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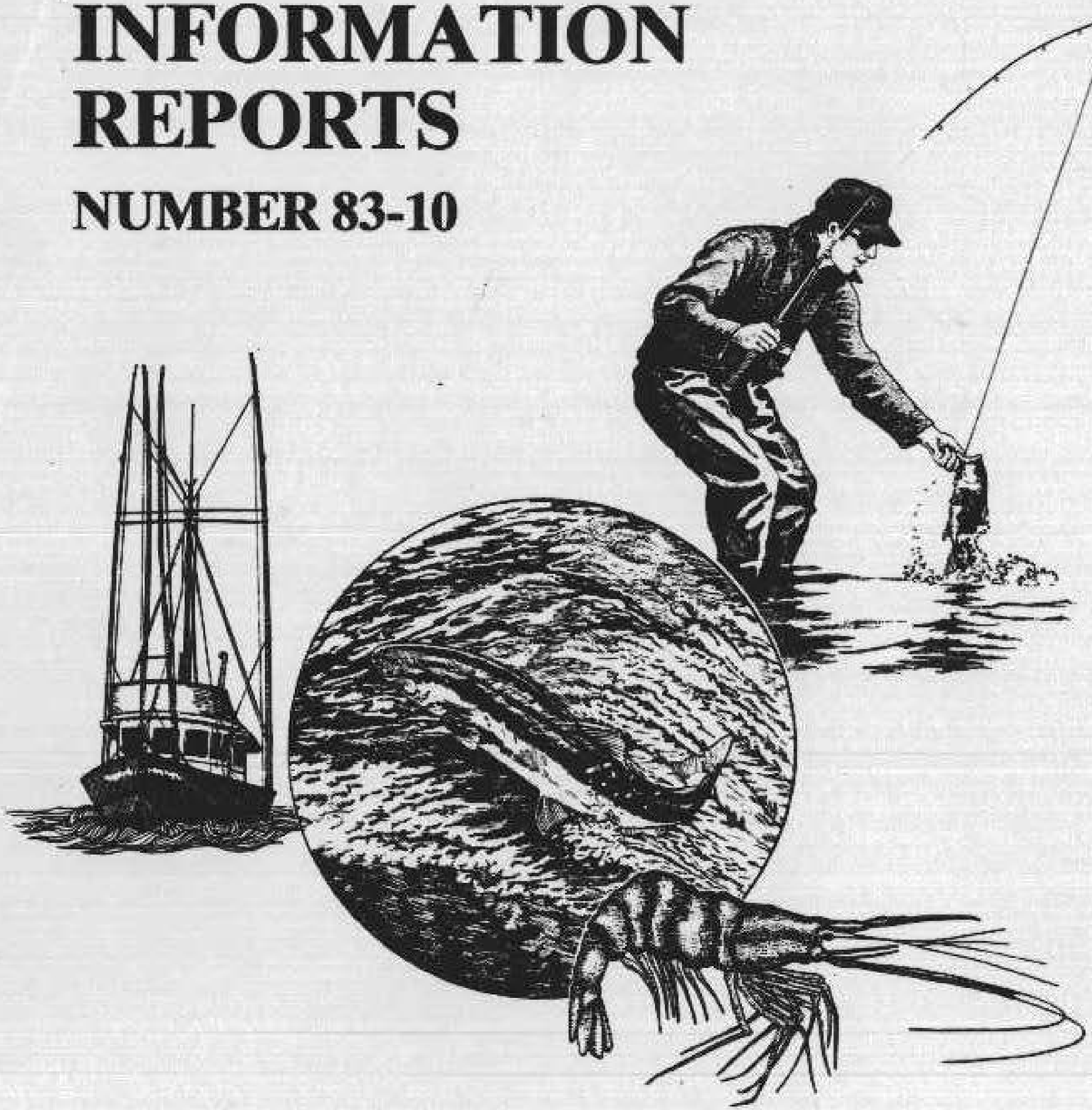

FISH DIVISION

Oregon Department of Fish and Wildlife

Weathervane Scallop (*Patinopecten caurinus*)
Investigations in Oregon, 1981-1983

Weathervane Scallop (*Patinopecten caurinus*) Investigations in Oregon, 1981-1983

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ABSTRACT

In April 1981 two east coast vessels landed scallops in Coos Bay, Oregon, and stimulated intense fishing efforts by local and non-local vessels. Scallop catch per hour was high initially, but quickly declined, as did landings. Scallop landings and catch per hour stabilized after the third month of the fishery and have been consistent since that time.

Results from a logbook program and two cruises showed that scallop distribution and relative abundance in 1981 was similar to 1963 and 1967. Height, weight, and growth parameters varied with depth within a study area, but varied more between study areas. Year-class success also exhibited geographic variation. Spawning time ranges from February through July.

Results from gear trials suggest that liners reduce the catch of adult scallops, but increase the catch of prerecruits. Liner size influences the size distribution of prerecruits caught. A dredge with a 25 mm mesh size liner caught significantly ($P \leq 0.05$) more scallops less than 30 mm in shell height than a dredge with 38 mm mesh size liner. The larger liner caught significantly ($P \leq 0.05$) more scallops in the 30-70 mm size range than the smaller liner, indicating a pressure wave effect.

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INTRODUCTION

Surveys performed by the Bureau of Commercial Fisheries (now the National Marine Fisheries Service) in 1963 and 1967 identified two areas containing weathervane scallops (Pecten [Patinopecten] caurinus) in commercially harvestable quantities. Although groundfish and shrimp trawlers had reported incidental catches of scallops, few Oregon boats had attempted to fish for scallops prior to the 1963 survey. Several subsequent attempts to target on scallops (the most recent being 1979) failed to produce a viable fishery because of small catches and lack of interest from processors.

In late April 1981, two 29 m (94 ft) vessels enroute to Alaskan scallop grounds fished off Coos Bay, Oregon and landed large quantities of scallops. In the first 11 fishing days, the two boats landed 19,846 lb of shucked meats and received a price of $5.00 per lb. With these large landings it was readily apparent that scallop concentrations were much greater than the 1963 or 1967 surveys revealed, and boats rapidly entered the fishery. By the ninth week of the new fishery 69 vessels had landed 7,488,737 lb [round weight (rd wt)].

Faced with a rapidly expanding fishery we encountered numerous questions regarding the nature, extent, and harvest of the resource, market conditions, and management strategies. In an attempt to answer some of the foremost resource questions, we placed observers on fishing vessels, implemented a scallop logbook program, and collected market samples.

We also needed a biological data base for a management program, so we designed a two year research project to provide information on scallop distribution, relative abundance, age and sex composition, height, weight, meat yield, and growth. Included in the research design were studies to provide data on those aspects of the commercial harvest which would enable us to evaluate harvest rates, gear efficiency, gear selectivity, and incidental catch.

Thus, the objectives of the two year PL 88-309 funded research project were:

(1) To collect and consolidate existing information pertaining to scallop life history and management,
(2) To develop a scallop information retrieval and data analysis system,
(3) To analyze data from research cruises and commercial harvest,
(4) To compare the selectivity and efficiency of gear used to harvest scallops, and
(5) To develop new information regarding Oregon scallop life history.

A literature review and use of a microcomputer established the reference base and storage capacity needed to study scallop life history. In 1981 we conducted a cooperative research cruise aboard the National Marine Fisheries Service (NMFS) R/V Chapman with the NMFS and Oregon State University (OSU) to obtain population characteristics and learn about scallop distribution and relative abundance. In 1982 we chartered the F/V Granada to test techniques for catching prerecruit scallops.

On the F/V Granada cruise we wanted to identify a suitable technique for catching prerecruit scallops to learn more about juvenile life history and to use as a predictor for assessing incoming year-class strength. Data from the two research cruises and commercial harvest market samples provided information about scallop population parameters and new theories concerning the life history of Oregon weathervane scallops.

An earlier report (Starr and McCrae 1982) detailed the methods and preliminary results of the R/V Chapman cruise. This report highlights the results of our 1982 work, provides a description of *P. caurinus* population characteristics, and summarizes the 1981-1982 commercial harvest.

CRUISE METHODS

R/V Chapman Cruise

Two areas were selected for the 1981 scallop survey, one west of Coos Bay and one west of Tillamook Head (Fig. 1). In each area two transects were established perpendicular to the depth contours. Survey stations were designated every 5 fm on the transect and tows were completed at each station parallel to the depth contours. The survey areas were chosen to coincide with areas fished commercially in 1981 and the tow locations (stations) duplicated those of the 1963 and 1967 R/V Cobb scallop investigations (Pereyra and Hitz 1969).

We completed dredge hauls at each of the R/V Cobb stations, then proceeded to tow in both deeper and shallower water, in 5 fm increments, until no live scallops were collected in two successive tows. We also towed next to a commercial vessel to compare catches. The commercial comparative tows were all located in 50-52 fm off Tillamook Head on the established commercial fishing grounds.

A 2.5 m (8 ft) wide New Bedford scallop dredge without rock chains was the primary sampling device; it was the same type of dredge the R/V Cobb used. The dredge had a bag of 102 mm (4 in) steel rings with a 32 mm (1.25 in) stretch mesh liner attached to the sweep chain. A more detailed discussion of methods used on the R/V Chapman cruise was presented in our 1982 annual report (Starr and McCrae 1982).

F/V Granada Cruise

Since the primary objective of our 1982 cruise was to test methods of catching juvenile scallops, we returned to the area off Tillamook Head that exhibited the greatest juvenile density in the 1981 R/V Chapman survey (Fig. 2). We chose the area of greatest abundance to provide a greater statistical basis for differentiating the catch of each gear type.

The principal sampling tools used were two 3.7 m (12 ft) wide New Bedford dredges outfitted with tickler chains and polypropylene bags containing mesh sizes of 90 mm (3.5 in). The starboard dredge bag held a liner of 25 mm (1 in) stretch mesh made from #18 nylon seine twine. A catch net of 13 mm (0.5 in) stretch mesh on the outside of the dredge bag covered one-fourth of the circumference of the codend. The port dredge bag encompassed a liner of 38 mm (1.5 in) stretch mesh made from #18 nylon seine twine. A 13 mm mesh catch net covered one-fourth of the circumference of the port dredge codend as well. We also built hoods for the port side dredge and net to determine if scallops escaped over the dredge. OSU's 3 m (10 ft) beam trawl with 13 mm (0.5 in) stretch mesh bag and their 0.5 m^2 (5.4 ft^2) epibenthic sled (Hessler and Sanders 1967) completed the array of tools used for sampling scallops.

We planned to conduct the gear trials in sets of ten tows. Each tow was planned to last 0.5 h. Table 1 displays the intended sampling design.

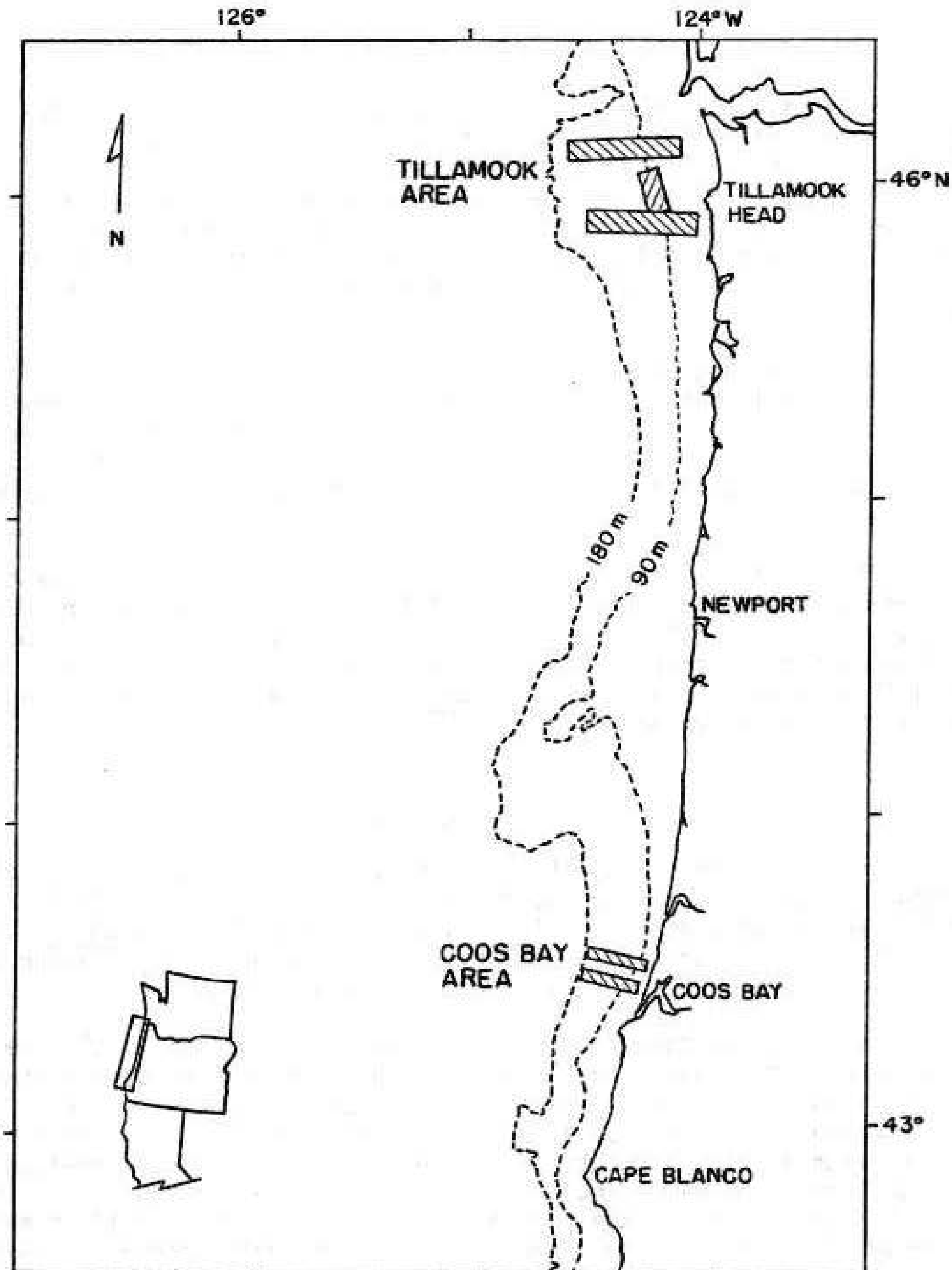

Fig. 1. Location of scallop study areas, R/V Chapman cruise, Nov. 1981.

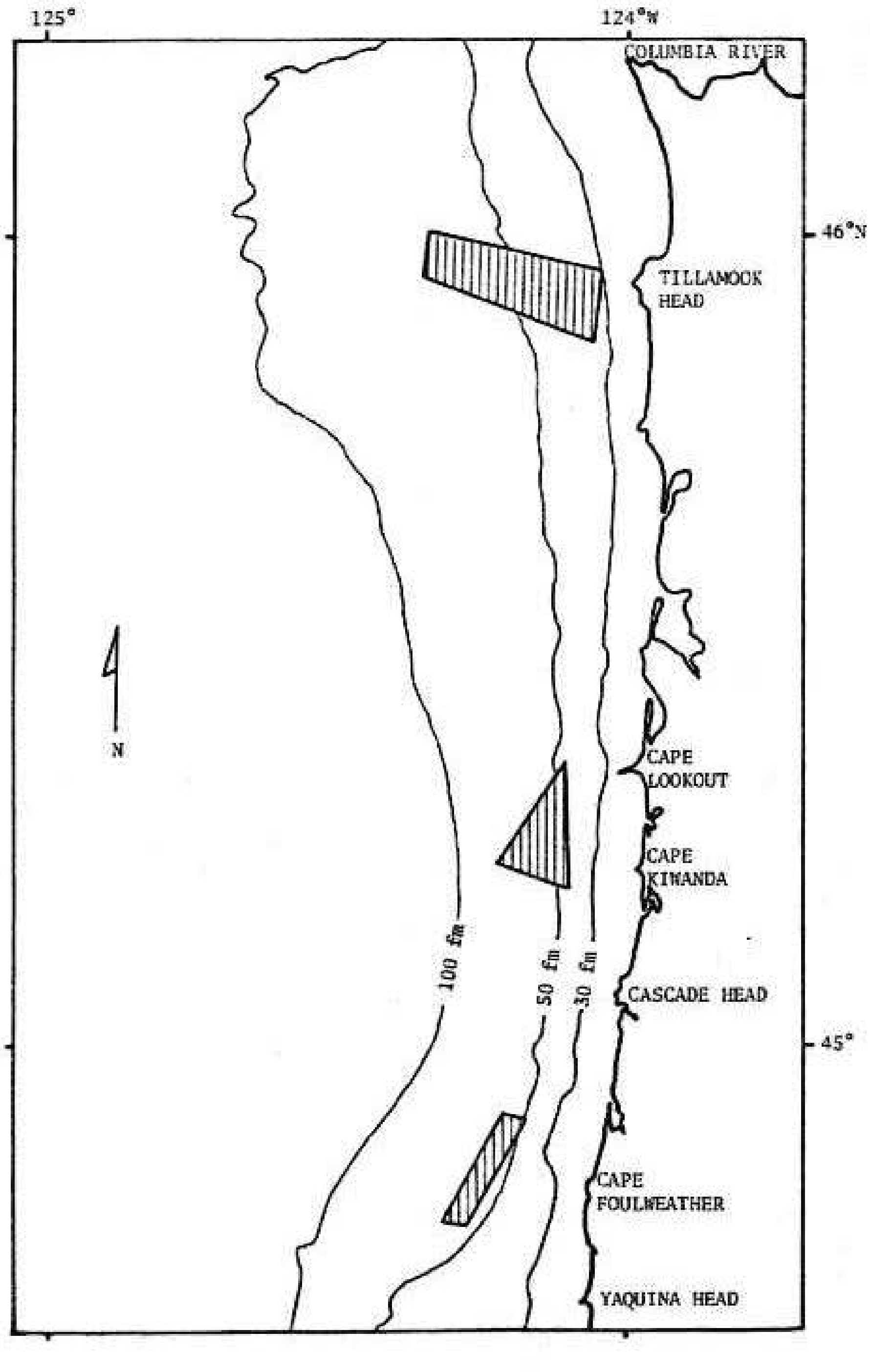

Fig. 2. Location of scallop study areas, F/V Granada cruise, Aug. 1982.

Table 1. Intended sampling design for F/V Granada cruise, Aug. 1982.

Set	Number Tows	Speed (knts)	Scope	Gear
1	10	4	3:1	S. Dredge with 25 mm mesh liner (catch net on end) P. Dredge with 38 mm mesh liner (catch net on end)
2	10	5	4:1	S. Dredge with 25 mm mesh liner P. Dredge with 38 mm mesh liner
3	10	6	5:1	S. Dredge with 25 mm mesh liner P. Dredge with 38 mm mesh liner
4	9-12	4-6	3:1-5:1	S. Dredge with liner P. Dredge with liner and hood (13mm mesh bag)
5	9-12	1 1/2	4 1/2:1	S. OSU epibenthic sled P. OSU beam trawl w/camera
6	As needed			As needed to conduct transects across range of juvenile distribution.

We modified our sampling design because we did not locate enough juvenile scallops in the area to adequately test our gear. We decided to search elsewhere for juveniles and resume our tests when we encountered large quantities of juveniles. We moved both shallower and deeper and sampled with the dredges at two speed and scope settings at each station until we were beyond the range in which we located adult scallops in 1981 (Fig. 3). As we still did not locate many juvenile scallops, we moved south and continued searching off Cape Kiwanda and Yaquina Head (Figs. 4, 5). We completed transects across the range of scallops from shallow to deep water off Cape Kiwanda, but still found few juveniles. We finally encountered larger concentrations of juveniles off Yaquina Head.

After each tow the codend of the dredge nets was brought on board. We first checked the catch nets to see what passed through the liner and dredge bag. We then opened the codend of each net and placed the catch in separate bins on the sorting table. We identified the by-catch by major species groups as either present (number less than 5% of the total catch) or abundant (number greater than 5% of the total catch). We counted all juvenile scallops and placed them in labeled jars for OSU's analysis. We counted, measured, and weighed adult scallops and Dungeness crabs. Scallop shells were counted and checked for spat. We saved samples of adults from each transect for age, height, weight, and gonad analysis.

Scallops returned to the laboratory were remeasured, weighed to the nearest gram and shucked. We then weighed the adductor and auxillary adductor muscle to the nearest 0.5 gm and noted the sex of each animal. Later the right valve was washed and used for aging, using the same techniques as in 1981; we counted and marked all annuli and measured the distance from the hinge to each annulus for each individual.

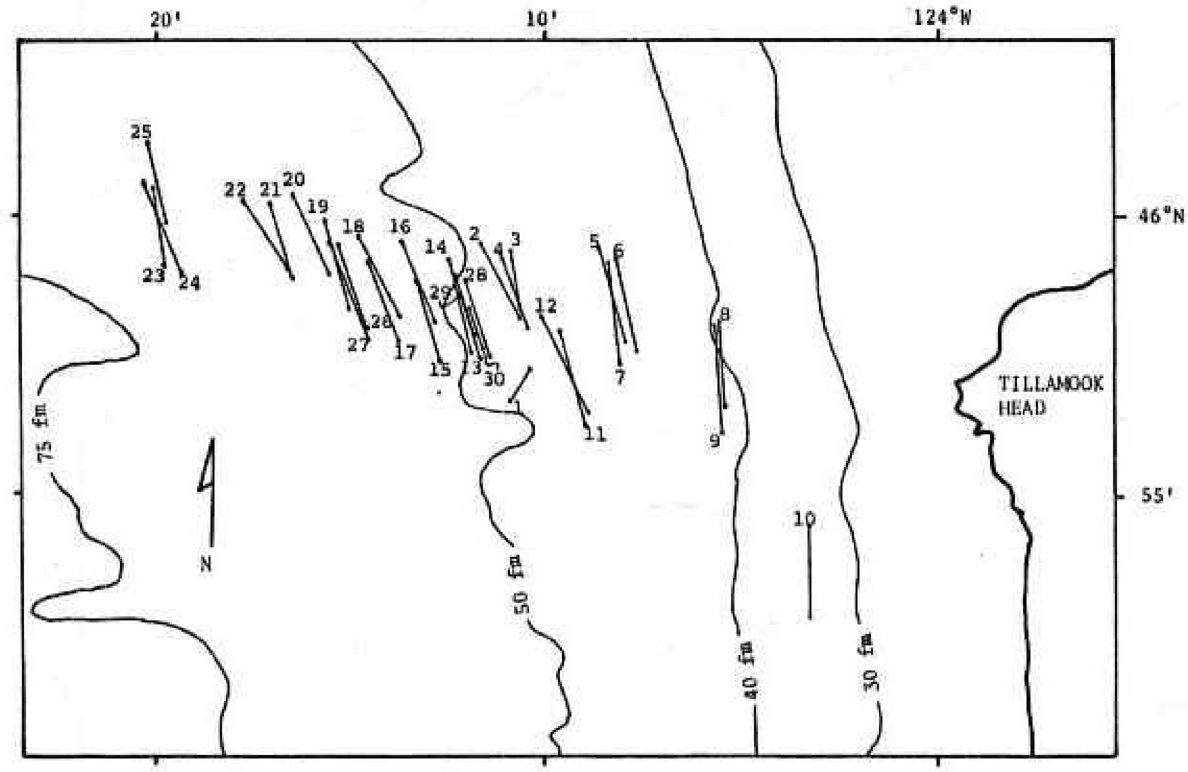

Fig. 3. Location of scallop dredge tows, Tillamook area, F/V Granada cruise, Aug. 1982.

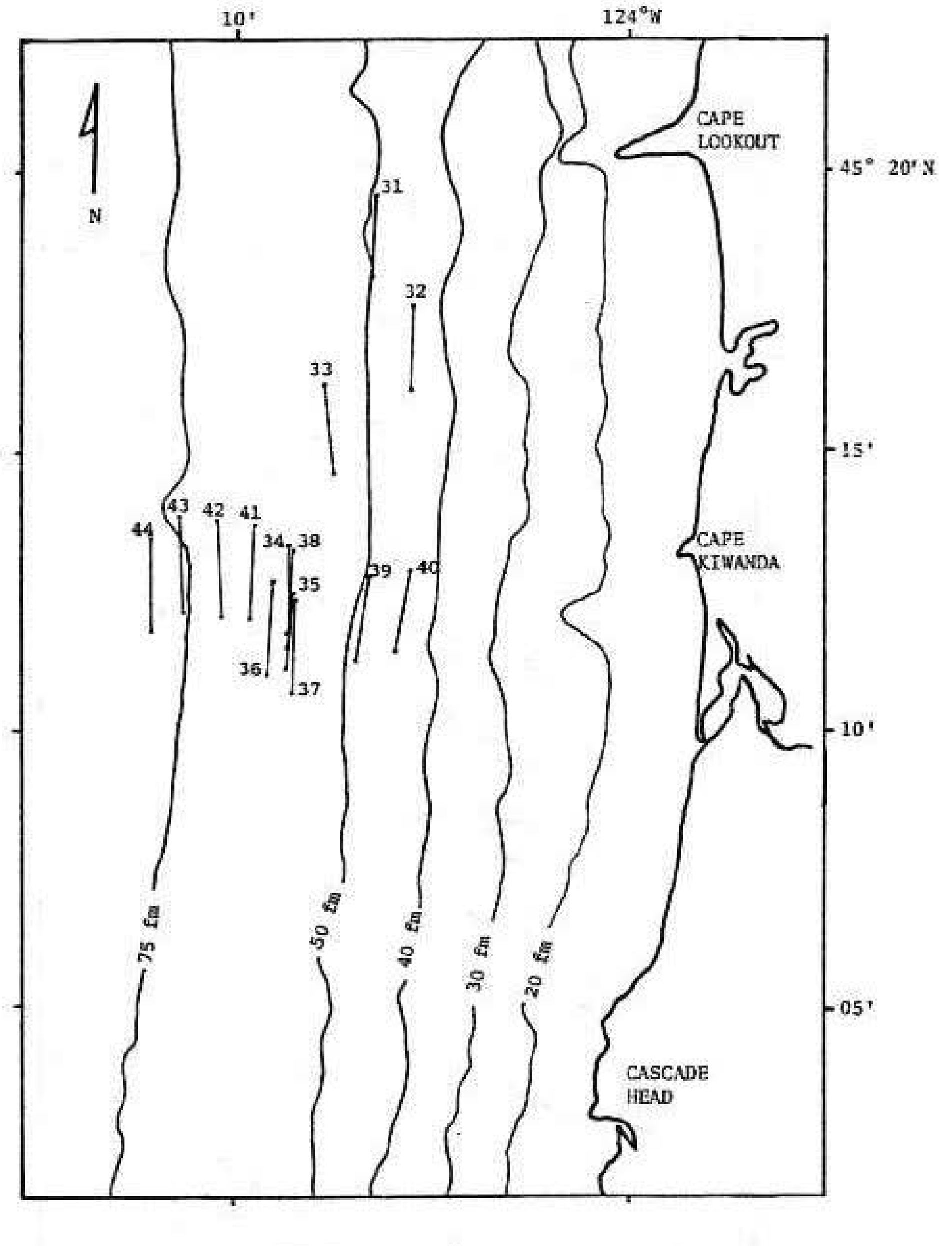

Fig. 4. Location of scallop dredge tows, Cape Kiwanda area, F/V Granada cruise, Aug. 1982.

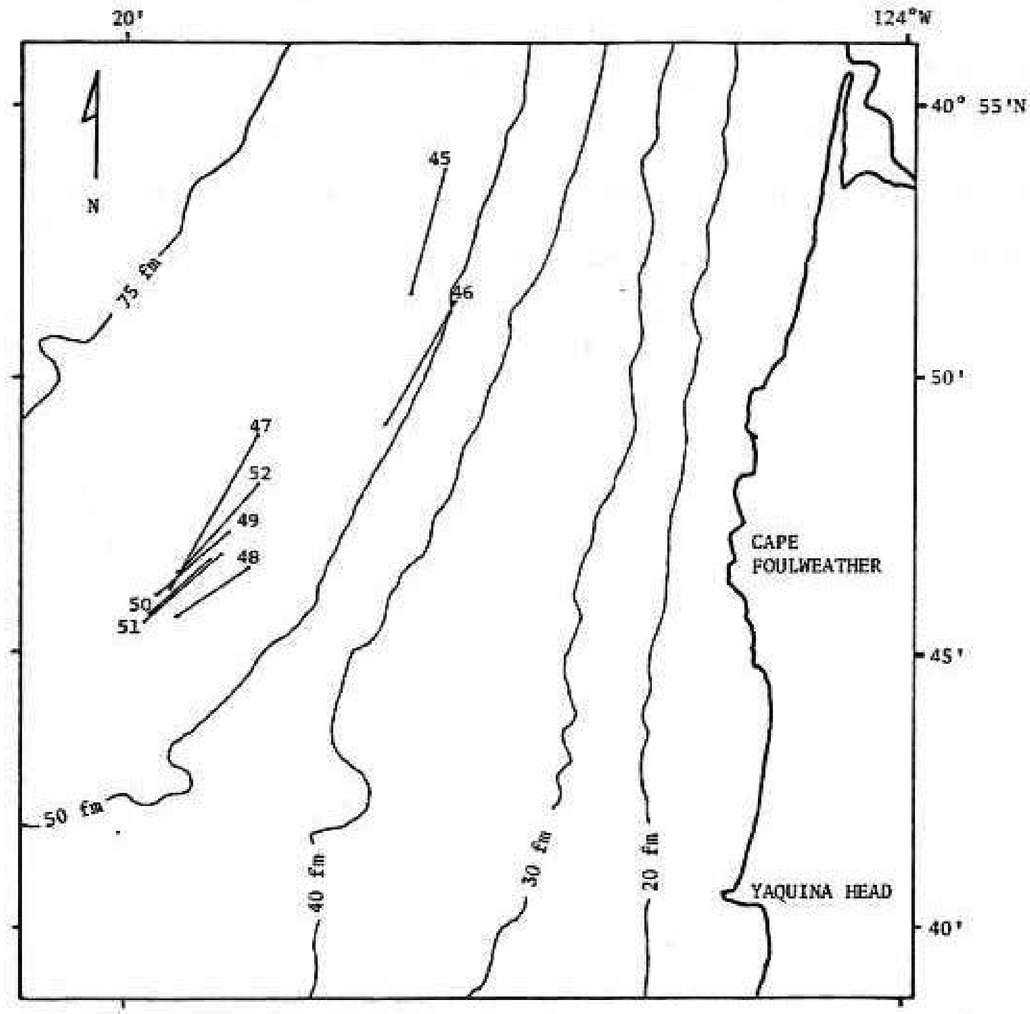

Fig. 5. Location of scallop dredge tows, Yaquina Head area, F/V Granada cruise, Aug. 1982.

Aging

We aged scallops using marks on the shell surface. We investigated other methods but used surface aging because of its greater speed. Aging techniques were verified using shell height-frequency histograms. Departing from other authors (Haynes and Hitz 1971, Stevenson and Dickie 1954), we aged the right value because the left valve of P. caurinus in our coastal waters is heavily infested with boring organisms which obscure annuli.

We shucked a sample of scallops, separated the valves, and measured each valve. A significant difference ($P \leq 0.05$) existed between the heights of the right and left valves with the right valve larger by an average of 2.1 ± 1.4 mm (N=767). In a smaller sample of cluckers (both valves still attached) we noticed that the right valve was larger in all cases. This difference should be noted when comparing our data with other investigators which use the left valve for aging (Haynes and Hitz 1971, Haynes and Powell 1968, Hennick 1970, 1972).

COMMERCIAL HARVEST

An incidental harvest of scallops was commonplace for many years along the Pacific coast, until two east coast scallop draggers initiated a commercial fishery in Alaska in 1967. The fishery proved lucrative for a few years, peaked in 1969, then quickly declined (Hennick 1972), only to show a resurgence in the early 1980's (Kaiser 1982).

The resurgence in the Alaska fishery attracted vessels from the depressed eastern U.S. scallop fishery. Two vessels enroute to Alaska stopped and searched for scallops off the Oregon coast. Information obtained from the R/V Cobb investigations led them to the Coos Bay beds where they located commercial quantities of scallops.

Processors refused to buy the first deliveries into Coos Bay, probably due to the volume of landings and lack of a ready market. The vessel skippers, however, experienced in marketing scallop meats, shipped their catch to markets in Los Angeles, California. The scallops moved quickly into the California marketplace. Thereafter, local fishermen and processors became interested in scallops, and vessels rapidly entered the fishery.

Effort

Primarily out of state vessels fished in the first few weeks, but local boats rapidly geared up for scallop fishing. By the fourth week of the fishery, 15 boats landed scallops. By week nine, 69 boats landed 7.5 million lb of scallops (Fig. 6). Seventy-five percent of the vessels in the fishery at that time were locally owned. By the end of December, 118 boats had landed scallops, although 42 vessels made only one landing. Probably most of these vessels landed just once to ensure a right to a scallop permit, or because of a combination of inexperience and lower scallop densities off Coos Bay at the time of participation in the fishery.

Vessels entering the fishery were either designed for scallop fishing, or had modified their gear to fish for scallops. The vessels designed for scallop fishing were primarily from the east coast, usually carried crews of twelve people, and were equipped to spend up to 10-12 d at sea. Crew members worked 6 h shifts, day and night, operating the gear and shucking scallops. After shucking the scallops, the crews stored the meats on ice in cotton bags, 40 lb of meats per bag.

The majority of boats entering the fishery had to be converted for scallop fishing. Many of the converted vessels were shrimp trawlers. The 1981 shrimp season was poor, and skippers hoped to increase their income by scallop fishing. These vessels carried a crew of three and landed whole scallops. Many of the converted shrimp boats found scallop fishing unprofitable, though, and comprised most of the 42 boats that made only one landing in 1981.

The designed scallop boats and the numerous conversion boats brought many different types of gear into the fishery. Scallops were harvested with the traditional New Bedford type dredges and with several modified dredges. Some

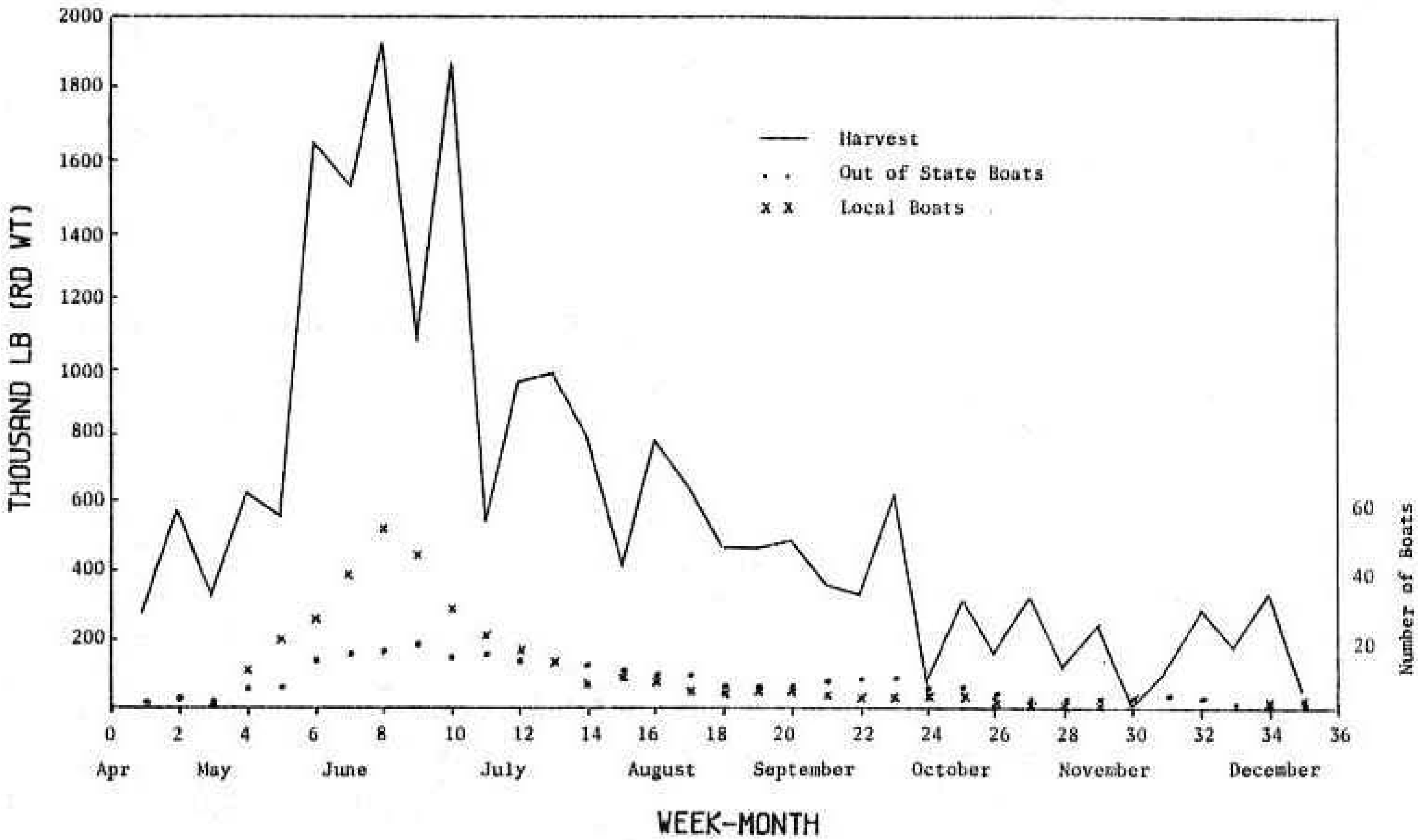

Fig. 6. Commercial harvest of P. caurinus in thousands of pounds (round weight), and number of boats participating in the fishery, by week, 1981.

of the dredges had steel cutting bars, sweep chains, and bags of steel rings; others had steel cutting bars, sweep chains, and nylon mesh bags. Combinations of metal rings and nylon mesh were also found in the codend of the dredges on some boats. Additionally, the size and basic shape of dredges varied between boats. Numerous vessels used beam trawls or wing dredges. Shrimp nets were also commonly used.

Many local fishermen thought that the design scallop vessels from other states should not be allowed to fish in Oregon waters. As a result of prompting from several coastal representatives, the Oregon State Legislature enacted House Bill 2520, requiring all vessels to have a scallop permit to land scallops in Oregon. The bill further stated that with a few exceptions only those vessels that were licensed in Oregon and had landed 10 lb of food fish prior to July 1, 1981 could obtain an annual license.

Harvest

House Bill 2520 did little to provide more scallops for Oregon boats in 1981. The fishery peaked about the time of passage of the bill, thereafter landings steadily declined until October 1981 (Fig. 6). Scallop landings essentially remained steady from October 1981 through December 1982 (Fig. 7).

In the first eight weeks of the 1981 fishery, scallop landings steadily increased (Fig. 6); Coos Bay processors received almost all the scallops landed. Statewide landings then dropped in week nine as several larger production vessels left the Coos Bay beds and searched elsewhere for scallops. The vessels encountered productive beds off the Siuslaw estuary and off Tillamook Head, causing landings to again increase in the fishery's tenth week. This redistribution of fishing effort after the ninth week created landings in most ports in the state. By the end of 1981, effort and harvest from three other state statistical areas almost equalled the effort and harvest from the Coos Bay bed (Table 2, area 22A).

Although the 1981 harvest occurred in seven state statistical areas, Coos Bay and Astoria processors received 92 percent of the scallops landed (Table 3). In 1982, 96 percent of the landings occurred in Newport and Coos Bay. The 1982 Coos Bay landings do not represent a sustained fishery; however, as 49 percent of the landings occurred in February. Two of the production vessels that had been fishing in Alaska fished for one month off Coos Bay enroute to their home ports on the east coast. The harvested scallops came primarily from the Coos Bay and Siuslaw beds. Expanded effort statistics (Table 2) show that the area off Newport (statistical area 24) received the most fishing pressure in 1982.

Large boats landed a disproportional amount of scallops. Vessels over 24 m (80 ft) long comprised 20 percent of the fleet but landed 75 percent of the catch (Table 4). The non-local vessels 27 m - 30 m (90-99 ft) designed for scallop production comprised 3 percent of the fleet but landed 40 percent of the catch.

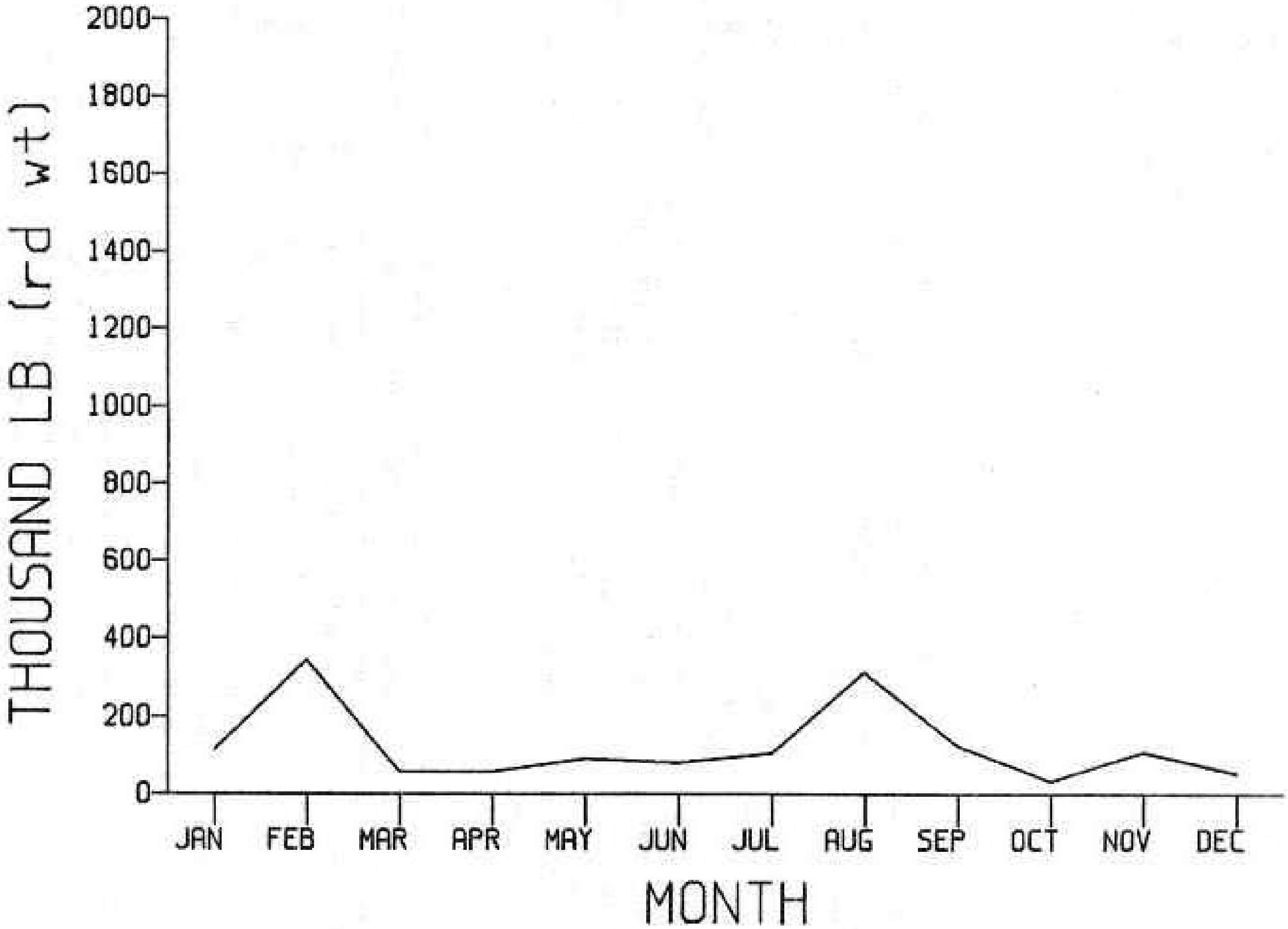

Fig. 7. Commercial landings of *P. caurinus* in thousands of pounds (round weight) by month, 1982.

Table 2. Expanded catch and effort estimates listed by state statistical area, 1981 and 1982.

Area[c]	1981		1982	
	Hours Fished	lb (rd wt) landed	Hours Fished	lb (rd wt) landed
19	19.4	[a]	-	-
20	19.9	[a]	-	-
21	1121.2	741,252	94.1	39,282
22A	4046.1	4,430,668	781.1	401,745
22B	4465.8	3,320,474	642.2	309,046
24	1518.8	963,628	1227.7	468,851
26	4317.4	3,067,774	516.9	176,470
28	5490.3	4,332,957[b]	292.9	92,550
Total	20,999	16,856,753	3555	1,487,944

a/ Scallops harvested in these areas may have been landed in California

b/ Does not include scallops harvested in area 28 but landed in Washington

c/

Area	Location
19	California border to Rogue River
20	Rogue River to Cape Blanco
21	Cape Blanco to Cape Arago
22A	Cape Arago to Umpqua River
22B	Umpqua River to Cape Perpetua
24	Cape Perpetua to Cascade Head
26	Cascade Head to Cape Falcon
28	Cape Falcon to Columbia River

Table 3. Reported weathervane scallop landings listed by port, 1981 and 1982.

Port	1981			1982		
	lb (rd wt)	lb (shucked)	Total (rd wt)	lb (rd wt)	lb (shucked)	Total (rd wt)
Astoria	505,575	456,496	6,074,826	62	-	62
Tillamook	62,732	1,679	83,216	2,060	949	13,638
Newport	396,957	48,791	992,207	160,277	53,280	810,293
Florence	-	42	512	-	-	-
Winchester Bay	117,220	12,590	270,818	-	3,276	39,967
Coos Bay	1,449,743	649,183	9,369,776	28,452	48,814	623,983
Port Orford	-	283	3,453	-	-	-
Gold Beach	-	67	817	-	-	-
Brookings	-	4,182	51,020	-	-	-
Total	2,532,227	1,173,313	16,846,646	190,851	106,319	1,487,943

Table 4. 1981 Oregon weathervane scallop harvest, listed by boat length[a].

(m)	Vessel length (ft)	# Vessels	Catch (lb rd)	# Trips	Mean # Trips/vessel	Mean Catch/Trip (lb rd)	Max Catch/Trip (lb rd)
6-9	20-29	3	1,823	3	1.0	608	1,232
9-12	30-39	13	14,792	27	2.0	548	4,685
12-15	40-49	22	843,887	187	8.5	4,512	59,933
15-18	50-59	21	290,304	114	5.4	2,546	6,696
18-21	60-69	19	1,000,708	95	5.0	10,534	44,286
21-24	70-79	16	2,029,620	160	10.0	12,685	35,237
24-27	80-89	13	3,243,258	65	5.0	49,896	171,842
27-30	90-99	4	6,690,990	58	14.5	115,362	144,330
30-33	100-109	4	2,314,957	32	8.0	72,342	104,426
>33	>109	3	423,497	5	1.7	84,699	136,717
Total		118	16,853,836	746	6.3	22,592	

[a] Includes some scallops harvested in Oregon but landed in Washington

Catch Per Effort

Longer boats had greater catch per effort statistics as well as greater landings. In 1981 the mean catch per trip of boats over 24 m (80 ft) was 4-9 times as great as the vessels in the 21-24 m (70-79 ft) size range. In 1982 the mean catch per trip of production boats 27-30 m long doubled that of 21-24 m vessels (Table 5). The mean catch per trip of larger vessels exceeded that of smaller vessels primarily because of trip length, and secondarily because of larger dredges. The larger vessels carried large crews and fished constantly for 4-6 d. The smaller vessels, often converted shrimp or crab boats, usually carried small crews and fished only during the daylight hours. Trip length varied from 1-4 d. The catch per hour in 1981 (Table 6) also was generally greater for larger vessels, probably due principally to the larger dredge size.

Table 5. 1982 Oregon weathervane scallop harvest listed by boat length.

Vessel (m)	Length (ft)	Catch (lbs rd)	# Trips	Mean Catch/Trip (lbs rd)	Max Catch/Trip (lbs rd)
6-9	20-29	-	-	-	-
9-12	30-39	5,990	12	499	499
12-15	40-49	-	-	-	-
15-18	50-59	366	5	73	73
18-21	60-69	23,203	11	2,109	2,114
21-24	70-79	923,947	50	18,479	23,517
24-27	80-89	28,452	3	9,484	9,484
27-30	90-99	505,921	14	36,137	47,165
30-33	100-109	-	-	-	-
>33	>109	-	-	-	-
Total		1,487,879	95	15,662	-

Table 6. 1981 weathervane scallop mean catch (lb rd) per hour listed by vessel length, by state statistical area.

Length (m)	Length (ft)	Area 19	20	21	22A	22B	24	26	28	Total
12-15	40-49				502	362		95	119	356
15-18	50-59					643		177	221	283
18-21	60-69			1003	1172	614	490	741	913	900
21-24	70-79			535	479	418	349	340	485	429
24-27	80-89			351	469	762	627	668	927	741
27-30	90-99			1035	1630	863	709	1049	931	1114
30-33	100-109						407	564	609	548
>33	>109				1025	2470	2151	1736	1733	1905

The large production vessels were capable of making long trips and landing large amounts of scallops, but they needed large quantities of scallops to cover their costs. Early in the 1981 fishery scallop catch per hour was high, but as abundance decreased, so did scallop catch per hour. By the eighth week of the fishery, catch per hour for the large production vessels was half as large as in week one (Fig. 8). The production boats then moved from Coos Bay to a larger area off Tillamook Head and fished until catch per hour dropped there as well. At that point most of the production vessels left state waters.

Scallop catch per hour dropped steadily in all areas until late December, January, and February. For about two months the large production vessels returned to harvest scallops. They departed again as their catch per hour decreased. Since that time scallop catch per hour has been consistent but at a much lower level than during the summer of 1981 (Fig. 9).

Value of Harvest

The wholesale value of scallop meats in the United States is primarily determined by the price set on the east coast of the U.S. because of the large volume of scallops landed from Canada to Florida. The wholesale value is usually high in the winter when vessels are unable to fish and is even higher when scallop abundance is low. The cold storage scallop supply was low (3 million lb of meats) when harvest began off Coos Bay in 1981 (Anonymous 1981). Consequently in the first month of the fishery most skippers received well over $4 per lb for shucked meats.

The ex-vessel price dropped constantly as the season progressed. Vessels delivered a high quality product in the beginning of the fishery. Scallop meats were large (30-35/lb) and the product was cared for properly. However, quality problems occurred soon after inexperienced skippers landing whole scallops entered the fishery. In some cases skippers left whole scallops sitting on the deck too long before returning to port. These problems ended quickly after local skippers learned the low stress tolerance of live scallops. The early quality problems depressed the ex-vessel price, however. Also the price dropped as a large harvest of calico scallops (<u>Argopecten gibbus</u>) off Florida increased the national supply to 7 million lb of meats by August (Anonymous 1981). Thus, by August 1981, Coos Bay processors paid $1 per lb less on the average for shucked meats than they did in May (Table 7). The price rose as winter approached and the national scallop supply diminished, but never regained the level occurring at the onset of the fishery. Curiously, the ex-vessel price remained relatively constant throughout 1982, perhaps as a function of the lower Oregon production, and consumption of the product in local markets.

The price paid to fishermen landing whole scallops did not fluctuate as much as the price of scallop meats (Table 7). This is probably due to the higher costs incurred by processors at the beginning of the fishery. Many processors reluctantly bought whole scallops because they were not equipped to process scallops. Processors incurred large costs training shuckers and rearranging plant schedules. Plant managers passed these costs on to the fishermen. Therefore, skippers who landed whole scallops at the fishery's inception probably received proportionally less value for their product than they did later in the summer.

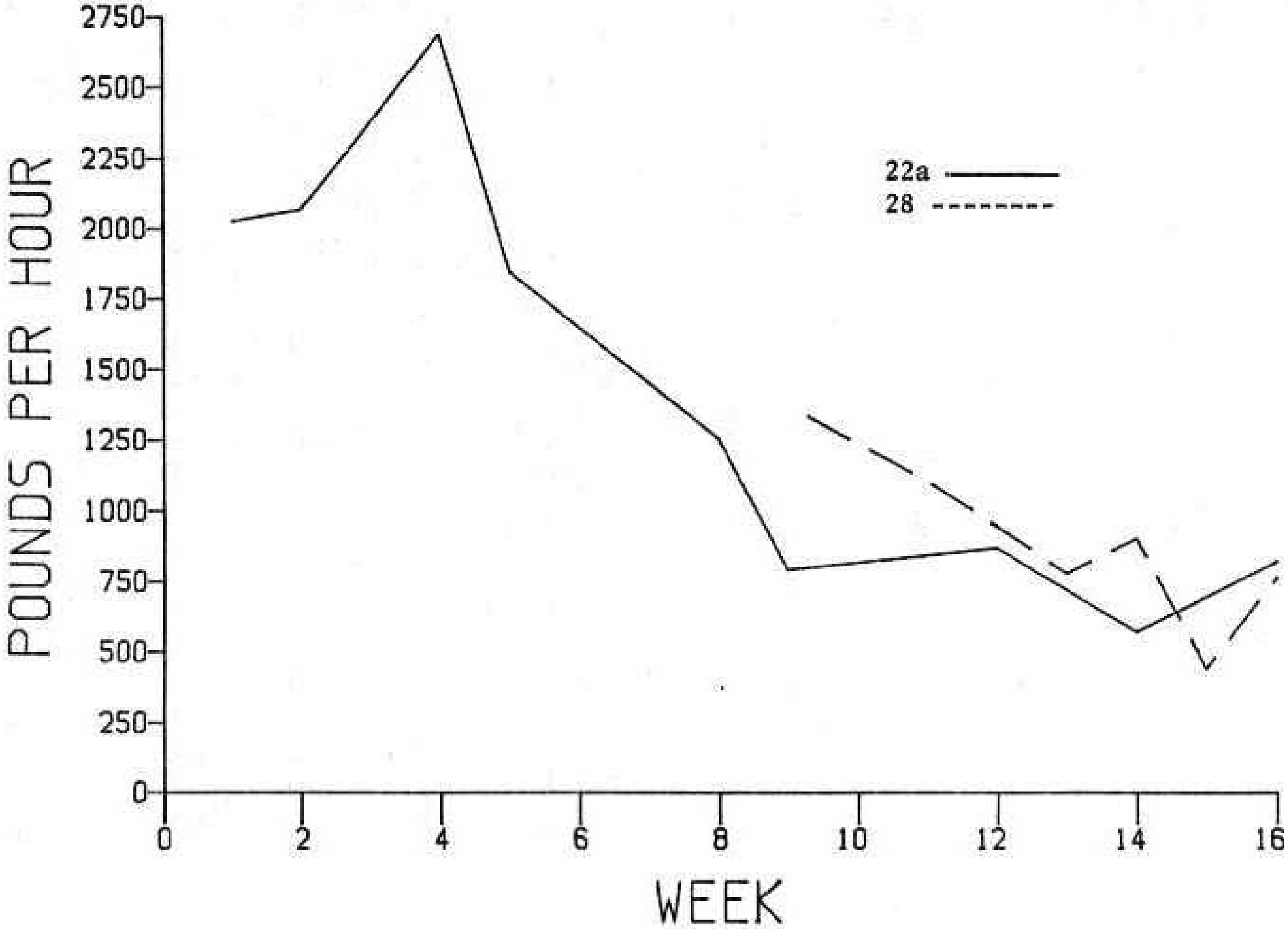

Fig. 8. Catch per unit effort (pounds per hour) by week in state statistical areas 22 a and 28, 1981.

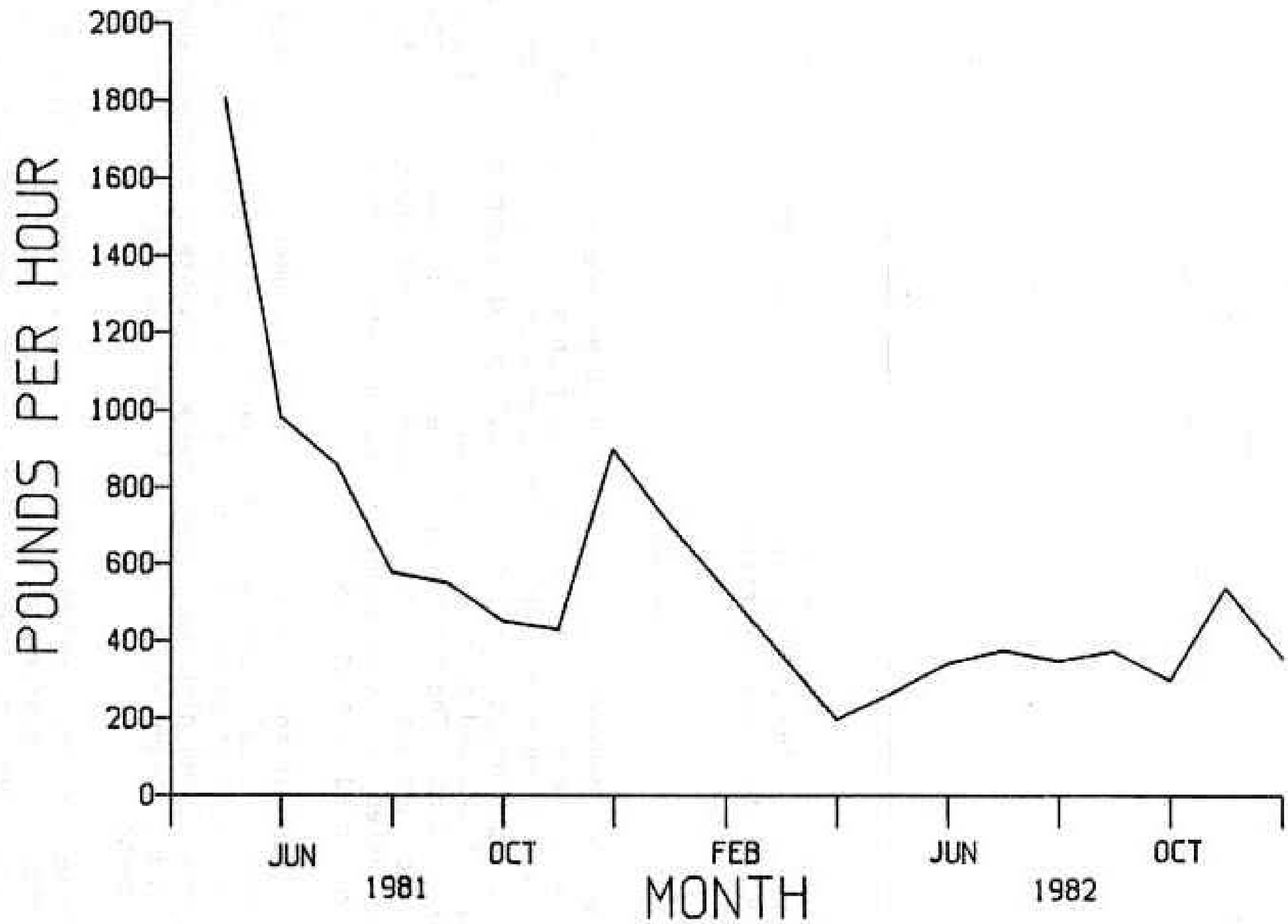

Fig. 9. Catch per unit effort (pounds per hour) by month, 1981 and 1982.

Table 7. Mean ex-vessel price ($/lb) of weathervane scallops by month, 1981-1982.

Month	Meats 1981	Meats 1982	Whole 1981	Whole 1982
January	--	3.82	--	--
February	--	3.70	--	.25
March	--	3.80	--	.25
April	4.44	3.60	--	--
May	4.20	3.50	.18	--
June	3.67	3.50	.21	--
July	3.11	3.52	.20	--
August	3.10	3.42	.19	.23
September	3.23	3.50	.20	--
October	3.43	3.50	.21	--
November	3.71	4.25	--	.24
December	3.49	4.33	--	.25

When combined, the total value of whole and shucked scallops landed in 1981 was $4.7 million. The 1982 ex-vessel value of $470,000 is evidence of the dramatic decline to a smaller fishery.

Harvest Summary

The 1981 scallop harvest off Coos Bay had three phases. The first phase occurred when two vessels designed for scallop fishing explored Oregon coastal waters and discovered areas of high scallop abundance. The production vessels made long trips, experienced high rates of scallop catch per hour, and landed large quantities of shucked meats. The skippers received a high price per pound for their product. The first phase ended quickly; however, as scallop catch per hour declined and local boats changed gear and entered the fishery. The first phase lasted less than eight weeks, but over 50 percent of the total annual harvest occurred in that time.

The second phase of the 1981 fishery started as numerous local vessels entered the fishery. Local fishermen either modified existing gear, bought scallop gear from the east coast, or made their own gear. Catch rates were lower but landings stayed high due to the number of vessels in the fishery. Many of the skippers landed whole scallops rather than add a shucking crew to the ships' complement.

Landing whole scallops created industry turmoil, however. Problems developed in the shoreside processing of scallops due to a lag time in the development of processing capability. Some quality problems were encountered.The value of scallop meats declined and the fishermen who landed whole scallops received proportionately less money than fishermen who landed scallop meats. The second phase ended as catch rates declined and local vessels dropped out of the fishery. Phases one and two occurred in other scallop beds, but to a lesser extent as fishermen learned from the Coos Bay experience.

Phase three began when catch rates dropped in all areas and most boats left the fishery. The depressed value and lower scallop densities caused most local vessels to return to more traditional fisheries. The larger production vessels departed for other states. At that time landings dropped dramatically but remained consistent. Phase three is characterized by 3-7 vessels working to produce a relatively constant supply of scallops. This trend continues and changes only when a large production vessel reenters state waters.

POPULATION CHARACTERISTICS

Distribution and Relative Abundance

To evaluate scallop distribution and relative abundance we transformed the total number of scallops caught per tow to a catch per mile base for two 3.7 m (12 ft) New Bedford dredges. Table 8 summarizes the scallop catch per mile by depth for all areas surveyed in 1981 and 1982. The distribution of animals in 1982 was similar to that observed in 1981. Scallops were caught from 30-75 fm with the majority of scallops occurring in 45-60 fm. Juveniles ranged from 35-90 fm; with the majority also collected in 45-60 fm.

In 1982, adult scallops were significantly ($P \leq 0.05$) more abundant in the Yaquina Head area than in any of the other study areas. A small area near Cape Kiwanda also exhibited high abundance. Yaquina Head had significantly ($P \leq 0.05$) more juveniles than all other areas in 1982, but we caught far fewer juveniles in 1982 than in 1981. The maximum average catch per mile in 1982 was only 53 percent of the maximum mean catch per mile in 1981. In 1981 juvenile abundance was greatest off Tillamook Head whereas in 1982 our largest catches occurred off Yaquina Head.

Scallop distribution also varied somewhat between years. Off Tillamook Head in 1981, scallops were most abundant in the 45-49 fm range, whereas in 1982 we caught the most scallops in 40-44 fm. Although we do not believe scallops migrate large distances, this change in abundance with depth suggests scallops are capable of moving short distances.

Sex Composition

Of the 1207 mature scallops we sexed, the ratio of males to females was nearly 1:1. This was expected, since Hennick (1970) noted the same relationship in Alaskan scallops, as did Robinson and Breese (1982) for a sample of scallops from Coos Bay. All the scallops we examined were dioecious, again similar to the Alaska situation and confirming the work of Robinson and Breese.

We calculated mean ages of scallops by sex for different areas, transects, and depth regimes. We observed no significant differences ($P > 0.05$) between sexes when we compared mean ages using a student's "t" test. We also compared mean shell heights, meat weights, and meat yields of males and females for different areas, transects, and depths. From these data we concluded that the population characteristics of males and females are essentially identical, and the rest of our analyses were completed without regard to sex.

Gonad Condition

In both 1981 and 1982 we collected samples for gonad analysis to determine both sex composition and stage of maturity. Scallop gonads were identified as male or female, then sliced and preserved in Bouin's solution for sectioning and histological analysis. Anja Robinson of OSU microscopically analyzed the scallop gonads.

Table 8. Mean catch per mile of P. caurinus by depth and area, R/V Chapman cruise, Nov. 1981*, and F/V Granada cruise, Aug. 1982 (N = number of tows).

Adults	Coos Bay-1981			Tillamook-1981			Tillamook-1982			Cape Kiwanda-1982			Yaquina Head-1982		
Fm	x	S.D.	N	x	S.D.	N	x	S.D.	N	x	S.D.	N	x	S.D.	N
25-29	0		3	0		1									
30-34	0.9	0.8	3	0		2									
35-39	8.1	11.3	3	0		2	30.6		1						
40-44	27.6	16.8	7	62.7	25.0	2	192.5	64.2	5	67.7	37.3	2			
45-49	30.0		1	104.7	25.2	4	123.9	23.6	2	94.0	132.9	2			
50-54	23.1	13.6	3	106.8	53.7	12	135.2	65.9	6	11.3		1	1048.1		1
55-59	0		3	39.0	70.5	5	25.2	31.9	4	373.2	267.5	5	798.2	726.3	5
60-64	0		4	1.2	1.9	3	3.6	3.1	5	8.0		1			
65-69	0		2	0		2	5.6	5.3	2	1.2		1			
70-74	0		2	1.5		1				0.6		1			
75-79	0		2	0		2				0		1			
80-84	0		2	0		3									
85-89	0		2												
Overall	8.7	14.7	37	51.9	61.8	39	87.3	86.8	25	157.9	228.7	14	839.8	657.6	6
Juveniles															
25-29	0		3	0		1									
30-34	0		3	0		2									
35-39	0		3	0.9	1.1	2	0.6		1						
40-44	0		7	1.8	2.3	2	0.2	0.3	5						
45-49	0		1	18.0	20.1	4	0.9	0.4	2	0.4	0.5	2			
50-54	0		3	20.7	14.4	12	0.8	0.8	6	0		2			
55-59	0		3	1.5	2.1	5	0.4	0.4	4	0		1	7.5		1
60-64	1.8	1.4	4	0.6	0.9	3	0.3	0.4	5	1.8	1.8	5	11.0	9.9	5
65-69	6.0	4.2	2	0.9	1.1	2	0.4	0.5	2	1.8		1			
70-74	2.4	3.4	2	3.3		1				1.2		1			
75-79	4.5	4.2	2	0		2				2.4		1			
80-84	1.5	2.1	2	0		3				0		1			
85-89	0.8	3.3	2												
Overall	1.2	2.1	37	8.7	13.5	39	0.5	0.5	25	1.1	1.4	14	10.4	8.9	6

* Catches of the one 2.5 m (8 ft) dredge used in 1981 were expanded to be comparable with the catches of the two 3.7 m (12 ft) dredges used in 1982.

Hennick (1970) reported that Alaskan scallops spawn primarily in July, but the R/V Chapman data surprisingly indicated many scallops contained nearly ripe gonads in November (Starr and McCrae 1982). Furthermore, scallops collected in August 1982 off Tillamook Head also exhibited ripe gonads (Table 9). Scallop gonads collected at that time from other locations were flaccid.

Table 9. Female gonad condition (%), F/V Granada cruise, Aug. 1982*.

Location (depth)	% Stage 1	% Stage 2	% Ova	N
Tillamook Head (52fm)	29.2	0	70.8	7
Cape Lookout (45fm)	84.8	4.4	10.9	11
Cape Lookout (50fm)	66.2	3.9	29.9	16
Cape Lookout (60fm)	92.9	4.2	2.8	4
Cape Lookout (63fm)	89.2	3.5	7.2	7
Yaquina Head (60fm)	100.0	0	0	9

* Data courtesy of Anja Robinson, OSU.

Stage 1: Small oocytes attached to follicle wall
Stage 2: Larger oocytes being released from follicle wall.
Ova: Fully developed ova filling the lumen.

All scallops less than 70 mm in shell height contained gonads without gametes. Scallop sex could not even be determined in the small scallops. This seems to confirm the Alaskan work (Hennick 1970) suggesting that scallops become mature at age three or older. Some of the small scallops may have contained gametes later in the year; however, as almost all the scallops less than 70 mm high were collected off Yaquina Head where the adult scallops contained flaccid gonads as well. Nevertheless, since the larger scallops had identifiable gametes we suspect the smaller scallops were immature.

The histological data from both research cruises indicate a wide range of spawning times for Oregon scallops. Our observations and Robinson and Breese's (1982) histological studies of commercially landed scallops strongly suggest the spawning time of Oregon scallops varies from February through July. Also, scallop stage of maturity varies with depth (Table 9), possibly due to differences in water temperatures.

Shell Height

Scallops collected in 1981 exhibited nearly equivalent shell heights as scallops collected on the R/V Cobb cruises (Pereyra and Hitz 1969). Table 10 displays mean shell height by age for scallops collected on the R/V Chapman cruise. There were no significant differences in shell heights at age within either the Coos Bay or Tillamook areas. There is, however, a difference between Coos Bay and Tillamook. For all scallops older than the 1977 yc, the scallops in Coos Bay are significantly larger ($P \leq 0.05$) at a given age than Tillamook scallops. This indicates that scallop growth is greater in the Coos Bay area than in the Tillamook area.

Table 10. Mean shell height (mm ± SD) of *P. caurinus* by year-class, R/V Chapman cruise Nov. 1981. (N)

Year class	Coos Bay			Tillamook		
	North transect	South transect	Overall	North transect	South transect	Overall
1977	-	98.0 (1)	98.0 (1)	97.3 ± 7.2 (8)	99.0 ± 7.1 (2)	97.6 ± 6.8 (10)
1976	114.0 ± 5.8 (16)	111.6 ± 4.6 (20)	112.7 ± 5.3 (36)	101.4 ± 5.1 (36)	105.4 ± 6.9 (28)	103.1 ± 6.2 (64)
1975	117.0 ± 6.2 (41)	116.6 ± 5.4 (54)	116.8 + 5.7 (95)	103.8 ± 4.5 (31)	105.9 ± 7.1 (13)	104.4 ± 5.4 (44)
1974	119.0 ± 5.2 (10)	117.7 ± 7.5 (29)	118.1 ± 6.9 (39)	107.9 ± 8.4 (15)	109.0 + 6.3 (7)	108.2 ± 7.6 (22)
1973	124.1 ± 8.2 (7)	126.9 ± 7.5 (21)	126.2 ± 7.7 (28)	109.4 ± 7.1 (27)	110.1 ± 5.0 (58)	109.9 ± 5.7 (85)
1972	147.0 (1)	130.5 ± 5.1 (13)	131.7 ± 6.6 (14)	110.2 ± 7.0 (36)	112.8 ± 5.2 (82)	112.0 ± 5.9 (118)
1971	142.0 (1)	135.5 ± 9.3 (4)	136.8 ± 8.5 (5)	113.8 ± 8.3 (19)	113.8 ± 5.3 (21)	113.8 ± 6.8 (40)
1970	139.5 ± 10.6 (2)	143.8 ± 10.0 (4)	142.3 ± 9.4 (6)	121.9 ± 8.5 (10)	120.4 ± 7.3 (5)	121.4 ± 7.9 (15)
1969	162.0 (1)	150.0 (1)	156.0 ± 8.5 (2)	115.0 ± 2.8 (2)	-	115.0 ± 2.8 (2)

We graphed our 1982 height frequency data (Fig. 10) and obtained mean shell heights by depth for each area (Table 11). These data showed the same trend by depth as the 1981 data; larger animals occurred in shallow depths. The 1982 data are also similar to mean scallop heights reported from the 1963 R/V Cobb investigations (Ronholt & Hitz, 1968). Because of this gradient of size by depth and the high abundance in shallower mid-depths (Table 8), it would seem that these areas (45-55 fm) would be best suited for a commercial fishery. However, that is not the case for all areas. In the Cape Kiwanda area, older and larger scallops were also caught in shallow depths, but because of the high abundance of the 1975 year-class in 60-64 fm, it may prove to be more efficient to fish for the younger, smaller sized scallops in the deeper depths (>55 fm) in this area. The Yaquina Head area also showed a very high abundance of small scallops in the deeper depths.

Table 11. Mean shell height (mm ± S.D) of *P. caurinus* by depth and area, F/V *Granada* cruise, Aug. 1982*. (N)

	Tillamook Head	Cape Kiwanda	Yaquina Head
35-39f	118.2 ± 8.2 (48)		
40-44f	114.7 ± 7.9 (939)		
45-49f		128.3 ± 8.9 (193)	
50-54f	115.1 ± 5.6 (696)	120.7 ± 8.3 (307)	
55-59f	109.5 ± 4.7 (145)		
60-64f	105.5 ± 5.5 (28)	103.1 ± 8.0 (545)	92.9 ± 9.1 (204)
65-69f	103.4 ± 7.0 (16)		
Overall	112.9 ± 7.3 (1872)	112.9 ± 13.4 (1045)	92.9 ± 9.1 (204)

* All of the differences by depth and area are significant ($P \leq 0.05$) except in the Tillamook Head area, between 60-64 fm and 65-69 fm depths. Yaquina Head overall is significantly different ($P \leq 0.05$) from Tillamook and Cape Kiwanda.

Using the height-to-weight conversion developed from the R/V Chapman cruise (Fig. 11), we determined that the minimum shell height necessary to yield 45 meats per pound (minimum meat size desired by most processors) is approximately 100 mm. The mean height of the scallops in the deeper depths of the Cape Kiwanda area is greater than 100 mm. Therefore, many of the animals in this area should satisfy market requirements. However, only 35% of the scallops from the Yaquina Head area were larger than 100 mm (mean height of 92.9 mm), making this area less desirable for commercial harvest. The Yaquina Head area has supported commercial harvest, though, due to a large abundance of animals.

In all areas, but especially in areas where scallop size may be marginal, harvesters and processors could improve yield if they would process and market scallop mantles as well as adductor muscles. Adductor muscles from a sample of 51 scallops from Yaquina Head weighed 1541 gm. The mantle weight of those same scallops turned out to be 1126 gm, or 73% of the adductor muscle weight. Thus, processors could improve their yield 1.7 times on these smaller scallops if they would process mantles as well as adductor muscles.

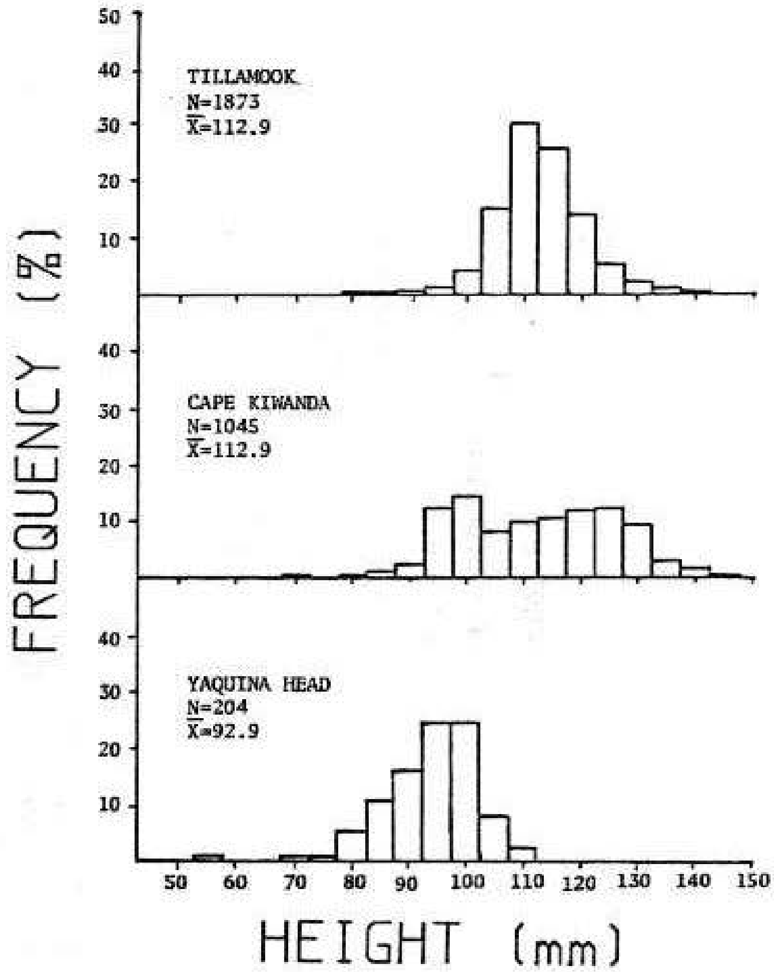

Fig. 10. Height frequency of P. caurinus caught on F/V Granada cruise, Aug. 1982.

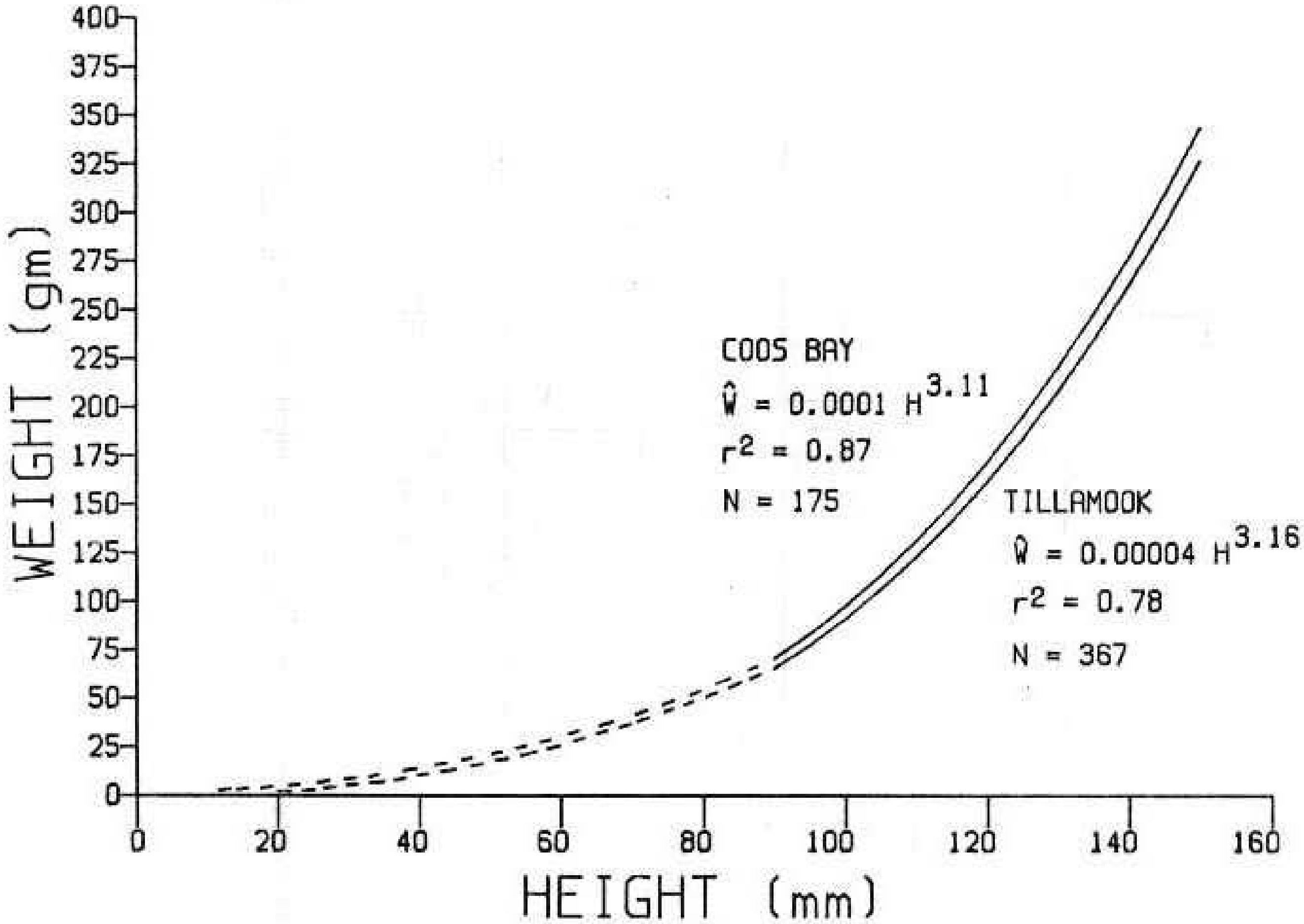

Fig. 11. Relationship of height to round weight of P. caurinus, R/V Chapman cruise, Nov. 1981.

Age Composition

In 1981 the Coos Bay area was dominated by one year-class whereas the Tillamook area displayed a more even age structure (Fig. 12). The predominance and abundance of the 1975 year-class in the Coos Bay area probably stimulated the large 1981 commercial harvest. This strong year-class was concentrated in one depth regime, and allowed high CPUE's. The more even age structure in the Tillamook area combined with more evenly distributed research catches indicates that recruitment off Tillamook Head was more constant.

In 1982 the Tillamook, Cape Kiwanda, and Yaquina Head areas all exhibited a similar age structure. A predominance of the 1972, 1975, and/or 1976 year-classes, and a lack of the 1974 year-class (Fig. 12) indicates that survival for a given year-class was similar between areas. This also indicates that our aging techniques were consistent between the two years.
Although survival was similar between areas as a whole, year-classes were not successful in the same depth regime in all areas. Moreover, year-classes were not equally abundant between depth regimes within the same area (Table 12).

Table 12. Relative abundance (catch per tow) of 1972, 1975, and 1976 year-classes by depth, F/V Granada cruise, August 1982.

Depth (fm)	Tillamook			Cape Kiwanda			Yaquina Head		
	1972	1975	1976	1972	1975	1976	1972	1975	1976
40-44	56	95	83	-	-	-	-	-	-
45-49	-	-	-	28	4	1	-	-	-
50-54	54	14	16	31	7	9	-	-	-
55-59	17	0	0	-	-	-	-	-	-
60-64	-	-	-	82	292	30	431	191	257
65-69	8	0	0	-	-	-	-	-	-

In the Cape Kiwanda area mean age decreased with increasing depth, whereas mean age increased with depth in the Tillamook area (Fig. 13). Off Tillamook Head, shallower depths contained a predominance of the 1975 and 1976 year-classes (6 and 5 yr olds). Those two year-classes were unrepresented in depths greater than 54 fm. Off Cape Kiwanda the 1972 year-class (9 yr olds) was most abundant in the shallower depths, with deeper areas dominated by the 1975 year-class.

The age frequency data indicate either scallop larvae settle out in all areas but only thrive in some, or there is differential settlement. We believe the difference in age composition with depth, and the differences between areas, is a result of differential settlement of larvae, rather than a differential survival after settlement. The 1972 yc, for example, occurred in all areas and depths, indicating that growing conditions are suitable for *P. caurinus* between 35 and 60 fm. However, the fact that abundance varied greatly with depth, and peak abundance for a year-class occurred in different depths in different areas, suggests that scallops did not equally

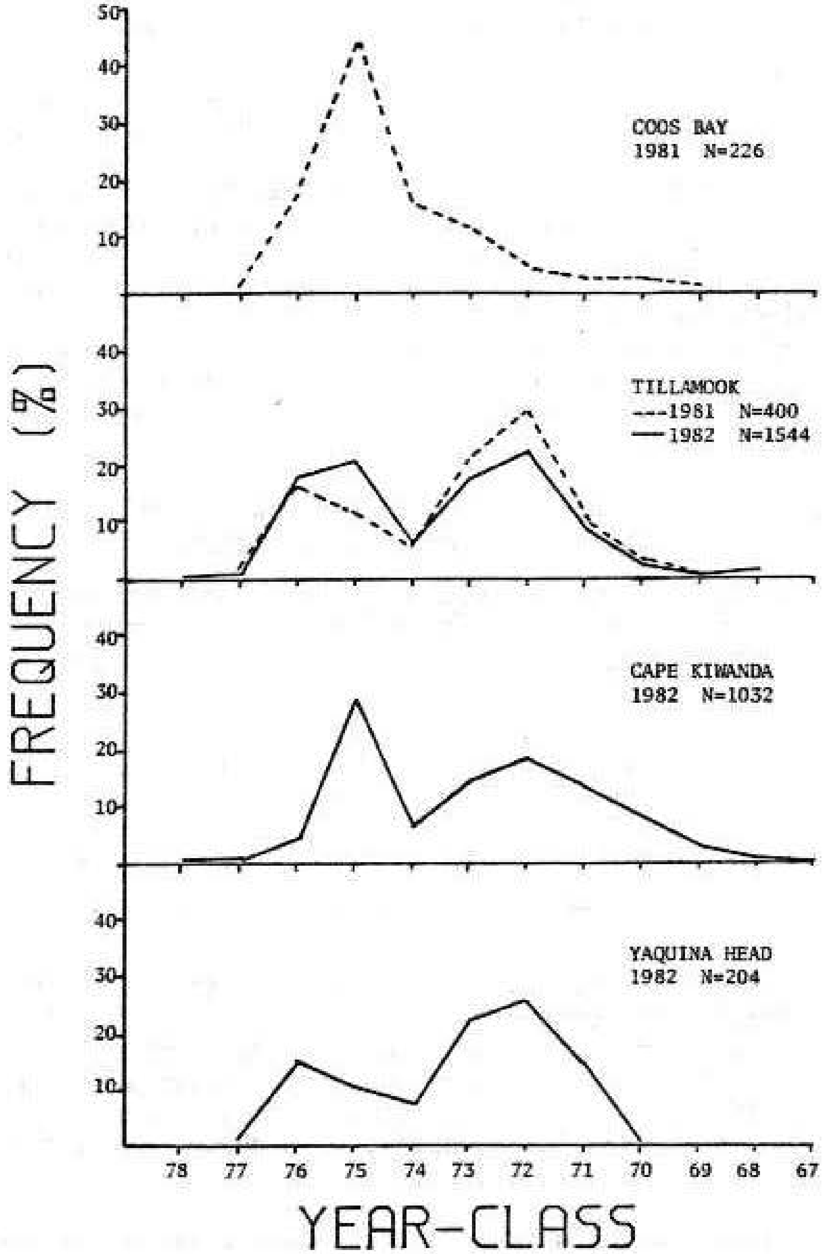

Fig. 12. Year-class composition of P. caurinus, by area, R/V Chapman cruise, Nov. 1981, and F/V Granada cruise, Aug. 1982.

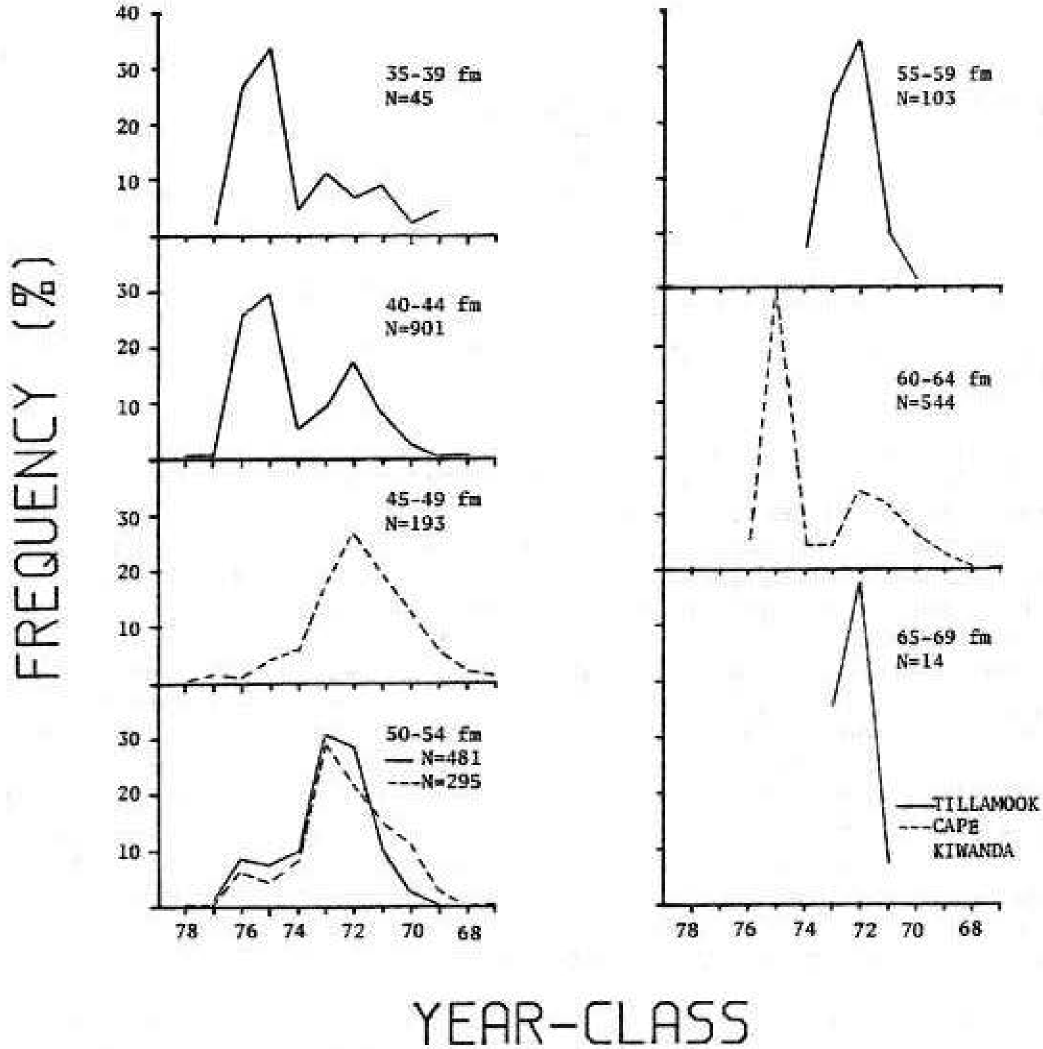

Fig. 13. Year-class composition of P. caurinus, by area, by depth, F/V Granada cruise, Aug. 1982.

settle out. Dow (1962) suggested that water temperature was a significant factor influencing spatfall success in Maine waters. Dickie (1955), Dickie (1958), and Dickie and Medcof (1963) also suggested that annual water temperature variation influences spatfall success. Dickie further concluded that changes in scallop abundance are attributable to the combined action of temperature and circulation on the pelagic larvae. We suspect that coastal upwelling variations off Oregon also determine larval survival and spatfall location.

Spatfall and resulting success of a year-class is probably a function of spring weather conditions when P. caurinus larvae are in the water column 4-6 wk and the larvae are subject to variable currents. Spring is a transitional weather period; northwest winds can create localized upwelling resulting in offshore flow one week, then southwest winds the following week can create the opposite onshore flow. The wind patterns may occur along the entire coast or may be quite localized. In some years the strong northwest winds do not materialize until June, or remain weak the entire year. We believe these variations in wind greatly influence spatfall location. If the larvae are transported to and settle out in a favorable location, they probably thrive, if not high mortalities occur.

The similarities between the 1981 and 1982 Tillamook Head age curves (Fig. 12) indicates there was no differential mortality between age-classes over the nine month period between cruises. There was no differential mortality between depth regimes, either (Fig. 14). Each age-class showed a similar survival rate. Because survival of the older age-classes (10-12 yr olds) was similar to the other age-classes, we cannot assume that the low abundance of these individuals is entirely due to increased natural mortality at a given age. The low frequency may indicate a poor year-class survival rather than increased natural mortality with age. For example, if natural mortality was the reason for the decrease in frequency between the nine and ten year-olds (1970, 1971 yc) in 1981, we would expect to see a similar decrease in frequency between nine and ten year-olds (1971, 1972 yc) in 1982. This did not occur; the frequency of the 1971 year-class was essentially the same for both years. Although we believe Oregon scallops do not live as long as Alaska scallops (15-18 yr) we cannot assume the 1969-1971 year-classes have reached their maximum age. A few 13-14 yr old scallops were caught in our 1982 cruise but we do not expect to see scallops much older.

The similar shape of the age curves (Fig. 14) on the lower end also indicates there was no differential mortality between the younger age-classes. Our gear collected scallops with shell heights much smaller than shell heights measured for the 3-4 yr olds (1977, 1978 yc) therefore we believe the low frequency of occurrence of these age classes is due to a lack of year-class survival. However, we temper this belief by knowing that other researchers (Jamieson and Lundy 1979) have suggested that New Bedford dredges have poor retention rates for prerecruit scallops.

Fig. 14 also suggests that there was no movement of adult scallops by depth from November 1981 to August 1982, nor any seasonal variation by depth between August and November.

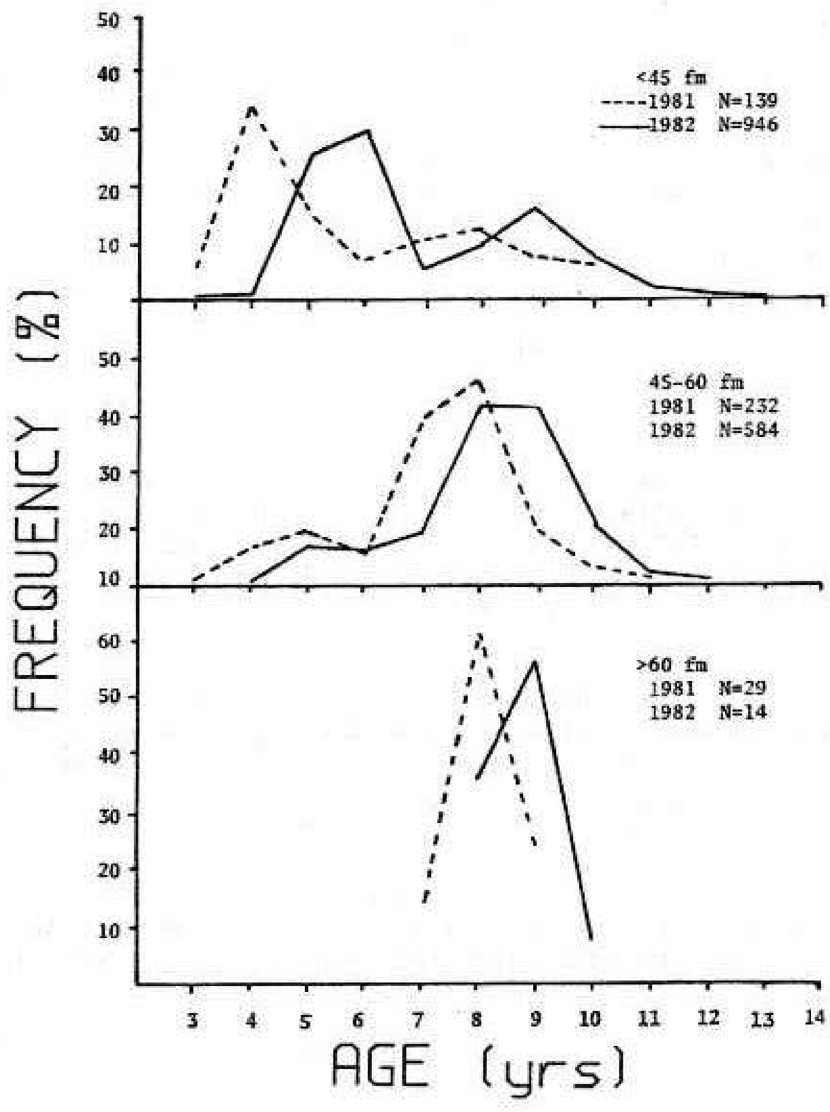

Fig. 14. Age composition of P. caurinus in the Tillamook area, by depth, R/V Chapman cruise, Nov. 1981. and F/V Granada cruise, Aug. 1982.

Growth

The observed size variations within and between scallop beds led us into an examination of growth. We measured the distance from the posterior margin of the hinge to each annulus for samples of scallops collected from every location surveyed on the two research cruises. The data allowed us to employ the von Bertalanffy growth model (Fabens 1965) to calculate mean heights at annuli and develop growth parameters. The von Bertalanffy model describes the predicted shell height at any age, the theoretical asymptotic maximum shell height, a growth constant, and the hypothetical age when shell height is zero. From the generated parameters we plotted growth curves for each 1981 study area (Fig. 15), and for depth regimes within the 1982 study areas (Fig. 16). The derived growth curves display a growth variation between depths in an area; scallops grew significantly faster ($P \leq 0.05$) in shallow water in all areas when compared using the Hotelling's T^2 statistic described by Bernard (1981). Note that we used only one year-class for comparison of growth between depths to mask any effects of growth differences caused by annual variations in growing conditions.

Although growth varied somewhat with depth; a greater variation occurred between areas. The curves indicated that the Coos Bay area scallops exhibited significantly greater growth rates ($P \leq 0.05$) than scallops in other Oregon areas, but they were not as great as rates Kaiser (1982) calculated for Alaskan scallops from the work of Haynes and Powell (1968). Oregon scallops thus are not only shorter lived than Alaskan scallops, they also do not grow as fast.

The growth curves for individual year-classes provide a clue to the reason for the discrepancy between Oregon and Alaskan scallops. We used the von Bertalanffy growth model to look for annual variations in growth. The growth curves suggest that growth in the Tillamook area is remarkably consistent (Fig. 17). The apparent faster growth of the younger year-classes in Figure 17 provides an excellent example of Lee's phenomenon in the positive sense (Ricker 1969). A positive Lee's phenomenon is the name commonly given to the situation in which the mean height at a given annulus decreases as the age of the individuals being studied increases. Ricker (1969) identified four possible causes of Lee's phenomenon:

(1) incorrect back calculation at earlier ages;
(2) biased sampling from the catch;
(3) size selective mortality resulting from commercial fishing methods, and;
(4) natural size selective mortality.

The first three possible causes may be ruled out because we measured annuli directly (did not back calculate), and analyzed the entire catch. Also there was no scallop fishery prior to 1981. Therefore, one may assume the Lee's phenomenon is observed because of size selective natural mortality. Size selective mortality may be caused by predation by sea stars or some other organism. Parasitism by the shell infesting polychate Polydora websteri may also be a cause of size selective natural mortality. Occasionally shells are weakened or broken in the area of the adductor muscle by this infestation. Quite possibly faster growing animals put more energy into increasing shell height at the expense of shell thickening. Faster growing animals may thus have thinner shells and be more susceptible to shell weakening by the

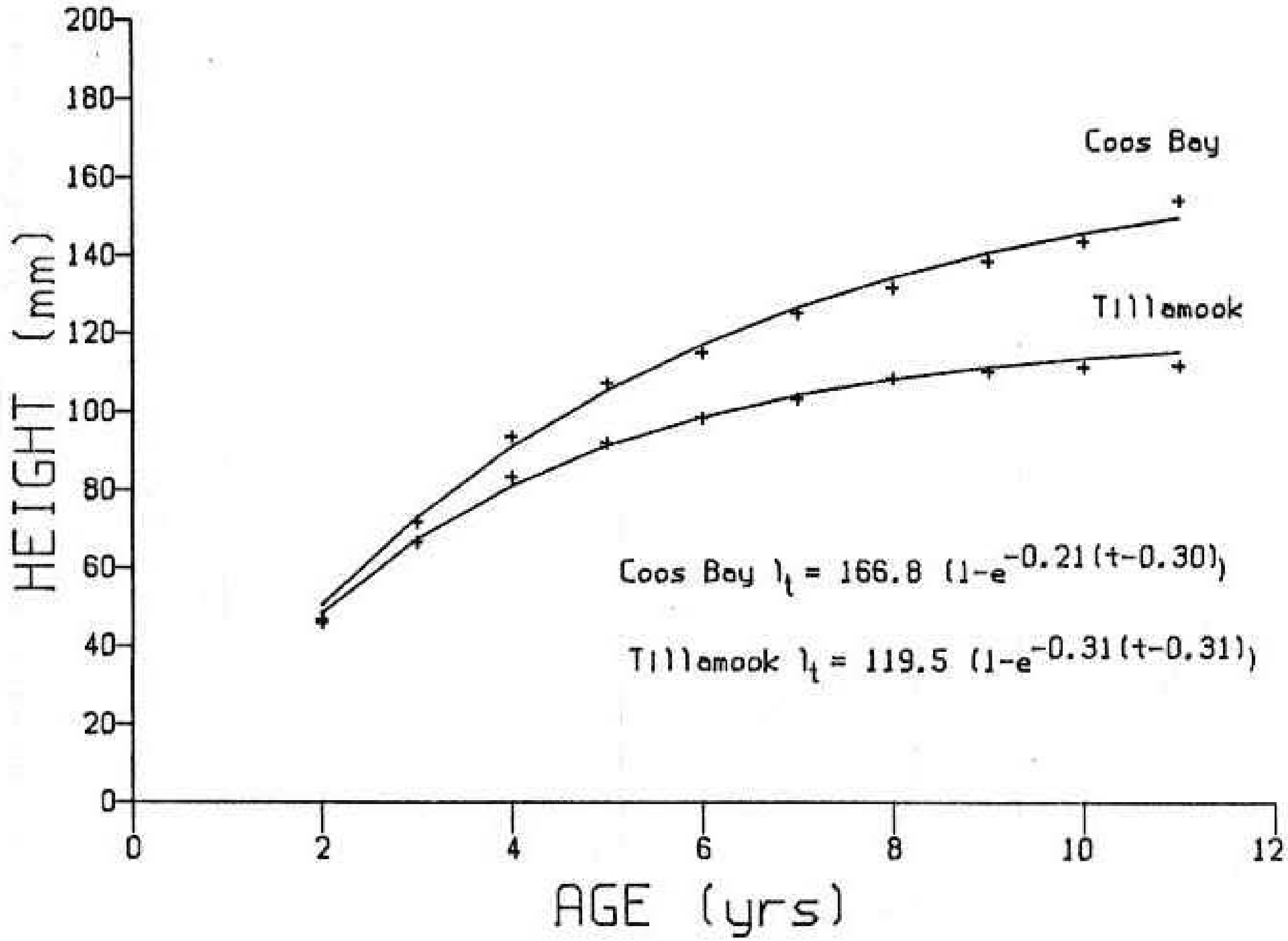

Fig. 15. Coos Bay area and Tillamook area back-measured mean height at age with fitted growth curves of P. caurinus, R/V Chapman cruise, Nov. 1981.

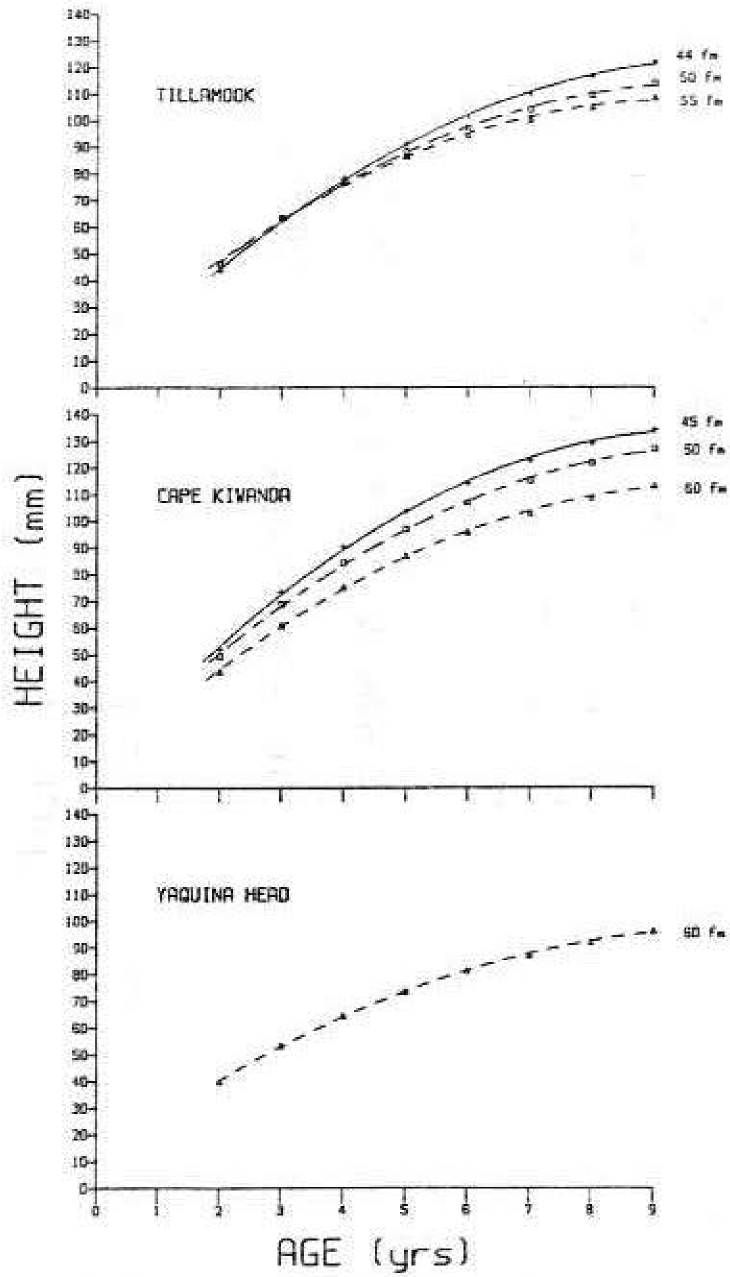

Fig. 16. Fitted growth curves of the 1972 P. caurinus year-class by area, by depth, F/V Granada cruise, Aug. 1982.

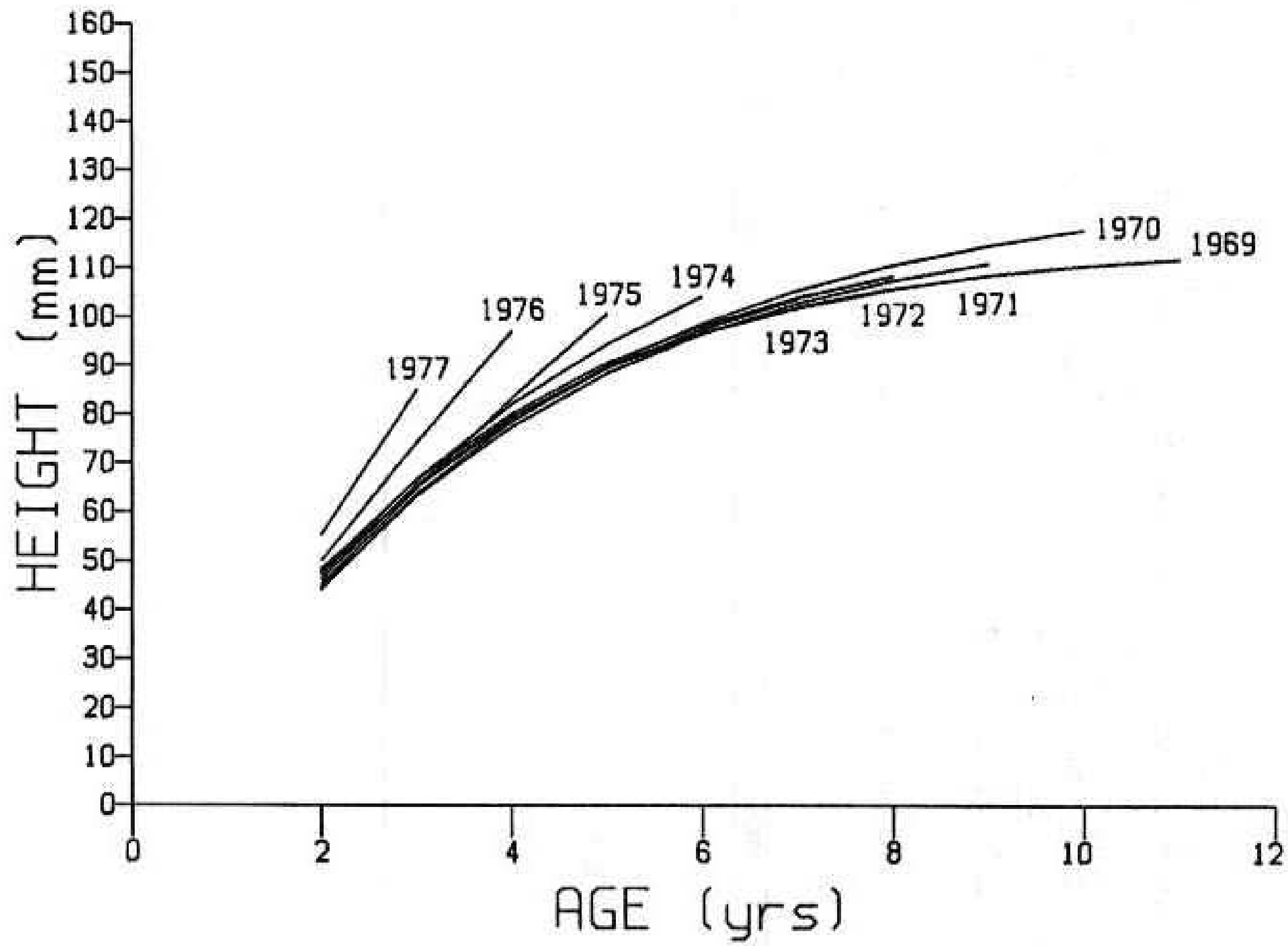

Fig. 17. Fitted growth curves of the 1969 to 1977 P. caurinus year-classes, Tillamook area, R/V Chapman cruise, Nov. 1981.

Polydora, resulting in a greater mortality rate for faster growing animals. This may be one reason why no scallops older than 12 y have appeared in the commercial catch, whereas the relatively uninfested Alaskan scallops are often caught at 15 y of age (Haynes and Powell 1968).

Shell Injuries

While aging the scallop shells we noticed a number of repaired injuries to the shells between the last and next to the last annulus (representing the 1981 growing season). Table 13 summarizes the percent of shell with repaired injuries at this location by depth for each area. Although the data were not collected, we noticed very few repaired injuries at other locations on the shell (before 1981). During 1981 most of the commercial activity in the Tillamook area took place between 40-50 fm and there was little or no activity in the other areas. Therefore, these injuries during the 1981 season may have been caused by the commercial activity.

Table 13. Percent of scallops with repaired injury that occurred during the 1981 growing season. Scallops were collected on the F/V *Granada* cruise, Aug. 1982.

(fm)	Tillamook	Cape Kiwanda	Yaquina Head
35-39	6.7		
40-44	25.7		
45-49	-	1.0	
50-54	8.7	0.7	
55-59	1.9		
60-64	-	0.9	0
65-69	0		
Total	18.1	0.8	0

GEAR TRIALS

Beam Trawl and Epibenthic Sled Tests

We towed OSU's beam trawl and epibenthic sled in the Tillamook area with poor results. The beam trawl probably was too light and based on the small catch may have fished off the bottom. The epibenthic sled also proved to be a poor tool for our purposes. The sled came up full of mud indicating it dug into the bottom. Because of its capacity to collect sediment, the epibenthic sled may be a useful tool for collecting scallop spat. However, it probably moves too slowly to catch the relatively mobile juvenile scallops.

Net Liner Tests

Scallop researchers typically line nets to catch small scallops, but few have quantified the difference between lined and unlined dredges. Jamieson and Lundy (1979) studied the difference between lined and unlined dredges and reported that lined scallop dredges caught significantly more prerecruits than unlined dredges. They also reported; however, that for 10 minute tows with small scallop drags, lined dredges fished effectively for only one-half the distance of unlined dredges.

We used a 32 mm (1.25 in) liner in 1981 to catch adults and 1 yr old scallops. In 1982 we tested the effect of liner size on the size or number of juveniles caught and the number of adults caught. We hypothesized that the smaller liner might create a pressure wave in front of the dredge which would push scallops out of the path of the dredge. Jamieson and Lundy (1979) suggested the pressure wave phenomenon might dramatically reduce scallop catch. They reported that unlined scallop dredges caught almost twice as many scallops as lined dredges.

The first question addressed was which liner size caught the most small (<70 mm shell height) scallops. A preliminary analysis of the data indicated that there was no statistical difference between the number of scallops caught by the larger liner (port side) and the number of scallops caught by the smaller liner (starboard side). However, the frequency histogram of small scallops (<70 mm shell height) caught indicated that the 25 mm stretch mesh liner accounted for 98% of the scallops caught less than 30 mm in shell height. Thus the 38 mm stretch mesh liner was not suitable for catching 1 yr old scallops. If an objective is to catch 1 yr old scallops, a liner smaller than 38 mm (1.5 in) should be used.

If the objective is to catch 2 yr old scallops; however, the 38 mm liner would prove more suitable than a 25 mm (1 in) liner. A one-tailed paired student's "t" test indicated that the 38 mm liner caught significantly more ($P \leq 0.05$) small scallops in the 30-70 mm size range than did the smaller liner.

The reason for this starboard-port difference is probably that the dredge with the 25 mm liner created a pressure wave which pushed small scallops out of the way, but retained those scallops less than 30 mm in shell height which entered the net. The larger 38 mm liner did not create as large a pressure wave and thus more small scallops entered the net. Probably, though, the scallops less than 30 mm high passed through the webbing.

The liner tests were designed to identify a method for assessing incoming year-class strength. Since we caught many 1 yr old scallops in the Tillamook area in 1981, but few in 1982, and we caught numerous shell of 1 yr old scallops, we suspect there may be a high mortality when juvenile scallops reach a shell height of about 25 mm. Thus the 38 mm liner which collects primarily 2 yr old and older scallops may be a better tool to use to assess year-class strength. More data are needed to verify this, however.

The suggestion of a pressure wave reducing the number of scallops caught caused us to investigate the possibility that the liner size affected the catch of adult scallops as well. We used a one-tailed paired student's "t" test to determine if the port dredge with the larger liner caught significantly more scallops than the starboard dredge with the smaller liner.

For tests conducted at 5 knts with a 4:1 scope the larger (38 mm) liner caught significantly ($P \leq 0.05$) more scallops than the smaller (25 mm) liner. In areas of greater scallop abundance the difference was highly significant ($P \leq 0.01$). These data support the findings of Jamieson and Lundy (1979) and further suggest that a liner induced pressure wave reduces scallop catch. Also, the data indicate that our relative abundance estimates may not be directly transferable to commercial vessels even though we used commercial gear in our tests.

Speed and Scope Tests

Most scallop fishermen say that the towing speed of the vessel and the scope of the towing cable greatly influence scallop catches. Fishermen usually suggest that towing a dredge faster will result in larger catches. We conducted tests to determine if the number and size of recruits and prerecruits caught were affected by speed and scope changes. Unfortunately we caught too few juveniles to provide meaningful results.

We collected enough data for analysis of adults, however. We tested two combinations of speed and scope in two different depth ranges off Tillamook Head. We towed at 4 knts with a scope of 3.5:1, and at 6 knts with a scope of 5:1. Tows occurred in 47-55 fm, and 55-64 fm. We used speed and scope combinations typically used in the industry (and faster) and towed in similar depths to ensure that any variation noticed was attributable to the gear and not to environmental differences.

One way analysis of variance indicated no significant difference ($P > 0.05$) in number of large scallops caught in either depth regimes on the basis of speed and scope. Similarly the data displayed no significant difference ($P > 0.05$) in size of large scallops caught in either depth regime on the basis of speed and scope.

We suspect that the statistical analysis of our data is misleading; however, because almost all of the commercial fishermen we have talked with indicate that speed and scope are critical factors influencing scallop catch. A visual inspection of the data also suggests some differences. First the number of tow replications may be insufficient to provide a statistically robust data base. More tow replications may have displayed a difference. A second possible answer is that the pressure wave caused by the dredge liners influenced the catch sufficiently to create a large variance between tows and thus invalidate the analysis. The third possible cause is that scallop catch increases as vessel speed increases until a velocity threshold is reached then scallop catch decreases, perhaps due to the dredge flying off the bottom as the vessel speed continues to increase.

INCIDENTAL CATCH

Total Catch

One of our cruise objectives included an evaluation of incidental catch, in order to anticipate conflicts between the scallop fleet and other fisheries. Table 14 summarizes total catch and Table 15 summarizes the catch of fish in 1981 by percent of total weight. Table 16 is a species list of incidental catch for 1981. We calculated a Shannon index of general diversity (H) (Odum 1971) for each tow in order to compare the catch between transects and depth regimes.

Table 14. Summary of total catch, R/V Chapman cruise, Nov. 1981.

	Percent by Weight
miscellaneous invertebrates	25.8
fish	21.8
heart urchin	11.0
debris	8.6
sea stars & brittle stars	7.8
adult scallops	5.4
large scallop shell	4.9
sea cucumbers	3.9
basket stars, sea pens, and sea whips	3.6
Dungeness crab	3.4
algae	3.0
small scallop shell	0.4
pink shrimp	0.3
other crabs	0.1
octopus	0.1
juvenile scallops	0.1
squid	*

* Less than 0.1%

We observed no significant difference ($P > 0.05$) in mean diversity index between depths within a transect, except between depth regime 2 (45-60 fm) and depth regime 3 (>60 fm) in the Tillamook South, Coos Bay North, and combined transects. There was also no significant difference ($P > 0.05$) between transects or areas except between the total of Tillamook north and south. These differences were probably due to the higher catches of heart urchins in the deeper areas. We noted that, although the difference was not always significant, depth regime 2 (45-60 fm) had a higher mean diversity index than depths regime 1 (<45 fm) or 3 in each transect.

Table 17 is a species list of the total catch of the Granada cruise. We observed little difference in the catch between the port (38 mm liner) and starboard (25 mm liner) dredges. We did notice some increase in the number of occurrences of some of the smaller fishes (eelpouts, poachers, sculpins, and

Table 15. Summary of fish catch of all dredge tows, R/V Chapman cruise, Nov. 1981.

	Percent by Weight
Dover sole	24.7
slender sole	20.5
rex sole	18.2
Pacific sanddab	12.1
poacher sp.	4.7
sculpin sp.	3.6
butter sole	3.3
sand sole	2.0
English sole	1.4
shiner perch	1.4
eelpout sp.	1.1
Pacific hake	0.9
longnose skate	0.8
warty poacher	0.7
Pacific tomcod	0.7
gray starsnout	0.6
skate sp.	0.6
Pacific staghorn sculpin	0.6
snailfish sp.	0.5
juvenile rockfish sp.	0.4
spotted ratfish	0.3
smelt	0.3
petrale sole	0.2
big skate	0.1
northern spearnose poacher	0.1
curlfin sole	*
rougheye rockfish	*
sturgeon poacher	*
arrowtooth flounder	*
shortfin eelpout	*
sable	*
Pacific hagfish	*
Pacific electric ray	*
northern anchovy	*
prickleback	*
yelloweye rockfish	*
tubenose poacher	*
spinycheek starsnout	*
Total	99.6

* Less than 0.1%

Table 16. Species list of catch of F/V Chapman cruise, Nov. 1981.

Common Name	Scientific Name
sea pen, sea whip	Pennatulacea
sea star	Asteroidea
sea cucumber	Holothuroidea
brittle star	Ophiuroidea
basket star	Gorgonocephalus eucnemis
heart urchin	Brisaster latiforns
weathervane scallop	Patinopecten caurinus
market squid	Loligo opalescens
octopus	Octopodidae
pink shrimp	Pandalus jordani
Dungeness crab	Cancer magister
other crab	Brayura
Pacific hagfish	Eptatretus stouti
Pacific electric ray	Torpedo californica
big skate	Raja binoculata
longnose skate	Raja rhina
other skates	Rajidae
spotted ratfish	Hydrolagus colliei
northern anchovy	Engraulis mordan
smelt	Osmeridae
Pacific hake	Merluccius productus
Pacific tomcod	Microgadus proximus
shortfin eelpout	Lycodes brevipes
other eelpout	Zoarcidae
shiner perch	Cymatogaster aggregata
prickleback	Stichaeidae
rougheye rockfish	Sebastes aleutianus
yelloweye rockfish	Sebastes ruberrimus
juvenile rockfish	Scorpaenidae
sablefish	Anoplopoma fimbria
Pacific staghorn sculpin	Leptocottus armatus
other cottids	Cottidae
northern spearnose poacher	Agonopsis vulsa
sturgeon poacher	Agonus acipenserinus
gray starsnout	Bathyagonus alascanus
spinycheek starsnout	Bathyagonus infraspinatus
warty poacher	Occella verrucosa
tubenose poacher	Pallasina barbata
other poachers	Agonidae
snailfish	Cyclopteridae
Pacific sanddab	Citharichthys sordidus
arrowtooth flounder	Atheresthes stomias
petrale sole	Eopsetta jordani
rex sole	Glyptocephalus zachirus
butter sole	Isopsetta isolepis
slender sole	Lyopsetta exilis
Dover sole	Microstomus pacificus
English sole	Parophrys vetulus
curlfin sole	Pleuronichthys decurrens
sand sole	Psettichthys melanostictus

Table 17. Species list of catch of F/V Granada cruise, Aug. 1982.

Common Name	Scientific Name
sea pen, sea whip	Pennatulacea
anemone	Actiniaria
sea star	Asteroidea
sea cucumber	Holothuroidea
basket star	Gorgonocephalus eucnemis
heart urchin	Brisaster latiforns
weathervane scallop	Patinopecten caurinus
market squid	Loligo opalescens
stubby squid	Rossia pacifica
octopus	Octopodidae
pink shrimp	Pandalus jordani
Dungeness crab	Cancer magister
other crab	Brayura
Pacific hagfish	Eptatretus stouti
dogfish shark	Squalidae
Pacific electric ray	Torpedo californica
big skate	Raja binoculata
longnose skate	Raja rhina
other skates	Rajidae
spotted ratfish	Hydrolagus colliei
Pacific herring	Clupea harengus pallasi
northern anchovy	Engraulis mordan
smelt	Osmeridae
Pacific hake	Merluccius productus
Pacific tomcod	Microgadus proximus
shortfin eelpout	Lycodes brevipes
other eelpout	Zoarcidae
Pacific saury	Cololabis saira
shortspine thornyhead	Sebastolobus alascanus
juvenile rockfish	Scorpaenidae
sablefish	Anoplopoma fimbria
lingcod	Ophiodon elongatus
cottids	Cottidae
northern spearnose poacher	Agonopsis vulsa
other poachers	Agonidae
snailfish	Cyclopteridae
Pacific sanddab	Citharichthys sordidus
arrowtooth flounder	Atheresthes stomias
petrale sole	Eopsetta jordani
rex sole	Glyptocephalus zachirus
butter sole	Isopsetta isolepis
slender sole	Lyopsetta exilis
Dover sole	Microstomus pacificus
English sole	Parophrys vetulus
sand sole	Psettichthys melanostictus

hagfish) in the starboard dredge. These species were also caught in the catch nets attached to the codend which indicates they were being collected by the dredge and were passing through the liner.

Since we did not count and weigh the incidental catch by major species groups in 1982, we did not calculate diversity indices for each area by depth as was done in 1981. Qualitatively the 1982 catch was similar in composition to the catch of 1981, with some species variation. For example, in 1981, the catch of squid was exclusively *Loligo opalescens*, whereas in 1982 we collected numerous *Rossia pacifica* as well as *L. opalescens*. There was also a greater occurrence of shiner perch in 1981 and hagfish in 1982. We feel these differences may be due to seasonal variations between November and August.

Both year's data displayed the same trend of the mid-depth tows having a higher average number of species per tow then the shallow or deeper depths (Table 18). In all depths, the 1982 catch had a significantly ($P \leq 0.05$) higher average number of species per tow than the 1981 catch. This is probably due to the 1982 dredges having three times the cross sectional area of the 1981 dredge. The wider dredges were probably able to collect some of the fishes that would have gotten around the 2.5 m dredge.

Table 18. Average number of species per tow, collected in Tillamook Head area, R/V *Chapman* cruise, November 1981, and F/V *Granada* cruise, Aug. 1982.

Depth (fm)	1981	1982
	$\bar{x}$ ± S.D. (N)	$\bar{x}$ ± S.D. (N)
<45	12.5 ± 2.1 (8)	17.8 ± 4.5 (6)
45-60	14.3 ± 2.7 (6)	22.9 ± 2.0 (12)
<60	13.1 ± 2.7 (11)	19.3 ± 2.9 (8)
overall	13.2 ± 2.5 (25)	20.6 ± 3.6 (26)

Many of the anemones that were collected were attached to scallop shells (empty shells and live animals). Since some of the commercial fishermen land their scallops whole there may be a reduction in substrate for the anemones. With the sediment in fishing grounds largely mixtures of sand and mud, there are probably few hard surfaces on which the anemones can attach.

Dungeness Crab

We were especially interested in the impact of scallop gear on Dungeness crab. Table 19 summarizes the numbers of Dungeness crab caught per tow, by depth, in the Tillamook area. Similar to last year, there appears to be some

Table 19. Number of Dungeness crab caught per tow by depth, Tillamook area, F/V Granada cruise, Aug. 1982.

Depth (fm)	#Tows	#Crabs	Males	Females	Total
40-44	5	59	7.2	4.6	11.8
45-49	2	30	8.5	6.5	15.0
50-54	6	103	9.2	8.0	17.2
55-59	4	63	5.3	10.5	15.8
60-64	6	91	3.3	11.8	15.1
Total	23	346	6.5	8.5	15.0

segregation of sexes by depth, perhaps due to migration. The number of male crabs per tow was higher in the shallow depths, whereas the number of females per tow was higher in the deeper depths. Past studies (Cleaver 1949 as cited in Barry 1983; Pacific Fishery Management Council 1979) have suggested there may be a trend for crab to move onshore in the spring and summer and offshore in the fall and winter. Barry (1983) presented some data which suggested the opposite; a movement of crab inshore in the fall and winter. Our data collected in November 1981 and August 1982 support the conclusion of Barry. In August, male crabs were found mostly in shallow depths but scattered through all depths, whereas in November, male crabs were found only in shallow depths. This suggests a movement inshore during the fall and winter.

Shell condition differed between males and females in both years (Table 20). Females were predominantly in condition I and the males were

Table 20. Number and percentage of Dungeness crab caught by depth and shell condition, Tillamook area, F/V Granada cruise, Aug. 1982.

Shell	Males			Females			Total		
Condition	I	II	III	I	II	III	I	II	III
Depth (fm)									
40-44	3	10	18	19	1	1	22	11	19
45-49	0	3	13	11	1	1	11	4	14
50-54	7	17	30	39	4	5	46	21	35
55-59	1	13	7	33	3	5	34	16	12
60-64	3	5	12	63	4	4	66	9	16
Total	14	48	80	165	13	16	179	61	96
				By Percent					
40-44	9.7	32.3	58.1	90.5	4.8	4.8	42.3	21.2	36.5
45-49	0	18.8	81.2	84.6	7.7	7.7	37.9	13.8	48.3
50-54	13.0	31.5	55.5	81.3	8.3	10.4	45.1	20.6	34.3
55-59	4.8	61.9	33.3	80.5	7.3	12.2	54.8	25.8	19.4
60-64	15.0	25.0	60.0	88.7	5.6	5.6	72.5	9.9	17.6
Total	9.4	32.2	53.7	83.8	6.6	8.1	51.7	17.6	27.7

Condition I: hard shell
Condition II: medium shell
Condition III: soft shell

condition II and III. We expected to see a greater male mortality due to their softer condition. The data suggest that softer shelled crab are more heavily impacted by scallop dredges (Table 21).

Table 21. Number and percentage of mortality of Dungeness crab by depth, Tillamook area, F/V *Granada* cruise, Aug. 1982.

Depth (fm)	Males		Females		Total	
	No.	%	No.	%	No.	%
40-44	10	27.8	2	8.7	12	20.3
45-49	3	17.6	2	15.4	5	16.7
50-54	5	9.1	3	6.3	8	7.8
55-59	1	4.8	1	2.4	2	3.2
60-54	0	0.0	0	0.0	0	0.0
Total	19	12.8	8	4.1	27	7.8

Generally, crab seasons have been set to restrict the harvest of crabs to time periods when male crabs are not in condition III, to reduce handling mortalities (PFMC 1979). Barry (1983) suggested that mortalities of soft-shelled male crabs due to handling may cause a significant loss to the crab fishery. If female crabs do have a molting period at a different time than male crabs, it raises questions concerning the impact of scallop fishing as well as crab fishing during the female molting period as well as during the male molting period. The low numbers of crab caught by scallop fishermen indicate this is probably not a problem.

There may be lower mortalities in deeper depths for both sexes (Table 21). We did not see a change in condition of the crabs by depth (Table 20), so we do not feel this accounts for the differential mortality. It may be due to a change in substrate from more sandy in the shallow depths to softer, more muddy in the deeper depths. Perhaps a softer substrate would cushion the crabs as they are caught by the dredges.

SUMMARY

The state of Oregon was the recipient of a major new scallop fishery in the spring of 1981. The fishery was characterized by initial large landings produced by out-of-state vessels, followed by a surge of interest by local processors and fishermen. Scallop catch per unit effort was high initially but quickly declined; consequently landings also peaked then rapidly declined as vessels departed the fishery. A few vessels remained in the fishery after the initial boom, and since then have produced a small, but relatively constant, supply of scallops to local processors.

With the surge of interest by local vessels came controversial limited entry legislation designed to discourage scallop harvest by large non-local scallop vessels. The legislation was enacted in part due to the larger harvest capability of the production scallop vessels. The large production vessels exhibited harvest capabilities twice those of the local fleet. After the initial large landings local fishermen became concerned about the prospect of overharvest before they could enter the fishery.

The fears of overharvest by the larger production vessels proved true in a limited sense. The east coast vessels did not biologically overharvest scallops, but did reduce scallop densities so that local boats had to expend more effort to harvest scallops. The large production vessels from the east coast fished 24 h shifts and rapidly cropped the scallop population to the point that catch per hour for all vessels dramatically declined. The larger boats could not economically fish at those reduced CPUE's and left state waters. Apparently the reduced densities made scallop fishing only marginally profitable for local boats as well, since the fleet size sharply decreased as mean catch per hour decreased.

In response to the volatile fishery we designed a research project to provide us with biological data needed to adequately manage the resource. Initial field work occurred as a joint cruise with the NMFS and OSU aboard the NOAA/NMFS R/V Chapman. We also implemented a logbook program, collected market samples, and in 1982 conducted gear trials to test methods for catching prerecruits.

Results from the logbook program and two cruises showed that scallop distribution and relative abundance in 1981 was similar to the 1963 and 1967 surveys. Scallops were most abundant in the 45-60 fm range, and located in somewhat distinct beds. Mean sizes were similar in 1963 and 1981. The ratio of male to female scallops was nearly 1:1, and all were dioecious similar to Alaskan *P. caurinus* stocks. Population characteristics of males and females were not significantly different.

We did observe significantly different population characteristics between different scallop beds. Age, size, and growth parameters differed between areas we surveyed, and between depth regimes within an area. Shallower depths contained larger and often younger scallops than deeper depths; growth was correspondingly greater in shallow waters. Growth differed more greatly between areas than between depth regimes, however.

Year-class success also varied geographically. Scallops in the Tillamook, Cape Kiwanda, and Yaquina Head areas exhibited a relatively even age distribution whereas one year-class predominated in the Coos Bay beds. Also tow data indicated a lack of younger year-classes in all areas except Yaquina Head.

Results from the gear trials suggest that a standard commercial dredge with a liner larger than 25 mm stretch mesh may be the most suitable gear for collecting prerecruits. A secondary objective of the gear trials was to determine if juvenile scallops migrate. Although we collected no direct evidence, age frequency histograms by depth provided no evidence of scallop migration.

Gonad maturity varied spatially and temporally as well. Spawning time seemingly ranges from February through July, and most likely varies with location depending on water temperatures. More data are needed to determine the range of spawning times.

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Many people contributed to our research efforts in the past two years. Darrell Demory and Laimons Osis of ODFW handled the initial surge of interest in the commercial scallop fishery and were highly responsible for the design and smooth operation of the R/V *Chapman* cruise. We thank the crews of the R/V *Chapman* and F/V *Granada*; they provided necessary fishing expertise. Fred Matzke of the F/V *Granada* in particular provided valuable expertise in 1982. The juvenile and gonad condition data were collected cooperatively with OSU; Dr. Andrew Carey, Gene Ruff, Wilbur Breese, and Anja Robinson receive special consideration for their assistance. We thank Tom Gaumer for his constant support and guidance throughout the project. Denise Herzing, Paul Boehne, and Steve Jones deserve credit for spending long hours processing the cruise and logbook data. Thanks again to Margie Lamb, Becky Henry, and Kathy Murphy for typing this report.

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