History and Status of the Oregon Sea Urchin Fishery, 1986-1996

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INTRODUCTION

The commercial sea urchin fishery expanded rapidly in the 1980's along the U.S. west coast, in response to increased market demand for Japanese gourmet products, especially uni (urchin gonads). Urchin fisheries in southern California, Washington and southern British Columbia were well established before the inception of the Oregon fishery. Fishery development in northern California preceeded Oregon's by less than two years, with some of the same divers and processors involved in developing the Oregon fishery. Oregon's commercial fishery for red sea urchins (*Strongylocentrotus franciscanus*) began in 1986 in Port Orford. The Oregon and Northern California coastlines are characterized by relatively rough seas and ports remote from transportation centers. Favorable market conditions during the second half of the decade fueled aggressive fishery development into virgin red urchin habitats. A limited fishery for purple sea urchins (*Strongylocentrotus purpuratus*) began in Oregon in 1992. Urchins are harvested by divers using surface supplied air, working off of small vessels usually less than 40 feet in length.

This report reviews the Oregon sea urchin fishery from 1986 through 1996. Included in this report is a history of management actions and summaries of harvest activity (landings and effort), catch data from diver logbooks, and market sample data collections. An earlier report (McCrae 1989) reviewed the first three years of the fishery. The fishery, marketing, and biology of red sea urchins has been previously described (Kato and Schroeter,1985). Results of ongoing population surveys will be reported in a subsequent publication.

METHODS

Management and Regulations

To describe the history of fishery management, we referred to a series of unpublished staff reports which were prepared for all proposed regulatory changes in the fishery. These staff reports are prepared for the consideration of the Oregon Fish and Wildlife Commission (OFWC), and their decisions on management issues are reflected in the current version of Chapter 635 of the Oregon Administrative Rules (hereafter referred to as "rules"). For ease of discussion, the fishery history has been divided into three parts: fishery development, 1986-1988; fishery expansion, 1989-1991; and fishery stabilization, 1992-1996.

Harvest and Effort

Sea urchin landings data are obtained primarily from fish receiving tickets submitted by wholesale buyers. Fishery landings datasets are maintained by the fisheries information section of the Oregon Department of Fish and Wildlife (ODFW), and are summarized annually (Lukas and Carter, 1986-1996). In addition, we obtain harvest area, depth, and dive-time data from the required logbook records submitted by the harvesters. Each urchin landing was assigned to a fixed set of harvest areas by one of two methods. When logbook data were available, daily landings were assigned to the reported harvest area. Landings without logbook information were assigned to harvest areas in proportion to the annual catch-area distribution of landings from known harvest areas. Total dive hour estimates were derived similarly, with annual average hours per landing from logbook data applied to the number of landings without logged dive time.

Market Sampling

Market samples were obtained from randomly encountered urchin landings known harvest areas. Test diameters of 50 randomly selected urchins from each sampled landing were measured with calipers to the nearest millimeter. Each sampled landing consisted of the daily catch of the diver(s) working from a single vessel. Sample data from Orford reef were arranged into sample years from October 1 of one year through September of the next year, to conform earlier sample sets to the current six month open season at this area. All other areas were sampled on a calendar year basis. We also subsampled a limited number of urchins to obtain measurements of whole weight, drained weight, and gonad weight.

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We conducted a preliminary investigation of minimum sample size by randomly resampling one of the larger annual data sets. To achieve this, we used a random number generator to resample five groups of samples per interval, in intervals of five samples up to a maximum of sixty samples. To test for long-term changes in the average size of urchins harvested from Orford Reef, we compared mean test diameters from market samples between years using analysis of variance.

RESULTS AND DISCUSSION

History of Sea Urchin Fishery Management: Fishery Development, 1986-1988.

Prior to 1988, red sea urchins could be commercially harvested by anyone possessing both a commercial fishing license and a (free) invertebrate harvest permit. At the request of several members of the urchin industry, the 1987 Oregon legislature adopted legislation directing the Oregon Fish and Wildlife Commission (OFWC) to develop a limited participation system for the commercial sea urchin fishery (Oregon Regulatory Statutes, 508.760). The guideline provided by the legislation stated that the limited participation system would be established "in order to provide a sea urchin commercial fishery with optimum profits to those engaged in the fishery and to prevent a concentration of fishing effort that would deplete the resource". The fear of industry was that Oregon would experience the uncontrolled fishery growth which California was experiencing. The legislation gave the responsibility to the OFWC, to develop the criteria for initial eligibility, permit renewal and transfer of participation rights.

The new permit system adopted by the OFWC became effective January 1,1988. The number of permits was set at 92, the number which had been issued prior to the legislation. Key features included non-transferable permits issued to individual divers, and a permit renewal requirement of 20,000 lb of urchins landed in the previous two years. After a January renewal deadline, any unissued permits were issued through a lottery each spring. Other regulations adopted at the same time included a three inch minimum size limit, a minimum harvest depth of 10 ft at mean-lower-low water (to protect intertidal and adjacent shallow subtidal areas), a daily catch logbook requirement, and a maximum of two divers allowed in the water at any time, per boat.

History of Sea Urchin Fishery Management: Fishery Expansion, 1989-1991.

In the spring of 1989, the OFWC conducted a review of commercial sea urchin regulations. The Commission took no action but expressed an interest to move in a conservative direction in management of the sea urchin fishery, instructing staff to analyze options for controlling effort. In June of 1989, the Commission established a temporary rule to allow a permittee to temporarily transfer his permit if he suffered injury or illness as a result of activities in the sea urchin fishery.

The Commission reviewed the fishery again in November 1989, primarily in response to the fast pace of the fishery and concerns of potential economic overharvest in several areas. The Commission chose to reduce the number of permits through attrition (failure to renew) to 46, and changed the 20,000 pound landing requirement for permit renewal from a biennial requirement to an annual requirement. Because of enforcement concerns over non-permitted people diving for urchins, the Commission restricted the maximum number of non-permitted people on an urchin dive boat to two. The temporary rule allowing medical transfers was made permanent and a two year time limit for the transfer was established.

By fall 1990, many divers expressed concern that the harvest rate was exceeding the goal of sustained economic benefits. Industry leaders were calling for a minimum size increase to 3.5 inches. Staff conducted a yield-per-recruit analysis (Golden et al, 1991) which indicated that an increase in size limit would increase the total gonad weight per harvested urchin. The increased size also offers additional protection to younger urchins, allowing them increased opportunity to spawn before attaining harvestable size. In February 1991, the Commission raised the minimum size limit to 3.5 inches, with an undersize tolerance of 100 urchins between 2 and 3.5 inches. The undersize limit was reduced to 50 urchins per diver in 1992.

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Also in 1990, marine mammal researchers raised concerns regarding interactions between the sea urchin fishery and Northern (Stellar's) sea lions which utilize the offshore reefs. This species produces more pups in southern Oregon than any other area south of Alaska, where sharply declining numbers of animals caused the species to be listed as "threatened" on the federal endangered species list. After a workshop and several public meetings, the OFWC established 1000 ft buffer zones around three major sea lion pupping rocks on Orford and Rogue Reefs. The divers pledged to exercise precautions when operating near the sensitive areas. Buffer zones were closed to all fishing from May 1 through August 31 around Seal Rock and Long Brown Rock on Orford Reef and Pyramid Rock on Rogue Reef. Rules were adopted requiring urchin vessels to display vessel registration numbers on a weather deck to aid aerial enforcement efforts. The industry pledged to work with ODFW staff to annually set and retrieve marker buoys at the four corners of each of the three buffer zones.

Prior to the fall of 1990 very little harvest occurred under the medical transfer provision. Subsequently, a number of medical transfers were approved, and harvest by transferees became significant. Concerns were raised regarding the intent, and possible abuse, of these temporary permit transfers. In 1991, the Commission amended the rules for medical transfers, including: 1) landings on transferred permits were limited to either the poundage taken in the previous calendar year by the original permit holder or 20,000 pounds, whichever was greater; 2) a requirement that the Department limit each medical transfer to 90 days; and 3) no limit on the number of transfers.

History of Sea Urchin Fishery Management: Fishery Stabilization, 1992-1996

Due to interest in experimental harvest of purple urchins, industry asked for a separate size limit for purple urchins. In 1991, the Commission adopted a 2 inch minimum size limit for purple urchins, with harvesting allowed under a special harvest permit. The special permit system allows staff to control harvest, monitor stocks, and create reserve areas. Preharvest surveys are required for prospective harvest areas, and an annual harvest rate (quota) is set at 10 percent of the midpoint of the legal size urchin estimate (12 percent if high numbers of sublegals are present). These rates are based on a harvest philosophy of setting annual exploitation rates equal to estimates of natural mortality in purple sea urchins, using average natural mortality rates taken from Russell (1987). Whenever the cumulative harvest in an area equals two annual quotas, the area is closed. ODFW divers will then resurvey and set quota for a subsequent year, until densities decline to approximately 30 percent of original numbers. Close consultation and cooperation between staff and industry is required. Purple urchin reserves have been established as controls near all harvested areas.

In 1992, the urchin industry established a voluntary closure of Orford Reef from May through October. This closure reduced concerns of economic overharvest on Orford Reef. The intent was to conserve the available resource for harvest for late fall through spring, when weather often precludes harvest from other areas and wholesale prices tend to be higher. As a result of the voluntary closure at Orford Reef, seasonal sea lion buffer zone buoys were deployed only at the Rogue Reef site in 1993 and 1994.

Part of a long term management goal was achieved in March of 1993, when the Commission established subtidal reserves at Gregory Point near Cape Arago and Pirate's Cove in Depoe Bay. The sport and commercial harvest of subtidal invertebrates is prohibited, creating two representative red urchin habitat areas to serve as unfished controls. The two reserves were heavily harvested for red urchins in the past. In addition, Whale Cove (near Depoe Bay), has been closed to all fishing for more than three decades, providing an unharvested third urchin reserve.

Permit lottery cancellations were adopted by the OFWC for the issue years of 1994 and 1995, during a period of fishery permit review by the Oregon legislature. At industry's request, the OFWC adopted rules in December of 1994 to formally close Orford Reef to harvest from May 1 through October 31 of each year. At the same time, the rules for sea lion buffer zones at the two

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areas on Orford Reef were deleted, since urchin harvesting would not be occurring there during the sensitive months. The seasonal no-fishing zone continues at the Rogue Reef site but the use of marker buoys was discontinued effective 1995, ending five seasons of buoy system assembly, placement and retrieval work .

In October of 1995, after nearly two years of debate and dialogue, staff and industry proposed a stable permitting plan which was adopted by the Commission. A new permit target level was set at 30. If permit renewals fall below 30, a lottery will be held for unissued permits. Annual permit renewal poundage was dropped to 5,000 pounds. A new permit may now be created for an individual who buys three "original" permits, effectively retiring two permits. When permit numbers reach 30, single permits will then be directly transferable from one individual to another, no more than once per year. The 90 day medical transfers were restricted to the new annual renewal poundage of 5,000 pounds or 25 percent of the original permit holder's catch in the previous year, whichever is greater. A two year limit on continuous medical transfers was also reinstated.

Red Sea Urchin Harvest and Effort: Statewide

Through 1988, harvest and effort was sporadic due to market limitations. Demand was driven by external forces such as availability of product in other west coast areas closer to established processors. The export uni market has always been highly variable due to seasonal fluctuations in worldwide supply, Japanese demand and local quality. Gonad quality from unfished beds of red urchins is typically low. By 1989 market demand was more stable, with as many as four Oregon processors competing with up to five buyers representing out-of-state processors. Markets were developed for quantities of relatively low quality urchin, creating a more consistent and year-round harvesting pattern. The number of competent divers and boats also increased during this time, as did marketing and processing expertise. The fishery now occurs in numerous harvest areas and is significant in six Oregon ports, from Brookings northward to Depoe Bay (Figure 1).

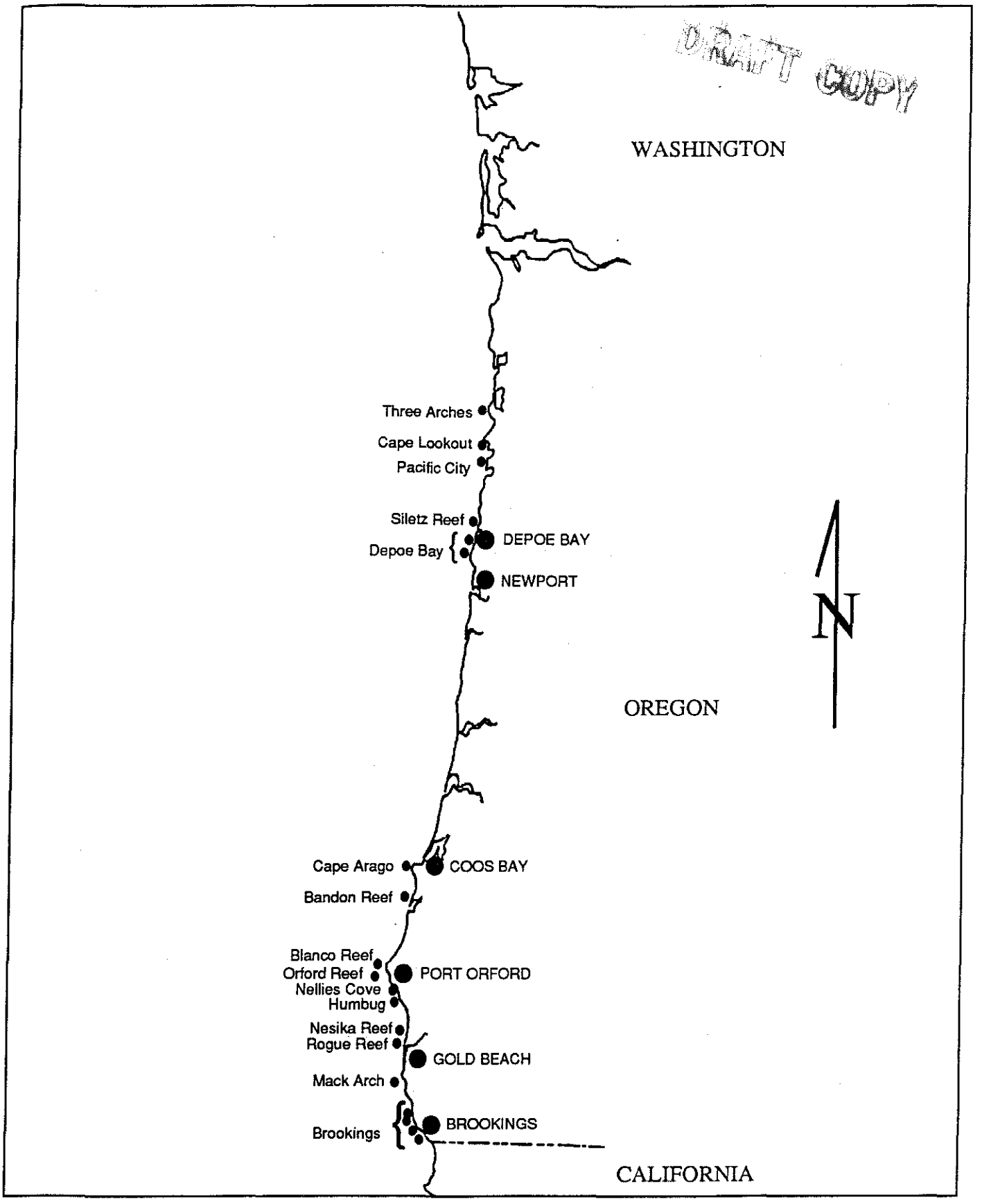

Figure 1. Areas of commercial harvest of sea urchins in Oregon, 1986-1996

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Until 1990, 92 urchin harvest permits were issued annually, either through renewals or lottery. The lotteries held in 1988 and 1989 added substantial numbers of experienced divers, as non-producing permittees dropped out. Only one permit lottery (for two permits) has been held since then, when the number of permits dropped below 46 in 1993. Due to the reduction in the allowable number of permits in 1990, and again in 1995, permit numbers have been decreasing since 1989 (Table 1). The permit reduction trend will continue until the target number of 30 is achieved. 34 permits were renewed for 1997, including the first two permits created under the new 3:1 transfer rule in 1996. The annual number of harvesters includes all permittees which harvested, plus individuals which held temporary medical permits. The contribution to the fishery by these temporary permit holders is described in Table 2. As described earlier, a variety of harvest limitations have applied to the temporary permit holders. The increased numbers of medical transfers in the past three years probably result from the combination of the physical demands of commercial diving on an aging corps of divers and the fact that permanent permit transfers were not allowed until 1996.

Table 1. Summary catch and effort statistics for the Oregon red sea urchin fishery.

	Year										
Category	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Permits Issued	19	162	92	92	72	60	49	46	43	39	39
Harvesters	5	21	47	61	66	58	46	46	45	38	37
Landings (No.)	31	137	869	3,102	4,417	3,389	2,528	2,298	2,031	1,648	948
Pounds (1,000's)	56	203	1,971	7,843	9,321	4,737	2,857	2,183	1,790	1,504	819
Pounds/landing	1,800	1,480	2,268	2,528	2,110	1,397	1,130	949	881	912	864

Table 2. Summary of medical permit transfer activity.

	Year							
Transfer Activity	1989	1990	1991	1992	1993	1994	1995	1996
Number of transfers	7	7	8	0	3	17	16	21
Number of transferred permits	6	6	8	0	3	12	12	13
Number of transfer divers	7	7	8	0	3	9	7	8
# of permits transferred more than once	1	1	0	0	0	3	4	5
% of annual total lbs transferred*	0.0	1.2	6.5	0.0	3.8	5.8	13.7	11.9
Total pounds transferred (1,000's lbs)	0	110	309	0	85	114	212	97

* Includes both red and purple urchin landings.

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Annual catch and effort show a typical pattern of fishery development on unfished stocks, followed by heavy exploitation and most recently, stable but lower catch and effort statistics (Figure 2). Peak numbers of landings and dive hours occurred in 1990 followed by six years of decline. Since late 1994, recurring problems of poor gonad condition have plagued the industry. This is thought to be primarily due to several years of low algal food availability, particularly bull kelp (*Nereocystis leutkeana*). Concurrently, the Japanese market demand for uni has dropped, causing lower and more unstable prices. These marketing conditions have caused divers to be much more selective of what they harvest (quality) and when they harvest (price). While there is undoubtedly less resource available for harvest, highly variable market conditions and selective harvest complicate analysis of trends in catch and effort statistics. Among Oregon fisheries, the urchin fishery is unique in that the harvesters are paid primarily on a cost recovery basis. As all uni is graded before sale, there is incentive to search for and pick what are thought to be the most valuable urchins. This means that at times, not all legal size urchins encountered are equally vulnerable to harvest.

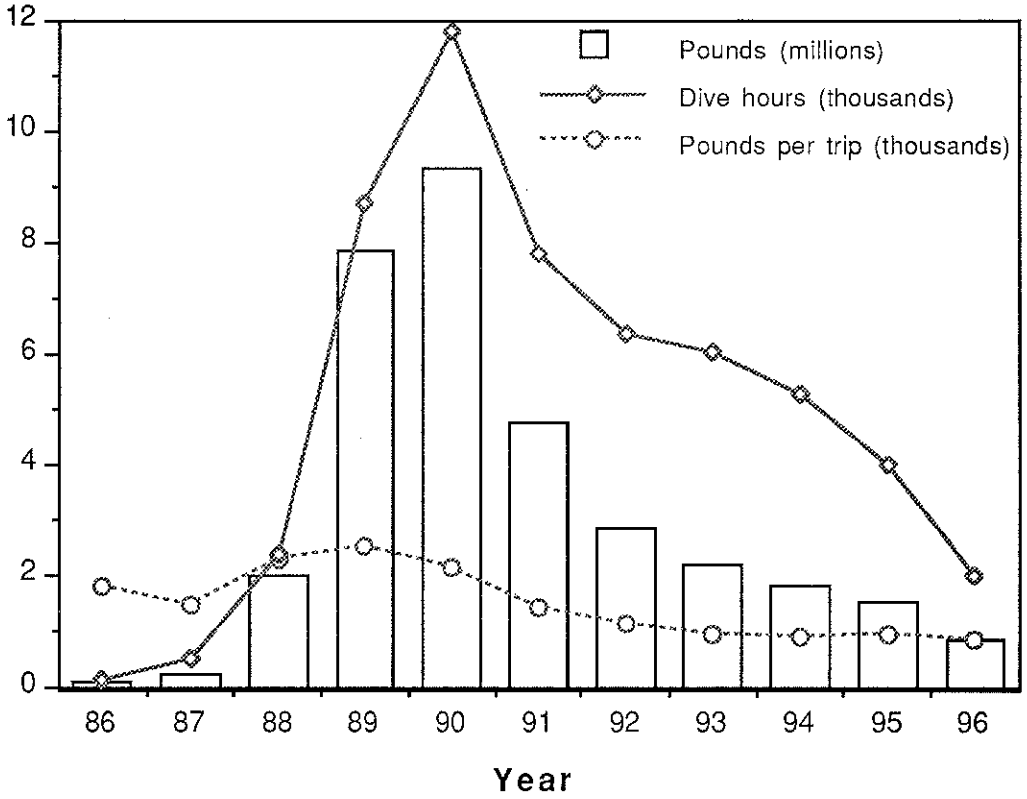

Figure 2. Trends in red sea urchin annual catch, total effort and catch per day.

Oregon urchin divers are fishing more days than initially expected. In a study of the economic viability of harvesting sea urchins in Oregon, Washburn (1984) estimated a maximum of 100 days of harvest would be practical in Oregon due to weather conditions. Even with wide fluctuations in market conditions and weather, the divers have averaged at least one delivery in 265 days of the year since 1988 (Table 3). The lowest year of effort since the fishery developed was 1996, when poor market conditions limited harvest to 188 delivery days. Much of the harvest in Oregon has been at Orford and Rogue reefs. During periods of rough seas, diving conditions at these offshore reefs are more manageable than in nearshore habitats.

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Table 3. Monthly patterns of red sea urchin fishing effort in Oregon (number of fishing days per month).

	Year										
Month	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Jan			7	17	20	20	16	24	21	11	16
Feb		2	14	18	20	23	17	20	20	23	12
Mar		1	9	16	28	27	29	14	26	17	14
Apr		9	14	26	30	25	22	11	23	23	8
May		6	22	31	29	30	30	26	25	24	20
Jun	6	4	22	28	30	29	22	22	26	18	17
Jul	1	1	27	29	29	30	31	25	27	27	6
Aug	5	5	22	30	30	25	24	26	27	31	18
Sep	2	10	27	28	28	25	21	28	25	20	25
Oct	8	21	16	25	20	28	21	26	23	23	22
Nov	5	12	7	22	28	19	24	28	16	14	17
Dec	1	7	16	24	27	22	24	15	17	16	13
Total	28	78	203	294	319	303	281	265	276	247	188

Providing for year-round harvest has been an important management objective of the Oregon urchin industry. Oregon processors require consistent production to be successful, and divers desire year-round harvest opportunity. While weather and markets certainly influenced production, substantial monthly production from early 1988 until late 1995 helped create a niche for Oregon uni in the competitive Japanese export market (Table 4). In contrast, the fishery in Washington is closed for at least April through September and in northern California, a variety of closures occur each month (since 1989) from May through September. These spring to fall closures in neighboring states improve the demand for Oregon urchins at these times, even though gonad recovery rates (quality and quantity) are typically lower.

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Table 4. Oregon sea urchin harvest by month (in thousands of pounds).

	Year										
Month	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Jan			20	218	466	293	167	236	179	45	62
Feb		2	68	358	670	545	233	228	179	253	35
Mar		0.5	36	218	730	489	358	121	235	198	63
Apr		15	56	744	1,022	566	313	116	167	166	38
May		19	135	857	1,012	506	382	266	151	114	58
Jun	17	7	222	865	1,399	401	130	191	147	78	36
Jul	3	0.3	281	819	1,077	625	356	186	171	173	10
Aug	12	6	356	819	922	380	168	148	115	164	45
Sep	3	30	462	1,150	737	272	128	199	182	119	93
Oct	8	74	108	698	310	261	178	175	102	70	126
Nov	11	36	35	462	456	179	229	206	101	81	156
Dec	2	14	192	636	518	221	215	110	61	43	98
Total	56	203	1,971	7,843	9,321	4,737	2,857	2,183	1,790	1,504	819

Until 1994, a substantial portion of the harvest was shipped whole to processors in California, Washington, or British Columbia. More recently, most of the product has been processed in-state. Oregon has had only one consistent processor since 1992, although by late 1996 this company was having difficulty maintaining its processing capability due to poor market acceptance of Oregon urchins. Since late 1994, most of the remaining year-round Oregon divers began exploring at least seasonal alternatives to urchin fishing due to the combination of low ex-vessel prices and reduced urchin abundance. The other permit holders had already established a pattern of seasonal participation in the Oregon fishery by this time.

Red Sea Urchin Harvest and Effort: By Port

The Oregon urchin fishery began in Port Orford, which continues to be the leading port of landing (Table 5). Over the eleven year history of the fishery, a cumulative 62 percent of all urchins have been delivered here. Geographically, Port Orford is well-situated to access many of the offshore reefs and onshore urchin habitats of southern Oregon, including Orford reef, Rogue reef, Humbug mountain, Blanco reef and Nellie's cove. In addition, it supports the only continuously operating processing facility in the state, originally established in 1987 by a company from Fort Bragg, California. It is a unique port, providing safe, direct access to the ocean for the relatively small dive boats. More than half of the kelp bed area in Oregon occurs within a few miles of the port (Waldron, 1955, Ecoscan, 1991), providing a large potential food source for urchins.

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Table 5. Oregon red sea urchin harvest by port (in thousands of pounds).

	Year										
Port	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Garibaldi					20						
Pacific City					20	10					
Depoe Bay / Newport		0.8	11	98	1,373	485	549	549	134	157	17
Coos Bay		0.5	178	64	290	322	86	148	35	19	25
Port Orford	56	153	1,502	6,032	4,915	2,380	1,696	1,099	1,057	698	446
Gold Beach			226	1,586	2,589	1,201	383	260	505	500	300
Brookings		48	54	63	114	339	143	128	58	131	32
Total	56	203	1,971	7,843	9,321	4,737	2,857	2,183	1,790	1,504	819

Gold Beach has been the second most important port in Oregon. Landings there are hampered by nearly constant shoaling problems at the mouth of the Rogue River. During the summer and early fall period, Depoe Bay and Newport have also been important ports. Brookings and Coos Bay have contributed to the landings in a more sporadic manner as they access smaller and more patchy nearshore harvest areas.

Begining in 1990, summertime effort began shifting away from Port Orford, in part due to the placement of seasonal no-fishing zones around nearby sea lion rookeries and as divers expanded their search for urchin concentrations. A consistent summertime shift away from Port Orford occured in 1992, when the current industry-sponsored six month closure of Orford Reef began. Generally milder ocean conditions in the summer allow divers to better work the nearshore areas common to the other ports, plus the offshore Rogue Reef area from the port of Gold Beach.

After 1990, annual landings declined precipitously. In 1991, the average daily landings per diver show a sharp drop in Port Orford and Gold Beach (Table 6), indicative that the known beds had been hit hard, and no substantial new urchin beds were exploited. A nearly identical trend occurred in the following year at the ports of Depoe Bay/Newport, Coos Bay and Brookings, where relatively smaller harvest areas experienced heavy fishing pressure as fishermen expanded their search for urchins.

Table 6. Average pounds per landing of red sea urchins, by port.

	Year										
Port	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Depoe Bay-Newport		193	781	2,731	2,735	1,988	1,313	1,148	1,118	1,111	1,024
Coos Bay		,499	2,442	3,756	3,873	2,387	1,328	1,003	536	924	682
Port Orford	1,801	1489	2,300	2,540	1,942	1,226	1,078	858	842	781	827
Gold Beach			2,481	2,431	2,087	1,337	1,049	948	966	1,032	933
Brookings		1,662	1,411	2,756	2,070	2,040	1,326	1,074	865	1,203	918

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Red Sea Urchin Harvest and Effort: by Harvest Area

Diver logbook returns have covered a minimum of seventy percent of red urchin deliveries each year. The list of red urchin harvest areas naturally grew as the scope of the fishery expanded. The catch areas hailed in logbooks have been aggregated into 15 harvest areas. Table 7 reports the annual and cumulative harvest estimates by area since the fishery began. Some of the listed harvest areas are combinations of subareas as follows: Depoe Bay area is the entire strip from Government Point on the north to the isolated rocks south of the Otter Crest/Cape Foulweather area; Cape Arago area extends from the Coos Bay jetties on the north to the south cove of Cape Arago; Bandon reef includes the rocky areas south of the Bandon jetties; Humbug Mountain includes the coastline of Humbug mountain plus nearby Redfish Rocks and Island Rock; and the Brookings area includes the entire coastal strip from the California border up to (not including) Mack Arch. The harvest areas not described above are discrete geographical areas named on navigational charts, except for Siletz reef (north of the Siletz river mouth) and Nesika reef (off Nesika Beach, also referred to as Breakers reef).

Table 7. Red sea urchin catch by harvest area, in thousands of pounds.

	Year					
Area	1986	1987	1988	1989	1990	1991
Three Arches	0	0	0	0	9	0
Cape Lookout	0	0	0	0	19	5
Pacific City	0	0	0	0	28	0
Siletz Reef	0	0	0	0	382	9
Depoe Bay	0	0	14	110	1,053	398
Cape Arago	0	0	185	86	336	317
Bandon Reef	0	0	61	0	0	0
Blanco Reef	0	0	20	16	28	251
Orford Reef	0	54	1,291	5,341	3,477	2,018
Nellies Cove	52	77	118	8	47	19
Humbug Mt.	4	22	30	149	569	99
Nesika Reef	0	0	0	0	429	62
Rogue Reef	0	0	205	2,102	2,880	1,146
Mack Arch	0	0	0	0	0	0
Brookings	0	50	45	39	75	403
Total	56	203	1,971	7,843	9,321	4,737

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Table 7 (Continued). Red sea urchin catch by harvest area, in thousands of pounds.

Area	Year					
	1992	1993	1994	1995	1996	Cumulative
Three Arches	0	0	0	0	0	9
Cape Lookout	0	0	0	0	0	23
Pacific City	0	0	0	0	0	28
Siletz Reef	89	146	0	62	0	688
Depoe Bay	514	505	151	125	19	2,889
Cape Arago	74	184	29	8	14	1,234
Bandon Reef	0	0	0	0	0	61
Blanco Reef	49	50	38	20	14	485
Orford Reef	1,349	695	931	321	286	15,763
Nellies Cove	14	7	5	5	4	355
Humbug Mt.	103	149	39	147	81	1,391
Nesika Reef	51	10	0	100	19	670
Rogue Reef	446	295	482	546	340	8,441
Mack Arch	0	52	34	42	11	139
Brookings	166	94	79	127	33	1,110
Total	2,857	2,183	1,790	1,504	819	33,284

In the first two years, urchins from Nellie's cove provided the largest share of the modest totals. This relatively small, protected area consists of the coves immediately adjacent to Port Orford. For the next seven years, Orford Reef was the leading harvest area. This offshore collection of seastacks has a nearly continuous rocky seafloor of approximately ten square kilometers in surface area. The cumulative harvest here is an estimated forty-seven percent of all urchins harvested in Oregon(Figure 3). Rogue Reef is another significant offshore reef composed of seastack islands, contributing an additional twenty-five percent of the total harvest. In 1995 the annual harvest here exceeded Orford Reef for the first time. Rogue Reef is similar to Orford Reef but somewhat smaller and more difficult to access on a year-round basis. The high removal rates from 1989 through 1991 at these two reefs give some indication of prefishery urchin abundance.

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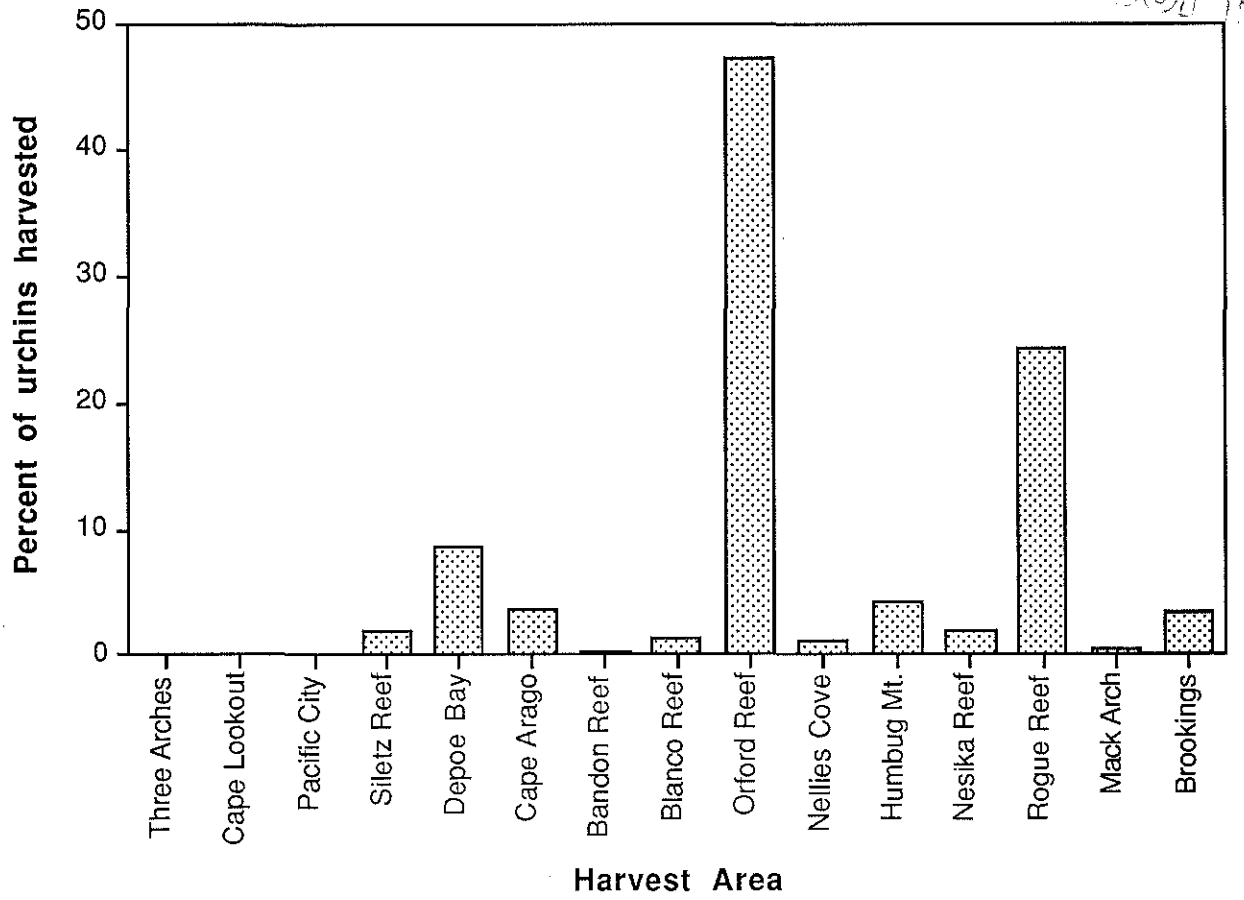

Figure 3. Proportion of total fishery removals by harvest area

The pattern of high volume fishing through 1990 is evident from the pounds per landing trend (Figure 2), but this level was maintained by expansion of the fishery into unfished areas. In the summer of 1990, many of the divers moved to a variety of areas, including Depoe Bay, Siletz Reef, Humbug Mountain, Nesika Reef and Cape Arago. These areas had been relatively lightly fished or unfished in prior years. Statewide catch per hour was also temporarily supported in this way, but dropped sharply from 1991 to 1993 as fewer new areas were discovered (Table 8). Catch per hour has since leveled off, remaining at about 350 pounds per hour. The available fishing grounds were also expanded as divers gradually increased their time spent in deeper waters, reaching an average depth of 51.6 feet in 1991 (Figure 4). As urchins in the deeper areas were harvested, divers spent more time in previously harvested areas looking for "regrowth". Average depth of harvest has remained at less than 50 feet since 1991. Divers now rely on recruitment of new year-classes and movement of deep or cryptic urchins into workable areas. Because harvesters are paid on a complex recovery basis, there is incentive to work the shallower algae beds, where higher quality can offset lower quantity. In general, shallow water diving is preferred, where the physical risk of diving is less unless sea surface conditions are severe.

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Table 8. Red sea urchin catch per unit of effort in lb/dive hr, by harvest area.

	Year										
Area	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Siletz Reef					929	535	507	366	243	346	
Depoe Bay			125	844	1069	702	458	400	381	441	321
Cape Arago			811	1187	1029	636	340	336	215	455	302
Blanco Reef			600	812	364	680	106	487	676	381	509
Orford Reef		173	927	729	736	551	461	366	294	316	403
Nellies Cove	147	386	84	733	679	413	540	443	247	201	245
Humbug Mt.	886	465	804	777	700	503	137	345	283	255	312
Nesika Reef					776	559	792	567		460	321
Rogue Reef			766	1314	832	615	346	439	451	499	493
Mack Arch								611	401	793	704
Brookings		353	794	933	1087	740	721	412	442	521	481
Statewide	412	412	825	899	789	608	450	362	339	376	421

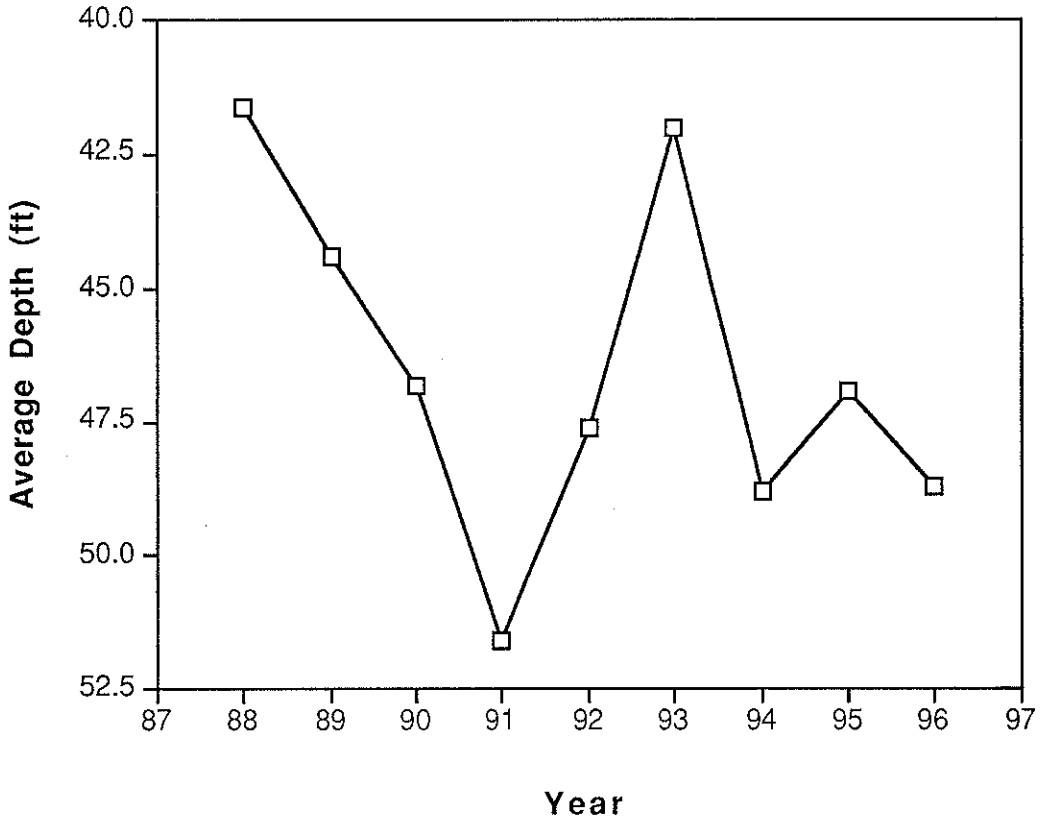

Figure 4. Average reported depth of red sea urchin harvest in Oregon.

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Red Sea Urchin Market Sampling

We have attempted to gain representative sets of market samples annually from each of three indicator areas, chosen for both proximity to samplers and importance to the fishery. Annual stratification of samples should adequately document trends in landed size composition, since average annual growth of legal size red sea urchins has recently been shown to be less than 10 mm, often much less (Ebert, 1997). We have not dedicated large amounts of staff time to the sampling effort, although at times we have been able to opportunistically sample in combination with other projects and programs. Most notably, in certain years we had help from ODFW salmon and finfish samplers in Port Orford and Newport. In recent years, the reduced size of the fishery has limited sampling opportunities. A summary of sampling efforts by year and area is presented in Table 9.

Table 9. Test diameter (mm) of red sea urchins from market samples.

			Area					
	Total		Depoe Bay		Orford Reef**		Rogue Reef	
Year	average (mm)	N (urchins)	average (mm)	N (urchins)	average (mm)	N (urchins)	average (mm)	N (urchins)
1986	107.8	150						
1987	121.4	185						
1988	113.5	732			113.2	702	120.6	30
1989	122.1	3,232	113.6	33	120.4	2,521	128.6	678
1990	127.0	11,571	130.4	367	129.2	6,711	126.8	1,761
1991	117.7	5,025	113.5	330	116.6	3,095	122.6	975
1992	117.1	2,974	119.0	350	117.2	1,999	119.7	150
1993	108.5	3,645	105.1	1,149	109.8	2,022		
1994	111.5	1,919	111.2	262	110.2	1,307	120.2	200
1995	116.4	950			116.3	700	114.3	200
1996	109.4	1,000	101.1	50	108.5	350	110.6	600
1997					106.5	1000		

** Sample year: Oct. 1 of preceeding year through Sept. 30.

As a result of a somewhat patchy sample distribution, we chose only the Orford Reef data set to investigate trends in average landed size. Estimates of average size, 95% confidence limits and percentage greater than 127mm are presented in Figure 5. We resampled the 1991 data set (N=62 samples) to probe the relationship between sample error and numbers of samples. Five trials of randomly selected samples were chosen in increments of 5 up to 55 samples. A power curve was constructed with the 95% confidence interval expressed as a percent of the mean versus the number of samples (Figure 6). Visual inspection of both the power curve and the distribution of sample means led us to exclude from the ANOVA the sample years with less than 20 samples. The three sample years exluded were 1988, 1995 and 1996.

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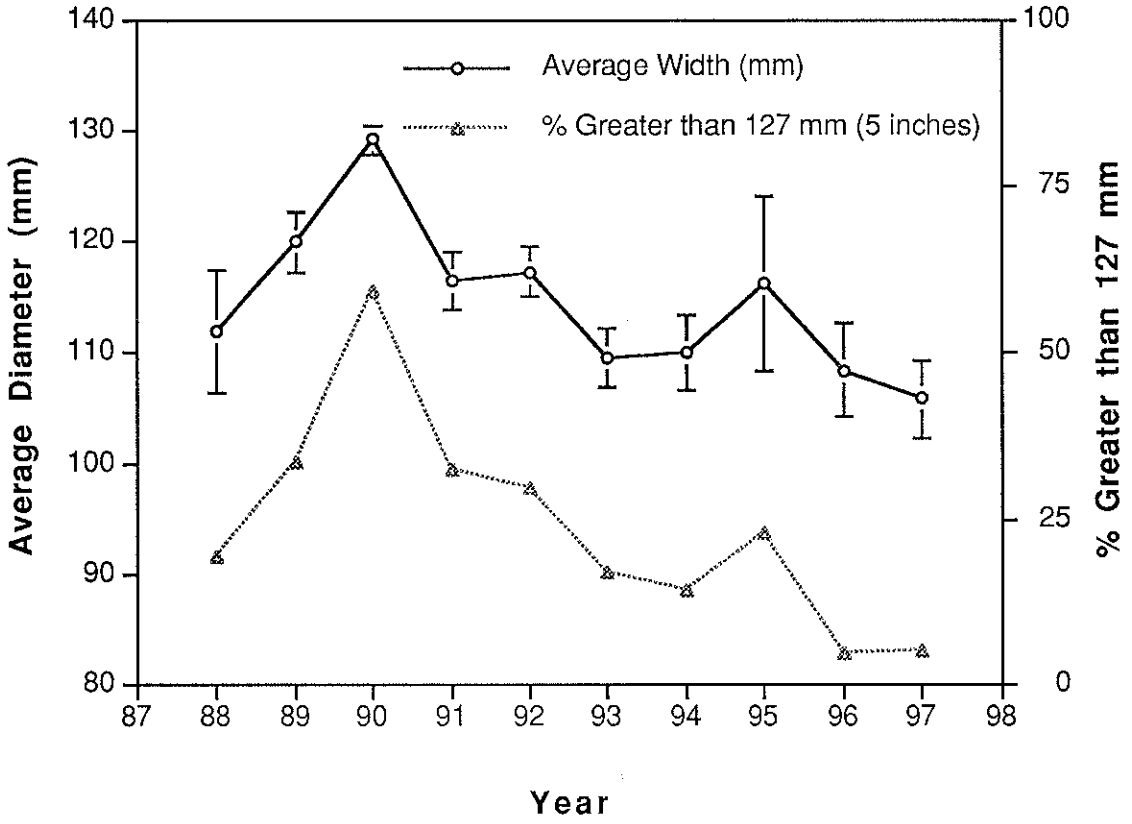

Figure 5. Average size and proportion greater than 127 mm of red sea urchins at Orford reef from market samples (error bars indicate 95% confidence limits of average diameter) .

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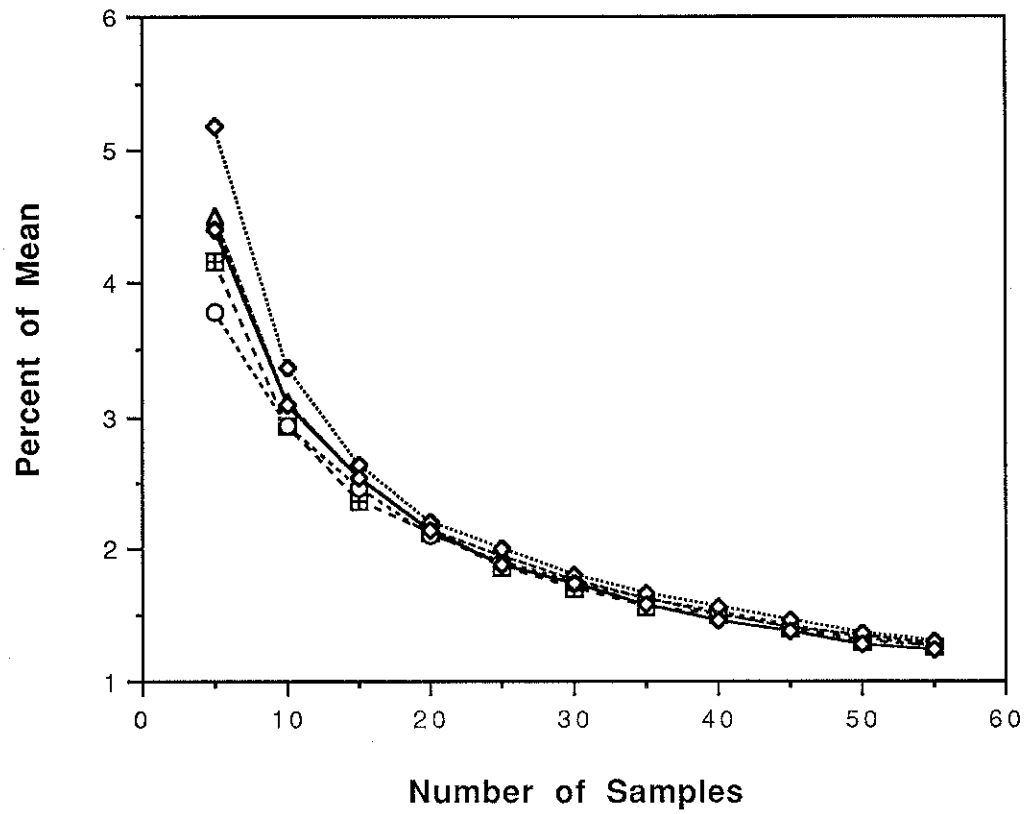

Figure 6. Relationship between the 95% confidence interval expressed as a % of the mean and the number of market samples from Orford Reef, using resampled data from 1991.

The results of the ANOVA included paired comparisons between seven years with adequate sample size, using the annual mean of sample means as the dependent variable and year as the independent variable. The years where the hypothesis of non-equal means was rejected (at specified levels of significance) are presented in Table 10. The mean size for 1990 was significantly larger than all other years, which reflects the peak of the virgin stock fishery. The lower mean size in 1989 probably reflects a more size selective harvest in the early years, before markets were fully developed to accept the very largest urchins. The 1997 mean size is significantly smaller than all years prior to 1993.

Table 10. Significant between-year differences of red urchin mean size, from Orford Reef market samples: results of one-factor ANOVA.

Year	N (samples)	Mean Size (mm)	Years Larger	Years Smaller
1989	59	120.0	1990**	1993**, 1994*, 1997**
1990	135	129.3		1989**, (1991 - 1994)**, 1997**
1991	62	116.5	1990**	1997*
1992	40	117.3	1990**	1997*
1993	42	109.7	1989**, 1990**	
1994	26	110.2	1989*, 1990**	
1997	20	106.5	1989**, 1990**, 1991*, 1992*	

* $P < .01$
** $P < .001$

A limited set of market samples was taken in 1987 and 1988 which included measurements of diameter as well as sex, total weight, drained weight, and gonad weight. Sex ratio was 49:51 males to females from two samples which were in obvious spawning condition. Urchins of the same diameter can exhibit large differences in all three of the above weight measurements. These differences are due to a variety of factors including food availability, spawning condition, and water and ingested material retention within the test. Figure 7 is a plot of total weight versus test diameter from mid-summer samples of 208 urchins landed at Port Orford in 1986.

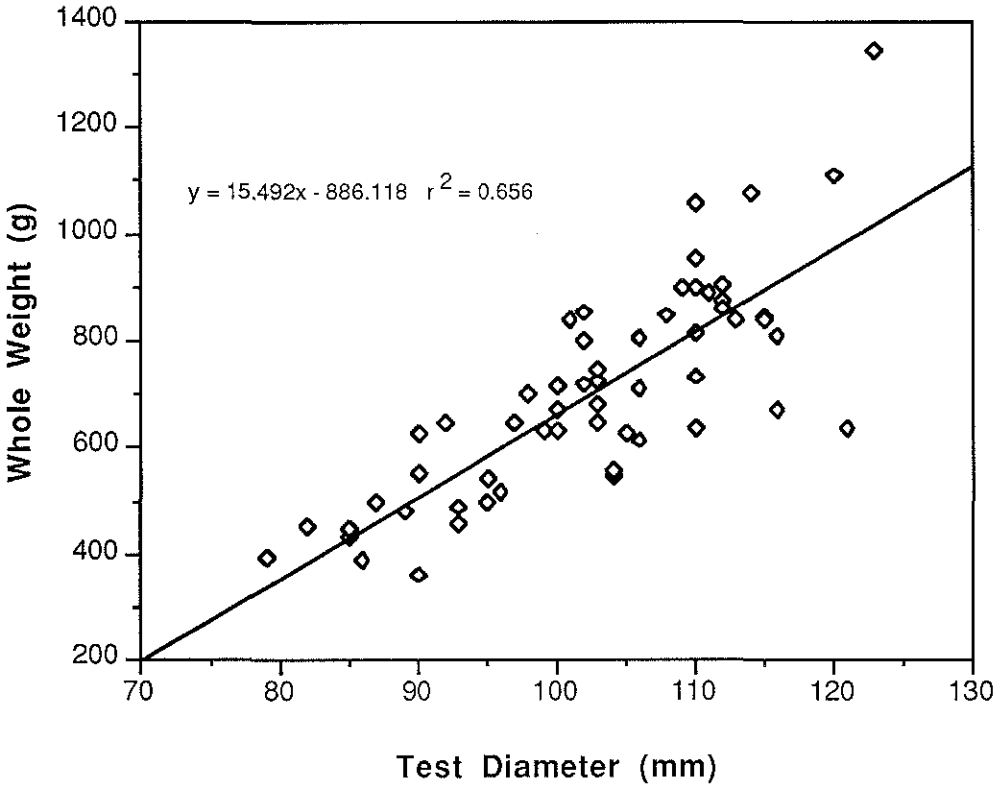

Figure 7. Relationship between red urchin test diameter and total weight.

We found highly variable amounts of water and ingested organic matter inside red urchins sampled from the commercial landings. A single sample of 58 red urchins (size range 79 to 123 mm) exhibited a mean weight loss of 21.9 percent after being cracked and drained of water and ingested material for several minutes. We observed no trend in proportional weight loss as a function of urchin size. The drained weight lost by individual urchins varied greatly, ranging from 3.3 percent to 38.6 percent of the whole weight.

To minimize this source of variablility we used drained urchin weight to investigate the gonad recovery relationship. To account for seasonal variability in gonad mass, the available data were divided into two seasonal sets of gonad weight/drained weight data pairs. Figure 8 displays the seasonal relationships between urchin drained weight and gonad weight. Samples from two separate time periods were available: April and May, when most animals are spawning or recently spawned; and September through November, a time of gonad recovery when food in excess of somatic growth needs is being converted to gonad mass. We found very little relationship between test diameter and gonad mass for any seasonal grouping, other than a weak correlation (r^2 = .5) for April-May samples.

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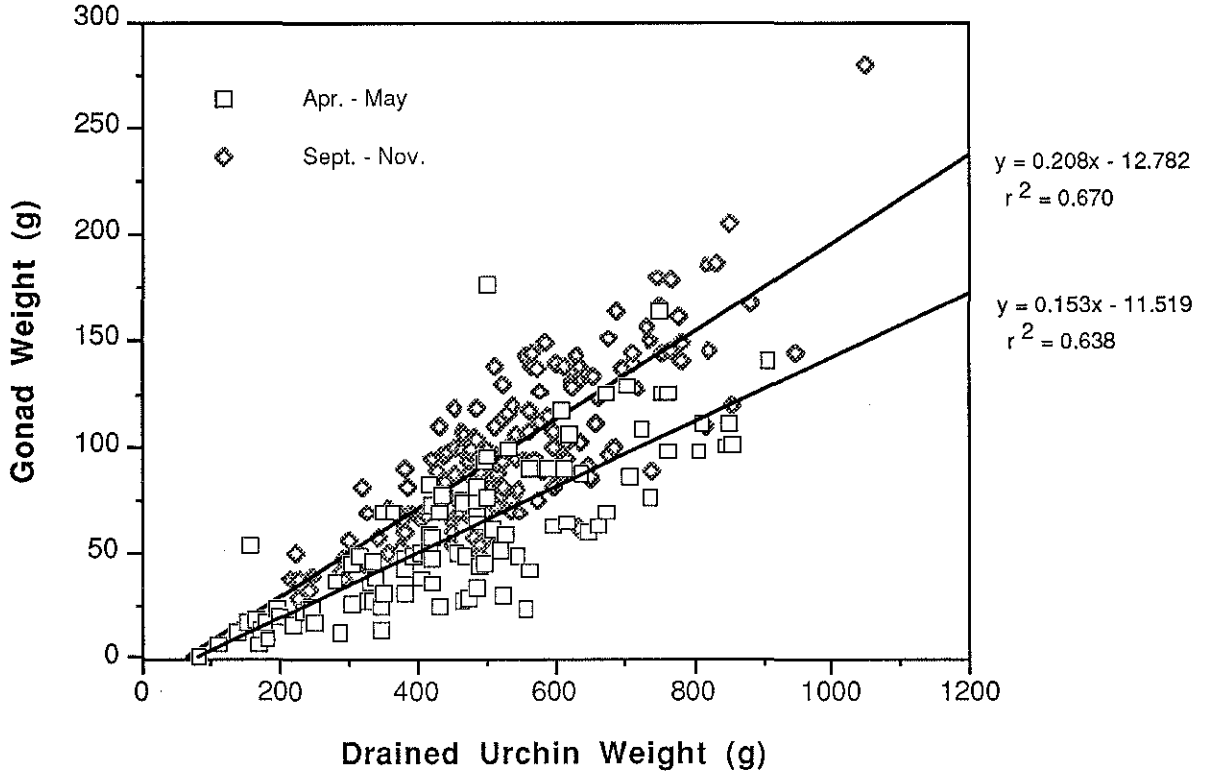

Figure 8. Relationship between red urchin drained weight and gonad weight.

Purple Sea Urchin Surveys, Harvest and Effort

A limited purple urchin fishery began in 1991. This species apparently does not have an established niche in the Japanese market, and only Oregon and California allow for limited fisheries within the species' range (at least north of the Mexican border). Contained in Table 11 are the results of preharvest purple urchin surveys by commercial divers; also included are the cumulative harvest quotas established for each area. Figure 9 is a series of maps of the permitted harvest areas. Annual and cumulative purple urchin harvest estimates by permit area, are presented in Table 12. The pattern of harvest has been episodic, with quality and marketing controlling all harvest. The pulses of fishing effort have mostly occurred from August through October, reflective of efforts to matchup markets and gonad quality. The highly-aggregated habit of purple urchins apparently causes highly-variable gonad condition, such that most of the urchins are unmarketable for much of the year.

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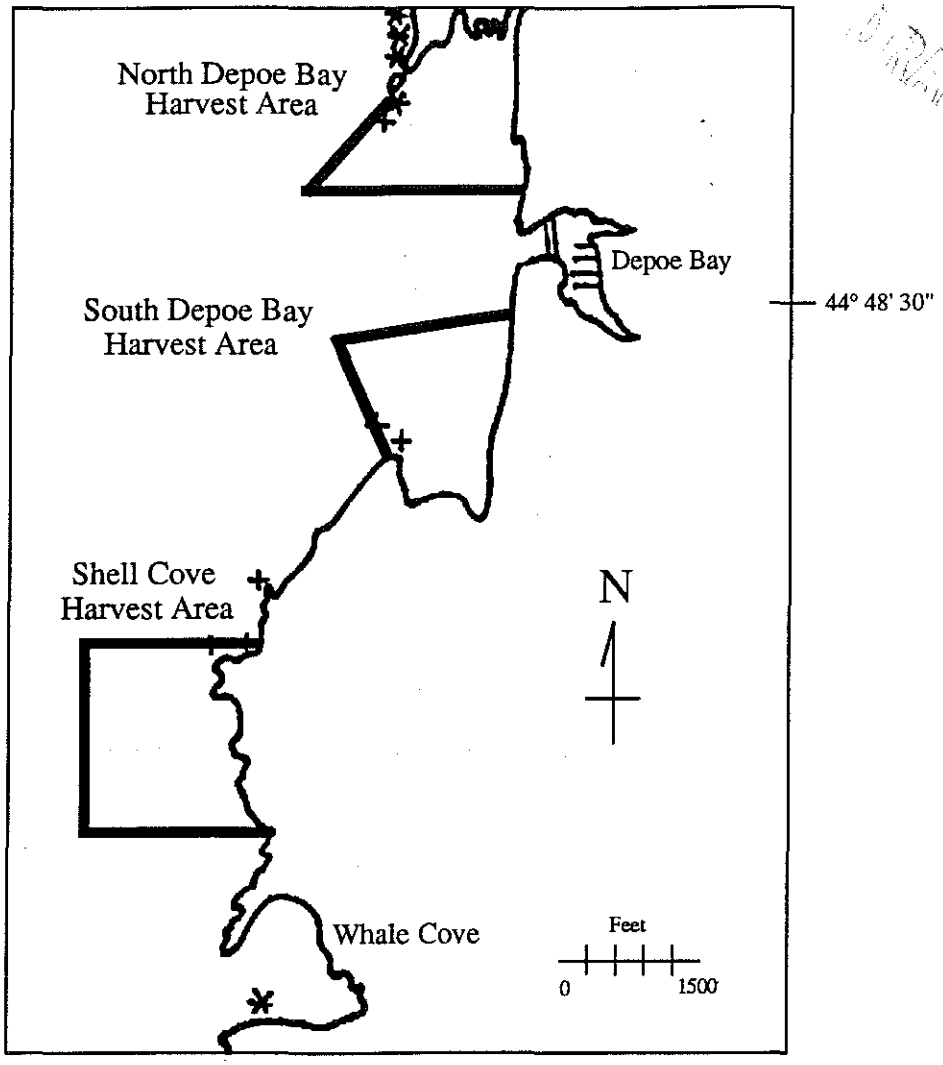
Table 11. Purple urchin pre-harvest density, mean size, and percent sublegals from commercial diver surveys.

Area	Density (sq m)	Mean Size (in)	Percent < 2 in	Quota Established
N Depoe Bay	108	2.5	2.1	100,000
S Depoe Bay	72	2.6	13.4	100,000
S of Shell Cove	49	2.4	8.3	100,000
Cape Foulweather	51	2.0	42.5	0
Gull Rk	114	2.6	5.6	50,000
Arago Lighthouse***	164	2.9	11.5	0
Sunset Bay***	185			0
Simpson Reef A (Survey #1)	148	2.7	16.4	130,000 (A&B)
Simpson Reef A (Survey #2)	124	2.7	16.9	
Simpson Reef B	135	2.5	26.1	
Arago X	93	2.4	10.9	75,000
Arago C	60	2.7	9.0	30,000
Cape Blanco	128	2.5	27.8	10,000
Klooqueh Rk	112	2.4	26.9	10,000

*** Reserve area; no harvest permits issued

Table 12. Estimated harvest of purple urchins in Oregon, by area.

	Year					
Area	1992	1993	1994	1995	1996	5 year total
N Depoe Bay		5,488	10,003	2,224		17,715
S Depoe Bay	39,916	23,216	11,411	5,852	675	81,070
S of Shell Cove	26,981	317	702			28,000
Cape Foulweather	15,256		1,983			17,239
Simpson Reef (A & B)	16,279	5,214	124,796	33,192		179,481
Arago X			26,417			26,417
Arago C			16,800			16,800
Nellies Cove	89					89
Klooqueh			4,030	371		4,401
Blanco			966	720		1,686
Total	98,521	34,235	197,108	42,359	675	372,898



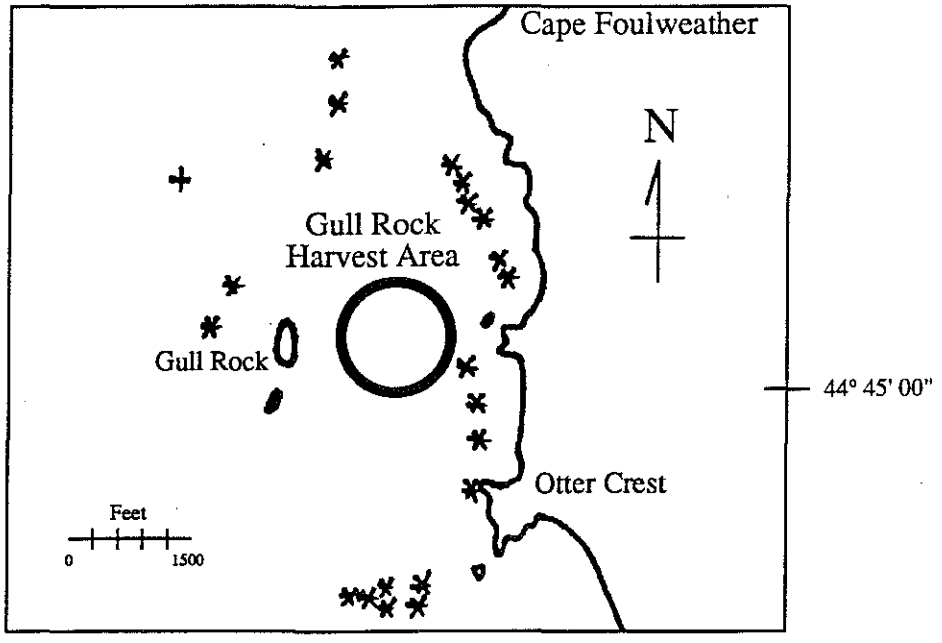


Figure 9a. Purple urchin harvest areas, Depoe Bay sites.

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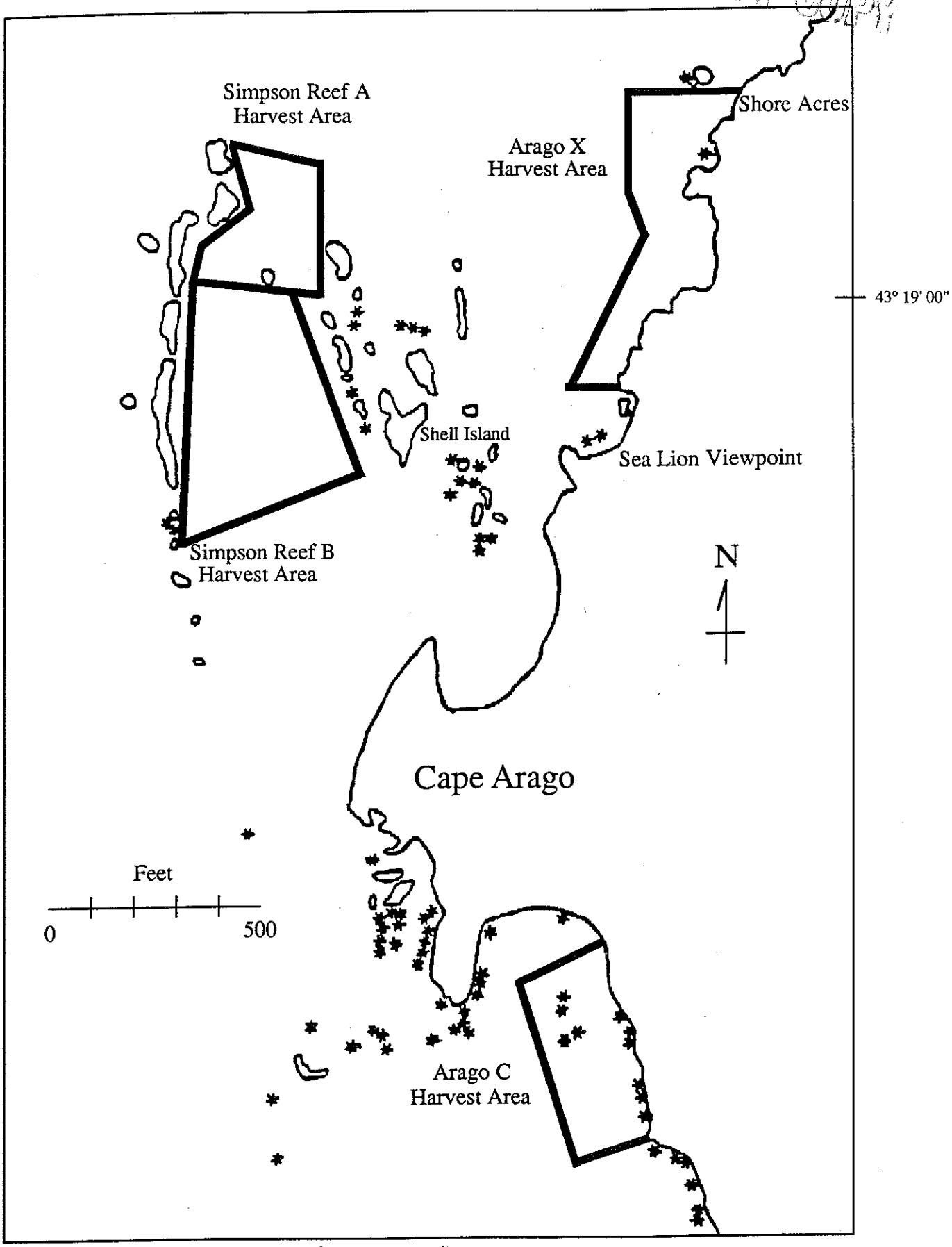

Figure 9b. Purple urchin harvest areas, Cape Arago sites.

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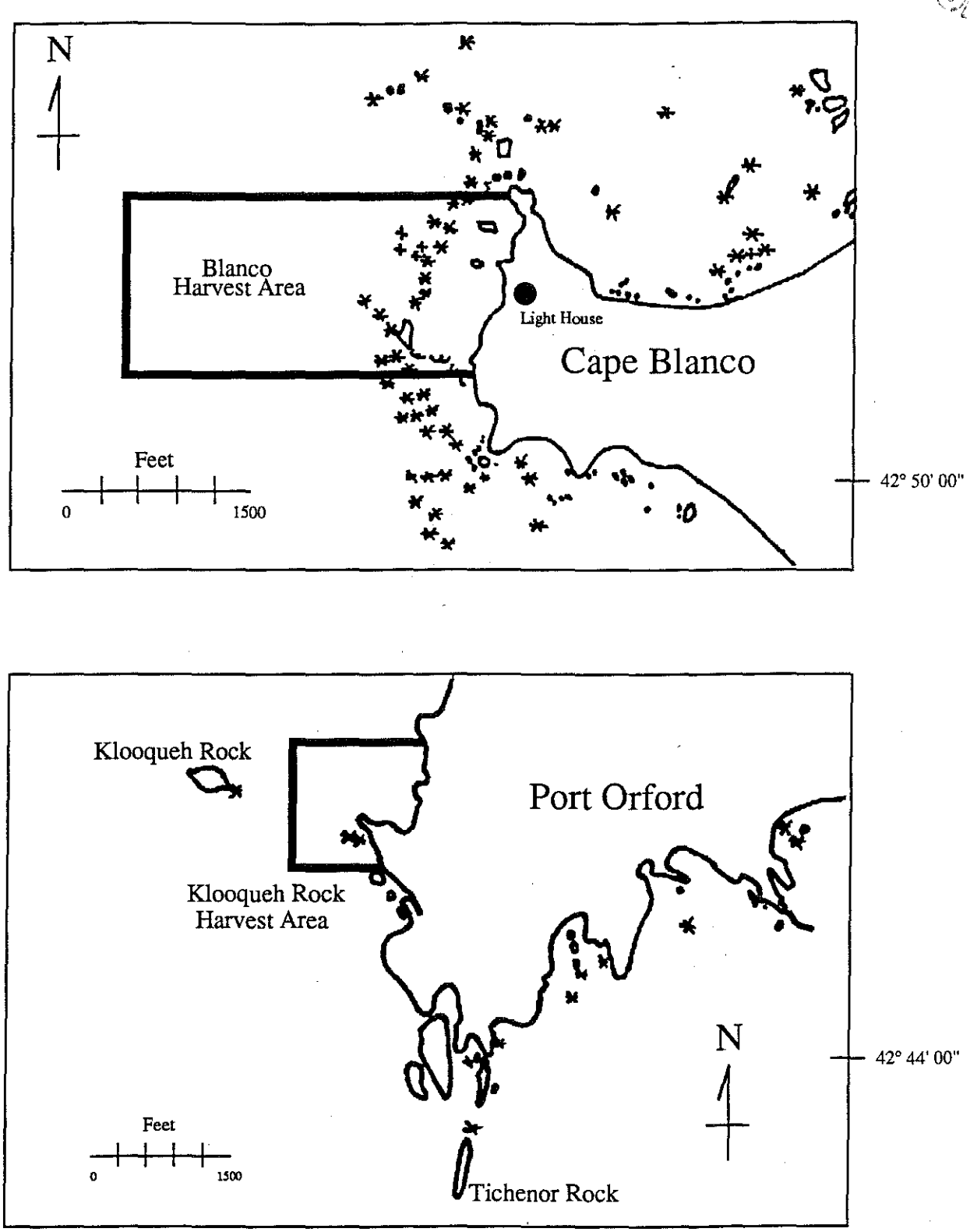

Figure 9c. Purple urchin harvest areas, Port Orford sites.

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Landed Value of Sea Urchins

The market for urchins is extremely volatile at all levels. Divers are currently paid based on a complex set of variables, including but not limited to foreign exchange rates, gonad recovery rates, quality of roe and worldwide supply and demand for competing urchin products. In the past, when the available resource was relatively large, markets were developed for large volumes of "sea-run" catch. Now, the divers and buyers are much more quality conscious and effort shrinks to very low levels when the ex-vessel price is low. There continue to be periods of time with no harvest effort, due to low market demand or because quality is unacceptable. These market conditions are apparently due to both unfavorable foreign currency exchange rates and low algal productivity. The latter problem has especially plagued the fishery since the fall of 1995 and presently continues into summer of 1997. The available ex-vessel price and value data are presented in Table 13.

Table 13. Ex-vessel price and value of the Oregon urchin fishery

Year	Lbs Landed	Annual Value	Ex-vessel Price per Pound: Yearly Average	Ex-vessel Price per Pound: High Monthly Average	Ex-vessel Price per Pound: Low Monthly Average
Red Urchins					
1986	55,820	$12,076	0.22	0.90	0.15
1987	202,799	$46,085	0.23	0.40	0.22
1988	1,970,963	$530,424	0.27	0.47	0.23
1989	7,842,658	$2,690,837	0.34	0.48	0.25
1990	9,320,868	$4,529,951	0.49	1.00	0.40
1991	4,736,872	$3,795,952	0.80	1.24	0.38
1992	2,857,392	$2,212,906	0.77	1.67	0.36
1993	2,183,066	$1,908,815	0.87	1.68	0.49
1994	1,789,598	$1,373,040	0.77	1.21	0.47
1995	1,504,272	$1,202,832	0.80	1.19	0.64
1996	819,483	$431,405	0.53	0.98	0.35
Purple Urchins					
1992	96,883	$65,849	0.68	1.08	0.23
1993	34,235	$20,808	0.61	0.95	0.50
1994	197,109	$105,248	0.53	1.45	0.45
1995	42,359	$21,186	0.50	0.73	0.20
1996	675	$68	0.10	0.10	0.10

SUMMARY

One key to the current status of the urchin fishery is the broad authority given to the OFWC by the legislature to control effort. The Oregon urchin industry also deserves much credit for advocating red urchin conservation and fishery management measures. Their strong stewardship of the resource is a direct benefit of the limited access permit system. The increase in size limit, reductions in permit numbers, and seasonal closure of Orford reef were all proposed by industry leaders. These three management adjustments were key changes that brought a new, explosive

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fishery into a more mature and stable period. While harvest rates were initially very high, the sheer volume of product early in the fishery helped insure the market development and subsequent quality of the Oregon urchin fishery.

The eventual decline in average size and catch per unit of effort should be expected in any virgin fishery on a species with life history traits such as the red sea urchin in Oregon. The challenge was to balance a small industry's survival with the needs of the resource. Total effort levels in the past three years are less than one fourth the peak levels of 1989 and 1990. Total fishery effort continues to drop, due to marketing problems more than resource abundance. Meanwhile catch per unit of effort declined to less than half of peak levels by 1993 but has since remained fairly steady. While high catch rates were maintained for several years, they were accomplished by divers steadily moving into new areas. Now that much of the accumulated older urchins have been harvested, the fishery will rely more on recruitment pulses and growth rates rather than finding pockets of unfished urchins. The recent permit transfer and limitation regulations represent years of deliberation over a long-term fishery plan. It is widely felt that the goal of 30 transferable permits will be a good match of potential effort to the size of the Oregon resource.

Overall, industry compliance with urchin fishery regulations has been good. The most serious offenses resulted in citations issued by Oregon State Police for two occurrences of harvesting without urchin permits. In both cases, the permitted individuals were acting as the dive tenders on boats while unpermitted people were harvesting urchins. In one case, the fishing vessel involved was seized as a result of repeated violations. Several cases of exceeding the harvest limits on medical transfers have been made, including one where the temporary diver claimed an unlimited right to harvest. Other violations include one case of purple urchin harvest in an unpermitted area and several cases of exceeding the undersize urchin limit. Protection of undersize urchins will be a primary enforcement focus in coming years.

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