
Redhead *A. americana*	-	-	rare	spring fall	-uncommon on salt water

Table 1. cont'd

NAME OF BIRD	NESTING	SUMMER	WINTER	MIGRATION	REMARKS
Ring-necked duck *Aythya collaris*	-	-	rare	-	-tidal estuaries and bays
Greater scaup *A. marila*	-	-	common	spring fall	
Canvasback *A. valisi*	-	-	rare	spring fall	
Bufflehead *Bucephala albeola*	-	-	common	spring fall	
Common goldeneye *B. clangula americana*	-	-	Oct-Apr	Mar-Apr Oct-Nov	-on the coast except when breeding and nesting
Barrow goldeneye *B. islandica*	-	-	rare	-	-winter on coastal rivers and estuaries
Old squaw (sea pheasant) *Clangula hyemalis*	-	-	X	-	-in coastal waters year-round
Harlequin duck *Histrionicus histrionicus*	-	juv	X	-	-breed in freshwater -winter on exposed coast
White-winged scoter *Melanitta deglandi*	-	juv	Sep-Apr	-	-marine except when breeding -non-breeding birds summer on the coast
Surf scoter *M. perspicillata*	-	X	X	-	-marine except when breeding
Black scoter *Oidemia nigra americana*	-	X	X	-	-marine except when breeding
Pacific eider *Somateria mollissima nigra*	-	-	-	-	-rare in B.C.
King eider *S. spectabilis*	-	-	-	-	-marine except when breeding
Subfamily Merginae					
Hooded merganser *Lophodytes cucullatus*	X	-	rare	-	-nests in fresh water

Table 1. cont'd

NAME OF BIRD	NESTING	SUMMER	WINTER	MIGRATION	REMARKS
Common merganser *Mergus merganser americanus*	X	-	X	-	-breeds regularlyamong the Broken Group Islands
Red-breasted merganser *M. serrator serrator*	-	-	rare	-	-winters in coastal salt water
Subfamily Oxyurinae					
Ruddy duck *Oxyura jamaicensis rubida*	X	-	rare	-	-primarily freshwater
Order Bruiformes Family Rallidae					
American coot *Fulica americana americana*	-	-	X	Mar-Apr Oct-Nov	-flock on salt water for fall migration
Order Charadriiformes Family Alcidae					
Marbled murrelet *Brachyramphus marmoratus*	X	X	X	-	-nest inland, adults forage at sea and carry food to young
Pigeon guillemot *Cepphus columba*	X	X	X	-	-nest on Seabird Rks. and Florencia Is.
Rhinoceros auklet *Cerorhinca monocerata*	X	X	rare	-	-nest on Cleland and Seabird Rks.
Horned puffin *Fratercula corniculata*	-	rare	X	-	-forages offshore in fall and winter -rare non-breeding summer visitor
Tufted puffin *Lunda cirrhata*	X	X	X	-	-nest on Seabird Rks. and Florencia Is. -winter offshore
Cassin's auklet *Ptychoramphus aleuticus*	X	X	X	-	-nest on Seabird and Cleland Rks. -winter record in Barkley Sound
Ancient murrelet *Synthliboramphus antiquus*	-	-	X	-	-winter transient
Common murre *Uria aalge*	X	X	X	- Jul-Sep	-nest on Cleland and Florencia Is. and Starlight Reef

Table 1. cont'd

NAME OF BIRD	NESTING	SUMMER	WINTER	MIGRATION	REMARKS
Thick-billed (Pallas) murre *Uria lomvia arra*	-	-	-	-	-casual on coastal B.C.
Family Charadriidae					
Surfbird *Aphriza virgata*	-	-	X	spring fall	-common transient -winter resident
Ruddy turnstone *Arenaria interpres*	-	-	-	spring fall	-common transient
Black turnstone *A. melanocephala*	-	-	X	spring fall	-common transient and winter resident
Killdeer *Charadrius vociferous*	X	X	X	-	-year-round resident
Semipalmated plover *C. semipalmatus*	-	juv	-	Apr-May Jul-Sep	-non-breeding birds summer off southern B.C. coast
American golden plover *Pluvialis dominica dominica*	-	-	-	spring fall	
Pacific golden plover *P. d. fulva*	-	-	-	- fall	-rare fall transient
Black-bellied plover *P. squatarola*	-	-	X	Apr-May fall	-winter in small numbers
Family Haematopodidae					
Black oystercatcher *Haematopus bachmani*	X	X	X	-	-common resident on outer coast
Family Laridae					
Herring gull *Larus argentatus*	-	-	X	spring fall	-abundant in migration
California gull *L. californicus*	-	X	rare	spring Oct-Nov	-uncommon non-breeding resident
Mew (Short-billed) gull *L. canus*	-	-	X	Apr-May Aug-Sep	-common in winter on B.C. coast -nests on Pacific Rim National Park lakes

Table 1. cont'd

NAME OF BIRD	NESTING	SUMMER	WINTER	MIGRATION	REMARKS
Ring-billed gull *Larus delawarensis*	–	–	–	rare	-rare migrant on B.C. coast
Glaucous-winged gull *L. glaucescens*	X	X	X	–	-common resident
Heermann's gull *L. heermanni*	–	Jun-Nov	–	–	-common non-breeding visitor
Glaucous gull *L. hyperboreus*	–	–	rare	rare	
Western gull *L. occidentalis*	–	–	X	–	-regular winter visitant
Franklin gull *L. pipixcan*	–	–	–	– fall	-rare fall migrant
Bonaparte gull *L. philadelphia*	–	–	rare	Mar-May Aug-?	-common migrant
Thayer's gull *L. thayeri*	–	X	X	–	-uncommon non-breeding resident
Pacific kittiwake *Rissa tridactyla tridactyla*	–	X	rare	–	-summer on open coast
Common tern *Sterna hirundo hirundo*	–	Aug-Sep	–	–	-transient in B.C.
Artic tern *S. paradisaea*	–	–	–	spring fall	-rarely seen, usually migrate offshore
Caspian tern *S. caspia*	–	X	–	–	
Sabine's gull *Xema sabini*	–	–	–	spring fall	-rare spring and fall transient
Family Phalaropodidae					
Northern phalarope *Lobipes lobatus*	–	–	–	May Jul-Sep	-common migrant along coast and offshore

Table 1. cont'd

NAME OF BIRD	NESTING	SUMMER	WINTER	MIGRATION	REMARKS
Red phalarope *Phaloropus fulicarius*	-	-	-	Apr-May Aug-Sep	-migrate well offshore
Wilson's phalarope *Steganopus tricolor*	-	-	-	rare	-casual migrant off B.C. coast
Family Recurvirostridae					
American avocet *Recurvirostra americana*	-	-	-	-	-casual in B.C. to coast
Family Scolopacidae					
Spotted sandpiper *Actitis macularia*	X	X	rare	-	-breed in Pacific Rim National Park
Upland sandpiper *Bartramia longicauda*	-	-	-	-	-rare transient in coastal B.C.
Sanderling *Calidris alba*	-	-	rare	spring fall	-regular migrant
Dunlin *C. alpina*	-	rare	common	-	-winters on beaches and mudflats
Red knot *C. canutus*	-	-	-	Apr-May Aug-Sep	-rare spring and fall transient
Common (Wilson) snipe *Capella gallinago*	-	-	rare	-	-freshwater during breeding
Willet *Catoptrophorus semipalmatus*	-	-	-	-	-casual in southwestern B.C.
Western sandpiper *C. mauri*	-	-	-	Apr-May Jul-Sep	-common migrant
Semipalmated sandpiper *C. pusillus*	-	-	-	Apr-May Jul-Aug	-rare migrant
Sharp-tailed sandpiper *C. acuminata*	-	-	-	- fall	-rare fall migrant
Baird's sandpiper *C. bairdii*	-	-	-	spring Jul-Sep	-rare spring and uncommon fall migrant

Table 1. cont'd

NAME OF BIRD	NESTING	SUMMER	WINTER	MIGRATION	REMARKS
Pectoral sandpiper *Catoptrophorus melanotus*	-	-	X	May Aug-Sep	-casual in winter -rare spring migrant
Least sandpiper *C. minutilla*	-	-	-	spring fall	-often fly, flock and feed with the Western sandpiper
Aleutin (Rock) sandpiper *C. ptilocnemis*	-	-	common	-	
Wandering tattler *Heteroscelus incanus*	-	-	-	Apr-May Jul-Sep	-frequent rocky outer coast during migration
Short-billed dowitcher *Limnodromus griseus*	-	-	-	Apr-May Jul-Aug	-common migrant
Long-billed dowitcher *L. scolopaceus*	-	-	-	Apr-May Jul-Aug	-common migrant
Marble godwit *Limosa fedoa*	-	-	-	- fall	-rare fall migrant
Stilt sandpiper *Micropalama himantopus*	-	-	-	spring fall	-rare migrant
Whimbrel (Hudsonian curlew) *Numenius phaeopus phaeopus*	-	-	-	Apr-May Aug-Oct	-Victoria is northernmost wintering record
Greater yellowlegs *Tringa melanoleucus*	-	-	rare	Apr-May Jul-Aug	-frequents estuaries and protected bays
Lesser yellowlegs *T. flavipes*	-	-	-	Apr Jul-Aug	-rare transient
Solitary sandpiper *T. solitaria*	-	-	-	spring fall	-rare migrant
Buff-breasted sandpiper *Tryngites subruficollis*	-	-	-	- fall	-rare fall migrant
Family Stercorariidae					
Skua *Catharacta skua lönnbergi*	-	-	-	-	-non-breeding visitant to offshore waters

Table 1. cont'd

NAME OF BIRD	NESTING	SUMMER	WINTER	MIGRATION	REMARKS
Long-tailed jaeger *Stercorarius longicaudus*	-	-	-	-	-migrates offshore, rare along coast
Parasitic jaeger *S. parasiticus*	-	-	-	spring Aug-Nov	-migrates north well offshore, returns in the fall nearer the coast
Pomarine jaeger *S. pomarinus*	-	-	-	- fall	-migrates offshore

Table 2. Seabird nesting colonies of Pacific Rim National Park and vicinity, number of breeding pairs 1974-75 (Campbell 1976).

NESTING COLONY (* indicates colonies within Pacific Rim National Park)	Fork-tailed storm-petrel	Leach's storm-petrel	Brandt's cormorant	Pelagic cormorant	Glaucous-winged gull	Common murre	Pigeon guillemot	Tufted puffin	Rhinocerous auklet	Cassin's auklet	TOTAL PAIRS
Lacrois Group	-	-	-	-	1	-	-	-	-	-	1
*Gowlland Rocks	-	-	-	-	2	-	-	-	-	-	2
*White Islet	-	-	-	19	61	-	-	-	-	-	80
*Sea Lion Rocks	-	-	6	10	167	-	-	-	-	-	183
*Cormorant Rock	-	-	-	25	-	-	-	-	-	-	25
*Florencia Island	-	-	+	79	479	1	25	3	-	-	587+
Fletcher's Beach	-	-	-	12	-	-	-	-	-	-	12
George Fraser Island	-	-	-	-	10	-	-	-	-	-	10
Starlight Reef	-	-	66	-	306	1	-	-	-	-	373
Great Bear Rks. and Alley Rk.	-	-	-	3	277	-	-	-	-	-	280
*Sail Rock	-	-	-	-	1	-	-	-	-	-	1
*Wouwer Island	-	-	-	-	1	-	1	-	-	-	2
*Effingham and Austin Islands	-	-	-	30	-	-	-	-	-	-	30
*Faber Islets	-	-	-	-	2	-	-	-	-	-	2
*Dempster Island	-	-	-	19	-	-	-	-	-	-	19
*Gibraltar Island	-	-	-	1	-	-	-	-	-	-	1
Baeria Rocks	-	-	-	32	210	-	5	-	-	-	247
San Jose Islets	-	-	-	-	2	-	-	-	-	-	2
Leach Islet and Folger Island	-	-	-	2	-	-	2	-	-	-	4
Haines Island	-	-	-	-	-	-	2	-	-	-	2
*Cape Beale	-	-	-	20	-	-	-	-	-	-	20
*Seabird Rocks	10	500	-	-	400	-	50	20	150	100	1230
*Whyac	-	-	-	50	-	-	-	-	-	-	50
Providence Cove	-	-	-	15	-	-	-	-	-	-	15
TOTAL PAIRS	10	500	72+	317	1919	2	85	23	150	100	3178

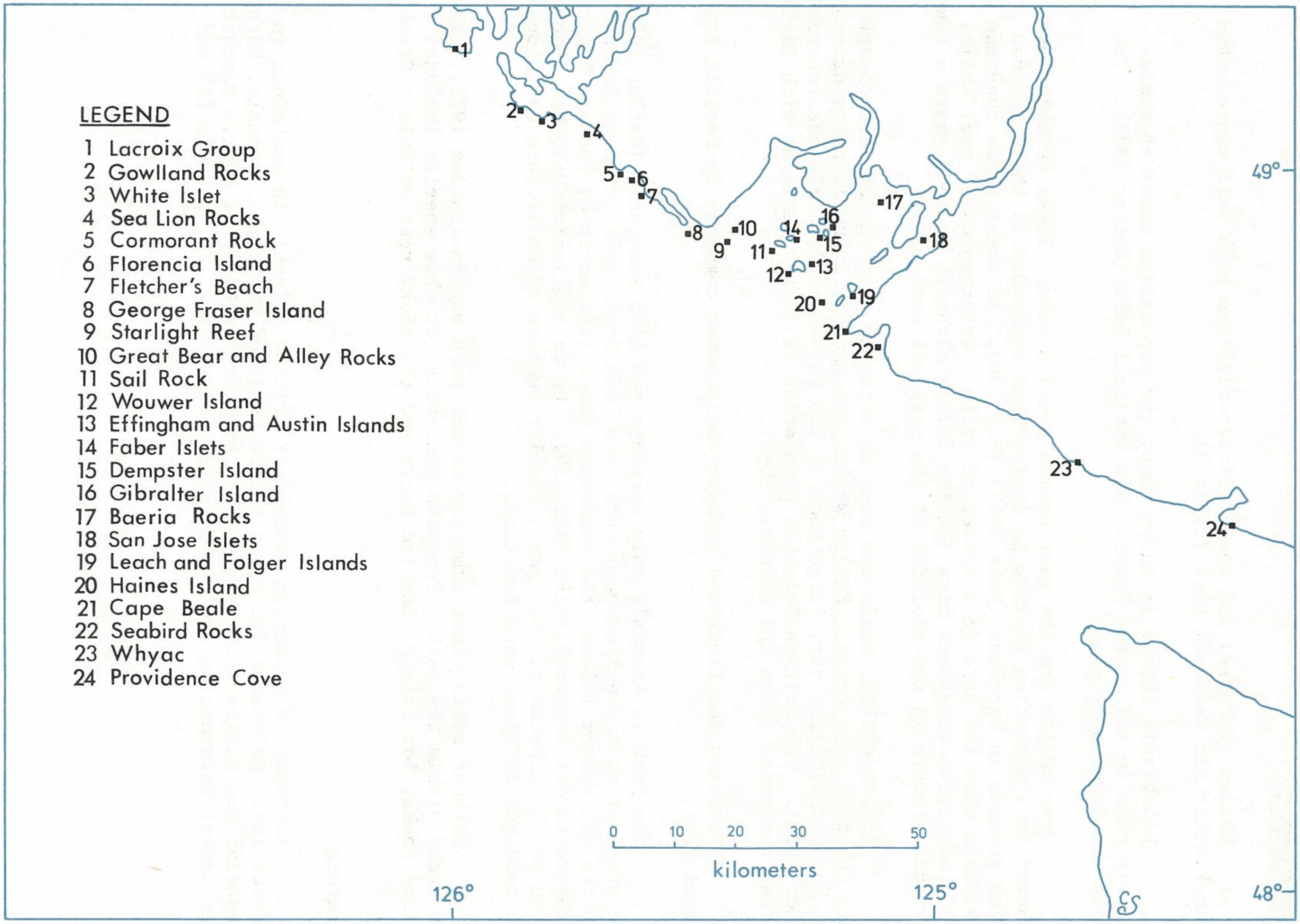


Fig. 29. Seabird colonies of Pacific Rim National Park and vicinity (Hatler, Campbell and Dorst 1978)

MARINE MAMMALS

Whales (Cetacea) and seals (Pinnepedia) are both well represented within Pacific Rim National Park (Table 3).

Relatively little is known about the population sizes of whales regularly seen in and around Pacific Rim National Park (Hatler 1972). Two species are frequently seen.

Grey whales are the most common species seen. These animals move northward in a migration peaking in April, then southward to their Mexican calving grounds in December (Pike 1962) (Fig. 30). At these times hundreds of individuals pass the park in a matter of weeks. Occurrences of grey whales outside migration times are rare (Hatler 1972); although in some years a few individuals remain in the vicinity of the park all summer.

Killer whales, while not seen as often as grey whales, are observed within the park year round. Killer whales are usually found in pairs or small pods, but occasionally very large pods of 200 to 400 individuals are recorded (Hatler 1972). The British Columbia population is likely resident with little seasonal variation (Pike and MacAskie 1969).

Northern sea lions and harbour seals occur commonly in Pacific Rim National Park.

The park is Canada's only northern sea lion sanctuary (Hatler 1972). There are four main sea lion haul-outs: Sea Lion Rocks just off Long Beach, the rocks off Wouwer Island, the sandstone bench just north of Pachena Point and the rocks off Carmanah Point (Fig. 30). Up to 400 individuals have been seen on Sea Lion Rocks at one time. Smaller numbers of California sea lions often haul out in these same locations.

Harbour seals occur commonly in all park waters (Hatler 1972). These seals breed within the park. Favoured haul-outs for this species include: Gowlland Rocks, Box Island, Seabird Rocks and the rocky reef at Kulaht Creek (Fig. 30).

Literature

Information on marine mammals of British Columbia is contained in reference 164. Reference 100 gives a more detailed account of mammals, both terrestrial and marine, occurring within Pacific Rim National Park. Further marine mammal information can be found in references 7, 18, 34, 47, 163 and 192.

Table 3. Marine Mammals of Pacific Rim National Park (Banfield 1974, Darling 1973, Hatler 1972, Pike and MacAskie 1969).

NAME OF MAMMAL	REMARKS
Order Cetacea	
Suborder Ondontoceti	
Family Ziphiidae	
Giant beaked whale *Berardius bairdii*	-seen May to Sept.
Moore's beaked whale *Mesoplodon carlhubbsi*	-park specimen
Stejneger's beaked whale *M. stejnegeri*	-park specimen -Pacific Rim National Park may be in the region of sympatry of Moore's and Stejneger's beaked whales
Curvier's beaked whale *Ziphius cavirostris*	-cosmopolitan on the west coast of Vancouver Island
Family Physeteridae	
Sperm whale *Physeter catadon*	-rarely sighted, but has been seen off the park
Family Delphinidae	
Baird's dolphin *Delphinus delphis bairdii*	-northern limit of distribution is southern B.C.
Pacific pilot whale *Globicephala macrorhyncha*	-sightings in Barkley Sound
Grey grampus (Risso's dolphin) *Grampus griseus*	-sightings off Vancouver Island
Pacific striped dolphin *Lagenorhynchus obliquidens*	-common -no records from the park
Northern right-whale dolphin *Lissodelphis borealis*	-common visitor off B.C. coast - 1 taken 110 km SW of Amphitrite Point
Killer whale *Orcinus orca*	-common
Dall's porpoise *Phocoenoides dalli*	-specimen from Barkley Sound
Harbour porpoise *Phocoena phocoena*	-most common cetacean in B.C. waters -common in Broken Group Islands
Long-beaked (Blue) dolphin *Stenella caeruleoalba euphrosyne*	-2 specimens from the park

Table 3. cont'd

NAME OF MAMMAL	REMARKS
Suborder Mysticeti	
Family Eschrichtidae	
Grey whale *Eschrichtius robustus*	-regular spring and fall migrant -peak northward migration in April, south in Dec. -usually seen close to shore
Family Balaenopteridae	
Minke whale *Balaenoptera acutorostrata davidsoni*	-4 park specimens
Sei whale *B. borealis*	-sighted off Long Beach
Blue whale *B. musculus*	-rarely seen
Common finback *B. physalus physalus*	-arrive in March, common all summer -most common baleen whale in the park
Humpback whale *Megaptera novaeangliae*	-numbers reduced by whaling
Family Balaenidae	
Black right whale *Balaena glacialis japonica*	-formerly common in summer and during migration
Order Pinnipedia	
Family Otariidae	
Northern fur seal *Callorhinus ursinus*	-frequent coastal B.C. waters in winter and during spring and fall migrations -migrate offshore
Northern sea lion *Eumetopias jubata*	-common in winter
California sea lion *Zalophus californianus californianus*	-regular visitor to Barkley Sound
Family Phocidae	
Northern elephant seal *Mirounga angustirostris*	-seen April to Oct. -usually solitary
Harbour seal *Phoca vitulina richardii*	-non-migratory (Bigg 1969) -seen in all phases of the park
Order Carnivora	
Family Mustelidae	
Sea otter *Enhydra lutris lutris*	-very rare -reintroduced on northern B.C. coast, beginning in 1969

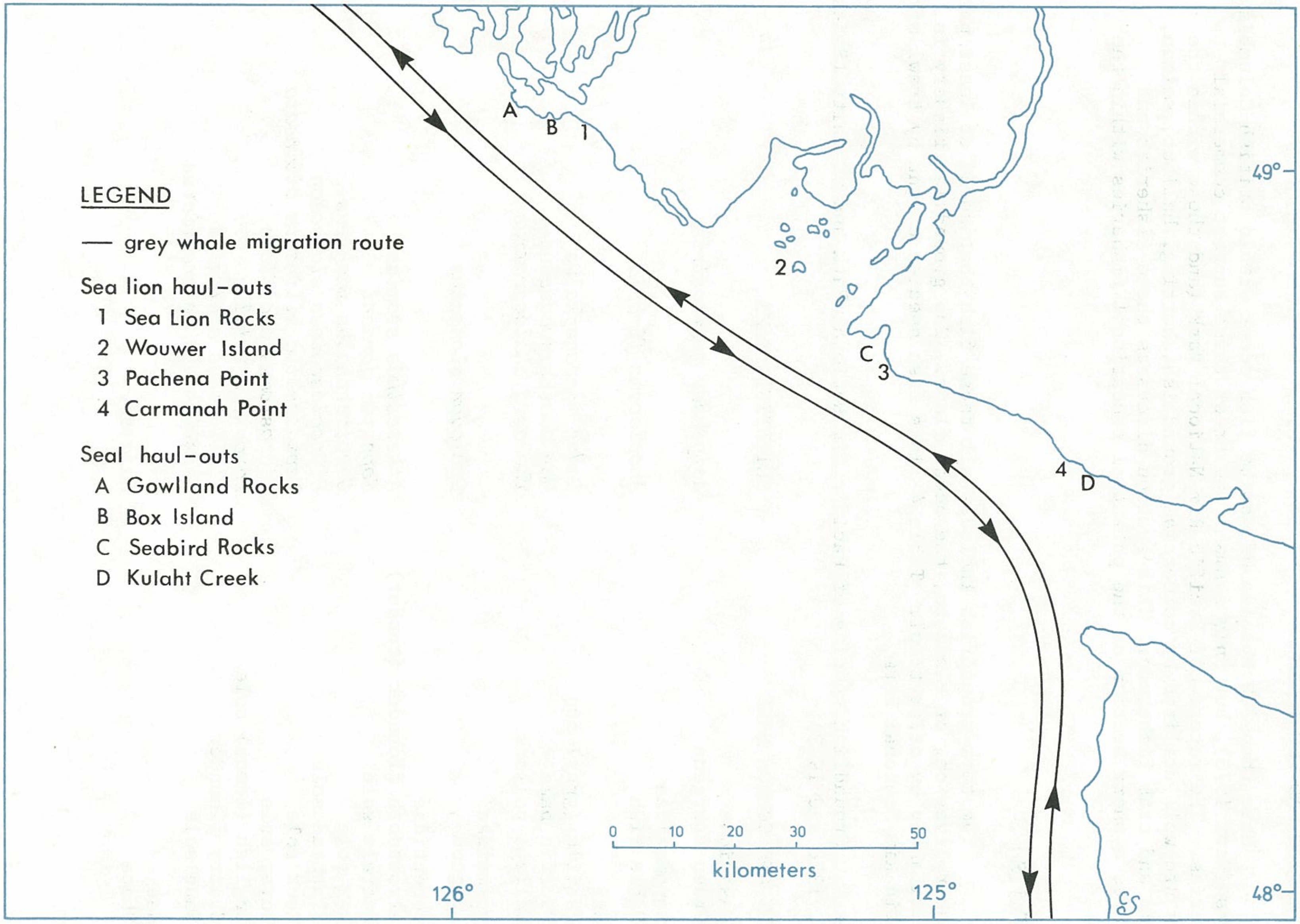


Fig. 30. Marine mammals (Hatler 1972)

MARINE FISH AND CRUSTACEA

More than 300 species of marine fish occur within British Columbia waters (Hart 1973), but only a small number of these support commercial fisheries. The waters off Pacific Rim National Park (and those within the park) are well utilized by commercial groundfish, herring, halibut, salmon, shrimp and crab fishermen. This section discusses these fisheries and includes a short section on the potential receational fisheries within the park.

Groundfish

The term groundfish includes all those fish that spend at least part of their lives on, or close to, the ocean floor. The groundfish fishery is predominantly by otter trawl. Table 4 lists fish species caught by trawl off Pacific Rim National Park.

Table 4. Groundfish species of Pacific Rim National Park and vicinity (Smith 1977, 1978 and 1979).

FAMILY AND COMMON NAME	SCIENTIFIC NAME
Acipenseridae	
Green sturgeon	*Acipenser medirostris*
Anoplopomatidae	
Sable fish	*Anoplopoma fimbria*
Gadidae	
Pacific (grey) cod	*Gadus macrocephalus*
Pacific hake	*Merluccius productus*
Walleye pollock	*Theragra chalcogrammus*
Hexagrammidae	
Lingcod	*Ophiodon elongatus*
Pleuronectidae	
Arrowtooth flounder (turbot)	*Atheresthes stomias*
Petrale sole	*Eopsetta jordani*
Rex sole	*Glyptocephalus zachirus*
Flathead sole	*Hippoglossoides elassodon*
Rock sole	*Lepidopsetta bilineata bilineata*
Dover sole	*Microstomus pacificus*
English (lemon) sole	*Parophrys vetulus*
Starry flounder	*Platichthys stellatus*
Sand sole	*Psettichthys melanostictus*
Rajidae	
Skate	*Raja sp.*

Table 4. cont'd

FAMILY AND COMMON NAME	SCIENTIFIC NAME
Scorpaenidae	
Pacific ocean perch	*Sebastes alutus*
Silvergrey rockfish	*S. brevispinis*
Yellowtail rockfish	*S. flavidus*
Bocaccio	*S. paucispinus*
Canary rockfish	*S. pinniger*
Redstripe rockfish	*S. proriger*
Yellowmouth rockfish	*S. reedi*
other rockfish	*Sebastes spp.*

Pacific cod (33%), lingcod (21%), other rockfish (17%), Pacific ocean perch (12%) and petrale sole (9%) were the main commercial species caught off the west coast of Vancouver Island between 1965 and 1974 (Westrheim 1977). Petrale sole, although a small trawl component by weight, has a strong market demand.

The principal groundfish trawling grounds near Pacific Rim National Park are shown in Figure 31. Pacific cod is caught primarily on the Firing Range-Cabbage Patch, LaPerouse Bank and Clo-oose grounds. Lingcod is most plentiful on LaPerouse Bank and Firing Range-Cabbage Patch. Petrale sole is usually found on LaPerouse Bank and off Cape Flattery. Pacific ocean perch is fished on the outer continental shelf and upper slope from Estevan Point to Cape Flattery (Westrheim 1977).

Herring

The herring *(Clupea harengus pallasi)* fishery is important in British Columbia. One of the major herring fishing sectors in the province is Barkley Sound. In 1978, 12 644 tons of herring were caught in Barkley Sound (Hourston 1979). In the Broken Group Islands of Pacific Rim National Park, Hand and Nettle Islands are herring spawning grounds. Nearby channels are nursery areas for juvenile herring.

Herring schools are usually located near or just below a sharp drop-off (Miller 1979). Schools of adults have been found along the edges of La Persouse Bank (Miller 1979). In the Broken Group Islands roe fishing is carried out in Imperial Eagle Channel, Coaster Channel, Peacock Channel and Sechart Channel (pers. comm. D. Outram) when the fish are moving in to spawn.

Halibut

The halibut *(Hippoglossus stenolepis)* long-line fishery off the west coast of Vancouver Island represents less than 10% of the total British Columbia fishery. The mean catch off Vancouver Island between 1971 and 1973 was 270 metric tonnes (Fisheries and Environment Canada 1977b) of which Canadian fishermen took approximately 75%.

Halibut stocks have declined greatly since 1960. The catches in the mid 1970's were less than half those of the early 1960's. This decline is contributed to poor recruitment caused by excessive capture of juvenile fish by

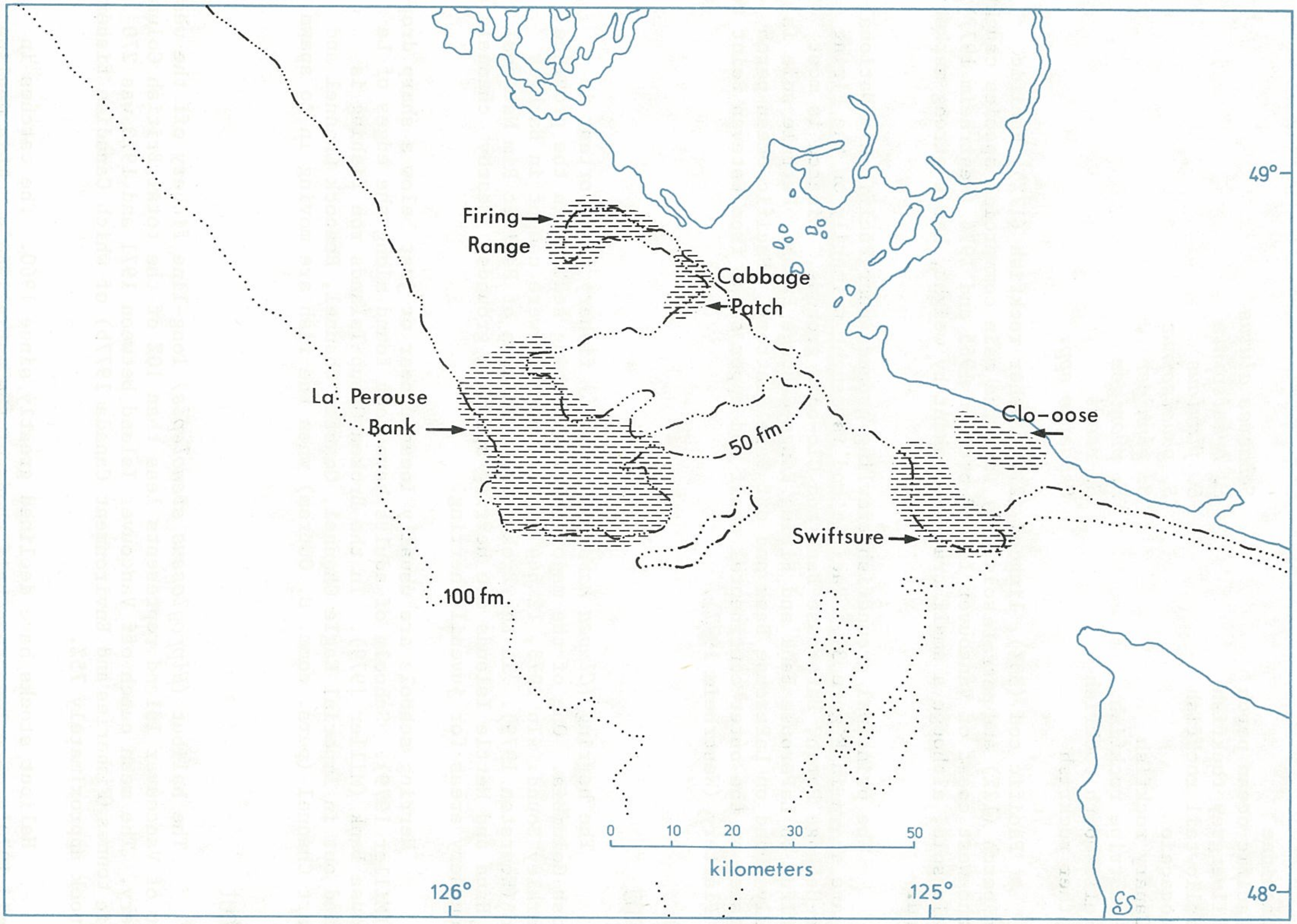


Fig. 31. Groundfish trawling grounds off southwestern Vancouver Island

foreign and domestic trawlers (Fisheries and Environment Canada 1977b). Landing of trawl-caught halibut is now prohibited in both Canada and the United States.

Salmon

The salmon fishery is the largest commercial fishery in British Columbia. All five species of Pacific Salmon are utilized. These are:

sockeye *(Oncorhynchus nerka)*
pink *(O. gorbuscha)*
coho *(O. kisutch)*
chum *(O. kita)*
and chinook or spring *(O. tschawytscha)*

The waters to the west of Pacific Rim National Park are productive salmon fishing grounds. In 1978, over 4 000 metric tonnes of salmon were caught, about 6% of the British Columbia total (Fisheries and Oceans Canada 1979a) while in 1977 this small area provided 7 800 tonnes of salmon, over 12% of the provincial total (Fisheries and Environment Canada 1978).

Significant salmon runs occur in six streams in Pacific Rim National Park. In addition, considerable numbers of several salmon species pass through Barkley Sound and Nitinat Lake during their spawning migration. Mean annual salmon escapement for these streams and areas are given in Table 5.

Table 5. Mean annual salmon escapements for Pacific Rim National Park streams and adjacent areas (Brown, Comfort and Marshall 1979; Brown, Musgrave, Demontier, Marshall and Comfort 1979; Marshall, Brown, Chahley and Demontier 1977).

STREAM	SOCKEYE	CHINOOK	COHO	CHUM	PINK
Kootowis Creek	-	-	570	1 070	-
Lost Shoe Creek	-	-	270	120	-
Barkley Sound	105 000	12 800	61 000	128 700	950
Pachena River	-	-	800	500	-
Klanawa River	-	-	280	few	-
Nitinat Lake	4 700	1 640	2 430	48 500	-
Cheewhat River	1 060	-	460	85	-
Gordon River	-	470	3 200	800	*325

(* no pink salmon observed since 1967)

Shrimp and prawns

Five species of shrimp and one prawn species (Table 6) support a small fishery in British Columbia. The average annual catch off the west coast of Vancouver Island between 1972 and 1975 was about 700 metric tonnes (Fisheries and Environment Canada 1977a). Shrimp, which make up the bulk of the catch, are harvested by trawlers on muddy or sandy bottoms. Prawns live on rocky substrates and are caught in traps.

There are two main shrimp fishing areas on the west coast of Vancouver Island: one off Tofino (Boutillier, Yates and Butler 1977), and the second within Barkley Sound. Smooth pink shrimp *(Pandalus jordani)* are found in Imperial Eagle and lower Trevor Channels, while the sidestriped shrimp *(Pandalopsis dispar)* are concentrated in north and west Imperial Eagle Channel and throughout Trevor Channel (Boutillier 1979).

British Columbia shrimp and prawn stocks declined from 1976 to 1978 and started to increase in 1979. This fluctuation of stock size is explained by variable recruitment (Boutillier, Cooper and Dodimead 1979). The stocks west of Tofino are thought to be under utilized (Fisheries and Environment Canada 1977a) while those within Barkley Sound are considered only large enough for small beam trawlers to work economically (Boutillier 1979).

Table 6. Shrimp and prawn species of British Columbia.

COMMON NAME	SCIENTIFIC NAME
sidestripe or giant red shrimp	*Panalopsis dispar*
pink shrimp	*Pandalus borealis*
prawn or spot shrimp	*P. platyceros*
humpback or king shrimp	*P. hypsinotus*
smooth pink shrimp	*P. jordani*
coonstripe shrimp	*P. danae*

Crab

The Dungeness crab *(Cancer magister)* is the primary species of a minor crab fishery in British Columbia. The average annual catch from 1972 to 1975 was 1 080 metric tonnes(Fisheries and Environment Canada 1977a). Although much of the catch comes from the northern Queen Charlotte Islands, there are fishing areas in southern British Columbia. One of these is near Tofino on the west coast of Vancouver Island (Fisheries and Forestry Canada no date).

Crab are generally found on firm sandy bottom and are taken by crab traps. These traps are usually set between low tide and 40 m deep. The legal minimum crab size in British Columbia is 16.5 cm (Fisheries and Oceans Canada 1980).

The Dungeness crab production in the 1970's has been between 50 and 60% of the level of the 1950's and 1960's. The causes of this stock decline are unknown (Fisheries and Environment Canada 1977a).

Marine sport fishing

Sport fishing is a large and growing industry in British Columbia. Anglers from all over the world visit our coast (Haig-Brown 1967). For many people the only significant contact they have with the marine environment is through sport fishing.

Chinook and coho are the traditionally important game fish but beach-fishing for springs and coho as they feed on spawning herring is becoming increasingly popular (Haig-Brown 1967). Salmon fishing is the major recreational use of the Alberni Inlet/Barkley Sound area (Dalziel 1975).

Sea bass, red snapper, cod, flounder, perch and dogfish are abundant along the Pacific coast. These white meat fish are relatively easy to catch and provide delicious eating (Fisheries and Oceans Canada 1980). For the more adventuresome, halibut and lingcod are popular.

Also included in the term sport fish are clams, scallops, mussels, oysters, abalone, crabs, shrimp, prawns, sea urchins and sea cucumbers. These marine animals are harvested by residents and tourists alike.

For all sport fishing, bag limits, licensing restrictions, closures and gear regulations must be observed. These are set each year by the Dept. of Fisheries and Oceans and published in a tidal waters sport fishing guide (Fisheries and Oceans Canada 1980). With careful management the many marine sport species occurring within Pacific Rim National Park will be an increasingly important asset and interpretive resource.

Literature

General information on Pacific fishes can be found in references 33, 34, 39, 74, 78, 227 and 237. Groundfish information is contained in references 66, 73, 85, 97, 133, 188, 189, 190, 219, 220 and 221 while herring data can be found in references 65, 77, 110, 111, 144, 154 and 155. Halibut are discussed in reference 73, salmon in references 4, 74, 78, 81, 98, 233, 234 and 238 while information on shrimp and prawns is presented in references 21, 22, 23, 24, 67, 72, 228 and 229. References 72 and 75 are concerned with crab fishing while sport fishing details are provided in references 45, 80 and 207.

ARCHAEOLOGY

The abundant and varied resources of the Pacific Rim National Park area were heavily utilized in aboriginal times (St. Claire 1976). Nootka people populated the west coast of Vancouver Island as far south as Port San Juan (Jenness 1972). Within the park, archaeological sites are tangible evidence of the rich history of the Nootkas (Fig. A, confidential). The sites are most commonly shell middens which mark locations of long term habitation sites. Other features which have been found within the park include fish traps, burial caves and petroglyphs.

Table A (confidential) is a listing of archaeological sites occurring within Pacific Rim National Park as catalogued by the Heritage Conservation Branch of the British Columbia Provincial Government. The apparent scarcity of sites within the West Coast Trail Section of the park is likely more indicative of the lack of systematic site surveys in this area than of actual abundance of archaeologically significant locations (pers. comm. Neil Wilton, Resource Management Div., Heritage Conservation Br.)

If they are to remain intact, these archaeological sites must be protected from inadvertent or deliberate degradation by park visitors. Education of the public about the existence and locations of Indian reserves within the park area is a first step. These reserves are not part of the park, but through ignorance, are often used as such. In addition, the public must be informed of provincial site protection laws[1] and the reasons for their existence. The third, most difficult measure is enforcement of park policy toward the reserves and archaeological resources of Pacific Rim National Park.

Literature

General information on the Indians of Canada can be found in reference 114. Laws governing heritage sites in B.C. are found in reference 236.

[1]The Heritage Protection Act, in section 6, subsection 2, prohibits the knowing destruction, desecration, alteration, excavation, defacement or digging of a burial place, kitchen-midden, habitation site, cairn, fortification, North American Indian painting, rock carving or other Provincial heritage site. The Heritage Conservation Act was proclaimed on Sept. 22, 1977 (Government of B.C. 1977).

A REVIEW OF COASTAL CLASSIFICATION SYSTEMS

The biophysical approach to land classification for northern Canada was developed originally under the National Committee on Forest Land (1966-1972). However, the National Committee was disbanded when the Canada Land Inventory was completed.

After 1972, a growing number of biophysical type surveys and research clearly showed the need for a technical coordination committee (Thie and Ironside 1976). In May 1976 the Canada Committee on Ecological (Biophysical) Land Classification was founded to meet this requirement. The committee has representatives from federal and provincial agencies, universities and private industry.

The technical work of this committee is carried out by five working groups, of which Land/Water Integration is one. This working group was established to develop a coastal and inland water classification and subsequently to investigate their compatibility and integration with land classification (Thie and Ironside 1976).

While land classification concepts and procedures in Canada have been accepted since the Canada Land Inventory program in the 1960's, efforts to extend these biophysical concepts to the coastal zone have been minimal. British Columbia and the Atlantic provinces are just beginning to study the coastal zone and its resource use problems in some orderly fashion.

Although coastal zone classification within Canada is in its infancy, the study and analysis of coastal processes and morphology has been developing since the mid 1800's (Lopoukhine and Hirvonen 1976; Silk 1975a and 1975b). Until recently, these studies concentrated on geological aspects, being divided into genetic and descriptive classifications.

Davis (1898) presented an emergence/submergence classification scheme which proved to be the catalyst for further modifications. Modifications and more precise definitions of the emergence/submergence concept were put forth by Johnson (1919), Cotton (1952) and Valentin (1952). Bloom, in 1965, imposed a time axis to the existing ones of erosion/deposition and developed a three-dimensional basis for describing coasts (Silk 1975a).

Several other approaches were also drawn up for coastal classification. Shepard (1937) advanced the concept of primary and secondary coasts; Davies (1964) outlined the application of oceanographic processes to coastal classification; and Odum and Copeland (1974) introduced a classification based on energy source and stress of natural and man-modified ecosystems. A more detailed historical outline on coastal classification is given in Appendix 5.

With the advent of the Coastal Zone Management Act of 1972 in the United States, most coastal states set up coastal zone management programs; some with continuing inventory programs. This has led to the proposal and utilization of several classification systems for the United States coastline.

Two hierarchical approaches are favoured (Lopoukhine and Hirvonen 1976). One, termed the tier system, divides the coastal zone into three zones:

1) offshore, 2) estuary and 3) shore and coastal upland. Each tier is individually studied and delineated and then integrated with the other two tiers for a total overview of the coastal section under study. This approach was used by Thompson and Snow (1974) in the resource inventory prepared for the Oregon Coastal Conservation and Development Commission.

The second approach is a biogeographic regional system that has been developed and used particularly along the western seaboard. Biogeographical regions are divided into subregions with further divisions into reaches based on differentiation of climate, landform, vegetation and land-water configuration (Sather 1976; Terrell 1977; Sather, Cowardin, Carter, Golet and LaRoe 1977; Cowardin 1978).

The most recent published coastal classification systems in Canada relate to the Atlantic coast. Owens (1974) outlined a ten-order hierarchical system (primarily geologically oriented) for the southern Gulf of St. Lawrence. This system is complex in description and implementation but is a valuable aid in understanding the problems associated with coastal classification (Lopoukhine and Hirvonen 1976). Silk (1975a, 1975b) produced two reports for the Atlantic Regional Office of the Lands Directorate. The first report reviews the chronological development (by author) of coastal classification from 1866 to 1974. The second report is similar and includes an analysis of existing coastal classification types emphasizing concepts of particular value.

A pilot study of two areas in Newfoundland, St. George's Bay and Conception Bay, was undertaken as a trial application of the classification system developed at that time (Warren and Anderson 1975a, 1975b). The classification scheme was adapted from Lacate's (1969) hierarchical land classification and is based on the following general principles:

<u>Coastal Region</u>: (Scale of mapping - 1:1 000 000 or smaller). A coastal zone area characterized by a distinctive regional climate as expressed by vegetation and gross marine characteristics such as the seasonal occurrence of ice, macrotidal influences and coastal orientation features.

<u>Coastal District</u>: (Scale of mapping - 1:250 000 to 1:1 000 000). A coastal zone area characterized by a distinctive pattern of geology, geomorphology, vegetation, coastal configuration, bathymetry and water quality. These serve to identify the homogeneous units which make up the coastal region.

<u>Coastal System</u>: (Scale of mapping - 1:50 000 to 1:250 000 depending upon complexity). A coastal zone area characterized by a recurring pattern of landforms, shoreforms and marine parameters. This level, in particular, takes into account the processes which have led to the development of and maintenance of these patterns.

<u>Coastal Type</u>: (Scale of mapping - 1:10 000 to 1:20 000). At this detailed level of mapping, each tier of the coastal zone would be considered independently for field data purposes. The land component would conform to the land type definition of Lacate (1969). The intertidal component or shoretype would be form-centred with vegetation, stability and soil modifiers. The water component or water type would be differentiated on the basis of quality and process modifiers.

The classification was based primarily on interpretation of aerial photography and a minimum of field work. The coastal type level was not mapped.

In 1976, a second experiment on the Atlantic coast involved mapping the Bay of Fundy to provide data on the intertidal zone for the Fundy Tidal Power Project. A biophysical inventory at a land system and land type level was to be an integral aspect of the program (Lopoukhine and Hirvonen 1976; Hirvonen 1977).

Warren and Anderson (1975a, 1975b) and Thie and Ironside (1976) point out that the main constraint in coastal classification is the necessity to integrate dynamic marine parameters and their various influences with the relatively stable biophysical land patterns. A problem also exists in determining which marine and shoreline parameters can be delineated, at a practical cost, to provide coastal managers with the necessary baseline data for resource management decisions.

Literature

Detailed classification information can be found in references 42, 84, 106, 108, 132, 176, 177, 178, 179, 185, 186, 201, 202, 203, 215, 216, 217, 223, 152 224, 225 and 226. Appendix 5 deals with the history of coastal classification, giving short descriptions of references 2, 3, 5, 11, 19, 26, 41, 43, 46, 48, 49, 51, 59, 60, 62, 71, 82, 95, 96, 113, 115, 117, 120, 135, 136, 137, 151, 153, 157, 158, 166, 168, 169, 170, 171, 182, 183, 184, 194, 196, 197, 200, 206, 209, 213, 214, 218, 230 and 231.

METHODOLOGY

The terms of reference for the 1979-80 project (Appendix 6) outline the basic requirements of developing an ecological (biophysical) coastal classification for the intertidal and subtidal environments of Pacific Rim National Park. This classification system is to be used for effective park planning, interpretation and resource management with emphasis placed on:
1) sensitivity or suitability to visitor use,
2) importance of the units for park interpretation,
and 3) scientific importance.

CLASSIFICATION METHODOLOGY

The basis for the biophysical land classification systems utilized by Parks Canada - Western Region has been Lacate's (1969) hierarchical land classification. After reviewing as much of the available literature as possible, it was felt that a classification system similar to Lacate's should be drawn up for the marine environment of Pacific Rim National Park, if possible. The use of such a system would facilitate the comparison of definitions, terminology and scales of mapping between land and water classification systems.

The classification system utilized in this project is based on the four-level hierarchical coastal classification proposed by Warren and Anderson (1975a, 1975b), adapted from Lacate (1969). Hereafter, the classification system discussed in this report will be called a coastal classification system.

With land classification systems, aerial photographs are an important mapping tool. The coastal classification system, with its heavy emphasis on water characteristics, dictated a different approach. Data from field surveys (1975-79) and literature reviews were required to define and develop the hierarchical levels of the coastal classification. Data from field work were utilized to compile the detailed flora and fauna information for the nearshore and beach, and particulars of beach energy level, slope and substrate. A literature review was conducted to obtain information on climate, geology, soils, water properties, nearshore slopes and upland vegetation and topography.

This information was then used to determine the extent of the four levels of the hierarchy which, from highest to lowest, include Coastal Region, Coastal District, Coastal System and Coastal Type.

Coastal Region: (Scale of mapping 1:1 000 000 or smaller)

A coastal region is a coastal zone area characterized by a distinctive regional climate as expressed by vegetation and gross marine characteristics, such as the seasonal occurrence of ice, macrotidal influences and coastal orientation features (Warren and Anderson 1975a, 1975b).

The areal extent of the coastal region relative to Pacific Rim National Park is from Sitka, Alaska to Point Conception, California (most of the North Temperate Zone). Similar marine fauna and flora assemblages occur throughout this area as well as nearly uniform environmental conditions (Ricketts and Calvin 1968; Dodimead, Favourite and Hirano 1963; Favourite, Dodimead and Nasu 1976).

The weather is relatively uniform along the coastline; fogs and cool weather during the summer are the rule, with no great extremes of heat or cold and no occurrences of ice during the winter.

Tides along the Pacific coast of North America are of the mixed semi-diurnal type. This type of tidal fluctuation affects the zoning or the level at which animals occur according to the relative lengths of their exposure to air and water. Local conditions may affect the animals' level, eg. where higher summer temperatures force the animals down to a lower level than they would normally assume. However, the animals' relative positions remain the same. There is merely a compression of the life zone into something less than the expected norm.

Although the actual tidal ranges vary from more than 7 m at Juneau, Alaska to less the 2.4 m at San Quintin Bay, Mexico, the zonation of organisms is similar with either compressed or expanded levels depending on tidal range (Ricketts and Calvin 1968).

From Sitka to Point Conception the outer coast is bluff and largely unprotected with few islands and no high submarine ridges for thousands of miles. The great unobstructed expanses of the Pacific Ocean and prevailing northwesterly to westerly winds combine with the coastal configuration to result in likely the most powerfully wave shocked coast of the Northern Hemisphere (Ricketts and Calvin 1968).

Coastal District: (Scale of mapping 1:250 000 to 1:1 000 000)

A coastal district is a coastal zone area characterized by a distinctive pattern of geology, geomorphology, vegetation, coastal configuration, bathymetry and water quality (Warren and Anderson 1975a, 1975b).

The coastal region (Sitka, Alaska to Point Conception, California) can be divided into two coastal districts. The northern coastal district extends from Sitka to northern Washington; while the southern coastal district lies between northern Washington and Point Conception. Although the geology, vegetation and water quality of these two districts are similar, the geomorphology, coastal configuration and bathymetry differ considerably.

Within the two coastal districts, bedrock geology is largely igneous rock although a thin layer of sedimentary rock covers this in many places. Vegetation and water quality remarkably similar up and down the coast.

Along the California coast there is an upwelling of relatively cold water such that the resulting water temperature is lower than would be expected, considering the latitude. In the north, the Subarctic Current sweeps inshore with the result that the waters along the outside coast of British Columbia and southeastern Alaska are almost as warm as those along the California coast as far south as Point Conception. The summer-winter variation in water temperature is only a few degrees. Water properties (dissolved oxygen, salinity and water temperature) are similar throughout the area.

Geomorphology, superficially uniform in the two coastal districts, is dominated by coastal mountains (Fig. 3). However, north of northern Washington these mountains change considerably. Glaciation has modified the mountain peaks and upland surfaces and deepened and shaped lower valleys (Holland 1976).

The glacial modification of the topography has also affected the coastal configuration. Inlets, deep fiords and rocky islands are frequent coastal features in northern Washington, British Columbia and southern Alaska.

Although bathymetry is generally uniform along the coast there are important bathymetric differences between the two coastal districts. A wide continental shelf lies off most of the west coast of northern United States, British Columbia and southern Alaska. The shelf off Oregon and Washington has relatively smooth topography with a few rock knolls in some locations. From the Juan de Fuca Strait north the continental shelf is more rugged. Glacial characteristics such as shallow banks, deep basins and troughs are common (Shepard 1963).

<u>Coastal System</u>: (Scale of mapping 1:50 000 to 1:250 000 depending upon complexity)

A coastal system is a coastal zone area characterized by a recurring pattern of landforms, shoreforms and marine parameters. This level, in particular, takes into account the processes which have led to the development and maintenance of these patterns (Warren and Anderson 1975a, 1975b).

This hierarchical level is described in detail for Pacific Rim National Park in the "Coastal system and map unit descriptions" section of this report. A biological dimension has been added to the description of coastal system, for the shoreform patterns and marine parameters are jointly reflected in the dominant flora and fauna.

Landforms are defined in terms of slope and bedrock type. Shoreforms include headlands, cliffs, pocket beaches and flats. The shoreforms are further described as to substrate type and slope. Marine parameters important at this level are long-term localized salinity and temperature environments (such as colder, brackish water which may form a persistent surface layer in an estuary), and wave climates. The wave climate of a particular location is described in terms of energy impingement on the shore. Wave impact and wind force are the major factors contributing to the energy level. The terms high, moderate and low describe coastal energy levels.

Processes such as erosion (fluvial, glacial or mass wastage) and deposition of material are considered at the system level. Constant erosion of unconsolidated material (eg. at Florencia Bay, Long Beach Section) can provide a beach with its substrate nourishment; therefore maintaining the shoreform pattern.

When specific coastal system designations were assigned, two parameters were used to make initial groupings; these were energy level and substrate type. This information was taken from the sample sites studied from 1975 to 1979 as well as the habitat type maps illustrated in Fisheries and

Marine Service Manuscript Report 1436 (Lee and Bourne 1977). Arbitrarily, a difference in the major substrate on the beach and the energy level of the location was used to differentiate between coastal systems. Further differentiation was made when at least two other factors showed distinct differences. For example, although Grice Bay (GB) and Wouwer Island (WR) both describe low energy mud flats, they have different landforms; substrates and configuration of the area at the back of the beach also differ.

Coastal Type: (Scale of mapping 1:10 000 to 1:20 000)

At this detailed level of mapping, each tier of the coastal zone is considered independently for field data purposes. The land component conforms to the land type definition of Lacate (1969). The intertidal component or shoretype is form-centred with vegetation, stability and soil modifiers. The water component or water type is differentiated on the basis of quality and process modifiers (Warren and Anderson 1975a, 1975b).

When collecting field data the nearshore, beach, bank and uplands were considered as separate components of the coastal type (Fig. 32). The beach, for ease of description, was subdivided into low, mid and high intertidal zones and splash zone (where applicable). In each of these areas the specific flora, fauna and substrate stability or movement were considered. The soils of the uplands were noted. Substrate type was important, especially where the coastal system was defined in terms of a combination of substrate sizes. If the system had a gravel/sand/shell beach substrate then gravel/sand and gravel/shell were considered different coastal types within that system.

To differentiate between coastal types belonging to the same coastal system each tier (nearshore, beach, bank and upland) was considered. If any of these differed significantly from the system concept the location was considered a different coastal type. However, because the most detailed and complete data came from the beach and bank areas, these had to correspond most closely to the system concept. Because nearshore data was incomplete and the uplands were not within the primary focus of this project, they were allowed to vary to a greater extent before the location was assigned to a different coastal type. For example, if the nearshore slope of two locations was significantly different but other parameters remained similar the two locations were considered the same coastal type. However, if the beach slopes differed to the same degree, this would usually reflect a significant difference in the substrate stability and result in widely divergent flora and fauna patterns. In this case the two locations would be assigned different coastal type designations.

MAPPING METHODOLOGY

The information used to determine coastal system and coastal type designations for the shoreline within Pacific Rim National Park was gathered from a variety of sources. Fisheries Resource Board of Canada Manuscript Report 1389 and Fisheries and Marine Service Manuscript Reports 1436, 1467 and 1514 (Lee and Bourne 1976, 1977, 1978, 1979) provided detailed data for specific sample sites throughout the park as well as substrate and energy level information for the entire shoreline. Field notes from the past four years included general information for many locations without specific sample sites.

Upland soils, geology, vegetation and topography information was collected from other studies conducted within Pacific Rim National Park and the terrain classification maps compiled by the Resource Analysis Branch (no date). In addition, three short field trips were made in 1979-80 to gather bank and upland information in the Long Beach, Broken Group Islands and Pachena Bay areas of the park.

This plethora of data was consolidated on site forms which were grouped into coastal systems, and then subdivided into coastal types. The stretches of coast between sample sites were then assigned to the appropriate coastal system. At times, the information for these areas was not detailed enough to further classify them as to coastal type.

The map units labelled on the three large maps at the back of this report are of two different varieties. Most commonly, the map unit represents a coastal type, designated by two letters and a number. When the number is a one (1), the location belongs to the coastal type which most closely follows the system concept and was considered central to the definition of that coastal system. When the number is a 2, 3 or greater, the location belongs to a coastal type which is a variation on the system concept. When the map unit represents a coastal system where the coastal type could not be determined, then the designation is two letters without a number.

Some map units are labelled with two sets of letters and numbers separated by a slash (eg. MT1/CP1). This labelling method was used when two coastal types were identified but were separately less than 5 mm in width on the scale of map used and therefore too small to map. The designation is not meant to indicate a recurring association of coastal types but rather a cartographer's necessity. The large map of the Broken Group Islands has several examples of this situation (eg. TR1/TT1, SB1/NT).

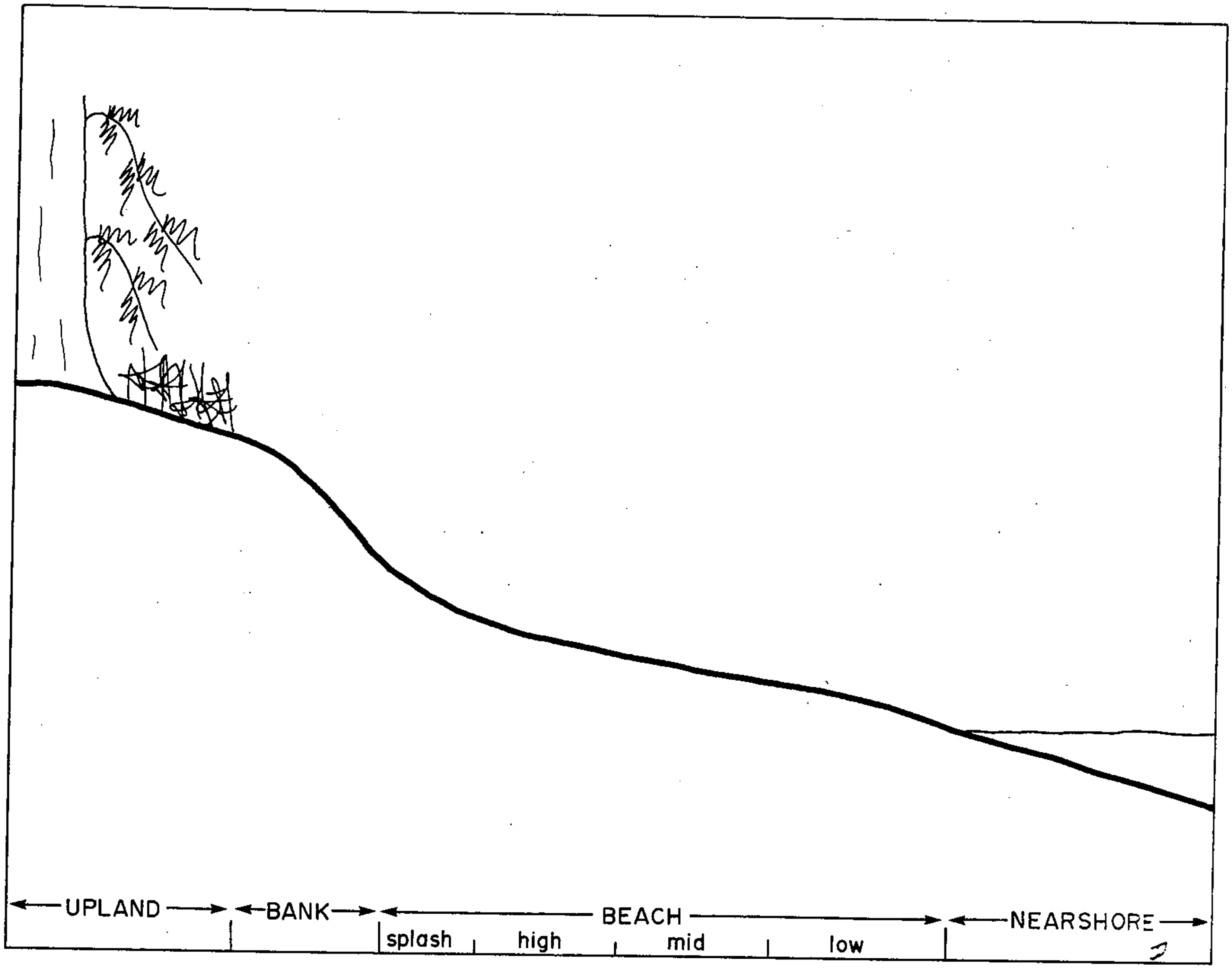


Fig. 32. Shore profile defining the extent of nearshore, beach, bank and upland

COASTAL SYSTEM AND MAP UNIT DESCRIPTIONS

This section presents detailed descriptions of the map units which appear on the three large maps at the back of the report. The "representative location" describes a location which was considered representative of the coastal system described. The "system concept" describes the central features of the coastal system giving information on substrate, slope, soils and energy level of the shore; and dominant flora and fauna of the area. The "types" section defines the coastal types of the coastal system, starting with that type which follows the system concept with little or no variation. Other coastal types are defined in terms of the system concept, detailing how they differ from the system concept and each other. The section titled "remarks", which may or may not be included, presents information of interpretive, scientific or managerial significance.

Slope and substrate terms used in the coastal system and map unit descriptions are defined in Tables 7 and 8. Indices listing coastal systems in order of presentation and alphabetical order are included.

Literature

The coastal system and map unit descriptions include information drawn from references 6, 15, 25, 28, 61, 64, 123, 124, 125, 126, 130, 148, 162, 172, 173, 211, 212 and 239.

Table 7. Terminology of topography and slope used in presentation.

Simple Topography Single Slopes	Complex Topography Multiple Slopes	Slope (%)
nearly level	nearly level	0 to 0.5
very gently sloping	gently undulating	0.5+ to 2
gently sloping	undulating	2+ to 5
moderately sloping	gently rolling	5+ to 9
strongly sloping	moderately rolling	9+ to 15
steeply sloping	strongly rolling	15+ to 30
very steeply sloping	hilly	30+ to 60
extremely sloping	very hilly	over 60

Table 8. Terminology of substrate types used in presentation.

Substrate	Definition
mud or silt	very fine unconsolidated sediment, <0.01 cm
sand	granular, 0.01 to 0.5 cm
shell	crushed shell
gravel	0.5 to 5.0 cm
cobble	5.0 to 50.0 cm
boulder	>50.0 cm
bedrock	continuous or repeated strata
rock	used collectively to indicate bedrock, boulder and/or cobble

Index to coastal systems in order of presentation

Alphabetical index to coastal systems

Table 9. Faunal terms used on shore profiles.

PROFILE TERM	COMMON NAME	SCIENTIFIC NAME
ascidian	ascidian	-
barnacle	barnacle	*Balanus glandula*
	barnacle	*B. cariosus*
	barnacle	*Chthamalus dalli*
bat star	bat star	*Patiria miniata*
beach hopper	beach hopper	*Orchestoidea californiana*
	isopod	*Exosphaeroma* sp.
burrowing anenome	burrowing anenome	*Pachycerianthus fimbriatus*
Cancer spp.	red rock crab	*Cancer productus*
	Dungeness crab	*C. magister*
clam	bent-nosed clam	*Macoma nasuta*
	butter clam	*Saxidomus giganteus*
	horse clam	*Tresus* sp.
	littleneck clam	*Protothaca staminea*
	Manila clam	*Venerupus japonica*
	soft-shell clam	*Mya arenaria*
	tellen	*Tellina bodogensis*
	tellen	*T. carpenteri*
limpet	finger limpet	*Collisella digitalis*
	limpet	*C. pelta*
	limpet	*Notoacmea scutum*
	limpet	*N. persona*
moon snail	moon snail	*Pollinices lewisi*
mussel	bay mussel	*Mytilus edulis*
	California mussel	*M. californianus*
olive shell	olive shell	*Olivella biplicata*
periwinkle	Sitka periwinkle	*Littorina sitkana*
	periwinkle	*L. scutulata*
razor clam	razor clam	*Siliqua patula*
sand dollar	sand dollar	*Dendraster* sp.
sea anenome	sea anenome	*Anthopleura elegantissima*
	green sea anenome	*A. xanthogrammica*
sea cucumber	sea cucumber	*Parastichopus californicus*
	burrowing sea cucumber	*Cucumaria miniata*
sea urchin	sea urchin	*Strongylocentrotus purpuratus*
	red sea urchin	*S. fransiscanus*
shore crab	hermit crab	*Pagarus* sp.
	porcelain crab	*Petrolisthes cinctipes*
	shore crab	*Hemigrapsus nudus*
	shore crab	*H. oregonensis*

Table 9. cont'd

PROFILE TERM	COMMON NAME	SCIENTIFIC NAME
shrimp	ghost shrimp	*Callianassa californiensis*
	mud shrimp	*Upogebia pugettensis*
snail	red top shell	*Astraea gibberosa*
	black turban snail	*Tegula funebralis*
	northern brown turban snail	*T. pulligo*
	spindle shell snail	*Searlesia dira*
	snail	*Thais emarginata*
	snail	*T. lamellosa*
sponge	sponge	*Haliclona permollis*
	sponge	*Ophlitaspongia pennata*
starfish	ochre starfish	*Pisaster ochraceus*
	leather star	*Dermasterias imbricata*
	sunflower star	*Pycnopodia helianthoides*

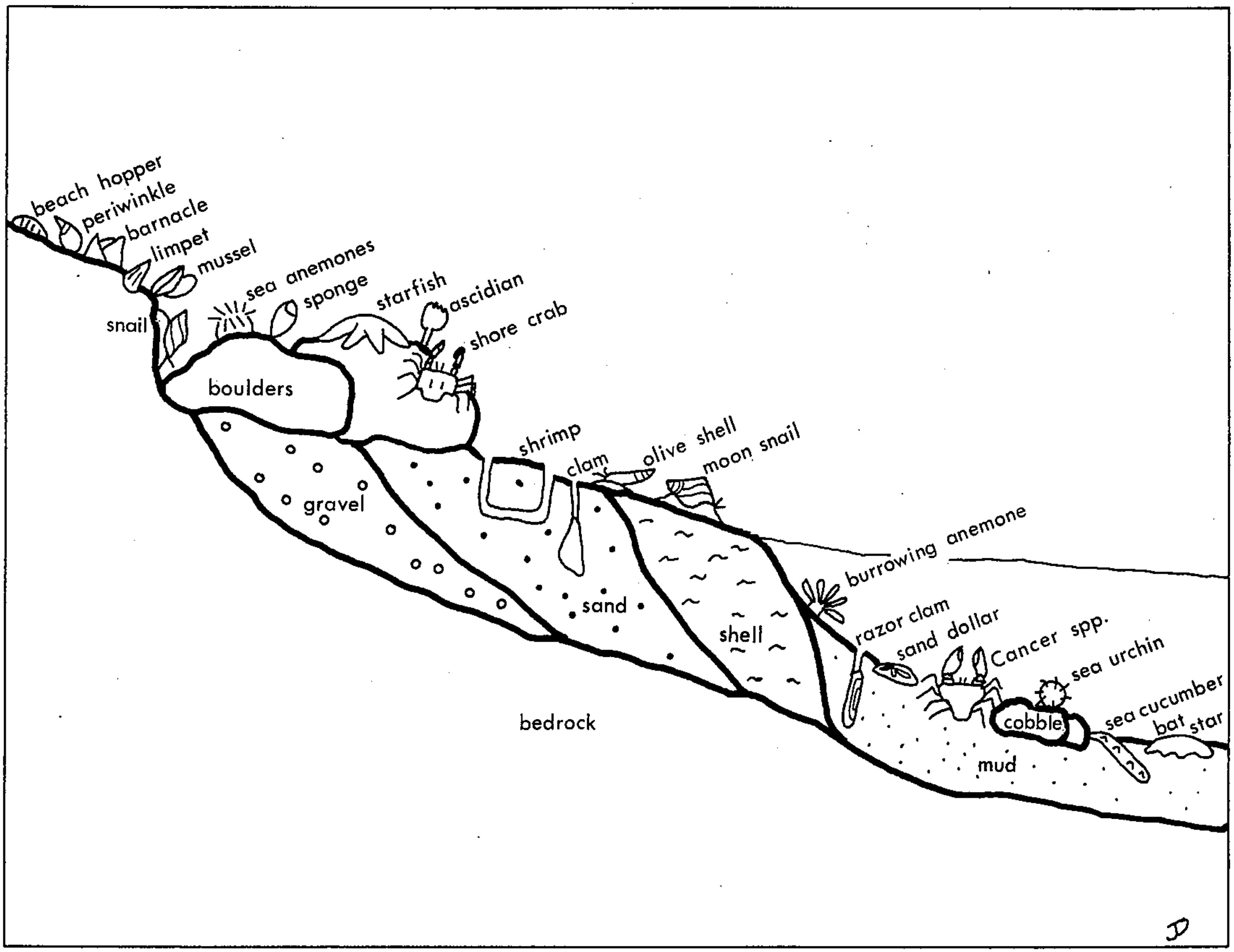


Fig. 33. Fauna and substrate key for schematic shore profiles

Table 10. Floral terms used on shore profiles.

PROFILE TERM	COMMON NAME	SCIENTIFIC NAME
Agarum	brown alga	*Agarum fimbriatum*
Alaria	brown alga brown alga	*Alaria marginata* *A. nana*
bladed red alga	red alga red alga	*Gigartina exasperata* *Halosaccion glandiforme*
Costaria	brown alga	*Costaria costata*
Desmarestia	brown alga	*Desmarestia ligulata*
Egregia	feather boa kelp	*Egregia menziesii*
Eisenia	brown alga	*Eisenia arborea*
encrusting red alga	encrusting red alga	*Lithothamnion sp.*
Enteromorpha	green alga	*Enteromorpha intenstinalis*
Fucus	rockweed	*Fucus distichus*
grass	glasswort grass grass sea rocket	*Salicornia pacifica* *Elymus mollis* *Carex macrocephala* *Cakile edulenta*
Hedophyllum	brown alga	*Hedophyllum sessile*
Laminaria setchellii	brown alga	*Laminaria setchellii*
Laminaria spp.	brown alga brown alga	*Laminaria groenlandica* *L. saccharina*
Leathesia	brown alga	*Leathesia difformis*
lichen	lichen	-
Macrocystis	giant kelp	*Macrocystis integrifolia*
moss	moss	-
Neoagardhiella	red alga	*Neoagardhiella baileyi*
Nereocystis	bull kelp	*Nereocystis leutkeana*
Pelvetiopsis	brown alga	*Pelvetiopsis limitata*
Postelsia	sea palm	*Postelsia palmaeformis*
Prasiola	green alga	*Prasiola mertridionalis*
Sargassum	japweed	*Sargassum munitum*
sea grass	eel grass surf grass	*Zostera marina* *Phyllospadix scouleri*
shrub	evergreen huckleberry salal	*Vaccinium ovatum* *Gaultheria shallon*

Table 10. cont'd

PROFILE TERM	COMMON NAME	SCIENTIFIC NAME
Spongomorpha	green alga	*Spongomorpha coalita*
tree	western hemlock	*Tsuga heterophylla*
	western red cedar	*Thuja plicata*
	Sitka spruce	*Picea sitchensis*
turf red alga	red alga	*Gelidium robustum*
	red alga	*Gastroclonium coulteri*
	red alga	*Endocladia muricata*
	red alga	*Rhodomela larix*
Ulva	sea lettuce	*Ulva* sp.
Verrucaria	black lichen	*Verrucaria* sp.

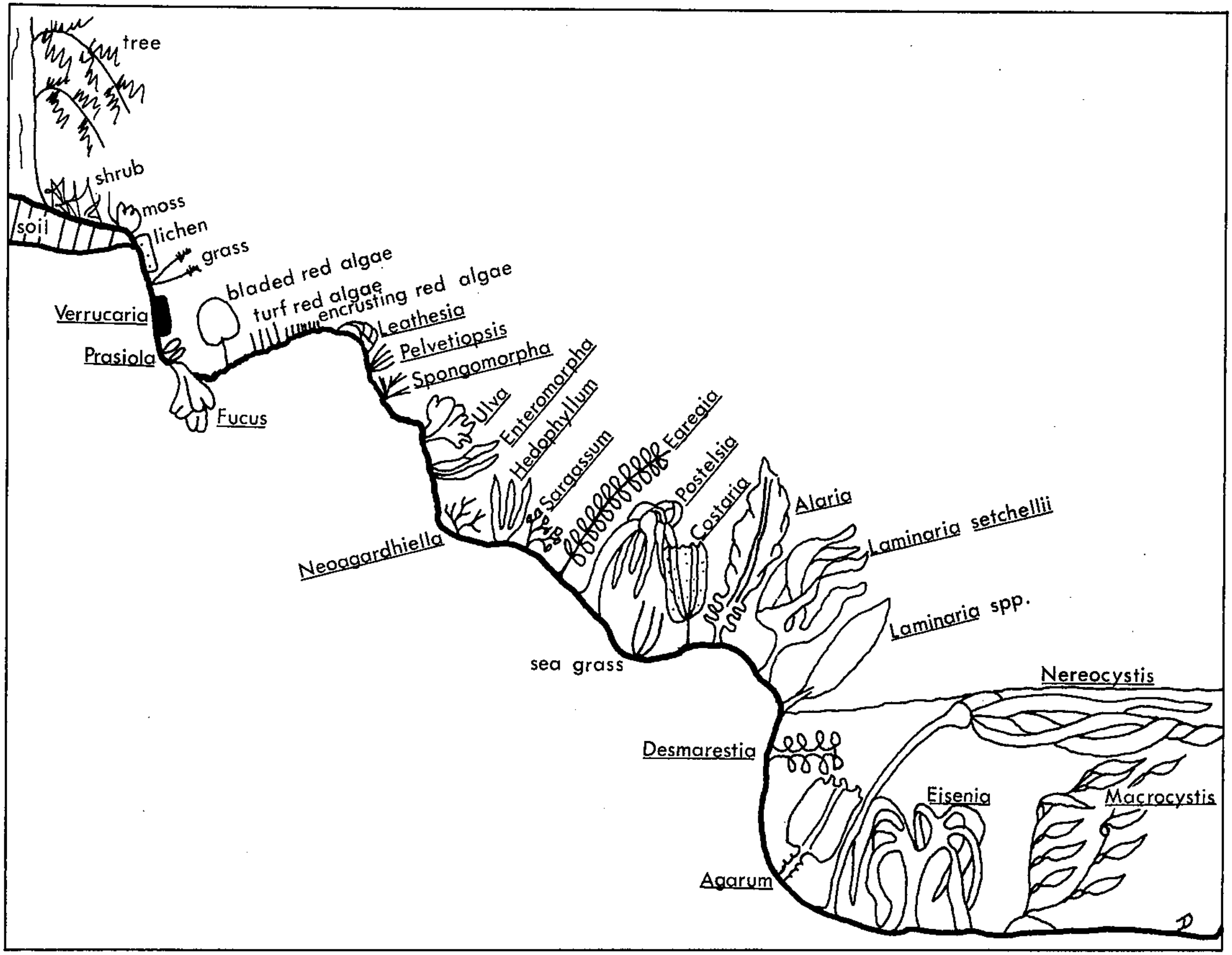


Fig. 34. Flora key for schematic shore profiles

WOUWER ISLAND (WR1, WR2)

representative location: mud flat on the S side of E Wouwer Island

system concept

The Wouwer Island system is a low energy (sheltered) mud flat. The nearshore substrate is mud and shell with occasional boulders and has a very gentle slope. The beach is a very gently to gently sloping mud flat. The outer edges of the mud flat may have scattered boulders or actually grade into boulder beaches. Pockets of hydrogen sulfide (H_2S) occur where decaying organic material is trapped beneath the mud. This material may be bark and wood chips; dead or dying clams may also occur in this layer. The bank is usually a moderately sloping boulder/bedrock area. The uplands are covered by colluvial veneer with rocky outcrops. The topography is gently to strongly rolling and the till soils are designated as humo ferric podzols.

The nearshore area of the mud flat is dominated by eelgrass *(Zostera marina)*. Horse clams *(Tresus sp.)* and bat stars *(Patiria miniata)* are also common.

The beach displays little apparent zonation. Species present include eelgrass, littleneck clams *(Protothaca staminea)*, blood worms *(Euzonus mucronata)* and mud shrimp *(Upogebia pugettensis)*. The bank supports lichens, mosses and patches of glasswort *(Salicornia pacifica)*. The upland forest is primarily western red cedar/western hemlock *(Thuja plicata/Tsuga heterophylla)* type with an evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)* shrub layer.

types

WR1 is defined by the system concept.

WR2 occurs where small pockets of mud accumulate above sheltered boulder beaches. This mud is too high in the intertidal area for either eel-grass or bivalve populations to occur. However, it will accomodate mud shrimp *(U. pugettensis)* populations.

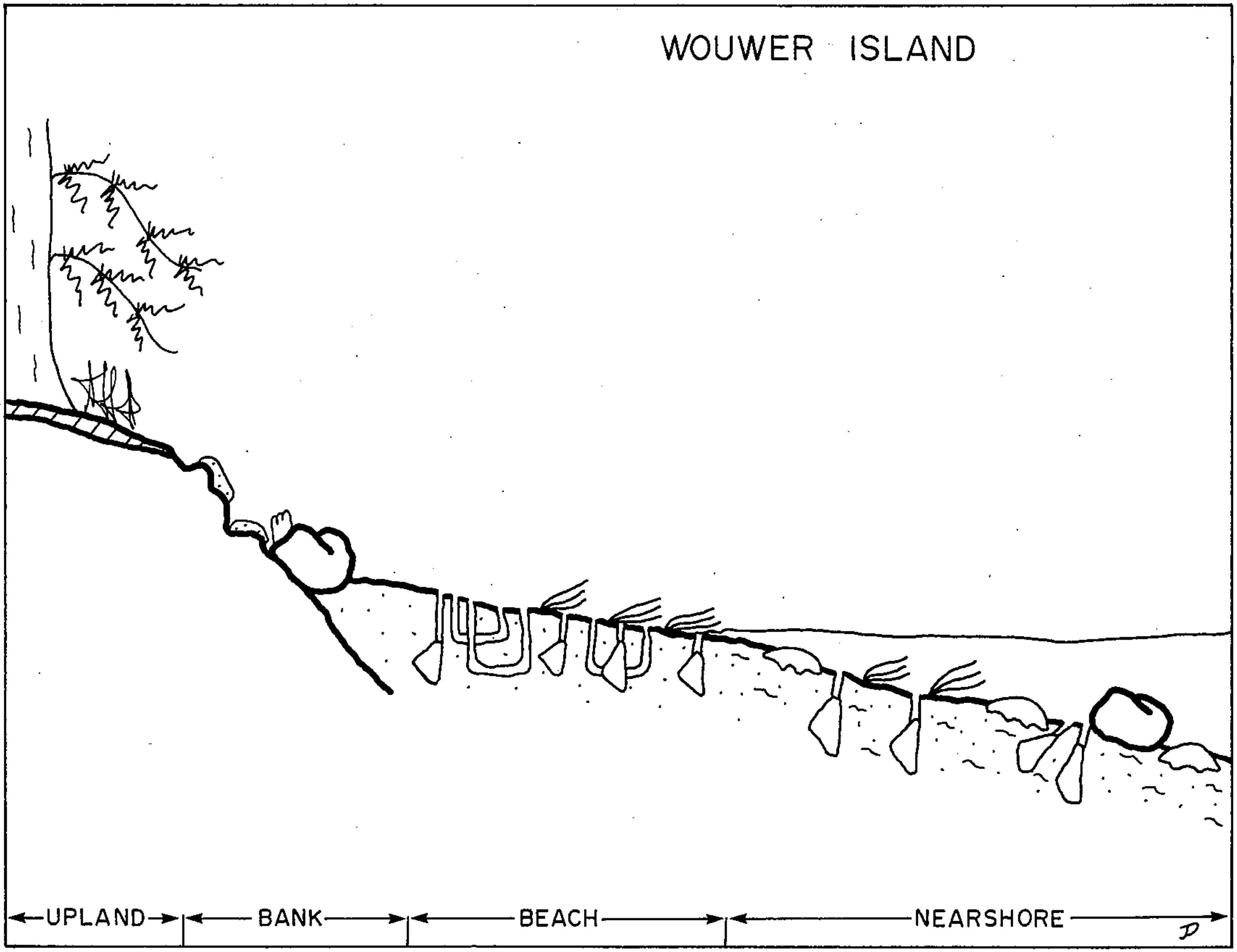


Fig. 35. Schematic profile of Wouwer Island system concept

GRICE BAY (GB1)

representative location: Grice Bay

system concept

The Grice Bay system can be defined as a low energy (sheltered) mud flat. The nearshore is an extensive, silted, nearly level area with a few shallow channels. The beach is very gently sloping, with a few channels formed by several small creeks in the bay. These creeks decrease the salinity within the bay, especially when runoff is high. The beach is also silt with a narrow band of gravel and boulder in the high intertidal zone. The bank consists of a low (less than 1 m) cut face in the unconsolidated upland material or a bedrock outcrop where the uplands are igneous rock (GR system). The uplands are generally covered with a marine-deposited blanket of sand, sand and silt or silt and clay. This material is gullied by fluvial erosion. The soils of the GB system are varied and imperfectly to very poorly drained. The upland slope is predominantly gently undulating with some strongly rolling to hilly sections.

The nearshore biota of Grice Bay is dominated by eelgrass *(Zostera marina)*. Among this vegetation red rock crabs *(Cancer productus)* and sea cucumbers *(Parastichopus californicus)* are common inhabitants. This area is also an important migration route for salmon on their way to spawning streams and a nursery ground for the juvenile salmon.

The beach is divided into three biotic zones. The low intertidal zone also supports eelgrass along with two bivalve species, the bent-nosed clam *(Macoma nasuta)* and the tellen *(Tellina carpenteri)*. The dominant species of the mid intertidal zone are ghost shrimp *(Callianassa californiensis)* and soft-shell clams *(Mya arenaria)*. The high intertidal zone has a few isolated barnacles *(Balanus glandula)* and bay mussels *(Mytilus edulis)* on the gravel/boulder. The bank has little or no vegetation. The uplands are forested with western red cedar *(Thuja plicata)*, western hemlock *(Tsuga heterophylla)*, alder *(Alnus rubra)* and the occasional Douglas fir *(Pseudotsuga menziesii)*. These trees are unstunted and overhang the shoreline.

types

GB1 is characterized by the system concept.

remarks

-salmon spawning migration route and juvenile rearing grounds
-waterfowl overwintering site and migration feeding stop
-area suitable for sports fishing, canoeing and picnic sites
-eelgrass beds important for spawning and rearing grounds of a wide variety of marine species and would be an interesting topic for an interpretive program

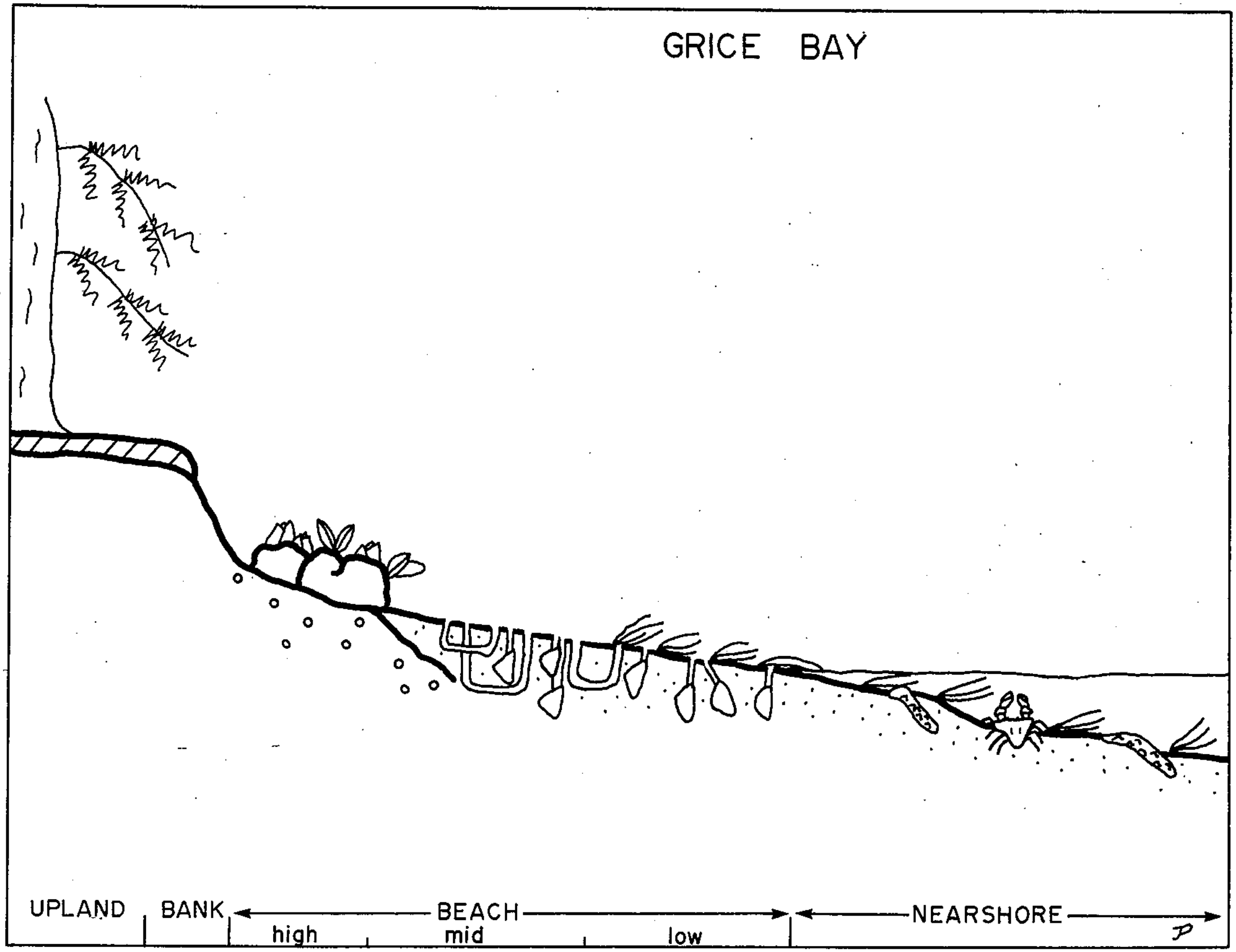


Fig. 36. Schematic profile of Grice Bay system concept

NETTLE ISLAND (NT1, NT2)

<u>representative location</u>: beach behind a small islet on the NE side of Nettle Island

<u>system concept</u>

The Nettle Island system is a low energy (sheltered) sandy shore. The nearshore is a gentle sandy slope. The moderately sloping beach is also sand but it may be silted or muddy. The bank may be composed of a variety of substrates, ranging from sand to cobble. The gently to strongly rolling uplands are primarily colluvial veneer but some areas may be covered with a morainal blanket. The soils are largely humo ferric podzols.

The nearshore area is divided into two zones. A horse clam *(Tresus sp.)* population occurs in the deepest zone. The zone adjacent to the beach supports eelgrass *(Zostera marina)* and horse clams.

The beach has little apparent zonation. Eelgrass, horse clams, littleneck clams *(Protothaca staminea)* and other bivalves are present. The bank vegetation is varied, lichens growing where the substrate is of larger fractions. The forested uplands are dominated by western red cedar *(Thuja plicata)* and western hemlock *(Tsuga heterophylla)*. The shrub layer consists mainly of evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)*.

<u>types</u>

NT1 is defined by the system concept.

NT2 is basically the same as NT1 but has less siltation of the beach area. In this situation eelgrass *(Z. marina)* may not occur in the beach area.

<u>remarks</u>

The bivalve populations are not extensive and are subject to variable recruitment. Recreational harvesting should be monitored closely.

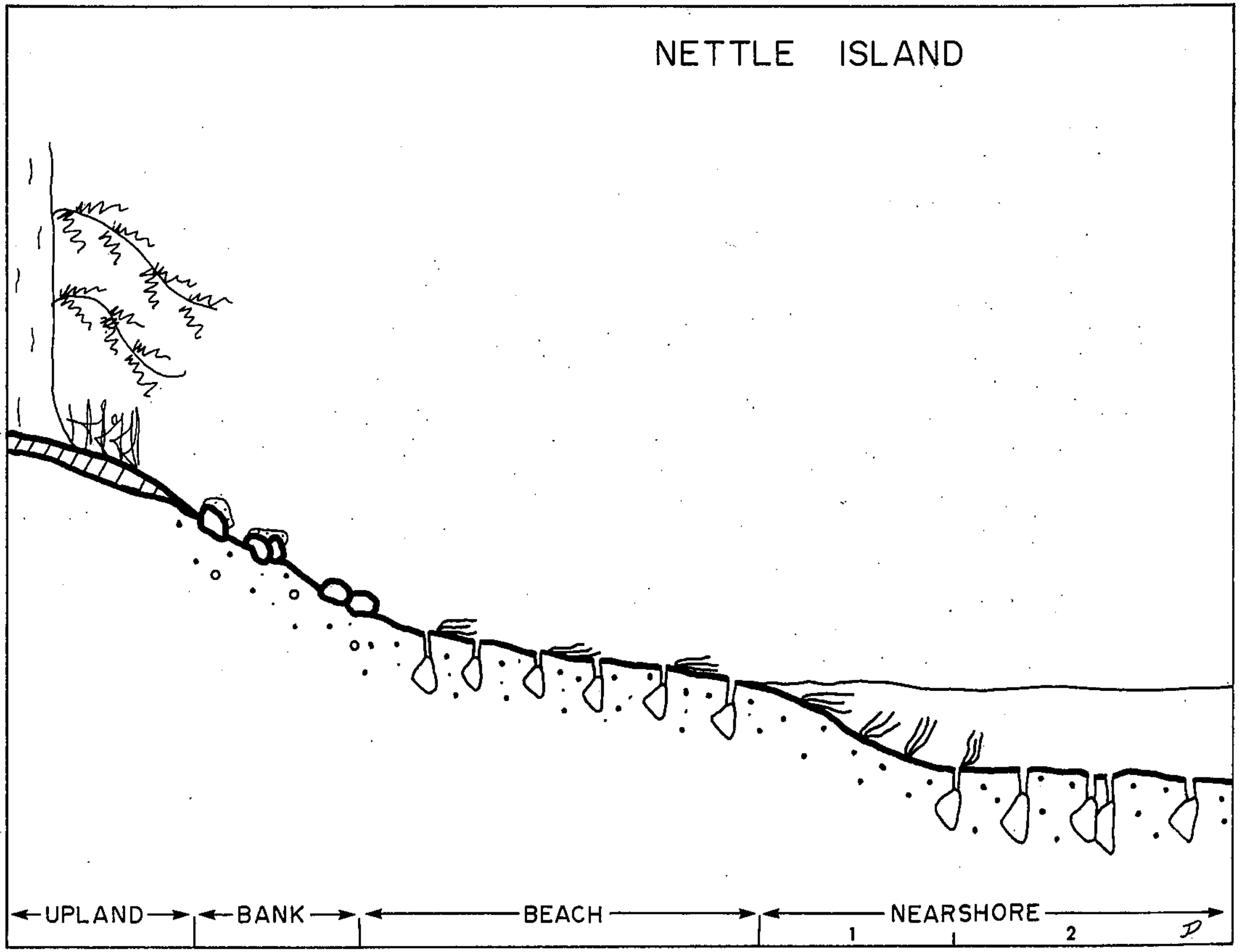


Fig. 37. Schematic profile of Nettle Island system concept

SOUTH GIBRALTAR ISLAND (SG1)

representative location: bay on the S side of Gibraltar Island

system concept

The South Gibraltar Island system represents a low energy (sheltered) sand/shell shore. The nearshore substrate is usually a combination of sand, shell and mud although there may be scattered boulders. A gentle slope is most common. The beach is usually a moderate slope with a combination of sand and shell substate with some mud accumulation in some locations. The bank may be a variety of substrates ranging from shell and gravel to boulder and bedrock. The slope is extremely variable. The upland surface geology is predominantly colluvial veneer with some hummocky bedrock. The upland till soils are mostly humo ferric podzols and the terrain is gently to strongly rolling.

The nearshore biota was not surveyed. The beach area shows little distinct zonation. The mud shrimp *(Upogebia pugettensis)*, littleneck clam *(Protothaca staminea)* and horse clam *(Tresus sp.)* are the most common species, but other bivalve species also occur. There are no attached algae on the beach. The bank supports little vegetation, there may be lichen and moss if the substrate is suitable. The western red cedar *(Thuja plicata)* and western hemlock *(Tsuga heterophylla)* are the most common tree species in the upland forest. Evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)* dominate the shrub layer.

types

SG1 is characterized by the system concept.

remarks

The bivalve populations are not extensive and are subject to variable recruitment. Recreational harvesting should be monitored closely.

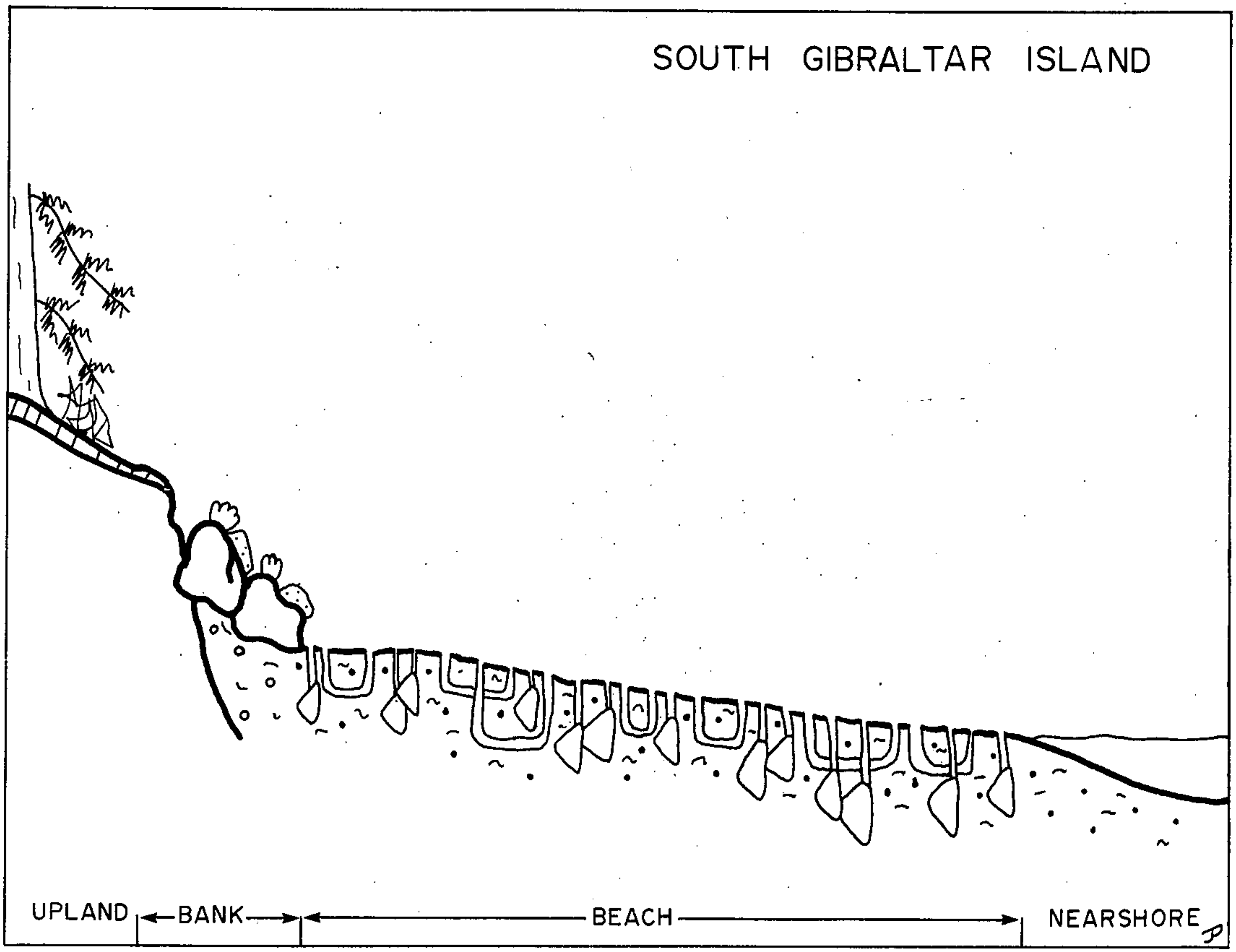


Fig. 38. Schematic profile of South Gibraltar Island system concept

SHELTERED SHELL (SS1)

representative location: bay on the SW side of Gibraltar Island

system concept

Sheltered Shell system is a low energy (sheltered) system with shell beach areas. The very gently sloping nearshore has a combination substrate of shell and mud. The shell beach is of gentle to moderate slope. The substrate of the bank area is variable, ranging from shell and gravel to boulder and bedrock. The slope varies from moderate to steep. Colluvial veneer covers most of the uplands, but hummocky bedrock does occur. The slope is gently to strongly rolling, and the soils are of the humo ferric podzol type.

The biota of the nearshore shows little zonation. Eelgrass *(Zostera marina)* and a brown alga, *Desmarestia ligulata* are the most common plants. The burrowing sea anenome *(Pachycerianthus fimbriatus)* is the only invertebrate which occurs in any numbers. Schools of black rockfish *(Sebastes melanops)* were observed by divers.

The beach may support populations of littleneck clams *(Protothaca staminea)*, butter clams *(Saxidomus giganteus)* and horse clams *(Tresus sp.)*. There is no attached algae on the beach. Shell beaches rarely have large populations of any species and may appear barren in some years. The bank often has a variety of grasses. The dominant trees of the uplands are western red cedar *(Thuja plicata)* and western hemlock *(Tsuga heterophylla)*. The shrub layer is composed of evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)*.

types

SS1 is described by the system concept.

remarks

This coastal type is not abundant in the park area.

The bivalve populations are not extensive and are subject to variable recruitment. Recreational harvesting should be monitored closely.

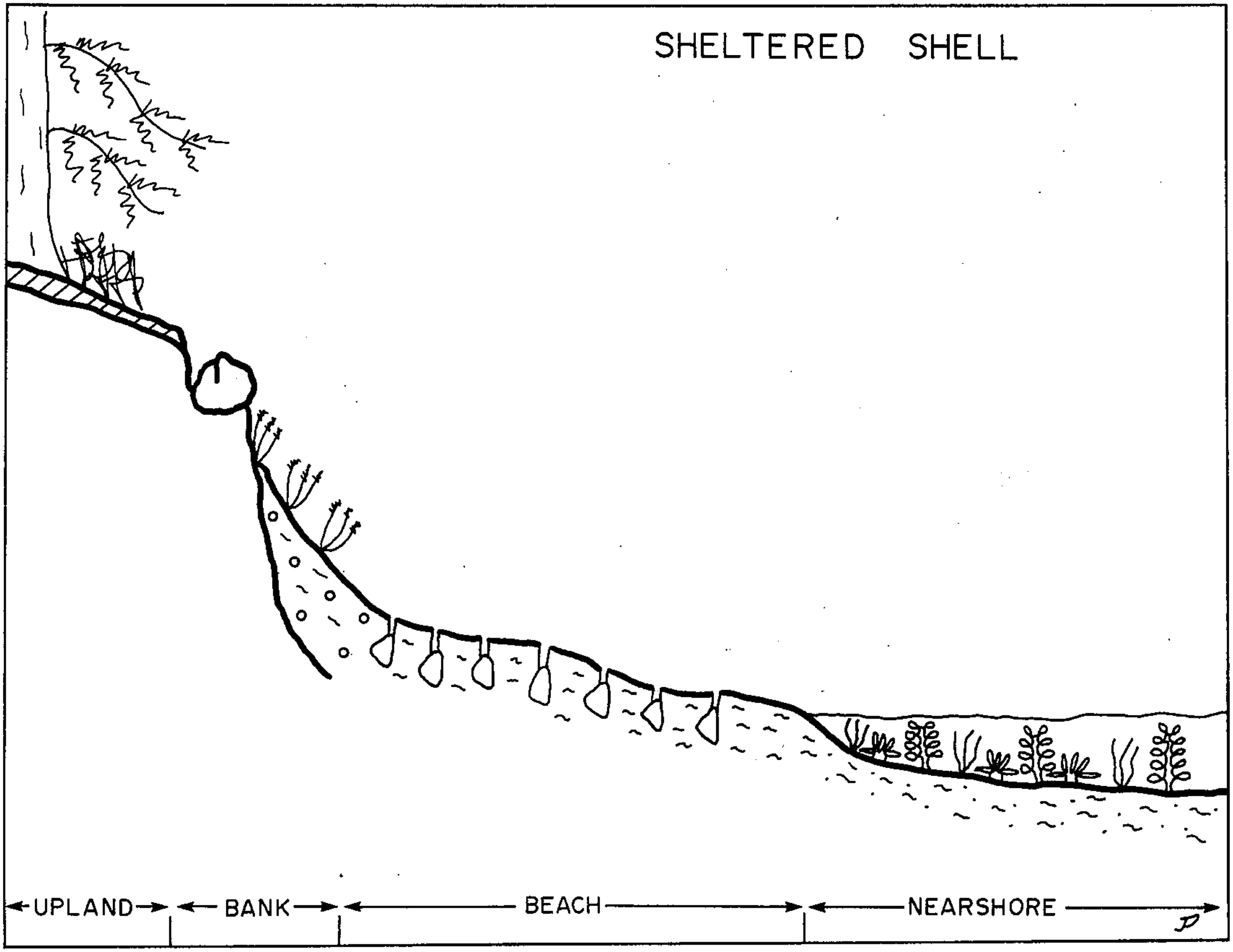


Fig. 39. Schematic profile of Sheltered Shell system concept

WALSH ISLAND (WH1)

representative location: E side of Walsh Island

system concept

The Walsh Island system is a low energy (sheltered) gravel shore. The strongly sloping nearshore has a combination substrate of gravel, silt and cobble. The beach is gravel, often with some silt accumulation. The slope is moderate. Gravel or cobble covers the bank area. The uplands are predominantly colluvial veneer and are gently to strongly rolling. Regosol and humo ferric podzol soils are common.

The nearshore is divided into three biotic zones. The deepest zone has the algae *Laminaria saccharina* and *Agarum fimbriatum* along with the burrowing sea anenome *(Pachycerianthus fimbriatus)* and jingle shells *(Pododesmus macroschisma)*. The middle zone supports the alga *Neoagardhiella baileyi*, bat stars *(Patiria miniata)* and horse clams *(Tresus sp.)*. The zone adjacent to the beach is dominated by eelgrass *(Zostera marina)* and bat stars.

The beach has populations of mud shrimp *(Upogebia pugettensis)*, little-neck clams *(Protothaca staminea)* and other bivalves. Lichen, moss and some grass grow in the bank area. The uplands are forested with a typical western red cedar/western hemlock *(Thuja plicata/Tsuga heterophylla)* association. Ever-green huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)* make up the shrub layer.

types

WH1 is defined by the system concept.

remarks

Bivalve populations are not extensive and recreational harvesting should be monitored closely.

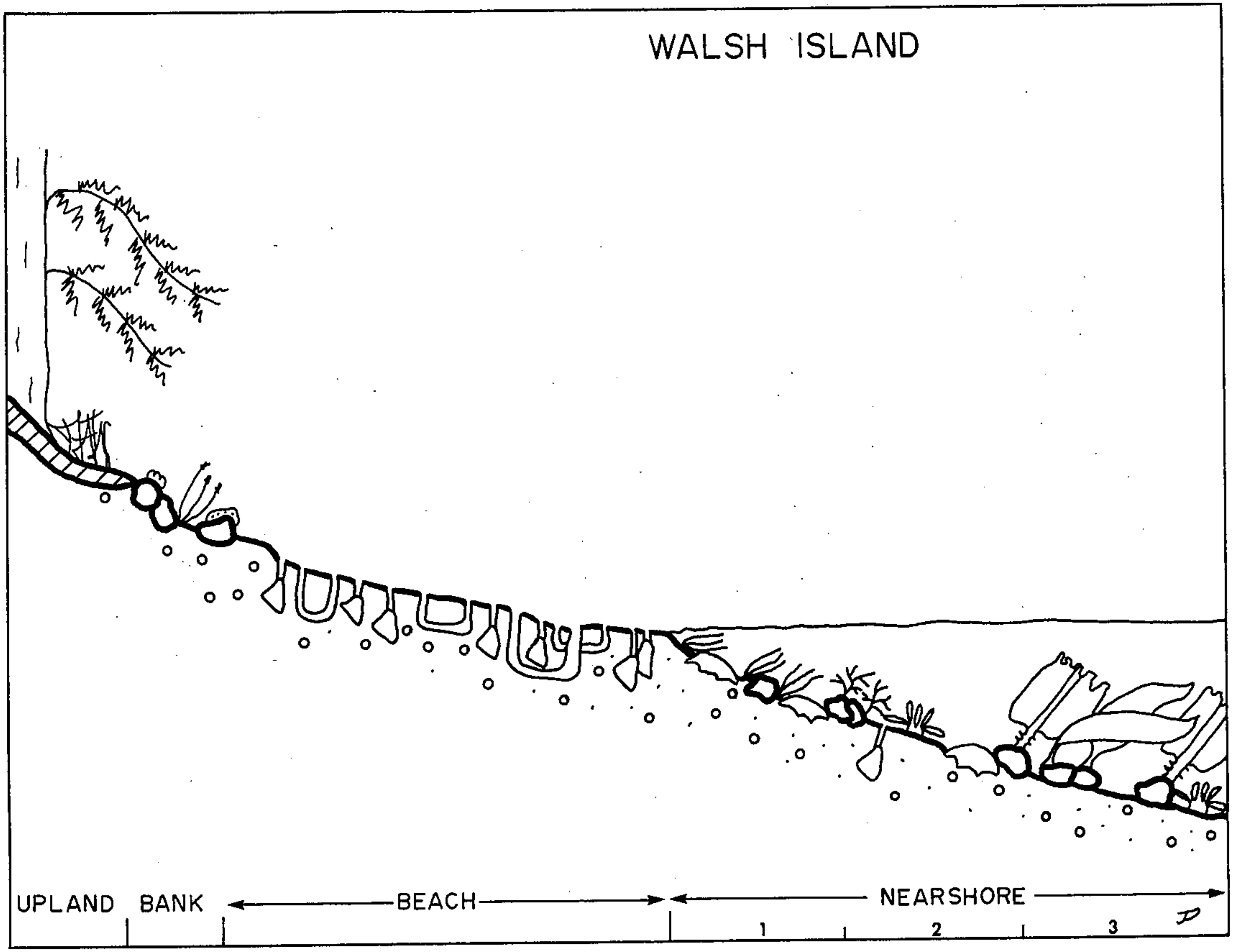


Fig. 40. Schematic profile of Walsh Island system concept

EFFINGHAM BAY (EB1, EB2, EB3, EB4)

representative location: small beach on the S side of Effingham Bay

system concept

The Effingham Bay system encompasses low energy (sheltered) gravel, sand, shell combination shores. The nearshore is very gently to gently sloping and the substrate ranges from sand to shell with some cobble. The beach has a gravel, sand, shell conbination substrate with mud also occurrring in some locations. The slope is moderate. The beach configuration of the EB system varies and includes bars and pocket beaches. The bank is composed of variable substrates, ranging from shell/gravel to boulder and bedrock. The gently rolling to hilly uplands are predominantly covered with a colluvial veneer. Often less extensive areas of morainal blanket or hummocky rock occur. The till soils are humo ferric podzols and regosols.

The nearshore biota depends largely upon the substrate, but eelgrass *(Zostera marina)*, burrowing sea anenomes *(Pachycerianthus fimbriatus)* and horse clams *(Tresus sp.)* are commonly present. The beach displays little distinct zonation. Littleneck clams *(Protothaca staminea)*, butter clams *(Saxidomus giganteus)*, horse clams or other bivalves are present. Eelgrass and mud shrimp *(Upogebia pugettensis)* may also occur.

The vegetation of the bank depends upon the substrate. Grasses tend to grow on the gravel/shell banks while lichens and mosses colonize the bedrock and boulder. The uplands are forested; western red cedar *(Thuja plicata)* and western hemlock *(Tsuga heterophylla)* are the most common tree species. Evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)* make up the shrub layer.

types

EB1 consists of the system concept.

EB2 varies from the system concept only in the substrate of the beach which may be gravel and shell with little or no sand. The biotic association remains similar to the system concept.

EB3 has gravel/sand beach substrates with little or no shell. The flora and fauna are described in the system concept.

EB4 coastal type has gravel/sand substrate like EB3 but the beach is more steeply sloping. The substrate is more unstable and shifts continually under tidal action. There is little conspicuous fauna or flora in either the nearshore or beach areas.

remarks

Bivalve populations are not extensive and have variable recruitment. Monitoring of recreational utilization should be implemented.

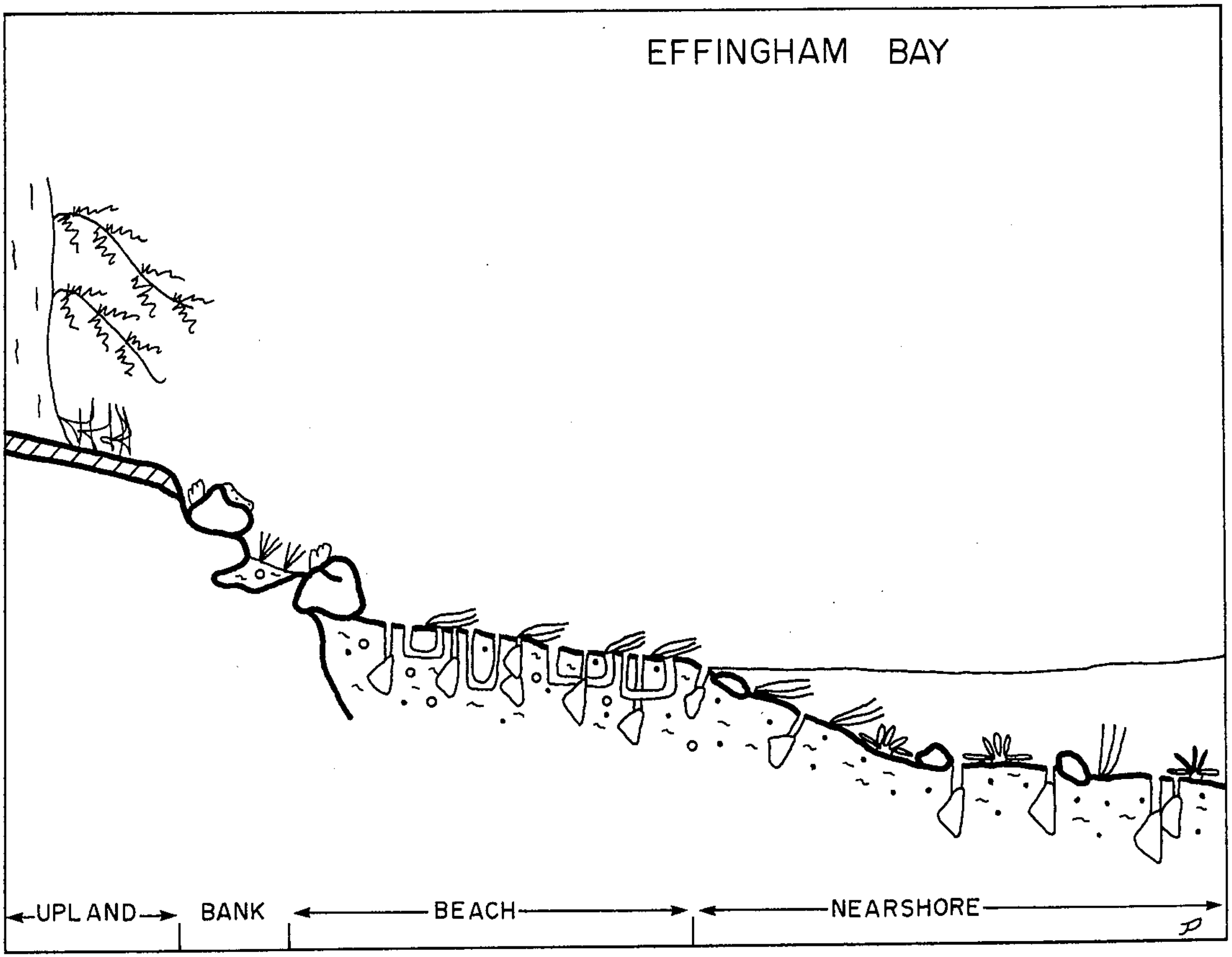


Fig. 41. Schematic profile of Effingham Bay system concept

EAST NETTLE ISLAND (EN1, EN2, EN3)

representative location: beach behind small islet on the E side of Nettle Island

system concept

The East Nettle Island coastal system represents the low energy (sheltered) shores with combination beach substrates of cobble, gravel and sand. The nearshore substrate is a combination of cobble, sand and shell; although some silt may also occur in certain locations. The slope varies considerably from site to site. The beach usually has the pocket beach configuration although, less commonly, it may form a bar. The cobble/gravel/sand beach has a very gentle to moderate slope. The substrates of the bank range from gravel to bedrock; slopes also show considerable variation. The gently to strongly rolling uplands are predominantly covered with a veneer of colluvial origin. Blankets of morainal material and marine sands are present but less common. The soils are commonly humo ferric podzols.

The nearshore can be divided into three biotic zones. The deepest zone supports the algae *Agarum fimbriatum* and *Eisenia arborea;* while in the middle zone the giant kelp (*Macrocystis integrifolia)* is dominant. In the zone adjacent to the beach eelgrass *(Zostera marina),* japweed *(Sargassum muticum),* bat stars *(Patiria miniata)* and barnacles *(Balanus glandula)* are common.

The beach is also divided into three distinct biotic zones. The low intertidal zone has japweed and a red alga *(Gigartina exasperata).* Littleneck clams *(Protothaca staminea),* butter clams *(Saxidomus giganteus),* bent-nosed clams *(Macoma nasuta)* and hermit crabs *(Pagarus sp.)* also inhabit the low intertidal zone. In the mid intertidal zone eelgrass or the brown alga *Leathesia difformis* are the most common vegetation. Shore crabs *(Hemigrapsus spp.),* Manila clams *(Venerupis japonica)* and black turban snails *(Tegula funebralis)* make up the invertebrate community. In the high intertidal zone rockweed *(Fucus distichus),* barnacles *(B. glandula)* and periwinkles *(Littorina sitkana)* are common.

Bank vegetation varies with substrate; lichens and mosses grow on the boulder/bedrock banks while grasses tend to be found on banks of gravel and sand. The dominant forest species are western red cedar *(Thuja plicata),* western hemlock *(Tsuga heterophylla),* evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon).* Red alder *(Alnus rubra)* and Sitka spruce *(Picea sitchensis)* occur less commonly.

types

EN1 is characterized by the system concept.

EN2 follows the description of the system concept but the slope of the beach is moderate to steep and bivalve populations are absent.

EN3 has substrates similar to the system concept. The nearshore biota is dominated by giant kelp *(M. integrifolia).* The beach is steeply to very steeply sloping and supports no conspicuous flora or fauna.

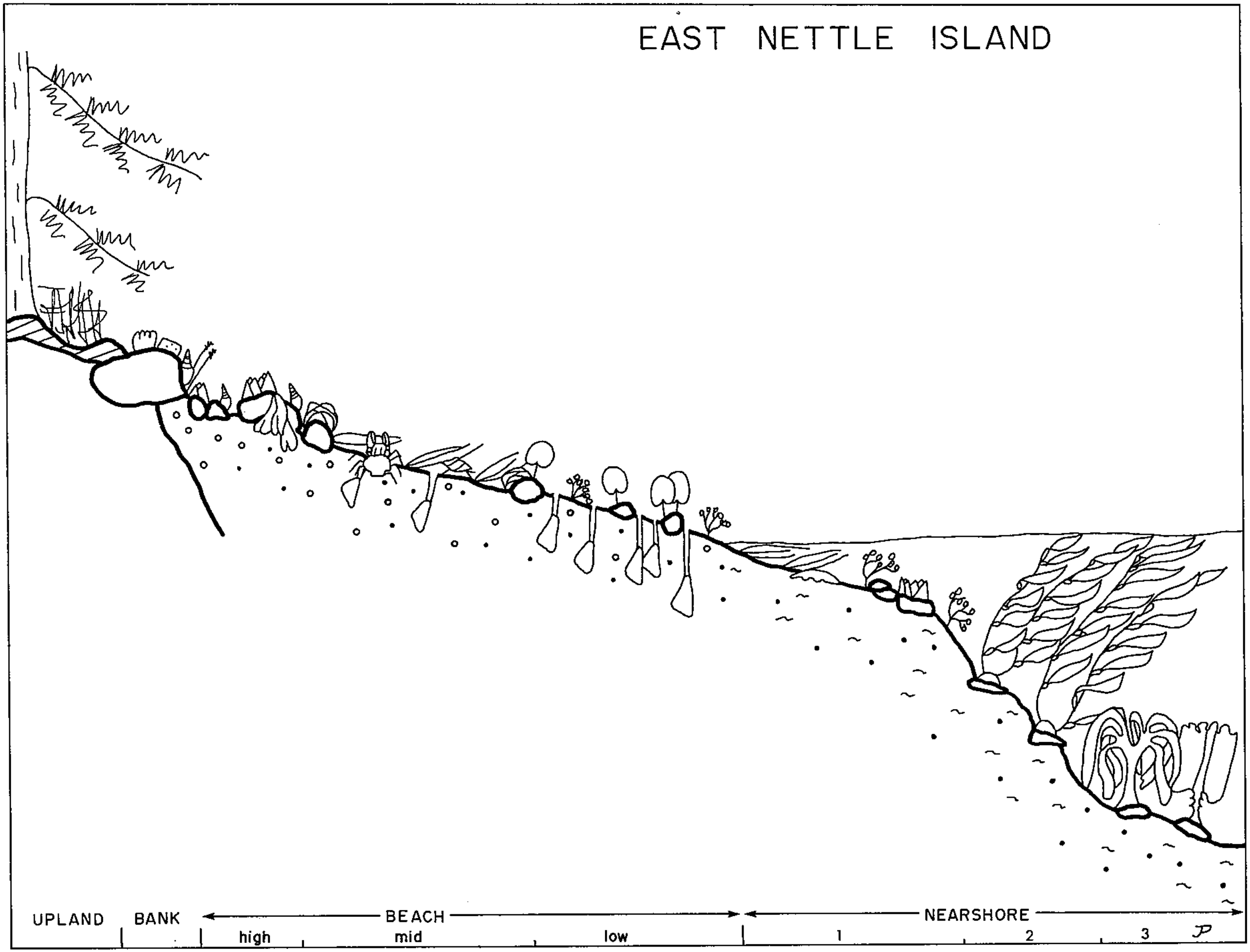


Fig. 42. Schematic profile of East Nettle Island system concept.

<u>remarks</u>

Small bivalve populations in these areas may not support extensive recreational harvesting.

GILBERT ISLAND (GT1)

representative location: E end of Gilbert Island

system concept

The Gilbert Island system includes low energy (sheltered) shores with boulder conbination substrates. The nearshore is moderately sloping and has a boulder/sand substrate. The beach is moderately sloping. Substrates on the beach grade from gravel/sand and some mud at the low tide level through cobble/gravel/sand/shell combinations to predominantly boulder/cobble at the high tide level. The bank substrate ranges from gravel/boulder to bedrock/ boulder and has a strong to extreme slope. The uplands are predominantly colluvial veneer with gently to strongly rolling topography. The till soils are classed as podzols.

The giant kelp *(Macrocystis integrifolia)*, sea lettuce *(Ulva sp.)* and two other algae *(Codium fragile, Enteromorpha sp.)* grow in the nearshore area. Bat stars *(Patiria miniata)* and horse clams *(Tresus sp.)* are also common.

The beach is divided into three biotic zones. The low intertidal zone is predominantly gravel and supports bivalve populations (littleneck clams *(Protothaca staminea)*, butter clams *(Saxidomus giganteus)* and horse clams) and bat stars but little vegetation. In the mid intertidal zone japweed *(Sargassum muticum)* occurs along with *Halosaccion glandiforme* and *Leathesia difformis*. Manila clams *(Venerupis japonica)* occur in gravel substrates while bay mussels *(Mytilus edulis)* and barnacles *(Balanus glandula, B. cariosus)* are the dominant species on cobble. The high intertidal zone supports a dense growth of rockweed *(Fucus distichus)* and barnacles *(B. glandula, Chthamalus dalli)*.

Vegetation on the bank ranges from mosses and lichens on rock substrates to grasses and glasswort *(Salicornia pacifica)* on gravel. The dominant tree species in the upland forest are western red cedar *(Thuja plicata)* and western hemlock *(Tsuga heterophylla)*. Evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)* are the most common shrubs.

types

GT1 is defined by the system concept.

remarks

Bivalve populations in these areas may not support an extensive recreational fishery.

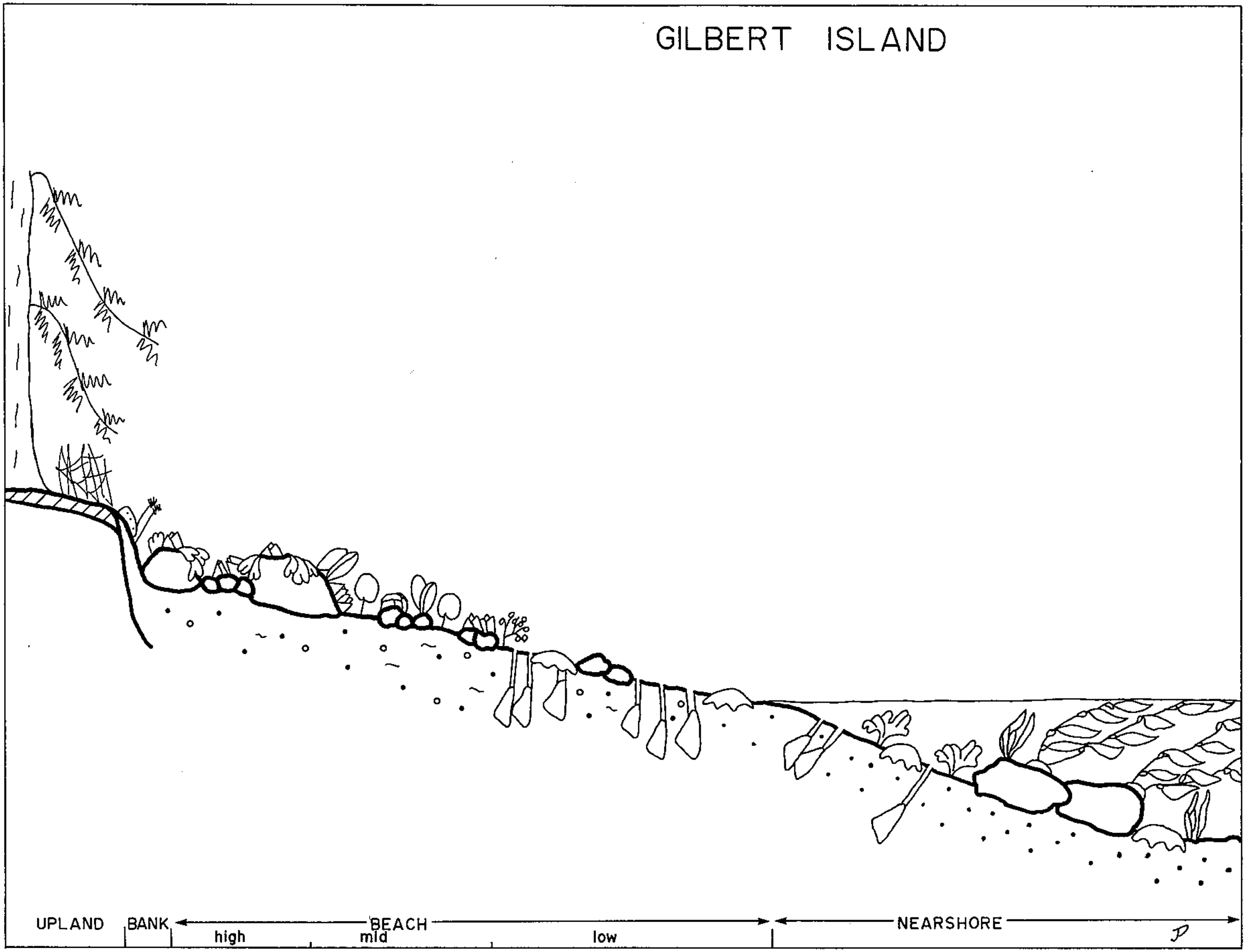


Fig. 43. Schematic profile of Gilbert Island system concept.

KEITH ISLAND (KH1)

representative location: W side of Keith Island

system concept

The Keith Island system can be described as low energy (sheltered) bedrock/cobble beaches. The cobble/shell/mud nearshore slopes gently into a steep bedrock/cobble beach. The bank is steep and substrates range from gravel to bedrock. The uplands are undulating to strongly rolling and are predominantly covered with a veneer of colluvial material. Podzol till soils are most common.

The giant kelp, *Macrocystis integrifolia*, a red alga *(Gelidium robustum)*, bat stars *(Patiria miniata)* and barnacles *(Balanus glandula)* occur in the nearshore area.

The beach is divided into four distinct biotic zones. In the low intertidal zone *G. robustum* and an encrusting red alga *(Lithothamnion sp.)* are the most common vegetation. Hermit crabs *(Pagarus sp.)* are abundant. The mid intertidal area supports japweed *(Sargassum muticum)*, eelgrass *(Zostera marina)* and the brown alga *Leathesia difformis*. Bay mussels *(Mytilus edulis)* and barnacles *(B. glandula)* are the dominant invertebrate species. The high intertidal zone has rockweed *(Fucus distichus)*, barnacles *(B. glandula, B. cariosus, Chthamalus dalli)* and Sitka periwinkles *(Littorina sitkana)*. In the splash zone the black lichen, *Verrucaria sp.*, grows on the rocks.

There are lichens and mosses growing on the rocks in the bank area. The uplands have the typical western red cedar/western hemlock *(Thuja plicata/ Tsuga heterophylla)* forest. Sitka spruce *(Picea sitchensis)* and red alder *(Alnus rubra)* occur less commonly. The shrub layer is primarily evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)*.

types

KH1 is defined by the system concept.

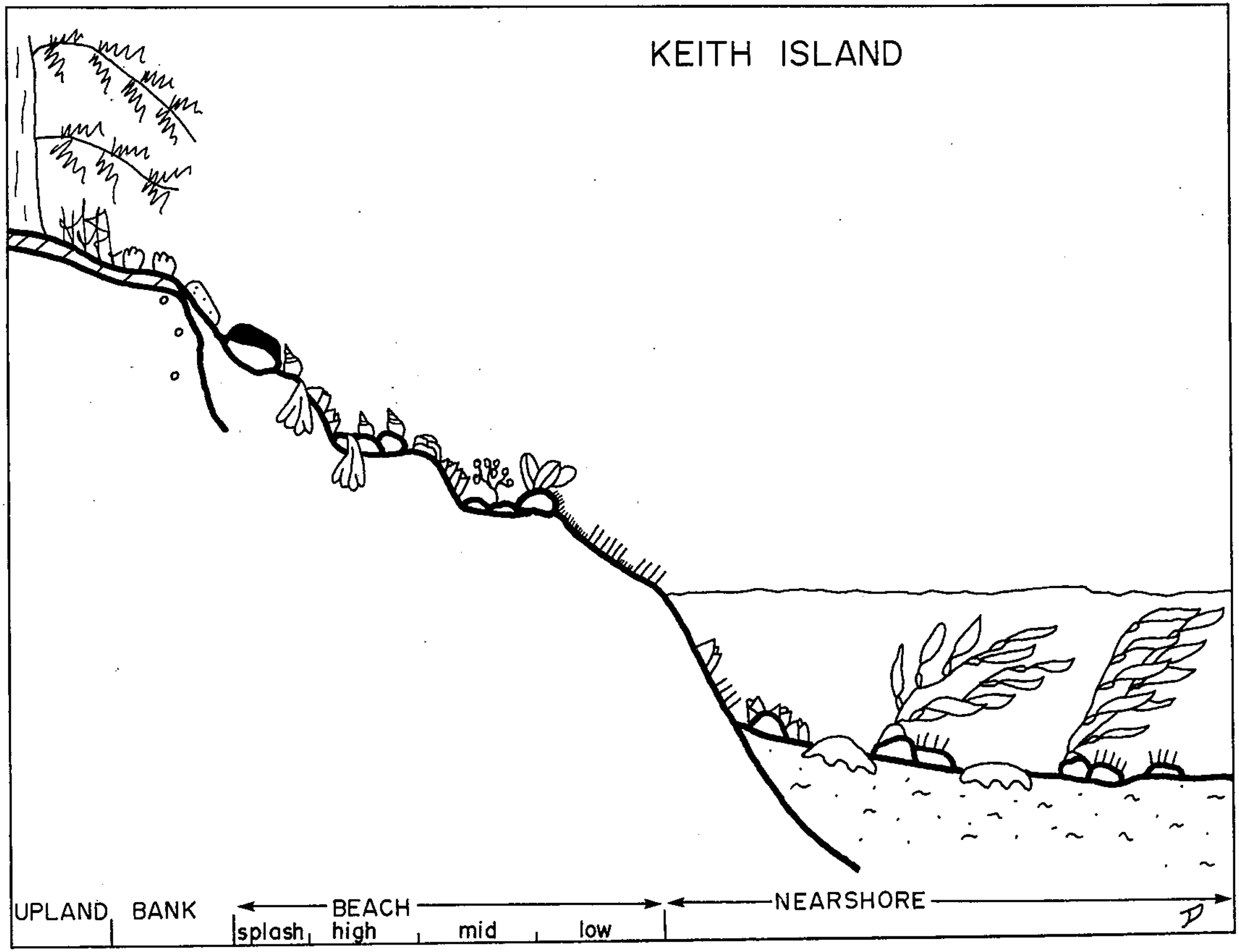


Fig. 44. Schematic profile of Keith Island system concept

EFFINGHAM ISLAND (EF1)

representative location: boulder beach on SW side of Effingham Bay

system concept

The Effingham Island system encompasses low energy (sheltered) bedrock/boulder combination substrate shores. There were no subtidal surveys done within this system, therefore there is no information available for the nearshore area. Substrates in the beach area are boulder and/or bedrock in combination with smaller size fraction material (cobble to mud). The beach has a moderate to strong slope. Bank substrate is boulder and bedrock with some cobble. The bank has a very steep to extreme slope. The uplands are rolling to hilly and are often covered with colluvial veneer. The most common soils are humo ferric podzols.

The nearshore biota immediately adjacent to the beach was recorded during intertidal surveys. Giant kelp *(Macrocystis integrifolia)*, red top shells *(Astraea gibberosa)*, sunflower stars *(Pycnopodia helianthoides)* and sea cucumbers *(Cucumaria miniata)* are the most common inhabitants of the nearshore area.

The beach is divided into three biotic zones. The low intertidal zone supports a growth of eelgrass *(Zostera marina)*, brown alga *(Laminaria groenlandica)* and sea lettuce *(Ulva sp.)*. *L. setchellii* occurs where there is more energy input by wave action and currents. Bat stars *(Patiria miniata)*, hermit crabs *(Pagarus sp.)* and sea anenomes *(Anthopleura xanthogrammica, A. elegantissima)* also occur in the low intertidal zone. *Leathesia difformis*, a brown alga, japweed *(Sargassum muticum)*, bay mussels *(Mytilus edulis)*, barnacles *(Balanus glandula)* and shore crabs *(Hemigrapsus nudus, H. oregonensis)* populate the mid intertidal zone. The high intertidal zone of the Effingham Island system is dominated by rockweed *(Fucus distichus)*, barnacles *(B. glandula)*, finger limpets *(Collisella digitalis)* and periwinkles *(Littorina sitkana, L. scutulata)*.

The rocks of the bank are partially covered with lichen and moss. The upland forest is the typical western red cedar/western hemlock *(Thuja plicata/Tsuga heterophylla)* association. Some Sitka spruce *(Picea sitchensis)* also occur. The shrub layer largely consists of evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)*.

types

EF1 is characterized by the system concept.

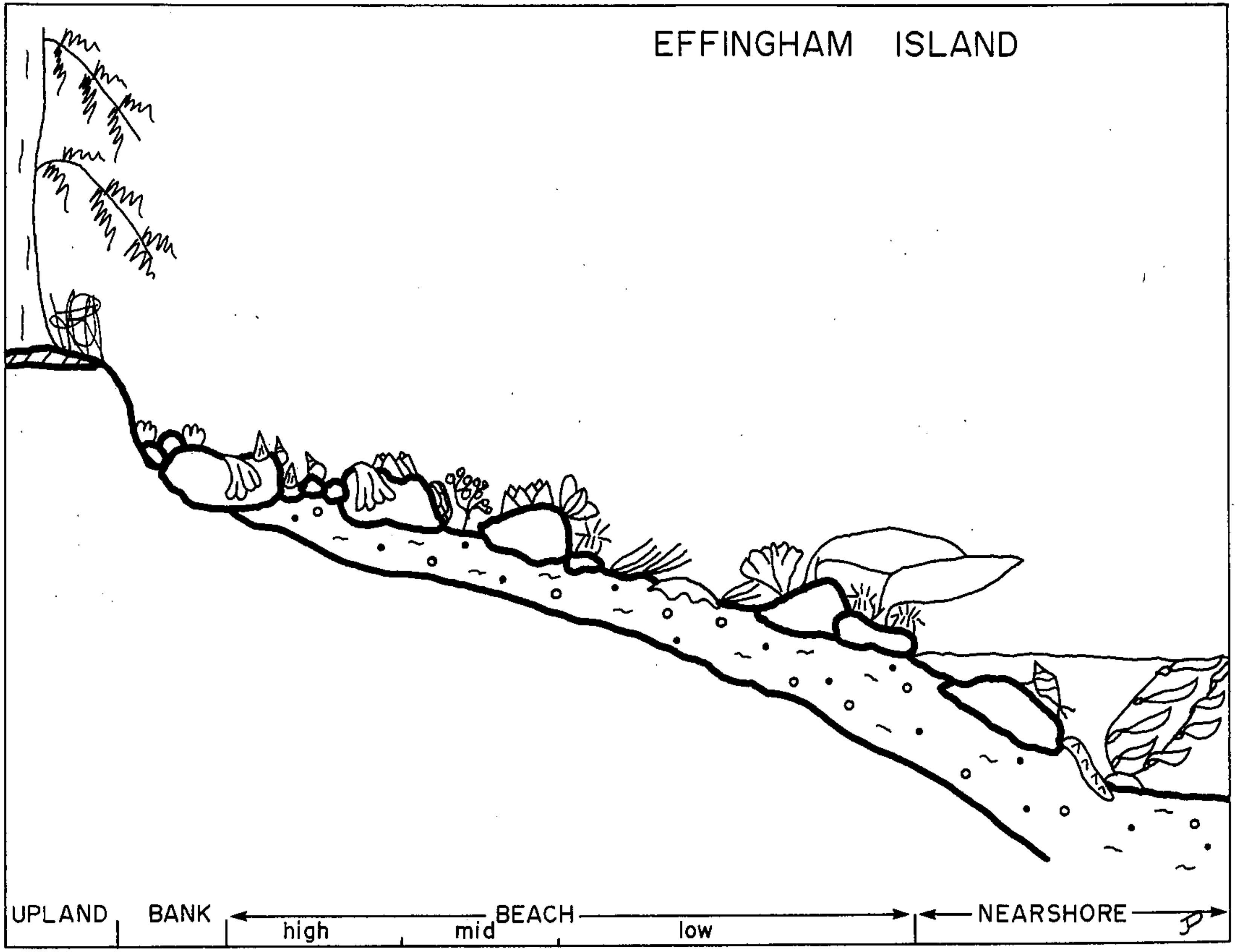


Fig. 45. Schematic profile of Effingham Island system concept

SHELTERED BEDROCK (SB1, SB2)

representative location: behind small islet on E side of Nettle Island

system concept

The Sheltered Bedrock system can be defined as low energy (sheltered) bedrock shores. The nearshore areas have a variety of substrates ranging from silt, sand and shell to cobble and boulder. On rocky shores localized water currents can impart a higher energy to the nearshore area than has the adjacent beach. Thus, what is called a sheltered bedrock coastal site will often have a moderate energy (semi-exposed) subtidal component. The bedrock beach is steep to extremely sloping. The bank is also bedrock with a range of slopes similar to the beach. The uplands are gently rolling to hilly and predominantly covered with colluvial veneer. Till soils denoted as humo ferric podzols are common.

The flora and fauna of the nearshore of the Sheltered Bedrock system can vary greatly, corresponding to the wide variety of possible substrates. However, where cobble, boulders or bedrock are present giant kelp *(Macrocystis integrifolia)*, (and in higher energy locations bull kelp *(Nereocystis luetkeana)*), bat stars *(Patiria miniata)*, red top shells *(Astraea gibberosa)* and hermit crabs *(Pagarus sp.)* commonly occur. In locations where the nearshore is of moderate energy (ie. bay on south Nettle Island) the biota is divided into zones. The lower zone is characterized by two brown algae *(Agarum fimbriatum, Eisenia arborea)*. The zone adjacent to the beach supports japweed *(Sargassum muticum)* and red coralline alga *(Corallina sp.)*. The invertebrates do not display the distinct zonation of the algae; tube worms *(Serpula vermicularis)*, bryozoans and sponges occur regularly.

The beach is divided into three distinct intertidal zones. In the low intertidal zone eelgrass *(Zostera marina)*, sea lettuce *(Ulva sp.)* and hermit crabs are common. The mid intertidal zone generally supports japweed *(Sargassum muticum)*, a brown alga *Leathesia difformis*, a red alga *Halosaccion glandiforme*, bay mussels *(Mytilus edulis)* and barnacles *(Balanus glandula)*. In the high intertidal zone rockweed *(Fucus distichus)*, finger limpets *(Collisella digitalis)*, periwinkles *(Littorina sitkana, L. scutulata)* and barnacles *(B. glandula, B. cariosus)* are the most common organisms.

Lichens and mosses grow on rocks in the bank area. Western red cedar *(Thuja plicata)* and western hemlock *(Tsuga heterophylla)* are the most common trees in the upland area. Sitka spruce *(Picea sitchensis)* occur infrequently and shore pine *(Pinus contorta)* are rare. The evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)* are common shrubs. Deer fern *(Blechnum spicant)* may also occur.

types

SB1 is described by the system concept.

The nearshore of SB2 is an extensive mud flat with eelgrass *(Z. marina)*. *Agarum fimbriatum* grows where the bedrock extends below the low tide level. The uplands of this coastal type are covered with a silty marine blanket or veneer. The soils are moderately well drained podzols.

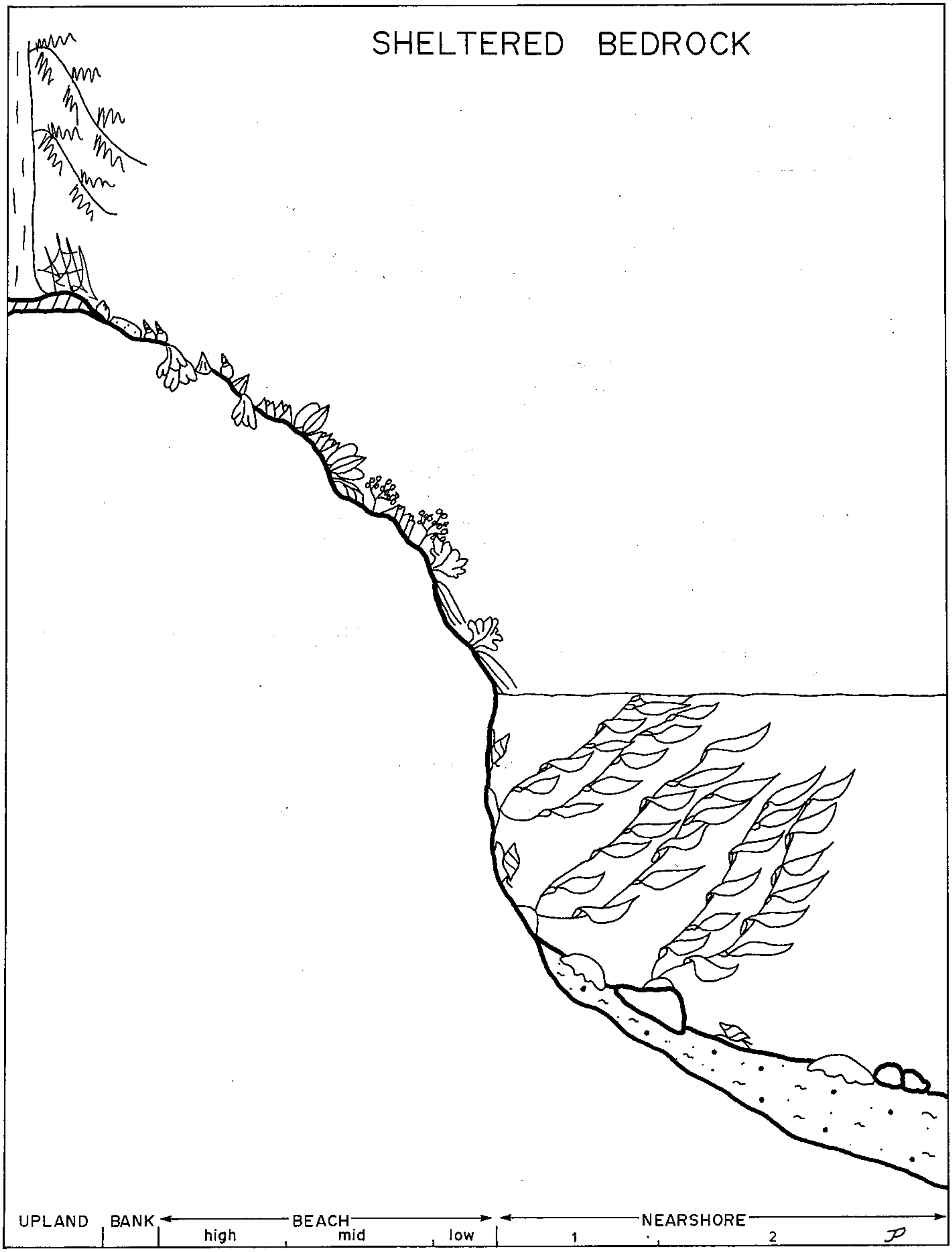


Fig. 46. Schematic profile of Sheltered Bedrock system concept.

NORTH WICKANINNISH (NW1, NW2)

<u>representative location</u>: NW end of Wickaninnish Bay, E of Round Island

<u>system concept</u>

The North Wickaninnish system is a moderate energy (semi-exposed) fine sand shore. The sandy nearshore has a very gentle slope. The beach is fine sand with some silt. The bank consists of a low cut face in the unconsolidated upland material. The uplands are a marine sandy blanket overlain with a veneer or blanket of wind-deposited sand. The soil consists of well drained regosols.

The biota of the nearshore is predominantly juvenile sand dollars *(Dendraster sp.)*, tellens *(Tellina bodegensis)* and Dungeness crabs *(Cancer magister)* along with adult olive shells *(Olivella biplicata)*.

The beach can be divided into three biotic zones, all without attached algae. The low intertidal zone has olive shells, razor clams *(Siliqua patula)* and lugworms *(Abarenicola sp.)*. The mid intertidal zone supports ghost shrimp *(Callianassa californiensis)* and blood worms *(Euzonus sp.)*. The lugworms and ghost shrimp indicate the presence of silt. The high intertidal zone has a population of beach hoppers *(Orchestoidea californiana)* which feeds on the decaying seaweed drift.

The bank is bare. The uplands are forested, the dominant trees are the Sitka spruce *(Picea sitchensis)*, with salal *(Gaultheria shallon)* in the shrub layer.

<u>types</u>

NW1 is defined by the system concept.

NW2 is similar to the system concept but shows some variation in the beach and bank areas. The beach substrate contains some gravel in patches in the mid and high intertidal zones; however, flora and fauna are similar to NW1. The bank is moderately sloping sand with some beach grasses.

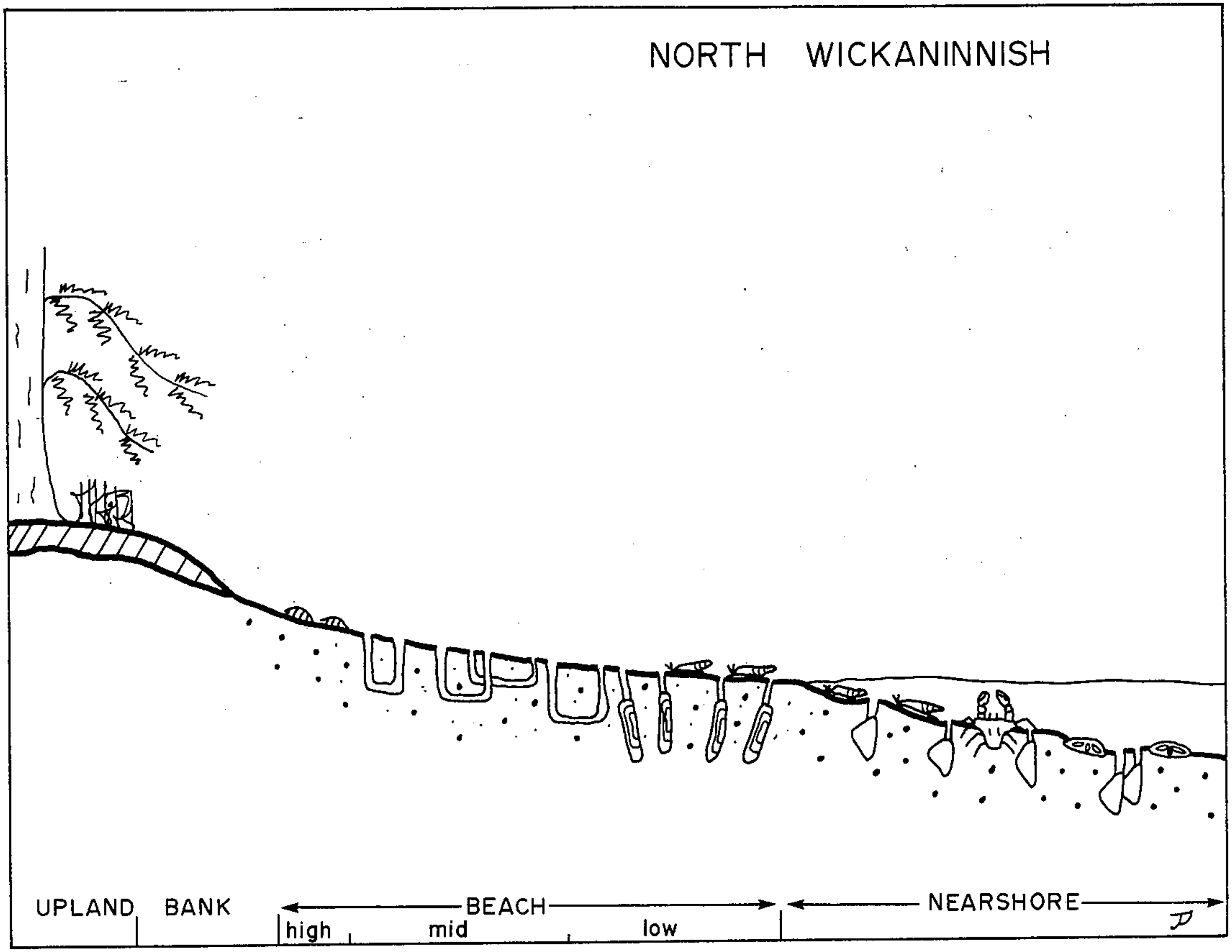


Fig. 47. Schematic profile of North Wickaninnish system concept

ROUND ISLAND (RD1)

representative location: NW end of Wickaninnish Bay

system concept

The Round Island system is a moderate energy (semi-exposed) fine sand shore. The sandy nearshore has a very gentle slope. The beach of fine sand is very gently or gently sloping depending upon the season. The unconsolidated bank is restricted in extent. The uplands consists of a gently sloping, sandy, marine deposited blanket. The soils are well drained regosols.

The biota of the nearshore is made up of juvenile sand dollars *(Dendraster sp.)*, tellens *(Tellina bodegensis)* and Dungeness crabs *(Cancer magister)* along with adult olive shells *(Olivella biplicata)*. The low intertidal zone is populated with tellens, olive shells and razor clams *(Siliqua patula)*. The mid and high intertidal and splash zones do not contain species typical of a sandy shore because a rock outcrop at this site extends down into these zones. The upland vegetation is typical of the Sitka spruce *(Picea sitchensis)* coastal fringe.

types

RD1 is defined by the system concept and also encompasses the inclusions of Round Island, Little Island and a rocky outcrop. These inclusions are hummocky ribbon chert, steeply or very steeply sloping.

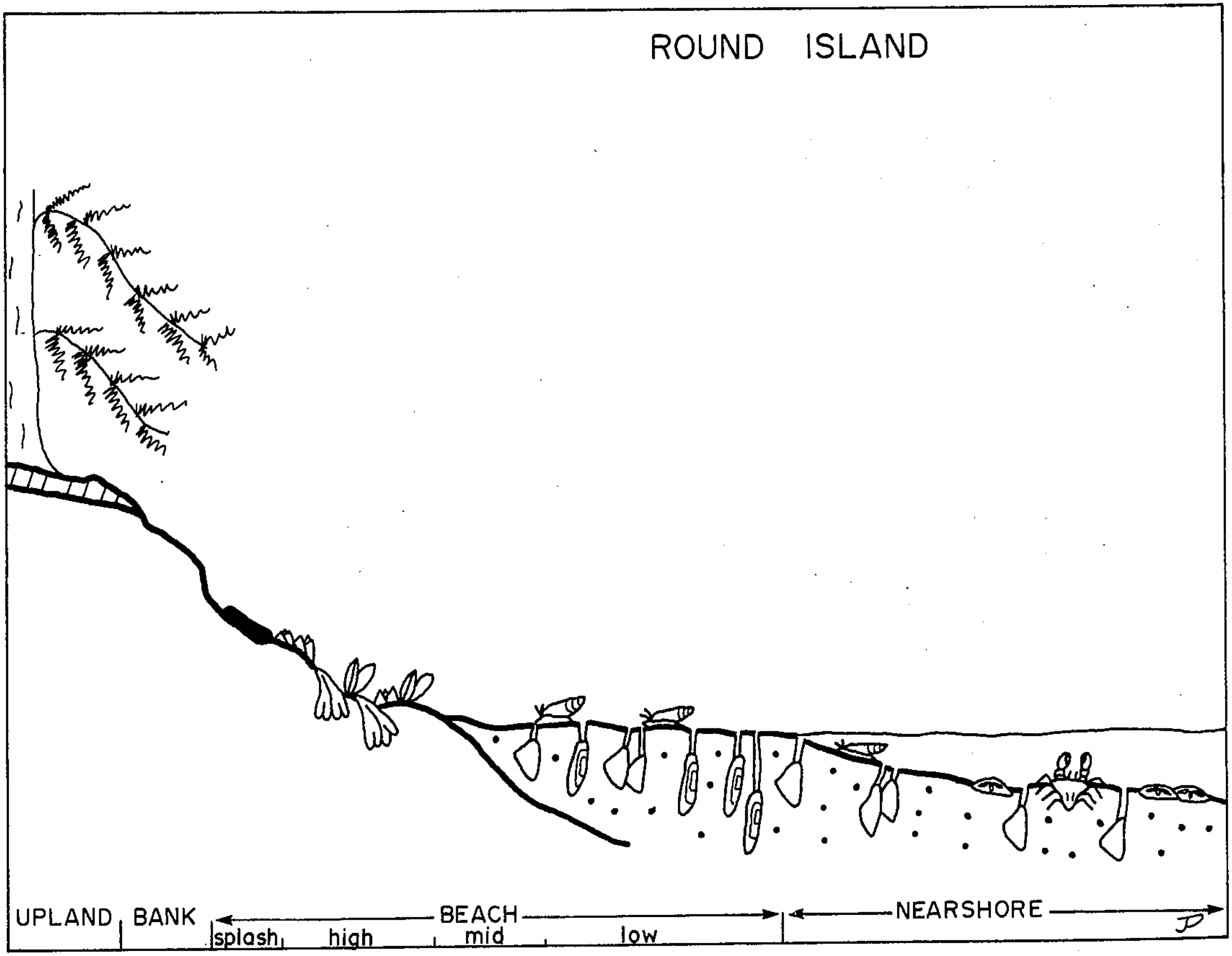


Fig. 48. Schematic profile of Round Island system concept

TURRET ISLAND (TT1)

representative location: N side of the W end of Turret Island

system concept

The Turret Island system is a moderate energy (semi-exposed) sand shore. The nearshore area is silt and sand. The beach is fine sand. Cobble and bedrock make up the very steeply sloping bank which is less than 1 m high. The uplands are gently to strongly rolling and predominantly covered with a veneer of colluvial material. The soils are humo ferric podzols.

The nearshore biota was not surveyed. The beach displays little zonation and supports neither attached algae nor infaunal species.

Lichens grow on the bedrock and boulder of the bank. The uplands are forested with western red cedar *(Thuja plicata)*, western hemlock *(Tsuga heterophylla)* and some Sitka spruce *(Picea sitchensis)*. The shrub layer along the shore is evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)*.

types

TT1 is defined by the system concept.

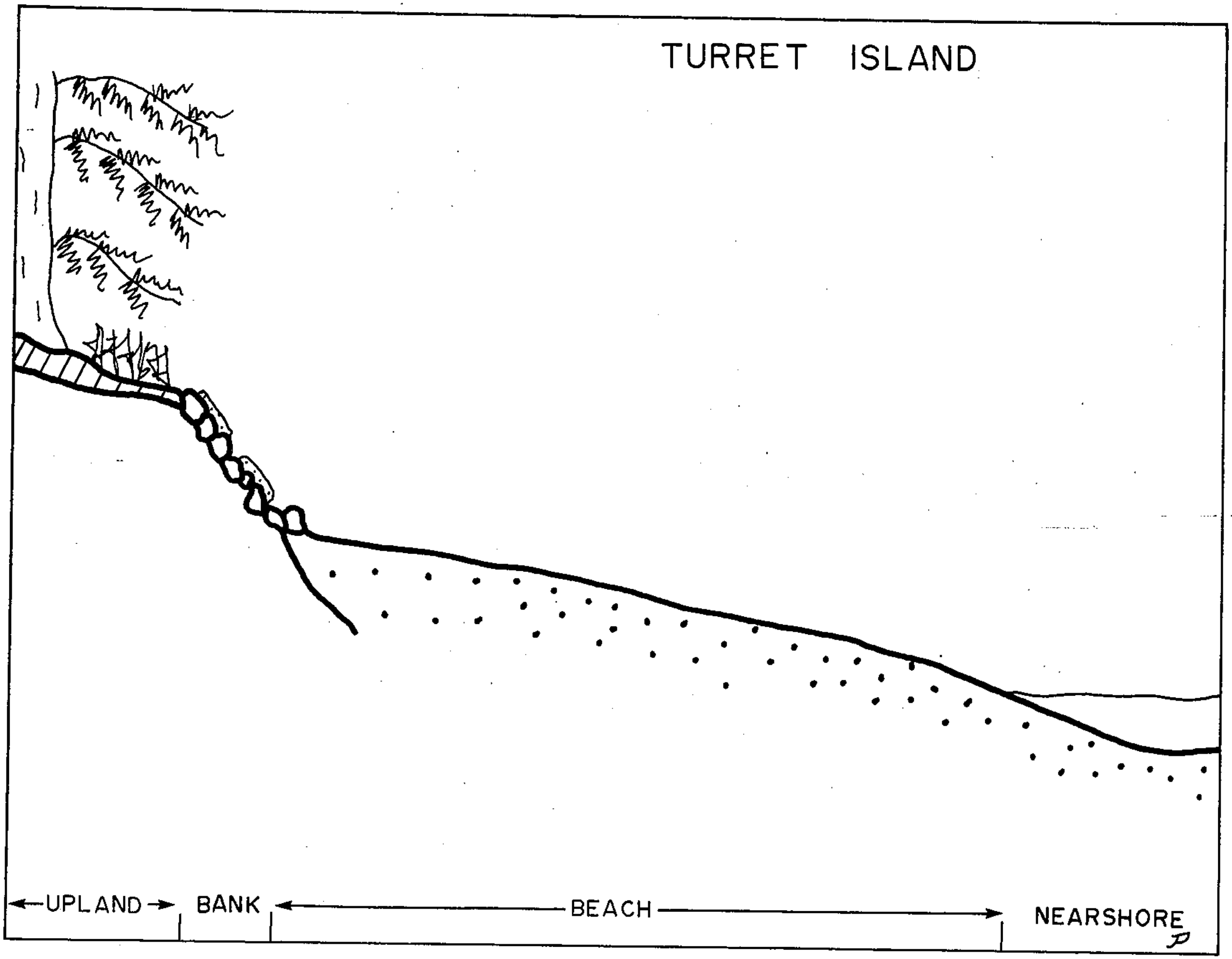


Fig. 49. Schematic profile of Turret Island system concept

TURRET SHELL (TS1, TS2)

representative location: adjacent to the small reef on the E side of Turret Island

system concept

The Turret Shell system represents moderate energy (semi-exposed) sand/shell shores. The nearshore area was not surveyed. The beach has a sand/shell substrate and may have a pocket beach configuration or be an accumulation of material along a rocky reef. The bank is steeply to very steeply sloping bedrock/boulder. The uplands are predominantly colluvial veneer and are gently to strongly rolling. The soils are designated as humo ferric podzols and regosols.

The nearshore biota was not surveyed. The beach shows no apparent zonation. Carnivorous snails *(Thais lamellosa)*, turban snails *(Tegula funebralis)*, ochre starfish *(Pisaster ochraceus)* and leather stars *(Dermasterias imbricata)* are the most common species on the beach.

The bank supports lichen growth. The uplands are forested. Western red cedar *(Thuja plicata)*, western hemlock *(Tsuga heterophylla)* and Sitka spruce *(Picea sitchensis)* are the dominant tree species. Evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)* are the most common shrubs.

types

TS1 is characterized by the system concept.

TS2 is a sand/shell beach with boulders at the low tide level and in the nearshore. The nearshore biota includes the giant kelp, *Macrocystis integrifolia*.

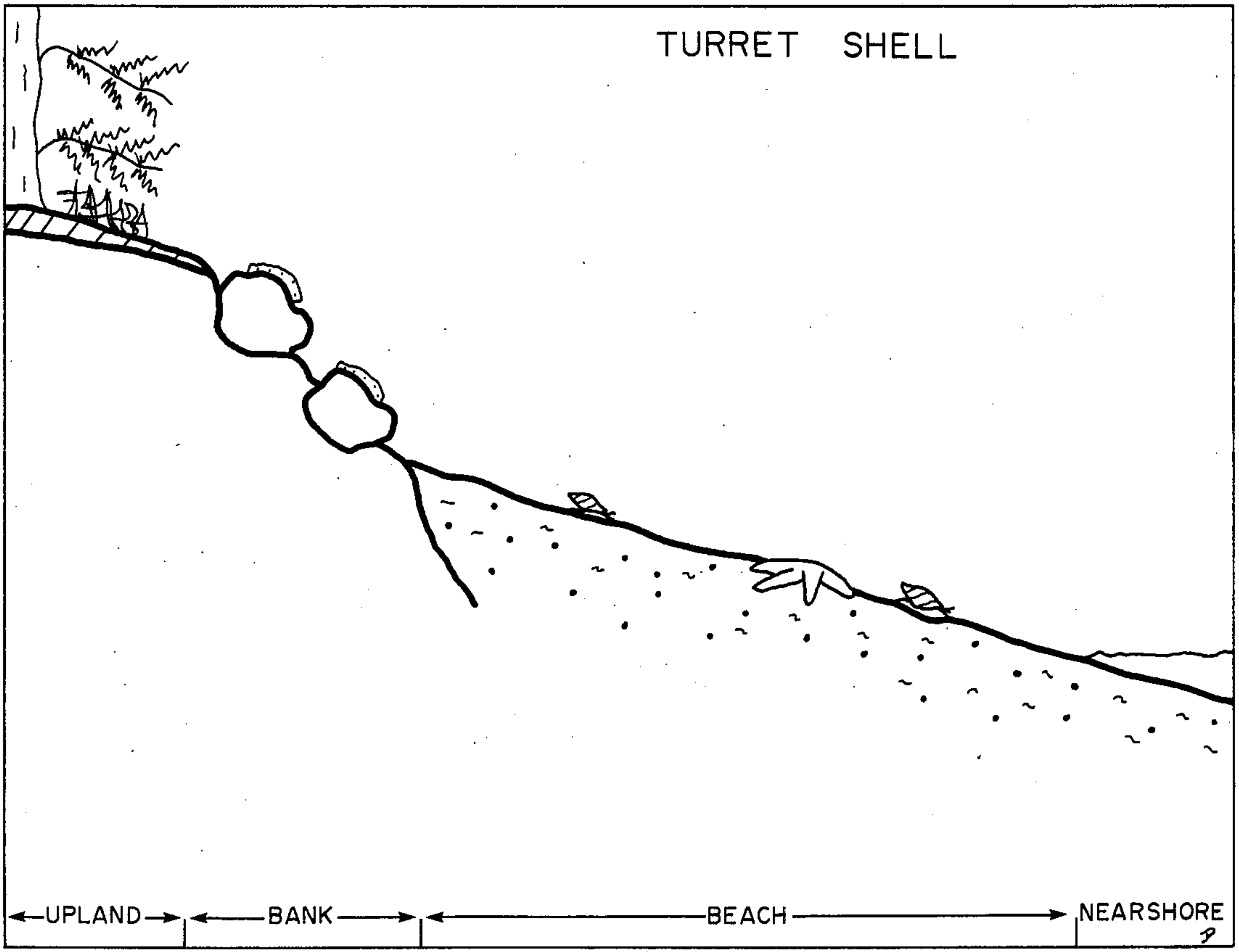


Fig. 50. Schematic profile of Turret Shell system concept

HAND ISLAND (HD1)

representative location: adjacent to bedrock outcrop on N side of Hand Island

system concept

The Hand Island system is a moderate energy (semi-exposed) shell shore. The nearshore was not surveyed. The moderately sloping beach is shell. Bedrock and boulders make up the bank area. The uplands are gently to strongly rolling and are largely covered with a colluvial veneer. Regosol and humo ferric podzol soils predominate.

The nearshore biota was not surveyed. The beach supports populations of littleneck clams *(Protothaca staminea)* and Pacific oysters *(Crassostrea gigas)*.

The bank has mosses and lichens growing on the rocks and logs with occasional clumps of grass growing between the boulders. The dominant canopy of the uplands forest is made up of western red cedar *(Thuja plicata)* and western hemlock *(Tsuga heterophylla)*. Sitka spruce *(Picea sitchensis)* grow in the sub-dominant story. Evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)* are common shrubs.

types

HD1 is described by the system concept.

remarks

The bivalve populations are not extensive and are subject to variable recruitment; they should be monitored so that recreational utilization can be set at appropriate levels.

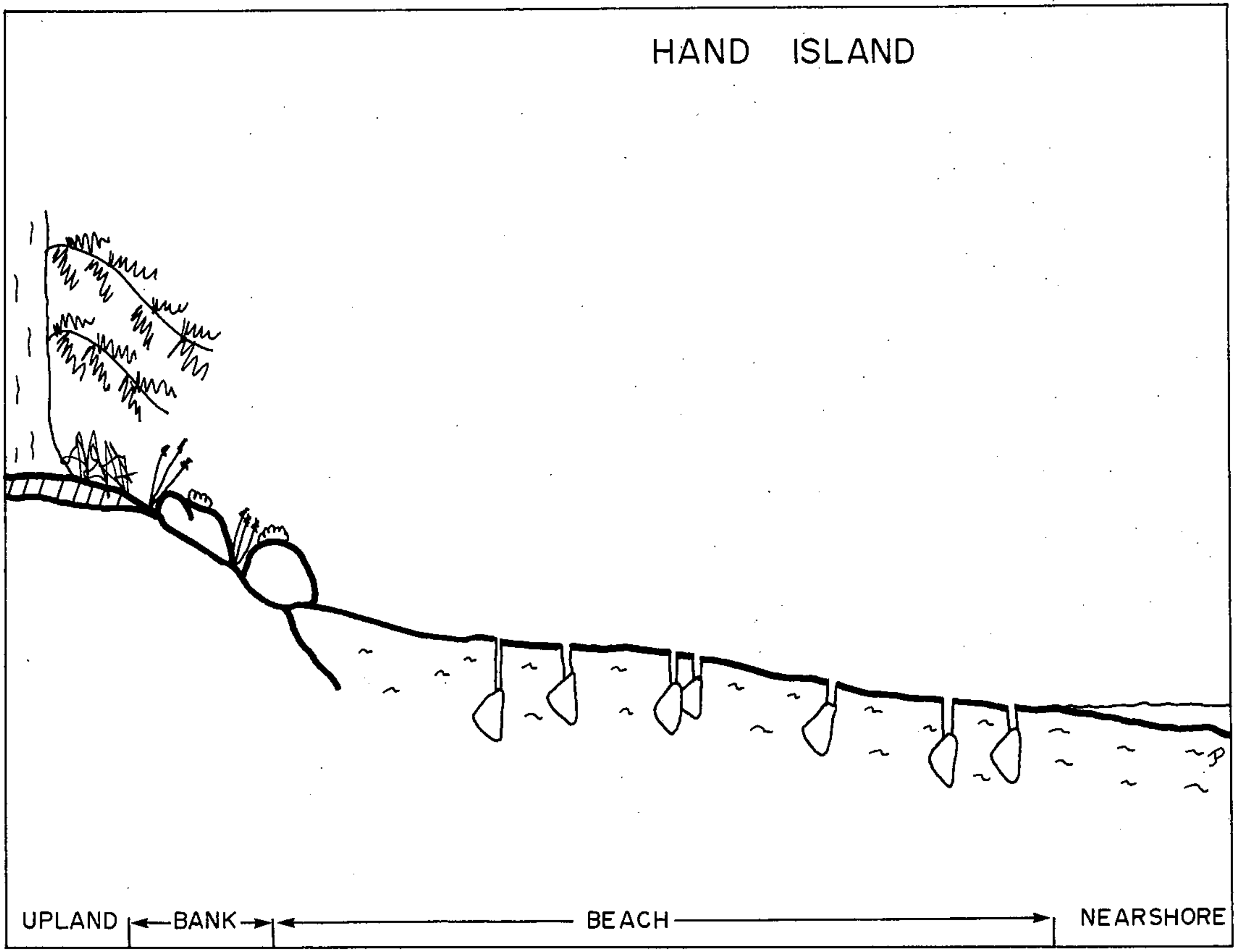


Fig. 51. Schematic profile of Hand Island system concept

TRICKETT BAR (TK1, TK2, TK3)

representative location: gravel bar between Trickett and Turret Islands

system concept

The Trickett Bar system describes moderate energy (semi-exposed) shores with gravel beach substrates. The nearshore was not surveyed. The substrate of the beach is gravel but may have some shell as well. The bank ranges from cobble to bedrock and is steeply to very steeply sloping. Uplands are undulating to strongly rolling and are predominantly covered with a veneer of colluvial material. The soils are regosols and podzols.

Nearshore biota was not surveyed. The beach supports populations of littleneck clams *(Protothaca staminea)* and Manila clams *(Venerupis japonica)*; butter clams *(Saxidomus giganteus)*, horse clams *(Tresus sp.)* and soft-shell clams *(Mya arenaria)* are also common. There are no attached algae on the beach.

The bank displays some lichen growth and the uplands are treed. Western red cedar *(Thuja plicata)*, western hemlock *(Tsuga heterophylla)* and Sitka spruce *(Picea sitchensis)* are the dominant tree species while evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)* grow in the shrub layer.

types

TK1 follows the system concept.

TK2 has some silted sand mixed with the gravel on the beach. The mud shrimp *(Upogebia pugettensis)* occurs on these beaches in addition to the bivalve species.

TK3 has a steeply sloping nearshore of gravel, shell and boulder. The beach is steeply sloping, steeper than the system concept, but the substrate is gravel. The nearshore area supports a variety of algae, a red alga *(Neoagardhiella baileyi)* is the most common. The beach appears barren, supporting no conspicuous flora or fauna.

remarks

The bivalve populations are not extensive and are subject to variable recruitment; they should be closely monitored in order to regulate recreational utilization.

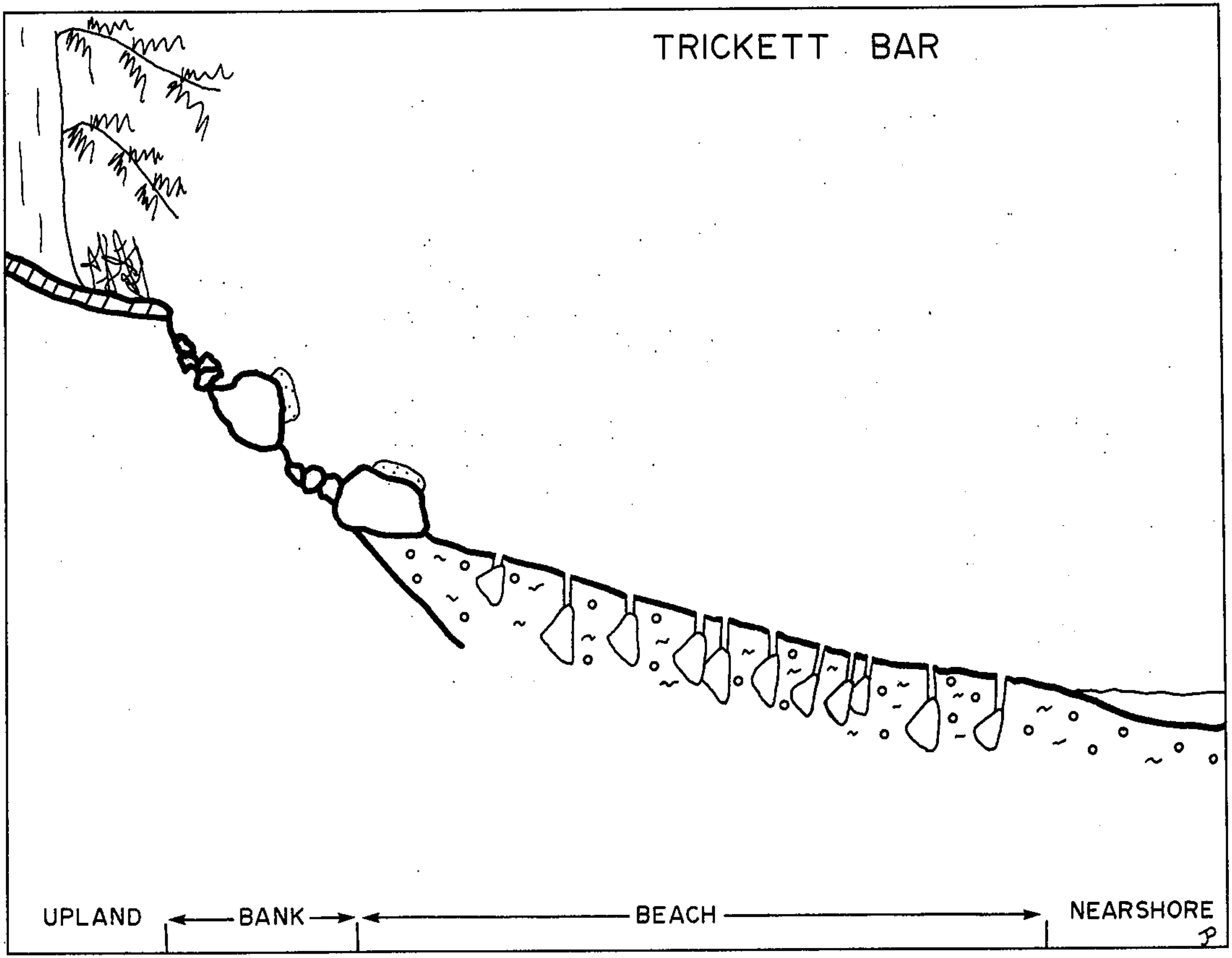


Fig. 52. Schematic profile of Trickett Bar system concept

FLORENCIA BAY (FB1)

representative location: NW and SE ends of Florencia Bay

system concept

The Florencia Bay system is a moderate energy (semi-exposed) gravel/sand/shell shore. The nearshore is very gently sloping sand. The gently sloping beach consists of a gravel/sand/shell substrate with scattered boulders. The bank is a bedrock outcrop. The uplands are composed of a veneer to blanket of wind deposited sand overlying a marine blanket of sand and silt. The uplands are either undulating or very steeply sloping. The soils within this system are imperfectly drained.

A small but rather unique population of littleneck clams *(Protothaca staminea)* is the most important biotic feature of this system. Littleneck clams and soft-shell clams *(Mya arenaria)* occur at the mid intertidal level of the beach. The bank supports lichens and the uplands are part of the Sitka spruce *(Picea sitchensis)* coastal fringe, with some small willows *(Salix sp.)* in the sub-dominant story.

types

FB1 is typical of the system concept.

remarks

The littlenck clam population is small and subject to variable recruitment; it should be monitored closely in order to regulate recreational utilization. Littlenck clams usually occur in lower energy locations.

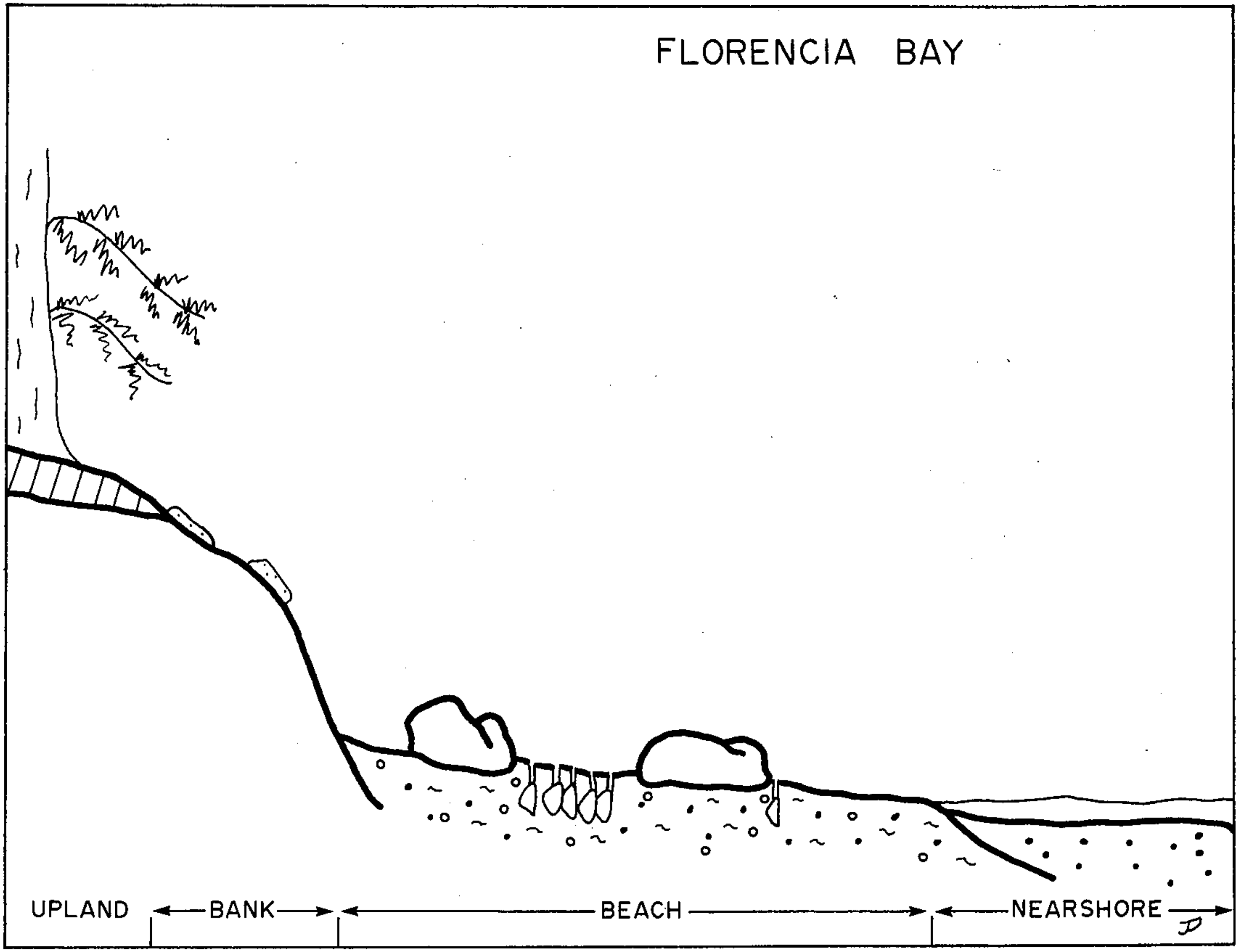


Fig. 53. Schematic profile of Florencia Bay system concept

MIDDLE WOUWER (MW1, MW2, MW3)

representative location: middle pocket beach on N side of Wouwer Island

system concept

The Middle Wouwer system encompasses moderate energy (semi-exposed) gravel/sand/shell shores. The nearshore substrate is commonly a combination of gravel, sand and shell with a steep slope. The steeply sloping beach is also gravel, sand and shell and may occur in either a pocket beach or bar configuration. The bank substrates range from gravel to bedrock. The bank is usually steeply sloping. The uplands are predominantly colluvial veneer with gently to strongly rolling topography. Regosol and humo ferric podzol soils commonly occur.

The biota of the nearshore area can be divided into two zones. The deeper zone supports kelps (*Macrocystis integrifolia*, and in higher energy areas *Nereocystis luetkeana*), a brown alga *(Costaria costata)* and an encrusting red coralline alga *(Lithothamnion sp.)*. There are small numbers of brown turban snails *(Tegula pulligo)* as well. The zone adjacent to the beach is steeply sloping. Surf grass *(Phyllospadix sp.)* and japweed *(Sargassum muticum)* occur in this zone. Limpets *(Collisella pelta, Notoacmea persona)*, the northern brown turban snail *(T. pulligo)*, and sea urchins *(Strongylocentrotus spp.)* are present in small numbers.

The beach supports little or no biota. Moon snails *(Polinices lewisi)* occur rarely.

The bank is similarly barren except for lichens on the larger rocks. The uplands are forested, western red cedar *(Thuja plicata)*, western hemlock *(Tsuga heterophylla)* and Sitka spruce *(Picea sitchensis)* occur in the dominant story. The evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)* are common shrubs.

types

MW1 is described by the sytem concept.

MW2 follows the sytem concept except that the beach substrate is gravel/shell with little or no sand.

MW3 is defined by the system concept but this coastal type has a gravel/sand beach substrate with little or no shell.

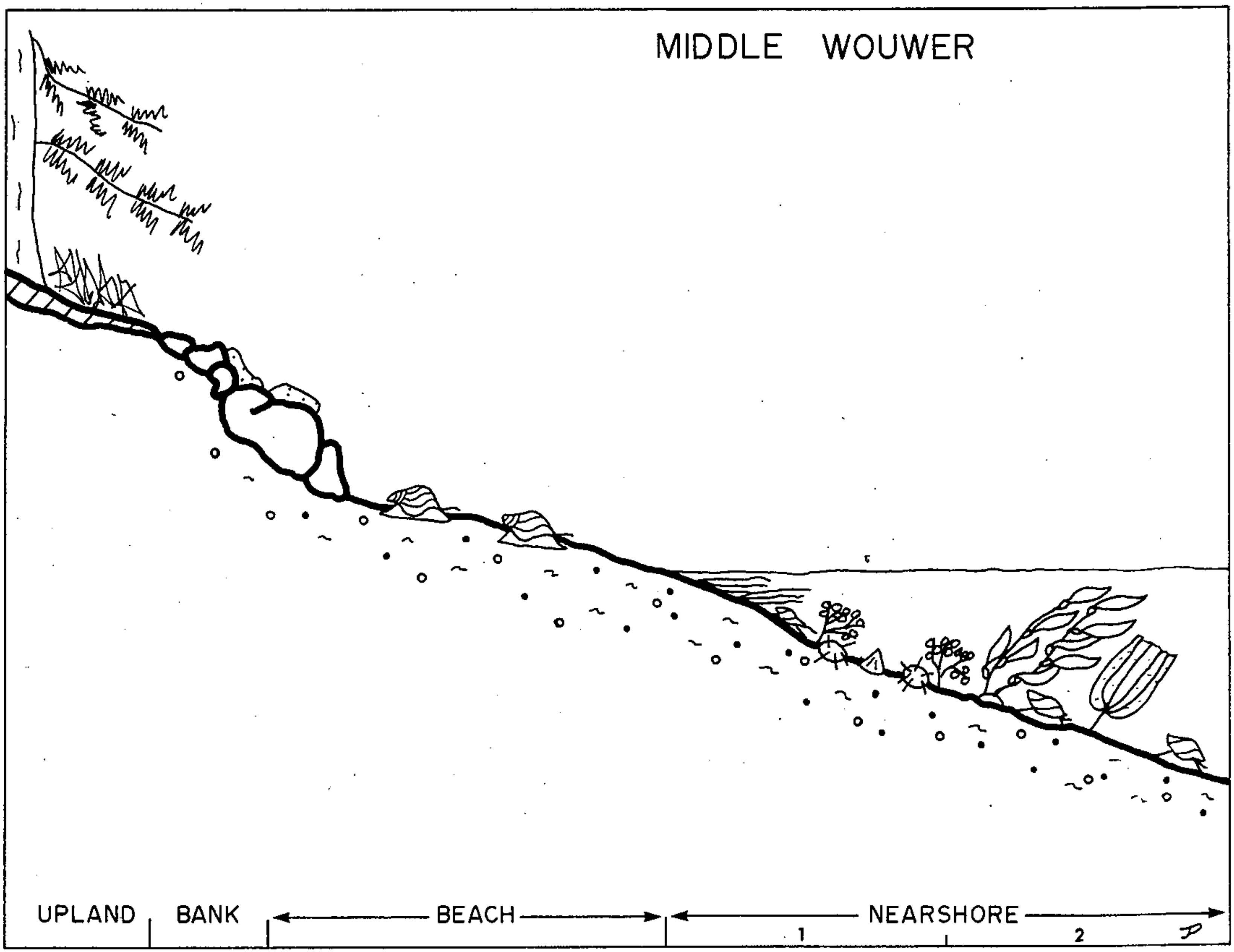


Fig. 54. Schematic profile of Middle Wouwer system concept

NORTH GILBERT ISLAND (NG1)

representative location: beach on the NW side of Gilbert Island

system concept

The North Gilbert system occurs on moderate energy (semi-exposed) shores with cobble/gravel/shell substrates. The nearshore was not surveyed. The steeply sloping beach is primarily cobble with gravel and shell occurring interstitially. A few scattered boulders are also present. The bedrock/ boulder bank slopes very steeply. The uplands are moderately rolling to hilly with colluvial veneer the predominant surface expression. The till soils are largely humo ferric podzols.

The biota of the nearshore was not surveyed. The beach area is divided into four biotic zones. The low intertidal zone was not surveyed. The mid intertidal zone supports red algae *(Gastroclonium coulteri, Gigartina exasperata)*, barnacles *(Balanus glandula)* and polychaete worms *(Spirorbis sp.)*. Rockweed *(Fucus distichus)*, barnacles *(B. glandula, B. cariosus)* and black turban snails *(Tegula funebralis)* occur commonly in the high intertidal zone. The splash zone has the black lichen, *Verrucaria sp.*, on the rocks. Periwinkles *(Littorina sitkana, L. scutulata)*, limpets *(Notoacmea scutum)* and finger limpets *(Collisella digitalis)* are also common.

Lichens grow on the bank. The upland forest is largely western red cedar *(Thuja plicata)*, western hemlock *(Tsuga heterophylla)* and Sitka spruce *(Picea sitchensis)* with salal *(Gaultheria shallon)* and evergreen huckleberry *(Vaccinium ovatum)* in the shrub layer.

types

NG1 is characterized by the system concept.

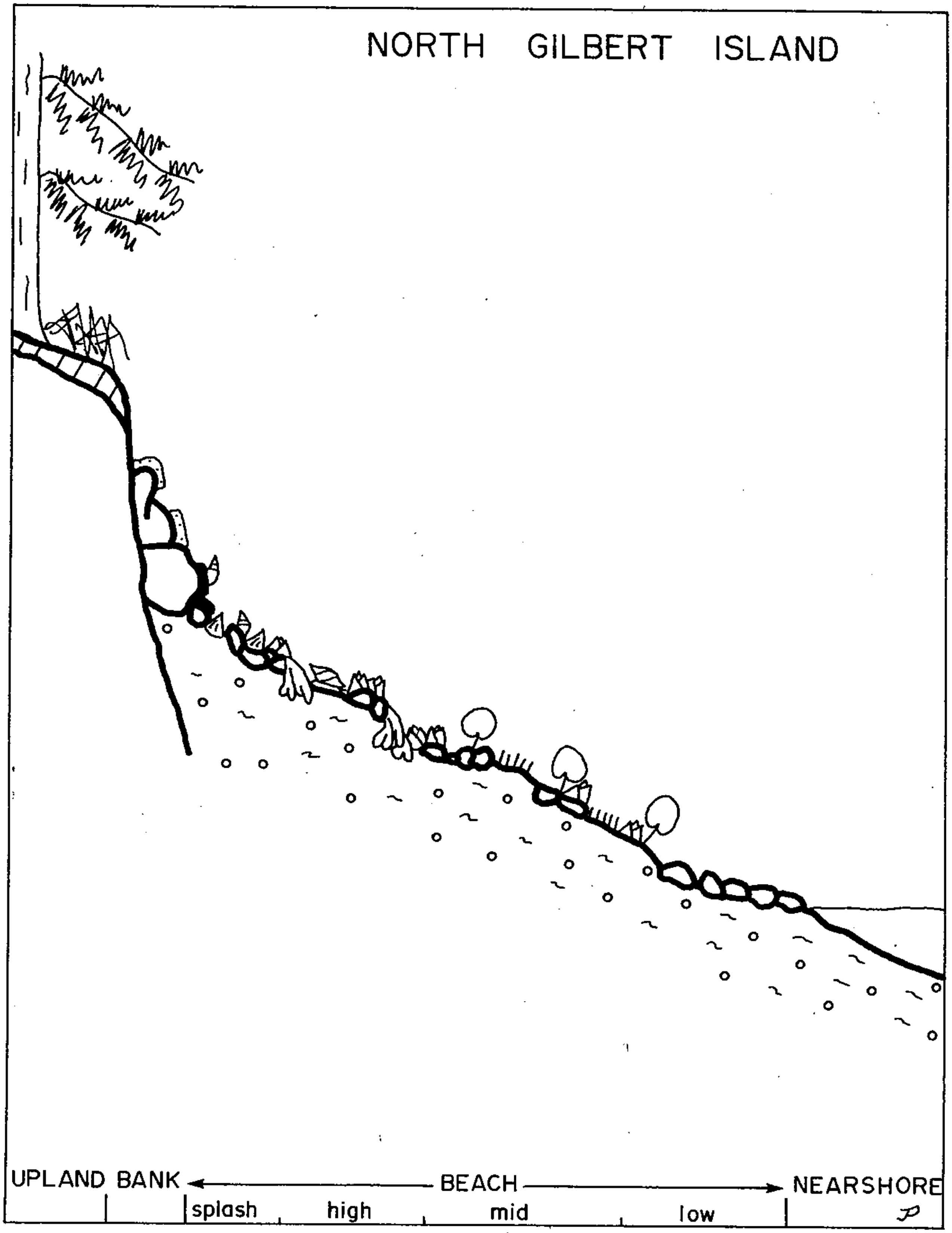


Fig. 55. Schematic profile of North Gilbert Island system concept

DICEBOX ISLAND (DB1)

representative location: SW side of Dicebox Island

system concept

The Dicebox Island coastal system encompasses moderate energy (semi-exposed) boulder shores. The nearshore was not surveyed. The beach substrate is boulder and the bank is composed of boulder and bedrock. The uplands are gently to strongly rolling with hummocky bedrock outcrops or very thin regosol soils.

Nearshore biota was not surveyed in detail but kelps (*Macrocystis integrifolia*, and in higher energy locations *Nereocystis luetkeana*) and red sea urchins *(Strongylocentrotus franciscanus)* were observed below the low tide level.

The beach area is divided into three biotic zones. The low intertidal zone supports the feather boa kelp *(Egregia menziesii)*, a brown alga *(Laminaria groenlandica)*, and a red alga *(Gigartina sp.)*. Leather stars *(Dermasterias imbricata)*, sponges *(Haliclona permollis, Ophlitaspongia pennata)* and sea anenomes *(Anthopleura xanthogrammica, A. elegantissima)* are also common. The vegetation of the mid intertidal zone includes three brown algae *(Hedophyllum sessile, Alaria marginata, Leathesia difformis)*. Bay mussels *(Mytilus edulis)*, barnacles *(Balanus glandula, B. cariosus)* and spindle shell snails *(Searlesia dira)* are also numerous in the mid intertidal zone. The high intertidal zone has a dense covering of rockweed *(Fucus distichus)*. Periwinkles *(Littorina scutulata, L. sitkana)*, barnacles *(B. glandula)*, finger limpets *(Collisella digitalis)* and the snail *Thais emarginata* are typical of this zone.

The bank has lichens growing on the rocks with grasses occasionally present. The uplands are forested with western red cedar *(Thuja plicata)*, western hemlock *(Tsuga heterophylla)* and Sitka spruce *(Picea sitchensis)*. The shrubs evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)* are common along the shore.

types

DB1 follows the system concept.

remarks

In addition to being a good representative location for a moderate energy boulder shore, the entire island of Dicebox Island has potential to become the basis of an interesting interpretive program. The island is rugged and picturesque with several different coastal types ranging from high energy bedrock to moderate energy gravel in close proximity with each other. At low tides, a natural path lends itself to the exploration of at least half the island.

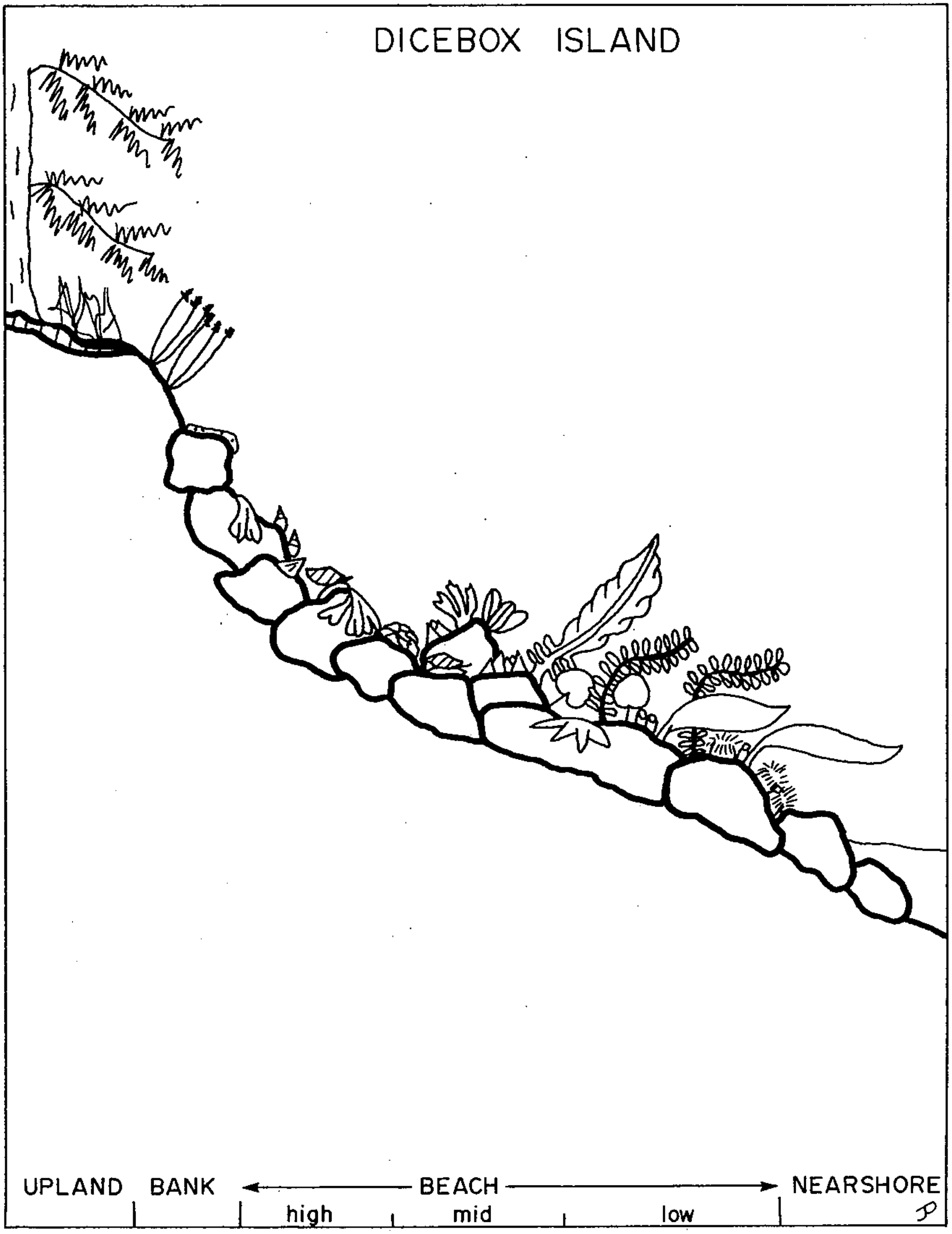


Fig. 56. Schematic profile of Dicebox Island system concept

COOPER ISLAND (CP1)

representative location: NE end of Cooper Island

system concept

The Cooper Island system defines moderate energy (semi-exposed) shores with boulder/gravel/sand/shell combination substrates. The nearshore was not surveyed. The strongly sloping beach has boulder/gravel/sand/shell substrate. The bank is bedrock/boulder. The uplands are moderately rolling to hilly and are predominantly colluvial veneer. The till soils are largely podzols.

The nearshore biota was not studied in detail. The beach, because of its range of substrates, supports both infaunal bivalve populations and species typical of rocky shores. Littleneck clams *(Protothaca staminea)*, butter clams *(Saxidomus giganteus)* and horse clams *(Tresus sp.)* are the bivalves present. The species typical of rocky shores can be divided into four biotic zones. The low intertidal zone was not surveyed. Bay mussels *(Mytilus edulis)* and the red alga *(Halosaccion glandiforme)* are typical of the mid intertidal zone. Other species occurring are: barnacles *(Balanus cariosus, B. glandula)*, finger limpets *(Collisella digitalis)* and sea anenomes *(Anthopleura elegantissima, A. xanthogrammica)*. The high intertidal zone is characterized by the dense growth of rockweed *(Fucus distichus)*. Periwinkles *(Littorina sitkana)*, finger limpets and barnacles *(B. cariosus, Chthamalus dalli)* are also common. The black lichen, *Verrucaria sp.*, occurs in the splash zone.

Lichens grow on the bedrock and boulder of the bank. The uplands vegetation is dominated by western red cedar *(Thuja plicata)*, western hemlock *(Tsuga heterophylla)* and Sitka spruce *(Picea sitchensis)*. The shrubs are predominantly evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)*.

types

CP1 is described by the system concept.

remarks

The bivalve populations are not extensive and are subject to variable recruitment; they should be monitored in order that appropriate recreational bag limits may be set.

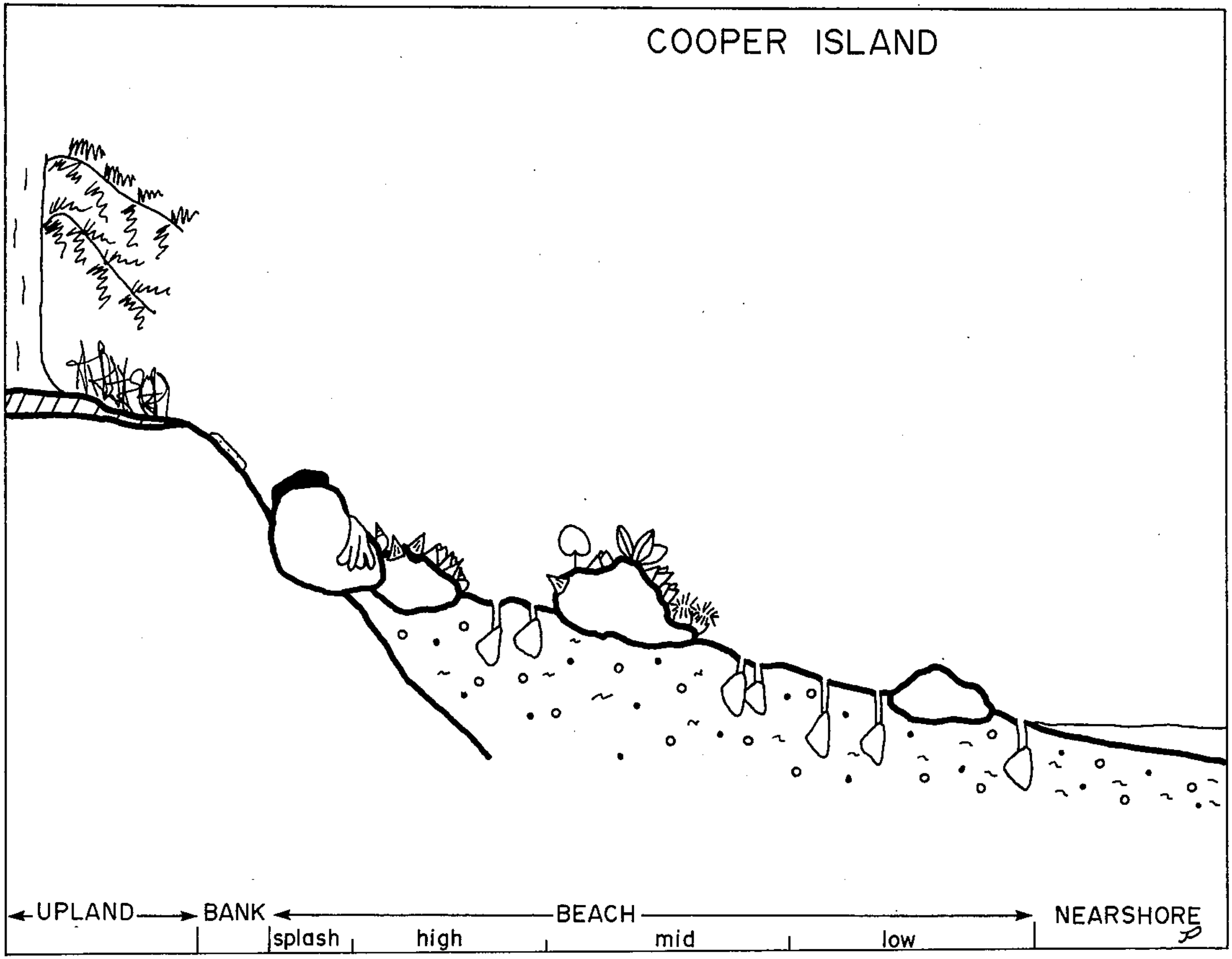


Fig. 57. Schematic profile of Cooper Island system concept

THRASHER COVE (TC1)

representative location: SW beach at Thrasher Cove, Hobbs Creek

system concept

The Thrasher Cove system describes moderate energy (semi-exposed) shores with substrates including materials from boulder to sand-sized particles. The nearshore consists of a range of substrates but bedrock and boulder are prevalent. Very gentle to gentle slopes are most common. The moderately sloping beach has a boulder/cobble/gravel/sand substrate. The bedrock bank is steeply to very steeply sloping. A veneer of colluvial material is the most common upland surface material, but hummocky or ridged bedrock and a veneer to blanket of morainal material also occur. The soils are well drained orthic regosols.

The biota of the nearshore was not studied in detail but beds of bull kelp *(Nereocystis luetkeana)* were observed below the low tide level.

The beach can be divided into four biotic zones. In the low intertidal zone a brown alga *(Alaria marginata)* and surfgrass *(Phyllospadix scouleri)* are the most common seaweeds. Ochre starfish *(Pisaster ochraceus)*, purple sea urchins *(Strongylocentrotus purpuratus)* and unidentified sponges are common in the low intertidal zone. A brown alga *(Hedophyllum sessile)* commonly occurs in the mid intertidal zone along with mussels *(Mytilus californianus, M. edulis)* and barnacles *(Balanus cariosus, B. glandula)*. The high intertidal zone is characterized by the presence of rockweed *(Fucus distichus)*. Barnacles *(B. glandula, B. cariosus, Chthamalus dalli)*, finger limpets *(Collisella digitalis)* and periwinkles *(Littorina sitkana)* are common in this zone. A black lichen *(Verrucuaria sp.)* occurs in the splash zone along with some barnacles *(B. glandula)* and periwinkles*(L. sitkana, L. scutulata)*.

The bedrock of the bank is largely bare with a sparse lichen cover. The uplands support a hemlock/spruce forest. Western hemlock *(Tsuga heterophylla)* and Sitka spruce *(Picea sitchensis)* are the most common trees.

types

TC1 is defined by the system concept.

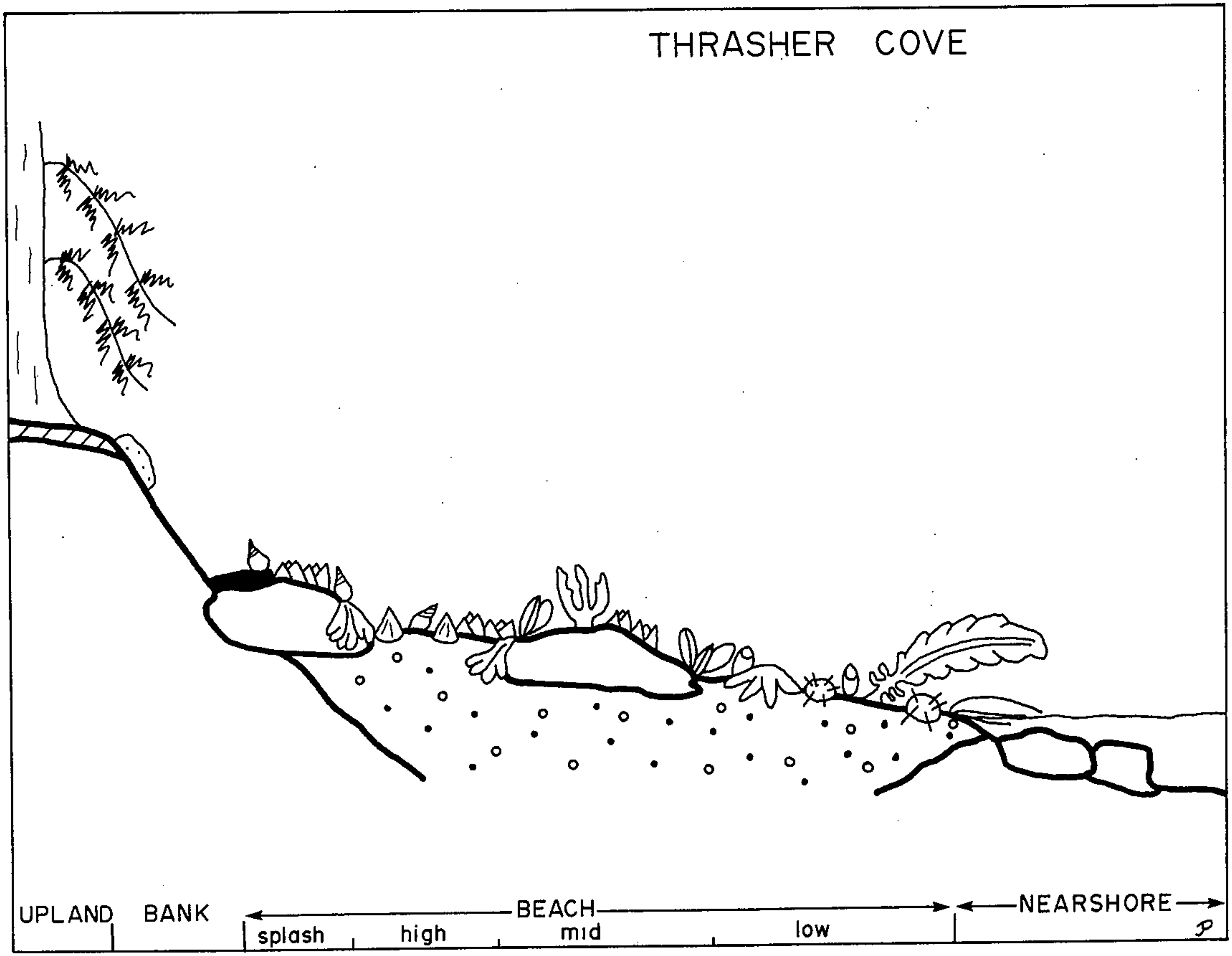


Fig. 58. Schematic profile of Thrasher Cove system concept

MORETON ISLAND (MT1)

representative location: rocky outcrops on either side of pocket beach on Cooper Island near Moreton Island

system concept

The Moreton Island coastal system includes moderate energy (semi-exposed) bedrock/boulder shores. The nearshore area is steeply to very steeply sloping and has a substrate of bedrock, boulder and shell. The bedrock/boulder beach is steeply sloping and may have some cobble. The bank has similar substrates and is steeply to very steeply sloping. The uplands are gently to strongly rolling with hummocky bedrock outcrops or thin humo ferric podzol soils.

The nearshore biota is divided into three zones. The deepest zone is dominated by two brown algae *(Agarum fimbriatum, Eisenia arborea)*. There are also polychaete tube worms *(Serpula vermicularis)* present in this zone. In the middle zone the giant kelp *(Macrocystis integrifolia)* is found and tube worms and bryozoans are present in small numbers. The zone adjacent to the beach supports japweed *(Sargassum muticum)* and two red algae *(Gelidium robustum, Gigartina sp.)*. Bat stars *(Patiria miniata)* and sea cucumbers *(Cucumaria miniata)* are also present.

The beach is divided into four biotic zones. The low intertidal zone supports the feather boa kelp *(Egregia menziesii)*, a brown alga *(Laminaria groenlandica)* and a red alga *(Gigartina sp.)*. Leather stars *(Dermasterias imbricata)*, sponges *(Haliclona permollis)*, and anenomes *(Anthopleura xanthogrammica, A. elegantissima)* are also common. The vegetation of the mid intertidal zone includes three brown algae *(Hedophyllum sessile, Alaria marginata, Leathesia difformis)* and surf grass *(Phyllospadix scouleri)*. Bay mussels *(Mytilus edulis)* and barnacles *(Balanus glandula, B. cariosus)* are also numerous in the mid intertidal zone. The high intertidal zone has a dense covering of rockweed *(Fucus distichus)*. Periwinkles *(Littorina scutulata, L. sitkana)*, barnacles *(B. glandula)*, finger limpets *(Collisella digitalis)* and snails *(Thais emarginata)* are typical of this zone. A black lichen *(Verrucaria sp.)* occurs in the splash zone.

Lichens grow on the bank but grasses are occasionally present. The uplands support western red cedar *(Thuja plicata)*, western hemlock *(Tsuga heterophylla)* and Sitka spruce *(Picea sitchensis)*. Evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)* are common shrubs along the shore.

types

MT1 follows the system concept.

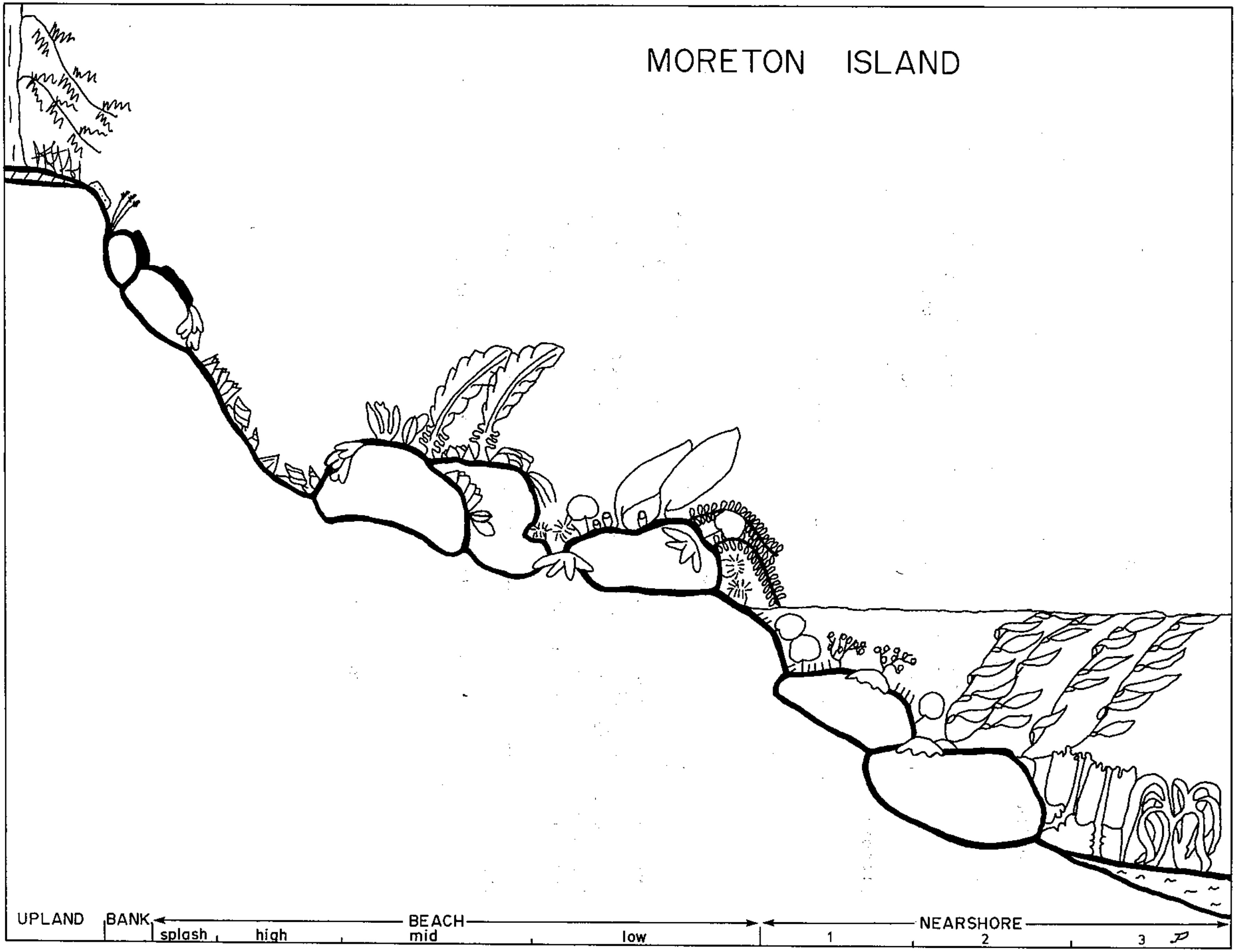


Fig. 59. Schematic profile of Moreton Island system concept.

PACHENA BAY (PA1)

representative location: E shore of Pachena Bay

system concept

The Pachena Bay system occurs in moderate energy (semi-exposed) locations where unconsolidated material accumulates above a bedrock shore. The nearshore is very gently sloping sand in the deeper areas, with strongly sloping bedrock occurring nearer the beach. The beach is moderately to steeply sloping bedrock. Accumulations of cobble, gravel, sand and/or shell are found in the upper beach area. The bank ranges from bedrock to cobble. The uplands are gently to strongly rolling. Gravelly sandy glacio-marine deposits overlying morainal material and sandy morainal blankets are the most common surface expressions.

The flora and fauna were not studied in detail but general descriptions are available. In the nearshore the feather boa kelp *(Egregia menziesii)*, surfgrass *(Phyllospadix scouleri)* and giant kelp *(Macrocystis integrifolia)* are common.

The beach biota can be divided into four zones. The low intertidal zone was not surveyed. The mid intertidal zone is predominantly bay mussels *(Mytilus edulis)* and acorn barnacles *(Balanus spp.)*. On more exposed headlands the California mussel/gooseneck barnacle *(Mytilus californianus/Pollicipes polymerus)* association may occur. The high intertidal zone is characterized by a rockweed *(Fucus distichus)* and a red alga *(Endocladia muricata)*. A black lichen *(Verrucaria sp.)* commonly occurs on the rock of the splash zone. Where the splash zone consists of unconsolidated material, little vegetation occurs.

Grasses and lichens occur on the bank. The spruce/sword fern forest grows on the uplands. Sitka spruce *(Picea sitchensis)*, salmonberry *(Rubus spectabalis)* and sword fern *(Polystichum munitum)* are characteristic of this forest type.

types

PA1 follows the system concept.

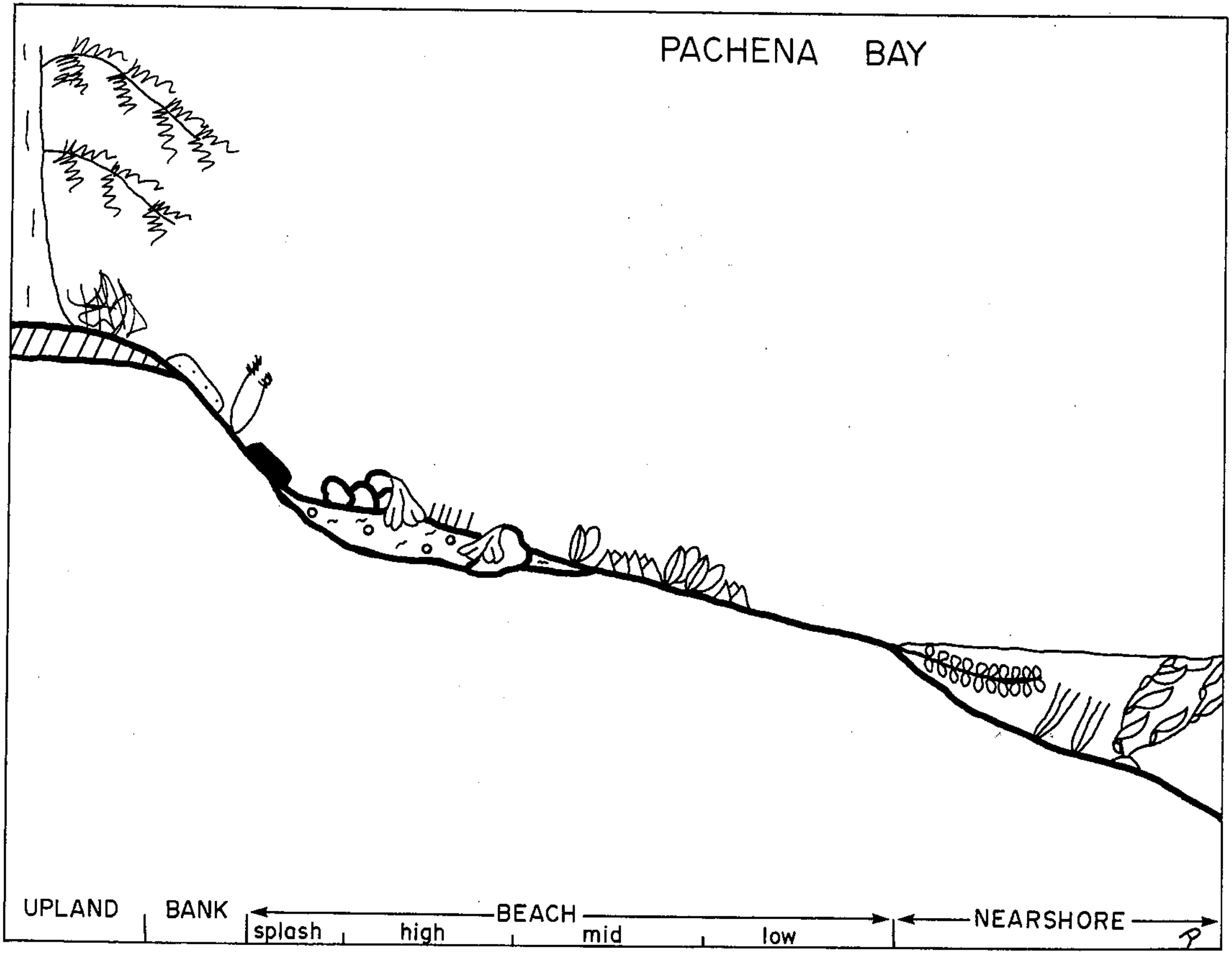


Fig. 60. Schematic profile of Pachena Bay system concept

TURRET REEF (TR1, TR2, TR3)

representative location: small reef on the E side of Turret Island

system concept

The Turret Reef system represents moderate energy (semi-exposed) bedrock shores. The nearshore substrate is bedrock/boulder, but where the site is between two small islands the bottom of the gut is largely cobble and shell. Nearshore slope varies, but steep to extreme slopes are most common. The beach is strongly to very steeply sloping with bedrock substrate. The bedrock bank is steeply to very steeply sloping. The uplands are gently to strongly rolling and are predominantly covered with a veneer of colluvial material although some islands have considerable amounts of hummocky bedrock with little or no soil. The most common soils are humo ferric podzols.

The nearshore area surveyed can be divided into three biotic zones although in shallow locations such as between islets, the deepest zone may not occur. Two brown algae *(Eisenia arborea, Agarum fimbriatum)* are found in the deepest zone. Zone two is characterized by giant kelp *(Macrocystis integrifolia)* and/or an encrusting red alga *(Lithothamnion sp.)*. In the uppermost zone a red alga *(Gelidium robustum)* is found, often with several other less numerous alga species. The distribution of nearshore invertebrates does not exhibit the distinct zonation of the vegetation. Bat stars *(Patiria miniata)*, sea cucumbers *(Parastichopus californicus, Cucumaria miniata)*, red top shells *(Astraea gibberosa)* occur along with assorted sponges, bryozoans and polychaete tube worms. The red sea urchin *(Strongylocentrotus fransiscanus)* occurs sporadically and usually in zone two or below.

The beach is divided into four biotic zones. The low intertidal zone commonly supports a red alga *(Gigartina exasperata)*, brown algae *(Egregia menziesii, Laminaria spp.)* and surfgrass *(Phyllospadix scouleri)*. Conspicuous fauna of the low intertidal zone includes sea stars *(Patiria miniata, Pisaster ochraceus)*, anenomes *(Anthopleura elegantissima)* and sea urchins *(Strongylocentrotus franciscanus)*. A red alga *(Halosaccion glandiforme)*, a brown alga *(Hedophyllum sessile)* and a brown alga *(Leathesia difformis)* are common in the mid intertidal zone. Barnacles *(Balanus glandula, B. cariosus)* and bay mussels *(Mytilus edulis)* are indicative of this zone although California mussels *(M. califonianus)* are often present in smaller numbers than when they occur in high energy locations. The high intertidal zone is characterized by a rockweed *(Fucus distichus)* and barnacles *(B. glandula)*. Periwinkles *(Littorina spp.)* and snails *(Thais emarginata)* are also common. The splash zone is not as extensive as in high energy sites but the biota is similar. *Verrucaria sp.*, a black lichen, is found on the rocks in the splash zone. Finger limpets *(Collisella digitalis)* and periwinkles are the most common fauna.

The bank support lichens on the otherwise bare rock, but grasses and deerfern *(Blechnum spicant)* grow where more fresh water is available. The uplands are forested. Western red cedar *(Thuja plicata)*, western hemlock *(Tsuga heterophylla)* and Sitka spruce *(Picea sitchensis)* are the most common trees. Evergreen huckleberry *(Vaccinium ovatum)* and salal *(Gaultheria shallon)* dominate the shrub layer.

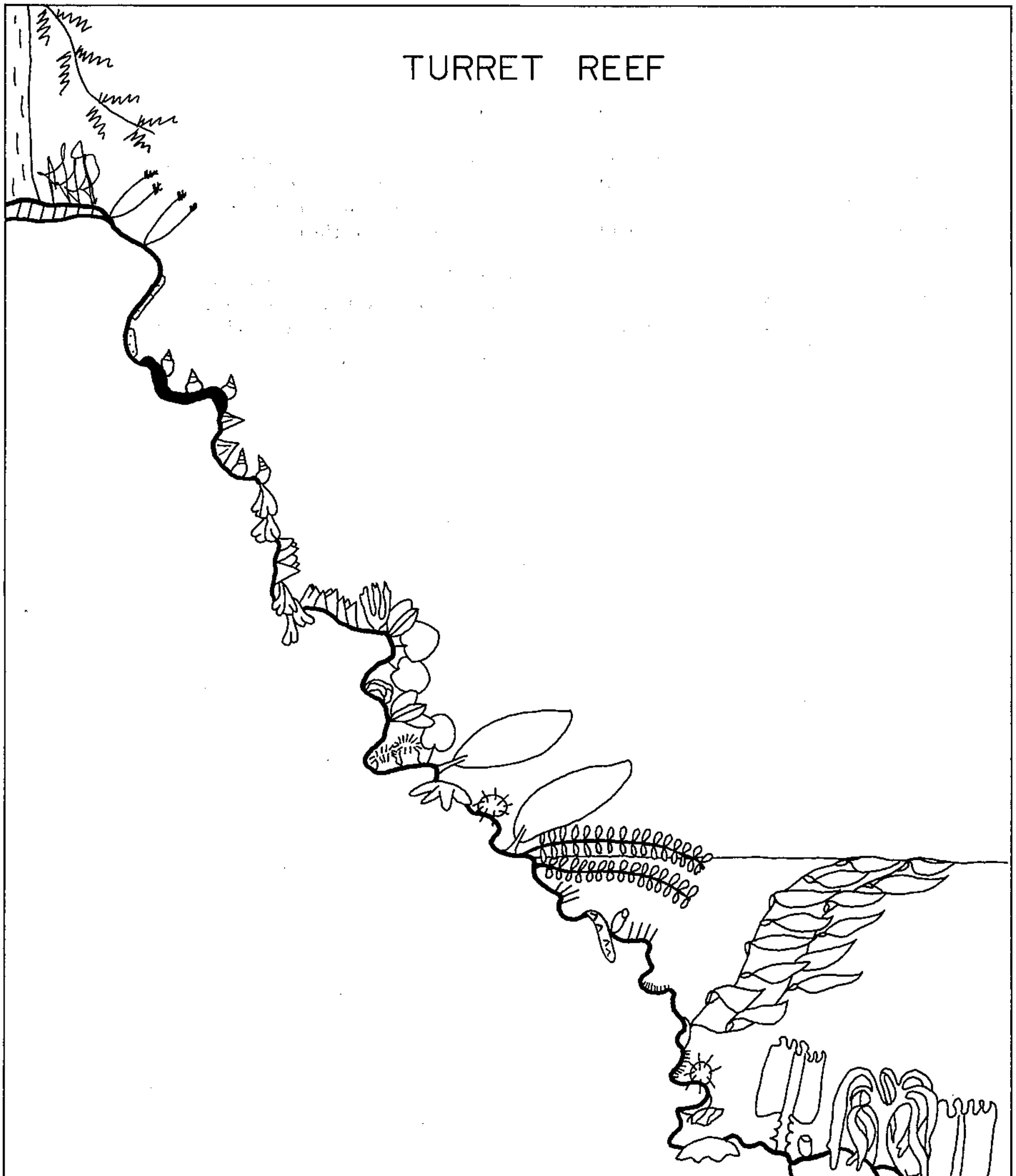


Fig. 61. Schematic profile of Turret Reef system.

types

TR1 follows the system concept.

TR2 deviates from the system concept in the uplands. Here the soils are imperfectly to very poorly drained podzols which overlie a fan of fluvial/ glacial gravel. The uplands are level to undulating. This coastal type is a component of the headland/pocket beach association (HP1).

TR3 is subject to sand scouring in the low intertidal zone. Scouring may cause this zone to become depauperate. The abundant population of starfish *(Pisaster ochraceus)* has reduced the density of the California mussel *(Mytilus californianus)*. The beach is very steep to extremely sloping.

SAN JUAN BENCH (SJ1, SJ2)

representative location: E side of small point on SE side of Carmanah Point

system concept

The San Juan Bench Coastal system describes a moderate energy (semi-exposed) bedrock bench shore. This system is closely related to the West Coast Bench, the primary difference is the energy level. The nearshore is very gently to gently sloping bedrock, usually sandstone or schists which are common in Port San Juan. The beach is a wave-cut shelf of gently sloping bedrock which may have boulders scattered across it. At the back of this shelf accumulations of cobble, gravel and sand occur. This unconsolidated material may form all or most of the very steeply sloping bank. The uplands are generally steeply to very steeply sloping. Bedrock and colluvial veneer occur in approximately equal frequency in the uplands. Well drained orthic regosols are the most common soils.

The nearshore biota was not surveyed in detail but bull kelp *(Nereocystis luetkeana)* was oberved in the nearshore area.

The beach has an energy gradient from the front edge of the shelf (the highest energy) to the back (lower energy), because the waves lose their force as they wash up the rock slope.

The beach can be divided into three biotic zones. The low intertidal zone commonly supports surfgrass *(Phyllospadix scouleri)*, and two brown algae *(Alaria marginata, Egregia menziesii)*. Chitons *(Mopalia sp.)* were found to be common in this zone. The mid intertidal zone common species include a brown alga *(Hedophyllum sessile)*, acorn barnacles *(Balanus glandula)*, mussels *(Mytilus claifornianus, M. edulis)* and finger limpets *(Collisella digitalis)*. In the high intertidal zone a red alga *(Rhodomela larix)* and rockweed *(Fucus distichus)* are common. Acorn barnacles *(B. glandula, B. cariosus)*, finger limpets and periwinkles *(Littorina scutulata, L. sitkana)* also occur in the high intertidal zone. There is not splash zone in this coastal system as the waves no longer have enough energy to splash when they reach the upper end of the beach.

The bank supports little conspicuous biota. Spruce/salal forest and spruce/sword fern forest commonly occur in the uplands. Sitka spruce *(Picea sitchensis)*, salal *(Gaultheria shallon)* and bracken *(Pteridium aquilinum)* are representative of the spruce/salal forest while Sitka spruce, salmonberry *(Rubus spectabalis)* and sword fern *(Polystichum munitum)* characterize the other.

types

SJ1 is described by the system concept.

SJ2 generally follows the system concept, but this coastal type occurs where the uplands support a hemlock/spruce forest. Western hemlock *(Tsuga heterophylla)* and Sitka spruce *(P. sitchensis)* are the dominant tree species.

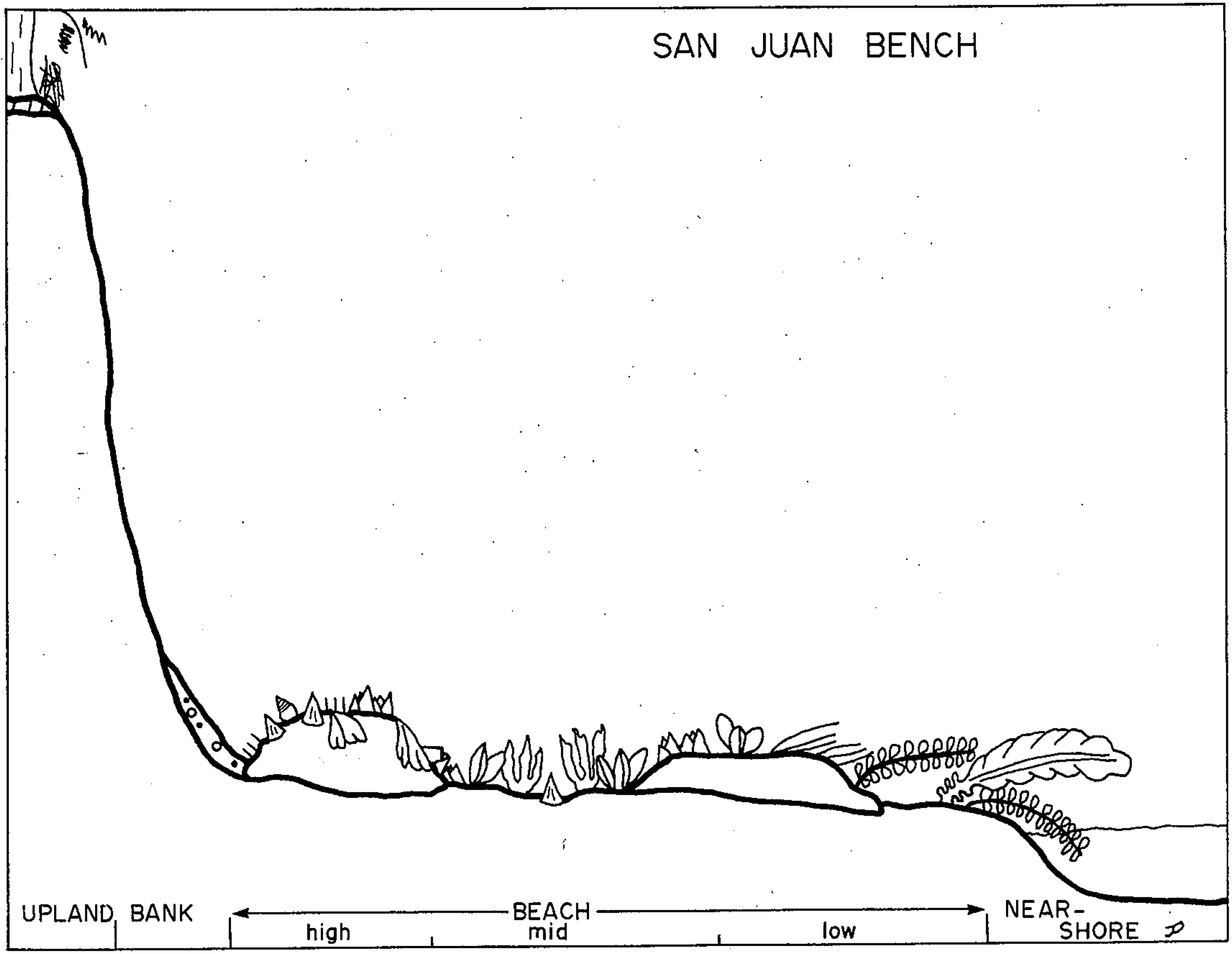


Fig. 62. Schematic profile of San Juan Bench system concept

LONG BEACH (LB1, LB2, LB3, LB4, LB5, LB6)

representative location: Wickaninnish Bay

system concept

The Long Beach system is a high energy (exposed) sandy shore. The nearshore is predominantly sand and has a very gentle slope. The sand of the beach is of marine deposition and has a seasonal variation of slope between a very gentle to gentle slope. The bank of this system varies from a well developed dune at the south end of Wickaninnish Bay to a low cut face at the north end. The dunes are wind deposited sand which forms a veneer to blanket overlying a marine blanket of sand and silt. The topography of the dunes is described as undulating. The uplands display a variety of soil types and drainage patterns. The multiple slopes of the uplands immediately adjacent to the dunes are undulating while the uplands beyond this have a very steeply sloping simple topography.

The nearshore and beach of the Long Beach system have no attached macroscopic algae. The most common nearshore species are the Dungeness crab *(Cancer magister)*, razor clam *(Siliqua patula)*, olive shell *(Olivella biplicata)* and sand dollar *(Dendraster sp.)*.

The beach is divided into three biotic zones. In the low intertidal zone razor clams and olive shells are found while a band of blood worms *(Euzonus mucronata)* occurs in the mid intertidal zone. Beach hoppers *(Orchestoidea californiana)* dominate the high intertidal zone where they feed on decaying seaweed drift. The vegetation of the bank consists mainly of beach grasses *(Elymus mollis, Carex macrocephala)*, dune flowers and stunted Sitka spruce *(Picea sitchensis)*. The upland vegetation is part of the Sitka spruce/salal *(P. sitchensis/Gaultheria shallon)* forest.

types

LB1 is defined by the system concept but also encompasses the inclusions of Grassy Island and Green Point which are exposed bedrock with the biotic association typical of this substrate and exposure (QP1). Small offshore islands and islets such as Lovekin Rock and Sealion Rocks are also bedrock inclusions in this type.

LB2 differs from the system concept in the high intertidal zone and bank portions. There is a cobble/gravel band in the high intertidal zone. This substrate is periodically covered with sand deposited by wind and waves. The bank is a cliff wave-cut into silt and sand of marine deposition. The face of the cliff is partially stabilized by upland vegetation. The uplands are a gravelly fluvioglacial fan, nearly level or undulating; or colluvial veneer. The soils are imperfectly drained (gleyed ortho humo ferric) podzols.

LB3 differs from the system concept in the bank area. The bank consists of a low (<1 m) cut bank in the sandy material of the uplands.

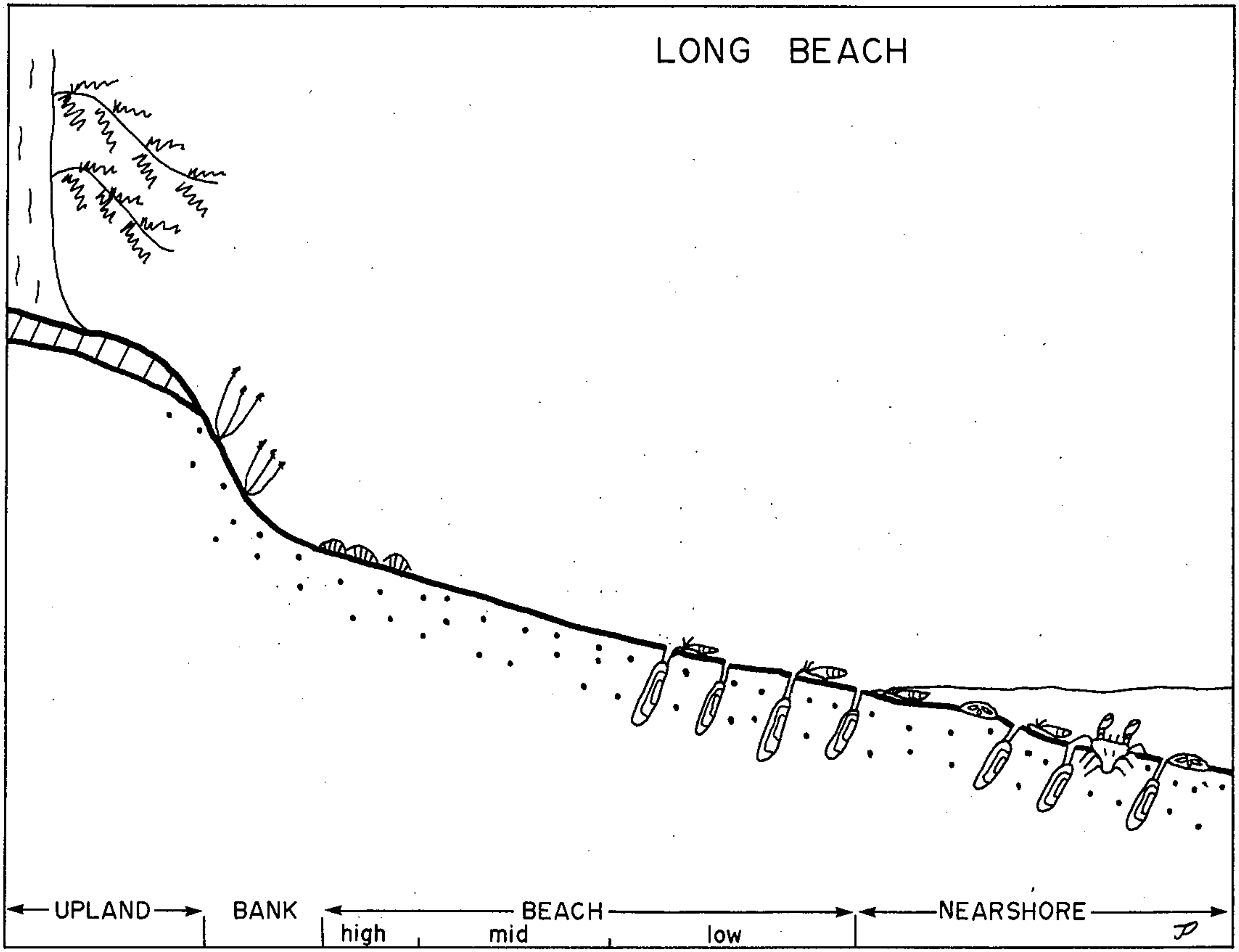


Fig. 63. Schematic profile of Long Beach system concept

LB4 is also a high energy sand shore but the beach is steeply sloping and lacks the biota described in the system concept. The nearshore is gently sloping bedrock. The dunes of LB4 are less well developed than those of LB1, but support similar vegetation. The uplands follow the system concept.

LB5 follows the system concept in most aspects but the nearshore is a moderately sloping sandstone bench. The beach supports the organisms mentioned in the system concept with the exclusion of bloodworms *(E. mucronata)* which were not found in this coastal type.

LB6 generally follows the system concept. However, the beach is steeply to very steeply sloping. No detailed surveys of the beach flora and fauna were completed. The nearshore and uplands follow the system concept but the dunes of the bank are not as extensive as those of LB1. Vegetation on the bank and uplands is similar to the system concept.

remarks

LB1 - The dunes should be protected from direct traffic by boardwalks and vehicle restrictions if they are to be preserved. Over use will disturb the vegetation and increase the likelihood of excessive erosion occurring (Pierce 1973).

LB2 - Florencia Bay has an unstable bank. Access to the beach should be via elevated pathways to minimize erosion; buildings, roads and parking areas should be set well back from the edge of the cliff.

The Long Beach coastal system is both unique and representative in that few extensive sandy beaches occur in British Columbia.

CARMANAH CREEK (CC1)

representative location: gravel/sand beach between Carmanah Point and Carmanah Creek

system concept

The Carmanah Creek system represents high energy (exposed) gravel shores. The nearshore area is a very gently to gently sloping sandstone bench although gravel may accumulate on this bedrock surface. The steeply sloping beach is gravel with sand and cobble. Scattered boulders may also be present. The bank is steeply to very steeply sloping gravel/sand substrate of marine deposition. The uplands are strongly sloping. Colluvial veneer is the most common surface covering; morainal material in a veneer to blanket and a veneer of organic material also occur. The various soils of this coastal system are well to moderately well drained.

The nearshore biota was not surveyed. The beach supports no conspicuous organisms because wave action keeps the substrate in motion.

The bank is colonized primarily by dunegrass *(Elymus mollis)* and sea rocket *(Cakile edulenta)* along with a complex mixture of other grasses and herbs. The upland vegetation is part of the spruce/salal forest. Sitka spruce *(Picea sitchensis)*, salal *(Gaultheria shallon)* and bracken *(Pteridium aquilinum)* are the representative species.

type

CC1 is defined by the system concept.

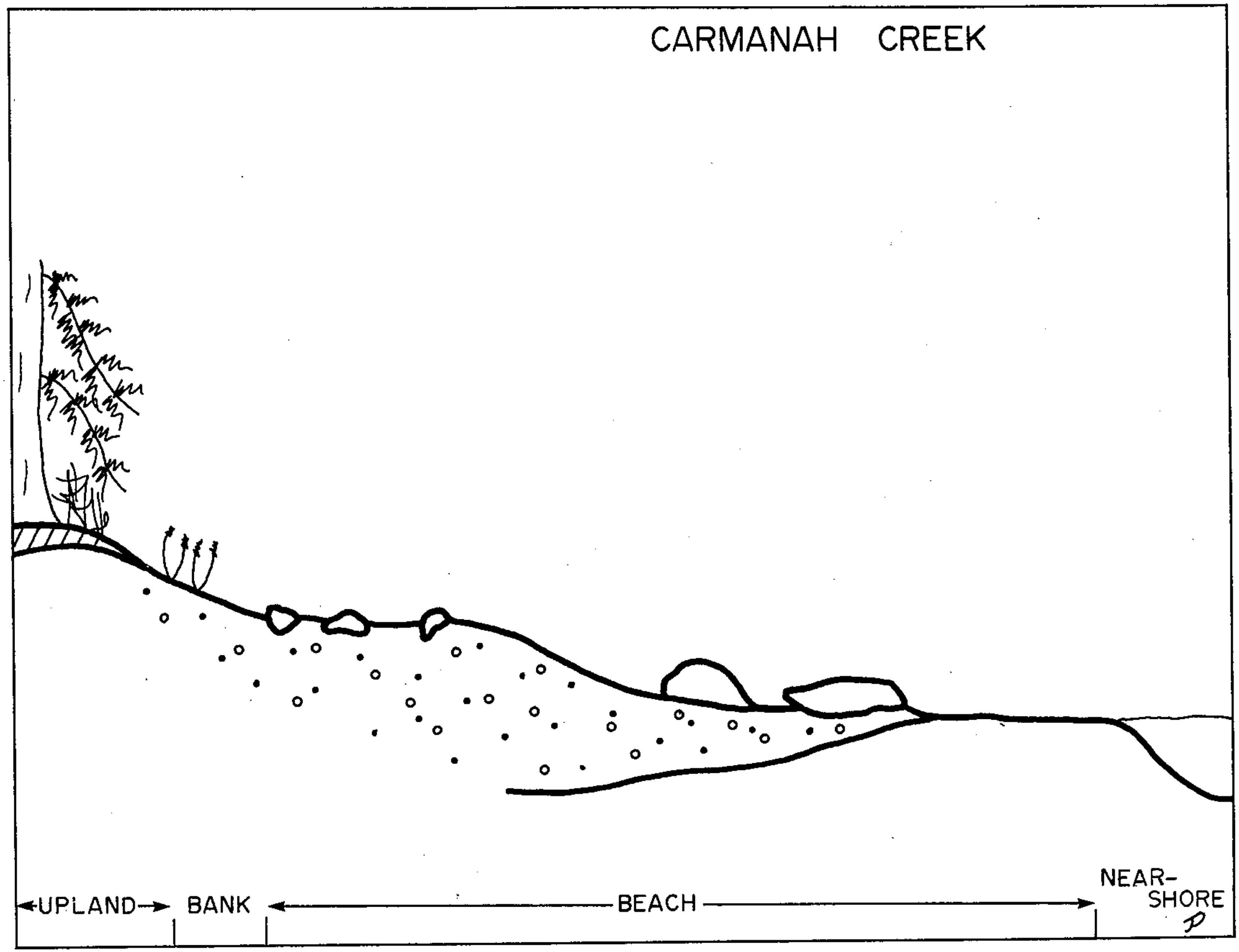


Fig. 64. Schematic profile of Carmanah Creek system concept

CAMPER CREEK (CR1)

<u>representative location</u>: beach on the E side of Camper Creek mouth

<u>system concept</u>

The Camper Creek coastal system is high energy (exposed) locations with cobble/gravel substrates. In the West Coast Trail Section of Pacific Rim National Park this coastal system occurs as small beaches at creek mouths. The gently to moderately sloping nearshore often has a bedrock substrate. The beach is steeply sloping cobble and gravel. The cobble/gravel bank is steeply to very steeply sloping. The uplands are primarily covered with a colluvial veneer, but hummocky bedrock outcrops also occur. The soils near the creek are moderately well to imperfectly drained podzols, with very steep to extreme slopes.

Biota of the nearshore was not surveyed. The beach can be divided into two biotic zones, but they do not correspond to the zones described in the "Zonation of marine fauna and flora" section. In the low intertidal zone a brown alga *(Alaria marginata)* and sea lettuce *(Ulva sp.)* are most common. California mussels *(Mytilus californianus)*, barnacles *(Balanus glandula, B. cariosus)*, and unidentified amphipods are also present. A green alga *(Spongomorpha coalita)* occurs in the upper zone along with barnacles *(B. glandula, B. cariosus)*, bay mussels *(Mytilus edulis)* and isopods *(Exosphaeroma sp.)*.

The bank supports little vegetation. A hemlock/spruce forest covers the uplands. Western hemlock *(Tsuga heterophylla)* and Sitka spruce *(Picea sitchensis)* are the most common tree species.

<u>types</u>

CR1 is defined by the system concept.

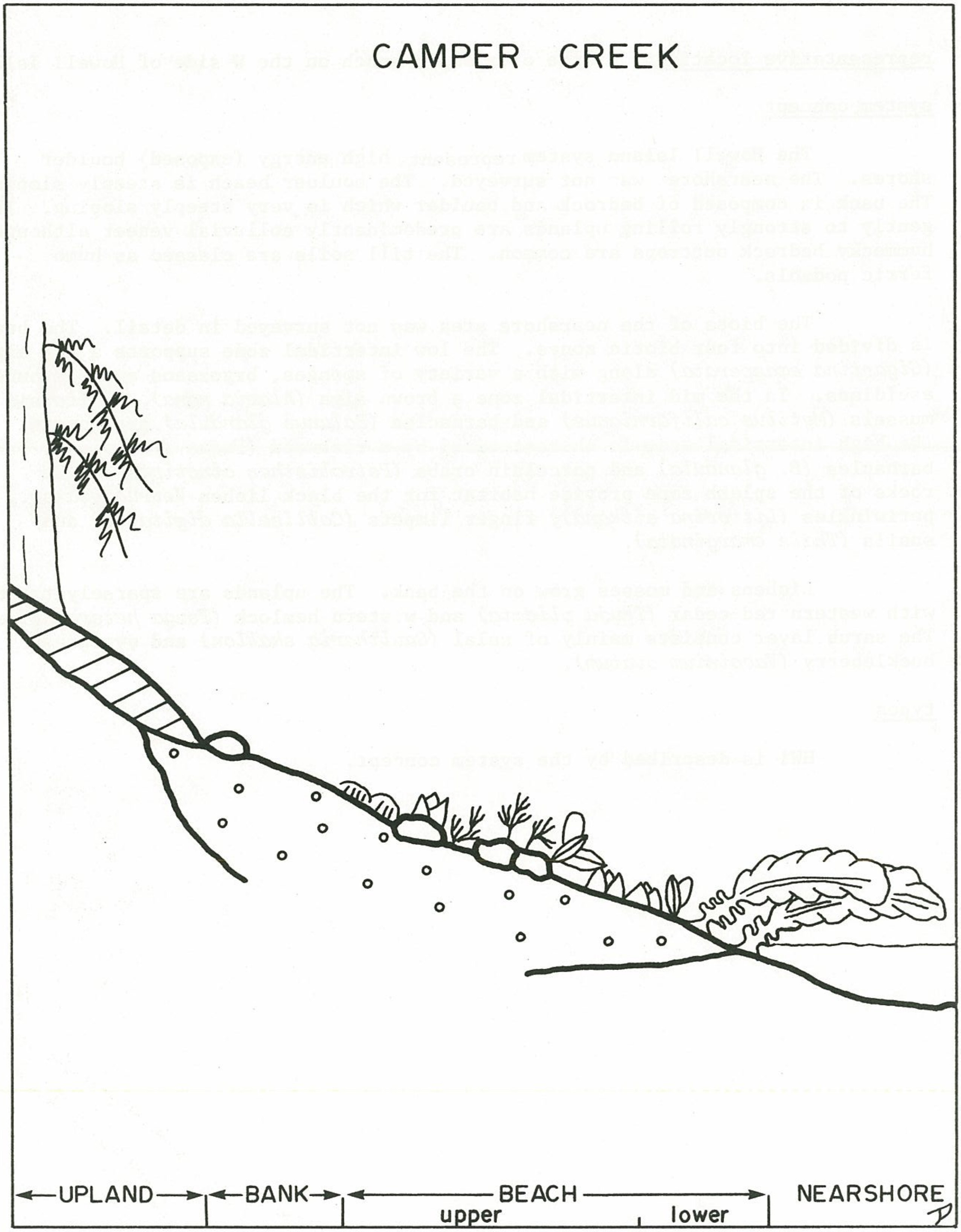


Fig. 65. Schematic profile of Camper Creek system concept

HOWELL ISLAND (HW1)

<u>representative location</u>: S side of a small beach on the W side of Howell Island

<u>system concept</u>

The Howell Island system represents high energy (exposed) boulder shores. The nearshore was not surveyed. The boulder beach is steeply sloping. The bank is composed of bedrock and boulder which is very steeply sloping. The gently to strongly rolling uplands are predominantly colluvial veneer although hummocky bedrock outcrops are common. The till soils are classed as humo ferric podzols.

The biota of the nearshore area was not surveyed in detail. The beach is divided into four biotic zones. The low intertidal zone supports a red alga *(Gigartina exasperata)* along with a variety of sponges, bryozoans and compound ascidians. In the mid intertidal zone a brown alga *(Alaria nana)*, California mussels *(Mytilus californianus)* and barnacles *(Balanus glandula)* are common. The high intertidal zone is characterized by a rockweed *(Fucus distichus)*, barnacles *(B. glandula)* and porcelain crabs *(Petrolisthes cinctipes)*. The rocks of the splash zone provide habitat for the black lichen *Verrucaria sp.*, periwinkles *(Littorina sitkana)*, finger limpets *(Collisella digitalis)* and snails *(Thais emarginata)*.

Lichens and mosses grow on the bank. The uplands are sparsely treed with western red cedar *(Thuja plicata)* and western hemlock *(Tsuga heterophylla)*. The shrub layer consists mainly of salal *(Gaultheria shallon)* and evergreen huckleberry *(Vaccinium ovatum)*.

<u>types</u>

HW1 is described by the system concept.

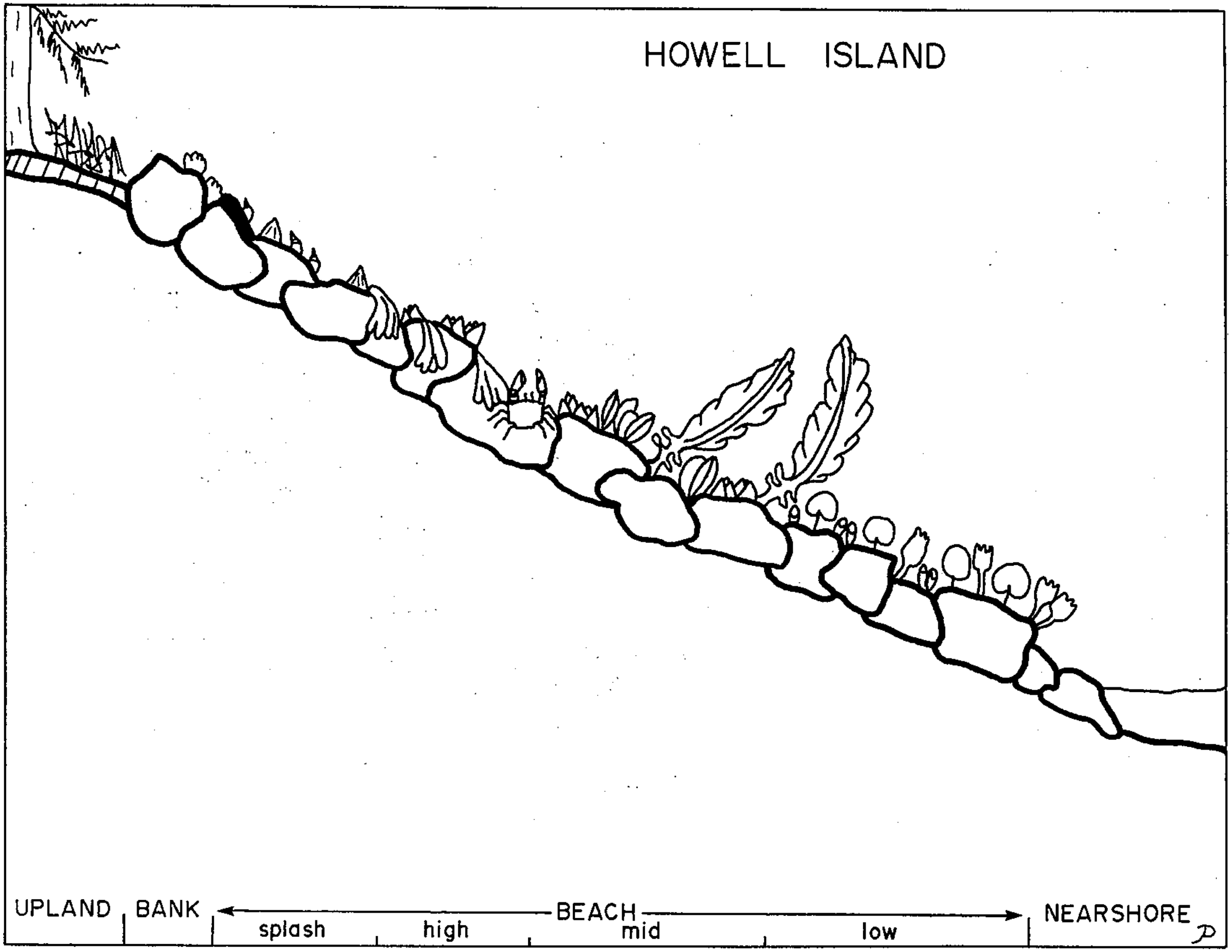


Fig. 66. Schematic profile of Howell Island system concept

SOUTH WOUWER (SW1)

<u>representative location</u>: beach on the S side of Wouwer Island

<u>system concept</u>

The South Wouwer system consists of high energy (exposed) bedrock shores. The nearshore substrate is primarily bedrock but may have some boulder as well. Slopes range from nearly level to extremely sloping, but very steeply sloping to extremely sloping are most common. The beach is steeply to extremely sloping bedrock. The bank is also bedrock with slopes similar to the beach. The uplands are gently to strongly rolling. Colluvial veneer is more common than hummocky bedrock as an upland surface expression. The thin till soils are humo ferric podzols.

The nearshore biota can be divided into two biotic zones. The lower zone supports an encrusting red alga *(Lithothamnion sp.)* often with a variety of other species of algae. Red sea urchins *(Strongylocentrotus fransiscanus)*, tube worms *(Dodecaceria fewkesi, Serpula vermicularis)*, sponges and bryozoans also occur in this zone. In the zone adjacent to the beach bull kelp *(Nereocystis luetkeana)*, a brown alga *(Desmarestia ligulata)* and *Lithothamnion sp.* are the most common flora. The tube worms common in the lower zone are also found in the upper zone.

The beach can be divided into four biotic zones. The low intertidal zone is characterized by brown algae *(Laminaria setchellii, Alaria nana, Lessoniopsis littoralis)*, and a red alga *(Gigartina exasperata)*. Few animals occur in this zone. The mid intertidal zone in high energy locations is identified by the California mussel/goose neck barnacle *(Mytilus californianus/ Pollicipes polymerus)* association. Acorn barnacles *(Balanus glandula)* are also common. A variety of algal species may be abundant, these include: *G. exasperata*, surfgrass *(Phyllospadix scouleri)* and *A. nana*. The brown algae *Fucus distichus* and *Pelvetiopsis limitata* are characteristic of the high intertidal zone. Limpets *(Collisella digitalis)* and barnacles *(B. glandula)* are common beneath the algae. The splash zone is dominated by finger limpets *(C. digitalis)*, periwinkles *(Littorina sitkana)*, barnacles *(B. glandula, Chthamalus dalli)* and the black lichen *Verrucaria sp.*

The bank often appears to be a wide strip of bare rock. Lichens and mosses may become established in crevices where they are not exposed to the full effect of the sun and wind. The uplands nearest the shore are vegetated by a dense bank of wind-sculptured shrubs *(Vaccinium ovatum, Gaultheria shallon)* and stunted trees. Further inland the trees are taller but widely spaced and many of the western red cedar *(Thuja plicata)* have dead tops. Other tree species present are western hemlock *(Tsuga heterophylla)* and Sitka spruce *(Picea sitchensis)*.

<u>types</u>

SW1 follows the system concept.

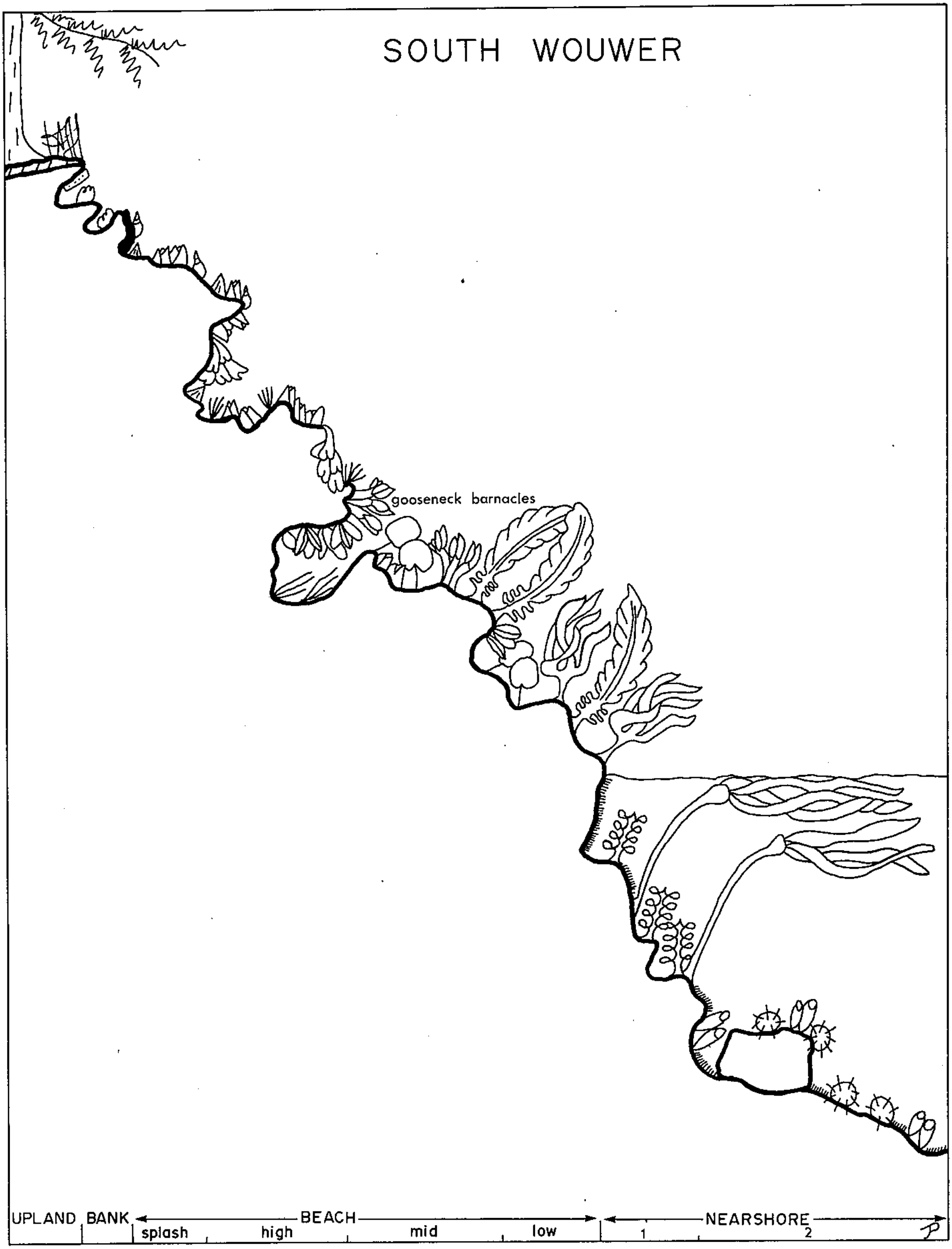


Fig. 67. Schematic profile of South Wouwer system concept.

<u>remarks</u>

Areas where this coastal system occurs would be suitable for supervised beach walks as there is a wealth of biota to be seen and explained.

QUISITIS POINT (QP1)

representative location: S side of Quisitis Point, adjacent to Florencia Bay

system concept

The Quisitis Point system is a high energy (exposed) bedrock shore. The nearshore is a very gentle to gentle sandy slope. The beach area is hummocky bedrock which ranges from very steeply sloping to near vertical. The bank is also bedrock with the same range of slopes as the beach. The uplands immediately adjacent to the shore are bedrock with thin, rapidly to well drained soils. The uplands are nearly level to undulating.

The nearshore biota was not surveyed in detail but includes the bull kelp *(Nereocystis luetkeana)* in higher energy locations and giant kelp *(Macrocystis integrifolia)* in lower energy areas.

The beach is divided into four distinct biotic zones. The low intertidal zone is characterized by the sea palm *(Postelsia palmaeformis)*, a brown alga *(Laminaria setchellii)* and the black turban snail *(Tegula funebralis)*. The mid intertidal zone supports *Hedophyllum sessile* and the goose neck barnacle/ California mussel *(Pollicipes polymerus/Mytilus californianus)* association which characterizes high energy rocky shores. The high intertidal zone supports primarily rockweeds *(Fucus distichus, Pelvetiopsis limitata)* and barnacles *(Balanus glandula)*. *P. limitata* occurs only on high energy rocky shores. In the splash zone the ubiquitous black lichen, *Verrucaria sp.*, green alga *(Prasiola meridionalis)* and finger limpets *(Collisella digitalis)* are the dominant species.

The bank may be bare or sparsely colonized by various terrestrial lichens. The upland vegetation is typical of the Sitka spruce *(Picea sitchensis)* coastal fringe.

inclusions

High energy rocky shores regularly include distinctive features too small to be mapped. The most common are tide pools and surge channels.

Tide pools occur at all intertidal levels. These depressions in the rock hold water after the tide receeds thus providing a less harsh environment for intertidal organisms. This results in an upward displacement of intertidal species relative to their "normal" distribution.

A surge channel is a fissure in the rock, usually perpendicular to the shoreline, which is formed when an intrusion of softer rock erodes away. The bottom of the surge channel is often filled with sand or gravel which churns continually under the force of the incoming waves. Waves entering the seaward end of the channel rush up it with great force, often breaking well above the waves on the surrounding shore. This feature tends to extend the intertidal associations upward when compared to the unindented shore. The flora and fauna of a surge channel are typical of exposed, wave-beaten coasts, although longer channels may exhibit a gradation of exposure from exposed at the outer end to protected at the head. Because of the upward displacement of organisms the goose neck barnacle/California mussel association may be found well above the mid intertidal zone where it usually occurs. The feather boa kelp *(Egregia menziesii)* often occurs in the low intertidal areas within a surge channel along with numerous sponges, tunicates, and encrusting and upright coralline algae.

types

QP1 is defined by the system concept. The system concept is also one component of the rocky headland/pocket beach association which is common within the Long Beach Section of Pacific Rim National Park.

remarks

Supervised beach walks could be conducted in areas where this coastal system occurs because there is a wealth of marine organisms to be seen and explained.

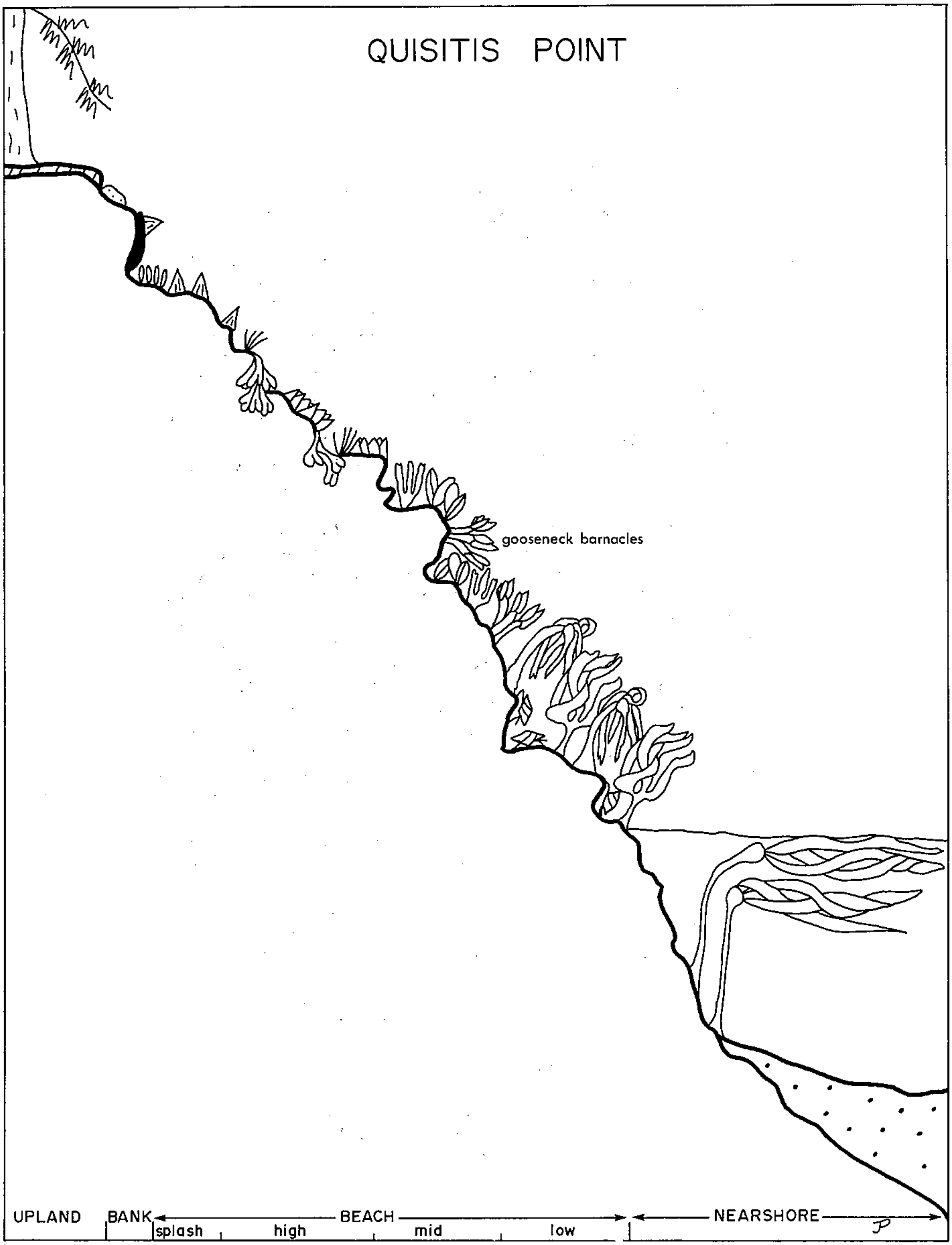


Fig. 68. Schematic profile of Quisitis Point system concept.

WEST COAST BENCH (WB1)

representative location: bench 4 km W of Klanawa River mouth

system concept

The West Coast Bench system defines a high energy (exposed) bedrock shore common in the West Coast Trail Section of Pacific Rim National Park. The very gently to gently sloping nearshore usually consists of bedrock with sand occurring farther from shore. The beach is a bedrock bench which is nearly flat to gently sloping. This wave-cut platform is usually sandstone and/or siltstone, although conglomerate occurs in some locations. The bench may be strewn with boulders or relatively clear. In the upper beach area and above the high tide line accumulations of cobble, gravel and sand are common. These slumping gravity deposits are steeply to extrememly sloping and form part or all of the bank. In some locations there is a vertical rock face behind this accumulation of unconsolidated material, while elsewhere the forest slopes gradually back from the shore. The uplands near the shore are strongly sloping with gently rolling multiple slopes. A colluvial veneer is the most common surface but morainal veneers or blankets and organic veneers also occur. The various soils are moderately well to imperfectly drained.

The nearshore biota was not surveyed in detail but beds of bull kelp *(Nereocystis luetkeana)* were observed below the low tide level. The bench configuration of the beach area dissipates the energy of the incoming waves as they wash over the bedrock surface. The organisms at the front edge of the bench (which often corresponds closely with the low tide level) are typical of high energy bedrock shores. Farther back along the bench flora and fauna of moderate or low energy shores are found. This situation creates a peculiar association of three biotic zones in the beach area. The low intertidal zone commonly supports sea palms *(Postelsia palmaeformis)*, surfgrass *(Phyllospadix scouleri)* and brown alga *(Alaria marginata)*. Goose neck barnacles *(Pollicipes polymerus)*, purple sea urchins *(Strongylocentrotus purpuratus)* and ochre starfish *(Pisaster ochraceus)* are commonly abundant in the low intertidal zone along with two species of sponge *(Haliclona permollis, Ophlitaspongia pennata)*. In the mid intertidal zone a brown alga *(Hedophyllum sessile)* and a red alga *(Halosaccion glandiforme)* are most common. Barnacles *(Balanus glandula, B. cariosus, Chthamalus dalli)*, California mussels *(Mytilus californianus)* and anenomes *(Anthopleura elegantissima)* occur in the mid intertidal zone. The algae most common in the high intertidal zone are rockweed *(Fucus distichus)* and a red variety *(Rhodomela larix)*. The barnacles present in the mid intertidal zone also occur in the high intertidal zone along with periwinkles *(Littorina sitkana, L. scutulata)* and finger limpets *(Collisella digitalis)*. There is no splash zone on the West Coast Bench because by the time the waves reach the back of the beach they no longer have enough energy to splash.

The organisms described above are not distributed evenly over the substrate. The front face of the bench is usually densely populated with algae and invertebrates. These are the low intertidal organisms. The mid and high intertidal species tend to be concentrated in crevices and behind protective bedrock structures. The flatter bedrock surfaces are covered sparsely, if at all.

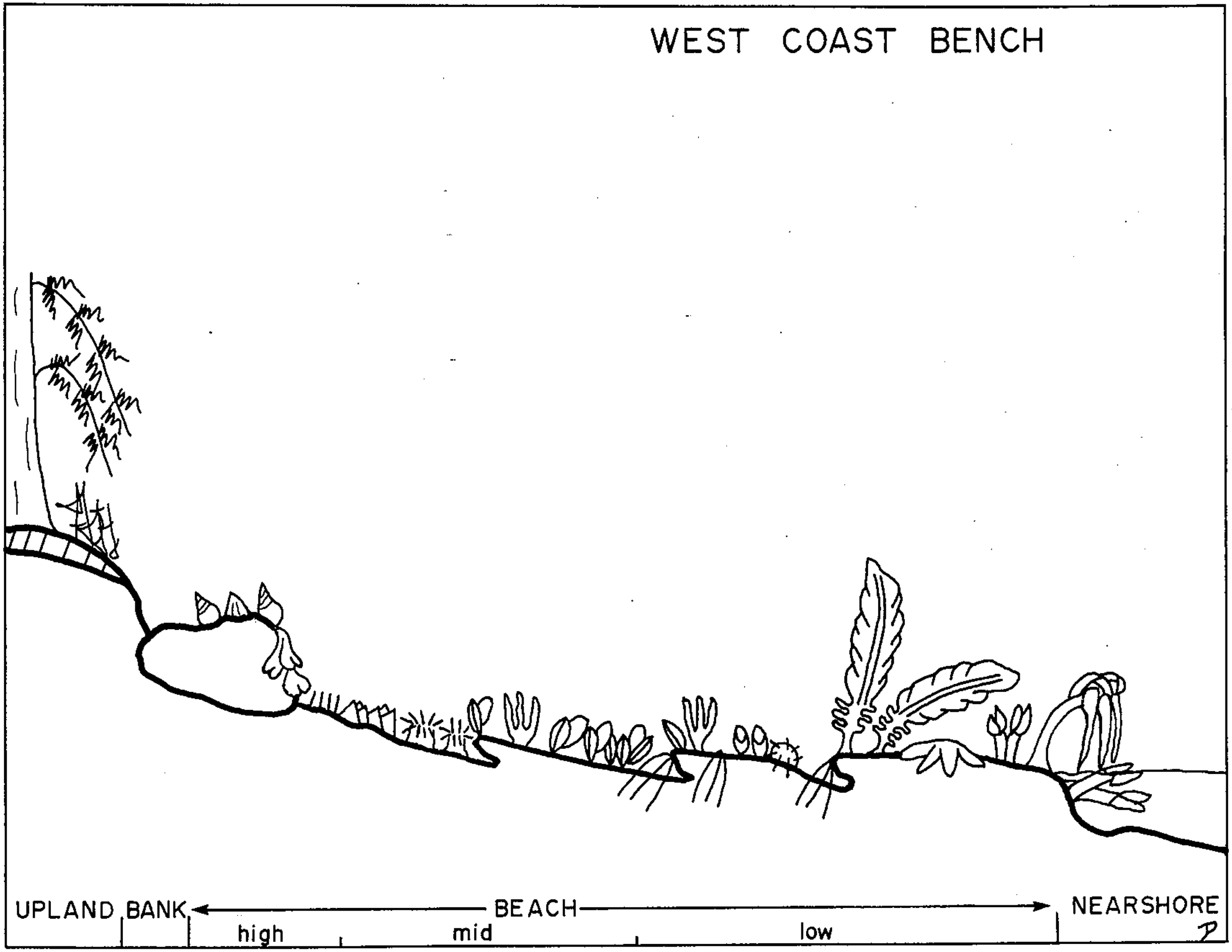


Fig. 69. Schematic profile of West Coast Bench system concept

The bank, regardless of whether it is a bedrock cliff or an accumulation of cobble, gravel and sand, supports few plants. The uplands are forested. Two forest types are common. The spruce/salal forest, with Sitka spruce *(Picea sitchensis)*, salal *(Gaultheria shallon)* and bracken *(Pteridium aquilinum)* as the representative species; and the spruce/sword fern forest characterized by Sitka spruce, salmonberry *(Rubus spectabalis)* and sword fern *(Polystichum munitum)*.

types

WB1 is defined by the system concept.

remarks

This coastal system could be the basis of an interesting interpretive program because the configuration of the bench lends itself to having organisms typical of high energy and low energy situations within close proximity of each other.

POCKET BEACH (PB1)

representative location: Radar Beaches

system concept

The Pocket Beach coastal system is not directly analagous to other coastal systems presented in this report. It was developed to designate map units where the specific substrate and associated biota were not known at the time of mapping.

The Pocket Beach coastal system is a moderate to high energy shore (semi-exposed to exposed) of variable substrate. The nearshore is a very gentle sandy slope. The beach may be composed of sand, shell, gravel or boulder or a combination of these. Substrate movement is primarily in the onshore-offshore direction. The slope is variable ranging from gentle to strong and the beach profile may change substantially from season to season. The bank is usually a very steep to extreme bedrock slope. The uplands may be of various soils, slopes and drainage patterns.

The nearshore biota is usually similar to that of the surrounding coastal types. The variety and density of biota on a pocket beach is related to the stability of the substrate. Small pocket beaches at the head of what are little more than wide surge channels are often barren and steep. The sand, shell or gravel on these beaches is in such constant turmoil that no macroscopic organisms can become established. Rarely, if ever, does macroscopic algae occur. Larger pocket beaches, which provide a more stable environment, support biotic associations. The vegetation of the bank and uplands is similar to that of the surrounding area.

types

PB1 is defined by the system concept and is one of the components of the Headland/Pocket Beach Association (HP1).

PB is used as a map unit designation where the actual substrate of the pocket beach and associated biota were not known at time of mapping.

HEADLAND/POCKET BEACH ASSOCIATION (HP1, HP2)

representative location: shore between Cox and Portland Points

system concept

The Headland/Pocket Beach Association occurs along moderate to high energy (semi-exposed to exposed) shores. The major components which generally make up this association include high energy bedrock (QP1, SW1), moderate energy bedrock (TR) and pocket beaches (PB1).

The topography, substrate and biota have been discussed under the appropriate component of the association.

Where bedrock and pocket beaches are alternately recurring units or where both units occurred but were too small (less than 5 mm on scale of map used) to be mapped separately, the designation for Headland/Pocket Beach Association (HP1 or HP2) was used.

types

HP1 is the designation used in predominantly high energy locations. In the Long Beach Section larger pocket beaches, as illustrated in Radar Beaches, are included in this map unit designation.

HP2 includes the same components as HP1, but is used in largely moderate energy locations.

GLOSSARY

ADVECTION -heat transfer by the horizontal movement of air or water

BANK -transition zone between beach and uplands where vegetation is strongly influenced by salt water (eg. dunes)
-face of cliff with marine vegetation below and terrestrial vegetation above

BATHOLITH -a body of intrusive rock more than 40 square miles in extent (Holland 1976)

BEACH -refers to intertidal zones 1 to 4 (where applicable)
zone 1 = splash or spray zone
zone 2 = high intertidal zone
zone 3 = mid intertidal zone
zone 4 = low intertidal zone (Lee and Bourne 1976, 1977, 1978, 1979)
-from ELWS to EHWS which includes zone of splash from breaking waves.

BENTHIC -that which lives on the sea bottom

BENTHOS -the assemblage of plants and animals living on the sea bottom

BRACKISH -somewhat saline, briny

BRECCIA -a clastic rock composed principally of large angular fragments; usually the clasts are all derived from the same parent formation

CLASTIC ROCK -a sedimentary rock formed from mineral particles (clasts) that were mechanically transported

CONVERGENCE -the act, fact or state of coming together by gradual approach

CORIOLIS FORCE -the deflecting effect of the earth's rotation whereby freely moving air masses, water masses, etc., are deflected to the right in the northern hemisphere and to the left in the southern hemisphere

DECIBAR -a unit of pressure equivalent to 10^5 dynes/cm^2
-roughly numerically equivalent to depths in the ocean measured in meters

DIVERGENCE -the act or state of moving outward from each other

DOWNWELLING -a downward flow of water

ENTRAINMENT -upward transfer of salt from the more dense oceanic water to the overriding estuarine discharge when there is a velocity shear between the zones
-greatest shear occurs in the halocline

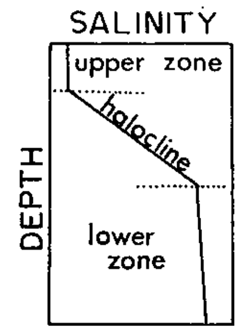
ESTUARY -where the tide meets a river current; expecially an arm of the sea at the lower end of a river

ESTUARINE WATER -water pertaining to an estuary

FETCH -as used in describing the formation of wind waves, the fetch is the horizontal length of the generating area in the direction of the wind

GYRE -a circular motion or path

HALOCLINE -a salinity boundary between low salinity and high salinity water



INDURATE -to make hard

INFAUNA -animal species that live within the substrate (eg. clams and cockles)

INSOLATION -exposure to the rays of the sun

ISO (ISOHALINE, ISOTHERMAL, ETC.) -combining form; equal, the same, identical

ISOHALINE -of uniform salinity

ISOTHERMAL -of uniform temperature

KNOT -unit of velocity (50.2 cm/sec)

MELANGE -a formation consisting of a heterogeneous mixture of rock materials on a mappable scale. Fragments of diverse composition, size and texture have been mixed and consolidated by tremendous deformational pressure.

MODERN SEDIMENT -sediment deposited during the conditions still previling in the area
-see also relict sediment

NAUTICAL MILES -1 minute of latitude = 6080 feet = 1853 m = 1.853 km = 1 nautical mile
-used on Mercator charts

NEARSHORE -refers to subtidal zone (Lee and Bourne 1976, 1977, 1978, 1979)

PENEPLAIN -an area worn down by erosion until it is almost a plain

PHYTOPLANKTON -the marine plant organisms that drift or float with currents, waves, etc., unable to influence their own course: distinguished from benthos

PRIMARY PRODUCTIVITY -the rate at which energy from light is absorbed and utilized with carbon dioxide in production of organic matter in photosynthesis

PYCNOCLINE -when the halocline and thermocline coincide a density boundary, or pycnocline, develops between low density and high density water

RELAXATION -the state when water masses are neither converging nor diverging

RELICT SEDIMENT -sediment deposited during an earlier environment, under conditions no longer prevailing
-see also modern sediment

RIA -a long narrow inlet, with depth gradually diminishing inward

ROCK -any naturally formed, consolidated or unconsolidated material (but not soil) composed of two or more minerals, or occasionally of one mineral, having some degree of chemical or mineralogical constancy
-therefore, rock includes deposits such as clay, sand and gravel

SET -the direction of a current or wind

SLOPE -the degree of inclination of the surface
-in this report, slopes are given in terms of vertical distance as a percentage of horizontal distance; thus a 45° slope = 100% slope

SOIL -finely divided rock mixed with vegetable or animal matter, constituting that portion of the surface of the earth in which plants grow

STRUCTURE (Temperature and Salinity)
-the term structure refers to the distribution of properties of the water, usually in the vertical sense
-in this report salinity struture is depicted by a graph of salinity as a function of depth

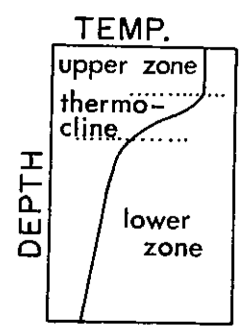
TECTONIC -characteristic of, or relating to, the structure of the earth's crust, especially as due to deformation

TERRIGENOUS -of, or pertaining to, marine deposits formed of material washed from the land, and to the sedimentary rocks consolidated from this material

TIDE -the periodic rising and falling of the water that results from gravitational attraction of the moon and sun acting upon the rotating earth. Although the accompanying horizontal movement of the water resulting from the same cause is also sometimes called the tide, it is preferable to designate the latter as tidal current, reserving the name tide for the vertical movement.

TIDE, SEMI-DIRUNAL MIXED -two complete tidal cycles daily with inequalities both in height and time reaching the greatest values when the declination of the moon has passed its maximum

THERMOCLINE -a temperature boundary between cold water and warmer water



UPLANDS -area above bank extending away from beach for undetermined distance; vegetation essentially terrestrial

UPWELLING -deep water rising to the surface

ZOOPLANKTON -the marine animal organisms that drift or float with currents, waves, etc., unable to influence their own course: distinguished from benthos

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APPENDIX 1: SUMMARY OF RESEARCH PROJECTS - 1975-1979

The marine resources study, begun in 1975 in Pacific Rim National Park (Lee and Bourne 1976) was completed April 1979 on behalf of Parks Canada, Western Region, by Lee and Adkins Ltd. in affiliation with the Pacific Biological Station (Nanaimo), Fisheries and Marine Service, Department of Fisheries and Oceans. This program was designed to provide information on marine communities for park planning, interpretation and management. Investigations, conducted in all three sections of the park, included identification of habitat types, fauna and flora surveys and recreational impact studies.

Habitat types in the intertidal areas were identified and mapped for all three sections of the park. Although investigations of subtidal habitats were undertaken in the Broken Group Islands, insufficient data was collected to map their distribution. Criteria used to define habitat types were degree of wave exposure, substrate and "indicator" species, where applicable (Lee and Bourne 1976). Maps showing intertidal substrates and exposures to surf are given in Lee and Bourne (1977).

Fauna and flora surveys in 1975 included studies of the distribution and relative abundance of biota in the intertidal area. These data were used to broaden species lists and habitat types, to identify unique areas and areas of high recreational use for long term studies (Lee and Bourne 1976). From 1976 to 1979, emphasis was placed on obtaining quantitative data in order to determine yearly and seasonal levels of marine populations within the park. These data were collected from representative intertidal and subtidal sites, where possible. Results were recorded and discussed by habitat type in annual reports (Lee and Bourne 1977, 1978, 1979).

Recreational impact studies were conducted in the Long Beach and Broken Group Islands Sections. Razor clam *(Siliqua patula)*, littleneck clam *(Protothaca staminea)*, and sea mussel *(Mytilus californianus)* were the bivalve populations studied in the Long Beach Section. Investigations on the purple olive snails *(Olivella biplicata)* and starfish *(Pisaster ochraceus)* were undertaken to assess population distributions. Bivalve population studies in the Broken Group Islands included a general distribution survey and a detailed assessment of population size and structure.

Intertidal and subtidal distribution and density of the adult razor clam population at Long Beach were measured from 1975 to 1977. Studies included measuring growth rates, determining time of spawning and measuring density of the incoming year class. Study results indicated recruitment was poor and the adult population was small. Growth rates and time of spawning agreed with data reported by Bourne and Quayle (1970). The major clam population at Long Beach has not changed significantly over a ten year period (Bourne and Quayle 1970; Lee and Bourne 1976, 1977, 1978).

Before 1971, the littleneck clam population in Florencia Bay was considered fairly large and was moderately exploited. In 1971, due to increased numbers of people using this beach, this population was thought by parks personnel to be seriously depleted. From 1975 to 1976 a study was undertaken to determine the size and density of this population.

The littleneck clam population in Florencia Bay is small and rather unique as this species usually inhabits beaches in quieter waters. The amount of habitat suitable for this clam is small and constantly changing. It is unlikely that the population will increase much over present levels, and the extent of the future population will depend primarily on the regularity of recruitment.

Sea mussels are found in the intertidal area on exposed rocky shores in all three sections of the park. These mussels will probably become more popular as a seafood and therefore populations of this species will receive increasing exploitation. Studies were undertaken (from 1975 to 1979) to determine the re-establishment pattern and recovery time of a completely denuded mussel bed area and (from 1976 to 1977) to obtain some information on the effect of different exploitation rates on sea mussel beds.

The recolonization of the cleared mussel plot followed the sequence of: 1)Within 3 months - growth of an algal film accompanied by an influx of herbivores (snails and limpets). 2)After 1 year - a noticeable macroscopic algal coverage along with mussel and barnacle settlement and an increase in numbers and species of limpets and snails. 3)After 2 years - an increase in mussel density occurred with an increase in red alga *(Endocludia muricata)* coverage. Although the total numbers of animals and plants continued to increase in the cleared area, recolonization to the original level of 1975 had not been attained by the spring of 1979.

In 1976 and 1977 varying numbers of large mussels were removed from 10 plots marked in a mussel bed. By May 1979 the outlines of these areas were barely distinguishable from the remainder of the mussel bed. Removal of the surface layer of mussels may have allowed for some movement of mussels adjacent to the removal areas.

Olivella biplicata are collected in large numbers by the public during the summer. Studies to assess intertidal populations and distribution of *O. biplicata* on Long Beach were conducted from 1975 to 1979. The density of *Olivella* increased throughout the summer; their range up the intertidal beach also increased during this time. However, this population was not distributed homogeneously throughout the sample area and tended toward a clumped distribution. Each year the disappearance of this species from the intertidal area coincided with a series of fall storms.

A brief subtidal survey of *O. biplicata* was conducted in 1976 and 1977. As in the intertidal population, the distribution of subtidal *Olivella* was not homogeneous. Subtidal density of this species throughout the year showed that *Olivella* may migrate into the intertidal area in spring and then return to the subtidal area in fall.

Starfish are also collected by tourists; the most common species taken is *Pisaster ochraceus*. A study begun in 1975 to determine seasonal changes in density of starfish populations at Long Beach was conducted until 1977. Numbers of *Pisaster* steadily decreased at two sites throughout the summer. This decrease was not considered to be due to removal by tourists, because no collecting was reported in these areas. Decreases may be due to migration into deeper water during the summer (to reduce dessication), since both sites had a western exposure and received considerable direct afternoon sunlight.

Littleneck, butter and Manila clams and Pacific oysters are bivalve species commonly harvested in the Broken Group Islands. A survey to determine the distribution of intertidal bivalve populations in the Broken Group Islands was conducted in 1975 and 1976. In general, populations of these species in the beaches sampled were not extensive. Detailed studies on clam population size and structure were undertaken at five of the nine locations that supported larger bivalve populations. Clam populations at these sites could support moderate exploitation. Digging would remove older clams which would be replaced by smaller clams in the population. Further exploitation would depend on survival of smaller clams and future recruitment.

APPENDIX 2: RECOMMENDATIONS

Studies of marine communities within Pacific Rim National Park were undertaken between 1975 and 1979. Both quantitative and long term studies were included because they are essential to understanding the ecology and community structure of marine life and establishing baseline levels. The studies were divided into the following categories:

1) systematics and distributional studies
2) fauna and flora surveys including zonation pattern studies

and 3) recreational impact studies.

Systematics and distributional studies of marine biota should be constantly reviewed since they are essential to an understanding of marine population and community associations.

Fauna and flora surveys and recreational impact studies not only contributed to the understanding of population fluctuations on seasonal and yearly bases but also provided baseline information for further management of the marine resources within the park. These studies should be continued on a monitoring basis to provide further information on recruitment in areas where recreational pressures have or will become concentrated.

Over the past five years, the recreational fishery within the park has substantially increased in importance. Pressure from this fishery has also increased and must be monitored closely. It should be pointed out that recreational fisheries include not only edible species but also those species collected for souvenirs, since populations of the latter can frequently be damaged as easily as the former. Isolated or "esthetically pleasing" populations could be quickly reduced by recreational fishery.

One solution to existing or potential recreational fishery over-exploitation may be to prohibit the removal of any marine organisms in the park, making exceptions with size and daily bag limits for edible species. Closures and limits such as these are outlined in the current B.C. Tidal Waters Sports Fishing Guide (Fisheries and Oceans 1980). Where certain populations, such as razor clams (Long Beach Section) and abalone and rock scallops (Broken Group Islands) may support only low or moderate exploitation, monitoring programs, bag and size limits, and closures should be reviewed yearly to ensure that these populations are not depleted.

For those species collected by the tourists but not covered under the Sports Fishing Guide (eg. starfish, olive snails, mussels), monitoring programs should be continued and interpretive programs intensified (Lee and Bourne 1976). Knowledge on recruitment and survival of these and similar populations in areas where recreational pressures are more intense is essential to resource management.

Recreational fishery of residential marine fish stocks (eg. rockfish species) has also increased steadily. This situation, which is particularly prevalent in the Broken Group Islands, should be monitored closely to prevent over-exploitation of these stocks.

As little information is available on residential marine fish stocks within the park boundaries, detailed baseline studies should be undertaken. Information on distribution, abundance, age composition and growth rates would provide a sound basis for the formulation of management policies governing the future of residential marine fish stocks within Pacific Rim National Park.

SCUBA divers are another group of recreational fishermen who may engage in spearfishing (lingcod are a favourite prey), shellfish collection (abalone and scallops, particularly) or collection of other marine organisms. The establishment of underwater trails could be used to reduce exploitation of marine biota and increase diving pleasure. The trails could cover a range of diving situations taking into consideration technical difficulty (currents, depth), esthetics (shape, form and colour; shipwrecks), topography (cliffs, reefs) and scientific interest (typical and unique biotic associations). These trails could become the focus of an interpretive program on the subtidal areas of the park.

An underwater "no collecting" policy should be instituted with these trails. Regular monitoring of the trails by parks personnel would be needed to enforce this policy.

Potential pollution problems must also be considered in monitoring programs.

Heavy seasonal boat traffic in the Broken Group Islands may lead to a situation where bilge effluent dumped in protected bays may contaminate the clam beds found in these locations. A careful check on coliform counts should be instituted where large numbers of boats occur.

The extensive use of the West Coast Trail by hikers necessitates the establishment and maintenance of adequate outhouse and garbage disposal facilities. These measures must be taken to ensure the preservation of adequate drinking water supplies and the esthetic beauty of the trail.

Within Pacific Rim National Park there are numerous recognized archaeological sites (see confidential Archaeology section) ranging from shell middens to burial caves. These sites are protected by provincial law under the Heritage Protection Act (Government of B.C. 1977). Interpretive programs should include information on these existing laws and on the locations of Indian reserves which, although they are not part of the park, are often used as such. Management policies paralleling the Heritage Protection Act should be developed covering all archaeologically important locations within the park.

Geological considerations often have to be taken into account during the formulation of park management strategies.

The silty clays which form the cliffs at Florencia Bay are stable when dry but become plastic and unstable and prone to slumping when wet. Such slumping can be largely avoided by minimizing topsoil and vegetation disturbance, and by providing piped or guttered drainage from these cliffs (Muller 1974). Any development must be set well back from the edge of the cliff (Pierce 1973).

The dunes at Long Beach act as a natural sand storage reservoir and dissipate incoming wave energy. These areas, while resilient to natural forces, can be quickly eroded by human activities. It is suggested that no development or groundwater extraction be allowed in dune areas. Extraction of fresh groundwater may allow saltwater intrusion, killing existing vegetation and exposing the dunes to extensive erosion. Pedestrian traffic should be restricted to elevated walkways and no vehicular traffic permitted (Bara, Tiner and Newkirk 1977).

Decisions regarding the location of future development within the park should be made after considering the degree of erodability of the soil. Studies such as that done by T.W. Pierce (1973) should provide adequate background information for the formulation of sound management decisions.

Literature

Recommendations specifically pertaining to Pacific Rim National Park can be found in references 123, 148 and 162. More general management information is contained in references 8, 12, 17, 26, 27, 28, 31, 38, 45, 99, 103, 119, 138, 146, 147, 149, 174, 175 and 180.

APPENDIX 3: GEOLOGIC TIME SCALE
(Holland 1976, Muller 1974)

PERIOD	DISTINCTIVE RECORDS OF LIFE	APPROXIMATE NUMBER OF YEARS AGO
	CENOZOIC ERA	
Quaternary		
Recent		last 10 000
Pleistocene (ice age)	Appearance and development of man	10 000 to 1 000 000
Tertiary		(Millions)
Pliocene	Dominance of elephants, horses, large carnivores	1 to 13
Miocene	Development of whales, bats, monkeys	13 to 25
Oligocene		25 to 36
Eocene	Development of primitive mammals	36 to 58
Paleocene	Earliest horses	58 to 63
	MESOZOIC ERA	
Cretaceous	Development of flowering plants; extinction of dinosaurs	63 to 135
Jurassic	Climax of dinosaurs; first birds	135 to 181
Triassic	First dinosaurs; first primitive mammals	181 to 230
	PALAEOZOIC ERA	
Permian	Conifers abundant; reptiles developed	230 to 280
Pennsylvanian	First reptiles, great coal forests, abundant insects	280 to 325
Mississippian	Echinoderms abundant	325 to 345
Devonian	First amphibians, earliest forests	345 to 405
Silurian	First land plants and animals	405 to 425
Ordovician	Earliest primitive fishes	425 to 500
Cambrian	Large invertebrate faunas, trilobites predominant	500 to 600
	PROTEROZOIC ERA	
Keweenawan and Huronian	Earliest known records of simple organisms	600 to 2 000
	ARCHAEAN ERA	
Temiskaming and Keewatin	Oldest dated rocks	2 000 to 4 800

APPENDIX 4: LATE PLEISTOCENE GLACIATIONS OF SOUTHWESTERN BRITISH COLUMBIA

(Muller 1974)

GLACIATION	FORMATION	AGE (1 000 years)
Fraser Glaciation	Sumas Drift	10 to 11
	Capilano Sediments	11 to 14
	Vashon Drift	13 to 21
Olympia Interglaciation	Quadra Sediments	25 to 36
Salmon Springs (?) Glaciation	Dashwood Drift	37

APPENDIX 5: CHRONOLOGICAL HISTORY OF COASTAL CLASSIFICATION

RESEARCHER(S)	DATE	LOCATION	MAJOR CONTRIBUTION TO COASTAL ZONE MANAGEMENT
Dana	1849	N. America	-observed the effect of submergence
vonRichtofen	1866		-first ordering of shorelines
Suess	1888	N. America	-noted the different geological trends of the Atlantic and Pacific coasts
Davis	1898		-emergence/submergence theory on coastal classification -defined two classes of coastline
Gulliver	1899		-described shoreline topography by geological process and geomophological form
Johnson	1919		-formulated a system to classify coastal landforms -added neutral and compound categories to emergent/submergent concept
Putman	1937	Pacific	-advanced the concept of cyclic marine erosion to the Pacific coast
Shepard	1937		-advanced the concept of primary and secondary coasts; further classified these by process
Stewart	1945	N. America	-developed physiographic system for use by navigators; acknowledged man-made features
McCurdy	1947	U.S.A.	-added vegetative, man-made and ice cap categories to Johnson's system in a U.S. Navy manual for use with aerial photographs -presented a set of map symbols
Stephensen and Stephensen	1948	Australia	-published a now standard reference on intertidal zonation as applied to Australian coastlines
Cotton	1952	New Zealand	-presented concept of stable and mobile coast regions
Valentin	1952	Germany(?)	-developed a system based on continuous changes; two classifications, the first in terms of configuration based on past processes (advancing or retreating), the second, a diagramatic method of distinguishing between advancing and retreating coasts
Price	1954	U.S.A. Gulf of Mexico	-subdivided coasts into zero, low, moderate & high energy classes calculated from ramp angles and mean breaker heights
Putman	1954	U.S.A.	-proposed an essentially physiographic system that could be based almost entirely on aerial photography

Fleming and Elliott	1956	U.S.A. Mexico	-proposed a delineation of coasts based on factors such as size of drainage basins, supply of fresh water and sediments to the ocean and degree of coastal indentation
McGill	1958	Global	-described the development of a world map of coastal landforms, largely a physiographic approach
Guilcher	1958	Europe	-presented a wholly geological classification -divided coasts initially into: ria, fjord, glacial lowland, unglaciated lowland and structurally dominated coasts
Powers	1958	Lake Michigan	-developed a geomorphological system for fresh water shorelines, subdividing backland, shore and landface into mapping elements
Putman, Axelrod, Bailey and McGill	1960	U.S.A.	-published an illustrated description of the coastal zones of the world; not actually a classification system; designed for U.S. Navy use
Tanner	1960	U.S.A.	-introduced an equilibrium concept based on a balance between coastal energy and littoral drift for the Florida coast
Ballantine	1961		-developed an exposure scale for rocky shores based on biological factors
Alexander	1962	California	-proposed a system based on vertical shore profile and the shore outline in plan
Ottman	1962	France	-proposed a five-category geological typing of coastlines based on form including submarine morphology
Davies	1964	Global	-outlined the application of oceanographic processes (tidal range, storm waves) to coastal classification
Bloom	1965		-proposed a three-dimensional framework encompassing time, the emergence/submergence theory and local processes to describe shorelines
Ottman	1965		-published a book on marine geology
Alexander	1966	Tanganyika	-proposed a set of mapping symbols to represent shore forms
Zendovich	1967	U.S.S.R.	-introduced a classification of coastal accumulation forms
Lacate	1969	Canada	-developed a biophysical land classification system based on geomophology, soils, vegetation and climate -the basis for a biophysical coastal classification (Warren and Anderson 1975)

Mann et al.	1970		-coordinated a group that produced a report describing techniques for evaluating and classifying coastal landscapes
Brown, Fisher, Erxleben and McGowen	1971	Texas	-introduced "resource capability units" for the Texas coastal zone encompassing physical, biological and process units as well as man-made units
Inman and Nordstrom	1971		-developed a hierarchical morphologic system of coastal classification with first order divisions based on tectonic plates
Owens	1971	Nova Scotia Chedabucto Bay	-a descriptive approach to mapping sediments and shoreline features
Davies	1972	Global	-published a book on coastal classification advocating an approach based on climatic considerations
Dolan, Hayden, Hornberger, Zieman and Vincent	1972	N. and S. America	-introduced a classification of world coastal environments incorporating various marine, biological and geological parameters
Fisher, McGowen, Brown and Groat	1972	Texas	-published environmental geologic information on the Texas coast in atlas form; management orientated
King	1972		-a contemporary text on coastal geomorphology with a review of major coastal classification systems
Dolan, Hayden, Fisher, Vincent, Vincent, Resio and Biscoe	1973		-continuation of 1972 work, proposed a biophysical system to classify characteristics across the coastal zone
Dubois	1973	Saint Lawrence River	-produced a system of mapping physiographic and sedimentological units for parts of the St. Lawrence R. coastlands
Zoltai, Pollett, Jeglum and Adams	1973	Canada	-prepared a hierarchical classification for wetlands and aquatic habitats incorporating morphology, soils and vegetation information
Bauer	1974	Oregon	-proposed a shore zone classification emphasising geo-hydraulic action, and recognizing backshore, foreshore and offshore features
Odum and Copeland	1974	U.S.A.	-presented a novel classification based on energy source and stress of natural and man-modified ecosystems
Owens	1974		-proposed a 10-order hierarchical, geologically oriented classification ranging from continental to micro-morphological features

Warren and Anderson	1975	Newfoundland	-used a revision of Lacate's (1969) biophysical land classification to inventory St. George's Bay and Conception Bay, Newfoundland
Cowardin, Carter, Golet and LaRoe	1976	U.S.A.	-added detail, especially to the marine units, to Zoltai et al. (1973)
Thie and Ironside (eds.)	1977	Canada	-proceedings of the first meeting of the Canada Committee on Ecological (Biophysical) Land Classification, May 25-28, 1976 -topics discussed under general headings of present status in Canada, developments in classification methodology and project reports
Welch (ed.)	1977	Canada	-minutes of the first meeting of the working group on land/water integration, Feb. 17-18, 1977, Canada Committee on Ecological (Biophysical) Land Classification
Welch (ed.)	1978	Canada	-review of water classifications and proposals for water integration into ecological land classification
Rubec	1979	Canada	-proceeding of second meeting of Canada Committee on Ecological (Biophysical) Land Classification, April 4-7, 1978 -topics discussed under general headings of reports by chairmen and workshops, reports by provincial and federal agencies, and background papers on applications in Canada

APPENDIX 6: TERMS OF REFERENCE 1979-80

For a
MARINE BIOPHYSICAL INVENTORY
of
PACIFIC RIM NATIONAL PARK, B.C.

INDIAN AND NORTHERN AFFAIRS
PARKS CANADA

March 31, 1979
(Year Five of a Five Year Project)

1) INTRODUCTION

The following terms of reference were originally prepared by Charlene Lee and Dr. N. Bourne, Fisheries and Marine Services in February 1975, and subsequently modified as follows:

a) March 1975 by C. Zinkan, to satisfy Parks Canada's format requirements.

b) February 18, 1976 by C. Zinkan to update the terms of reference as agreed at a review meeting in the Park - February 11, 1976.

c) March 31, 1977 by P. Benson and L. McIntosh to update the terms of reference as agreed at a review meeting in the Park, March 9, 1977 and to accommodate a change in the contract responsibility with Lee and Adkins Ltd., from Fisheries and Marine Services, D.O.E. to Parks Canada.

d) March 1978 by D. Reynolds and M. Elder to satisfy final year field requirements.

e) February 16, 1979 by P. Benson, K. Seel and M. Elder to detail final year report requirements.

Effective the 3rd year of the project (1977/78), the Pacific Biological Station no longer administered this project. The contract will now be directly between Lee and Adkins Ltd., Biomarine Consultants and Parks Canada. The latter will assume contract administration.

The intent of these terms of reference remains unchanged from those developed when the project was initially envisaged. The principal researcher (Miss Charlene Lee), principal advisor (N. Bourne), and the privileges offered by the Pacific Biological Station (consultation, lab facilities, publication) will also remain. The continuing interest of the Station in this project and their offer of assistance to ensure that the project requirements are adequately met are recognized as essential by all.

2) PURPOSE

2.1 The principal aim of this project is to undertake a biophysical approach to a resource inventory of the marine flora and fauna of Pacific Rim National Park. The study shall include, but not necessarily be limited to the following:

2.1.1 a qualitative assessment of the marine flora and fauna within the proposed Park boundaries;

2.1.2 a quantitative assessment of the organisms described in 2.1.1;

2.1.3 a description of their habitat type (2.1.1);

2.1.4 an evaluation of the effect of recreational pressure and human encroachment.

2.2 The information required in 2.1 is to ensure effective Park planning, interpretation and resource management, and is an integral part of the resource inventory program for Pacific Rim National Park.

3) PROJECT AREA

Marine biophysical inventory will incorporate all three phases of Pacific Rim National Park (Long Beach, Broken Group Islands and West Coast Trail). The boundaries of the study area will extend from the high tide to subtidal depth of 18 m (10 fathoms (60 ft.)).

4) PROJECT REQUIREMENTS

4.1 The major emphasis of the inventory is on the invertebrate population within the Park. In addition, attention will also be given to the fish populations.

Because the lower limit of the photosynthetic zone and of most recreational diving is 15 m (50 ft.), data requirements for depths greater than 15 m will be extrapolated from sampling, etc., done at shallower depths where possible.

4.2 More specifically, but without limiting the generality of the foregoing, the project requirements for 1979/80 include:

4.2.1 To develop a biophysical marine classification for the intertidal and subtidal environments of Pacific Rim.

4.2.2 To present the marine environment as recurring map units, in report and map format similar to: Walker, B.D., S. Kojima, W.D. Holland and G.M. Coen. 1976. Land classification of the Lake Louise study area, Banff National Park. Envir. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alberta. Inf. Rep. NOR-X-160.

and handouts.

4.2.3 To provide interpretation of the data for Park's purposes.

4.2.4 To provide a summary of the research projects and its achievements over the past 5 years.

4.3 The biophysical approach for this marine project will include:

4.3.1 Vertical zonation will be described within map units. (three-dimensional concepts)

4.3.2 Type local for each map unit will be delineated.

4.3.3 Mapping sysmbols will be limited to not more than 5 alpha numeric characters and will appear on the maps and in the reports. Additional details should be presented in an extended legend and report.

4.3.4 Polygon boundaries separating intertidal and subtidal units will be selected by the researcher in consultation will Parks Canada.

4.3.5 Each biophysical unit will indicate a pattern of habitat, flora and fauna within defined environmental limits.

4.3.6 Terminology used in the annual reports will be retained. Rigorous definition of terms is desirable, as is standarized usage.

4.4 Scale of biophysical presentation is to be at 1:25 000.

5) SUBMISSION REQUIREMENTS

5.1 The contractor shall submit 25 copies of the final report, on or before August 31, 1980. The report shall include but not be limited to:

5.1.1 A summary of a review of pertinent literature outlining marine biophysical classification systems developed for other areas.

5.1.2 Reference to all previous reports on Pacific Rim National Park authored by the contractor.

5.1.3 A description of standards, procedures and criteria used in definition of the biophyscial units for Pacific Rim.

5.1.4 An explanation of the maps and the information presented on them.

5.1.5 A description of each map unit and systems of map units.

5.1.6 A discussion of the significance of the various map units in terms of National Parks management and interpretation. These interpretations to be based on the past 4 years research in Pacific Rim as well as the contractors' expertise and knowledge of the marine environments, with emphasis placed on:
1. sensitivity or suitability to visitor use.
2. importance of the units for park interpretation.
3. scientific importance.

5.1.7 A section deccribing any monitoring or updating programs. It should recommend a schedule and make reference to the methodology and comparative results. It should be geared to the Warden Service.

5.1.8 Recommendations to be contained in a separate appendix.

5.1.9 The report to be suitably bound, with illustrations, maps and photos as appropriate.

5.2 The contractor shall submit one copy of biophysical map in black and white and appropriately labelled detailing each of the map units. The scale for Long Beach and West Coast Trail shall be 1:25 000. The presentation scale of the Broken Broup Islands map shall be 1:12 500 although the biophysical concepts and map unit definitions shall be those of the 1:25 000 scale. All 25 copies of the report shall make reference to the maps.

5.3 The contractor shall submit progress reports as follows.

5.3.1 On or before August 1, 1979, the report table of contents.

5.3.2 On or before October 1, 1979, a draft of the biophysical legend.

5.3.3 On or before December 1, 1979, a draft of one of the biophysical maps.

6) PROJECT COSTS
The total cost of work for the 1979/80 contract year shall be
Following Teasury Board approval of the contract, payment will be made as follows:

6.1 Upon receipt of the August 1 progress report, the sum of

6.2 Upon receipt of the October 1 progress report, the sum of

6.3 Upon receipt of the December 1 progress report, the sum of

6.4 Upon receipt of a satisfactory final report and completion of all contract requirements on or before August 31, 1980, the sum of

Total

7) COMPLETION SCHEDULE
1979/80 is the final year of the five year project which began in 1975/76.

8) MATERIALS SUPPLIED BY PARKS CANADA
The contractor (Lee and Adkins Ltd.) shall provide all material and equipment required for the completion of the study with the exception of:

8.1 Chronoflex base maps, transparencies, and/or paper prints of the area at a scale of 1:12 500, 1:25 000 and 1:50 000 for final mapping.

8.2 For the field seasons 1976/77 to 1979/80 inclusive Parks Canada will make available one Zodiac boat (Grand Rapid III) with 20 hp. motor and a smaller 7 hp. backup motor. Parks Canada will also attempt to provide cabin facilities in the Broken Group Islands, Jaques Island and will encourage staff assistance in diving when staff time permits.

8.3 For the field season 1979/80 Pacific Rim Naiional Park will provide one VHF radio with charger and alkaline battery, 3 life vests (DOT approved), 2 Coleman stoves, 2 Coleman lanterns (with carrying cases), rain gear, herbarium paper, underwater paper, field books, whirl pac bags, colour slide film, Coleman fuel and marine gas.

9) SPECIAL CONDITIONS

9.1 The contrator shall be:
Lee and Adkins Ltd.
Biomarine Consultants
Box 47, Norasea Drive
R.R. #1, Lantzville, B.C. VOR 2HO

9.2 The principal researcher shall be: Miss J. Charlene Lee

9.3 The contract supervisor shall be the Resource Studies Manager, Parks Canada, Calgary.

9.4 The field supervisor shall be the Superintendent, Pacific Rim National Park.

9.5 All reports shall be sent to:
Director
Western Region - Parks Canada
Dept. of Indian and Northern Affairs
134 - 11th Ave. S.E.
Calgary, Alberta T2G 0X5
Attention: Resource Studies Manager

9.6 The contractor agrees not to transfer the responsibility to a third party without the consent of the Department.

9.7 The contract price includes all expenses which may be recovered by the contractor from Parks Canada in connection with the work.

9.8 The contractor shall supply all equipment and materials required for the study, except where otherwise specifically noted in this contract, and shall provide all necessary assistance and pay all incidental expenses.

9.9 The final report will be professionally adequate in content, presentation and terminology, and of a quality such that it could, at the descretion of the Director, Western Region, Parks Canada, be published. The reports paid for under this contract are the property of Parks Canada.

9.9.1 In this section:

(a) "copyright work" means any work in which a copyright may subsist, produced in or as a result of performing the contract.

(b) "publication" or "publish" do not include disclosure to an academic supervisor or appraiser for the sole purpose of academic evaluation.

9.9.2 Copyright in any copyright work vests in Parks Canada but in any publication of such work by or on behalf of Parks Canada the contribution of the contractor and of the author shall be acknowledged.

9.9.3 The contractor and the author each shall have a royalty free non-exclusive licence to publish or have published any copyright work in the course of the normal dissemination of knowledge in the subject field, but they shall not publish or have published any copyright work during the performance of the contract or for a period of three months thereafter without the prior written consent of the Director, Western Region, Parks Canada.

9.9.4 Any copyright work published by or on behalf of the contractor or the author shall acknowledge that the work was performed under contract with Parks Canada unless the Director gives notice to the contrary.

9.9.5 The copyright and all proprietory rights of ownership or use of any and all slides, photographs (positives and/or negatives) sketches or other illustrations made, or taken by the contractor in any way related to the work to be performed under this contract shall belong to Parks Canada.

9.10 Collection of specimens will be strictly limited to those specified or made necessary by the terms of the contract. The contractor and his designated assistants shall comply with the following requirements when collecting specimens under the contract agreement.

9.10.1 Carry the collecting permit supplied by Parks Canada at all times when engaged in collecting activities or when in possession of specimens and present it upon request of Parks Canada staff or R.C.M.P. officers.

9.10.2 Obtain any permits that may be required by other agencies relating to collection of certain species or types of specimens.

9.10.3 Obtain specific authorization from the Director, Western Region, Parks Canada, before collecting specimens of species considered to be rare or endangered in Canada.

9.10.4 Refrain from collecting specimens where such action may hazard the status of the species in the Park or when an in dividual is associated with a nest or with young.

9.10.5 Refrain from collecting specimens in the Park when the intent of the contract can be met by collection of taxonomically comparable specimens from areas adjacent to the Park.

9.10.6 Comply with conditions specified on the permit.

9.11 The contractor shall be allowed access to reports in the Research and Resource Inventory collection which pertain to the project and, when necsssary, may be provided access to pertinent information from Branch files. Such material is located at Headquarters, Regional and Park Offices and shall be utilized at these places.

9.12 The contractor shall inform the field supervisor in advance of plans for field work in the Park and shall make arrangements that the field supervisor is kept informed of progress.

9.13 At the start of the field work in the Park (each season), the contractor or an authorized representative shall meet with the field supervisor and such Park staff as he designates to review his plans for the season.

9.14 Prior to leaving the Park (for the season), the contractor or a designated representative shall meet with the field supervisor to review progress and inform him of any important results to date.

9.15 Interim reports shall be submitted in 25 copies. The original of the final and annual reports including original illustrative material (eg. negative) will be deposited at the Pacific Biological Station.

9.16 The contractor shall maintain a close liaison with the Resource Studies Manager, Western Regional Office, and shall arrange for the work to be reviewed at critical stages of the project.

9.17 Upon completion of both the annual and final reports, the contractor should be prepared to give a seminar on the research to provide all interested Park personnel with a better understanding of the results, purpose and methodology of this study.

9.18 If requested, the contractor shall incorporate into the field party one Park Warden, designated by the Field Supervisor, and shall instruct the Park Warden in any techniques on methodologies which might be required to supplement or update the marine biophysical inventory data. Warden involvement will be encouraged, but due to manpower limitations it may be restricted by previous scheduling or emergency operations.