AN ABSTRACT OF THE THESIS OF

Jose D. Nunez for the degree of Doctor of Philosophy

in Fisheries presented on December 21, 1987

Title: The Fishery Biology of the Weathervane Scallop [*Pecten* (*Patinopecten*) *caurinus* Gould, 1850] in Oregon Coastal Waters

Redacted for Privacy

Abstract approved: ______________________

Howard F. Horton

Samples of weathervane scallops taken on Oregon Department of Fish and Wildlife cruises off Oregon waters during 1981-1982 were analyzed for a comparative growth study. No evidence of internal growth marks were found in the shell structure when analyzed by the acetate peel technique. Internal growth lines formed in the ligament lateral layers were reliable for age determination purposes; each band was formed by 12 striae deposited at fortnightly intervals and spaced close together during periods of slow growth. The von Bertalanffy growth model fit the observed data in most cases. At any given age, scallops from Coos Bay were larger than those from off Tillamook Head, Cape Kiwanda, Yaquina Head and Heceta Head. Scallops from Yaquina Head grew slowest. Differences in growth were associated with food availability and temperature. The weathervane scallop fishery currently is a sporadic fishery following a successful beginning in 1981. Dropping CPUE and increased availability of shrimp in Oregon waters can partly explain the dramatic decline of the weathervane scallop fishery.

The Fishery Biology of the Weathervane Scallop [*Pecten* (*Patinopecten*) *caurinus* Gould, 1850] in Oregon Coastal Waters

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Doctor of Philosophy

Completed: December 21, 1987

Commencement: June 1988

APPROVED

Redacted for Privacy

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Date thesis is presented: December 21, 1987

Typed by LaVon Mauer for: Jose D. Nunez

ACKNOWLEDGEMENTS

I wish to thank my major professor, Dr. Howard F. Horton, for guidance, counsel, friendship, and encouragement throughout the entire period I worked for my doctorate. I wish to thank my committee members, Dr. Richard Tubb, Dr. Frederick Smith, Dr. John Rohovec, and Dr. David McIntire for their advice and review of the manuscript.

I wish to thank Mr. Rich Starr of the Oregon Department of Fish and Wildlife, Newport, Oregon, for providing the data for my research and his valuable help while I was processing the data. I am grateful to Jean McRae also from the ODFW for her help.

I am in debt to the Instituto Profesional de Osorno (IPO), Chile, for its support and also to the Tinker Foundation for its financial aid.

I am grateful to the Horton family for their hospitality and support when I was far away from my family.

I wish to thank LaVon Mauer who kindly gave shape to the final copy of the thesis.

I am particularly indebted to my wife, Teresa, for her support, patience and the hope and strength she inspired over the years it took to complete my doctoral program.

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THE FISHERY BIOLOGY OF THE WEATHERVANE SCALLOP [*PECTEN* (*PATINOPECTEN*) *CAURINUS* GOULD, 1850] IN OREGON COASTAL WATERS

INTRODUCTION

The weathervane scallop (*Pecten* [*Patinopecten*] *caurinus*, Gould 1850) is a benthic marine bivalve found in the Northeastern Pacific Ocean. It occurs on soft muddy bottoms and is distributed from the Aleutian Islands to Point Reyes in northern California (Abbott 1974).

This species represents a new fishery resource in Oregon since 1981, and little is known about its biology and its response to fishing activity. This study was designed to analyze scallop samples taken during two research cruises in 1981 and 1982 on the main fishing grounds along the Oregon coast. The study was conducted at the Oregon State University Department of Fisheries and Wildlife during the 1986-1987 academic year and was oriented to increasing the understanding of the weathervane scallop biology and stock dynamics.

On the Oregon continental shelf, *P. caurinus* is distributed between 50 and 160 m depth, with the juvenile scallops generally found in deeper water than the adults (Carey and Ruff 1985). These authors found that the juveniles probably have high mortality and are highly variable in space and time, suggesting that recruitment varies greatly from area to area and from year to year.

Age determination methods are needed for evaluation of age composition in assessment studies of animal populations. Seasonal variations occur in the rate of growth of many marine organisms and give rise to distinctive annual marks on their hard structures. Such marks have been widely used to identify year-classes in studies of populations of fish and lamellibranchs, and together with suitable criteria of size, have facilitated growth studies of a variety of animals (Stevenson and Dickie 1954; Johannessen 1973; Thompson et al. 1980).

The most popular method of estimating growth rates in bivalve molluscs has been to identify annual growth checks, or lines, on the exterior of shells (Kerswill 1944; Stevenson and Dickie 1954; Caddy and Billard 1976). This method has been considered misleading in some bivalve studies, because with increasing age and size the earlier bands are often obliterated by erosion. Later bands may also become too crowded at the valve margins and produce unverifiable and incomplete records for age analysis (Ropes 1985).

New methods based on the study of internal shell deposits, which form growth lines or bands that are relatively unaffected by external environmental conditions, have been described by Ropes (1985). These techniques were intended for use in this study for a comparison with previous studies on _P. caurinus_ using external shell characteristics

Historically, the U.S. Pacific Coast scallop fishery has been incidental to fishing for other species and of minor economic significance (Ronholt and Hitz 1968). Despite large fluctuations in abundance and distribution, commercial fisheries of varying size and duration have developed in Puget Sound, Washington (1935-52), the Gulf of Alaska (1967-present), and the offshore waters of Washington, Oregon and California (1981-present) (Ronholt and Hitz 1968; Capps 1981; Kaiser 1986).

The Oregon scallop fishery began in the spring of 1981 when two 29-m vessels enroute to Alaskan scallop grounds discovered dense populations of _P. caurinus_ off Coos Bay and landed large quantities of scallops (Starr and McRae 1983). This was the beginning of an apparently promising fishery in which after a few weeks more than 100 boats from Washington, Oregon, California, and the East coast were fishing for scallops.

Unfortunately, the Oregon scallop fishery developed and declined very rapidly during a period when very little biological information was available. In the last few years, valuable information on this fishery has been produced mainly on the distribution, abundance, and ecology of the species (Carey and Ruff 1985).

After six years of _P. caurinus_ exploitation, it is important to review the status of knowledge on the Oregon weathervane scallop fishery to consolidate the available information, and to generate new information oriented toward a better understanding of this resource and its fishery. Thus, the general objective of my study was to analyze the biology and fishery for _P. caurinus_ in Oregon from its begining in 1981 until 1986.

Specific objectives of this study are:

1. To characterize the oceanographic environment occupied by _P. caurinus_.
2. To summarize the exploration and research on _P. caurinus_ in Oregon during 1963-1986.
3. To review the known life history of the weathervane scallop.

4. To determine body-structural morphology oriented toward gaining a better understanding of the growth process.
5. To determine the usefulness of schlerochronology techniques to assess age and growth of *P. caurinus*: H_0: internal growth banding structures are more accurate than external growth criteria for aging scallops.
6. To determine whether structural characteristics of the shell and ligament can be used as a reliable basis for age determination: H_0: growth banding of the shell is correlated with growth marks in the ligament.
7. To determine if differences in growth patterns of *P. caurinus* concentrations in Oregon waters can be used for stock differentiation.
8. To characterize the 1981-86 Oregon scallop fishery with regard to its development, geographical locations, commercial catch and effort statistics, vessel descriptions, gear types, and fishing methods.

LITERATURE REVIEW

Oregon Coast Environment

The Pacific Northwest coastal waters, the environment of *P. caurinus*, have been characterized as an extremely dynamic oceanographic system, in which the physical and chemical properties fluctuate seasonally, weekly, and even daily due to the action of winds, currents, and biological, biochemical, and chemical processes (Atlas et al. 1977). A general description of this system is presented in the following paragraphs as general background information which will be utilized and discussed later in assessing the growth patterns of *P. caurinus* at the different locations studied.

Circulation.

Circulation of shelf waters is influenced by the winds. Winds along the Oregon coast are non-seasonal, although southwesterly winds prevail during the winter from October through March, and northwesterly winds prevail during the summer from May through September (Petersen 1980). Currents usually are almost near parallel to the local isobath with an alongshore component, and are also highly variable in direction and speed. This variability is correlated with fluctuations in the alongshore component of the wind and in the sea level (Huyer 1977). The alongshore component of the current seems to present a significant seasonal variation generally being southward during spring and summer, and northward during fall and winter (Fig. 1C) (Huyer 1977). Specifically, there is a cycle that can be characterized by northward currents at all depths in winter with little or no shear; southward currents at all depths in spring with strong vertical shear in the

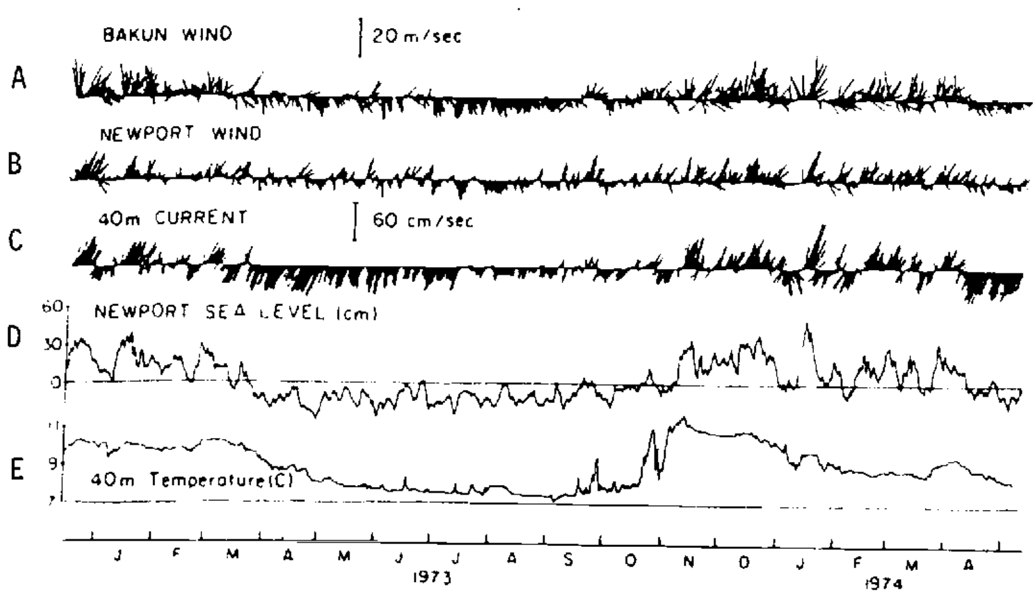


Figure 1. Oceanographic characteristics off the Oregon coast: A) and B) wind; C) currents; D) sea level; and E) temperature.

lower half of the water column; and southward surface currents over northward undercurrents in summer, with a weak vertical shear (Huyer 1977). Mean circulation velocity values are estimated to be around 8-10 cm/sec, but extreme currents at depths greater than 20 m have been measured around 50 cm/sec in summer and around 100 cm/sec in winter (Huyer 1977).

The seasonal prevailing wind (Fig. 1A, 1B) also affects the system in the onshore-offshore-bottom surface direction; thus, northerly winds in summer cause the warm surface water to be driven offshore and be replaced by cool water from depth called, "upwelling". Southerly winds produce the opposite effect when warm offshore surface water is brought onshore creating, "downwelling". This phenomenon, plus the influence of the Columbia River plume (with its relatively warm, low salinity waters) oriented northward in winter and southward in summer, make this particular environment quite different from a typical northern temperate sea (Huyer 1977).

<u>Temperature</u>

Changes in water temperatures follow quite different patterns according to depth. Thus, surface temperatures vary from about 10^{o} C in late spring, to about 14^{o} C in early summer, decreasing in summer due to the upwelling process to about 10^{o} C, increasing again in early fall to about 15^{o} C, and returning later to the 10^{o} C winter temperature. At depths where scallops live on the bottom, temperatures oscillate from 10^{o} C in winter to a low of 6.5^{o} C during summer. Thus, temperature at that depth is highest in winter and lowest in summer (Fig. 1E) (Huyer 1977).

Salinity

Salinity also shows different patterns at the surface than at the bottom. Surface salinity decreases in spring to about 31.6 ‰ from its winter value of about 32.5 % , and increases to about 33 ‰ in summer. At the bottom, salinity increases from about 32.8 ‰ in winter to about 33.8 ‰ in summer.

Water mass characteristics given by temperature-salinity (TS) diagrams, show a seasonal pattern, too. In winter during the northward advection over the continental shelf, the halocline temperatures are warmer due to the presence of water of southern origin; in summer, during the southward advection, the water shows strong subarctic characteristics with a minimum temperature at the top of the halocline (Huyer 1977).

Density

Sea water density is a function of temperature and salinity and it is described in terms of Sigma-t (the specific gravity anomaly multiplied by one thousand); it is inversely correlated with temperature and directly correlated with salinity.

Stratification varies in response to wind fluctuations, and patterns of stratification vary with time of the year. In winter, significant density changes occur down to 100 m or more; thus, the surface mixed layer often exceeds 50 m in depth. During the summer, density changes occur in the upper 20 m in a coastal zone of 10-15 km wide, and during this period the surface mixed layer seldom exceeds 10 m. As a general pattern, Sigma-t values are 25.0 in winter and summer, and approximately 23.0 during spring and fall (Huyer 1977).

Waves

The waves of Oregon coastal waters are much higher in winter, with significant wave height values up to 5 m; in summer, significant waves height values are always less than 2.5 m (Huyer 1977).

Turbidity.

Ocean turbidity is due to material in suspension in the water column. This can be of organic origin, usually chlorophyll, and of inorganic origin from river run-off and wave action in the surf zone. The depth of the euphotic zone, with at least 1% of the light intensity surface value, has been determined for a location off Newport to oscillate between 30 and 60 m through the year (Huyer 1977).

Chemical characteristics.

Chemical characteristics of the coastal waters of Oregon are influenced mainly by three factors: the Columbia River plume, the upwelling, and the intense biological activity, with the largest change in chemical properties occurring in summer (Atlas et al. 1977). The Columbia River introduces water of low salinity, moderate nitrogen, comparable phosphate, and high silicate into the Northeast Pacific Ocean. The Columbia River plume effect on Oregon waters is confined to shallow areas during the summer time, having little effect during the winter (Atlas et al. 1977).

Oxygen.

Oxygen percent saturation values vary according to location and season. Surface waters influenced by the Columbia River plume are over 100% saturated during spring, summer, and fall. Some locations on the central Oregon coast (i.e., Yaquina Bay) exhibit values of about 40% saturation in summer and $<75\%$ saturation during the fall (Atlas et al. 1977). The O_2 maxima for December to April are about 10 m below the surface, where values of about 6.7 ml/l in January increase by photosynthetic activity to 7.2 ml/l in July (Atlas et al. 1977).

Productivity.

Seasonal upwelling is a common feature in Oregon coastal waters. Thus, the typical mid-latitude cycle of primary productivity in the ocean with its low production in winter and summer, large production peak in spring, and a small peak in fall is not accomplished in the same manner here.

Primary production in Oregon waters is related to the interaction of daily radiation and degree of upwelling in summer, and it is a function of photic depth and daily usable radiation through the year (Small, et al. 1972). The winter phytoplankton community is well adapted to low light intensity, showing higher daily chlorophyll-specific production at comparable light intensities than spring phytoplankton communities, and on a non-chlorophyll basis, winter and spring production rates are relatively similar at given light levels (Small 1972).

Upwelling induced chemical changes occur in a more pronounced fashion in coastal waters (approx. 13 km offshore) and in the surface layer (0-20 m). During the upwelling process, Columbia River water disappears and is replaced by inshore waters at the same time that inshore waters are replenished by cool waters. These upwelled waters have low O_2, high nutrients, high alkalinity, low pH, and high PCO_2 (Atlas 1973).

Oregon Scallop Research

Before 1960, a few attempts were made to harvest the weathervane scallop resource, even though the presence of scallops off the Oregon coast had been known for many years through the reports from commercial fishermen.

During the 1960's, two exploratory surveys (1963, 1967) were made by the Bureau of Commercial Fisheries to delineate concentrations of scallops along the Oregon coast (Ronholt and Hitz 1968). The 1963 survey spent seven weeks exploring the grounds from Cape Arago to Heceta Head, from Alsea Bay to Yaquina Head, and from Cape Falcon to the Columbia River at depths from 52 to 120 m (Fig. 2). The 1967 three-week cruise covered areas between Cape Falcon and Cascade Head and just north of the Columbia River, plus previous 1963 surveyed areas off Tillamook Head (Fig. 2) (Ronholt and Hitz 1968). The largest concentrations of scallops detected came from hauls along the 74-101 m depth contours, and from areas between Cape Falcon and Tillamook Head (1963), and off Sand lake (1967). In both surveys, a 2.4-m New Bedford-type, scallop dredge was used.

A complete lack of studies occurred between these early surveys and 1981, the date in which the scallop fishery explosively began. Because of this lack of information the Oregon Department of Fish and Wildlife (ODFW) quickly began placing log books on all scallop fishing vessels, sent personnel to observe fishing operations and to obtain biological samples, and later performed two new exploratory and research cruises, one in November, 1981, and the other in August, 1982.

In 1981, the cooperative research cruise on board the National Marine Fisheries Service vessel R/V Chapman (10/19-11/14) covered two

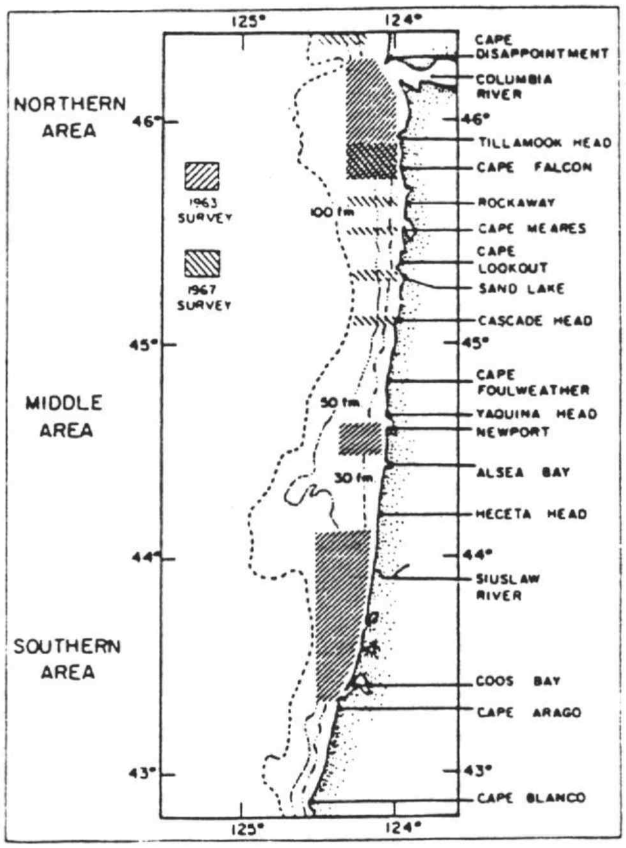


Figure 2. The areas surveyed for scallops off Oregon coast in 1963 and 1967. (After Ronholt and Hitz 1968).

areas, one west of Coos Bay and one west of Tillamook Head (Fig. 3A) (Starr and McRae 1983). A 2.5-m wide New Bedford scallop dredge without rock chains was used in two transects perpendicular to the depth contours in both areas. This survey was designed to gather information about those aspects of the scallop's population and life history which were needed to develop a management plan, and to compare scallop stocks in selected areas.

In 1982, the ODFW chartered the F/W Granada to survey the area off Tillamook Head, Cape Kiwanda, and Yaquina Head (Fig. 3B) (Starr and McRae 1983). A 3.7-m wide New Bedford dredge outfitted with tickler chains was used to try to test methods for catching juvenile scallops. Since 1982, no other field studies of the Oregon scallop populations have been conducted.

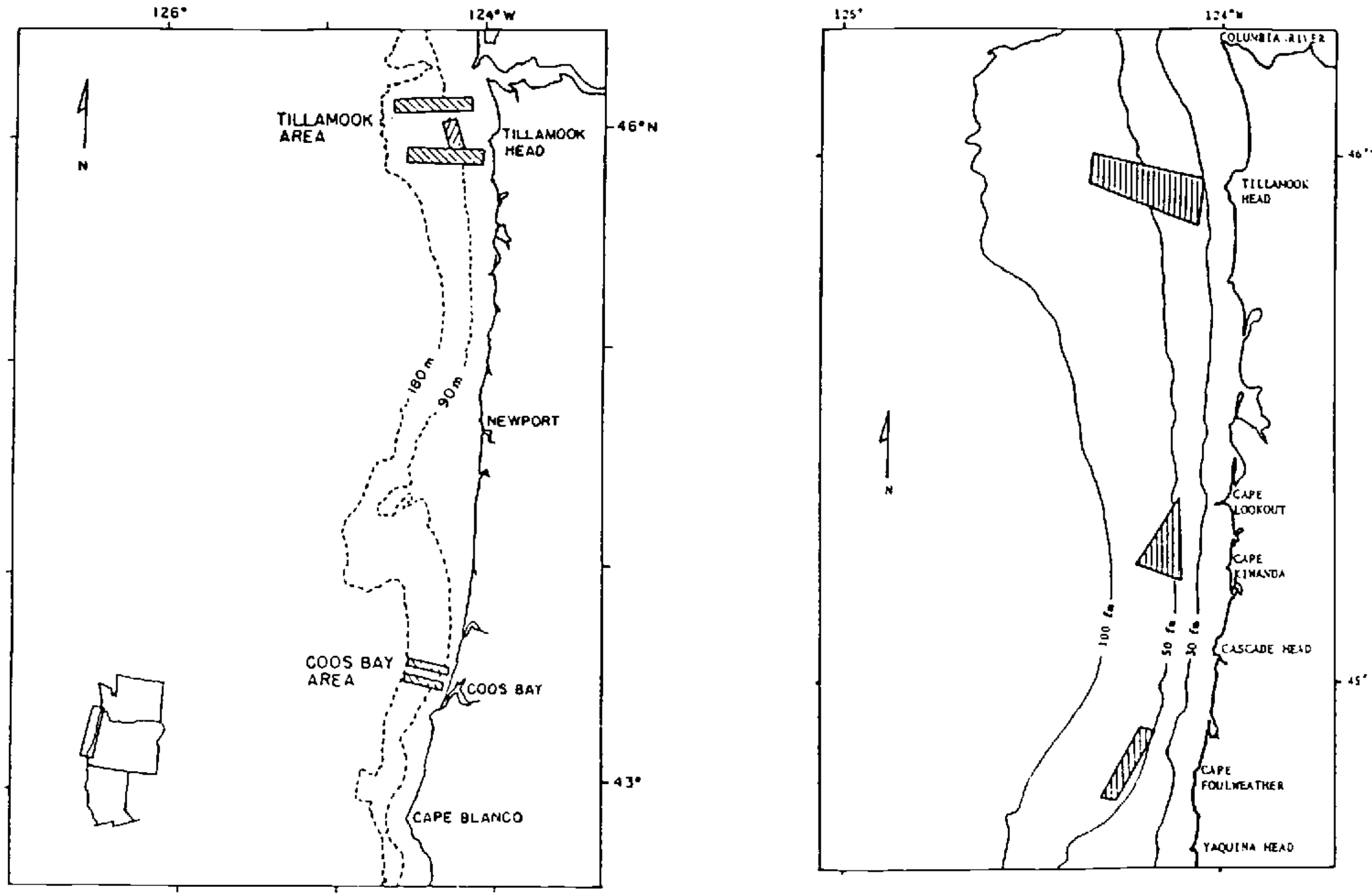
Life History

Taxonomy

The weathervane scallop is a benthic, marine bivalve, belonging to the family Pectinidae. According to modern taxonomists, and following Barnes (1980), the higher classification is as follows:

Phylum Mollusca
Class Bivalvia
Subclass Pteriomorphia
Order Mytiloida
Family Pectinidae, Rafinesque, 1815

It is important to point out that this classification follows that in the Treatise of Invertebrate Paleontology which has been widely adopted by malacologists, including Abbott (1974). The old subclasses of bivalvia (Protobranchia, Lamelibranchia and Septibranchia) are still



A

B

Figure 3. Location of scallop study areas: A) R/V Chapman cruise, Nov. 1981; B) F/V Granada cruise, Aug. 1982. (After Starr and McRae 1983).

used in many text book discussions due to simplicity and easy reference (Barnes 1980).

The Pectinidae are a large and heterogeneous family of marine pelecypod molluscs, worldwide in distribution, having a known geological history dating from the Triassic period (several thousands species described as fossils), and recorded living at a maximum depth of 4,550 m (Grau 1959). This family at the present time is represented by about 350 species, occurring most abundantly in shallow, warm waters like those off Japan, the East Indies and Caribbean regions (Hertlein 1969).

Genus *Pecten* Muller, 1776:

Shell equilateral or nearly so; right valve moderately convex and left flattish or slightly inflated; auricles rather large and nearly equal, convex on right valve and convex on left; byssal notch small, hinge with cardinal crura extending from each side of ligament pit, radial ribs well developed, usually flat topped, radial ridges often on/or between ribs, also fine concentric lamellae, usually more prominent on left valve (Grau 1959; Hertlein 1969).

Subgenus *Patinopecten* Dall, 1898:

The holotype came from the type locality of Port Townsend, Admiralty Inlet, Puget Sound, Washington and it is in the Museum of Comparative Zoology, Harvard College (Grau 1959).

Species *Pecten* (*Patinopecten*) *caurinus* Gould, 1850:

P. caurinus was referred to as a closely related species to *Patinopecten yessoensis* Jay (Mottet 1979), and Grau (1959) mentioned *Pecten caurinus yessoensis* as a Japanese subspecies of *Pecten caurinus* Masuda (1963), in a revision of the Japanese subspecies of

Patinopecten, said that almost all species of the so called Patinopecten of Japan can be distinguished from the true scallops of North America by the lack of auricular crurae with conspicuous distal denticle, rounded radial ribs in the right valve, very shallow byssal notch and large auricles. In his paper he proposed a new genus, Mizuhopecten Mosuda n. gen, including the older P. yessoensis as Mizuhopecten yessoensis (Jay 1857).

The four common scallops found on the West coast of North America are, Chlamys rubida (Hinds 1845) the pink scallop, C. hastata hericia (Gould, 1850) the spiny scallop, Hinnites multiruqosus (Gale) the rock scallop, and Pecten (Patinopecten) caurinus the weathervane scallop. The later is the largest scallop in the world and can exceed 288 mm in length and 198 mm in height (Grau 1959).

Reproduction.

Pecten (Patinopecten) caurinus is a dioecious animal. The gametes are produced in follicles of the gonad epithelium and when mature are spawned into the mantle cavity and discharged into the sea by clapping movement of the valves. Spawning takes place from mid January to late June (Robinson and Breese 1984) on the continental shelf in scallop beds and fertilization takes place after the sperm are activated by contact with sea water (Mottet 1979). Fertilized eggs settle to bottom in deeper depths (Fig. 4) and start embryonic development. A few days later, after the ciliated blastula and gastrula stages, a planktonic trochophora stage is produced (Fig. 5 b, c) while drifting with tides and currents near surface waters (Fig. 4). Then a metamorphosis occurs producing a larvae with a ciliated velum in which the body is enclosed in two straight-hinge valves called

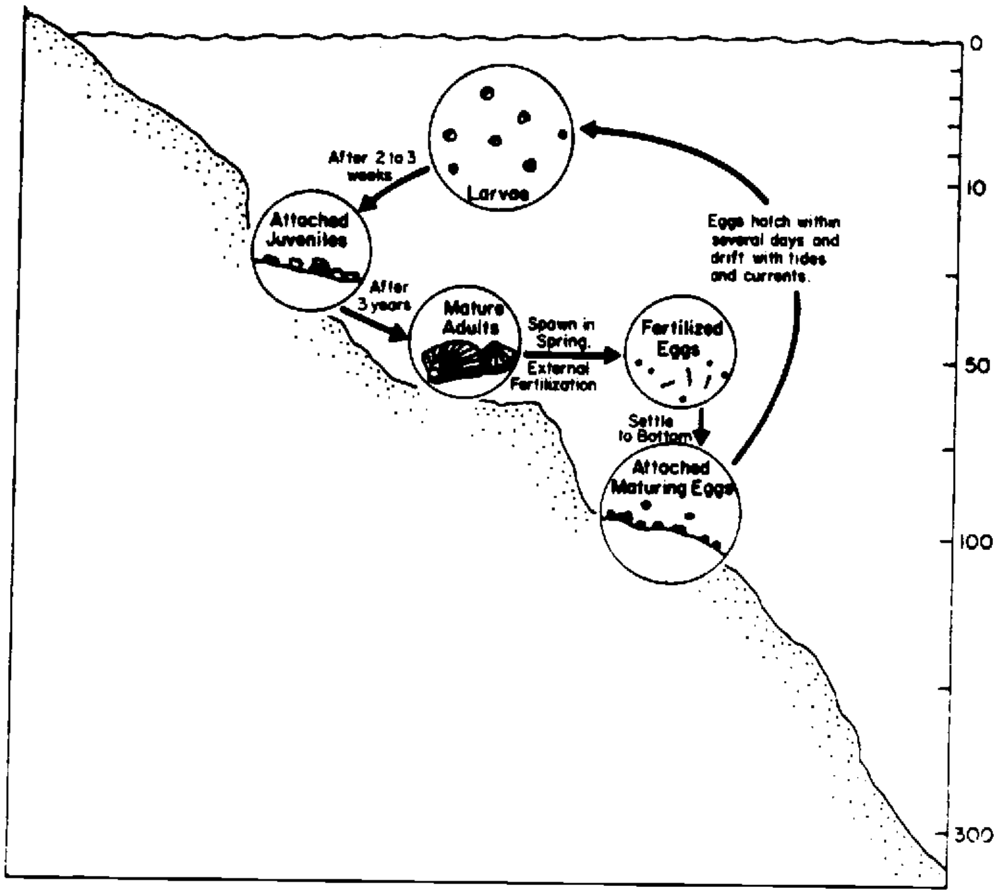


Figure 4. Weathervane scallop life cycle. Modified from Kaydak (1972). (After AEIDC 1975).

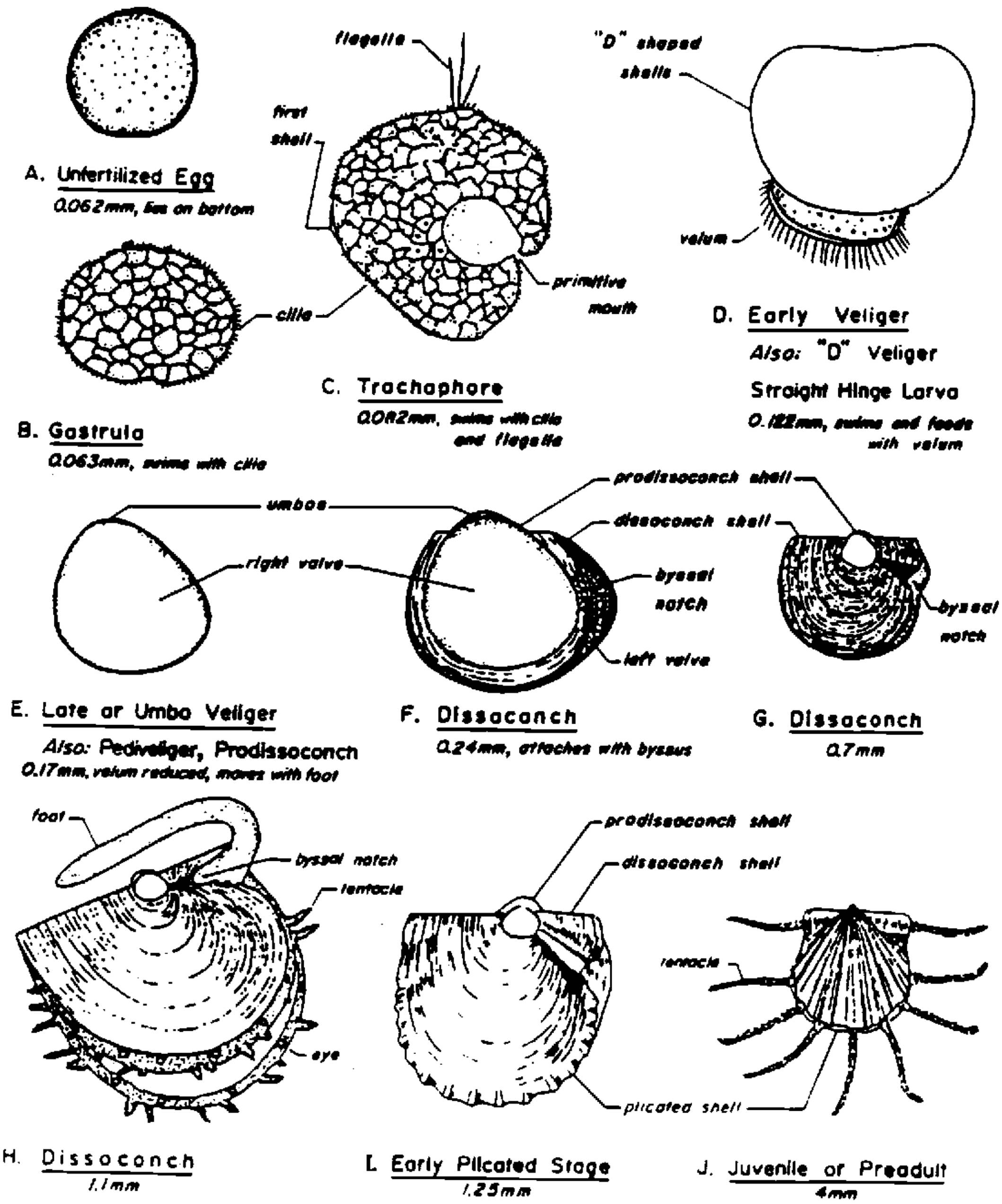


Figure 5. Larval and juvenile stages of the scallop. (After Mottet 1979).

the veliger or D-stage larvae (Fig. 5d). During the late veliger phase, the velum becomes reduced and the umbos are formed, the foot develops and the larva use it to crawl on the ocean bottom; after a few days a dissoconch stage with byssal threads is produced (Fig. 5f, g, h) by which the larvae can attach to the hard substrates on the bottom. The dissoconch metamorphoses to give a post-larva with radiating ribs known as the plicated stage (Fig 5i). This is the last larval stage and after a few months, the transparent shell of the juvenile becomes pigmented and they assume the adult physonomy (Mottet 1979). P. caurinus reach maturity after three years (Hennick 1970).

Shell morphology

Three distinct parts characterize a bivalve shell; two calcareous valves, laterally compressed, and the conchiolinic ligament that join the two valves together by the dorsal region (Fig. 6A). The bivalve shell structure is composed of a dark, horny (organic conchiolin) periostracum, covering two calcareous layers. The middle layer, or prismatic layer, of calcium carbonate has crystals arranged perpendicular to the surface of the shell, and the innermost nacreous layer has sheets of calcium carbonate laid down parallel to the surface of the shell (Fig. 7) (Johnson et al. 1977).

The periostracum and prismatic layer are secreted by the edge of the mantle, while the nacreous layer is secreted by the entire outer surface of the mantle. As a whole, the shell grows by the accretion of calcium carbonate and conchiolin around the valve margins in a very dynamic way (Rhoads and Lutz 1980). The calcium carbonate in the shell can be either aragonite, calcite or both, and in modern molluscs

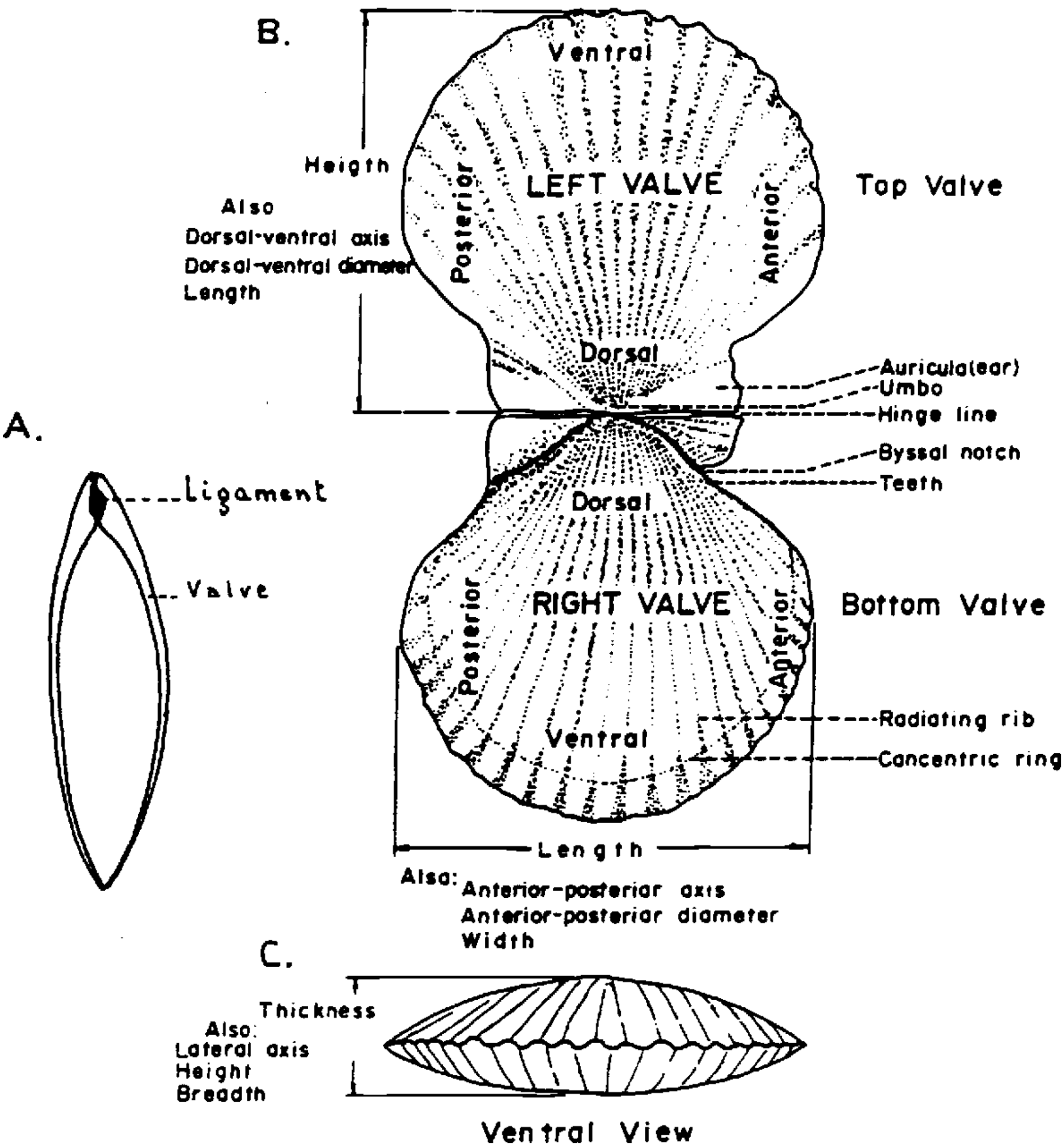


Figure 6. Orientation and morphology of scallop shell: A) lateral view; B) exterior of opened scallop; C) ventral view. (After Mottet 1979).

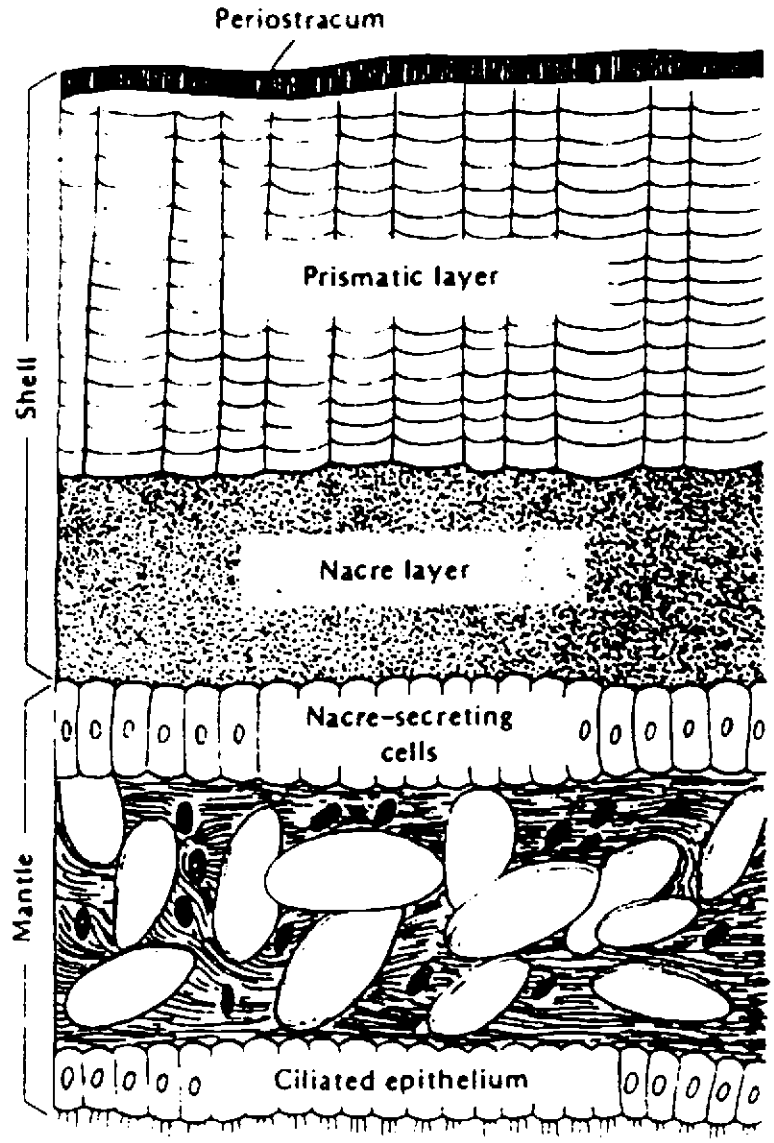


Figure 7. Diagrammatic cross section of a bivalve shell and the underlying mantle. (After Johnson et al. 1977).

the former is generally restricted to calcified portions of ligaments and at sites of shell-muscle attachment (myostracal layers) (Rhoads and Lutz 1980). When these compounds occur in the same shell, they form clearly defined, separated layers.

A common feature on bivalve shells is the presence of defined concentric rings or bands which are associated with the process of growth. Lutz and Rhoads (1977) have suggested that these growth surfaces or bands on molluscan shells are a reflection of alternative periods of aerobic shell deposition and anaerobic shell dissolution, with the later accounting for the growth line formation. These growth patterns are thus generated by physiological responses of the animal to the changing physico-chemical variables of the environment (Rhoads and Lutz 1980).

The Ligament

The ligament is a horny structure which holds the dorsal margins of the valves together. In Pectinacea, the valves are joined together dorsally along a hinge line and the ligament operates in opposition to the adductor muscle thus causing the valves to open when the adductor muscle relaxes (Fig. 8A) (Trueman 1953).

The ligament consists of two main layers secreted by the mantle (Fig. 8B), the outer and inner layers, and represent local modifications of the same two layers of the shell (Florkin and Scheer 1972). The outer layer, covered by a thin layer of periostracum, is laminated and composed of tanned proteins (Trueman 1953), and contains no calcium carbonate; its main function appears to be the prevention of the rotation of the valves, one about the other, and operates as a

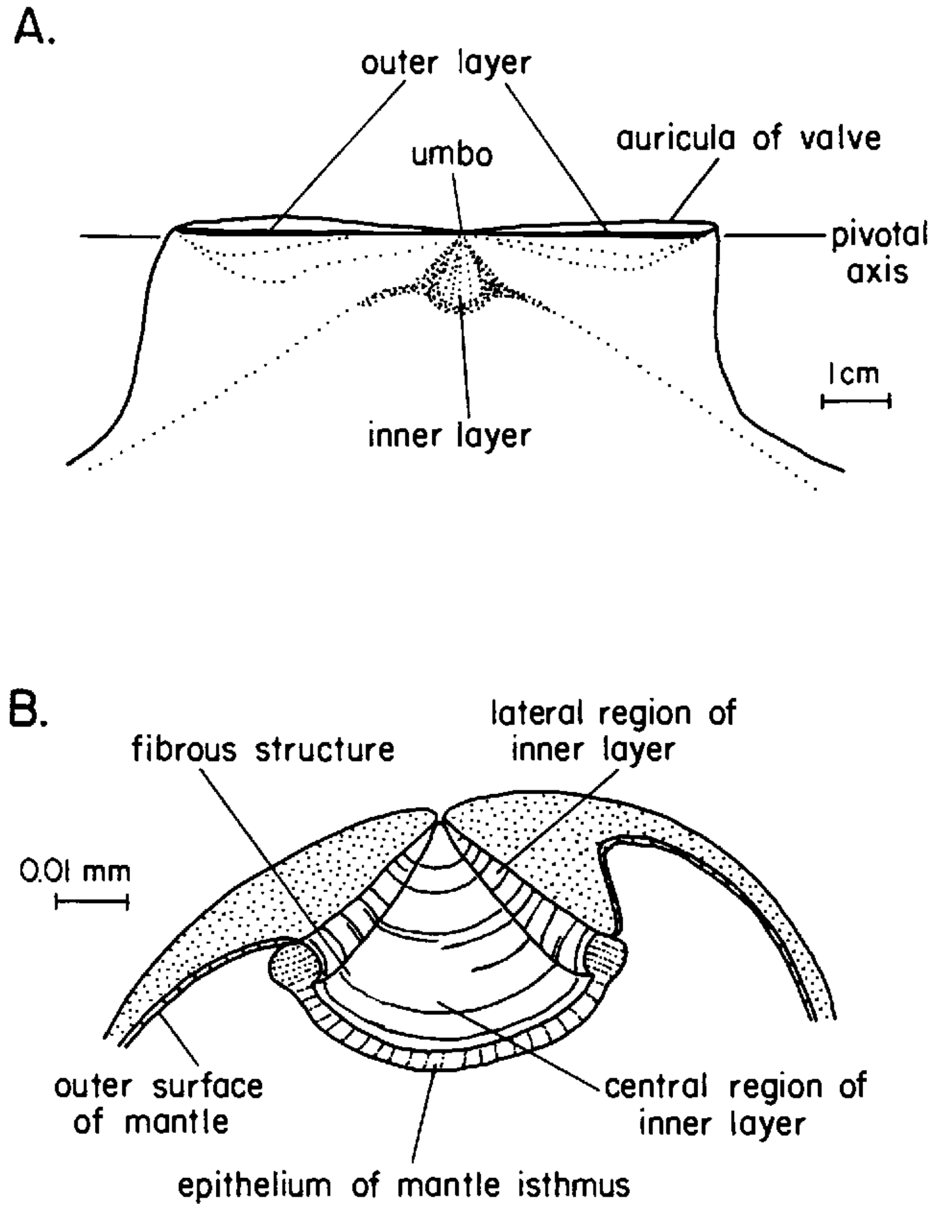


Figure 8. Umbonal region of Pectinids: A) interior of the dorsal region of the right valve with the ligament cut in longitudinal section; B) transverse section through the center showing the structure of the central and lateral regions. (After Trueman 1953).

rigid hinge structure (Trueman 1953). The inner layer, or resilium, is housed in a depression, the resilifer, and it is divided in three parts: a central fibrous of rubbery-like non-calcareous protein, and two lateral mineralized aragonitic layers (Merril 1961, Floorkin and Scheer 1972).

Biographical Variations

Biogeographical variations in age and growth have been suggested for this species in Eastern Pacific waters; thus, Haynes (1970) studying the Alaskan resource showed that scallops from the Kodiak Island area grew faster and to a larger size than scallops from other areas of the Gulf of Alaska. Scallops from Southeast Alaska grew much slower and did not reach as large sizes as scallops from the Kodiak Island area. Scallops living in areas between Southeastern Alaska and Kodiak Island had intermediate growth rates. The same phenomenon was observed by Haynes and Hitz (1971) on the P. caurinus populations from the Strait of Georgia and outer Washington coast. Thus, scallops from the Strait of Georgia grew faster and to a much larger size than those from the outer coast; for any given age they were about 1.5 times as large. These authors concluded, by comparison, that P. caurinus from Kodiak Island are more like scallops from the Strait of Georgia than scallops from the outer coast. Between ages II and V, Kodiak scallops were slightly smaller than those from the Strait of Georgia, while older Kodiak scallops were slightly larger than those from the Strait of Georgia. In my study, possible depth and geographical variations in growth will be analyzed for scallops from Oregon waters.

Oregon Scallop Fishery

During the early developmental period of the Oregon scallop fishery, vessels of various sizes (6-m to >33-m) and types (mainly shrimp trawlers) were converted to scallop fishing. Scallops were harvested with various kind of gear, including modified beam and otter trawls, shrimp nets, traditional New Bedford type dredges,and several modified dredges (Starr and McRae 1983).

Prices above $9.00/kg of scallop meat were paid at the time. This caused the fishery to spread both to Washington waters where the catch was the first recorded since 1952 (Kaiser 1986), and to Northern California where 136 metric tons were landed (Carey and Ruff 1985). This fleet landed over 9,000 metric tons of scallop meats in 1981, of which over 7,000 metric tons came from Oregon beds. The ODFW divided these Oregon fishing grounds into eight statistical areas (Starr and McRae 1983) as shown in Table 1 and Appendix 3.

During the first year of the fishery, 43.9% of the catch came from the region between Cascade Head and the Columbia River. The other significant amount harvested (30.7%) came from the region between Cape Blanco and the Umpqua River (Table 1). The hauls were made at depths between 55 and 114 m. The main landing ports were Coos Bay, Astoria, and Newport where scallops were landed either as round weight or shucked meats (Starr and McRae 1983). The 1981 fishery peaked in June (above 800 metric tons), and thereafter landings steadily declined until October when levels well below 200 kilograms per month were reached.

Table 1. State statistical areas and expanded catch (tons) of the scallop fishery in 1981 (modified from Starr and McRae 1983).

Area	Location	Landings
19	California border-Rogue River	===
20	Rogue River-Cape Blanco	===
21	Cape Blanco-Cape Arago	336.2
22A	Cape Arago-Umpqua River	2,009.7
22B	Umpqua River-Cape Perpetua	1,506.1
24	Cape Perpetua-Cascade Head	437.1
26	Cascade Head-Cape Falcon	1,391.5
28	Cape Falcon-Columbia River	1,965.4
	TOTAL	7,646.1

MATERIAL AND METHODS

Two sets of data obtained from the Oregon Department of Fish and Wildlife were used in my study. The first set corresponds to two cooperative research cruises carried out by personnel of the ODFW, the Oregon State University, and the National Marine Fisheries Service in 1981 and 1982, on board of the R/V Chapman and R/V Granada, respectively. These data were utilized in the age and growth studies which follow. The areas of Coos Bay, Tillamook Head, Cape Kiwanda, and Yaquina Head were sampled for scallops by these research cruises as described previously in the literature review. Additionally, a sample from Heceta Head (N=66) captured by the R/V Tatiana in October, 1983, was analyzed.

Shell Morphology: Age and Growth

Age determinations on a timely basis are needed for evaluations of age composition in assessment studies of populations. In molluscs, this process has evolved from a relatively simple visual examination of external marks on the shell to rather complex but accurate microstructural examinations. The enumeration of the concentric annual growth rings formed on the valves sometimes can produce misinterpretations because of the inability to distinguish true periodic structures from random disturbance marks; extreme crowding of annuli and external growth structures at the edge of old shells can also lead to incorrect estimates of age.

The right valve (or bottom valve in *Pecten caurinus*), was used for the analysis of shell structure and for age and growth determinations. This valve offers better characteristics in terms of cleanliness and preservation of growth features because it is less affected by parasites than the left valve.

In this study both external and internal schlerochronology techniques were used in aging scallop shells. Techniques for external observation included: 1. The determination and counting of growth concentric rings from the umbonal region to the ventral shell margin (Fig. 9a). These concentric marks were assumed to be formed annually following the procedures of Stevenson and Dickie (1954), Haynes and Hitz (1971), and Starr and McRae (1983). 2. Determination and counting of depression marks on the auriculae (Fig. 9b). 3. Change in tactile texture of the internal face of the shell (Fig. 9c). 4. Observation of the growth marks through transmitted light (Fig. 9d). 5. Changes in coloration on the shell. 6. X-ray photography.

Internal schlerochronology techniques require the preparation of acetate peels from which growth can be determined (Steward and Taylor 1965; Ropes 1985). In this procedure, the shell was cut from the ventral edge to the umbo along the height axis with a diamond blade (Fig. 10). The sectional surfaces were ground and polished using wettable silicon carbide paper and a cloth-covered disc polisher coated with cerium oxide. Polished surfaces were etched with 1% formic acid for 30 seconds and dried completely. Clear acetate peels (0.076 mm thick) were carefully melted on each etched surface with acetone and air dried for at least one hour. The peels were then removed from the shell and stored between glass microscope slides for subsequent analysis (Steward and Taylor 1968; Ropes 1985) (Fig. 10B). The optical analysis was performed using stereomicroscopy with a magnification of 20x and 50x.

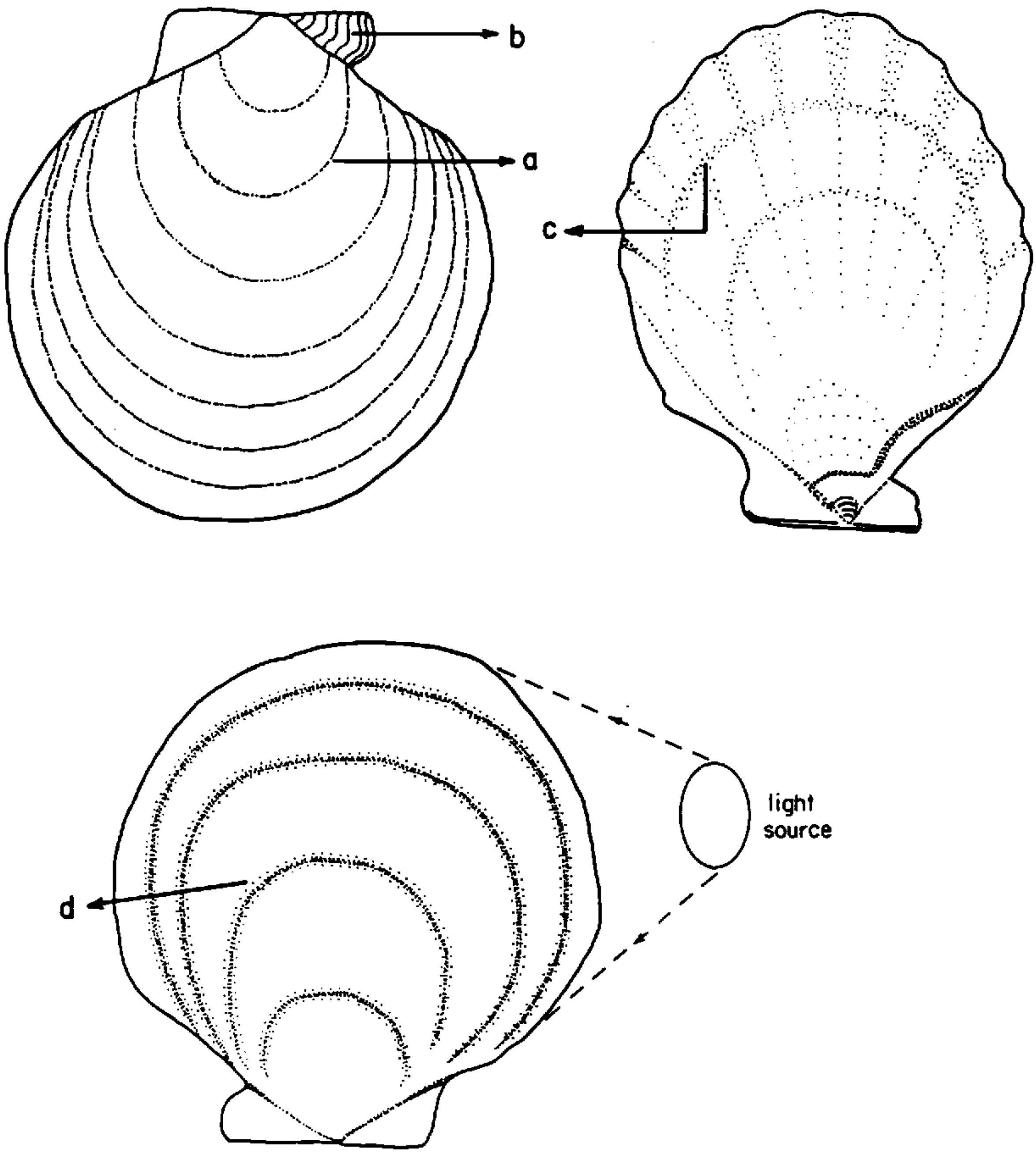


Figure 9. External features and techniques used in aging scallop shells: a) concentric rings (age 2) on external surface; b) depressions on auriculae; c) change in texture on internal face of shell; d) transmitted light applied to the shell.

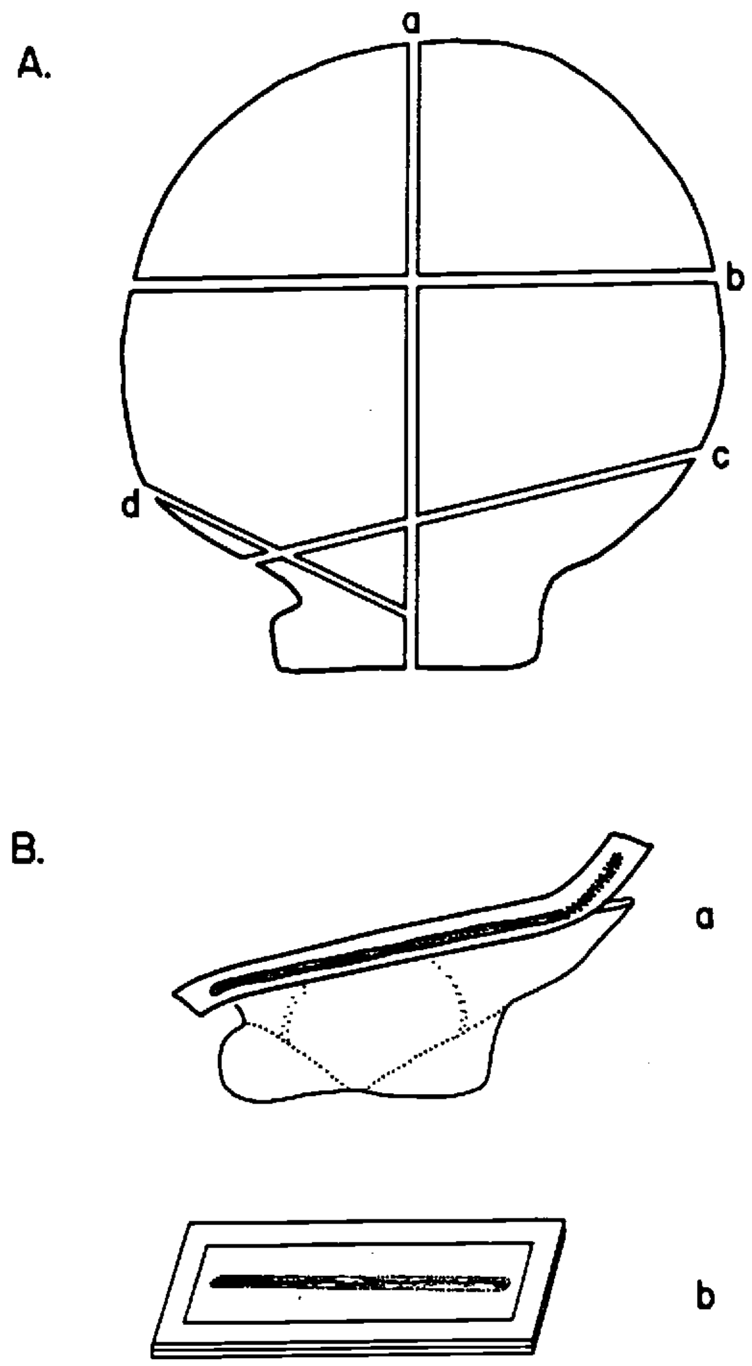


Figure 10. Different cuts performed on the shell: A) on the axis: a) height axis; b) width axis; c) and d) diagonal axis; B) acetate peel technique: a) peeling off; b) acetate peel for microscopic observation.

Several cuts were also made in different parts of the shell as indicated in Fig. 10 A. The acetate peel technique was also applied to the shell ligament. In this procedure the dried ligament was removed from the resilifer and cut, polished, and etched as previously described.

Fitting a Growth Model:

For the scallops in each sample, the mean shell height at every annulus was computed (Appendix 1). Because a sigmoid growth pattern has been demonstrated for scallops (Greenough and Haynes 1974, the Von Bertalanffy growth model was used according to:

$$lt = l_{\infty} [1 - e^{-k(t - t_0)}]$$

where lt is the length at age t, and l_{∞} , k and t_0 are parameters to be estimated. Least-squares estimates of the three parameters were accomplished by iterative methods using the Fishparm computer program (Michael H. Prager, National Marine Fisheries Service. Southwest Fisheries Center, La Jolla, California). In addition, the BMDP statistical package was used to run a non linear regression betweem height and age as a way to determine the correlation matrix of the parameters, which is not available in the Fishparm output. These values are necessary to run the Hotelling's T^2 test (see below).

To determine if biogeographical differences in growth occur between localities and depth, the fitted growth curves for each locality were plotted and compared. The variability was determined both graphically and using the Hotelling's T^2 test described by Bernard (1981) to compare the growth regression lines. This test was performed using a Lotus 1-2-3 template kindly provided by Dr. David Bernard. The T^2 values were transformed logarithmically and used to plot dissimilarity dendrograms by using the unweighted group average fusion technique (Sneath and Sokal 1973).

The second set of data provided by the ODFW came from the original logbooks of the commercial fishermen who participated in the fishery from 1981 to 1986. A standard logbook sheet includes the date of the trip, number of drags, the time the gear was set and retrieved, the depth of the drag in fathoms, the LORAN reading in microseconds at these times, and the estimated weight or bushels of scallops caught.

Using a minutes to hours conversion table, the hours fished per drag were calculated; the depth in fathoms was converted to meters by multiplying the values by 1.84. From the LORAN readings, the statistical area of each drag was estimated. The hauls for each area were converted to pounds round weight by multiplying the number of bushels of scallops times 55 pounds (Rick Starr, ODFW, Newport, Or., personal communication). The catch per haul in pounds round weight was converted to metric tons by multiplying by 0.00045359.

The ODFW uses official catch records for each boat to adjust the estimated catch (hauls) to actual catch reported; thus, the adjusted catch from logbooks for each area was added to get a total catch for the state. By dividing this value by the actual catch for the state (official landing records), a ratio R was obtained and this value was used to calculate the actual catch for each state area according to:

$$\text{Actual catch} = \frac{\text{logbook catch for state area}}{R}$$

These values constitute the expanded values used in the present study and also are the values that appear in the national fisheries statistics.

Expanded hours fished were calculated according to:

$$\text{Ac. hrs fished} = \frac{\text{hrs fished logbook} \cdot \text{actual landings}}{\text{landings from logbooks}}$$

The catch per unit of effort (CPUE) was calculated according to:

$$\text{CPUE} = \frac{\text{reported catch}}{\text{hrs. fished}}$$

Also an analysis of the landings by port and landings per month was conducted for every year of the fishery.

RESULTS

Shell Characteristics.

External Aspects:

The morphology of the shells examined in this study is in agreement with the taxonomic characteristics given by Gould (1850) for *Pecten* (*Patinopecten*) *caurinus*. The most conspicuous external features observed are the ribs which range in number from 17 to 23 with an average of 18 ribs per shell. Also prominent are the fine concentric circuli that constitute annual growth marks (annuli) when they crowd together during periods of slower growth.

In Figure 11, both circuli and annuli are evident in the auriculae and in the posterior region of the shell. The thin, brown, external periostracum is also evident. These features are easily observed on the right valves, but are usually obscured on the left valves by heavy infestation of the driller worm *Polydora websteri* (Annelida; Polychaeta) (Fig. 12A, B). In extreme cases of infestation, shells show drastic erosion of the margins and the internal face of the shell is also affected by invasion of the parasite (Fig 13A). Figure 13B shows how the worm invasion impairs the normal, smooth inner face of the scallop shell, while Figure 14A shows a portion of an infested shell through transmited light where the *Polydora* are easily seen. The x-ray picture in Figure 14B clearly shows the internal damage caused by the *Polydora* infestation to the scallop shell.

Figure 11. External view of P. caurinus showing annual growth marks.

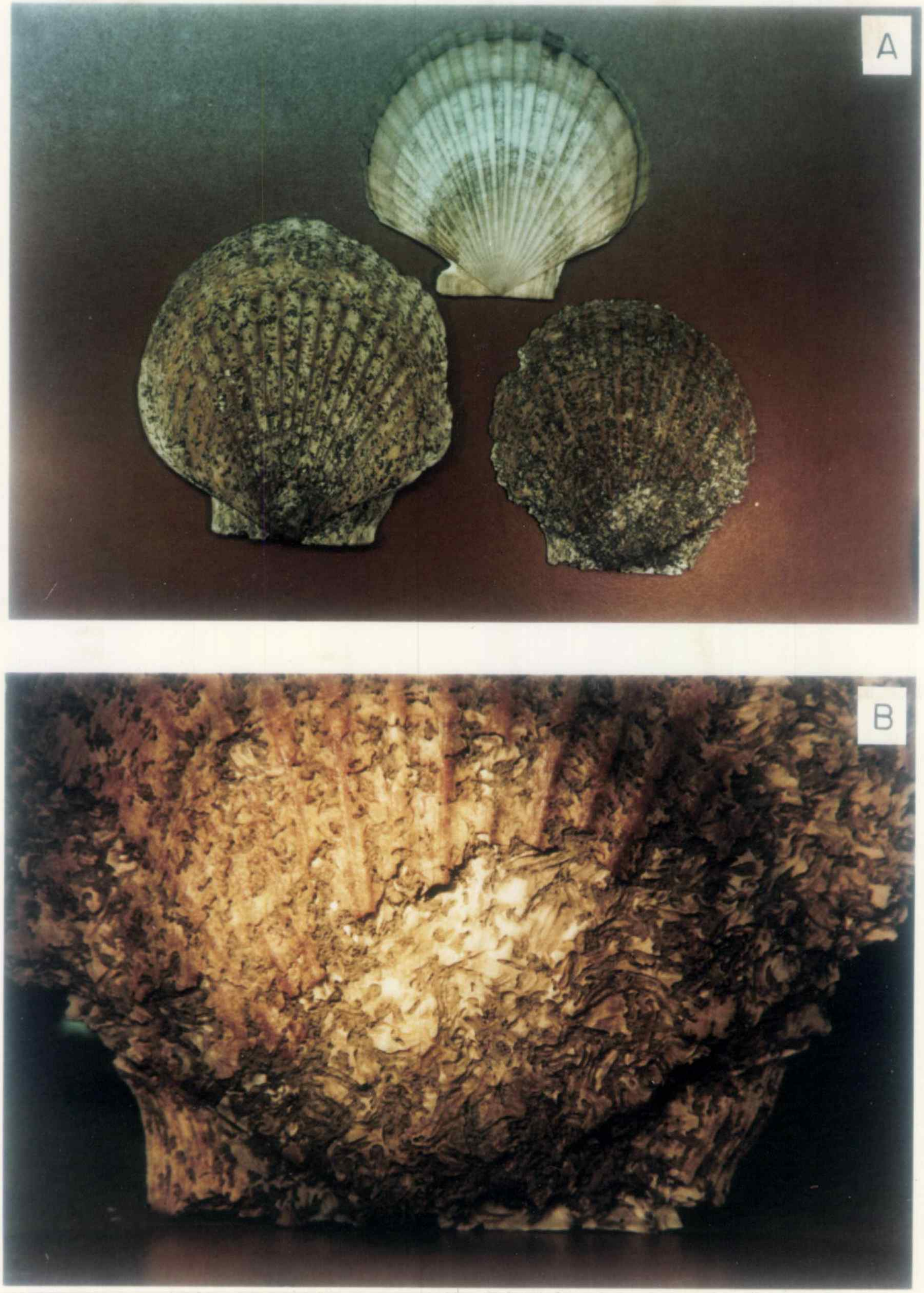


Figure 12. External view of scallop right valves: A) comparison between infested and non-infested shells; B) detail of infestation.

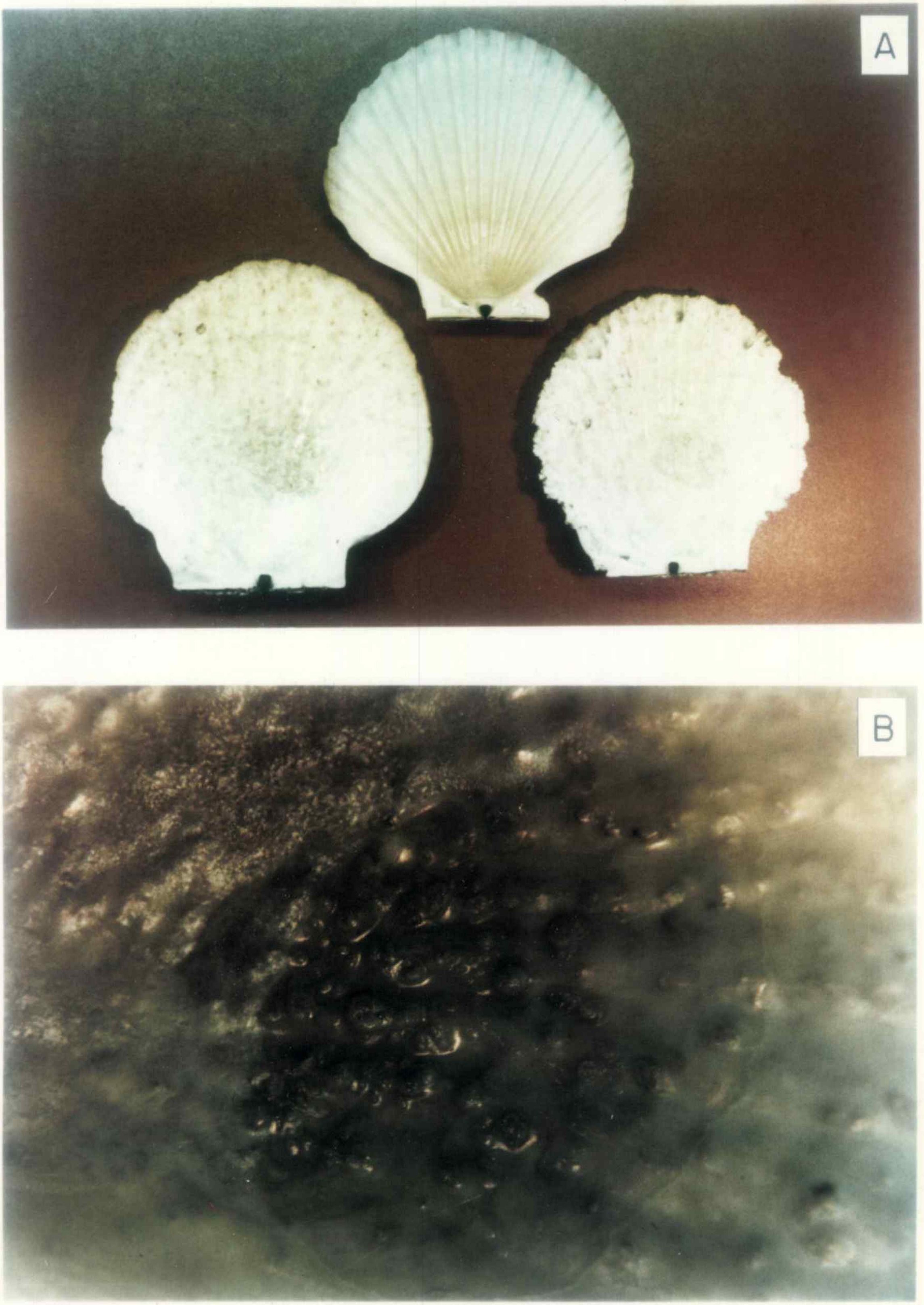


Figure 13. Internal view of scallop right valves: A) comparision between infested and non-infested shells; B) detail of infestation.

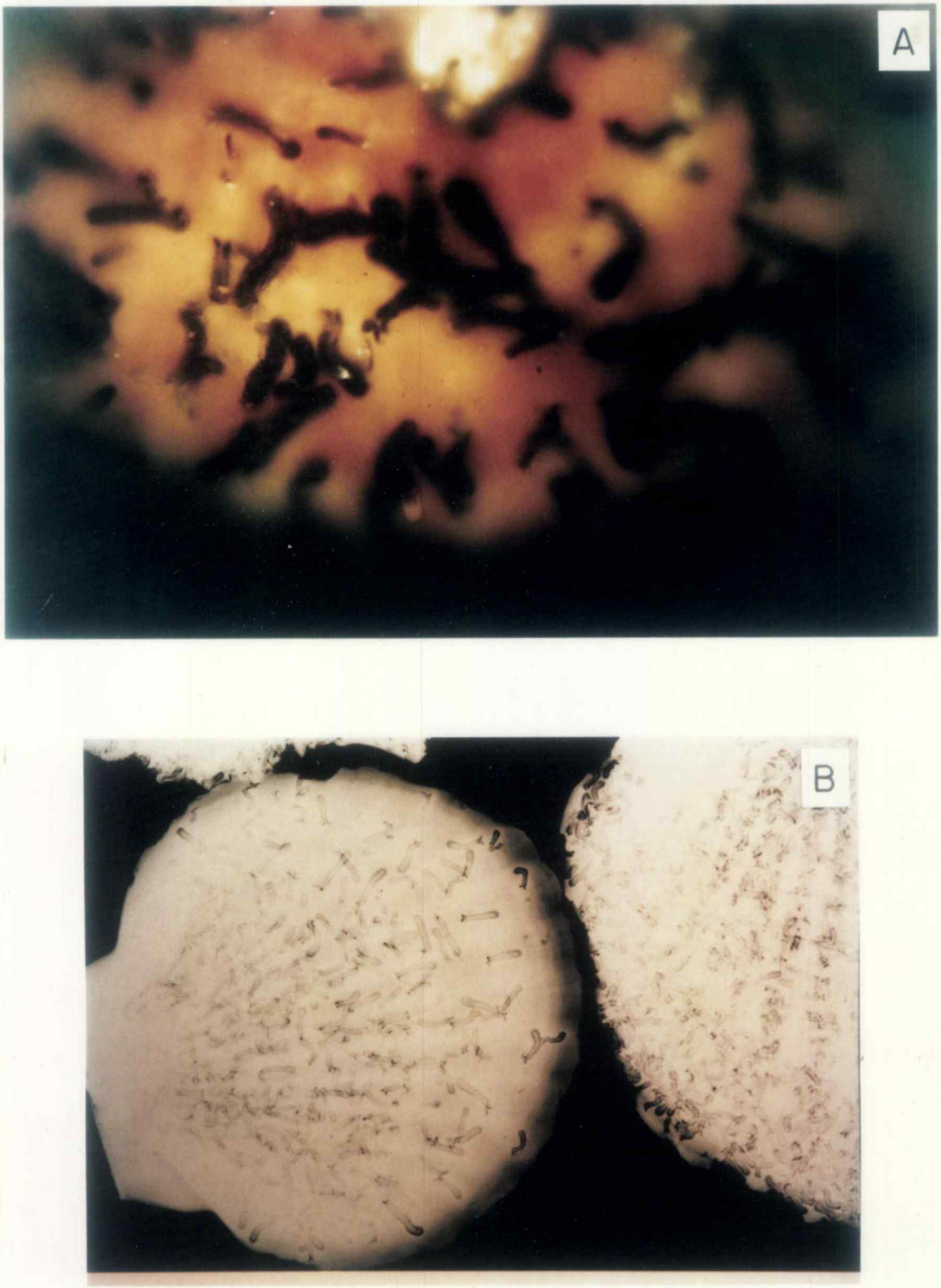


Figure 14. Details of infested shells: A) through transmitted light, B) x-ray photograph.

Internal Aspects:

The three common layers that form a typical bivalve shell are present in P. caurinus and can be visualized in a cross-section cut made perpendicular to the shell (Fig. 15). The periostracum is the thin outer colored layer that overlays the prismatic (middle) layer. The prismatic layer consists of an arrangement of crystals that form sublayers oriented parallel to the boundary of the shell (Fig. 15). These layers are composed of finer elements which diverge anteriorly in sublayers in some shells and posteriorly in others in an orderly alternating way. These sublayers gradually increase in number from one (in the umbonal region) to five at the level of the first external growth annulus; at the same time they travel down from the outer surface to the inner part of the shell. The portion of the middle layer on top of these sublayers is filled with a more foliated kind of crystal arrangement, which gives the top part of the shell a more porous appearance.

The inner or nacreous layer is built up of irregular parallel leaves which appear as a disorderly foliated structure (Fig. 15). This layer is thickest at the umbo level and becomes thinner when approaching the first external growth annulus. From this area, the nacreous layer is homogeneously thin until it reaches the posterior border.

An additional layer is located between the prismatic layer and the nacreous layer, and represents a distinctive feature between the umbonal region and the area of the first growth annulus. This layer runs from the upper umbonal region, down and parallel to the prismatic sublayers, with sharp and distinct boundaries (Fig.15). This layer

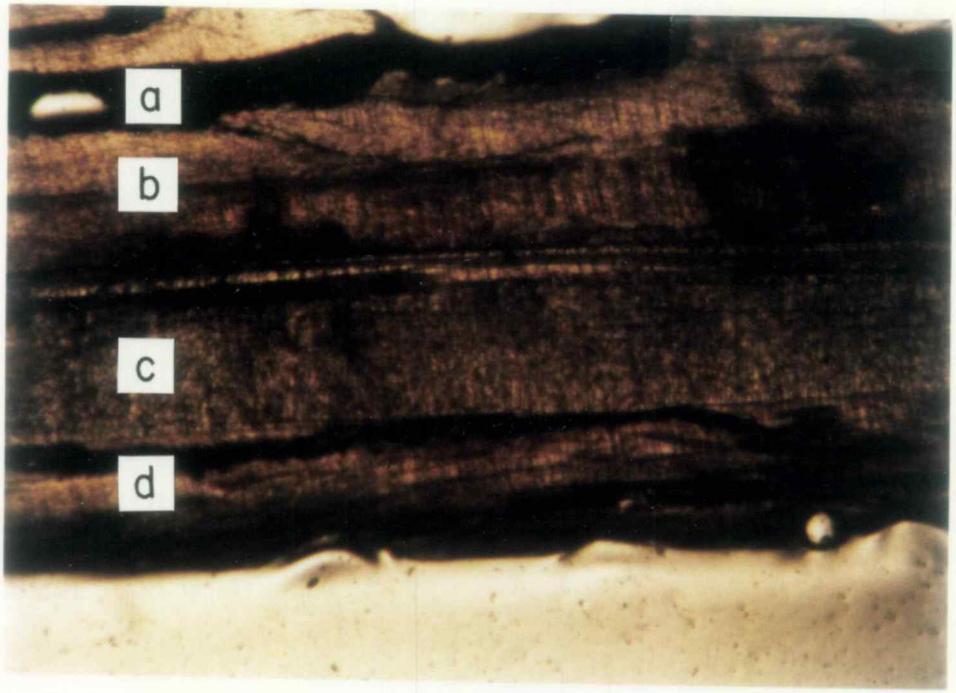


Figure 15. Internal structure of P. caurinus shell as viewed in an acetate peel. A) Periostracum, B) prismatic layer, C) myostracum, D) nacreous layer.

fractures on a vertical plane with respect to the shell surface, and the arrangement of the crystals appears to be relatively more homogeneous when viewed under the light microscope (Fig. 16).

Internal growth marks which could be clearly associated with periodic growth processes were not found in P. caurinus shells in any of the cuts made.

The Ligament.

The outer and inner ligament described by Trueman (1953) were present in P. caurinus, and their characteristics are in agreement with Trueman's description.

The two lateral mineralized aragonitic layers of the inner ligament show clearly defined growth marks as seen in Figure 17A. These marks appear as dark bands formed by the confluence of circuli during periods of slow growth and they extend deeply into the lateral layer as shown in Fig. 17B.

Table 2 shows the counts of annuli found in both the external shell surface and the lateral inner ligament layer of random subsample of Cape Kiwanda scallops. A correlation coefficient (r value) of .99 suggests a strong relationship between the counts under study.

Size Characteristics of Scallops.

The size (height) of each scallop in 5 mm intervals is presented in Table 3 for each collection analyzed in this study. The frequency of each size class in a collection was converted to a percentage of the total number and plotted in Figures 18 to 25. These figures show graphically much of the information contained in Table 4.

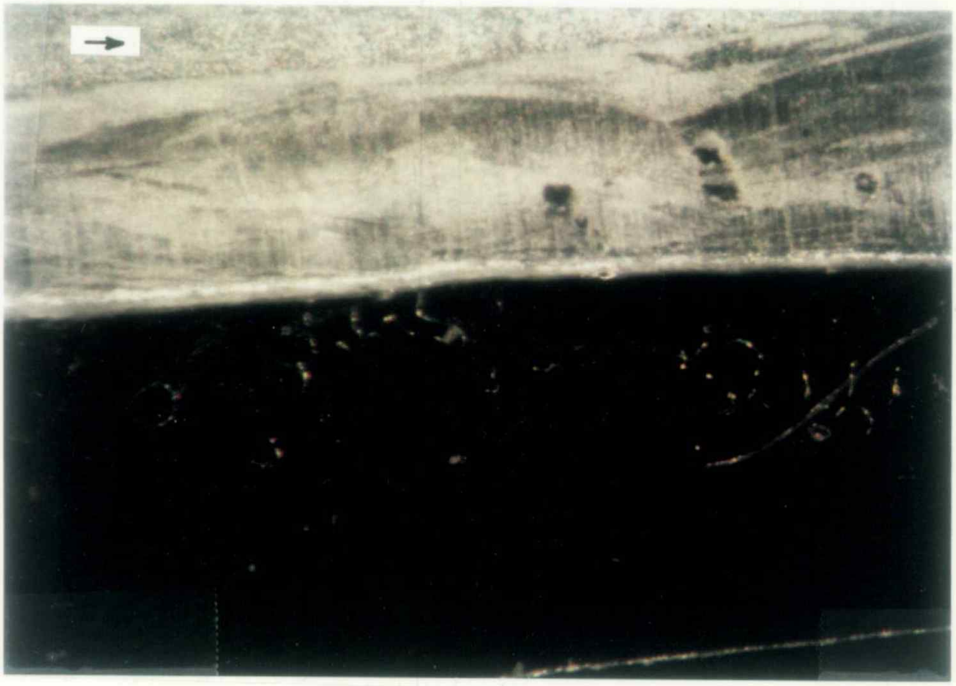


Figure 16. Detail of the myostracal layer observed on an acetate peel under the light microscope.

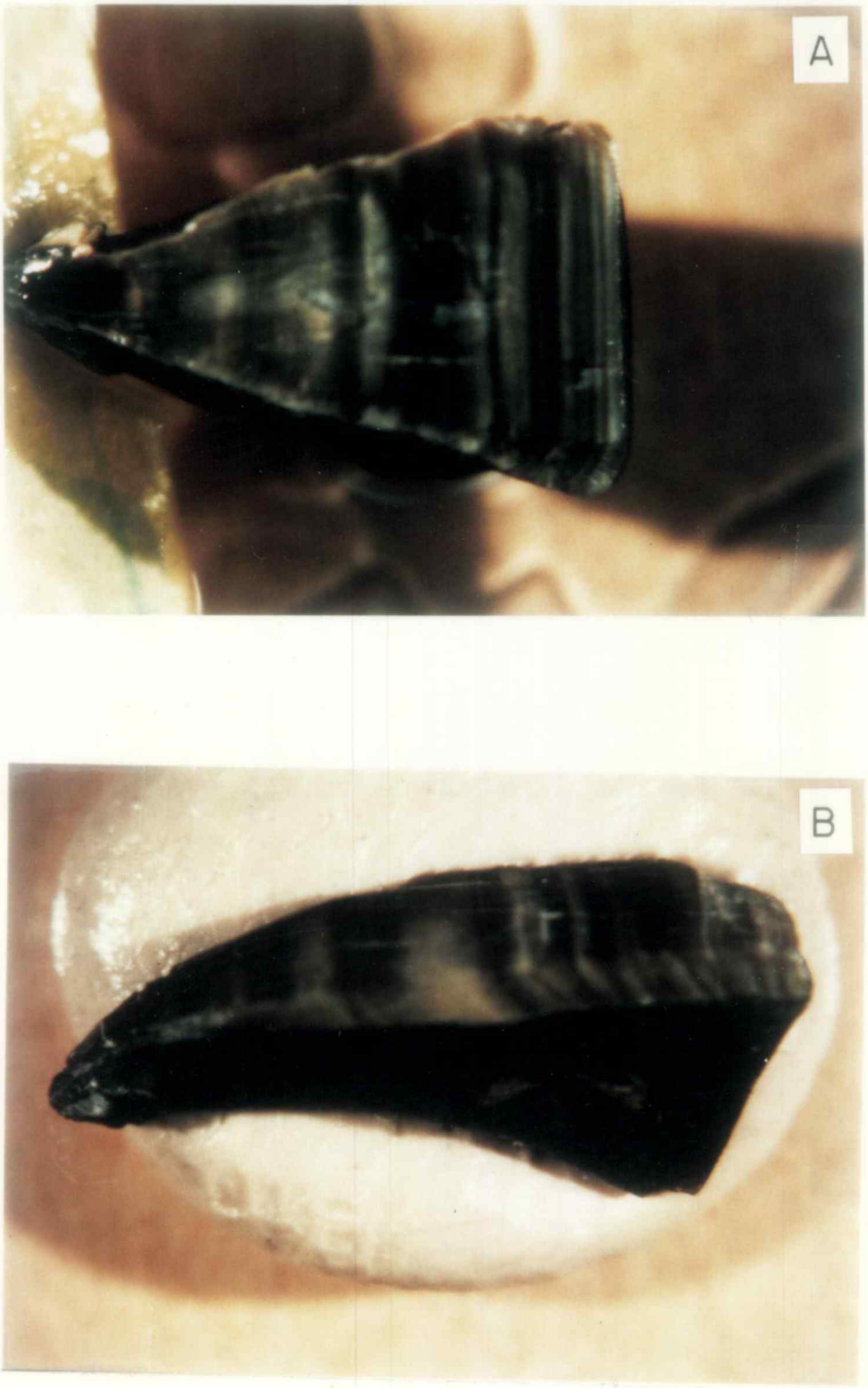


Figure 17. P. caurinus ligament. A) Frontal view of the lateral layer, B) lateral view of the ligament.

Table 2. Number of annuli at the shell and ligament, and the correlation coefficient between them. Cape Kiwanda, 1982.

Shell Number	Number of Annuli: Shell	Number of Annuli: Ligament	r
99	11	11	0.99
109	8	8	
64	8	8	
88	10	10	
76	8	8	
108	8	8	
32	11	11	
113	11	10	
70	10	10	
63	10	10	
22	12	12	
7	8	7	
100	11	11	
24	8	8	
54	8	8	
136	3	3	
83	10	10	
119	9	9	
131	9	8	
134	9	9	
48	11	11	
132	8	8	
28	6	6	
15	4	4	
37	12	12	
89	7	7	
56	9	9	
120	8	8	
14	12	12	
23	9	9	
51	11	11	
90	11	11	
12	9	9	
126	8	8	
61	6	6	
27	9	9	
44	9	9	
96	10	10	
103	8	8	
39	9	9	

Table 3. Shell height in 5 mm intervals and percent composition of weathervane scallops (*P. caurinus*) from the Oregon coast, 1981-1983.[1]

	TH82		TH92		TH96		TH101		THALL		YQ		HH		CB		Total Localities	
Height	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
75											5	3.3					5	0.5
80											6	3.9					6	0.7
85											12	7.8					13	1.4
90					1	1.2			1	0.2	23	15.0					25	2.7
95			1	0.6	3	3.5			4	0.8	21	13.7					26	2.8
100	4	2.6	8	4.8	6	7.1	8	7.8	26	5.1	45	29.4			1	1.7	72	7.8
105	22	14.1	29	17.3	14	16.4	27	26.2	92	18.0	30	19.6	1	1.5	1	1.7	124	13.4
110	36	23.1	53	31.7	30	35.2	45	43.6	164	32.0	9	5.8	5	7.6	6	10.3	184	19.9
115	45	28.8	55	32.9	22	25.8	19	18.4	141	27.5	2	1.3	25	37.8	7	12.0	177	19.2
120	29	18.6	15	9.0	5	5.9	4	3.9	48	9.3			20	30.3	15	25.8	93	10.1
125	16	10.3	2	1.2	3	3.5			23	4.5			9	13.6	11	18.9	66	7.2
130	3	2.0	3	1.8	1	1.2			9	1.7			6	9.1	10	17.2	69	7.5
135	1	0.7	1	0.6					3	0.6					5	8.6	40	4.3
140																	11	1.2
145															1	1.7	11	1.2
150																		
155															1	1.7	1	0.1
	156	100	167	100	85	100	103	100	511	100	153	100	66	100	58	100	923	100

[1] TH 45 = Tillamook Head, 82 m depth
TH 50 = Tillamook Head, 92 m depth
TH 52 = Tillamook Head, 96 m depth
TH 55 = Tillamook Head, 101 m depth
CK = Cape Kiwanda
YQ = Yaquina Head
HH = Heceta Head
CB = Coos Bay

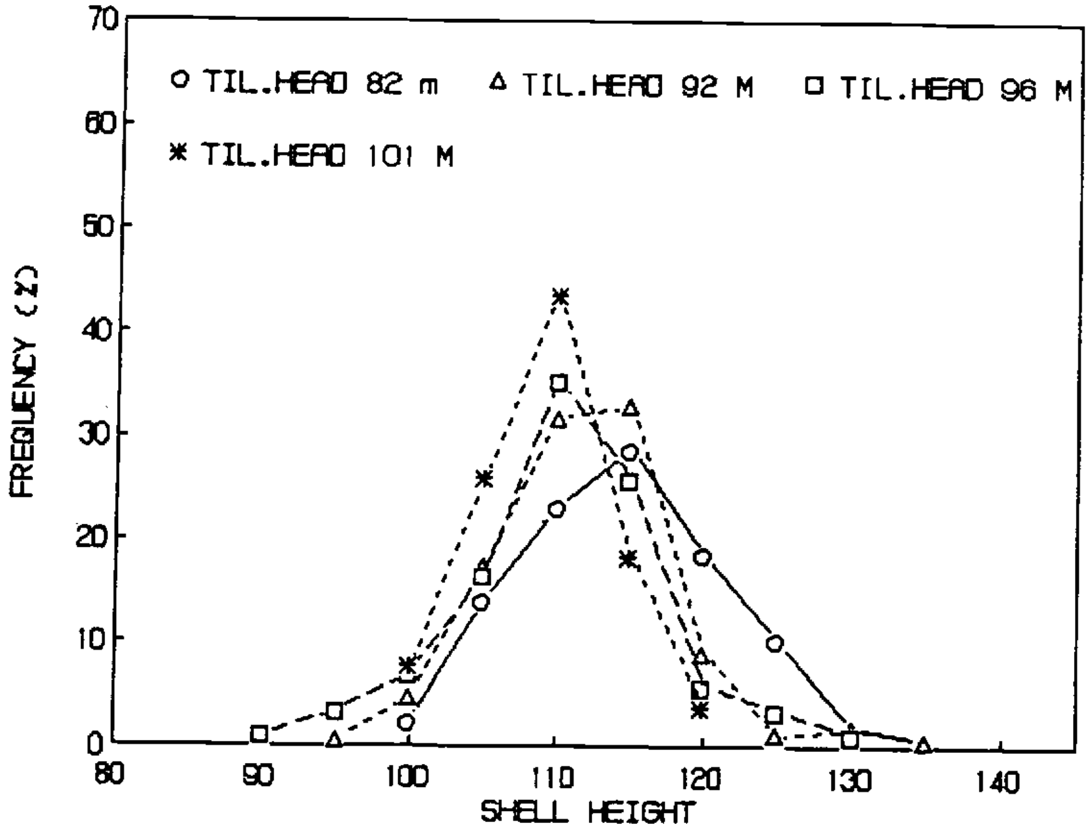


Figure 18. Scallop shell height distributions at different depths off Tillamook Head.

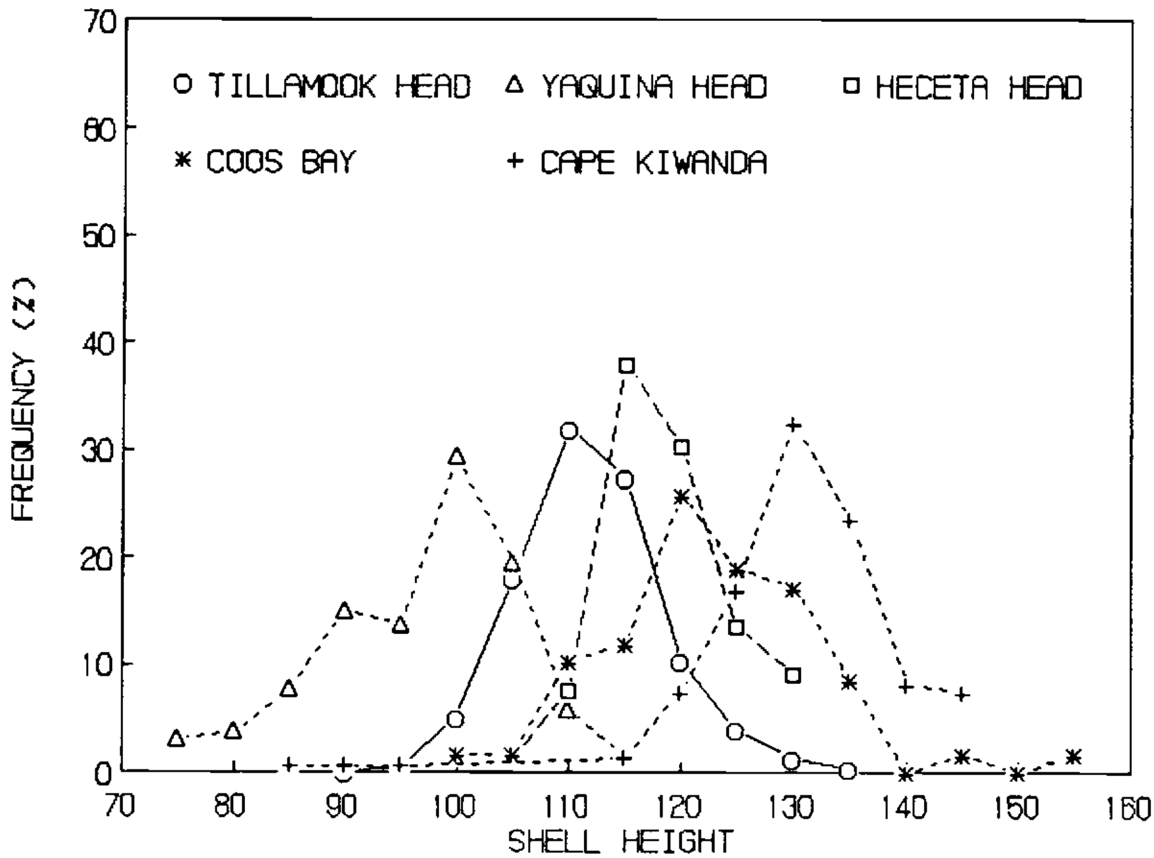


Figure 19. Scallop shell height distributions from five localities on the Oregon coast.

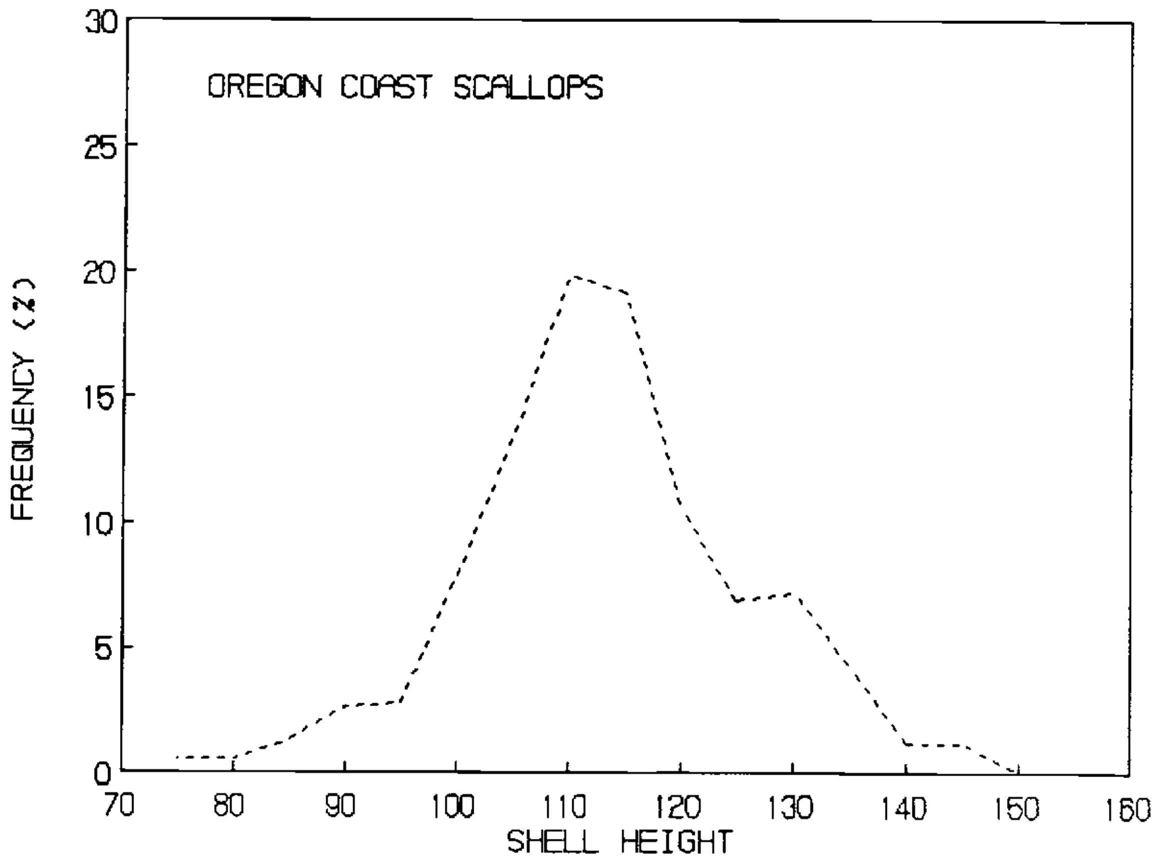


Figure 20. General scallop shell height distribution on the Oregon coast.

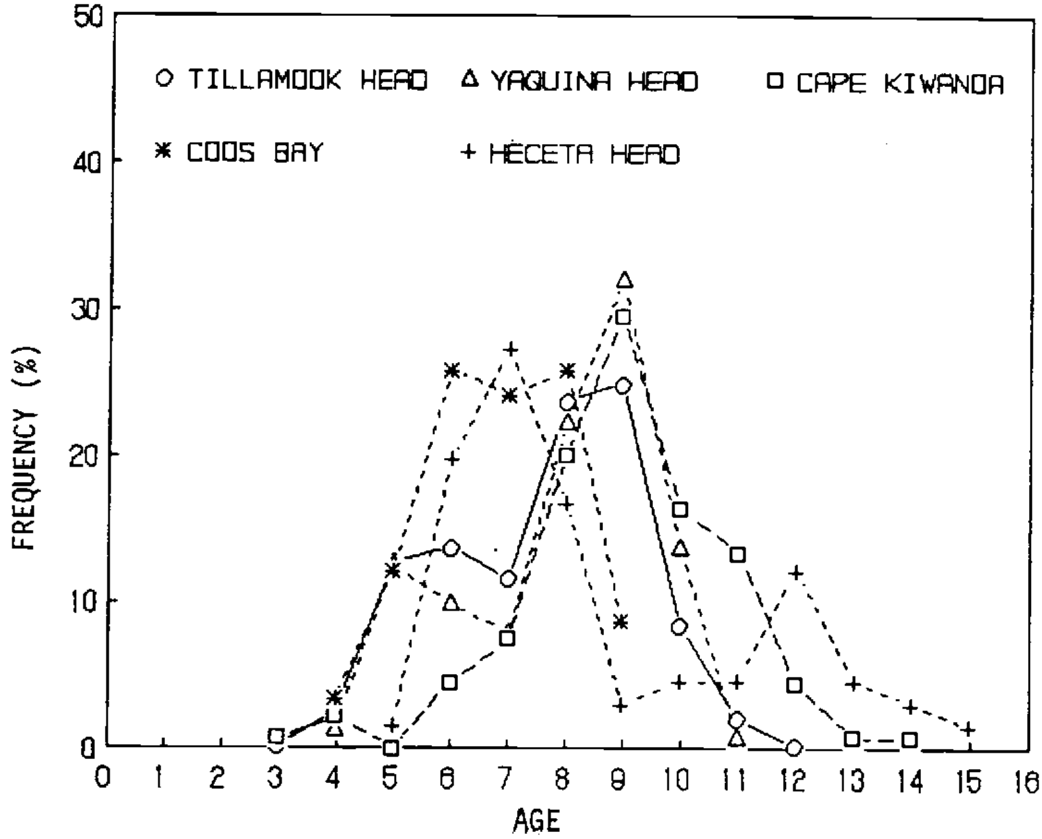


Figure 21. Scallop age distribution at the five studied localities.

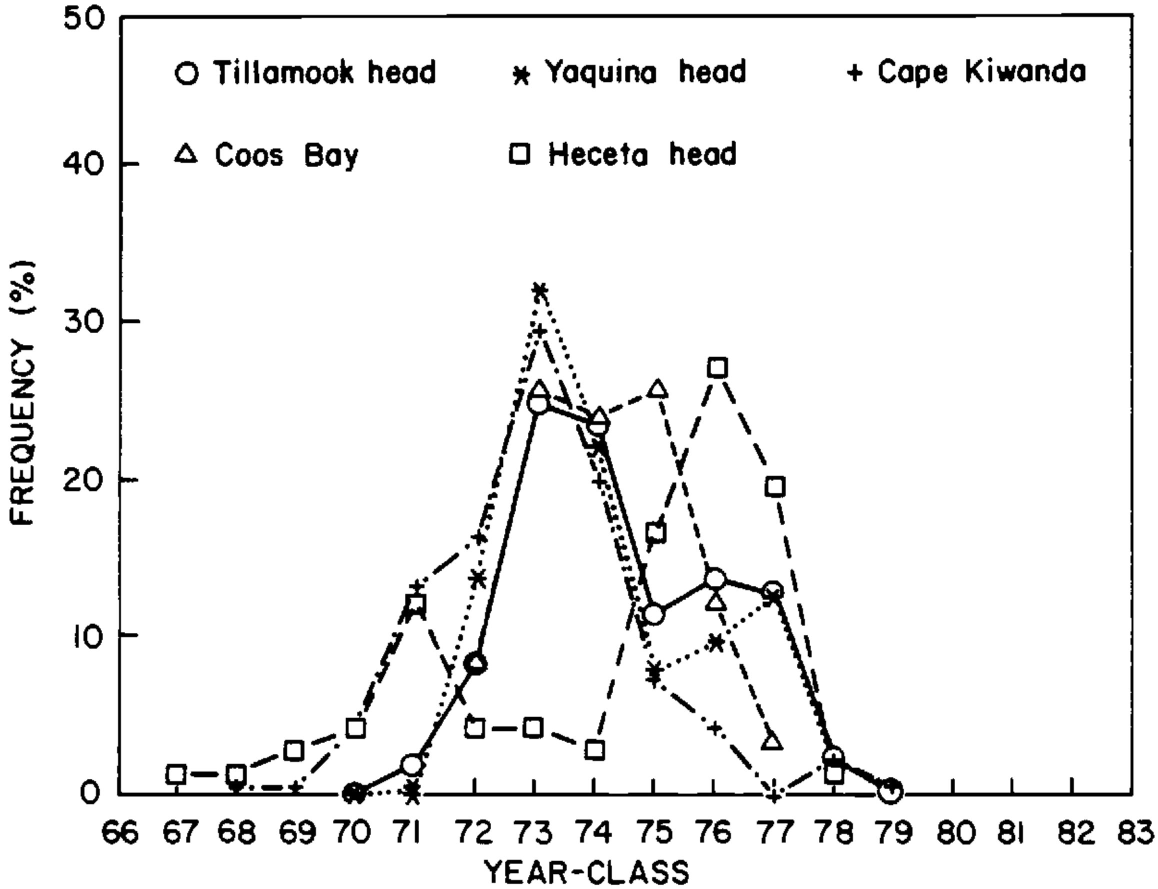


Figure 22. Scallop year-class distribution on the five studied localities.

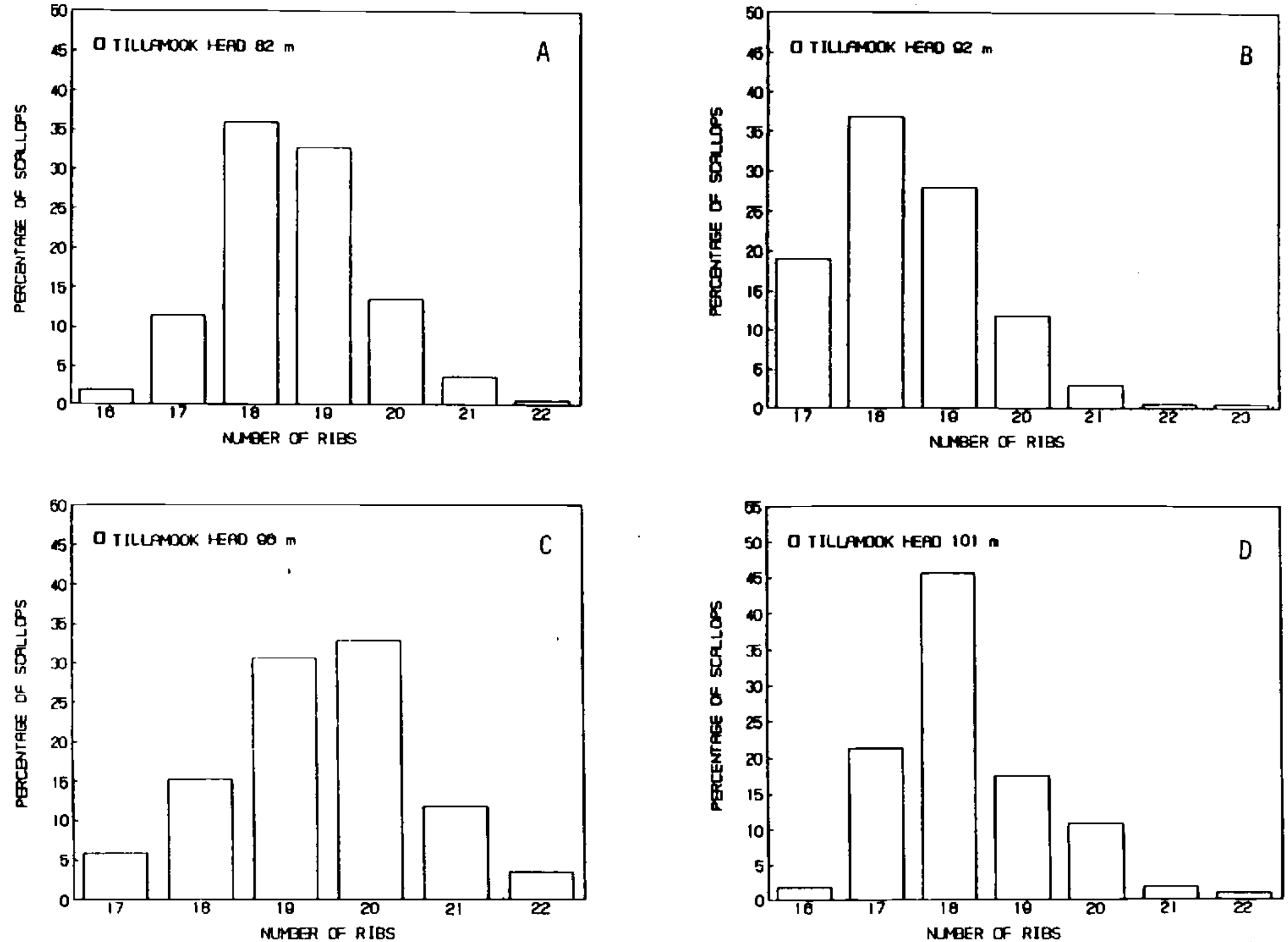


Figure 23. Number of ribs on scallop shells collected off Tillamook Head: A) 82 m; B) 92 m; C) 96 m; D) 101 m.

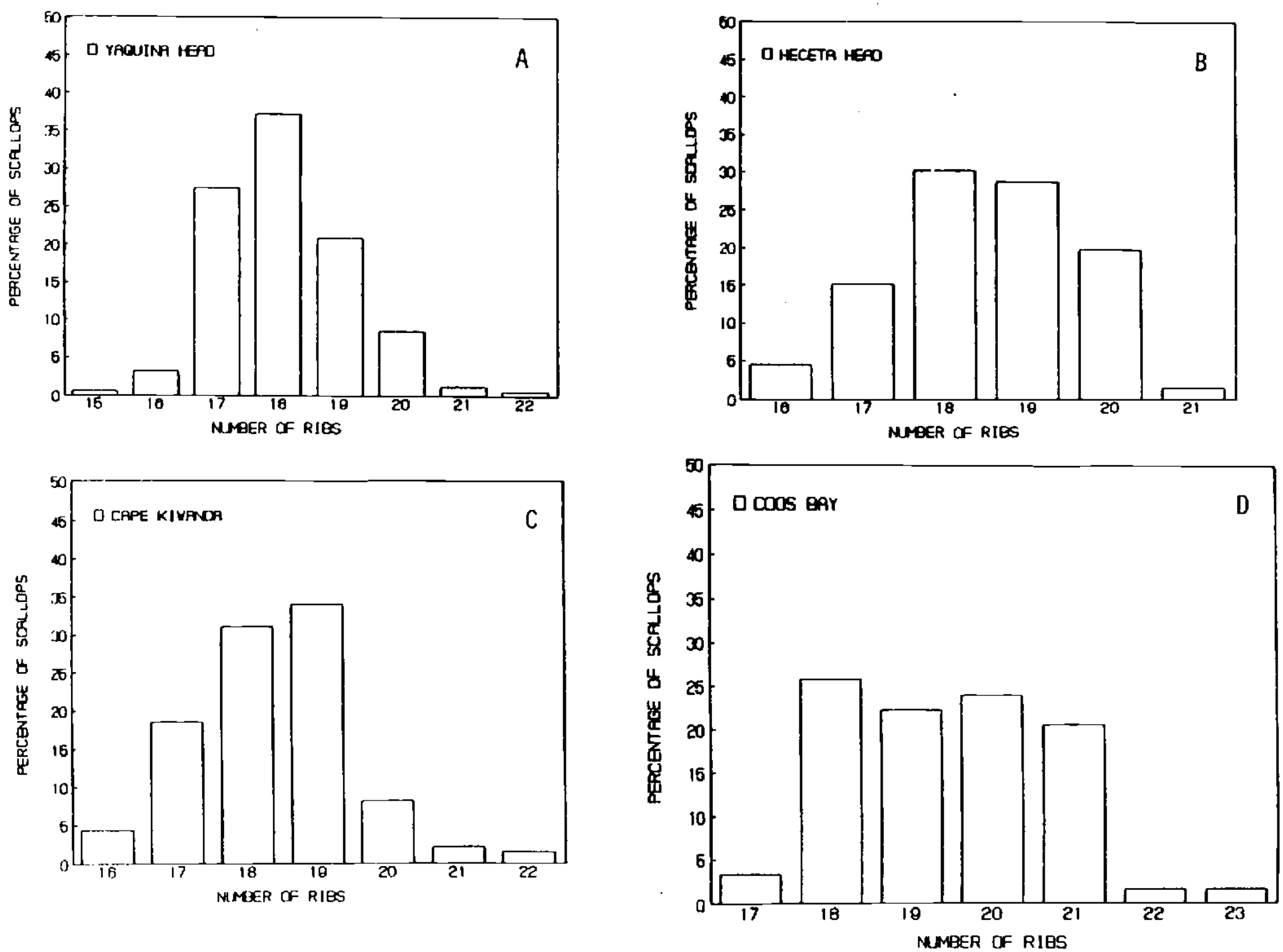


Figure 24. Number of ribs on scallop shells collected off: A) Yaquina Head; B) Heceta Head; C) Cape Kiwanda, D) Coos Bay.

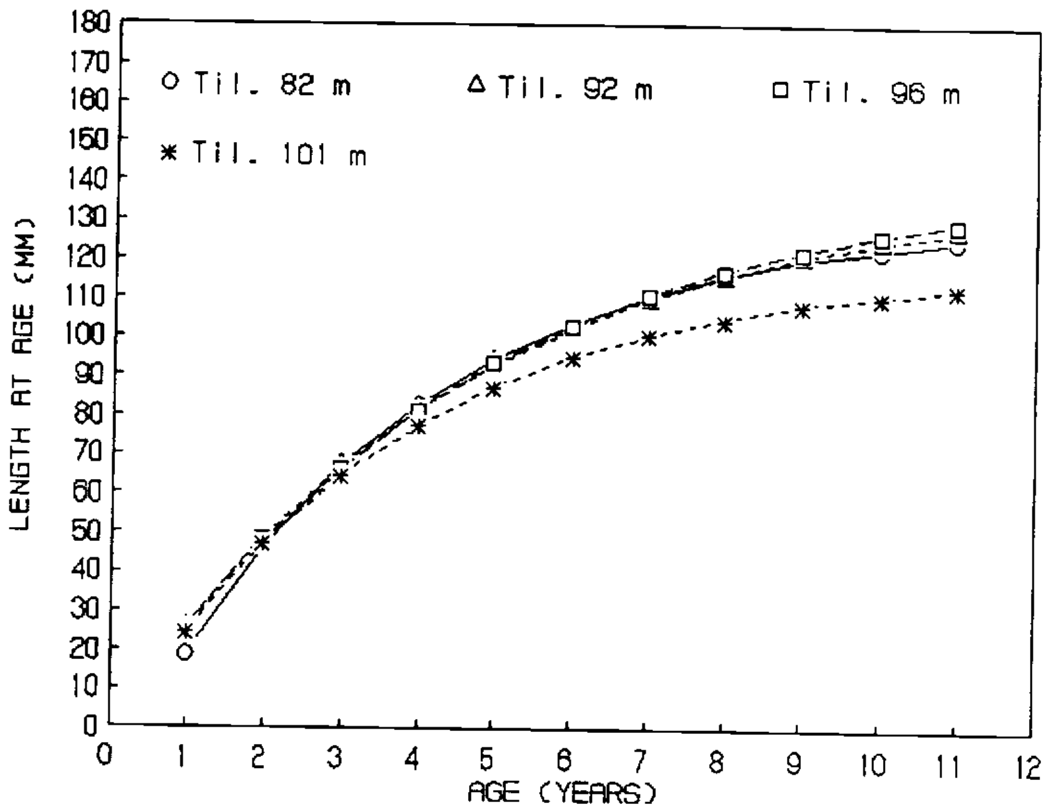


Figure 25. Fitted scallop growth curves at different depths off Tillamook Head.

Table 4. Age composition of the weathervane scallops (P. caurinus) from the Oregon coast, 1981-1983.[1]

	TH 82		TH92		TH96		TH101		CK		YQ		HH		CB		Total Localities	
Age	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
1																		
2																		
3					1	1.2			1	0.7							2	0.2
4	3	1.9	3	1.8	7	8.2			3	2.2	2	1.3			2	3.7	20	2.2
5	37	23.7	19	11.4	9	10.6					19	12.4	1	1.5	7	12.1	92	10.0
6	40	25.6	25	15.0	5	5.9			6	4.4	15	9.8	13	19.7	15	25.9	119	12.9
7	7	4.5	25	15.0	17	20.0	10	9.7	10	7.4	12	7.8	18	27.3	14	24.1	113	12.2
8	16	10.3	36	21.6	33	38.8	36	35.0	27	20.0	34	22.2	11	16.7	15	25.9	208	22.5
9	32	20.5	40	24.0	10	11.8	46	44.7	40	29.5	49	32.0	2	3.0	5	8.6	224	24.3
10	17	10.9	15	9.0	2	2.4	9	8.7	22	16.3	21	13.7	3	4.5			89	9.7
11	4	2.6	3	1.8	1	1.2	2	1.9	18	13.3	1	0.7	3	4.5			32	3.5
12			1	0.6					6	4.4			8	12.1			15	1.6
13									1	0.7			3	4.5			4	0.4
14									1	0.7			2	3.0			3	0.3
15													1	1.5			1	0.1
16													1	1.5			1	0.1
	156	100	167	100.2	85	100.1	103	100	135	99.6	153	99.9	66	99.8	58	100	923	100.0

[1] TH 45 = Tillamook Head, 82 m depth
TH 50 = Tillamook Head, 92 m depth
TH 52 = Tillamook Head, 96 m depth
TH 55 = Tillamook Head, 101 m depth
CK = Cape Kiwanda
YQ = Yaquina Head
HH = Heceta Head
CB = Coos Bay

All Tillamook samples are plotted in Figure 18, in which it is evident that scallops are generally smaller at deeper depths. Scallops taken in 1981 were smaller than those captured in 1982. The general pattern for the Tillamook scallops is they appear to be concentrated in the 101-105, 106-110, and 111-115 mm size interval, with a unimodal, bell-shape type of a curve for each collection. Collections from Coos Bay (1981), Yaquina Head, Cape Kiwanda (1982), and Heceta Head (1983), are plotted together with the Tillamook general curve in Figure 19. Scallops at Yaquina Head are smaller than the scallops from the other locations, with a main distribution from 71-75 to 111-115 mm height interval. Tillamook scallops are smaller than scallops from Coos Bay, Cape Kiwanda, and Heceta Head whose sizes range from 96-100 to 151-155 mm height interval (with a peak at 126-130 mm), and 101-105 to 126-130 mm (with a peak at 111-115 mm), respectively. The same trend of scallops concentrated in a few size classes is evident from these four locations, although in Coos Bay the trend is weakest.

Figure 20 is included to show the general scallop size distribution along the Oregon coast and the sizes that would be expected when using a traditional New Bedford dredge in sampling scallops.

Age and Growth.

The scallop age distribution for the 1981 Chapman cruise and 1982 Granada cruise are tabulated in Table 4.

In 1981, the Tillamook area was represented by individuals 3 to 11 years old and dominated by the 1973 year-class (8 years old). Year-classes from 1972 and 1974 were moderately represented, while year-classes for 1970, 1971, 1975, 1976, 1977, and 1978 were poorly represented. The Coos Bay area showed individuals 4 to 9 years old with age-classes for 1973, 1974, and 1975 (8, 7, and 6 year-olds) dominating the distribution.

In 1982, a similar age structure was found at the Tillamook, Cape Kiwanda and Yaquina Head areas, with a clear dominance of the 1973 year-class; the 1974 age-class was also well represented in these three locations at similar percentage frequencies. Commonly, year-classes were not equally abundant in the same areas at different depths. Thus, the Tillamook Head collection at 82 m has a bimodal distribution of age with a main peak at 6 years old, a secondary one at 9 years old, and a low representation of the 1975 year-class (7 years old). At deeper depths, the 1973 year-class dominated the area. Size distributions ranged from 4 to 11 years old at 82 m, 4 to 12 years old at 92 m, and 7 to 11 years old at 101 m depth.

As a whole, the more common age-classes along the Oregon coast during the 1981-1983 sampling period were ages 6, 7, 8, and 9 with the later being dominant (Fig. 21). The most common year-classes were the 1972, 1973, 1974, 1975, and 1976, with 1973 being the most important at four of the five locations (Fig. 22).

The aging procedures described in this study were used to generate the data presented in Appendices 1 and 2. Appendix 1 contains the tables for each locality, date, and depth, and includes the shell identification number, shell height, sampling date, the height at each annulus, number of ribs per shell, age of the shell, and the cohort in which each belongs.

Figures 23 to 24 were generated from Appendix 1 to analyze the number of ribs on the shells of the populations of Oregon coast scallops. Figure 23 shows the percent frequency distribution of the number of ribs on shells from the Tillamook area. The number of ribs varied from 16 to 23 at this location and are distributed in a bell-shaped curve having a peak at 18 ribs per shell for all depths except 96 m (Fig. 23C) in which the peak was located at 20 ribs per shell.

Yaquina Head (Fig. 24A) and Heceta Head (Fig. 24B) scallops show a similar bell-shape distribution with a peak at 18 ribs per shell, while at Cape Kiwanda this peak is found at 19 ribs per shell (Fig. 24C). Coos Bay scallops have a more even distribution of rib numbers with a good representation for 18, 19, 20 and 21 ribs per shell (Fig. 24D).

The average number of ribs per shell at different localities is presented in Table 5 which also includes the average size of scallops and the correlation found between the height of the shell and the number of ribs.

There is no correlation between the height of the shell and the number of ribs per shell in Oregon scallops.

Fitting A Growth Model.

The observed shell heights at age at each locality and depth are plotted in Appendix 2. Growth was described mathematically by fitting the mean of all shell heights at each annulus above the first inflection point to the Von Bertalanffy growth equation:

$$Lt = L_{\infty}[1\text{-Exp } -k(t - t_0)]$$

Table 5. Mean shell height, average number of ribs and the correlation of shell height to rib number for *Pecten caurinus* off the Oregon coast 1981-1983.

Locality	Depth (m)	N	Mean height (mm)	Ribs	r^2
Tillamook	82	156	116.5	18.5	0.0001
	92	167	113.6	18.4	0.0001
	96	85	112.2	19.4	0.01
	101	103	110.9	18.2	0.01
Cape Kiwanda	82	135	132.2	18.3	0.0001
Yaquina Head	110	153	8.7	18.0	0.01
Heceta Head		66	120.5	18.4	0.01
Coos Bay	82	58	124.5	19.4	0.003

where Lt is shell height in years; L_∞ is the theoretical maximum shell height; k is a constant expressing the rate of change in height increments with respect to t; and t_0 is the hypothetical age at zero height. Table 6 shows the parameter estimates and the asymtotic standard errors of the estimates derived from the Von Bertalanffy equation.

The Von Bertalanffy growth equations for scallops from the five localities and depths studied are:

Til. Head 82 m: Lt= 132.30 [1 - exp-0.2731 (t - 0.4126)]

Til. Head 92 m: Lt= 139.30 [1 - exp-0.2250 (t - 0.0839)]

Til. Head 96 m: Lt= 143.41 [1 - exp-0.2142 (t - 0.0773)]

Til. Head 101 m: Lt= 118.28 [1 - exp-0.2791 (t - 0.1735)]

Cap. Kiw. 82 m: Lt= 149.33 [1 - exp-0.2549 (t - 0.3373)]

Yaq. Head 110 m: Lt= 111.50 [1 - exp-0.2348 (t + 0.0252)]

Coos Bay 82 m: Lt= 160.92 [1 - exp-0.1579 (t + 2.3111)]

Hec. Head : Lt = 127.27 [1 - exp-0.2865 (t - 0.2736)]

Observed and fitted mean shell height values are presented in Tables 7 to 11 for all localities, showing a good correlation between the observed and fitted values.

Table 6. Parameter estimates and standard errors of the estimates derived from the Von Bertalanffy growth model for Pecten caurinus off the Oregon coast, 1981-1983. Lt = calculated shell height (mm) at age; L_∞ = calculated terminal (asymtotic) shell height; k = growth constant; t = age; t_0 = time when shell height is theoretically zero (i.e. Lt = 0).

Locality	Year	Depth	L	K	t_0	S.E. L	S.E.K	S.E. t_0
Tillamook H.	1982	82	132.30	0.273	0.413	2.054	0.084	0.880
	1982	92	139.30	0.225	0.084	1.544	0.010	0.954
	1981	96	143.41	0.214	0.077	3.163	0.018	1.244
	1982	101	118.28	0.279	0.174	9.186	0.330	5.848
Cape Kiwanda	1982	82	149.33	0.255	0.337	2.166	0.029	0.360
Yaquina Head	1982	110	111.50	0.235	-0.025	4.028	0.109	1.235
Heceta Head	1983		127.27	0.287	0.274	2.983	0.110	3.277
Coos Bay	1981	82	160.92	0.158	-2.311	9.650	0.0206	4.327

Table 7. Measured average height value, predicted value at age, and correlation coefficient between these values at 82 m for Tillamook Head, 1982.

Estimated Age (years)	Height: Measured	Height: Estimated	Correlation coefficient
1	25.0	25.04	0.97
2	40.7	46.98	
3	59.5	64.61	
4	83.6	78.79	
5	99.8	90.18	
6	107.8	99.34	
7	112.6	106.70	
8	116.2	112.62	
9	118.6	117.38	
10	120.8	121.20	
11	122.2	124.27	

Table 8. Measured average height value, predicted height at age, and correlation coefficient between these values for Cape Kiwanda, 1982.

Estimated Age (years)	Height		Correlation coefficient
	Measured	Estimated	
1	28.1	23.21	0.99
2	46.4	51.60	
3	67.1	73.59	
4	90.9	90.64	
5	109.0	103.85	
6	117.9	114.08	
7	124.1	122.02	
8	128.0	128.17	
9	132.0	132.93	
10	134.7	136.62	
11	138.3	139.49	
12	141.5	141.70	
13	144.0	143.42	

Table 9. Measured average height value, predicted height value at age, and correlation coefficient between these values for at 82 m for Yaquina Head, 1982.

Estimated Age (years)	Height		Correlation coefficient
	Measured	Estimated	
1	24.6	23.85	0.99
2	40.8	42.19	
3	56.3	56.70	
4	68.9	68.16	
5	77.7	77.22	
6	83.9	84.40	
7	89.8	90.06	
8	95.4	94.55	
9	99.0	98.09	
10	99.9	100.90	

Table 10. Measured average height value, predicted height value at age, and correlation coefficient between these values for Coos Bay, 1981.

Estimated Age (years)	Height		Correlation coefficient
	Measured	Estimated	
1	25.7	23.02	0.99
2	44.7	48.32	
3	66.6	69.18	
4	87.9	86.40	
5	103.5	100.61	
6	113.4	112.33	
7	121.7	122.01	
8	129.0	129.99	
9	136.0	136.58	

Table 11. Measured average height value, predicted value at age, and correlation coefficient between these values for Heceta Head, 1983.

Estimated age (years)	Height		Correlation coefficient
	Measured	Estimated	
1	26.9	23.88	0.99
2	45.6	49.61	
3	65.5	68.92	
4	83.6	83.43	
5	98.0	94.32	
6	106.9	102.50	
7	111.3	108.64	
8	113.6	113.25	
9	114.3	116.72	
10	117.0	119.32	
11	119.1	121.27	
12	122.2	122.74	
13	125.1	123.84	
14	125.7	124.67	
15	124.5	125.29	
16	127.0	125.75	

Fitted growth curves for Tillamook at all depths and for all localities are displayed in Figures 25 and 26, respectively. At Tillamook, scallops from deeper waters (i.e. 101 m) grew slower and to a shorter size than those from shallower depths. The larger sizes are reached faster in shallower waters (Fig. 25).

A comparison of the five localities in Figure 26 shows that scallops from Coos Bay grew faster than scallops from Yaquina Head, Tillamook, and Cape Kiwanda at all ages, and also grew faster than Heceta Head populations after the fifth year. Scallops from Yaquina Bay had the slowest growth and they were smaller at all ages compared to the scallops from the other locations. The Tillamook population grew at an intermediate rate and reached intermediate sizes compared with the Coos Bay and Yaquina Head populations. The fastest growth between the second and sixth year of age was exhibited by the Cape Kiwanda population, but declining growth rate thereafter resulted in a smaller asymtotic length at older ages than that of the Coos Bay population.

A cohort analysis of the mean shell height at each annulus is presented in Tables 12 to 19 for all localities and depths. Rosa Lee's phenomenon (in the positive sense), when the mean size at a given early age decreases as the age of the individuals upon which observations are made increases, is only apparent at some annulus numbers for Tillamook in the 82 and 92 m samples (Table 12 and 13).

Mean growth increments were calculated (Table 20) to analyze how a given cohort grew at different locations and depths. For all localities, first year growth ranged from 21 to 30 mm, with the mean around 25 mm. After the first year, growth rate decreased at varying

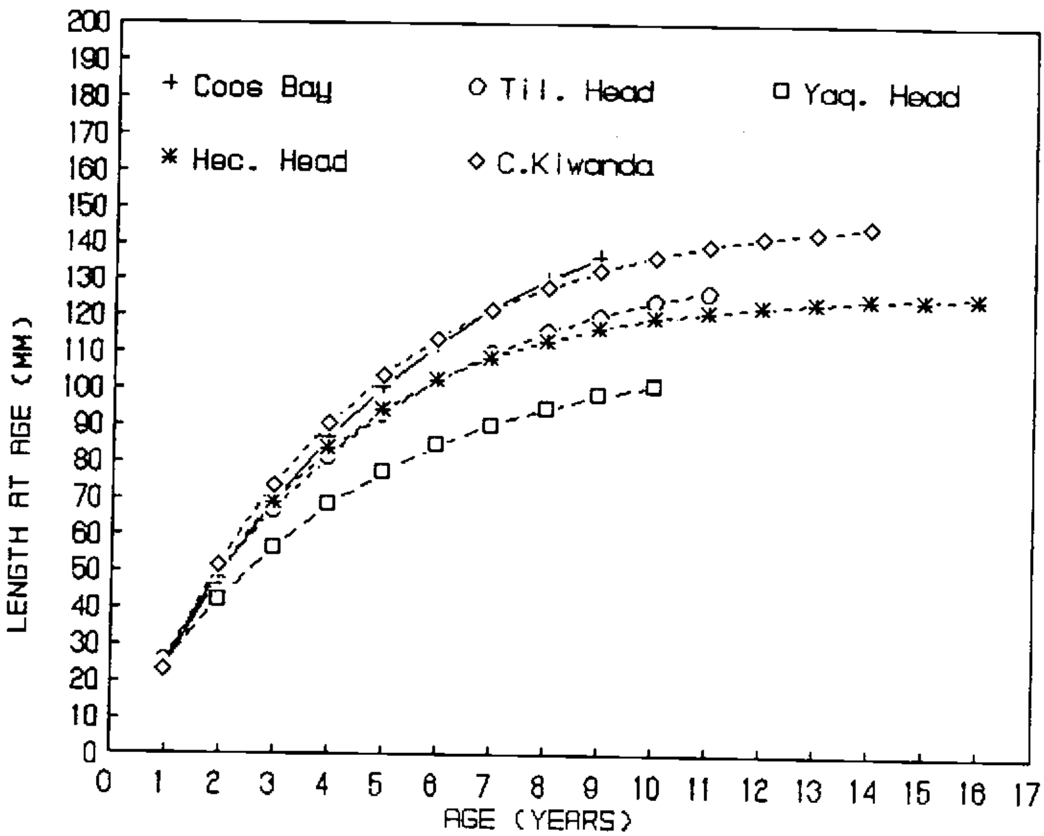


Figure 26. Fitted scallop growth curves on the five studied localities.

Table 12. Average size at age for Tillamook scallops at 82 m.

	ANNULUS NUMBER												
Cohort-age	1	2	3	4	5	6	7	8	9	10	11	12	N
Cohort78-(4)	25.0	50.0	75.6	94.3									3
Cohort77-(5)	25.5	44.0	67.4	92.2	104.0								37
Cohort76-(6)	24.5	39.1	54.6	80.2	100.0	110.2							40
Cohort75-(7)	25.7	41.1	59.5	71.5	97.7	107.7	115.2						7
Cohort74-(8)	25.0	40.5	60.2	82.8	99.1	108.1	113.3	117.6					16
Cohort73-(9)	25.1	38.8	56.1	81.4	97.3	106.5	112.5	116.3	119.1				32
Cohort72-(10)	25.1	39.7	58.4	79.1	95.8	105.5	111.8	115.3	118.0	121.1			17
Cohort71-(11)	24.7	40.7	53.5	74.7	90.7	102.7	109.2	136.5	116.7	119.5	122.0		4
													156

Table 13. Average size at age for Tillamook scallops at 92 m.

	ANNULUS NUMBER												
Cohort-age	1	2	3	4	5	6	7	8	9	10	11	12	N
Cohort78-(4)	23.3	51.0	76.0	92.6									3
Cohort77-(5)	25.7	44.3	65.7	89.9	101.2								19
Cohort76-(6)	27.2	44.6	64.7	83.4	97.0	105.4							25
Cohort75-(7)	26.1	46.3	64.7	81.2	93.2	103.4	110.0						25
Cohort74-(8)	25.9	45.6	64.8	80.9	92.4	100.4	106.8	111.8					36
Cohort73-(9)	25.1	43.6	62.8	78.9	90.7	98.9	104.9	110.0	114.0				40
Cohort72-(10)	27.2	44.5	62.7	79.8	93.5	102.2	107.6	112.6	116.2	119.9			15
Cohort71-(11)	21.3	38.6	60.6	78.3	91.7	99.3	104.0	109.0	112.3	115.0	117.0		3
Cohort70-(12)	21.0	33.0	56.0	82.0	101.0	113.0	121.0	125.0	128.0	131.0	133.0	134.0	1
													167

Table 14. Average size at age for Tillamook scallops at 96 m.

	ANNULUS NUMBER											
Cohort-age	1	2	3	4	5	6	7	8	9	10	11	N
Cohort78-(3)	25.0	50.0	80.0									1
Cohort77-(4)	24.2	49.7	74.7	96.4								7
Cohort76-(5)	26.6	45.7	63.0	84.2	101.0							9
Cohort75-(6)	26.0	43.0	58.8	73.2	87.6	98.6						5
Cohort74-(7)	26.3	47.6	66.6	82.8	92.5	100.3	106.3					17
Cohort73-(8)	25.8	48.5	67.5	82.7	92.6	99.9	105.9	111.6				33
Cohort72-(9)	25.7	45.5	65.7	83.6	95.5	103.0	108.6	112.4	115.0			10
Cohort71-(10)	25.5	50.0	72.0	91.5	98.0	103.5	111.0	115.5	119.0	122.0		2
Cohort70-(11)	23.0	39.0	56.0	69.0	89.0	107.0	116.0	122.0	125.0	128.0	131.0	1
												35

Table 15. Average size at age for Tillamook scallops at 101 m.

	ANNULUS NUMBER											
Cohort-age	1	2	3	4	5	6	7	8	9	10	11	N
Cohort75-(7)	26.6	46.2	64.4	77.9	89.4	97.8	104.1					10
Cohort74-(8)	25.8	75.5	63.1	77.5	87.2	94.3	101.1	106.5				36
Cohort73-(9)	25.2	46.2	64.9	78.6	88.0	95.0	100.6	105.8	110.0			46
Cohort72-(10)	24.0	43.6	62.6	78.0	87.8	94.2	98.8	103.5	108.0	111.1		9
Cohort71-(11)	23.5	44.0	59.5	71.5	85.5	92.5	97.5	102.0	105.5	108.5	111.5	2
												103

Table 16. Average size at age for Cape Kiwanda scallops.

	ANNULUS NUMBER													
Cohort-age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	N
Cohort79-(3)	30.0	52.0	74.0												1
Cohort78-(4)	26.0	47.3	71.0	89.7											3
Cohort76-(6)	28.3	51.0	71.0	98.8	111.8	120.0									6
Cohort75-(7)	28.1	45.9	64.8	90.7	110.0	119.0	123.8								10
Cohort74-(8)	28.7	45.8	66.1	89.2	107.9	116.1	122.5	126.4							27
Cohort73-(9)	28.2	46.9	67.6	90.9	109.0	117.4	123.9	128.1	131.7						40
Cohort72-(10)	27.3	45.9	66.0	90.8	108.0	117.8	124.0	127.6	130.7	133.2					22
Cohort71-(11)	28.5	46.2	66.8	93.9	111.1	120.0	126.9	130.3	133.4	135.8	138.2				18
Cohort70-(12)	28.0	46.0	63.1	88.0	106.87	118.1	124.5	129.5	133.1	135.8	138.1	140.5			6
Cohort69-(13)	30.0	55.0	75.0	102.0	121.0	129.0	134.0	136.0	139.0	142.0	144.0	146.0	147.0		1
Cohort68-(14)	30.0	46.0	63.0	82.0	100.0	117.0	124.0	127.0	131.0	134.0	137.0	140.0	142.0	144.0	1
															135

Table 17. Average size at age for Yaquina Head scallops at 110 m.

	ANNULUS NUMBER											
Cohort-age	1	2	3	4	5	6	7	8	9	10	11	N
Cohort78-(4)	31.5	48.5	71.5	81.5								2
Cohort77-(5)	24.6	39.8	55.5	74.1	82.8							19
Cohort76-(6)	23.2	35.8	50.4	65.1	79.5	87.3						15
Cohort75-(7)	24.0	42.7	60.8	72.5	79.9	87.6	94.3					12
Cohort74-(8)	25.8	43.5	59.6	72.2	80.3	87.3	93.6	99.6				34
Cohort73-(9)	24.7	41.0	56.6	67.7	75.7	82.3	89.0	95.2	100.0			49
Cohort72-(10)	23.6	38.4	51.0	61.6	71.6	78.1	83.4	89.4	95.1	100.0		21
Cohort71-(11)	25.0	41.0	55.0	64.0	72.0	78.0	84.0	90.0	93.0	95.0	97.0	1
												153

Table 18. Average size at age for Heceta Head scallops.

Cohort-age	ANNULUS NUMBER																N
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Cohort78-(5)	23.0	39.0	62.0	84.0	101.0												1
Cohort77-(6)	27.7	46.9	70.0	93.1	105.4	112.9											13
Cohort76-(7)	21.1	45.7	67.2	84.8	99.6	109.8	115.5										18
Cohort75-(8)	26.6	44.8	63.1	77.5	94.7	106.5	114.5	119.3									11
Cohort74-(9)	29.0	48.5	67.5	87.0	99.0	105.0	109.0	112.5	115.5								2
Cohort73-(10)	29.6	51.3	73.6	89.3	98.0	104.3	109.6	114.6	119.0	121.6							3
Cohort72-(11)	25.3	40.6	57.0	76.3	90.3	98.0	104.3	109.3	112.0	115.0	117.3						3
Cohort71-(12)	26.0	44.3	62.0	80.0	94.6	101.8	106.2	110.0	113.0	115.8	119.1	121.6					8
Cohort70-(13)	24.3	45.6	61.6	78.0	90.7	97.3	102.3	109.6	115.0	118.6	121.6	125.0	127.3				3
Cohort69-(14)	30.5	48.5	61.5	74.0	90.5	105.0	112.5	115.5	118.0	120.5	122.5	125.0	127.0	129.5			2
Cohort68-(15)	24.0	38.0	61.0	80.0	95.0	102.0	105.0	108.0	110.0	112.0	115.0	118.0	121.0	123.0	125.0		1
Cohort67-(16)	26.0	44.0	56.0	75.0	90.0	97.0	102.0	106.0	110.0	113.0	115.0	117.0	119.0	121.0	124.0	127.0	1
																	66

Table 19. Average size at age for Coos Bay scallops, 1981.

Cohort-age	ANNULUS NUMBER 1	2	3	4	5	6	7	8	9	N
Cohort77-(4)	25.2	48.2	72.5	96.0						2
Cohort76-(5)	22.87	42.1	67.8	97.5	113.0					7
Cohort75-(6)	28.4	46.8	68.2	88.3	102.0	113.7				15
Cohort74-(7)	26.8	45.7	67.0	86.5	98.7	111.2	119.5			14
Cohort73-(8)	23.7	43.5	73.8	83.7	103.0	113.4	122.1	128.2		15
Cohort72-(9)	24.2	40.4	86.8	86.8	107.0	119.2	126.6	131.2	136.0	5
										58

Table 20. Mean growth increments for scallops by location and depths.

Age Interval	1970	1971	1972	1973	1974	1975	1976	1977	1978	Average
Tillamook Head 82. 82 m										
0-1		24.7	25.1	25.1	25.0	25.7	24.5	25.0	25.0	25.0
1-2		16.0	14.5	13.6	15.5	15.4	14.5	18.4	25.0	16.6
2-3		12.7	18.7	17.3	19.6	18.4	15.5	23.4	25.6	18.9
3-4		21.2	20.6	25.2	22.6	22.0	25.6	24.7	18.6	22.6
4-5		16.0	16.4	15.9	16.2	16.1	20.3	12.2		16.2
5-6		12.0	9.7	9.5	9.0	10.0	9.6			9.9
6-7		6.5	6.3	5.9	5.3	7.6				6.3
7-8		4.2	3.5	3.8	4.3					4.0
8-9		3.2	2.6	2.8						2.9
9-10		-2.7	3.1							2.9
10-11		2.7								2.7
Tillamook Head: 92 m										
0-1	21.0	21.3	27.2	25.1	25.9	26.1	27.2	25.7	23.3	24.8
1-2	12.0	17.3	17.2	18.4	19.7	20.2	17.4	18.5	27.6	18.7
2-3	23.0	22.0	18.2	19.2	19.2	18.4	20.0	21.4	25.0	20.7
3-4	26.0	17.6	17.0	16.0	16.0	16.4	18.6	24.1	16.6	18.7
4-5	19.0	13.3	·13.3	11.7	11.4	12.0	13.6	11.3		13.2
5-6	12.0	7.6	8.6	8.2	8.0	10.2	8.4			9.0
6-7	8.0	4.6	5.5	6.0	6.4	6.6				6.2
7-8	4.0	5.0	5.0	5.1	5.0					4.8
8-9	3.0	3.3	3.6	4.0						3.5
9-10	3.0	2.6	3.6							3.1
10-11	2.0	2.3								2.2
11-12	1.0									1.0
Tillamook Head 81: 96 m										
0-1	23.0	25.5	25.7	25.8	26.3	26.0	26.6	24.2	25.0	25.3
1-2	16.0	24.5	19.8	22.6	21.2	17.0	19.1	25.4	25.0	21.2
2-3	17.0	22.0	20.2	19.0	19.0	15.8	17.2	25.0	30.0	20.6
3-4	13.0	19.5	17.9	15.1	16.1	14.4	21.2	21.7		17.4
4-5	20.0	6.5	11.9	9.9	9.8	14.4	16.7			12.8
5-6	18.0	5.5	7.5	7.2	7.8	11.0				9.5
6-7	9.0	7.5	5.6	6.0	6.0					6.9
7-8	6.0	4.5	3.8	5.7						5.0
8-9	3.0	3.5	3.0							3.2
9-10	3.0	3.0								3.0
10-11	3.0									3.0
Tillamook Head 101 m										
0-1		23.5	24.0	25.2	25.87	26.6				25.0
1-2		20.5	19.6	21.0	19.6	19.6				20.1
2-3		15.5	19.0	18.6	17.6	18.2				17.8
3-4		12.0	15.3	13.7	14.4	13.5				13.8
4-5		14.0	9.8	9.4	9.7	11.5				10.9
5-6		7.0	6.3	7.0	7.0	8.4				7.1
6-7		5.0	4.5	5.6	6.9	6.3				5.7
7-8		4.5	4.7	5.1	5.3					4.9
8-9		3.5	4.4	4.2						4.0
9-10		3.0	3.1							3.1
10-11		3.0								3.0

Table 20. (Continued)

Age Interval	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	Average
Cape Kiwanda: 82 m													
0-1	30.0	30.0	28.0	28.5	27.3	28.2	28.7	28.1	28.3		26.0	30.0	28.5
1-2	16.0	25.0	15.0	17.7	18.5	17.7	14.1	17.8	22.6		21.3	22.0	19.2
2-3	17.0	20.0	20.1	20.6	20.0	20.7	20.2	22.8	20.0		23.6	22.0	20.7
3-4	19.0	27.0	24.8	27.0	24.7	23.2	23.0	22.0	22.8		18.6		23.2
4-5	18.0	19.0	18.8	17.2	17.3	18.1	18.7	19.3	18.0				18.2
5-6	17.0	8.0	11.3	8.9	9.8	8.4	8.2	9.0	8.2				9.9
6-7	7.0	5.0	6.3	6.8	6.1	6.4	6.4	4.8					6.1
7-8	3.0	2.0	5.0	3.4	3.6	4.2	3.8						3.6
8-9	4.0	3.0	3.6	3.1	3.1	3.7							3.4
9-10	3.0	3.0	2.6	2.7	2.5								2.7
10-11	3.0	2.0	2.3	2.3									2.4
11-12	3.0	2.0	2.3										2.4
12-13	2.0	1.0											1.5
13-14	2.0												2.0
Yaquina Head: 110 m													
0-1				25.0	23.6	24.7	25.8	24.0	23.2	24.6	31.5		25.3
1-2				16.0	14.8	16.3	17.7	18.4	12.6	15.2	17.2		6.1
2-3				14.0	12.5	15.6	16.0	18.0	14.5	15.6	10.0		14.5
3-4				9.0	10.6	11.0	12.5	11.7	14.7	18.5			12.6
4-5				8.0	9.9	8.0	8.1	7.3	14.4	8.7			9.2
5-6				6.0	6.5	6.6	6.9	7.7	7.8				7.0
6-7				6.0	5.3	6.6	6.3	6.6					6.2
7-8				6.0	5.9	6.3	6.0						6.1
8-9				3.0	5.8	5.6							4.8
9-10				2.0	4.9								3.5
10-11				2.0									2.0

Coos Bay 81: 82 m

Age Interval	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Average
0-1				24.2	23.7	26.8	28.5	22.8	25.5						25.3
1-2				16.2	19.8	18.9	18.3	19.2	23.0						19.2
2-3				24.6	20.2	21.2	21.4	25.7	24.5						22.9
3-4				21.8	20.0	19.5	20.1	29.9	23.5						22.5
4-5				20.4	19.4	12.2	14.0	16.1							16.4
5-6				12.0	10.2	12.4	11.4								11.5
6-7				7.4	8.7	8.4									8.2
7-8				4.6	6.1										5.4
8-9				4.8											4.8

Table 20. (Continued)

Heceta Head 83

Age Interval	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	Average
0-1	26.0	24.0	30.5	24.3	26.0	25.3	29.6	29.0	26.6	28.6	27.2	23.0			26.7
1-2	18.0	14.0	18.0	21.3	18.3	15.3	21.6	19.1	18.1	18.6	19.1	16.0			18.1
2-3	12.0	23.0	13.0	16.0	17.6	16.3	22.3	19.0	18.3	21.4	23.1	23.0			18.8
3-4	19.0	19.0	12.5	16.3	18.0	19.3	15.6	19.5	14.3	17.6	23.0	22.0			18.0
4-5	15.0	15.0	16.5	12.6	14.6	14.0	8.6	12.0	17.1	14.6	12.6	17.0			14.1
5-6	7.0	7.0	14.5	6.6	7.2	7.6	6.3	6.0	11.8	10.3	7.1				8.3
6-7	5.0	3.0	7.5	5.0	4.4	6.3	5.3	4.0	8.0	5.6					5.4
7-8	4.0	3.0	3.0	7.3	3.7	5.0	5.0	3.5	4.8						4.4
8-9	4.0	2.0	2.5	5.3	3.0	2.6	4.3	3.0							3.3
9-10	3.0	2.0	2.5	3.6	2.9	3.0	2.6								2.8
10-11	2.0	3.0	2.0	3.0	3.2	2.3									2.6
11-12	2.0	3.0	2.5	3.3	2.5										2.7
12-13	2.0	3.0	2.0	2.3											2.3
13-14	2.0	2.0	2.5												2.2
14-15	3.0	2.0													2.5
15-16	3.0														3.0

rates. Scallops at Coos Bay had the fastest growth rate at all ages, while scallops at Yaquina Head grew slowest at all ages. Between cohorts there were no clear differences in growth rates within localities. The 1977 age-class grew best at Tillamook Head at 82 and 96 m depth (when comparing the first four years where growth was most consistent); the cohort also did well the fifth year at 92 m depth. The 1977 age-class grew well the second year of age at Coos Bay and the fifth year of age at Yaquina Head.

In an attempt to describe years of exceptional growth, the mean growth increment tables for each locality were rearranged as shown in Table 21. Years of better growth at Tillamook Head were 1974, 1975, 1976, 1977, 1980, and 1981, in which values at most ages were above average. At Cape Kiwanda the best years for scallop growth were 1974, 1975, and 1980; at Yaquina Head 1977 and 1980 were good years for growth; the better years for Heceta Head scallops were 1975, 1976, 1981, and 1982; and the best years for Coos Bay scallops were 1975 and 1980. The criterium for selecting the good years was matching those years that appeared at least three times per locality in being above the average in a given age.

The Hotelling's T^2 statistic was used to test for differences (at 5% level) in growth among samples within a locality, and between localities. Table 22 is a matrix showing both the calculated T^2 when comparing these samples, and the 5% tabulated T^2 value for the corresponding degrees of freedom in making the comparison.

Growth was not significantly different between the Tillamook stations at 82-92 m, 82-96 m, 92-101 m, and 96-101 m, but was significantly different between the 82-101 m stations. Growth for

Table 21. Mean growth increments for scallops by location and depths.

Age Interval	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Average
Tillamook Head 82. 82 m													
0-1		24.7	25.1	25.1	25.0	25.7	24.5	25.0	25.0				25.0
1-2			16.0	14.5	13.6	15.5	15.4	14.5	18.4	25.0			16.6
2-3				12.7	18.7	17.3	19.6	18.4	15.5	23.4	25.6		18.9
3-4					21.2	20.6	25.2	22.6	22.0	25.6	24.7	18.6	22.6
4-5						16.0	16.4	15.9	16.2	16.1	20.3	12.2	16.2
5-6							12.0	9.7	9.5	9.0	10.0	9.6	9.9
6-7								6.5	6.3	5.9	5.3	7.6	6.3
7-8									4.2	3.5	3.8	4.3	4.0
8-9										3.2	2.6	2.8	2.9
9-10											2.7	3.1	2.9
10-11												2.7	2.7
Tillamook Head: 92 m													
0-1	21.0	21.3	27.2	25.1	25.9	26.1	27.2	25.7	23.3				24.8
1-2		12.0	17.3	17.2	18.4	19.7	20.2	17.4	18.5	27.6			18.7
2-3			23.0	22.0	18.2	19.2	19.2	18.4	20.0	21.4	25.0		20.7
3-4				26.0	17.6	17.0	16.0	16.0	16.4	18.6	24.1	16.6	18.7
4-5					19.0	13.3	13.3	11.7	11.4	12.0	13.6	11.3	13.2
5-6						12.0	7.6	8.6	8.2	8.0	10.2	8.4	9.0
6-7							8.0	4.6	5.5	6.0	6.4	6.6	6.2
7-8								4.0	5.0	5.0	5.1	5.0	4.8
8-9									3.0	3.3	3.6	4.0	3.5
9-10										3.0	2.6	3.6	3.1
10-11											2.0	2.3	2.2
11-12												1.0	1.0
Tillamook Head 81: 96 m													
0-1	23.0	25.5	25.7	25.8	26.3	26.0	26.6	24.2	25.0				25.3
1-2		16.0	24.5	19.8	22.6	21.2	17.0	19.1	25.4	25.0			21.2
2-3			17.0	22.0	20.2	19.0	19.0	15.8	17.2	25.0	30.0		20.6
3-4				13.0	19.5	17.9	15.1	16.1	14.4	21.2	21.7		17.4
4-5					20.0	6.5	11.9	9.9	9.8	14.4	16.7		12.8
5-6						18.0	5.5	7.5	7.2	7.8	11.0		9.5
6-7							9.0	7.5	5.6	6.0	6.0		6.9
7-8								6.0	4.5	3.8	5.7		5.0
8-9									3.0	3.5	3.0		3.2
9-10										3.0	3.0		3.0
10-11											3.0		3.0
Tillamook Head 101 m													
0-1	23.5	24.0	25.2	25.8	26.6								25.0
1-2		20.5	19.6	21.0	19.6	19.6							20.1
2-3			15.5	19.0	18.6	17.6	18.2						17.8
3-4				12.0	15.3	13.7	14.4	13.5					13.8
4-5					14.0	9.8	9.4	9.7	11.5				10.9
5-6						7.0	6.3	7.0	7.0	8.4			7.1
6-7							5.0	4.5	5.6	6.9	6.3		5.7
7-8								4.5	4.7	5.1	5.3		4.9
8-9									3.5	4.4	4.2		4.0
9-10										3.0	3.1		3.1
10-11											3.0		3.0

Table 21. (Continued)

Age Interval	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Average
Cape Kiwanda: 82 m															
0-1	30.0	30.0	28.0	28.5	27.3	28.2	28.7	28.1	28.3		26.0	30.0			28.5
1-2		16.0	25.0	15.0	17.7	18.5	17.7	14.1	17.8	22.6		21.3	22.0		19.2
2-3			17.0	20.0	20.1	20.6	20.0	20.7	20.2	22.8	20.0		23.6	22.0	20.7
3-4				19.0	27.0	24.8	27.0	24.7	23.2	23.0	22.0	22.8		18.6	23.2
4-5					18.0	19.0	18.8	17.2	17.3	18.1	18.7	19.3	18.0		18.2
5-6						17.0	8.0	11.3	8.9	9.8	8.4	8.2	9.0	8.2	9.9
6-7							7.0	5.0	6.3	6.8	6.1	6.4	6.4	4.8	6.1
7-8								3.0	2.0	5.0	3.4	3.6	4.2	3.8	3.6
8-9									4.0	3.0	3.6	3.1	3.1	3.7	3.4
9-10										3.0	3.0	2.6	2.7	2.5	2.7
10-11											3.0	2.0	2.3	2.3	2.4
11-12												3.0	2.0	2.3	2.4
12-13													2.0	1.0	1.5
13-14														2.0	2.0
Yaquina Head: 110 m															
0-1				25.0	23.6	24.7	25.8	24.0	23.2	24.6	31.5				25.3
1-2					16.0	14.8	16.3	17.7	18.4	12.6	15.2	17.2			6.1
2-3						14.0	12.5	15.6	16.0	18.0	14.5	15.6	10.0		14.5
3-4							9.0	10.6	11.0	12.5	11.7	14.7	18.5		12.6
4-5								8.0	9.9	8.0	8.1	7.3	14.4	8.7	9.2
5-6									6.0	6.5	6.6	6.9	7.7	7.8	7.0
6-7										6.0	5.3	6.6	6.3	6.6	6.2
7-8											6.0	5.9	6.3	6.0	6.1
8-9												3.0	5.8	5.6	4.8
9-10													2.0	4.9	3.5
10-11														2.0	2.0

Heceta Head 83

Age Interval	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	Average
0-1	26.0	24.0	30.5	24.3	26.0	25.3	29.6	29.0	26.6	28.6	27.2	23.0					26.7
1-2		18.0	14.0	18.0	21.3	18.3	15.3	21.6	19.1	18.1	18.6	19.1	16.0				18.1
2-3			12.0	123.0	13.0	16.0	17.6	16.3	22.3	19.0	18.3	21.4	23.1	23.0			18.8
3-4				19.0	19.0	12.5	16.3	18.0	19.3	15.6	19.5	14.3	17.6	23.0	22.0		18.0
4-5					15.0	15.0	16.5	12.6	14.6	14.0	8.6	12.0	17.1	14.6	12.6	17.0	14.1
5-6						7.0	7.0	14.5	6.6	7.2	7.6	6.3	6.0	11.8	10.3	7.1	8.3
6-7							5.0	3.0	7.5	5.0	4.4	6.3	5.3	4.0	8.0	5.6	5.4
7-8								4.0	3.0	3.0	7.3	3.7	5.0	5.0	3.5	4.8	4.4
8-9									4.0	2.0	2.5	5.3	3.0	2.6	4.3	3.0	3.3
9-10										3.0	2.0	2.5	3.6	2.9	3.0	2.6	2.8
10-11											2.0	3.0	2.0	3.0	3.2	2.3	2.6
11-12												2.0	3.0	2.5	3.3	2.5	2.7
12-13													2.0	3.0	2.0	2.3	2.3
13-14														2.0	2.0	2.5	2.2
14-15															3.0	2.0	2.5
15-16																3.0	3.0

Table 21. (Continued)

Coos Bay 81: 82 m

Age Interval	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Average
0-1					24.2	23.7	26.8	28.5	22.8	25.5					25.3
1-2						16.2	19.8	18.9	18.3	19.2	23.0				19.2
2-3							24.6	20.2	21.2	21.4	25.7	24.5			22.9
3-4								21.8	20.0	19.5	20.1	29.9	23.5		22.5
4-5									20.4	19.4	12.2	14.0	16.1		16.4
5-6										12.0	10.2	12.4	11.4		11.5
6-7											7.4	8.7	8.4		8.2
7-8												4.6	6.1		5.4
8-9													4.8		4.8

Table 22. Hotelling's T^2 statistic values for samples of P. caurinus 1981-1983 (tabulated 5% values in parentheses).[1]

	TH82	TH92	TH96	TH101	CK	YQ	HH	CB
TH82	1							
TH92	12.3	1						
	(10.3)							
TH96	8.8	0.1	1					
	(10.3)	(10.3						
TH101	37.5	9.5	5.1	1				
	(10.3)	(10.3)	(10.3)					
CK	129.0	592.2	293.0	616.2	1			
	(10.2)	(10.2)	(10.3)	(10.3)				
YH	283.8	106.5	44.8	83.0	872.8	1		
	(10.2)	(10.2)	(10.3)	(10.3)	(10.2)			
HH	1.3	1.2	1.2	37.9	266.8	188.4		
	(10.3)	(10.3)	(10.3)	(10.3)	(10.3)	(10.3)		
CB	99.5	140.8	71.7	70.0	9.7	182.1	57.9	1
	(10.3)	(10.3)	(10.3)	(10.3)	(10.3)	(10.3)	(10.4)	

[1] TH82 = Tillamook Head, 82 m depth
TH92 = Tillamook Head, 92 m depth
TH96 = Tillamook Head, 96 m depth
TH101 = Tillamook Head, 101 m depth
CK = Cape Kiwanda
YQ = Yaquina Head
HH = Heceta Head
CB = Coos Bay

Heceta Head scallops were not significantly different from the three shallowest stations of Tillamook (82, 92, and 96 m), but were significantly different from the 101 m Tillamook station. Coos Bay scallop growth was not significantly different from the Cape Kiwanda area growth, but growth was significantly different when comparing Yaquina Head with Coos Bay, and when Cape Kiwanda, Yaquina Head and Coos Bay were compared with the Tillamook Head stations.

A general comparison among localities is displayed in Table 23, where all Tillamook Head stations are considered together. Again, growth did not differ significantly between the Coos Bay and Cape Kiwanda stations, and scallop growth was significantly different between the Heceta Head and Tillamook stations. All the other comparisons among localities reflected a significant difference in scallop growth at the 5% level using the T^2 statistic.

The multivariate cluster analysis using the T^2 statistic as a dissimilarity criterium gave the relationships shown in Figure 27. A smaller T^2 value means less dissimilarity, thus in Fig. 27A the Tillamook stations are clustered together with similar patterns of growth which are also similar to the Heceta Head pattern of growth. Growth is almost identical in Tillamook at 92 and 96 m, and this pattern is less similar when compared to the shallower 82 m and deeper 101 m stations. The Tillamook - Heceta Head cluster shows a relatively high dissimilarity with the Yaquina Head station, which at the same time appears quite dissimilar to the cluster formed by the Cape Kiwanda and Coos Bay stations, the later cluster showing the most similar pattern of growth.

Table 23. Hotelling's T^2 statistic values for locatlities of P. caurinus 1981-1983 (tabulated 5% values in parentheses).[1]

	THall	CK	YH	HH	CB
THall	1				
CK	1,388.9	1			
	(10.2)				
YH	165.2	872.88	1		
	(10.2)	(10.2)			
HH	18.1	266.8	188.1	1	
	(10.2)	(10.3)	(10.3)		
CB	242.5	9.7	182.1	58.0	1
	(10.2)	(10.3)	(10.3)	(10.3)	

[1] THall = All Tillamook Head sample
CK = Cape Kiwanda
YQ = Yaquina Head
HH = Heceta Head
CB = Coos Bay

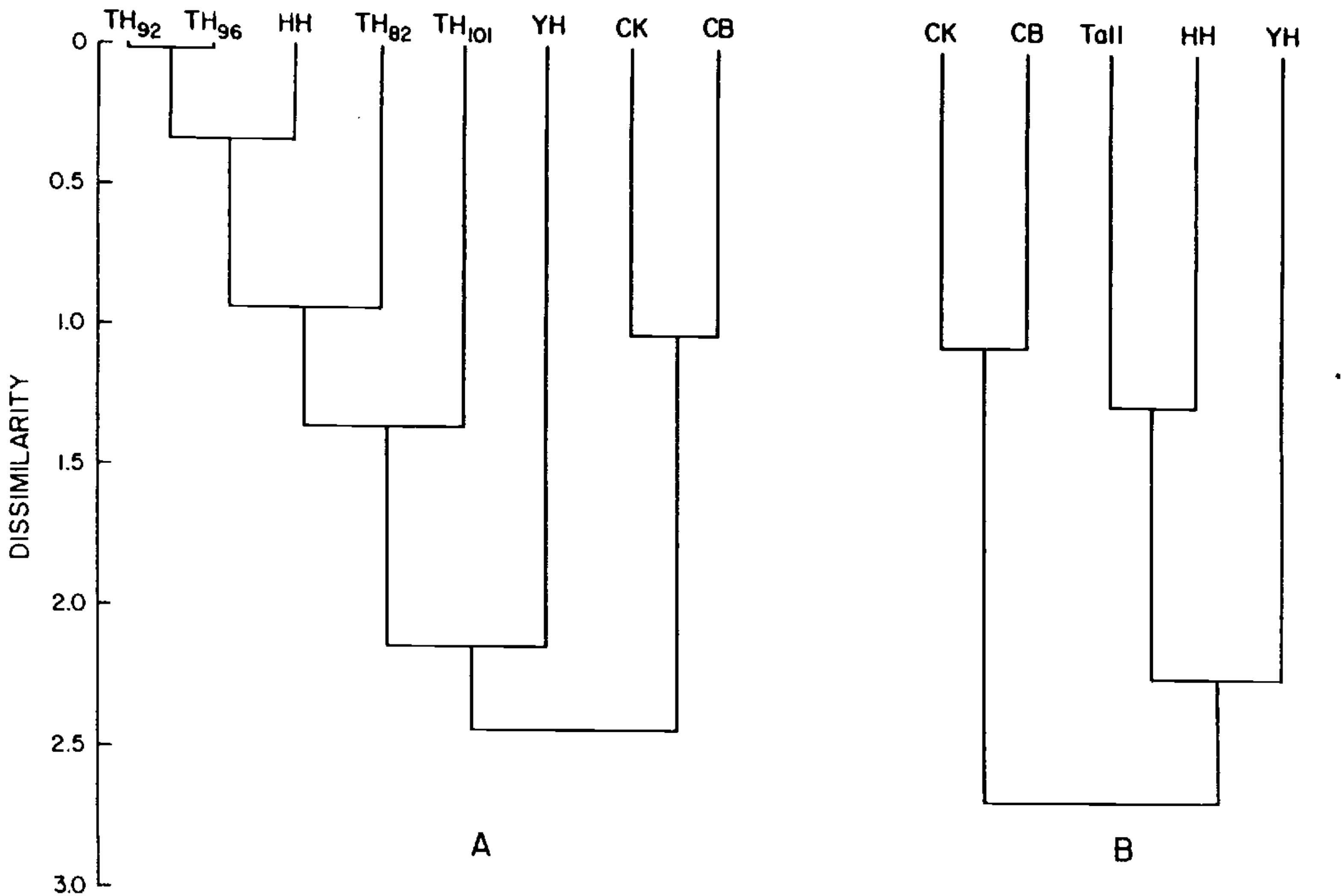


Figure 27. Weathervane scallop growth pattern relationships; A) between localities and depths; B) between localities. Th: Tillamook Head at 82, 92, 96 and 101 m; CK: Cape Kiwanda; CB: Coos Bay; Tall: All Tillamook Head; HH: Heceta Head; YH: Yaquina Head.

Figure 27 shows clearly that scallop growth is more similar between Cape Kiwanda and Coos Bay than among Tillamook Head as a whole and Heceta Head. Growth at Yaquina Head is different from all the stations considered, but its pattern is more closely related to the Tillamook Head - Heceta Head pattern than to the Cape Kiwanda - Coos Bay pattern of scallop growth.

The Scallop Fishery 1981-1986.

Weathervane scallops have been harvested off the coast of Oregon since 1981. The landing records in metric tons of round weight for the first six years of the fishery, listed by months, are displayed in Table 24. The 1981 values were estimated from Starr and McRae (1983) and transformed to metric tons (mt). From these data it is evident that the fishery began in April, 1981, and continued with a 12-month fishing period through 1984. There were 10 monthly landings in 1985, and only three monthly landings in 1986.

Figure 28 shows the annual landing values from Table 24. The first year of the weathervane scallop fishery had the highest landing values, with more than 7000 mt. The following year (1982) shows a drastic decline in scallop landings, with a consistent improvement during 1983 and 1984 when more than 1500 mt were landed. In 1985, landings decreased to less than 400 mt, and finally in 1986 only 48 mt were landed (Fig. 28).

In Figure 29, the monthly values from Table 24 are plotted for the six years of data. The 1981 fishery dominated the catches. In the second month of the fishery, the largest landing of the 6-year fishery was produced when over 1900 mt were landed. Values over 1000 mt also

Table 24. Oregon scallop fishery landings in round weight by month, 1981-1986. Values in metric tons.

Month	1981*	1982	Years 1983	1984	1985	1986
January		52.22	60.20	125.58	105.01	0.00
February		156.23	29.57	56.75	25.13	7.32
March		25.99	89.50	117.30	29.16	40.63
April	588.75	25.90	29.16	77.87	33.31	0.00
May	1918.17	41.91	40.83	184.62	44.04	0.00
June	1498.00	36.69	153.30	157.51	29.04	0.00
July	1009.26	48.11	143.30	238.98	43.55	0.00
August	694.80	142.23	138.18	210.69	11.10	0.00
September	1275.90	56.94	212.25	179.35	0.00	0.00
October	280.91	15.06	181.05	119.47	0.00	0.03
November	196.80	49.54	3.60	27.15	17.57	0.00
December	183.51	24.12	120.40	14.72	33.55	0.00
TOTAL	7646.10	674.94	1201.34	1509.99	371.46	47.98

* Values estimated from Starr and McRae (1983), Fig. 6.

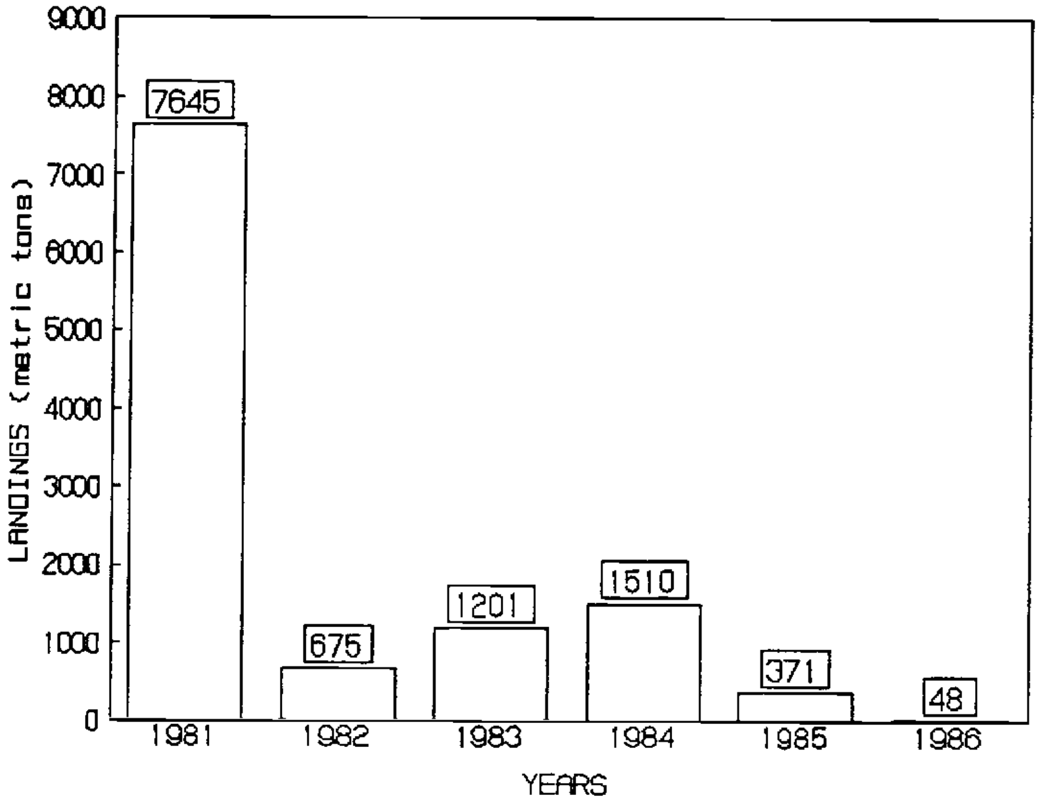


Figure 28. Oregon scallop fishery landing in round weight for the 1981-1986 period.

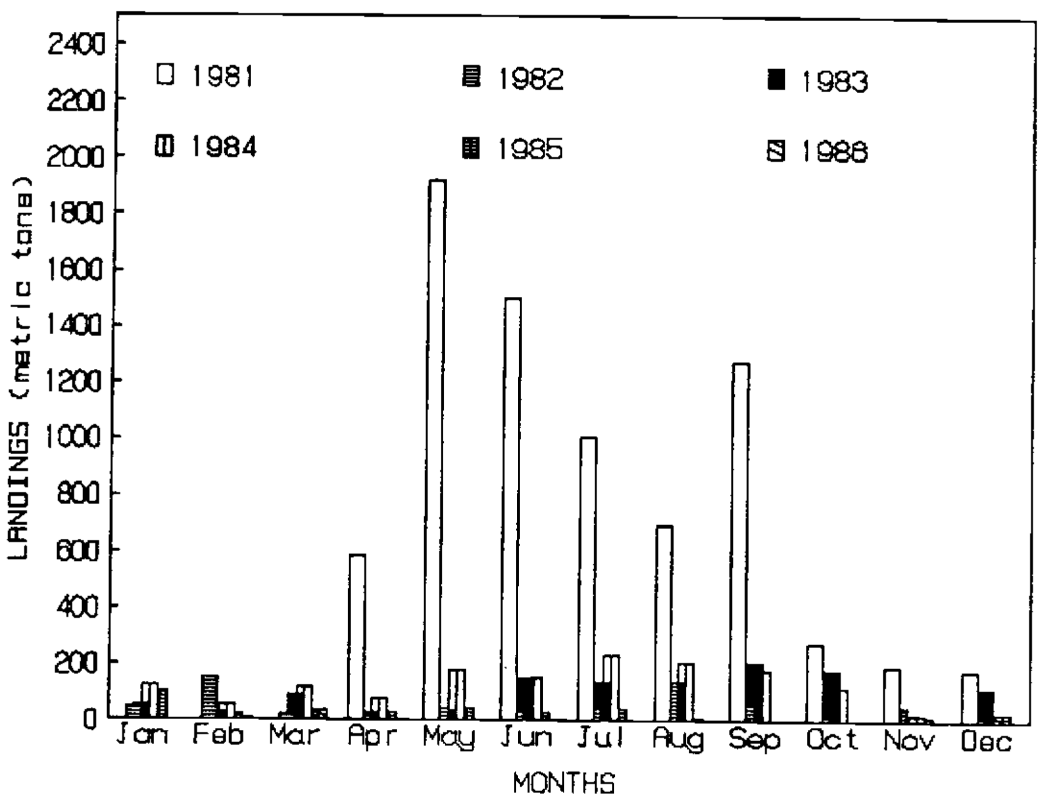


Figure 29. Oregon scallop fishery landings in metric tons round weight by months during the 1981-1986 fishing period.

were produced in June, July and September that year. The year ended with landings in the order of 200 mt.

Figure 30, in which the 1981 landing values were excluded, permits a better visualization of the fishery landing trends in the next five years (1982-1986). In 1982, there were landings in every month, from the lower October value of 15 mt to the larger February value of 156 mt; other than February, August was the only month that shows more than 100 mt landed.

In 1983, June, July, August, September, October, and December produced landing of over 100 mt, with the highest landing of over 200 mt produced in September, followed by October with 181 mt landed. The winter months (with the exception of December) were below 100 mt. The poorest landing was in October with only 3.6 mt.

In 1984, only November, December, February and April were below 100 mt landed, with December being the lowest with only 15 mt. The summer months of July and August were above 200 mt in landings, followed by May and June when over 150 mt of scallops were landed.

Scallop landings declined drastically in 1985, with no landings during September and October, and with only January having over 100 mt of scallops landed. None of the remaining months had landings over 50 mt.

The 1986 situation was even worse, when landings were only produced in the months of February, March, and October, with 48 mt being the total for that year (Table 24).

Figure 31 shows that for all the scallops caught from the beginning of the fishery, 67% were landed in the first year. Also

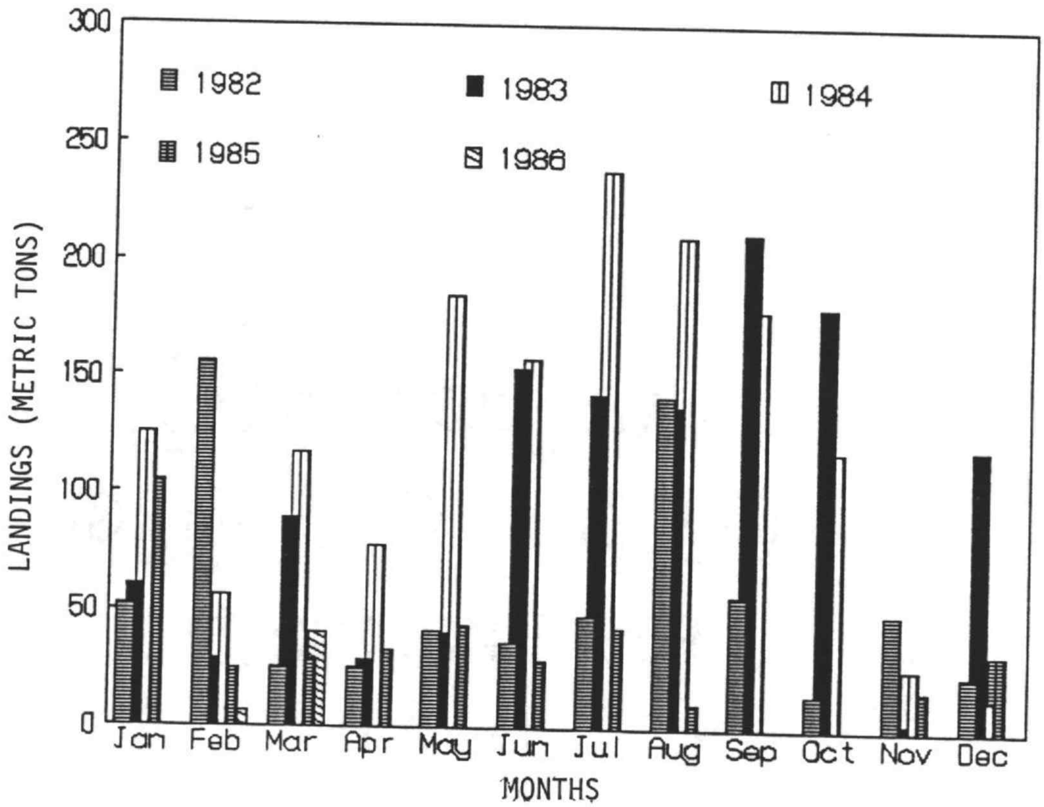


Figure 30. Oregon scallop fishery landings in metric tons round weight by months during the 1982-1986 fishing period.

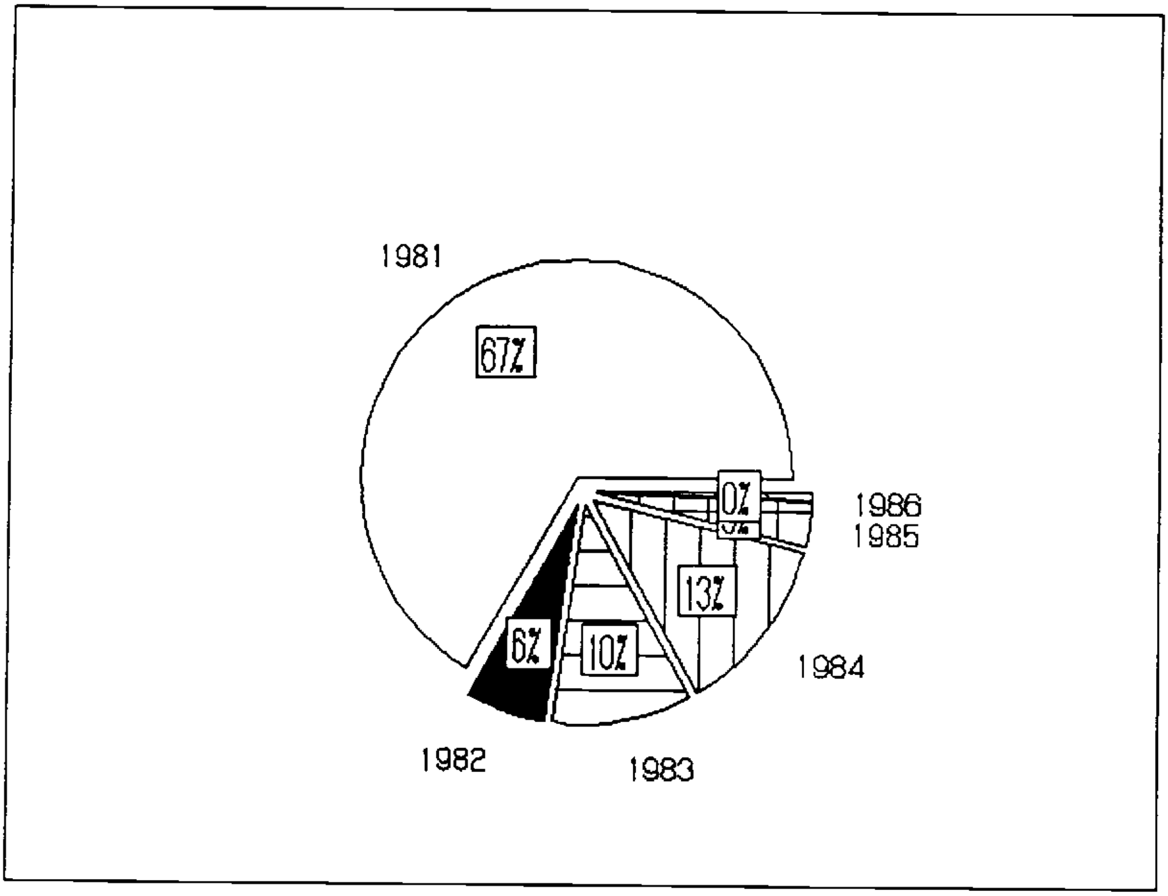


Figure 31. Percent by year of total scallops landed in Oregon during the 1981-1986 period.

shown is the decline in 1982 landings, and the partial recovery in 1983 and 1984, and the lower catches in 1985 and 1986.

The scallops referred to in Table 24 and Figures 28 to 31 were landed in different ports of the Oregon coast. Table 25 lists the ports and the landings of scallops received in 1981 and 1982. In 1983, Port Orford received a small number of scallops and the ports of Astoria, Tillamook, Newport, and Coos Bay remained as important places for receiving scallops. This was repeated in 1984 for these four ports, and in 1985 only Tillamook and Newport received scallops. The complete catch of scallops in 1986 was landed in the Port of Newport (Table 26).

Figure 32 shows the relative importance of these ports in receiving scallop landings during the 1981-1986 fishing period. Thus, in 1981 Coos Bay was the port that received the highest (55%) amount of scallops from the commercial fishery, followed by Astoria (36%), Newport (6%), and the other six ports (1%).

In 1982, Newport and Coos Bay received about 93% of the landings, with Newport being the most important port with 54.4% of all the scallop landed (Fig. 32). In 1983, Newport alone received 87% of the landings, followed by Astoria with 7.1% and Coos Bay with 5.3% (Fig. 32). In 1984, Tillamook became an important port in Oregon by receiving almost 30% of the scallop landings, surpassed only by Newport with over 61% of the landings (Fig. 32). In 1985, Newport received over 82% of the landings and the remaining 17% was landed in Tillamook (Fig. 32). In 1986, all the scallops caught in Oregon waters by the commercial fishery were landed in Newport (Fig. 32).

Table 25. Oregon scallop fishery landings by port (metric tons), 1981-1982 (transformed from Starr and McRae 1983).

	Landings m tons	
Port	1981	1982
Astoria	2755.49	0.03
Tillamook	37.75	6.19
Newport	450.06	367.54
Florence	0.23	
Winchester Bay	122.84	18.13
Coos Bay	4250.06	283.03
Port Orford	1.57	
Gold Beach	0.37	
Brookings	23.14	
TOTAL	7641.51	674.92

Table 26. Oregon scallop landings by port (metric tons), 1983-1986.

	1983		1984		1985		1986	
Port	NL	m tons	NL	m tons	NL	m tons	NL	m tons
Astoria	15	85.5	37	122.7				
Tillamook	3	3.3	10	444.5	7	64.6		
Newport	113	1048.1	57	924.5	41	307.0	8	47.9
Coos Bay	25	64.1	12	18.4				
Port Orford	1	0.6						
TOTAL	157	1201.6	116	1510.1	48	371.5	8	47.9

NL = Number of landings

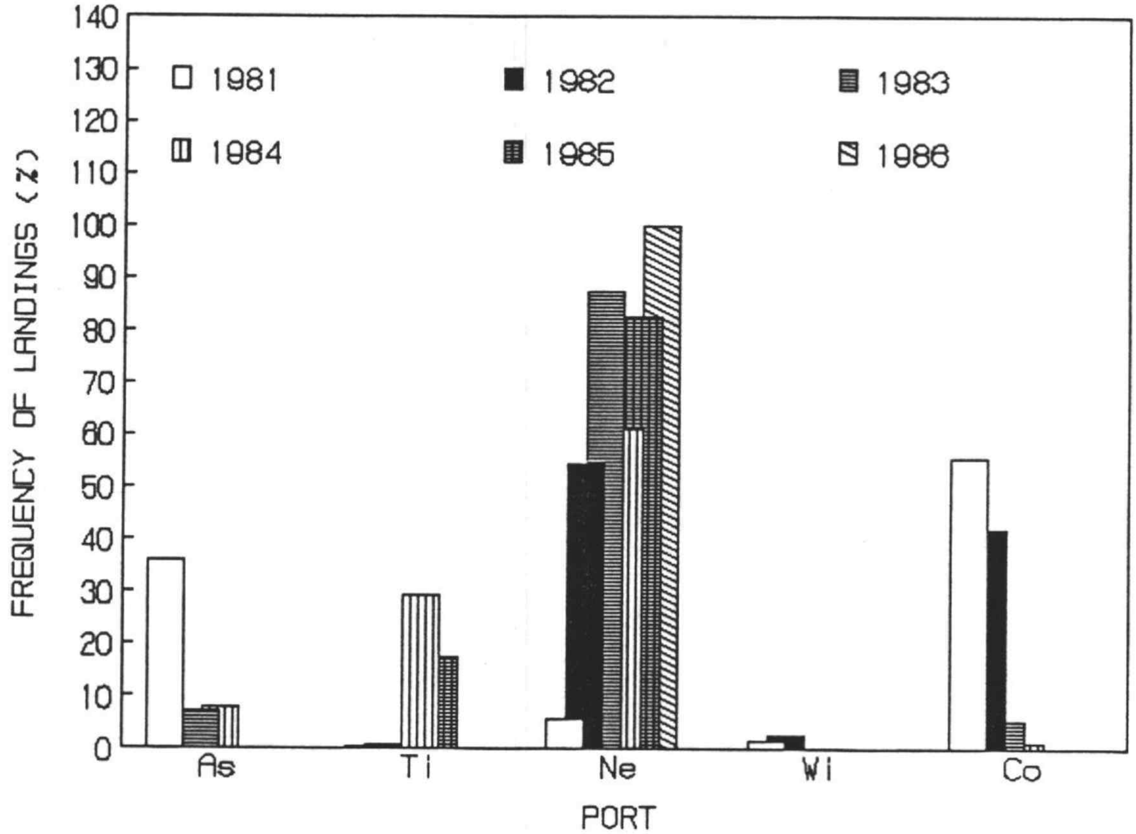


Figure 32. Oregon scallop fishery landings by port during the 1981-1986 period. As: Astoria; Ti: Tillamook; Ne: Newport; Wi: Winchester Bay; Co: Coos Bay.

In Tables 27 and 28, the effort, expanded catch, and the catch per unit of effort (CPUE) for the Oregon scallop fishery is listed by statistical areas (defined in Table 1). Table 27 was developed from the data in pounds that appear for 1981-1982 in Starr and McRae (1983); while Table 28 shows comparable data for 1983-1986 obtained from the analysis of fishermen's logbooks.

Most of the data from Tables 27 and 28 is displayed graphically in Figures 33, 34, and 35. Figure 33 shows the total effort (hours fished) expended by the scallop fishery by Oregon statistical area for the period 1981-1986. In 1981, statistical area 28, received the most effort with more than 5000 hr fished, followed by statistical areas 22B, 26, and 22, with over 4000 hr fished. The average effort for all areas was 3493.3 hr fished in 1981.

In 1982, effort as a whole declined to an average of 592.5 hr fished, with the strongest effort exerted in area 24 with about 1200 hrs fished. The effort in 1983 showed an average of 1191 hrs fished, with area 24 again supporting the heaviest effort of close to 3500 hrs fished (Fig. 33). During 1984, the average effort was 1285 hr fished and area 22B showed the strongest effort with over 2400 hr fished. In 1985, the average effort for the Oregon scallop fishery was 526.1 hr fished and only areas 22B and area 28 received an effort above the average value (Fig. 33). In 1986, the lowest value of average effort for the scallop fishery occurred with only 67.75 hr fished. Area 22B supported the strongest effort with 251 hr fished (Fig.33). In the 1981-1986 period the areas most heavily fished were areas 22B and 28, when both accounted for over 50% of the effort applied on the Oregon scallop beds.

Table 27. Expanded catch and effort estimates for scallops listed by Oregon statistical area for 1981 and 1982 (transformed from Starr and McRae, 1983).

Year	Area	Effort in hr fished	Expanded to MT	CPUE kg/hr
1981	21	1121.1	336.2	299.9
	22A	4046.1	2009.7	496.7
	22B	4465.8	1506.1	337.3
	24	1518.8	437.1	287.8
	26	4317.4	1391.5	322.3
	28	5490.3	1965.4	358.0
	TOTAL	20959.6	7646.0	364.8
1982	21	94.1	17.8	189.4
	22A	781.1	182.2	233.3
	22B	642.2	140.2	218.3
	24	1227.7	212.7	173.2
	26	516.9	80.0	154.9
	28	292.9	42.0	143.3
	TOTAL	3554.9	674.9	189.8

Table 28. Scallop catch and effort data by Oregon statistical area derived from analysis of fishermen's logbooks for the years 1983-1986.

Year	Area	N tows	Effort in hr fished	Expanded to MT	CPUE kg/hr
	21	133	479.8	22.8	47.6
1	22A	29	55.3	4.0	71.8
9	22B	916	1815.6	277.2	152.7
8	24	1156	3466.4	565.6	463.2
3	26	658	1598.8	216.4	135.4
	28	69	144.9	13.0	89.6
	29	435	775.5	102.6	132.3
TOTAL		3396	8336.3	1201.6	144.1
	19	8	10.3	0.0	0.0
1	21	19	28.8	1.3	46.5
9	22A	315	418.3	39.3	94.0
8	22B	1256	2428.5	318.5	131.2
4	24	264	551.9	65.9	119.4
	26	903	2173.6	307.9	141.6
	28	2163	4268.0	732.2	171.6
	29	325	399.8	45.1	112.7
TOTAL		5253	10279.2	1510.1	147.0
	21	1	1.8	0.1	38.9
1	22A	151	281.8	33.3	118.0
9	22B	743	1565.0	137.8	88.1
8	24	199	412.4	47.9	116.2
5	26	315	684.0	64.0	96.4
	28	295	713.3	80.1	112.3
	29	14	24.8	6.4	257.7
TOTAL		1718	3683.1	371.5	100.9
1	22B	134	256..	35.7	142.1
9	24	27	66.0	7.1	107.3
8	26	23	61.0	4.6	75.2
6	28	3	10.0	0.5	53.0
TOTAL		187	388	47.9	123.4

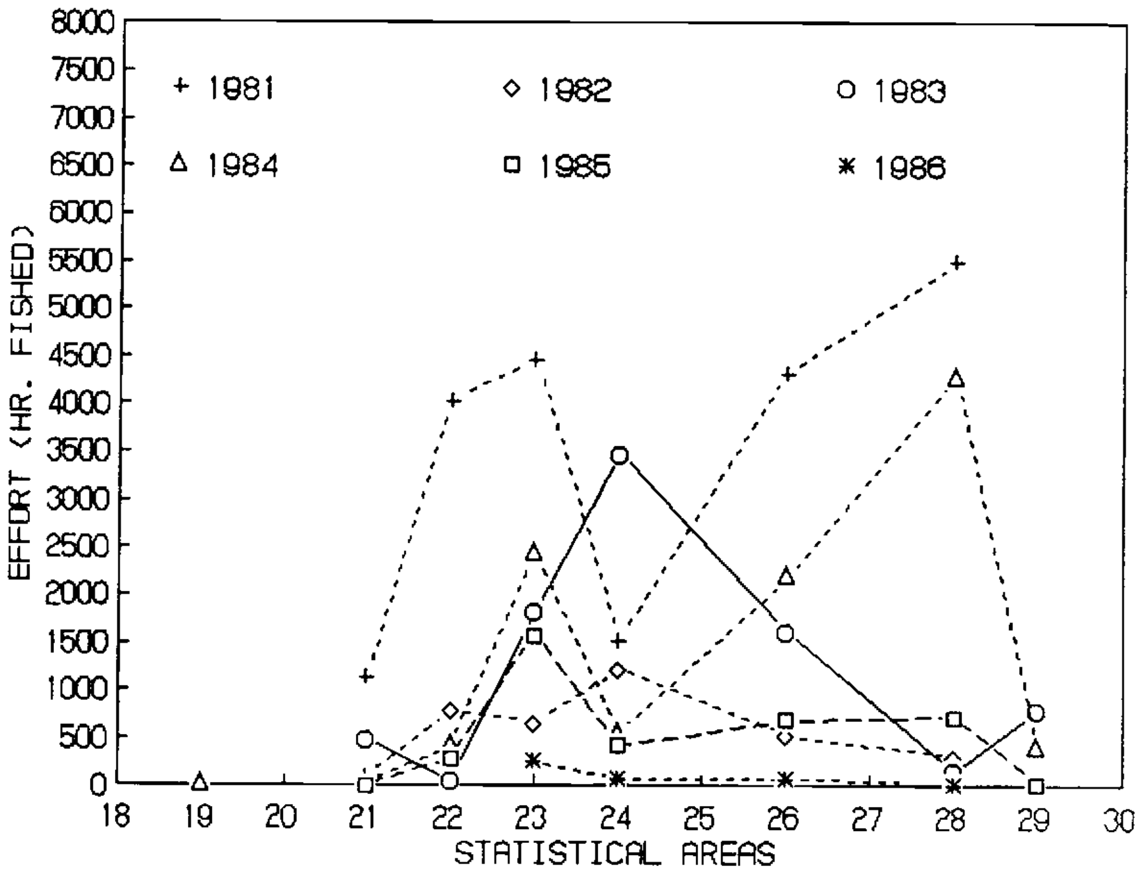


Figure 33. Fishing effort (hr) for the scallop fishery by Oregon statistical area for the period 1981-1986.

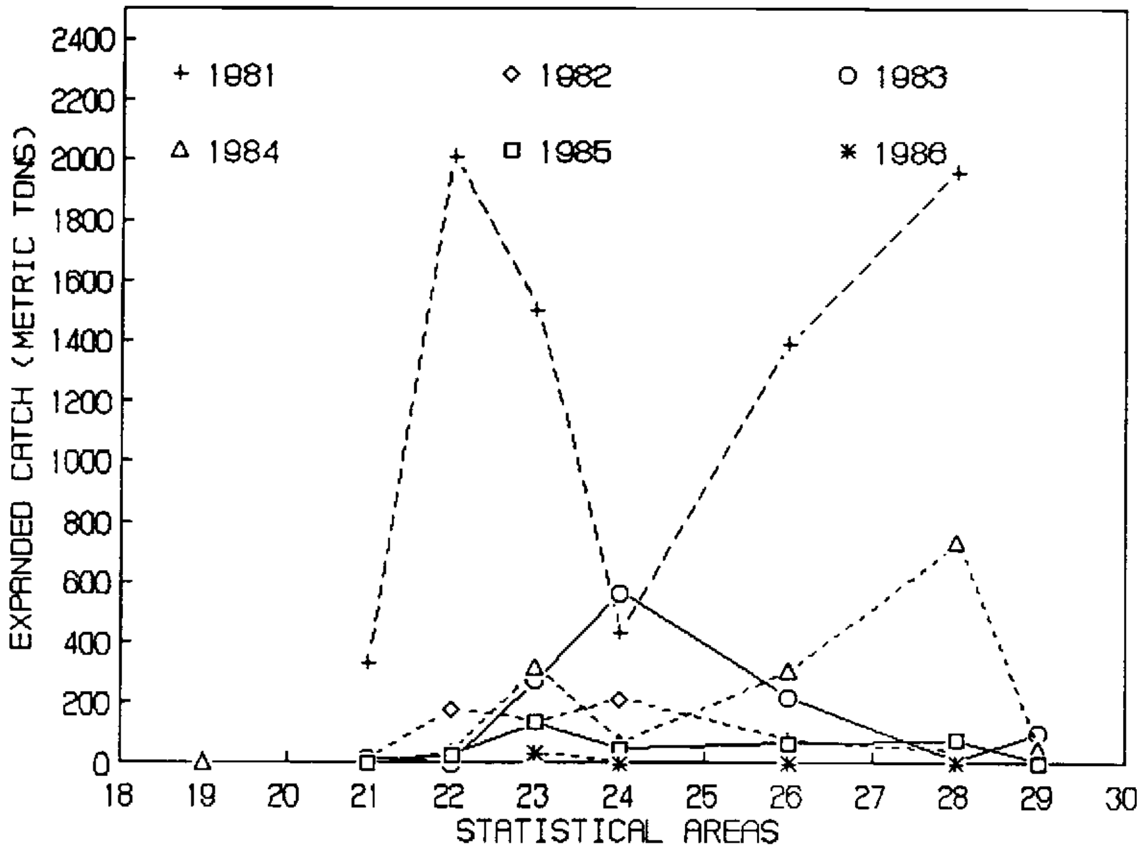


Figure 34. Expanded scallop catch (metric tons) by Oregon statistical area for the period 1981-1986.

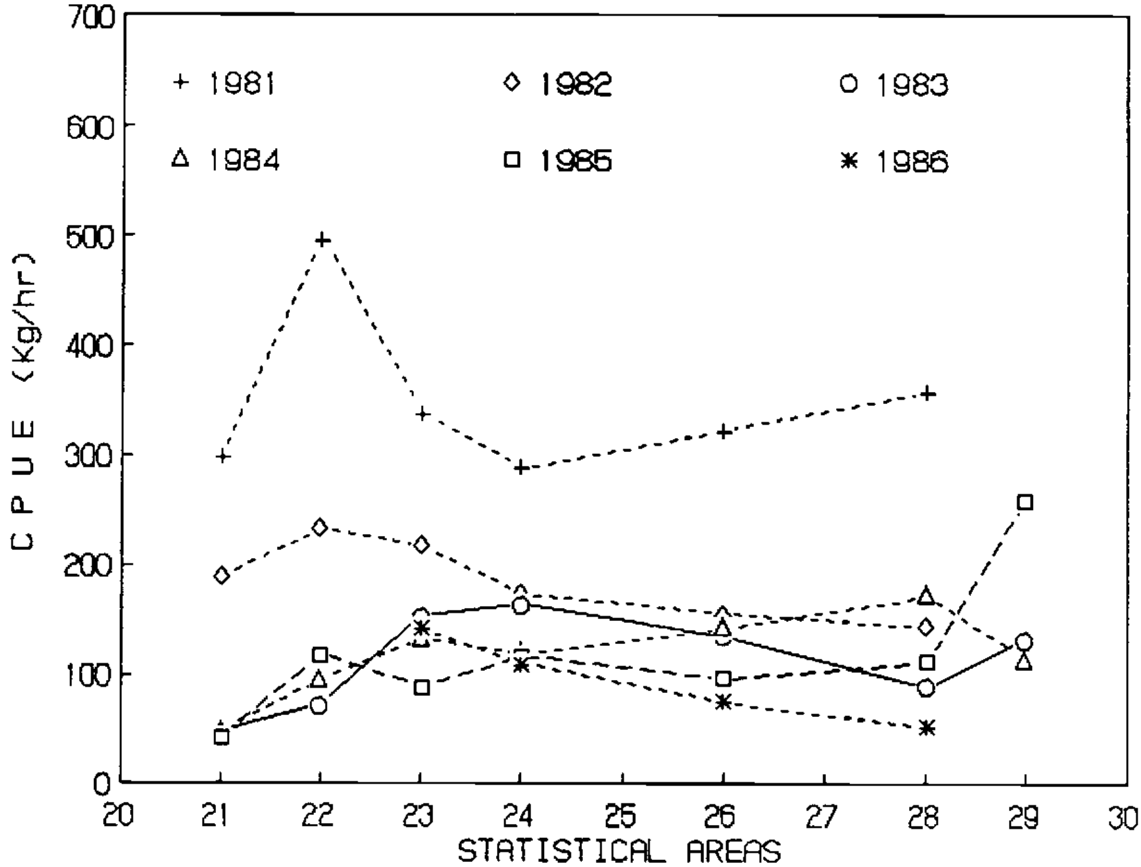


Figure 35. Catch of scallops per unit of effort by Oregon statistical area for the 19861-1986 period.

The expanded catch estimates for the Oregon statistical areas appears in Figure 34. As a whole in 1981, all the areas showed a higher catch than subsequent years of the fishery. The average catch was 1274 mt and areas 22A and 28 produced a similar harvest of around 2000 mt. In 1982, the average catch was 112.5 mt; in 1983, the average was 171.6 mt for all areas; in 1984, the average was 188 mt; in 1985, the average catch was 53 mt per area; and in 1986, the average catch per area was 11.9 mt. In the 1981-1986 period, area 22B produced the highest catch.

The CPUE curves plotted in Figure 35 show that the highest values obtained for the fishery in all statistical areas occurred in 1981. The average CPUE for 1981 was above 350 kg/hr; for 1982 the average CPUE was around 190 kg/hr; for 1983 the average CPUE value was 144 kg/hr; for 1984 the average CPUE value was 146 kg/hr; for 1985 the average CPUE value was 100 kg/hr; and in 1986 the average CPUE value was around 120 kg/hr (Fig. 35).

DISCUSSION

Malacologists have known for a long time that the typical lamellibranch shell is composed of calcium carbonate in the mineral form of calcite and aragonite which characterize the different layers of the shell (Barker 1962). Calcite is softer than aragonite, and enhances shells strength and resistance to abrasion. While calcite tends to break along well-defined cleavage planes, it gives the shell a more porous consistency and helps to reduce density of the shell (Rhoads and Lutz 1980).

Following Taylor et al. (1969), the middle layer of _P_. _caurinus_ corresponds to the crossed lamellar aragonite layer, which has the appearance of having a series of sublayers running parallel to the shell boundary. The portion of the middle layer on top of these sublayers corresponds to the foliated calcite outer layer of these authors, and the inner layer corresponds to the foliated calcite inner layer. In the same manner, the additional layer visible only at the umbo-first annulus level corresponds to the adductor myostracum prismatic layer of aragonite.

The layer distribution in _P_. _caurinus_ seems to be very functional. The strongest parts of the shell are the umbonal region with a thick inner layer, a strong myostracum layer, and an apparent extra thin layer as an intrusion into the thick inner layer of the umbonal region. This later structure could correspond to a prismatic pallial myostracum layer of aragonite (Taylor et al. 1969). In the region of the adductor muscle where the modified mantle epithelium originates, the adductor myostracum is located (Merril 1961).

The relative importance of these layers, in terms of thickness, change when going from the anterior to the ventral margin of the shell. Thus, the outer foliated calcite and the crosslamellar aragonite layers are approximately equally distributed in the mid region of the shell. Following the first external annulus and close to the ventral margin, the foliated calcite layer dominates the shell thickness.

The ligament of P. caurinus is pyramidal in shape, with a base that bulges ventrally between the valves. It has a non-calcareous central region that is black in color with a rubber-like consistency, and two smaller lateral calcified regions of aragonite which attach the former to the valves (Taylor et al. 1969) (Fig.17). The ligament is formed by secretions from the mantle and is subject to the same general growth patterns as the shell. This growth is reflected by the clearly defined marks that are evident in its lateral calcified zones (Fig. 17).

It is widely accepted that growth in lamellibranchs results from marginal increment due to the action of the mantle edge, which is responsible for the form of the shell (Owen 1953). The marginal growth of the molluscan shell was initially explained as the accumulation of new material on a substrate, which usually consists of the part of the shell that is in contact with the mantle. It is recognized that the organic component of the shell acts as a precursor to mineralization and that it may serve as a matrix to control the mineralization and direction of growth (Clark 1973). Clark (Ibid.) maintains that scallop marginal growth is produced by the movement of the mantle edge well beyond the calcified margin of the shell (Fig. 36A), and the subsequent withdrawal of it into the shell (Fig. 36B)

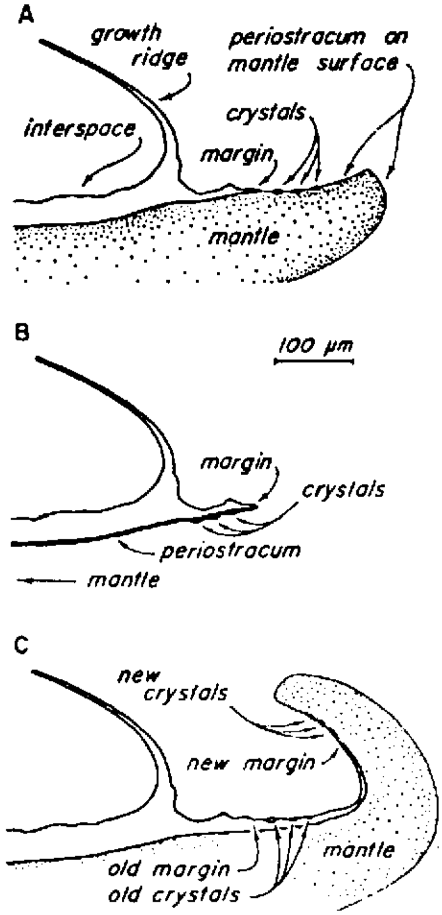


Figure 36. Growth of the shell margin in Pecten diegensis: A) mantle extended and crystals formation; B) mantle withdrawn, crystal carried under the shell; C) crystals have coalesced into solid shell. (After Clark 1973).

leaving a new projection of the edge beyond the shell margin (Fig. 36C). During the process, new crystals of $CaCO_3$ coalesce to form a new margin in the growing shell (Clark 1974).

In P. caurinus, this proposed mechanism can explain the formation of the typical striae (circuli) present on the shell. Thus, the shell grows as the mantle deposits lamellae, each of which emerge at the edge of the shell following the previous one. The annuli are the build-up of a number of small growth increments (striae) that from time to time are compressed closely together.

The ribs that characterize the scallop shell topography represent a sector of the shell which, during growth, has been secreted by the same, ever widening, region of the mantle (Owen 1953). The number of ribs per shell has been used as the main criteria to differentiate western Atlantic scallop populations that showed apparent differences in growth (Clark 1972). By this method, Clarke (1965) was able to separate four subspecies of Aequipecten irradians (Lamark) inhabiting the waters from Nova Scotia to Colombia.

Oregon coast weathervane scallops are quite uniform with respect to the number of ribs per shell, with a peak and mean of around 18 counts per shell. However, the Coos Bay population had a mean of 19.4 ribs per shell, and ranged of from 18 to 21 ribs without any defined peak. This is probably due to the small sample size (N = 58). Considering that the distribution of ribs in P. caurinus seems to be normal, we can assume that the mean number of ribs in the Coos Bay population is truly higher than in the scallops of the other areas studied.

The number of ribs per shell in P. *caurinus* is completely independent of the size of the shell, but could be a function of the rate of growth. For example in the case of A. *irradians* the faster growing population was the one with the higher mean value for the number of ribs per shell, as was the case in the Coos Bay population of P. *caurinus*. Architecturally, ribs add strength to the shell; thus, a higher number of ribs should be explained by the need to increase shell strength in animals that put more energy into increasing shell height rather than shell thickness, as is the case of the faster growing population of Coos Bay.

Several groups of organisms that have an additive mode of hard structure formation (as in bivalves), stop growing at times of environmental or biological stress. Such a pause usually leaves a distinct line of disturbance on the hard structure and is often accompanied by very close spacing of the growth lines. Generally these growth marks appear at regular intervals, giving the idea of a cyclical growth pattern. These patterns result from variable rates of $CaCO_3$ deposition or dissolution or both (Rhoads and Lutz 1980), causing alternation of $CaCO_3$-rich layers and organic-rich layers, respectively.

Lutz and Rhoads (1977) point out that shell deposition is produced during aerobic respiration when the valves of the mollusc are open and water is being pumped over the gills. Shell dissolution is the product of anaerobic metabolism that occurs during periods of shell closure. The alternation of shell deposition and shell dissolution result in growth increments in the shell.

The cyclical growth patterns could be semidiurnal or diurnal, fortnightly, lunar-month (cluster of tidal cycles), or annually (Rhoads and Lutz 1980). Diurnal periodicity was recorded for several species of corals (Knudson et al. 1972) and Anospora palmata (Wells 1963); and for the bivalves Mercenaria mercenaria (Panella and MacClintock 1968), Pecten irradians (Davenport 1938), and P. diegensis (Clark 1968). Fortnightly intervals of growth patterns have been recorded for several intertidal and shallow subtidal organisms (Panella and MacClintock 1968; Rhoads and Panella 1970; Kennish 1976). Various species of molluscs show a monthly microgrowth pattern within the shell as in M. mercenaria (Panella and MacClintock 1968), Nucula proxima (Rhoads and Panella 1970), and Nautilus macromphalus (Martin et al. 1977).

Seasonal variations in growth usually result in the formation of microgrowth increments with an annual periodicity (Rhoads and Lutz 1980). This variation is closely associated with seasonal temperature changes. Growth rate of poikilothermic animals tends to increase with temperature as a result of the increase in metabolic rate, provided enough food is available (Broom and Mason 1978). Thus, annual line formation (slow growth or no growth at all) has been attributed to low winter temperatures (Green 1973; Broom and Mason 1978; Shaul and Goodwin 1982; Starr and McRae 1983; Kaiser 1986) resulting in the term "winter annuli" becoming common in the literature.

Annual growth patterns have been described for Arctica islandica (Thompson et al. 1980); Tridagna gigas (Bonhom 1965); Panope generosa (Shaul and Goodwin 1982); Macoma balthica (Green 1973); Spisula solidissima (Jones et al. 1978); Chlamys opercularis (Broom and Mason 1978); C. islandica (Johannessen 1973); Placopecten magellanicus

(Merril et al. 1962), and for _P. caurinus_ (Hennick 1970; Starr and McRae 1983; Carey and Ruff 1985; Kaiser 1986).

Spawning has been implicated as a stimulus for deposition of growth lines in _Spisula solidissima_ (Ropes 1985; Jones et al. 1978), a species that shows no winter growth rings.

Temperature and spawning represent environmental conditions and a biological-clock mechanism that generate cyclical growth patterns. Different non-cyclical growth breaks can be produced by the action of environmental and physiological stress, freeze shock in winter, heat shock in summer, and severe storms (Rhoads and Lutz 1980). These factors are yet to be determined as affecting the growth pattern of _P. caurinus_ due to the depth of distribution of the species in Oregon waters. Thus, the _P. caurinus_ shells analyzed show, in most cases, only growth marks that represent annual periods of shell deposition.

Growth breaks, when found, were not a serious problem in aging scallops shells because usually they appeared only in the external shell surface. In that case, the use of the ligament resulted in an accurate assessment of age for that particular shell, because growth breaks generally were not reflected in the ligament lateral zones. The annuli in the ligament appeared as dark brown bands, each constituted by approximately 12 thin, dark brown lines (representing the striae or circuli of the external shell) spaced closely together, indicating a period of slow growth. Interbands, or periods of faster growth, were lighter in color than the annuli, and the thin striae appeared more widely spaced (Fig. 17).

Although not so clear though direct observation of the external shell, a careful examination of acetate peels applied to an annulus zone can reveal the 12 striae composition of the annulus. P. caurinus forms around 24 striae per year at fortnightly intervals. The meaning of this is not yet clear to me, because fortnightly periodicity of growth patterns is associated with the spring and neap tide effects on intertidal and shallow subtidal animals (Barker 1964; Rhoads and Lutz 1980). Options are that P. caurinus growth periodicity is generated by an endogenous biological-clock functioning coincidentally with these tidal periods, or that P. caurinus is sensitive to the centrifugal-gravitational forces that operate on the earth generating the tidal patterns.

The Oregon coast oceanographic features are complex and need to be taken into account in trying to understand the growth processes of the invertebrate fauna. Considering the temperature regime in the depth range occupied by P. caurinus, it is possible to infer that as a poikilotherm animal the weathervane scallop growth rate must follow the temperature variations throughout the year with faster growth during the warmer months and with slower growth during the colder months. This means that P. caurinus forms it "winter rings" during the summer months in which water temperature is at it minimum, and conversely it may produce faster growth during the winter season when temperature values are at a maximum.

A clearer picture is obtained when considering the weathervane scallop reproductive cycle. P. caurinus exhibits a distinct annual reproductive cycle (Fig. 37) (Robinson and Breese 1984). Gonad growth and maturation take place between July and December when the bottom water temperature is increasing, and spawning occurs from mid January to June when the bottom temperature is decreasing. Thus, there are at

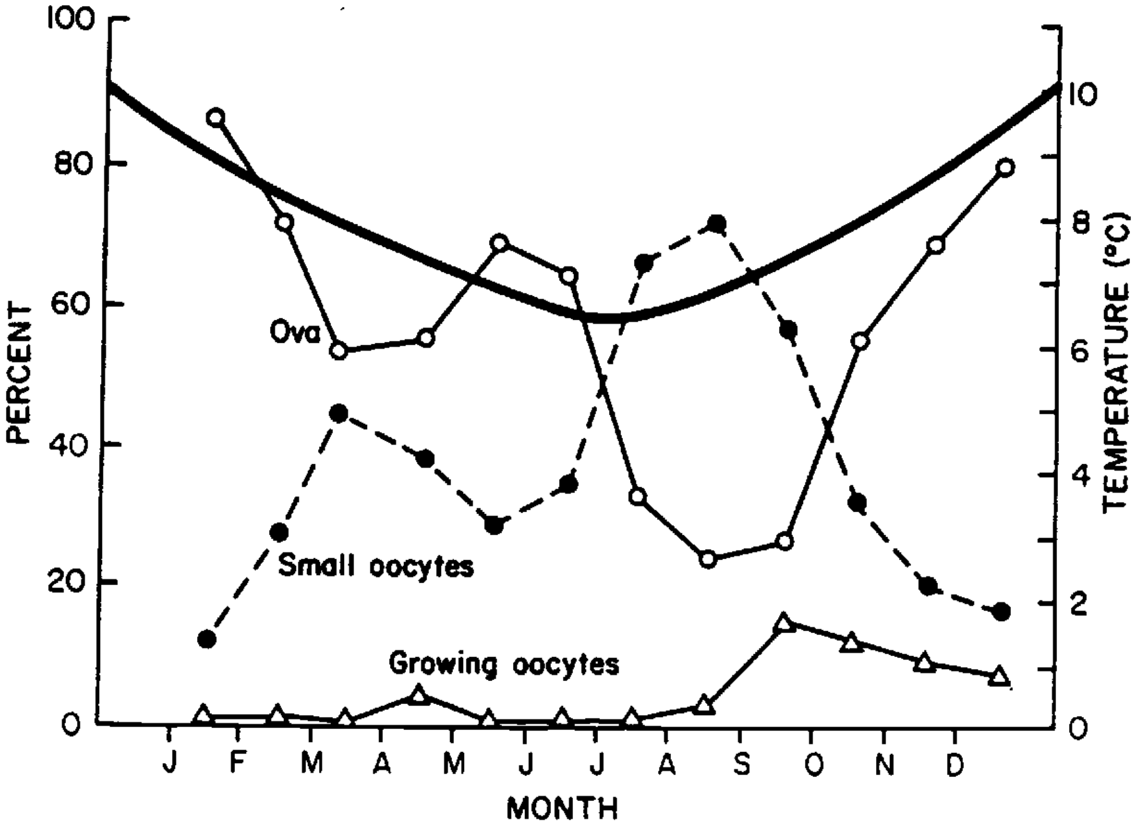


Figure 37. Annual cycle of gonadal development of the female <u>Pecten caurinus</u> on the Oregon coast. (Modified from Robinson and Breese 1984).

least two good reasons for a decrease in growth during the summer months - the lower temperature and the investment of energy for maturation and growth that otherwise would be invested in only growth and maintenance.

Another factor that must be considered is food availability. P. caurinus is a herbivorous pectinid that feeds by filtering phytoplankton and organic detritus from the water. The abundance of food at depth is dependent on the productivity of surface waters and productivity in Oregon waters is a function of solar radiation, bathymetry, and upwelling conditions (Small and Menzies 1981). Sometimes modest winter blooms occur in January or February, but the major spring phytoplankton bloom begins in April and lasts through October in years of strong upwelling (Peterson 1980). Small and Menzies (1981) indicated, however, that greater productivity can be achieved during relaxation of upwelling than during strong upwelling. In any case, phytoplankton is abundant in the upper 20 m of the water column from January to October (Peterson 1980).

If spawning is not an effective factor causing the cessation of growth in P. caurinus, as was documented for Pecten maximus (Mason 1957) and Chlamys opercularis (Broom and Mason 1978), the faster growing season for P. caurinus occurs from January to April when temperature is adequate and there is some food availability due to the modest blooms in January or February. Even though temperature is low in April, the sudden food increase can still stimulate growth. From May to September, growth is at its lowest rate because of the minimum temperature and the energy reallocation for gametogenesis. Growth probably begins to increase slowly at the end of October when temperature is increasing and there is some food still available, but does not reach high rates until higher temperature values and the next phytoplankton bloom are produced. This approach of considering temperature and food concentration together could be correct if a poikilotherm animal will not grow if temperature is too low, even when an excess of food is available; or conversely, if there is not enough food available, growth will not occur regardless of the temperature.

Food availability for scallops living at 50 m or deeper can be scarce in summer in spite of spring productivity due to shallower photic depth in the first 25 km offshore produced mainly by the turbid action of the phytoplankton biomass itself. In addition, the summer permanent pycnocline (located above the scallop distribution depth) could be a barrier for phytoplankton cells in reaching the scallop depths. During the winter months, the photic depth and the winter permanent pycnocline lie below the zone of scallop distribution, making the scarce food in the water column available for scallop growth (Fig. 38). It is also important to consider that the summer mixed layer is very shallow, and is restricted to the first few meters below the surface and limited by a shallow summer thermocline. During the winter, the mixed layer can easily reach 80 m depth, bringing phytoplankton and organic detritus to depths where scallops occur (Fig 38).

A comparison of the fitted growth curves to the measured height means (Tables 7 to 11) indicates that the Von Bertalanffy growth model fits the observed data in most cases. The growth pattern in Oregon weathervane scallops, as represented by the five areas studied, is very consistent during the first five years which are the faster growing

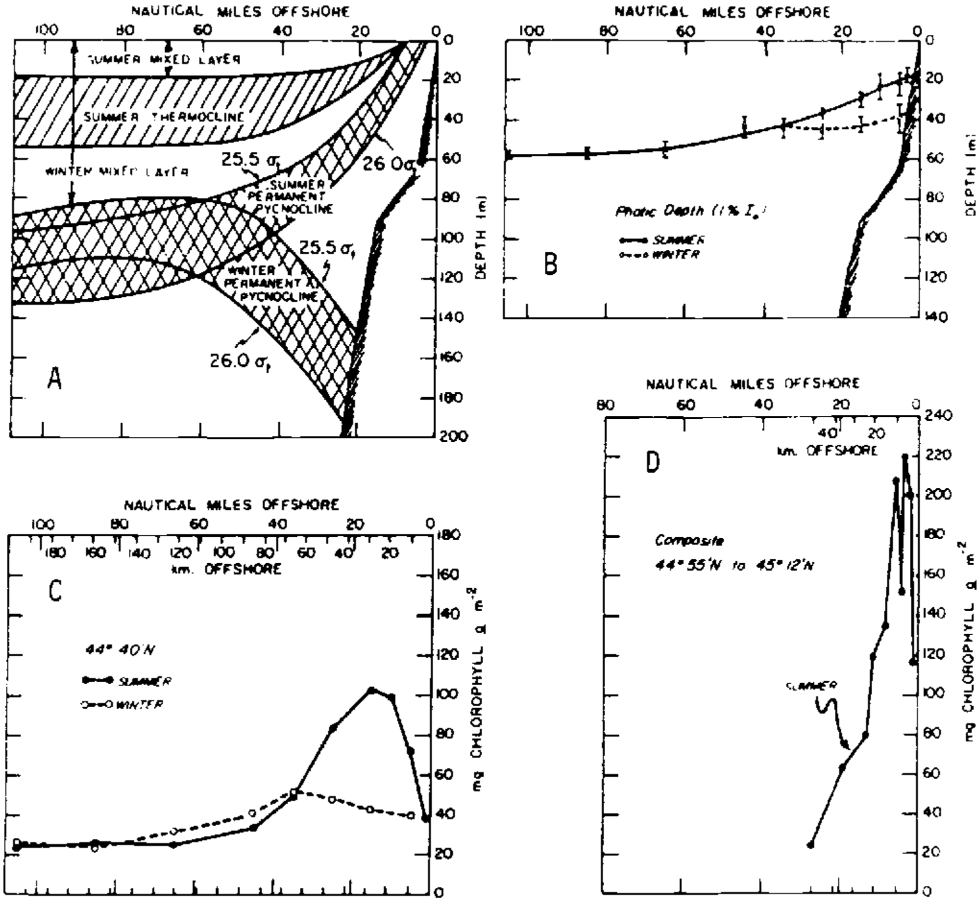


Figure 38. Historical distributions of: A) hydrography; B) photic depth; C) chlorophyll a (mg m^{-2}) along NH line; D) chlorophyll a (mg m^{-2}) along composite N, CH, SF, and SB lines. (After Small and Menzies 1981.)

periods (Fig. 25 and 26). It is also clear from these figures that there are differences in growth patterns between the different locations and depths. Local differences in growth rates in pectinids and other molluscan species have been described in the literature and associated with several factors such as currents (Gutsell 1930), parasitism, temperature, and phytoplankton concentration (Haynes and Hitz 1971).

In the present study, scallops living in the shallowest water (Tillamook Head 82 m, Coos Bay 82 m, Cape Kiwanda, 82 m) were found to growth more quickly than those in deeper water (Tillamook Head 101 m, Yaquina head 110 m) (Fig. 25 and 26). This relationship could be explained by the food availability arguments articulated in previous paragraphs. The same trend was found by Mason (1957) studying the scallop _Pecten maximus_ in Manx waters, who related the growth rates to differences in temperature.

Variations in growth resulting from geographical location are also evident in this study. The differences in growth between locations and depths were tested using the Hotelling's T^2 multivariable approach which was described by Bernard (1981) as a test for differences between like Von Bertalanffy growth parameter estimates from two fish groups, when these parameters are correlated. The hypothesis tested was to consider the growth patterns compared as equals; the hypothesis was rejected when the calculated value for T^2 was higher than the tabulated value.

Each of the localities studied showed its own pattern of scallop growth. The Tillamook samples were clustered together and clearly showed their differences in growth due to depth, differences that again can be explained by the availability of food. Conditions for growth were quite good at Tillamook Head for 1974 to 1987 (with the exception of 1978), and 1975 and 1980 were especially good for growth in all locations.

Geographical differences in growth were found for Washington coast scallop populations by Haynes and Hitz (1971). Scallops from an inner coastal area were about 1.5 times as large as those from an outer coastal area. The same trend is evident in Oregon scallop waters. The faster growing Coos Bay station was the closest to land (7.1 km), followed in order by Cape Kiwanda, Heceta Head, Tillamook head, and Yaquina Head being the farthest away from the coast line (24.3 km) (Fig. 39). This can be explained in terms of food availability. Scallops from inshore stations can take advantage of a higher concentration of food due to the presence of the inner core of productivity described by Small and Menzies (1981). This core is confined to the coast by the action of the shoreward edge of the Columbia River plume, which acts as a low-density surface barrier in stopping offshore surface flow (Small and Menzies 1981). In addition, the greater growth of Coos Bay scallops with respect to Tillamook populations can be attributed to a higher mean temperature probably throughout the year (at same depth) in that location. It can be inferred from Carey and Ruff (1985) that for Coos Bay the bottom water temperature on scallop beds for November, 1981, was around 10^{0} C, while off Tillamook Head bottom temperature only reached 8^{0} C at the same date.

Greenough and Haynes (1974), studying Alaska scallops, point out that there is a latitudinal trend with scallops of any age tending to

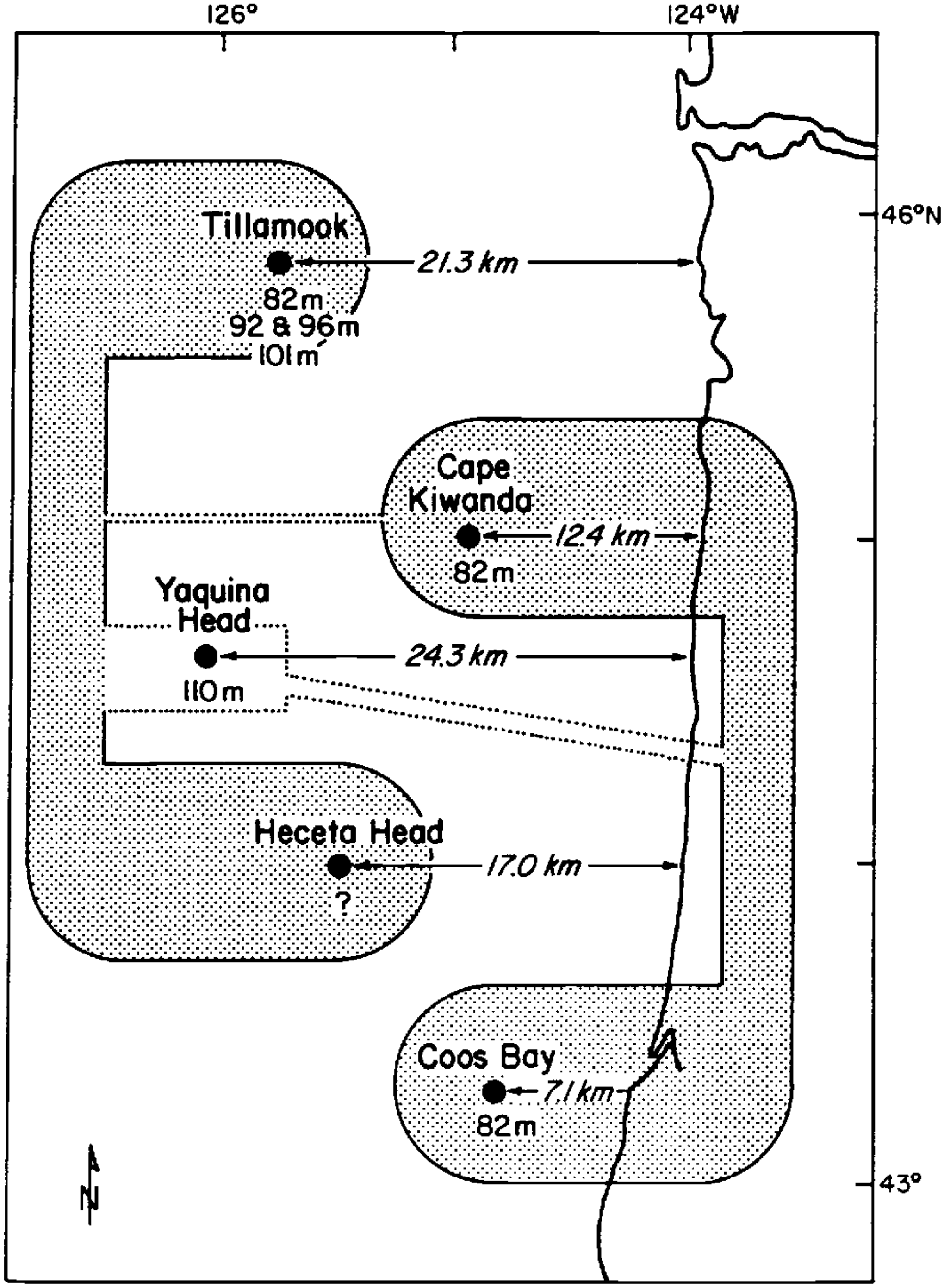


Figure 39. Relationships of the growth patterns of P. caurinus from different localities at the Oregon coast.

be larger as one moves northward along the Pacific coast and then westward around the perimeter of the Gulf of Alaska. This trend of decreasing size as one moves southward is not valid for P. caurinus from Oregon waters where the southernmost population analyzed (Coos Bay) showed better growth than the northernmost populations. This fact was previously observed by Ronholt and Hitz (1968), although these authors did not age the specimens of their samples, and by Starr and McRae (1983).

The Rosa Lee's phenomenon has been reported to occur in Alaska scallops (Greenough and Haynes 1974) and in Washington coast scallops (Haynes and Hitz 1971). Ricker (1969) noted four possible causes of Lee's phenomenon: sampling bias; incorrect back calculation; fishing selective mortality; and size-selective natural mortality.

The samples studied only showed Lee's phenomenon (in the positive sense) at some ages off Tillamook Head. I eliminated fishing-selective mortality as a possible cause because the fishery did not exist previous to 1981 at that location; shell height at age was measured directly, so back calculation cannot be considered as a possible cause either. Selectivity of the sampling gear could be a possibility, but in that case the Lee's phenomenon should have been a common fact in all the samples, which it was not. The only possible cause could be the size-selective natural mortality which can be operating over larger individuals of a given age.

Starr and McRae (1983) and Carey and Ruff (1985) noticed heavy infestation of Oregon coast scallops older than two years with the spionid polychaete Polydora websteri. These authors suggested that the worm infestation may interfere with the scallop in several ways, mainly weakening the shell and making it susceptible to breakage. As is seen in Figure 14B, the worm distribution covers the entire left valve, including the zone where the adductor muscle is attached. I am convinced that the worm infestation of Oregon scallops is detrimental to their potential growth, and am in agreement with these authors. I believe that the parasitic action places an upper limit on the longevity of P. caurinus in Oregon waters. This fact can also explain the slower growth rates found in Oregon scallops when compared with Alaskan populations where the Polydora has not been documented. A next step in scallop research should be the accurate assessment of Polydora infestation of Oregon scallops. This factor cannot be omitted when differences in growth rates of different populations need to be addressed.

The Oregon scallop fishery can be characterized as having two well defined phases. A first phase consisted of an extraordinary and disproportionate beginning in 1981, with all the elements that can characterize a successfull fishery; an apparent abundant stock, numerous boats participating in the fishery, large harvest with a high CPUE, numerous ports receiving the catch, good prices for the landed product, and adequate profits. The second phase from 1982 to 1986, was an antithesis of the first phase. Everything went down abruptly; the stock was not so abundant, the number of boats declined from over 100 to only two boats in the last two years of the fishery, the harvest was reduced to a negligible amount compared with the first phase catches, only one port participated in the activity, and so on. Until 1984, it could be considered as a sustained fishery, to be tranformed later to only a sporadic fishery.

There are many reasons for this decline in the scallop fishery. Maybe the most persistent one is the lack of incentive to go to the ocean and fish for scallops. This was because, among others, there were better alternatives than to fish for scallops; as an example, there was an excellent season for pink shrimp in 1986. Scallop boats can easily switch to shrimp trawling, so when shrimp are abundant, fishermen rapidly change gear and fish for shrimp. The scallop fishery is a hard one that requires powerful engines, and the risk of loosing gear is higher than in the shrimp fishery. Gear is more difficult to replace and is more easily damaged (R. Starr, personal comunication). The lack of interest can also be caused by direct economic reasons. In 1985 and 1986, the CPUE dropped dramatically and the activity was profitable for only two boats.

The fishery operated over the whole Oregon coast during the 1981-1986 period. The Heceta Head scallop beds were the most heavily fished, followed by the Cape Falcon to Columbia River and the Yaquina Head areas. Fishermen were right in going to these areas, because they gave the best catch.

The scallop fishery is a highly destructive one, not only because of direct fishing mortality, but also because the dredges drastically disturb the substrate where adult scallop live and larvae settle. This can account for the reduction of the CPUE during the fishing period considered; fishing causing a reduction of scallop densities and an alteration of the natural environment for scallop recruitment. In addition, if we consider that the age composition of scallop populations is formed by a few successful year-classes, after depletion of an area the CPUE will be low until a new successful year-class populates the area. From this we can infer that the Oregon scallop fishery is conditioned to the success of certain year-classes from time to time under natural and almost pristine conditions. With an intense fishery operating every year, the substrate could be less suitable for a normal succession of successful year-classes. This success of certain year-classes probably is caused by the variable and almost unpredictable dynamic oceanographic regime of the Oregon coast.

CONCLUSIONS

1. The number of ribs in *P. caurinus* appears to be correlated to rate of growth rather than to size of the shell. Rib numbers range from 16 to 23 with a mean of 18 ribs per shell.
2. No internal marks associated with periodic growth of *P. caurinus* were evident when the acetate peel technique was used. This technique was useful to reveal the different internal layers of the scallop shell.
3. The periostracum, calcite outer layer, crossed lamellar aragonite layer, adductor myostracum prismatic layer of aragonite, and the foliated calcite inner layer are evident in *P. caurinus* shells when using the acetate peel technique, and the distribution of these layers seems to be function-dependent.
4. Annual growth marks are present in the lateral layers of the ligament of *P. caurinus*. They appear as dark bands formed by the confluence of circuli during periods of slow growth. Circuli are formed at fortnightly intervals.
5. The growth marks in the ligament proved to be a reliable alternative method for aging scallops.
6. Annual rings in *P. caurinus* are formed during the summer months when subsurface waters are coldest; faster growth is accomplished during the winter and early spring when subsurface waters are warmest. These conclusions are supported by the oceanographic conditions of Oregon waters and by the reproductive cycle of *P. caurinus*.

7. The von Bertalanffy growth model was used to characterize growth in _P. caurinus_. Growth is consistent during the first five years, which are the periods of fastest growth.
8. Biogeographical differences in growth are present in Oregon _P. caurinus_ populations, with shallower and close-to-land populations growing at faster rates and reaching larger sizes than deeper and offshore populations. This phenomenon can be explained by food availability, which is conditioned by properties of the water column throughout the year, and by temperature.
9. In Oregon waters, _P. caurinus_ size distribution ranged from 75 to 155 mm with a dominance of around 110 mm in shell height.
10. Scallop age distribution varied from 3 to 15 years old, with ages 6, 7, 8, and 9 being more common. The 1973 year-class was the most prominent in the populations studied.
11. Cape Kiwanda and Coos Bay scallop populations showed similar patterns of growth; Tillamook Head and Heceta Head _P. caurinus_ populations were also similar in growth patterns. The Yaquina Head scallop population differed in growth pattern from the rest of the stations studied.
12. The scallop fishery currently is sporadic after being a sustained fishery from its beginning in 1981 through 1984. A decline in the catch of scallops in Oregon is probably due to a reduction of scallop densities and better fishing opportunities in the shrimp fishery.
13. The most heavily fished areas during the 1981-1986 period were off Umpqua River to Cape Perpetua and off Cape Falcon to Columbia River.

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APPENDICES

Appendix 1. Age, total height, height at age and number of ribs per shell in *P. caurinus* from the Oregon Coast.

TILLAMOOK HEAD
N = 156
Date: 08/14/82
Depth 82 m

		ANNULI														
N	Height	1	2	3	4	5	6	7	8	9	10	11	Ribs	Age	Cohort
125	103	25	50	78	95								18	4	1978
89	107	24	51	73	90								19	4	1978
129	103	26	49	76	98								17	4	1978
141	107	27	44	64	88	100							19	5	1977
122	112	29	41	65	94	105							20	5	1977
143	112	29	47	74	98	108							18	5	1977
150	109	22	46	75	96	108							20	5	1977
32	109	25	46	73	99	105							19	5	1977
44	104	22	33	52	80	96							17	5	1977
84	105	28	44	64	87	100							22	5	1977
83	114	22	42	67	96	108							18	5	1977
149	109	27	45	65	90	103							18	5	1977
73	116	28	50	74	101	112							18	5	1977
106	112	31	49	75	99	110							18	5	1977
130	116	28	49	66	91	110							20	5	1977
155	108	23	46	72	95	106							17	5	1977
94	116	21	37	65	95	110							18	5	1977
38	109	28	46	75	95	104							18	5	1977
134	106	28	41	61	85	97							18	5	1977
157	114	25	48	76	100	109							19	5	1977
133	108	25	50	66	85	101							19	5	1977
80	111	27	40	57	85	99							18	5	1977
58	104	23	33	50	78	95							19	5	1977
158	110	25	46	64	83	97							20	5	1977
107	109	23	45	67	93	103							17	5	1977
113	118	27	51	84	104	114							18	5	1977
48	105	29	42	66	92	99							19	5	1977
144	110	26	43	60	88	103							19	5	1977
69	118	25	46	77	103	115							19	5	1977
115	114	23	43	70	90	99							21	5	1977
21	110	25	36	54	90	103							20	5	1977
153	116	28	54	81	103	113							18	5	1977
75	114	24	45	78	101	110							19	5	1977
31	118	30	50	74	96	111							19	5	1977
142	109	25	40	59	87	103							19	5	1977
114	112	26	45	73	99	108							18	5	1977
136	108	23	45	72	92	104							18	5	1977
68	109	25	35	52	78	99							20	5	1977
91	105	23	40	57	82	95							20	5	1977
132	112	21	46	73	96	107							18	5	1977
59	118	27	49	20	88	104	111						18	6	1976
2	113	24	38	53	80	101	111						17	6	1976
63	105	26	41	51	78	97	103						19	6	1976

42	113	23	38	54	78	100	109			19	6	1976
29	119	25	35	52	83	106	116			19	6	1976
99	111	21	34	49	73	98	108			19	6	1976
87	113	27	40	54	82	102	111			19	6	1976
160	114	31	50	73	94	106	112			19	6	1976
100	113	22	36	57	77	98	110			17	6	1976
128	119	30	52	73	95	110	117			18	6	1976
135	112	22	47	66	80	101	110			16	6	1976
5	113	21	36	52	76	100	109			19	6	1976
37	118	21	33	52	82	104	114			19	6	1976
123	118	25	37	52	89	105	115			21	6	1976
140	117	25	38	54	79	103	114			17	6	1976
47	115	22	33	54	84	104	111			19	6	1976
95	115	21	34	50	77	100	110			19	6	1976
60	109	27	44	58	76	95	104			20	6	1976
137	118	26	39	55	72	91	109			21	6	1976
96	119	27	42	61	82	104	114			18	6	1976
152	110	21	47	69	88	102	107			18	6	1976
3	111	24	34	47	77	99	107			19	6	1976
121	112	27	38	56	82	100	108			19	6	1976
139	112	25	45	55	64	84	99			18	6	1976
30	115	25	37	51	76	103	111			17	6	1976
70	108	23	36	56	85	101	107			19	6	1976
54	110	23	34	46	77	99	108			18	6	1976
24	119	26	38	60	80	99	113			18	6	1976
93	110	21	34	52	75	88	108			20	6	1976
27	109	25	36	50	75	98	107			18	6	1976
124	113	20	34	55	84	105	111			18	6	1976
19	113	23	37	52	83	103	110			17	6	1976
138	120	27	40	56	85	108	117			19	6	1976
15	113	24	34	47	73	99	108			18	6	1976
64	109	24	36	51	74	100	107			18	6	1976
97	115	31	52	70	87	99	114			17	6	1976
82	114	22	36	51	79	101	112			18	6	1976
71	121	28	42	58	78	100	113			18	6	1976
45	117	21	34	44	74	101	112			17	6	1976
120	115	29	44	70	89	106	113			17	6	1976
105	121	28	41	53	74	94	112	119		19	7	1975
103	109	27	48	70	88	97	103	107		19	7	1975
85	115	23	35	53	78	96	108	113		18	7	1975
126	113	27	51	73	91	103	112	116		18	7	1975
131	121	23	33	48	69	91	99	118		18	7	1975
77	123	27	40	58	88	102	110	118		18	7	1975
52	118	25	40	62	83	101	110	116		18	7	1975
9	127	28	46	68	94	110	118	123	126	20	8	1974
92	119	26	42	58	79	98	107	112	116	18	8	1974
14	124	19	33	46	72	93	111	115	119	18	8	1974
6	126	27	40	61	87	108	117	121	123	21	8	1974
111	118	24	44	69	87	100	108	112	117	16	8	1974
23	121	22	34	58	78	96	104	111	116	18	8	1974

61	112	27	41	64	78	88	97	102	110			18	8	1974
116	118	23	40	57	80	95	103	108	114			18	8	1974
40	120	25	42	56	77	94	103	110	117			19	8	1974
112	120	30	42	57	83	100	110	117	120			19	8	1974
53	125	23	41	70	96	112	119	122	123			20	8	1974
13	123	23	37	58	84	99	108	116	120			20	8	1974
51	119	26	38	53	73	91	101	110	116			20	8	1974
7	120	25	44	60	84	100	109	114	118			19	8	1974
10	117	27	40	54	76	93	100	103	108			18	8	1974
43	121	25	45	75	98	109	115	118	120			17	8	1974
78	124	22	36	55	79	97	106	116	120	122		17	9	1973
55	119	27	42	57	78	93	102	110	116	118		19	9	1973
151	122	21	40	64	87	101	106	112	116	119		18	9	1973
88	118	24	40	61	81	97	104	111	114	116		19	9	1973
119	121	27	39	48	87	99	108	114	116	119		19	9	1973
74	119	22	33	57	82	97	106	111	115	118		19	9	1973
76	129	22	41	52	82	100	112	119	123	127		18	9	1973
11	119	25	37	53	75	91	101	107	112	116		18	9	1973
17	125	27	40	55	77	94	104	112	117	122		20	9	1973
118	117	22	34	52	79	97	107	111	113	115		18	9	1973
81	125	23	35	55	84	103	114	120	123	125		18	9	1973
1	125	28	40	55	77	95	106	116	119	123		19	9	1973
8	115	25	40	54	76	91	100	105	110	103		17	9	1973
67	124	22	39	55	81	97	107	113	117	120		18	9	1973
156	137	29	44	60	92	111	121	127	132	136		20	9	1973
90	122	30	42	56	77	96	106	112	116	120		17	9	1973
35	117	23	34	52	82	100	110	110	113	115		20	9	1973
101	124	30	40	59	88	94	103	110	115	121		19	9	1973
154	115	26	40	57	82	95	104	109	112	114		18	9	1973
117	128	26	41	55	87	106	115	121	124	127		19	9	1973
159	120	28	43	57	82	98	107	113	116	119		18	9	1973
72	131	26	37	57	82	103	114	120	125	128		19	9	1973
25	110	27	39	53	73	87	96	100	105	109		17	9	1973
20	126	27	41	60	87	101	109	113	118	121		18	9	1973
79	112	25	35	54	74	92	102	109	111	112		16	9	1973
108	125	28	44	59	85	101	112	119	122	124		19	9	1973
39	121	20	33	59	86	101	109	114	118	120		20	9	1973
66	121	28	41	59	83	97	105	110	113	118		19	9	1973
34	118	20	35	45	73	91	104	110	114	117		19	9	1973
62	117	25	39	60	82	94	99	104	107	113		18	9	1973
36	114	25	37	57	81	95	103	108	112	114		19	9	1973
109	123	24	41	64	84	101	109	115	118	122		18	9	1973
98	121	30	48	61	81	98	107	113	115	119	120	18	10	1972
104	121	25	36	56	84	98	107	111	115	118	120	21	10	1972
56	124	31	46	62	80	100	108	114	117	121	123	20	10	1972
65	115	25	44	52	60	81	97	108	110	112	114	18	10	1972
86	125	30	41	57	78	97	108	112	115	118	122	18	10	1972
127	123	27	40	56	78	94	102	110	113	118	122	20	10	1972
22	132	22	39	63	92	106	115	124	126	129	131	21	10	1972
102	125	23	52	78	97	107	112	116	120	123	125	19	10	1972

18	122	26	39	53	82	98	108	113	117	119	121		17	10	1972
110	126	24	48	76	95	107	114	117	120	123	125		20	10	1972
50	116	21	34	59	82	96	104	108	111	113	115		18	10	1972
33	119	25	34	52	78	94	103	109	112	116	118		20	10	1972
46	119	21	32	54	75	90	99	108	112	115	118		19	10	1972
26	120	23	32	53	74	91	99	107	111	105	119		19	10	1972
12	126	26	37	56	68	87	100	110	117	121	125		18	10	1972
57	117	25	35	52	72	93	103	108	112	114	116		19	10	1972
28	127	23	38	54	69	92	109	114	118	122	125		19	10	1972
49	122	24	38	51	75	92	103	109	112	114	117	120	19	11	1971
4	116	19	32	41	52	67	87	98	104	108	112	116	18	11	1971
16	126	28	51	65	85	99	108	112	115	119	121	124	19	11	1971
41	130	28	42	57	87	105	113	118	123	126	128	129	19	11	1971
$\bar{x}$	116.5	25.0	40.7	59.5	83.6	99.8	107.8	112.6	116.2	118.6	120.8	122.2	18.5	7.15	

Granada Cruise
TILLAMOOK HEAD
N = 167
Depth: 92 m

N	Height	1	2	3	4	5	6	7	8	9	10	11	12	Ribs	Age	Cohort
						ANNULI										
120	105	23	65	88	96									18	4	1978
61	105	24	45	72	94									18	4	1978
140	101	23	43	68	88									18	4	1978
60	104	27	44	65	88	98								19	5	1977
13	108	24	42	72	95	105								18	5	1977
90	106	28	46	70	92	101								20	5	1977
34	110	26	44	71	95	108								18	5	1977
6	105	25	38	59	88	98								19	5	1977
40	110	26	45	68	100	108								18	5	1977
94	105	23	40	60	82	99								21	5	1977
126	111	26	46	58	100	108								19	5	1977
150	116	25	44	63	91	100								21	5	1977
147	96	25	47	63	81	91								19	5	1977
149	105	24	47	69	91	102								19	5	1977
159	107	23	47	72	96	104								17	5	1977
117	110	25	41	61	82	92								18	5	1977
136	113	29	42	62	85	102								19	5	1977
48	109	32	50	70	91	104								19	5	1977
122	111	28	42	67	89	102								19	5	1977
62	106	23	43	60	81	99								20	5	1977
151	104	23	46	68	86	95								17	5	1977
35	113	28	49	72	96	108								20	5	1977
16	110	19	32	51	77	97	106							20	6	1976
12	115	28	42	57	75	93	106							19	6	1976
87	107	33	56	69	86	99	106							18	6	1976
109	102	24	41	66	87	95	100							18	6	1976
131	107	28	45	70	82	94	103							20	6	1976
76	117	31	45	60	76	97	111							19	6	1976
43	105	30	46	62	75	94	101							18	6	1976
148	111	23	41	66	84	95	108							18	6	1976
64	114	25	45	67	85	100	111							19	6	1976
38	111	31	47	66	86	102	109							17	6	1976
153	111	26	45	66	86	104	109							18	6	1976
95	107	21	39	65	82	92	100							18	6	1976
100	110	27	48	74	96	102	108							18	6	1976
66	108	28	47	69	82	94	102							18	6	1976
59	112	26	44	64	85	102	108							18	6	1976
101	106	25	41	60	81	99	105							19	6	1976
47	112	29	42	65	88	104	110							18	6	1976
42	107	28	47	65	81	93	103							18	6	1976
37	102	27	43	63	85	94	110							19	6	1976
36	109	25	48	68	93	99	106							19	6	1976
23	112	47	62	80	91	101	110							17	6	1976

132	106	27	44	67	81	94	103			17	6	1976
98	101	21	38	60	83	91	98			19	6	1976
49	107	25	41	53	75	96	103			18	6	1976
79	102	26	48	66	84	95	101			23	6	1976
7	115	30	45	64	79	89	99	108		18	7	1975
50	111	23	46	66	82	92	105	110		19	7	1975
96	115	25	41	55	72	86	98	103		19	7	1975
74	114	21	60	79	90	98	102	110		18	7	1975
112	110	25	48	66	79	88	109	111		19	7	1975
110	115	28	45	68	93	100	109	114		17	7	1975
56	106	26	48	67	83	92	100	105		18	7	1975
27	118	31	52	76	92	103	109	114		20	7	1975
77	113	25	45	65	81	92	101	109		20	7	1975
39	114	30	49	59	86	97	106	112		19	7	1975
144	117	26	45	64	82	94	106	114		18	7	1975
104	116	26	49	64	78	92	103	112		18	7	1975
115	114	28	55	71	87	97	105	117		18	7	1975
85	114	30	42	56	72	92	107	113		17	7	1975
127	116	29	43	63	81	94	103	112		19	7	1975
155	112	31	54	72	88	97	106	110		18	7	1975
93	108	20	36	54	68	86	100	106		19	7	1975
114	116	21	41	60	73	95	108	115		17	7	1975
166	108	24	40	58	73	89	103	106		18	7	1975
29	116	25	47	67	84	93	100	109		19	7	1975
1	116	24	43	60	78	90	104	111		17	7	1975
152	109	25	43	60	75	88	91	96		19	7	1975
157	113	24	40	62	80	91	102	109		18	7	1975
84	116	28	51	72	87	98	104	112		20	7	1975
139	120	28	50	71	87	98	105	113		20	7	1975
54	107	24	47	65	80	90	98	102	105	17	8	1974
146	109	30	48	65	80	88	95	100	107	19	8	1974
21	117	27	48	71	85	95	102	109	115	18	8	1974
24	119	28	40	52	67	84	92	106	114	19	8	1974
125	116	31	44	60	76	90	101	108	113	21	8	1974
22	114	21	43	62	80	89	99	105	111	17	8	1974
2	120	25	46	69	84	94	105	112	118	17	8	1974
8	112	28	46	67	83	93	102	107	110	18	8	1974
168	117	27	49	71	86	96	104	109	113	19	8	1974
75	111	20	38	65	79	90	97	104	109	18	8	1974
161	114	27	40	55	77	91	96	103	109	20	8	1974
57	115	28	46	66	82	93	102	107	111	19	8	1974
63	112	27	49	67	84	95	102	106	110	18	8	1974
121	122	31	51	69	85	96	104	112	119	17	8	1974
32	112	24	46	63	78	91	99	105	110	17	8	1974
163	112	24	45	71	86	95	99	105	108	17	8	1974
51	117	24	41	59	72	89	103	112	115	17	8	1974
142	115	26	45	66	82	93	102	108	114	20	8	1974
81	102	23	38	53	70	83	92	103	110	20	8	1974
156	113	25	47	64	79	90	96	103	109	18	8	1974
73	124	26	40	53	78	96	106	115	121	19	8	1974

42	118	26	50	67	84	95	103	107	112		17	8	1974
107	124	26	52	76	97	106	113	117	122		19	8	1974
160	116	25	50	69	85	94	103	108	114		21	8	1974
82	110	28	47	63	79	89	95	101	105		18	8	1974
20	113	27	46	65	80	91	100	106	114		19	8	1974
28	116	22	42	63	81	90	100	105	113		18	8	1974
113	113	24	46	62	79	90	96	102	112		18	8	1974
119	116	34	49	72	86	98	104	110	114		18	8	1974
67	113	25	46	63	80	89	97	104	112		18	8	1974
65	112	26	47	66	80	91	103	109	111		19	8	1974
134	108	24	41	68	86	94	101	104	107		17	8	1974
11	112	28	48	68	84	95	102	106	110		18	8	1974
78	114	23	51	70	85	96	103	107	112		17	8	1974
88	115	24	51	71	78	98	105	110	114		19	8	1974
26	113	26	41	60	77	88	95	109	104		17	8	1974
116	112	22	42	64	79	88	97	101	105	109	18	9	1973
158	112	28	42	62	83	94	100	103	107	110	18	9	1973
118	109	20	35	64	84	92	97	101	104	108	20	9	1973
3	122	23	38	50	72	84	95	102	112	119	17	9	1973
44	118	28	45	68	78	91	99	105	111	115	19	9	1973
83	114	25	44	55	70	85	93	100	104	110	20	9	1973
165	120	27	47	66	84	95	100	106	112	117	18	9	1973
58	118	26	48	66	80	92	101	108	112	116	19	9	1973
5	115	25	45	67	78	93	100	106	111	113	18	9	1973
106	117	24	46	72	88	96	102	106	110	115	18	9	1973
55	117	23	40	68	83	94	100	107	112	115	17	9	1973
89	115	26	46	63	78	91	98	105	110	113	19	9	1973
135	116	25	43	57	71	90	99	104	109	113	17	9	1973
99	118	29	46	64	88	99	107	112	115	117	18	9	1973
145	110	26	41	56	71	84	94	100	104	107	19	9	1973
143	113	25	44	59	74	92	100	105	107	110	17	9	1973
141	114	25	44	64	79	90	97	105	111	113	19	9	1973
17	117	21	42	63	81	93	101	106	111	116	18	9	1973
68	118	20	34	55	75	89	99	106	111	116	20	9	1973
18	112	27	47	64	79	88	96	101	108	111	19	9	1973
92	111	24	44	63	78	88	98	102	106	109	20	9	1973
137	113	24	38	58	65	82	93	101	106	112	17	9	1973
80	118	28	48	70	85	94	104	110	114	116	17	9	1973
70	114	24	43	62	78	87	95	104	109	114	19	9	1973
138	116	29	43	57	73	87	97	103	107	113	20	9	1973
31	116	29	45	66	84	93	101	105	110	115	18	9	1973
97	115	25	45	63	79	91	98	103	109	112	18	9	1973
25	116	25	48	72	85	94	100	107	111	115	19	9	1973
91	117	22	44	72	88	97	102	108	112	116	17	9	1973
45	118	25	42	67	82	92	99	105	112	116	18	9	1973
164	123	27	49	66	82	92	101	108	116	121	20	9	1973
4	112	25	46	63	75	85	94	101	107	111	19	9	1973
9	112	21	44	62	77	89	99	103	107	111	19	9	1973
162	115	24	45	62	78	90	98	104	110	114	17	9	1973
115	117	32	46	62	77	89	98	105	110	115	19	9	1973

123	118	27	51	78	82	93	101	108	113	115				18	9	1973
30	126	26	45	65	84	96	106	114	120	124				19	9	1973
16	118	28	43	54	79	87	97	104	109	114				18	9	1973
10	122	22	37	52	78	95	105	111	118	120				18	9	1973
133	116	24	39	53	72	86	96	102	109	115				17	9	1973
103	131	26	41	60	82	100	111	120	125	128	130			18	10	1972
86	116	28	50	62	79	88	96	102	108	111	115			18	10	1972
128	116	24	37	56	73	87	95	103	107	112	115			18	10	1972
105	132	32	54	66	81	100	113	119	124	127	130			18	10	1972
102	118	34	50	67	86	93	98	103	108	111	115			18	10	1972
124	118	28	47	69	88	97	105	103	110	112	116			17	10	1972
15	121	23	43	69	89	99	105	110	113	117	120			21	10	1972
108	123	25	44	60	78	92	104	110	115	119	122			20	10	1972
53	118	29	45	64	82	91	98	102	106	112	116			20	10	1972
33	121	24	42	62	75	91	104	110	114	117	120			18	10	1972
72	121	30	46	72	89	99	103	106	111	114	118			19	10	1972
129	130	26	39	57	69	92	101	110	118	123	127			22	10	1972
111	108	25	36	51	74	93	100	105	109	112	117			17	10	1972
154	125	30	53	69	80	96	107	113	117	120	123			18	10	1972
19	117	25	41	57	72	85	93	99	105	109	115			18	10	1972
46	119	20	41	68	83	93	100	104	109	112	115	117		19	11	1971
111	120	20	35	60	82	94	100	105	111	115	117	119		19	11	1971
69	120	24	40	54	70	88	98	103	107	110	113	116		18	11	1971
14	136	21	33	56	82	101	113	121	125	128	131	133	134	18	12	1970
$\bar{X}$	113.6	25.9	44.7	64.3	81.9	93.9	101.6	107.0	111.2	114.7	119.7	121.2	134	18.3	7.589285	

Chapman Cruise
TILLAMOOK HEAD
N=85
Date October 1981
Depth: 96 m

N	Height	1	2	3	4	5	6	7	8	9	10	11	Ribs	Age	Cohort
86	95	25	50	80									20	3	1978
40	106	28	52	80	101								19	4	1977
14	111	26	54	86	103								20	4	1977
54	104	26	55	76	98								19	4	1977
105	100	22	46	67	89								20	4	1977
82	97	24	51	70	84								20	4	1977
33	103	22	43	71	100								20	4	1977
87	105	22	47	73	100								20	4	1977
38	115	28	45	67	92	102							19	5	1976
85	108	25	44	59	75	94							18	5	1976
84	103	23	45	58	78	98							21	5	1976
74	99	27	45	62	79	97							18	5	1976
58	108	29	58	74	95	106							20	5	1976
81	115	29	45	70	93	102							19	5	1976
91	106	24	39	54	82	102							18	5	1976
50	110	25	49	63	80	104							20	5	1976
88	113	30	42	60	84	104							19	5	1976
20	108	28	40	54	71	90	103						20	6	1975
25	114	26	40	60	72	88	103						20	6	1975
93	109	20	48	74	87	97	103						19	6	1975
21	93	28	46	46	62	76	86						17	6	1975
73	112	28	41	60	74	87	98						19	6	1975
29	111	27	50	66	81	91	100	107					19	7	1974
47	113	26	46	69	85	95	103	110					20	7	1974
62	110	23	44	63	82	92	98	105					18	7	1974
30	112	29	48	66	82	93	105	110					18	7	1974
68	116	25	47	63	82	92	102	109					18	7	1974
31	100	25	40	68	79	86	90	94					19	7	1974
79	116	28	52	71	91	102	109	112					20	7	1974
10	110	24	42	63	82	92	100	108					19	7	1974
44	113	30	50	71	84	94	102	109					20	7	1974
49	116	27	50	66	93	102	108	115					18	7	1974
37	119	24	42	67	85	94	101	106					19	7	1974
76	110	25	46	65	79	88	96	103					18	7	1974
78	108	25	47	63	77	88	95	102					19	7	1974
61	113	26	48	63	77	87	98	104					19	7	1974
60	108	27	50	65	79	87	94	100					21	7	1974
66	112	27	51	70	82	92	100	106					22	7	1974
113	112	30	57	74	88	99	105	108					19	7	1974
67	114	26	46	64	76	87	97	105	112				18	8	1973
108	114	24	44	70	88	97	103	108	111				22	8	1973
36	115	24	36	57	74	86	95	103	109				20	8	1973
64	111	28	48	72	85	94	105	110	115				19	8	1973

83	112	22	49	67	82	94	103	106	108				20	8	1973
11	107	25	46	65	78	87	95	102	110				17	8	1973
95	118	24	49	66	80	90	99	108	117				21	8	1973
97	108	22	46	62	76	87	93	100	106				17	8	1973
100	103	29	55	70	82	91	98	102	108				20	8	1973
1	126	27	52	74	95	107	115	120	124				18	8	1973
71	111	28	49	65	80	90	98	103	110				20	8	1973
15	108	27	51	72	87	95	99	103	107				19	8	1973
24	117	25	47	66	82	95	102	109	116				18	8	1973
26	114	25	40	70	84	96	102	107	112				20	8	1973
16	119	28	51	70	87	96	104	111	118				18	8	1973
32	108	27	52	72	83	90	95	100	103				19	8	1973
19	118	26	48	67	84	94	102	109	117				20	8	1973
45	122	28	58	66	82	94	102	110	120				21	8	1973
56	112	29	52	69	82	92	98	103	110				19	8	1973
80	119	24	43	65	84	97	105	114	117				22	8	1973
109	118	27	51	70	86	96	103	108	116				19	8	1973
9	114	26	44	64	78	87	95	102	108				19	8	1973
53	120	28	52	68	83	93	102	109	117				20	8	1973
87	112	26	46	63	78	87	95	102	110				21	8	1973
7	116	26	47	68	91	101	107	111	114				21	8	1973
111	112	26	50	65	78	88	95	103	110				20	8	1973
8	112	23	51	70	84	94	101	106	110				21	8	1973
59	110	21	42	62	74	85	91	96	100				19	8	1973
2	113	26	49	70	84	92	98	104	109				20	8	1973
28	106	27	54	71	83	87	93	99	103				20	8	1973
18	117	29	53	71	89	96	101	106	111				17	8	1973
77	117	27	52	68	84	94	102	108	114				20	8	1973
41	117	22	48	71	88	99	104	108	113				19	8	1973
5	117	24	40	57	74	87	95	102	107	112			21	9	1972
114	115	23	42	68	84	92	99	103	107	112			20	9	1972
42	116	24	41	54	73	89	97	104	110	113			19	9	1972
102	110	30	44	63	82	94	100	104	106	108			18	9	1972
90	121	27	47	69	89	98	110	118	123	126			21	9	1972
70	126	29	57	83	99	108	115	120	122	124			19	9	1972
106	117	20	33	57	81	96	103	109	112	115			20	9	1972
23	121	26	55	69	85	101	111	115	118	120			21	9	1972
46	113	28	48	67	86	97	101	107	110	112			20	9	1972
13	115	26	48	70	83	93	99	104	109	112			19	9	1972
110	120	28	54	78	94	101	106	111	114	116	119		17	10	1971
107	128	23	46	66	89	95	101	111	117	122	125		20	10	1971
92	132	23	39	56	69	89	107	116	122	125	128	131	19	11	1970
$\bar{X}$	112.2	25.8	47.4	66.8	83.6	94.9	102.	108.5	114.7	126.4	124	131	19.4	7.17	

Granada Cruise
TILLAMOOK HEAD
N = 103
Date 08/14/82
Depth: 101 m

N	Height	1	2	3	4	5	6	7	8	9	10	11	Ribs	Age	Cohort
14	104	33	53	68	79	87	93	100					17	7	1975
86	116	27	45	65	80	96	105	112					20	7	1975
33	107	27	40	59	73	86	97	103					22	7	1975
13	105	25	48	62	77	85	95	101					18	7	1975
96	108	30	47	63	75	89	96	105					17	7	1975
100	102	22	47	65	76	85	90	98					18	7	1975
27	111	27	50	66	80	90	102	108					21	7	1975
49	107	24	46	66	82	96	101	104					18	7	1975
11	111	26	45	65	79	92	99	106					19	7	1975
54	108	25	41	65	78	88	100	104					18	7	1975
4	103	22	42	62	77	88	94	99	102				19	8	1974
88	105	20	34	59	80	88	93	98	102				17	8	1974
79	111	27	47	65	79	88	94	101	106				19	8	1974
21	115	21	46	66	81	91	98	108	112				19	8	1974
41	111	27	47	62	76	87	95	103	108				17	8	1974
93	112	28	49	66	78	87	95	101	108				17	8	1974
51	106	24	47	60	76	85	92	99	104				18	8	1974
69	106	31	43	63	80	87	92	101	104				18	8	1974
99	108	25	46	62	75	83	90	102	106				18	8	1974
3	115	27	38	57	72	84	92	98	106				16	8	1974
10	115	20	35	62	79	89	97	108	114				17	8	1974
95	111	30	44	60	82	93	105	107	110				18	8	1974
62	120	25	44	61	74	85	92	102	114				17	8	1974
12	117	26	48	64	78	90	97	107	112				18	8	1974
64	106	28	46	61	74	83	90	100	106				18	8	1974
37	110	26	49	66	87	95	99	104	107				18	8	1974
23	107	29	51	63	76	85	90	96	103				17	8	1974
67	112	26	49	67	79	91	97	104	109				18	8	1974
36	108	27	53	68	82	90	95	99	104				20	8	1974
94	110	27	50	68	76	87	96	103	108				18	8	1974
29	107	30	44	56	72	84	93	98	103				20	8	1974
65	112	25	50	69	83	93	99	105	109				18	8	1974
18	111	32	53	67	80	94	99	105	109				18	8	1974
72	115	22	44	56	69	78	92	99	107				20	8	1974
84	110	22	41	60	75	85	91	100	107				17	8	1974
5	102	25	41	62	73	81	88	94	100				18	8	1974
86	113	30	52	70	84	95	100	106	111				20	8	1974
60	105	24	44	60	74	82	89	97	103				17	8	1974
50	106	25	40	60	72	83	91	96	104				17	8	1974
82	107	24	44	61	72	82	90	100	106				18	8	1974
1	111	25	44	65	80	91	97	101	105				20	8	1974
9	100	25	43	61	78	83	89	93	98				18	8	1974
7	114	25	49	67	82	90	100	107	112				18	8	1974

89	103	25	46	62	79	89	95	102	108			19	8	1974
70	109	30	50	68	80	89	95	101	106			18	8	1974
45	107	25	45	68	79	86	92	98	102			18	8	1974
75	119	28	47	61	77	88	96	100	107	114		18	9	1973
19	114	29	48	62	75	85	92	101	109	113		19	9	1973
56	103	26	48	64	76	82	90	94	99	102		19	9	1973
58	110	30	53	68	78	86	94	98	102	107		18	9	1973
87	109	24	45	61	75	83	92	99	105	108		17	9	1973
57	115	24	52	71	82	91	97	104	111	115		19	9	1973
78	113	22	46	63	76	85	92	97	103	109		18	9	1973
43	118	21	41	71	85	96	103	108	114	117		20	9	1973
52	113	27	44	67	78	89	96	101	108	112		18	9	1973
59	110	20	40	58	71	83	91	97	103	109		18	9	1973
74	117	23	48	66	82	93	100	105	110	114		19	9	1973
92	117	24	44	63	75	86	93	102	109	115		17	9	1973
28	108	26	48	66	78	88	94	98	103	107		17	9	1973
34	116	27	52	72	86	96	102	107	112	115		18	9	1973
22	116	23	46	64	78	89	96	105	110	115		19	9	1973
90	112	26	45	67	82	91	97	102	108	111		17	9	1973
71	118	24	44	62	75	85	93	97	100	105		17	9	1973
101	113	26	45	62	76	85	92	100	108	111		18	9	1973
24	120	25	45	66	87	97	102	111	114	118		18	9	1973
44	115	30	52	72	84	92	99	104	110	114		18	9	1973
76	113	25	46	67	81	91	98	102	106	110		18	9	1973
47	114	25	48	63	78	89	96	100	104	110		19	9	1973
91	112	29	47	67	82	91	100	103	107	111		18	9	1973
55	111	25	45	64	79	87	92	98	102	108		18	9	1973
53	113	30	50	70	82	90	96	104	111	112		18	9	1973
5	111	27	42	59	74	84	90	98	101	106		18	9	1973
63	108	28	49	65	78	82	94	100	105	107		20	9	1973
73	107	22	42	59	75	85	91	97	100	103		18	9	1973
32	104	23	44	62	76	83	88	92	95	100		18	9	1973
102	109	26	46	65	76	86	94	98	104	107		20	9	1973
87	119	26	46	67	82	92	100	108	115	118		18	9	1973
80	109	24	47	61	74	84	92	98	103	107		17	9	1973
83	115	26	48	68	84	93	99	105	110	114		18	9	1973
85	113	21	46	64	78	88	96	99	106	111		19	9	1973
15	110	26	48	64	77	86	93	97	102	106		17	9	1973
97	105	26	45	64	77	84	92	97	101	104		19	9	1973
2	110	22	42	66	80	89	95	99	103	108		18	9	1973
40	111	23	49	68	82	92	97	102	105	109		19	9	1973
30	116	22	44	62	77	86	97	102	109	113		17	9	1973
81	113	21	37	60	76	89	96	104	107	112		18	9	1973
61	110	22	43	61	75	85	91	97	102	106		17	9	1973
39	120	25	45	70	82	92	98	103	108	115		18	9	1973
31	105	26	51	64	76	84	90	96	100	103		19	9	1973
48	114	25	48	70	84	94	98	102	108	113		19	9	1973
66	108	27	43	60	74	83	92	98	102	106		18	9	1973
16	112	33	53	70	82	90	95	102	106	110		21	9	1973
25	113	23	44	60	75	87	94	98	101	105	109	17	10	1972

26	114	21	48	64	79	89	94	98	104	108	111		20	10	1972
35	112	27	47	63	84	92	98	101	104	107	110		18	10	1972
47	120	22	35	58	74	86	93	99	107	114	118		18	10	1972
8	116	25	47	67	80	89	96	102	107	113	115		17	10	1972
77	111	20	37	59	73	84	92	97	100	103	108		18	10	1972
17	110	21	39	57	72	80	87	92	100	106	109		16	10	1972
38	111	27	49	70	85	95	99	103	105	107	109		19	10	1972
20	113	30	47	66	80	89	95	99	104	109	111		20	10	1972
46	112	22	50	64	71	87	93	98	102	106	109	111	19	11	1971
103	113	25	38	55	72	84	92	97	102	105	108	112	18	11	1971
$\bar{X}$	110.9	25.4	45.7	63.9	78	87.8	94.9	100.9	105.7	109.5	110.6	111.5	18.2	8.58	

Granada Cruise
CAPE KIWANDA
N = 135
Date: 8/17/82
Depth: 82 m

N	Height	1	2	3	4	5	6	7	8	9	10	11	12	13	14 Ribs	Age	Cohort
136	88	30	52	74											19	3	1979
35	97	27	46	66	84										19	4	1978
15	91	22	38	64	80										19	4	1978
17	124	29	58	83	105										19	4	1978
57	123	31	54	69	95	117	122								17	6	1976
98	122	25	39	58	90	112	120								22	6	1976
13	123	25	55	75	96	110	120								18	6	1976
28	117	29	52	74	97	111	115								19	6	1976
8	125	32	57	80	98	115	121								21	6	1976
61	126	28	49	70	87	106	122								17	6	1976
89	124	22	38	59	80	101	115	123							17	7	1975
43	117	22	35	57	74	98	109	113							18	7	1975
102	124	25	27	55	80	103	116	121							19	7	1975
130	132	27	45	66	94	114	126	130							19	7	1975
58	126	33	52	69	93	109	117	123							17	7	1975
121	121	31	62	85	100	109	115	118							17	7	1975
60	133	32	57	86	108	125	129	132							17	7	1975
19	123	28	43	61	86	109	117	121							19	7	1975
85	128	29	48	76	96	117	124	127							20	7	1975
129	133	32	52	73	96	115	122	130							18	7	1975
40	129	26	45	74	97	113	120	124	128						19	8	1974
36	128	30	46	65	89	104	112	119	122						18	8	1974
7	142	27	45	62	91	112	123	131	135						17	8	1974
109	131	28	51	68	88	111	119	124	128						19	8	1974
103	126	30	47	63	89	107	114	118	122						22	8	1974
126	126	30	50	70	94	107	114	119	123						17	8	1974
9	134	27	47	70	94	112	120	126	130						19	8	1974
53	134	28	47	68	93	113	121	130	132						19	8	1974
25	133	28	45	68	94	112	119	126	130						17	8	1974
133	130	27	46	64	90	109	116	122	127						19	8	1974
21	131	28	31	64	88	109	116	122	126						19	8	1974
20	130	33	51	68	93	110	119	125	128						19	8	1974
122	129	32	41	65	70	108	114	121	125						19	8	1974
31	124	25	45	62	86	105	112	118	122						16	8	1974
123	130	32	53	71	95	112	117	123	126						19	8	1974
74	126	25	41	58	73	94	109	116	124						17	8	1974
129	129	27	39	62	90	108	116	122	127						18	8	1974
76	134	28	43	60	85	107	117	125	129						19	8	1974
120	131	30	47	63	91	109	117	125	128						16	8	1974
108	125	37	61	88	102	112	119	122	124						20	8	1974
107	125	28	47	62	85	102	110	117	120						20	8	1974
54	128	28	47	65	90	108	114	122	126						18	8	1974

69	132	29	42	69	93	112	120	128	130			18	8	1974
135	130	30	46	71	92	109	118	123	127			19	8	1974
64	128	25	42	59	80	98	112	121	126			17	8	1974
6	124	29	49	67	90	105	113	118	122			19	8	1974
104	131	28	45	61	87	106	115	122	126			18	8	1974
72	132	25	40	69	89	109	120	124	128	131		18	9	1973
97	132	30	52	69	93	111	118	123	125	129		19	9	1973
101	138	31	45	67	93	111	119	126	130	136		18	9	1973
131	139	29	47	67	97	112	122	128	132	138		19	9	1973
42	128	26	46	68	90	105	103	119	122	126		18	9	1973
45	127	27	46	67	92	109	115	120	123	126		17	9	1973
44	135	25	41	65	93	112	122	129	132	134		20	9	1973
29	136	26	46	64	92	112	119	125	130	134		18	9	1973
106	135	29	46	67	86	108	115	122	127	131		18	9	1973
111	131	26	41	60	81	106	115	120	125	129		20	9	1973
79	134	23	39	58	82	105	113	121	127	131		18	9	1973
18	131	27	45	66	92	109	117	124	127	130		18	9	1973
80	132	27	44	64	89	109	117	123	128	130		18	9	1973
87	131	30	49	70	94	106	115	121	125	128		18	9	1973
118	134	27	48	68	95	110	118	124	128	132		28	9	1973
73	132	34	53	73	95	110	118	124	127	131		19	9	1973
39	130	30	46	65	88	108	116	122	125	129		20	9	1973
78	133	32	51	69	90	110	119	126	131	133		20	9	1973
12	135	25	41	60	90	110	120	127	132	135		18	9	1973
52	132	24	38	57	71	98	112	120	127	137		16	9	1973
116	139	29	49	69	96	113	121	126	133	137		18	9	1973
94	133	33	64	91	108	114	120	125	130	132		19	9	1973
119	136	27	45	67	92	111	120	127	132	135		19	9	1973
65	137	31	52	72	98	113	122	129	132	135		19	9	1973
27	131	30	50	66	89	110	118	124	126	129		18	9	1973
105	128	26	39	60	83	104	111	119	123	126		19	9	1973
92	135	29	48	68	94	110	117	122	127	132		18	9	1973
93	135	24	41	69	93	112	120	125	130	133		20	9	1973
87	145	31	54	75	100	121	129	137	139	143		19	9	1973
127	131	21	50	69	91	109	116	123	126	128		18	9	1973
1	135	34	65	91	110	118	124	128	130	133		19	9	1973
38	135	22	39	52	70	96	110	118	126	130		18	9	1973
56	137	30	41	66	95	112	120	128	132	136		17	9	1973
115	127	26	40	61	82	102	112	118	123	126		19	9	1973
23	132	29	49	75	100	103	119	124	129	132		19	9	1973
110	132	30	51	72	86	109	118	124	127	130		20	9	1973
11	133	29	50	65	88	109	118	124	127	131		17	9	1973
30	127	32	49	67	88	106	113	118	123	126		18	9	1973
81	136	33	50	68	88	109	118	124	128	133		17	9	1973
117	137	29	47	69	93	112	120	125	130	134		20	9	1973
125	143	24	42	61	86	111	123	128	132	137	140	19	10	1972
95	135	30	49	63	89	108	117	124	126	130	133	16	10	1972
88	135	22	35	50	75	100	116	121	127	130	133	18	10	1972
55	132	28	45	59	88	104	112	118	123	127	130	16	10	1972
71	140	25	43	74	102	118	125	131	133	135	138	17	10	1972

2	140	26	40	58	87	104	118	127	131	135	138					18	10	1972
96	131	26	49	70	97	110	117	121	124	129	131					17	10	1972
3	128	28	50	70	97	111	116	121	124	126	128					17	10	1972
26	125	25	45	63	88	105	112	117	120	122	124					19	10	1972
33	136	32	50	75	99	115	123	129	132	134	135					18	10	1972
112	134	25	39	59	85	104	116	124	128	131	133					17	10	1972
83	130	30	45	64	87	104	113	119	121	123	126					17	10	1972
49	135	24	42	67	79	100	115	124	128	131	134					18	10	1972
63	133	26	39	62	90	102	113	122	127	129	131					16	10	1972
84	127	27	42	65	90	108	116	120	122	125	127					18	10	1972
70	141	29	47	67	90	114	126	131	133	136	140					18	10	1972
75	142	26	42	59	92	110	122	132	137	139	141					19	10	1972
114	133	31	52	74	94	110	116	121	127	130	132					20	10	1972
128	139	30	57	71	96	112	119	126	131	136	138					17	10	1972
50	136	30	54	73	97	110	120	125	128	131	134					19	10	1972
41	134	27	42	60	89	109	120	124	127	129	132					19	10	1972
59	135	31	61	88	100	108	118	123	127	132	134					19	10	1972
47	139	27	42	62	88	108	119	125	128	132	135	137				18	11	1971
132	132	37	49	70	95	111	117	120	123	125	128	130				17	11	1971
99	143	28	47	70	99	115	121	133	135	137	140	142				17	11	1971
82	145	28	46	67	97	112	118	128	133	137	139	142				18	11	1971
24	139	27	45	69	99	116	123	129	132	135	137	139				18	11	1971
100	137	28	47	70	95	108	115	122	125	129	131	134				19	11	1971
4	140	27	45	65	93	107	123	128	132	135	138	140				19	11	1971
90	137	25	37	57	80	100	112	122	128	131	133	135				21	11	1971
5	138	28	46	69	96	115	122	128	131	132	134	136				18	11	1971
32	139	26	38	60	89	106	118	124	128	132	135	138				18	11	1971
113	132	31	50	67	97	110	118	123	126	128	129	131				19	11	1971
51	148	27	44	66	89	103	118	132	138	141	144	146				17	11	1971
16	136	26	45	62	89	110	118	126	128	132	134	136				19	11	1971
10	144	25	40	67	105	123	128	131	134	137	140	142				19	11	1971
48	141	28	50	73	100	118	126	128	130	133	136	140				18	11	1971
139	145	32	52	71	95	115	124	132	135	138	140	143				18	11	1971
62	145	33	49	63	94	115	123	131	134	138	141	143				18	11	1971
34	135	30	60	75	90	108	118	123	126	130	132	134				19	11	1971
77	133	30	43	62	87	95	107	113	121	126	128	130	132			17	12	1970
14	145	30	45	66	97	116	125	131	135	138	140	142	144			18	12	1970
37	145	29	45	66	85	112	121	128	132	137	139	142	144			21	12	1970
22	138	28	47	65	86	109	116	122	128	131	133	135	137			18	12	1970
86	149	26	41	65	98	113	126	133	137	140	143	145	148			18	12	1970
67	142	25	37	55	75	96	114	120	124	127	132	135	138			19	12	1970
46	148	30	55	75	102	121	129	134	136	139	142	144	146	147		19	13	1969
91	145	30	46	63	82	100	117	124	127	131	134	137	140	142	144	19	14	1968
$\tilde{x}$	132.2	28.1	46.4	67.1	90.9	109.0	117.9	124.1	128.0	132.0	134.7	138.3	141.1	144.5	144	18.4		

Granada Cruise
YAQUINA HEAD
N=153
Date: 8/18/82
Depth: 110 m

		ANNULI													
N	Height	1	2	3	4	5	6	7	8	9	10	11	Ribs	Age	Cohort
65	83	30	45	69	78								15	4	1978
28	89	33	52	74	85								18	4	1978
82	84	24	44	59	74	82							19	5	1977
105	93	26	47	64	82	91							18	5	1977
35	92	25	44	60	78	82							20	5	1977
69	87	23	35	51	74	82							19	5	1977
126	86	23	38	52	68	79							18	5	1977
17	93	25	45	62	83	92							17	5	1977
150	95	30	50	67	85	93							17	5	1977
136	76	21	36	50	66	76							17	5	1977
89	82	20	35	51	70	79							18	5	1977
101	93	26	38	54	76	89							18	5	1977
86	85	23	34	53	74	81							21	5	1977
9	75	26	42	52	66	72							18	5	1977
14	78	26	39	52	67	74							17	5	1977
36	80	21	31	45	65	73							19	5	1977
1	82	22	38	54	70	79							18	5	1977
42	92	21	36	52	75	87							21	5	1977
127	94	33	45	60	82	92							18	5	1977
50	90	24	37	57	77	85							18	5	1977
21	89	29	44	60	76	86							19	5	1977
139	79	26	37	50	60	70	76						18	6	1976
90	103	24	37	62	80	92	102						17	6	1976
117	97	26	45	62	72	81	89						18	6	1976
132	90	20	34	52	65	81	88						17	6	1976
91	91	22	32	48	64	81	89						18	6	1976
67	89	27	40	50	66	82	89						18	6	1976
123	91	24	40	50	65	81	89						17	6	1976
80	89	21	31	46	60	74	83						17	6	1976
71	92	21	34	46	63	80	89						17	6	1976
34	87	23	35	49	62	72	81						17	6	1976
33	91	23	36	46	63	81	90						16	6	1976
99	92	24	34	45	63	80	89						18	6	1976
68	81	20	32	45	58	73	79						17	6	1976
12	86	23	36	55	72	80	84						20	6	1976
64	97	25	35	50	64	85	93						18	6	1976
93	86	22	30	44	54	61	78	84					17	7	1975
41	92	20	42	56	63	72	80	89					18	7	1975
97	110	25	51	72	89	98	102	107					19	7	1975
84	94	24	40	61	74	81	86	92					17	7	1975
122	114	26	52	72	82	90	98	105					18	7	1975
73	103	24	46	57	67	74	82	92					19	7	1975
63	89	20	36	52	67	75	82	89					18	7	1975

74	91	24	42	65	76	83	88	93			18	7	1975
5	104	26	55	77	89	94	100	103			22	7	1975
54	110	30	46	66	80	87	94	106			17	7	1975
87	100	23	37	58	72	82	91	98			17	7	1975
104	78	24	36	50	58	62	71	74			18	7	1975
29	95	22	45	57	65	74	80	89	97		18	8	1974
103	105	28	50	72	84	90	95	100	104		20	8	1974
24	104	24	42	66	83	89	92	98	102		18	8	1974
95	97	23	39	57	67	72	78	85	94		19	8	1974
47	98	24	43	54	64	78	84	88	94		19	8	1974
55	101	28	42	49	64	71	82	87	97		17	8	1974
109	106	25	46	62	71	82	90	95	102		19	8	1974
61	105	27	53	61	71	79	89	96	101		17	8	1974
38	103	23	35	50	66	82	88	93	101		19	8	1974
66	103	27	49	60	68	80	89	97	102		18	8	1974
152	98	26	40	62	75	80	85	91	95		17	8	1974
11	101	30	50	69	84	89	93	99	103		18	8	1974
145	101	24	35	48	65	81	87	91	98		19	8	1974
45	107	28	50	67	73	81	89	95	103		17	8	1974
92	112	29	48	72	88	94	97	103	108		17	8	1974
83	100	26	39	50	64	72	82	92	97		19	8	1974
26	100	20	37	54	66	77	88	94	99		20	8	1974
135	107	30	45	55	70	80	86	95	102		16	8	1974
15	102	28	50	60	71	78	86	94	100		17	8	1974
153	104	23	36	50	62	72	82	91	100		18	8	1974
144	103	23	36	49	63	71	79	85	94		17	8	1974
133	92	28	40	52	65	72	81	87	90		18	8	1974
40	103	28	46	67	82	86	92	97	101		20	8	1974
120	108	25	40	65	77	85	91	96	102		19	8	1974
111	97	22	34	47	60	69	80	87	93		17	8	1974
22	90	25	36	47	57	66	75	83	88		18	8	1974
147	104	26	47	58	67	75	84	92	101		17	8	1974
7	102	24	49	68	81	87	92	99	102		18	8	1974
16	106	27	52	61	71	78	89	95	103		20	8	1974
56	104	26	42	64	83	87	91	96	99		19	8	1974
37	112	26	50	74	83	90	98	104	110		20	8	1974
13	102	31	43	68	79	86	89	92	97		18	8	1974
44	109	27	47	66	85	92	95	100	106		18	8	1974
4	104	25	46	67	81	86	90	97	102		18	8	1974
110	106	25	36	46	56	67	78	88	99	104	18	9	1973
85	93	27	37	48	58	63	70	78	85	92	17	9	1973
113	106	24	45	69	78	84	88	92	97	102	18	9	1973
43	106	23	43	65	78	86	92	95	99	105	19	9	1973
142	117	23	46	69	79	90	99	106	111	115	19	9	1973
10	116	29	49	76	85	94	102	108	113	115	20	9	1973
100	98	25	36	47	57	66	75	82	90	94	16	9	1973
72	93	22	34	45	56	62	70	76	82	90	16	9	1973
116	106	22	37	49	58	70	75	81	91	101	17	9	1973
46	109	25	42	55	69	81	89	97	104	109	19	9	1973
75	108	23	37	58	73	80	86	93	99	104	18	9	1973

102	100	23	44	61	69	82	87	91	94	98		18	9	1973
141	102	20	34	46	58	67	76	82	91	99		18	9	1973
119	102	26	41	55	65	79	82	88	93	98		20	9	1973
128	106	27	38	53	65	73	81	89	98	105		18	9	1973
125	106	27	47	67	81	86	92	97	102	106		19	9	1973
114	100	27	39	52	61	67	74	82	89	96		18	9	1973
58	91	21	38	50	57	65	72	78	85	91		19	9	1973
60	100	24	36	50	61	69	76	83	89	96		17	9	1973
148	109	29	54	68	75	82	90	98	105	109		18	9	1973
78	108	28	53	70	76	85	91	97	102	105		18	9	1973
2	103	25	40	51	64	72	79	88	95	104		17	9	1973
59	100	25	39	48	60	67	75	86	93	101		17	9	1973
81	102	26	42	55	65	74	83	90	96	103		18	9	1973
52	97	21	38	62	74	78	82	88	91	95		19	9	1973
3	110	23	39	54	69	82	87	93	100	105		17	9	1973
107	104	25	44	63	74	77	80	89	95	103		19	9	1973
118	98	25	37	49	60	68	77	84	91	95		18	9	1973
112	101	28	43	54	65	75	81	86	91	96		18	9	1973
77	107	21	40	53	65	78	85	91	95	100		19	9	1973
25	89	23	44	63	73	78	82	85	89	90		18	9	1973
30	103	27	43	60	71	78	82	92	97	102		19	9	1973
106	100	27	44	61	73	78	83	87	92	97		18	9	1973
19	106	24	36	58	69	74	81	88	96	103		17	9	1973
53	105	28	40	57	67	73	81	89	98	107		19	9	1973
98	105	29	43	52	66	73	78	86	96	104		19	9	1973
76	100	22	38	61	74	79	84	88	94	98		18	9	1973
49	110	24	40	54	66	74	82	90	97	107		18	9	1973
154	105	22	47	67	78	83	87	93	97	102		19	9	1973
29	98	29	41	60	73	78	82	86	94	98		18	9	1973
121	97	22	41	53	65	72	84	90	94	96		17	9	1973
79	100	25	51	69	79	85	87	90	93	97		18	9	1973
146	106	27	39	48	61	69	78	86	95	106		20	9	1973
143	98	26	43	54	63	75	82	87	93	99		18	9	1973
149	99	21	45	63	75	80	84	92	97	100		19	9	1973
8	104	24	36	46	59	70	80	90	98	105		18	9	1973
151	90	23	32	48	58	67	75	81	86	89		19	9	1973
138	107	24	42	54	61	72	81	89	94	100		18	9	1973
124	104	25	37	62	76	83	88	94	101	104		17	9	1973
39	107	26	40	53	65	77	82	87	91	97	104	17	10	1972
137	103	24	39	47	60	70	74	80	86	93	98	17	10	1972
23	91	23	34	45	54	60	67	72	82	88	91	17	10	1972
129	101	23	32	44	56	71	84	86	89	94	97	20	10	1972
18	102	23	42	62	74	77	81	84	91	97	101	20	10	1972
6	110	22	40	53	63	74	82	86	94	102	109	18	10	1972
131	107	29	50	60	72	82	88	93	98	102	106	18	10	1972
48	104	22	37	51	61	72	78	82	88	95	102	20	10	1972
94	98	25	38	50	58	68	72	79	84	90	96	18	10	1972
108	98	21	39	52	65	74	82	85	90	93	97	19	10	1972
20	105	20	37	51	60	73	79	86	93	99	105	18	10	1972
57	105	26	37	60	68	79	88	96	100	102	104	17	10	1972

27	98	24	36	46	54	59	66	74	82	91	97		17	10	1972
32	105	20	41	52	65	77	82	85	90	95	100		19	10	1972
115	95	21	36	46	57	65	70	76	82	86	92		19	10	1972
70	102	25	40	50	61	72	77	82	87	95	100		17	10	1972
51	95	23	40	52	64	72	78	84	88	92	95		19	10	1972
96	100	25	40	50	57	63	71	79	86	94	99		17	10	1972
140	111	27	41	54	64	80	85	91	98	103	110		18	10	1972
88	104	21	34	47	58	71	78	83	90	97	103		17	10	1972
134	98	26	35	46	59	68	77	82	88	94	97		16	10	1972
130	100	25	41	55	64	72	78	84	90	93	95	97	17	11	1971
$\bar{X}$	98.67	24.6	40.8	56.3	68.9	77.7	83.9	89.82	95.42	99.04	99.9	97	18.0	7.91	

F/V Tatiana
HECETA HEAD - Florence
N = 66
Date: 8/10/83

N	Height	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Ribs	Age	Cohort
48	112	23	39	62	84	101												17	5	1978
39	120	27	46	74	95	108	116											20	6	1977
35	120	30	49	69	83	103	113											19	6	1977
33	108	27	52	79	97	103	106											19	6	1977
55	118	25	43	73	98	109	115											20	6	1977
30	113	25	39	58	82	100	109											17	6	1977
42	121	28	47	68	98	112	117											18	6	1977
29	119	27	44	63	92	104	113											19	6	1977
25	118	28	48	62	86	104	113											19	6	1977
28	118	31	58	79	98	108	115											18	6	1977
61	117	30	46	76	97	108	113											20	6	1977
56	118	29	45	70	92	107	112											18	6	1977
40	120	25	47	65	99	102	112											18	6	1977
14	116	29	46	75	94	107	114											20	6	1977
34	123	28	48	71	86	102	115	120										17	7	1976
31	118	26	48	69	82	100	112	118										19	7	1976
32	118	25	41	58	78	92	107	115										19	7	1976
65	117	28	44	60	79	97	108	114										20	7	1976
4	120	30	55	74	93	105	115	119										17	7	1976
62	117	24	38	57	88	103	112	116										21	7	1976
54	118	27	44	66	93	107	112	116										19	7	1976
36	119	27	48	63	82	98	109	117										18	7	1976
60	115	27	43	60	72	91	104	109										19	7	1976
3	122	29	47	73	87	97	108	114										18	7	1976
37	118	28	47	79	84	102	111	117										19	7	1976
9	117	29	44	64	82	97	108	113										20	7	1976
26	120	31	50	71	85	102	113	119										18	7	1976
46	117	29	45	64	80	97	109	115										18	7	1976
7	112	25	42	68	82	98	105	110										19	7	1976
27	118	22	39	62	87	97	108	114										20	7	1976
57	116	27	56	78	91	102	110	115										16	7	1976
64	120	26	45	73	97	105	112	118										17	7	1976
21	121	28	45	67	79	97	108	114	118									20	8	1975
58	120	26	44	55	72	90	102	111	117									19	8	1975
52	130	27	48	70	83	102	115	122	127									20	8	1975
11	120	22	35	47	63	81	92	111	117									19	8	1975
13	117	25	45	66	78	93	105	111	116									20	8	1975
44	116	25	46	64	75	92	105	111	115									18	8	1975
24	120	28	45	62	79	94	106	114	118									20	8	1975
8	125	25	41	58	74	97	~~111~~	118	124									19	8	1975
38	125	30	45	68	78	99	113	118	122									20	8	1975
2	113	28	45	59	72	85	94	105	112									18	8	1975
5	128	29	54	79	100	112	121	125	127									18	8	1975

49	118	31	54	72	91	98	105	110	114	117								18	9	1974
45	118	27	43	63	83	100	105	108	111	114								19	9	1974
41	124	31	52	81	96	104	110	114	118	121	122							20	10	1973
50	118	28	54	71	90	98	102	105	109	114	117							18	10	1973
17	129	30	48	69	82	92	101	110	117	122	126							18	10	1973
1	114	23	34	48	66	81	92	103	108	110	113	113						19	11	1972
6	122	24	36	51	72	93	101	106	112	114	117	121						17	11	1972
51	121	29	52	72	91	97	101	104	108	112	115	118						18	11	1972
15	120	20	53	72	88	96	102	106	110	112	115	118	120					17	12	1971
53	122	27	46	68	88	97	103	107	110	112	115	118	121					18	12	1971
66	118	24	40	57	65	84	91	97	104	108	112	115	117					17	12	1971
19	122	28	43	55	75	92	100	105	108	112	114	117	119					18	12	1971
10	127	28	45	60	77	98	110	114	117	119	121	124	126					19	12	1971
63	131	27	40	63	86	103	112	116	119	121	124	126	129					19	12	1971
43	123	25	43	56	76	93	98	101	104	109	112	117	120					17	12	1971
59	126	29	45	65	85	94	99	104	108	111	114	118	121					16	12	1971
20	131	22	41	57	67	78	86	92	106	117	122	125	127	129				19	13	1970
47	131	27	55	75	94	104	108	112	116	118	121	124	127	130				16	13	1970
12	125	24	41	53	73	90	98	103	107	110	113	116	121	123				18	13	1970
23	130	30	52	64	77	87	104	111	115	117	120	122	124	126	129			17	14	1969
16	132	31	45	59	71	94	106	114	116	119	121	123	126	128	130			19	14	1969
18	128	24	38	61	80	95	102	105	108	110	112	115	118	121	123	125		18	15	1968
22	129	26	44	56	75	90	97	102	106	110	113	115	117	119	121	124	127	18	16	1967
$\bar{X}$	120.5	26.9	45.6	65.5	83.6	98	106.9	111.3	113.6	114.3	117.0	119.1	122.2	125.1	125.7	124.5	127	18.4	8.66	

COOS BAY
October 24-25/1981
N = 58
Depth = 82 m

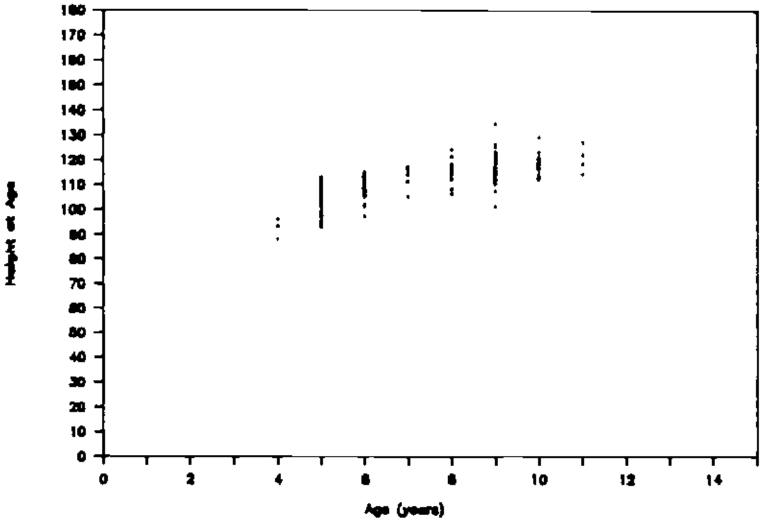
N	Height	1	2	3	4	5	6	7	8	9	Ribs	Age	Cohort
					ANNULUS								
9	116	31	60	73	91						20	4	1977
35	114	20	37	72	101						18	4	1977
13	120	19	39	72	100	115					19	5	1976
34	113	22	37	59	86	108					21	5	1976
36	110	30	53	74	94	107					20	5	1976
10	122	25	38	61	101	116					20	5	1976
7	125	14	38	73	105	119					18	5	1976
22	123	18	36	64	97	114					18	5	1976
31	120	32	54	72	100	117					20	5	1976
4	123	29	52	67	93	107	115				20	6	1975
18	118	31	52	68	86	96	112				21	6	1975
19	122	35	56	75	95	114	118				19	6	1975
12	127	26	50	80	99	113	123				19	6	1975
3	119	18	35	65	87	95	114				20	6	1975
14	121	25	38	59	75	103	117				18	6	1975
28	117	28	44	66	80	101	112				21	6	1975
16	110	19	40	66	77	93	109				20	6	1975
49	112	34	47	64	91	98	109				19	6	1975
58	122	30	43	68	98	116	121				21	6	1975
23	103	31	49	65	87	94	101				18	6	1975
57	135	42	74	83	110	116	121				19	6	1975
26	115	30	48	72	93	99	112				20	6	1975
33	116	20	34	57	75	95	112				21	6	1975
27	115	29	40	68	79	95	110				19	6	1975
30	108	21	38	55	69	83	93	107			19	7	1974
42	124	23	36	59	79	95	111	121			23	7	1974
43	113	16	29	55	75	86	97	106			18	7	1974
24	135	17	45	72	87	103	118	129			21	7	1974
44	122	29	57	70	95	104	110	119			18	7	1974
45	121	35	60	72	98	106	117	121			21	7	1974
5	125	32	49	68	90	99	114	121			17	7	1974
2	122	28	50	66	89	99	112	119			19	7	1974
48	130	34	49	77	97	110	122	127			21	7	1974
40	128	36	54	75	96	107	118	125			19	7	1974
46	126	27	56	86	100	108	116	122			20	7	1974
47	120	28	41	59	77	93	104	119			20	7	1974
50	122	20	35	52	67	85	109	116			19	7	1974
38	126	30	42	72	92	105	116	122			19	7	1974
25	136	21	40	54	69	92	107	120	131		20	8	1973
17	125	23	35	60	77	98	106	118	123		21	8	1973
32	134	26	39	57	76	94	109	121	129		21	8	1973
41	134	32	66	78	87	100	111	120	129		21	8	1973

55	134	20	40	69	87	112	118	125	131		18	8	1973
21	139	21	42	56	75	113	118	129	136		18	8	1973
20	126	23	37	56	75	98	109	119	124		20	8	1973
11	133	17	39	69	95	111	120	125	129		18	8	1973
51	133	19	36	52	72	96	118	126	130		20	8	1973
37	134	18	45	60	78	87	97	112	126		18	8	1973
52	124	21	34	53	73	96	106	115	122		18	8	1973
56	128	34	51	72	89	112	117	122	126		21	8	1973
54	131	18	38	72	111	117	123	126	130		17	8	1973
15	135	32	55	76	97	113	124	131	133		18	8	1973
53	126	31	56	72	95	108	118	123	125		19	8	1973
29	130	25	36	49	72	95	107	118	125	129	19	9	1972
6	128	30	46	78	87	96	106	111	116	123	18	9	1972
1	156	29	41	57	82	115	132	141	146	153	22	9	1972
39	131	14	35	73	103	112	121	125	127	130	18	9	1972
8	147	23	44	68	90	118	130	138	142	145	20	9	1972
$\bar{X}$	124.5	25.70	44.65	66.58	87.94	103.5	113.4	121.7	129	136	19.44	6.827586	

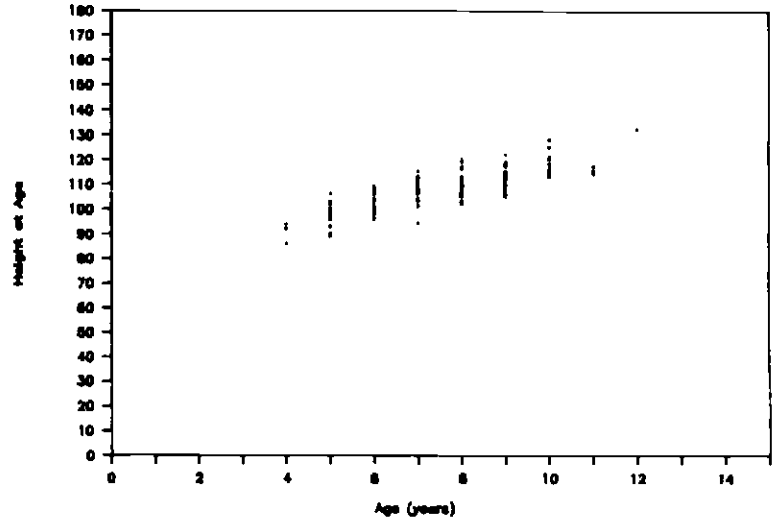
Appendix 2. Measured height at the last annulus versus age for *P. caurinus* populations off the Oregon Coast.

82th45: Tillamook Head at 82 m
82th50: Tillamook Head at 92 m
82th5052: Tillamook Head at 96 m
82th55: Tillamook Head at 101 m
82yq60: Yaquina Head
83hh52: Heceta Head
81cb: Coos Bay

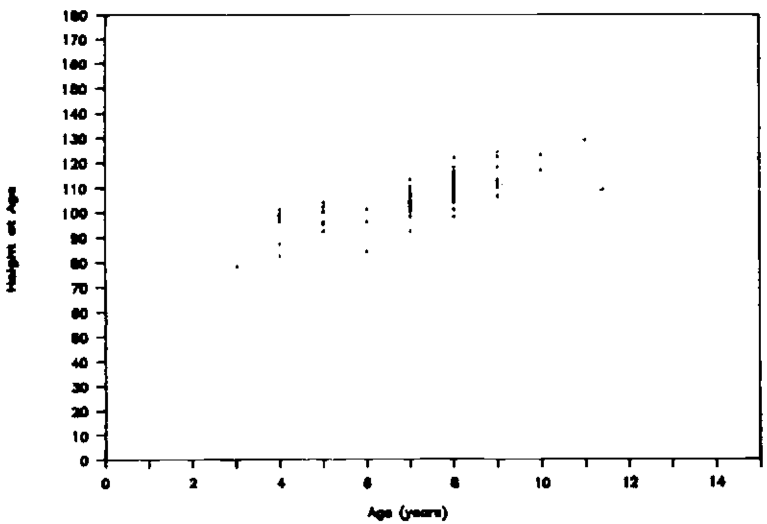
82th45



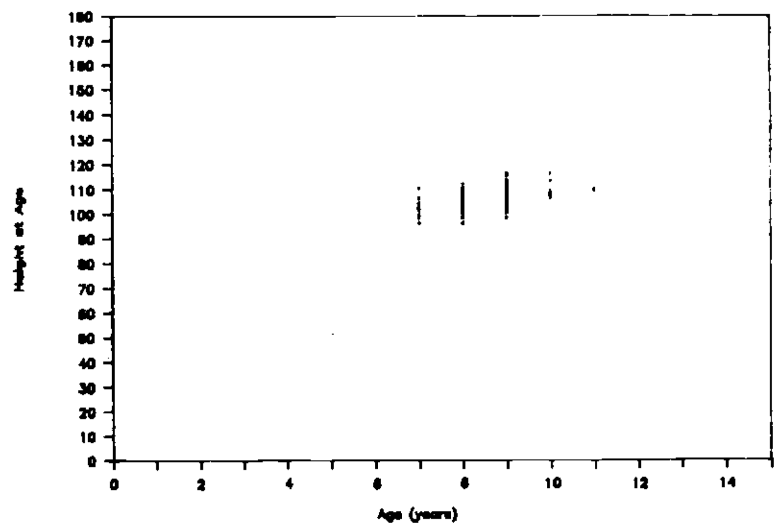
82th50



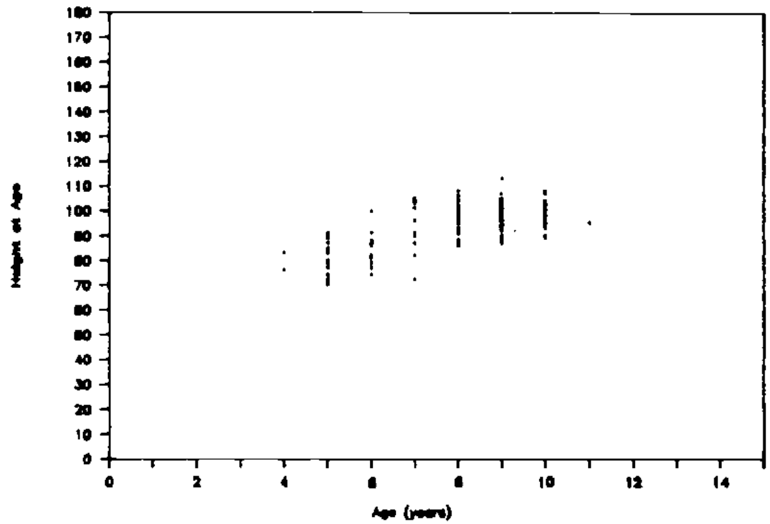
81th5052



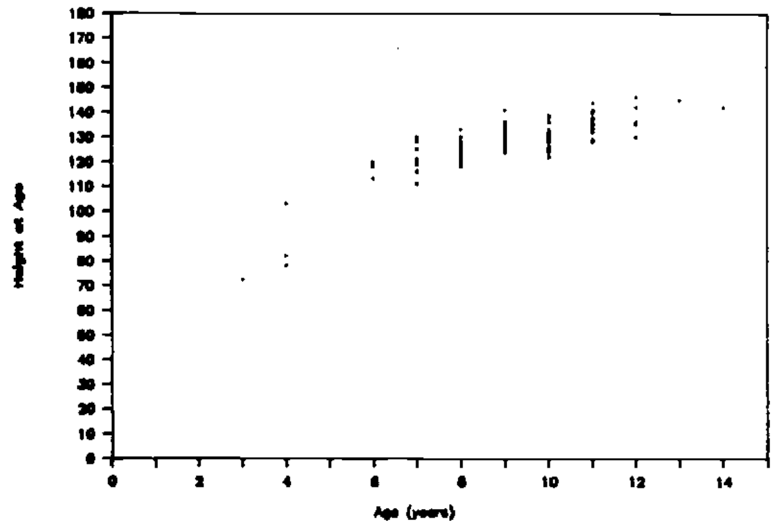
82th55



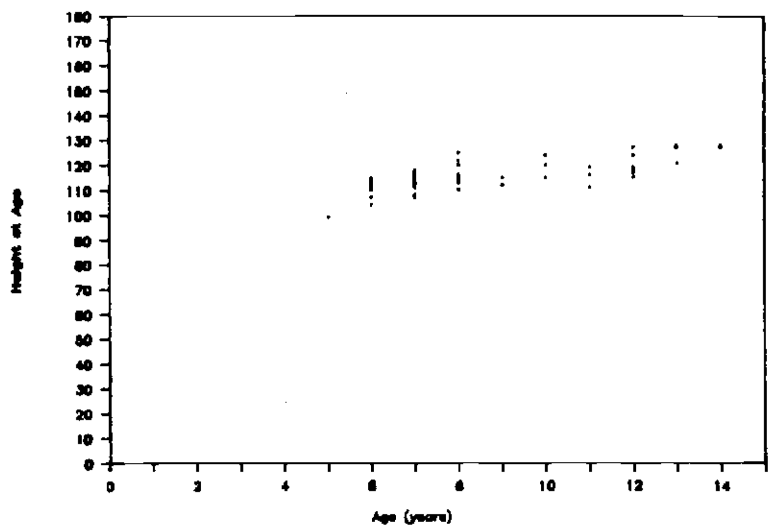
82yqh60



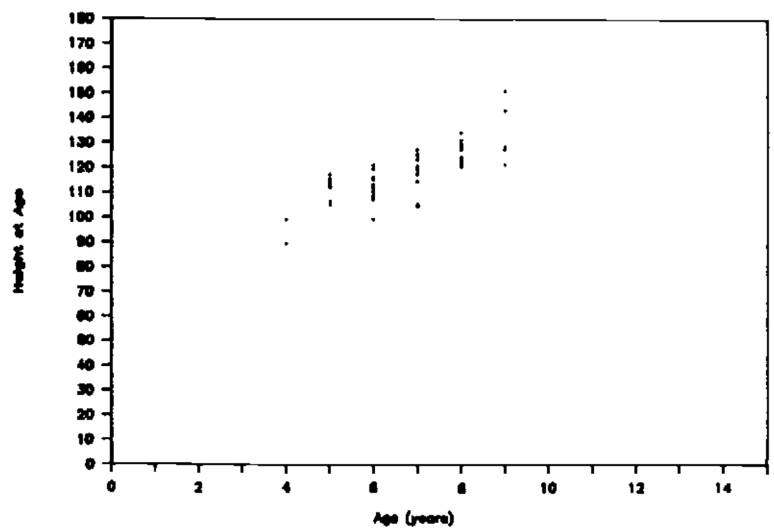
82ckiwa



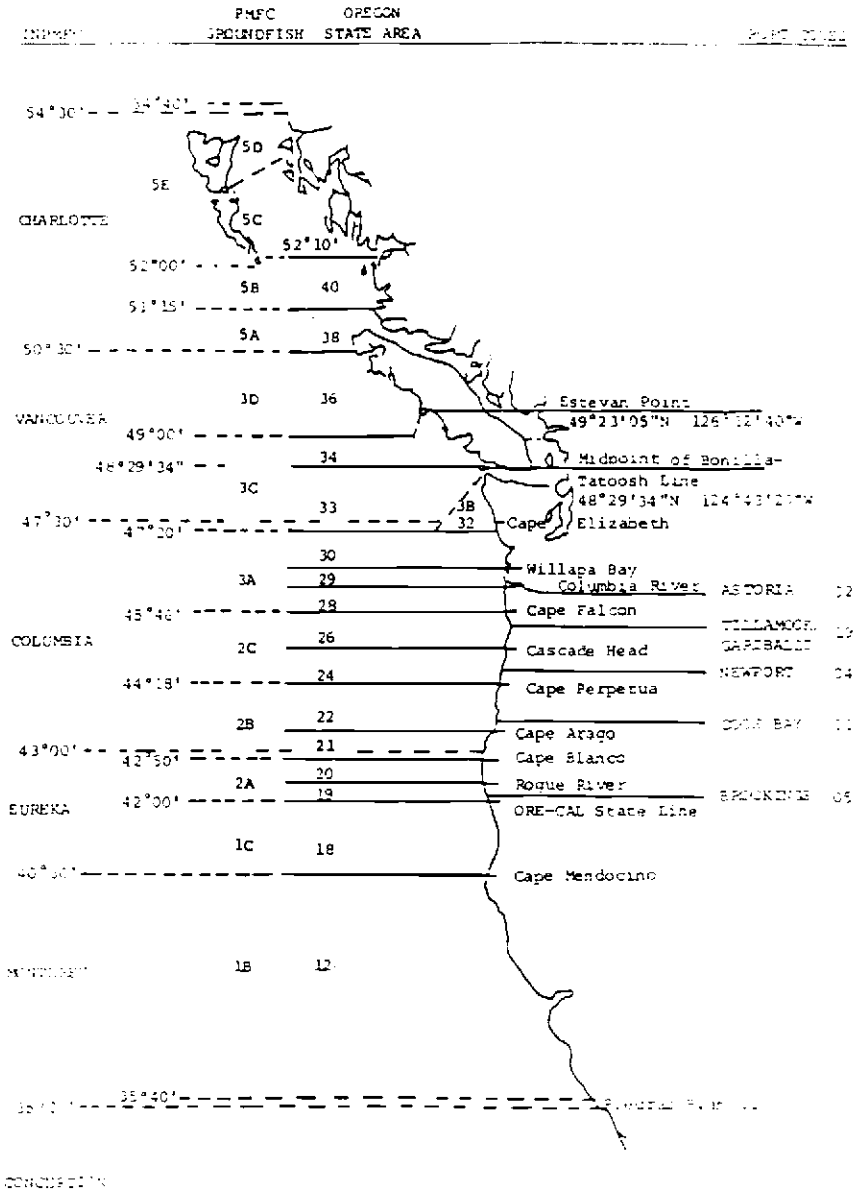
83hh52



81cb



Appendix 3. Eastern Pacific Coast fishing statistical areas.


PMFC GROUNDFISH
OREGON STATE AREA
54°30'
5D
5E
CHARLOTTE
5C
52°10'
52°00'
5B
40
51°15'
5A
38
50°30'
3D
36
Estevan Point
49°23'05"N 126°32'40"W
VANCOUVER
49°00'
34
Midpoint of Bonilla-Tatoosh Line
48°29'34"N
48°29'34"
3C
33
3B
32
47°30'
47°20'
Cape Elizabeth
30
Willapa Bay
3A
29
Columbia River
ASTORIA
28
Cape Falcon
45°46'
COLUMBIA
2C
26
Cascade Head
24
44°18'
Cape Perpetua
NEWPORT
2B
22
Cape Arago
21
43°00'
42°50'
Cape Blanco
2A
20
Rogue River
19
42°00'
EUREKA
ORE-CAL State Line
1C
18
40°30'
Cape Mendocino
1B
12
35°40'
CONCEPTION