REP. FRED MOORE III

State of Maine
118th Legislature
Second Regular Session - 1998

Sea Urchin Research Fund

A Report to the Joint Standing Committee on Marine Resources

January 1998

Submitted by

Maine Department of Marine Resources

Executive Summary

The Commissioner of the Department of Marine Resources (DMR) is required to submit a final report on expenditures from the Sea Urchin Research Fund and research findings to the Joint Standing Committee on Marine Resources by January 1, 1998. The Sea Urchin Research Fund was established from surcharges assessed on sea urchin licenses beginning in 1995. Input on research needs was obtained through an informal process with the industry and scientific community in 1995, and through a more formal process with the establishment of the Sea Urchin Zone Council in 1996.

This report summarizes the research that has been conducted by the Department and other researchers with funding from the Sea Urchin Research Fund. A competitive grants program was established in the Fall of 1995 to solicit research proposals on biological and economic questions posed by the industry and scientific community. Project proposals were solicited to better understand larval supply, juvenile distribution, settlement and growth; to define spatial and temporal patterns of distribution; to design a survey to obtain abundance and recruitment information; and to determine the economic characteristics of the fishery and markets for the green sea urchin in order to evaluate the use of a roe-yield standard as a management tool. At the same time, the DMR established a sampling program to collect biological and effort data from the fishery and a logbook program to collect landings data from the sea urchin processors and buyers. Research to address the impacts of sea urchin dragging were initiated in 1997. The Sea Urchin Zone Council has recommended continued monitoring of sea urchin catches and the establishment of conservation areas for research.

Table of Contents

Table of Contents, continued

Sea Urchin Research Fund, 1996-1997

In 1995 a working group of industry members and state and university scientists was established to discuss management and research needs for the sea urchin fishery. Extensive discussions led to the identification of four areas of sea urchin research:

1. Fishery sampling to collect information on catch and effort;
2. Dealer logbooks;
3. Life history; and
4. Economic characteristics of the fishery.

A fifth area of research was added in 1997: to determine the impacts of sea urchin drags. The Department of Marine Resources (DMR) initiated the fishery sampling and dealer logbook programs with existing staff. The other areas of research have been addressed through a DMR-administered competitive grants program with university researchers.

Status of the Fishery

Sea urchin landings rose sharply beginning in 1987, reaching a peak of over 41 million pounds in 1993 (Figure 1). The decline has been just as sharp with landings estimated at only 24.4 million pounds three years later in 1996 (Table 1). Sea urchin harvesting licenses have followed a similar pattern (Table 2).

Information obtained from commercial port sampling (CPUE - Catch Per Unit Effort) as well as anecdotal sources (discussions with commercial harvesters on the wharfs) indicates that the status of the resource has not improved and continues to decline. The rate of decline between the 1995/1996 and 1996/1997 dive fisheries was not dramatic however, and hopefully may indicate some progress toward stabilization. Recent size frequency information reveals that compliance with the 2-inch restriction has improved. The activities of Marine Patrol probably had a significant impact on this observation. One of the most common complaints voiced by harvesters on the wharfs concerns the matter of 120 calendar diving and dragging days. Harvesters believe they are subjected to serious safety risks when they feel they must dive under hazardous conditions in order to maintain a reasonable livelihood.

<u>Fishery Sampling</u>

Ted Creaser and Margaret Hunter, DMR scientists, established a dockside sampling program in December 1995 to monitor the status of the sea urchin fishery. The primary objectives of the commercial sea urchin port sampling program during the 1996/1997 season were to improve the methodology involved in the selection of buying/sampling stations as well as to collect catch, effort, CPUE and size (diameter, weight) sex, and condition factors through harvest interviews and samplings of the commercial catch. An attempt has been made to proportionally allocate the numbers of buying stations sampled within each county or combination of counties (Sagadahoc/Lincoln, Knox/Waldo). More interviews and samples have therefore been obtained in counties with more buying stations. The major difficulty encountered when sampling by proportional allocation, is the constant change in the numbers and locations of buying stations during the course of the season; buyers come and go and it is never certain how many active buyers there are in each county at one point in time. Attempts were made to sample two buying stations per week (one in each zone) during weather conditions when many harvesters were active. Different buying stations were sampled during each trip.

During the 1996/1997 season, port samplers interviewed 425 divers and 85 draggers. The breakdown of diver interviews by county was York (18), Cumberland (27), Sagadahoc/Lincoln (47), Knox/Waldo (101), Hancock (110), Washington (122). Dragger interviews were Sagadahoc/ Lincoln (1), Knox/Waldo (10), Hancock (12), Washington (62). Port samplers also measured and weighted 10,675 urchins; 3,721 from 186 catches in Zone 1 and 6,914 from 346 catches in Zone 2.

<u>Catch, Effort, CPUE, and Size Information From Interviews and Samples</u>

A summary of catch/effort and other information from diver and dragger interviews during the 1996/1997 season is shown in Appendix 1 (Tables 1 and 2). The average depth fished by divers is 8.4 - 24.5 ft, average catch (lbs) per diver day is 606.7 lbs, average percent roe is 12.2%, and average number of bottom hours is 3.4 hrs. The average depths fished by draggers is 22.6 - 54.8 ft, the average lbs per dragger day is 526.6 lbs, the average percent roe is 13.4%, average hours fished is 5.4, average minutes/tow is 7.4 and the average number of tows/day is 34.5.

CPUE for both divers and draggers (1996-1997) is presented in Appendix 1 (Table 3 and Figures 1). A comparison of pounds per bottom hour summarized from diver interviews conducted during the 1994/1995 and 1996/1997 seasons clearly shows that the CPUE has declined in every coastal county. The overall summary for dragger CPUE, expressed as pounds per foot drag width per tow hour also demonstrates this point.

Diameter frequency information summarized from samplings of the commercial catch is shown in Appendix 1 (Figure 2). Nine percent of the commercial catch is less than 2 inches in diameter, 23% is less than 2 1/8 inches, and 43% is less than 2 ¼ inches.

Dealer Logbooks

A logbook program was established by DMR to collect detailed landings data from buyers and processors (see attached). This project includes the administration of the logbook program for sea urchin processors and buyers and a port sampling survey of harvesters All Maine sea urchin processors and buyers must maintain a log book of purchases made from harvesters. Information that must be recorded includes: buyer/processor license number; harvester license number; landing date, zone, county, town, and method; total pounds of whole urchin harvested for each harvester; percent roe; number of harvesters or boats; and price/lb. Log books are turned in on a monthly basis and are summarized by the Department of Marine Resources. Difficulties have been encountered in obtaining timely reporting from some of the buyers. Logbook landings information for the 1996/1997 season are presented in Table 3. We believe that sea urchin landing records have not improved with implementation of the mandatory logbook requirement. A comparison of commercial port sampling and logbook information collected from the same source reveals that approximately 75% of the landings are being reported.

Life History

A research program was established in 1995 to better understand various aspects of the life history of the green sea urchin in Maine waters. Specific areas of needed research included larval supply, juvenile distribution, settlement and growth; spatial and temporal patterns of distribution; and survey methodology to obtain abundance and recruitment information. Three studies were initially funded through a competitive grant program, one of which was extended for an additional year.

Size, Maturity, and Fecundity in Green Sea Urchins

Dr. Robert L. Vadas, University of Maine, conducted a study to determine: patterns of reproduction at four sites along the coast and to correlate patterns of spawning with environmental and oceanographic variables; size and age at first reproduction; effect of size and habitat on maturation; effect of urchin size and age, and habitat on fecundity (number of eggs); and a roe yield standard based on temporal and spatial patterns of growth and gonad maturation.

Study sites were selected in Casco Bay, Port Clyde, Schoodic Peninsula, and Jonesport-Beals with two habitat types, kelp/agal habitat and barren grounds, at each site. Project results confirmed earlier findings that urchins consistently spawn 4-6 weeks earlier in the western regions of the coast. The age-size relationships were variable, with animals reaching legal size in 3-7 years. Most urchins appeared to attain legal size in 5-6 years. The age and growth data have not yet been validated by ongoing chemical marking studies with oxytetracycline. Different growth rates were observed at the Port Clyde site where a slower growing form does not appear to attain legal harvesting size.

Green sea urchins appear to reach maturity at about the legal size. Large urchins produce significantly more eggs than smaller animals. Urchins below the legal size of 2 inches produce less than a million eggs annually, whereas the smallest legal urchins 2-2.4 inches can produce 3.5 million eggs, and urchins 2.75-3 inches can produce up to 8-10 million eggs. These results suggest that preservation of larger individuals may be a viable strategy for enhancing future egg production. Urchins consistently spawn 4-6 weeks earlier in the western regions of the state.

Larval Settlement, Survival, and Juvenile Growth of Green Sea Urchins

Dr. Robert Steneck, University of Maine, is conducting a two-year project to investigate regional patterns of settlement and recruitment; variations in recruitment patterns; and substratum and algal cover effects on settlement and recruitment of green sea urchins. The project is comparing growth and survival rates at several widely dispersed regions, and substratum-specific and macroalgal-specific rates of growth and survival. Preliminary results are presented in Appendix 2.

Settlement rates increased at sites from east to west, from 24 urchins/m^2 at Jonesport to 16,000 urchins/m^2 at York in 1996. Results were similar for 1997. There doesn't appear to be a relationship between the local abundance of broodstock urchins and observed patterns of larval abundance or settlement. Natural mortality can be very high. At the York site, up to 99.9% of newly settled urchins apparently died in the first year. In eastern Maine where natural rates of settlement are low, survival seems to be higher. Kelp-associated predators, particularly small crabs, may be responsible for much of the post-settlement mortality. The abundance of predators appears to be controlled by seaweed abundance which has increased due to the reduction in grazers (urchins). It appears that algal community changes that result from urchin harvesting may reduce subsequent urchin population growth, thereby reducing the number of urchins that can be harvested.

Management implications include support for rotation of closed areas that allow sea urchins to grow and graze down seaweed. Preliminary results suggest that an optimum level of harvest may be possible if urchin densities can be maintained at levels where they continue to control macroalgal abundance. The most sustainable harvests are likely to come from regions where natural settlement if relatively high and natural mortality is relatively low. Regions between Boothbay Harbor and Mt. Desert Island appear to have the best combination of those characteristics of the four regions studied. Artificial seeding from hatcheries may have a low probability of success due to the high natural rates of settlement and high rates of natural mortality.

Effects of Sea Urchin Densities on Fertilization Success

Dr. Richard Wahle, Bigelow Laboratory for Ocean Sciences, conducted population surveys to determine sea urchin population density, gamete production, kelp cover at seven sites, sampled at two depths (5 and 15 m), in mid-coast Maine representing a natural range of population densities. Field experiments were conducted to determine the influence of body size, urchin density, and kelp canopy on fertilization success of urchins at different levels of aggregation. The purpose of the project was to improve knowledge of ecological conditions that influence gamete production, fertilization success, and larval supply, and will provide information on the effects of fishing and the need for spawning sanctuaries.

Results of the study indicate that gonad weight (roe yield) decreases with increasing population density (Appendix 4). Gonad weights were consistently low at deep locations and did not vary significantly with density. Fertilization success increased with increased population density. The conclusion of this research is that the reproductive benefits of aggregating (increased fertilization success) appear to outweigh the costs (lower individual gonad weights). Urchins at the highest density sites with small gonads may produce relatively large numbers of offspring compared to those at the lowest density sites which are not likely to successfully reproduce despite having the larger food supply and gonad development. This information could be used in the development and management of conservation areas for sea urchins.

Sea Urchin Dragging Studies

There has been a growing concern that dragging could have a negative impact on existing urchin stocks, other species, and the habitat. Ted Creaser, Maine Department of Marine Resources is overseeing a study to determine the impacts of various types of drags used in the sea urchin fishery on the sea urchin resource and to identify bycatch in the drag fishery. The study is comparing the different types of drags used and how each type impacts the catch. Samplers are documenting the condition of the sea urchins that are landed and culled overboard as well as recording the bycatch.

Two sea samplers have made 38 trips, 14 in Zone 1 and 24 in Zone 2, from October 1, 1997 through January 20, 1998. Trips have been made out of 15 ports in six counties. Three types of drags have been samples: drags with sweep chains (chain sweeps); drags with square chains ("urchin" drags); and pipe drags. Sampling will continue through the end of the season in February in Zone 1 and April in Zone 2. Data will be analyzed in May and June and the results will then be presented to the Sea Urchin Zone Council and the DMR Advisory Council.

Dr. Richard Wahle, Bigelow Laboratory for Ocean Sciences, began a study to investigate the impacts of urchin dragging on habitat in January, 1998. This study, which will be completed during the 1997-1998 urchin harvesting season, will determine the impacts of light urchin drags (Green drags) on cobble-boulder and ledge habitat at two sites in the western end of the region (Zone 1). The impact of heavy chain sweep drags will be compared to the lighter Green drag on ledge habitat in the eastern end of the region (Zone 2).

Economic Characteristics of the Fishery

Dr. James E. Wilen, University of California, and Dr. Cathy R. Wessells, University of Rhode Island, compiled an economic analysis of the market for Maine sea urchins. The primary goal was to describe the mechanisms which determine and influence prices and the market structure in the sea urchin market. Included in this description is an analysis of the complete marketing chain, from harvest to final consumption, focusing on the determinants of transactions and product flow, including quality, volume, seasonal factors, and other economic forces. Copies of this report is available from DMR and a summary is presented in Appendix 4.

Future Research

The Sea Urchin Zone Council has recommended that the Department of Marine Resources work with the sea urchin industry to establish a number of conservation areas along the coast. These areas will serve as spawning and research sanctuaries and allow scientists and managers to determine whether this is an effective management tool for the sea urchin resource. Establishment of these areas will require long-term monitoring of each area to evaluate their effectiveness. Continuation of port sampling and the log book program is necessary to provide information for management and for collection of landings data. In addition, a fishery independent survey, currently being designed in the Steneck et al. proposal, is needed to assess the status of the sea urchin resource. This program should continue as long as the fishery exists.

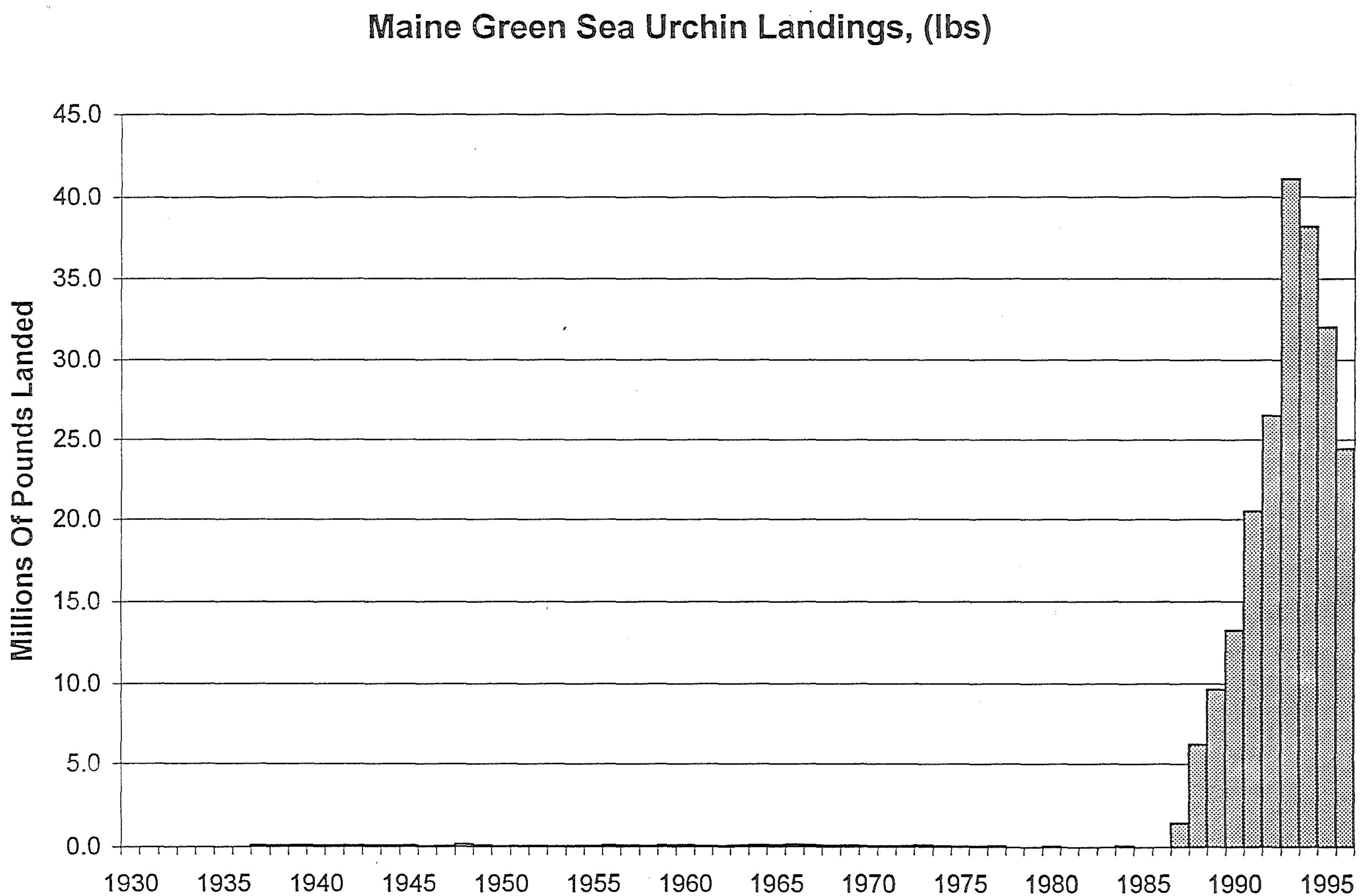


Figure 1. Landings of Maine Green Sea Urchins

Table 1. Landings of Maine Green Sea Urchins, 1929 - 1996.

Year	Landings lbs.	lbs.,Millions	Landings M.T.	Value ,$	Value,Millions	Price/Lb.
1929	3000		1.361			
1930		0.0	0.000		0.0	
1931		0.0	0.000		0.0	
1932		0.0	0.000		0.0	
1933	5800	0.0	2.631		0.0	
1934		0.0	0.000		0.0	
1935		0.0	0.000		0.0	
1936		0.0	0.000		0.0	
1937	79000	0.1	35.834	1500.00	0.0	0.019
1938	79000	0.1	35.834	1500.00	0.0	0.019
1939	79000	0.1	35.834	1500.00	0.0	0.019
1940	79000	0.1	35.834	1500.00	0.0	0.019
1941	79000	0.1	35.834	1500.00	0.0	0.019
1942	79000	0.1	35.834	1500.00	0.0	0.019
1943	79000	0.1	35.834	1500.00	0.0	0.019
1944	79000	0.1	35.834	1500.00	0.0	0.019
1945	79000	0.1	35.834	5000.00	0.0	0.063
1946	23151	0.0	10.501	537.00	0.0	0.023
1947	57777	0.1	26.207	2499.00	0.0	0.043
1948	180085	0.2	81.686	4448.00	0.0	0.025
1949	79490	0.1	36.056	2291.00	0.0	0.029
1950	34020	0.0	15.431	1388.00	0.0	0.041
1951	55140	0.1	25.011	1330.00	0.0	0.024
1952	71869	0.1	32.600	2413.00	0.0	0.034
1953	29580	0.0	13.417	1090.00	0.0	0.037
1954	54520	0.1	24.730	2792.00	0.0	0.051
1955	58345	0.1	26.465	1685.00	0.0	0.029
1956	118580	0.1	53.788	4756.00	0.0	0.040
1957	100654	0.1	45.656	7038.00	0.0	0.070
1958	63780	0.1	28.930	4260.00	0.0	0.067
1959	108020	0.1	48.998	5996.00	0.0	0.056
1960	110619	0.1	50.176	5602.00	0.0	0.051
1961	74158	0.1	33.638	1998.00	0.0	0.027
1962	73590	0.1	33.380	2660.00	0.0	0.036
1963	84438	0.1	38.301	2646.00	0.0	0.031
1964	120908	0.1	54.844	3377.00	0.0	0.028
1965	126047	0.1	57.175	2987.00	0.0	0.024
1966	142995	0.1	64.862	4193.00	0.0	0.029
1967	110565	0.1	50.152	2908.00	0.0	0.026
1968	82700	0.1	37.512	3180.00	0.0	0.038
1969	80972	0.1	36.729	5700.00	0.0	0.070
1970	60200	0.1	27.307	3512.00	0.0	0.058
1971	52105	0.1	23.635	4225.00	0.0	0.081
1972	49610	0.0	22.503	3837.00	0.0	0.077
1973	128398	0.1	58.241	9078.00	0.0	0.071
1974	46725	0.0	21.194	3365.00	0.0	0.072
1975	41973	0.0	19.039	2752.00	0.0	0.066
1976	36094	0.0	16.372	2234.00	0.0	0.062
1977	57402	0.1	26.037	7328.00	0.0	0.128
1978	7974	0.0	3.617	859.00	0.0	0.108
1979	3008	0.0	1.364	306.00	0.0	0.102
1980	33300	0.0	15.105	2391.00	0.0	0.072
1981	3656	0.0	1.658	420.00	0.0	0.115
1982	0	0.0	0.000	0.00	0.0	#DIV/0!
1983	0	0.0	0.000	0.00	0.0	#DIV/0!
1984	50790	0.1	23.038	4056.00	0.0	0.080
1985	0	0.0	0.000	0.00	0.0	#DIV/0!
1986	0	0.0	0.000	0.00	0.0	#DIV/0!
1987	1440161	1.4	653.253	236391.00	0.2	0.164
1988	6221604	6.2	2822.101	1758805.00	1.8	0.283
1989	9657158	9.7	4380.458	3698038.00	3.7	0.383
1990	13227430	13.2	5999.923	5955975.00	6.0	0.450
1991	20535411	20.5	9314.801	11158425.00	11.2	0.543
1992	26502068	26.5	12021.259	15426363.00	15.4	0.582
1993	41073687	41.1	18630.902	26519733.00	26.5	0.646
1994	38166941	38.2	17312.411	32803694.00	32.8	0.859
1995	31998065	32.0	14514.227	33180743.00	33.2	1.037
1996	24400000	24.4	11067.767	27400000.00	27.4	1.123

Table 2. **Maine Sea Urchin Licenses**

Maine Dept. of Marine Resources, December 17, 1997

1997 to Date	Zone 1	Zone 2	Totals
Divers	397	507	904
Draggers	125	279	404
Rakers/Trappers	1	2	3
Tenders			646
Buyers			62
Processors			19
Harvester Totals	523	788	1,311

1996	Zone 1	Zone 2	Totals
Divers	501	562	1,063
Draggers	167	327	494
Rakers/Trappers	2	4	6
Tenders			730
Buyers			70
Processors			19
Harvester Totals	670	893	1,563

1995	Zone 1	Zone 2	Totals
Divers	611	580	1,191
Draggers	237	404	641
Rakers/Trappers	3	5	8
Tenders			736
Buyers			96
Processors			18
Harvester Totals	851	989	1,840

(No Zones, No Buyer/Processor Permits)	1994	1993	1992
Divers	1,726	1,437	829
Draggers	1,000	567	246
Tenders	843	-	-
Harvester Totals	2,726	2,004	1,075

Table 3. Maine Green Sea Urchin Landings by month and county, from the dealer logbook program, 1996 - 1997.

August 1996 Maine Sea Urchin Landings, Preliminary

		Method/Gear				9/10/97
County		Diver	Dragger	Raker	Unknown	Grand Totals
Cumberland	Pounds Landed	253161		0		253161
	Value $	214326.67		0		214326.67
Hancock	Pounds Landed	73856		0		73856
	Value $	42044.80		0		42044.80
Knox	Pounds Landed	773924		0		773924
	Value $	561383.82		0		561383.82
Lincoln	Pounds Landed	443796		0		443796
	Value $	365302.50		0		365302.50
Sagadahoc	Pounds Landed	149495		0		149495
	Value $	115612.35		0		115612.35
Washington	Pounds Landed	68009		2083		70092
	Value $	36324.75		1519.075		37843.83
York	Pounds Landed	59802		0		59802
	Value $	53979.70		0		53979.70
Total Pounds Landed		1822043		2083		1,824,126
Total Value		1388974.59		1519.08		1,390,493.66

September 1996 Maine Sea Urchin Landings, Preliminary

		Method/Gear				9/10/97
County		Diver	Dragger	Raker	Unknown	Grand Totals
Cumberland	Pounds Landed	216,635		0	0	216,635
	Value $	225,635.80		0.00	0.00	225,635.80
Hancock	Pounds Landed	430,323		0	0	430,323
	Value $	381,028.93		0.00	0.00	381,028.93
Knox	Pounds Landed	902,372		0	0	902,372
	Value $	910,786.86		0.00	0.00	910,786.86
Lincoln	Pounds Landed	360,769		0	0	360,769
	Value $	384,169.93		0.00	0.00	384,169.93
Sagadahoc	Pounds Landed	89,778		0	0	89,778
	Value $	83,405.65		0.00	0.00	83,405.65
Washington	Pounds Landed	204,939		2,148	292	207,379
	Value $	161,853.68		2,084.20	233.60	164,171.48
York	Pounds Landed	13,519		0	0	13,519
	Value $	17,339.05		0.00	0.00	17,339.05
Total Pounds Landed		2,218,335		2,148	292	2,220,775
Total Value		2,164,219.90		2,084.20	233.60	2,166,537.70

Table 3

October 1996 Maine Sea Urchin Landings, Preliminary						
		Method/Gear				9/10/97
County		Diver	Dragger	Raker	Unknown	Grand Totals
Cumberland	Pounds Landed	120,213	0	0	0	120,213
	Value $	147,865.16	0.00	0.00	0.00	147,865.16
Hancock	Pounds Landed	658,631	47,458	0	0	706,089
	Value $	757,912.40	34,985.40	0.00	0.00	792,897.80
Knox	Pounds Landed	871,984	39,896	0	109,790	1,021,670
	Value $	1,051,580.60	31,437.90	0.00	128,147.73	1,211,166.23
Lincoln	Pounds Landed	353,519	16,116	0	0	369,635
	Value $	453,056.92	10,543.65	0.00	0.00	463,600.57
Sagadahoc	Pounds Landed	79,628	284	0	0	79,912
	Value $	91,458	196	0	0	91,654
Washington	Pounds Landed	322,994	513,415	2,510	4,482	843,401
	Value $	321,043.39	539,641.75	3,319.80	5,547.11	869,552.05
York	Pounds Landed	14,623	0	0	0	14,623
	Value $	19,503.70	0.00	0.00	0.00	19,503.70
Total Pounds Landed		2,421,592	617,169	2,510	114,272	3,155,543
Total Value		2,842,419.67	616,804.70	3,319.80	133,694.84	3,596,239.00

November 1996 Maine Sea Urchin Landings, Preliminary						
		Method/Gear				9/10/97
County		Diver	Dragger	Raker	Unknown	Grand Totals
Cumberland	Pounds Landed	178,214	0	0	0	178,214
	Value $	208,495.74	0.00	0.00	0.00	208,495.74
Hancock	Pounds Landed	745,429	112,884	0	37,616	895,929
	Value $	839,788.88	79,465.80	0.00	33,557.17	952,811.85
Knox	Pounds Landed	1,108,122	56,188	0	64,831	1,229,141
	Value $	1,332,301.77	40,964.15	0.00	73,707.81	1,446,973.73
Lincoln	Pounds Landed	401,148	12,568	87	0	413,803
	Value $	531,175.82	8,337.77	139.20	0.00	539,652.79
Sagadahoc	Pounds Landed	27,409	2,171	0	0	29,580
	Value $	27,547.95	1,630.50	0.00	0.00	29,178.45
Washington	Pounds Landed	575,226	318,950	3,388	7,568	905,132
	Value $	555,400.75	331,705.35	3,996.27	8,243.92	899,346.29
York	Pounds Landed	18,238	0	0	0	18,238
	Value $	25,136.20	0.00	0.00	0.00	25,136.20
Total Pounds Landed		3,053,786	502,761	3,475	110,015	3,670,037
Total Value		3,519,847.11	462,103.57	4,135.47	115,508.90	4,101,595.05

Table 3

December 1996 Maine Sea Urchin Landings, Preliminary						
		Method/Gear				11/4/97
County		Diver	Dragger	Raker	Unknown	Grand Totals
Cumberland	Pounds Landed	171,242	583	1,559	0	173,384
	Value $	260,822.65	787.05	1,870.80	0.00	263,480.50
Hancock	Pounds Landed	790,981	262,997	0	50,207	1,104,185
	Value $	1,234,274.72	296,935.60	0.00	62,920.90	1,594,131.22
Knox	Pounds Landed	801,831	131,555	0	14,012	947,398
	Value $	1,295,480.85	140,049.17	0.00	21,099.25	1,456,629.27
Lincoln	Pounds Landed	346,768	18,107	0	0	364,875
	Value $	569,691.44	17,733.30	0.00	0.00	587,424.74
Sagadahoc	Pounds Landed	33,316	7,838	0	0	41,154
	Value $	52,866.50	9,899.10	0.00	0.00	62,765.60
Washington	Pounds Landed	466,322	499,289	6,523	101,509	1,073,643
	Value $	596,487.47	734,459.94	10,293.13	124,996.17	1,466,236.71
York	Pounds Landed	8,467	0	0	0	8,467
	Value $	13,408.85	0.00	0.00	0.00	13,408.85
Total Pounds Landed		2618927	920369	8082	165728	3713106
Total Value		4,023,032.48	1,199,864.16	12,163.93	209,016.32	5,444,076.88

January 1997 Maine Sea Urchin Landings, Preliminary						
		Method/Gear				
County		Diver	Dragger	Raker	Unknown	Grand Totals
Cumberland	Pounds Landed	146,333	0	0	0	146,333
	Value $	191,784.91	0.00	0.00	0.00	191,784.91
Hancock	Pounds Landed	430,253	97,681	1,622	60,525	590,081
	Value $	538,032.70	97,351.75	1,163.20	66,633.92	703,181.57
Knox	Pounds Landed	435,392	104,357	0	0	539,749
	Value $	548,648.20	88,672.70	0.00	0.00	637,320.90
Lincoln	Pounds Landed	265,384	13,277	0	0	278,661
	Value $	374,638.00	10,483.40	0.00	0.00	385,121.40
Sagadahoc	Pounds Landed	19,549	6,897	0	0	26,446
	Value $	24,604.97	7,106.23	0.00	0.00	31,711.20
Washington	Pounds Landed	269,492	271,428	1,608	34,243	576,771
	Value $	304,891.46	344,313.56	1,701.55	39,387.05	690,293.62
Total Pounds Landed		1,566,403	493,640	3,230	94,768	2,158,041
Total Value		1,982,600.24	547,927.64	2,864.75	106,020.97	2,639,413.60

Table 3

February 1997 Maine Sea Urchin Landings, Preliminary						
		Method/Gear				1/26/98
County		Diver	Dragger	Raker	Unknown	Grand Totals
Cumberland	Pounds Landed	153,014	304	0	0	153,318
	Value $	179,474.31	486.40	0.00	0.00	179,960.71
Hancock	Pounds Landed	415,755	59,378	0	56,166	531,299
	Value $	477,039.50	51,604.05	0.00	58,764.28	587,407.83
Knox	Pounds Landed	437,548	85,345	0	0	522,893
	Value $	524,253.55	72,596.90	0.00	0.00	596,850.45
Lincoln	Pounds Landed	282,884	17,368	0	0	300,252
	Value $	340,435.85	15,519.96	0.00	0.00	355,955.81
Sagadahoc	Pounds Landed	22,694	8,302	0	0	30,996
	Value $	32,897.75	8,981.05	0.00	0.00	41,878.80
Washington	Pounds Landed	466,474	344,714	1,675	513	813,376
	Value $	536,917.85	424,033.81	2,021.95	602.00	963,575.61
Total Pounds Landed		1,778,369	515,411	1,675	56,679	2,352,134
Total Value		2,091,018.81	573,222.17	2,021.95	59,366.28	2,725,629.21

March 1997 Maine Sea Urchin Landings, Preliminary						
		Method/Gear				
County		Diver	Dragger	Raker	Unknown	Grand Totals
Hancock	Pounds Landed	745,085	30,038	0	0	775,123
	Value $	741,282.55	23,424.15	0.00	0.00	764,706.70
Knox	Pounds Landed	161,147	35,324	0	0	196,471
	Value $	168,400.10	22,705.40	0.00	0.00	191,105.50
Lincoln	Pounds Landed	602	360	0	0	962
	Value $	481.60	360.00	0.00	0.00	841.60
Sagadahoc	Pounds Landed	0	5,256	0	0	5,256
	Value $	0.00	2,752.85	0.00	0.00	2,752.85
Washington	Pounds Landed	707,709	409,509	4,672	4,274	1,126,164
	Value $	659,088.50	394,967.26	4,310.90	4,514.50	1,062,881.16
Total Pounds Landed		1,614,543	480,487	4,672	4,274	2,103,976
Total Value		1,569,252.75	444,209.66	4,310.90	4,514.50	2,022,287.81

April 1997 Maine Sea Urchin Landings, Preliminary						
		Method/Gear				
County		Diver	Dragger	Raker	Unknown	Grand Totals
Hancock	Pounds Landed	567,380	35,161	0	2,648	605,189
	Value $	529,328.05	23,106.45	0.00	2,384.40	554,818.90
Washington	Pounds Landed	624,279	265,786	197	16,875	907,137
	Value $	482,589.00	221,428.25	206.20	13,826.85	718,050.30
Total Pounds Landed		1,191,659	300,947	197	19,523	1,512,326
Total Value		1,011,917.05	244,534.70	206.20	16,211.25	1,272,869.20

Appendix 1

Table 1

A summary of catch/effort information collected from divers during the 1996/1997 season.

Maine Sea Urchin Diver Catch/Effort Summary for 1996-1997

Catch Location		Age (Yrs)	Exper (Yrs)	Depth Ft(Min)	Ft(Max)	M(Min)	M(Max)	Fa(Min)	Fa(Max)	Catch (per Diver-Day) Pounds	Price/Lb	Value($)	Net Roe %	Effort(per Diver-Day) BottmHrs	AwayHrs	Catch/Effort Statistics Lbs/AwayHr	$/AwayHr	Lb/BotmHr	$/BotmHr
York	Mean	37.0	5.1	3.9	13.4	1.2	4.1	0.6	2.2	404.6	0.94	382.1	12.3	3.6	8.5	46.0	44.3	122.0	113.6
County	StdDev	8.86	1.88	2.87	6.74	0.87	2.05	0.48	1.12	149.57	0.31	208.41	2.42	1.52	1.76	17.70	22.70	56.53	56.48
	StdErr	1.93	0.44	0.68	1.59	0.21	0.48	0.11	0.26	31.89	0.07	44.43	0.51	0.36	0.40	4.17	5.35	13.32	13.31
	N	21	18	18	18	18	18	18	18	22	22	22	22	18	19	18	18	18	18
Cumberland	Mean	33.8	5.1	7.2	23.9	2.2	7.3	1.2	4.0	439.8	1.08	472.5	12.3	3.3	7.0	65.7	73.2	130.4	141.1
County	StdDev	6.98	2.41	5.54	9.98	1.69	3.04	0.92	1.66	303.54	0.34	353.13	2.55	1.26	2.08	41.71	52.95	58.77	80.93
	StdErr	1.34	0.46	1.07	1.92	0.33	0.59	0.18	0.32	58.42	0.07	67.96	0.49	0.24	0.40	8.03	10.19	11.31	15.58
	N	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
Sagadahoc	Mean	32.5	6.5	7.8	28.5	2.4	8.7	1.3	4.8	480.8	1.13	505.3	12.7	3.5	6.6	75.3	78.4	141.7	151.3
- Lincoln	StdDev	7.86	4.02	7.33	14.16	2.23	4.32	1.22	2.36	225.72	0.34	201.14	2.08	0.96	1.38	36.06	30.52	55.79	54.49
Counties	StdErr	1.15	0.59	1.07	2.07	0.33	0.63	0.18	0.34	32.92	0.05	29.34	0.30	0.14	0.20	5.26	4.45	8.14	7.95
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
Knox-Waldo	Mean	32.8	5.7	6.9	22.1	2.1	6.7	1.2	3.7	573.0	1.01	576.0	11.9	3.7	7.3	81.8	82.3	167.2	164.5
Counties	StdDev	6.28	2.65	5.75	11.23	1.75	3.42	0.96	1.87	249.72	0.26	278.58	2.36	1.20	1.62	34.65	39.81	73.03	71.34
	StdErr	0.62	0.26	0.57	1.12	0.17	0.34	0.10	0.19	24.49	0.03	27.32	0.23	0.12	0.16	3.45	3.96	7.27	7.10
	N	104	101	101	101	101	101	101	101	104	104	104	104	101	101	101	101	101	101
Hancock	Mean	32.2	5.6	7.8	20.7	2.4	6.3	1.3	3.5	694.0	1.05	708.9	11.9	3.4	6.8	102.0	106.5	208.9	212.1
County	StdDev	7.23	2.86	8.44	11.31	2.57	3.45	1.41	1.88	348.34	0.40	386.71	2.32	1.10	1.52	43.33	56.98	81.40	97.34
	StdErr	0.69	0.27	0.80	1.08	0.25	0.33	0.13	0.18	32.92	0.04	36.54	0.22	0.10	0.15	4.13	5.43	7.76	9.28
	N	110	110	110	110	110	110	110	110	112	112	112	107	110	110	110	110	110	110
Washington	Mean	32.6	5.4	11.2	30.1	3.4	9.2	1.9	5.0	673.5	1.05	699.0	12.4	3.2	6.1	113.2	119.0	220.0	229.2
County	StdDev	6.66	2.34	8.41	14.67	2.56	4.47	1.40	2.45	323.51	0.25	347.19	2.05	0.99	1.59	45.09	54.43	90.21	101.25
	StdErr	0.59	0.21	0.76	1.33	0.23	0.40	0.13	0.22	28.48	0.02	30.57	0.18	0.09	0.14	4.07	4.91	8.17	9.17
	N	128	122	122	122	122	122	122	122	129	129	129	129	122	123	123	123	122	122
All	Mean	32.8	5.6	8.4	24.5	2.6	7.5	1.4	4.1	606.7	1.05	622.2	12.2	3.4	6.8	92.8	96.5	186.1	190.3
Combined	StdDev	7.03	2.78	7.63	13.23	2.33	4.03	1.27	2.20	310.58	0.32	338.37	2.25	1.12	1.69	44.18	52.49	84.28	93.30
	StdErr	0.34	0.13	0.37	0.64	0.11	0.20	0.06	0.11	14.79	0.02	16.11	0.11	0.05	0.08	2.14	2.54	4.09	4.53
	N	437	425	425	425	425	425	425	425	441	441	441	436	425	427	426	426	425	425

Table 2

A summary of catch/effort information collected from draggers during the 1996/1997 season.

Catch Location		Boat (Ft)	No. of Crew	Depth Ft(Min)	Ft(Max)	M(Min)	M(Max)	Fa(Min)	Fa(Max)	Catch (per Dragger-Day) Pounds	Price/Lb	Value($)	Net Roe %
Lincoln County	Mean	32.0	1.0	10.0	30.0	3.0	9.1	1.7	5.0	546.0	0.60	327.6	9.0
	StdDev	-	-	-	-	-	-	-	-	-	-	-	-
	StdErr	-	-	-	-	-	-	-	-	-	-	-	-
	N	1	1	1	1	1	1	1	1	1	1	1	1
Knox-Waldo Counties	Mean	34.3	1.9	16.9	54.3	5.2	16.6	2.8	9.1	469.9	0.85	387.2	11.0
	StdDev	3.47	0.32	13.55	28.09	4.13	8.56	2.26	4.68	260.93	0.16	229.77	1.76
	StdErr	1.10	0.10	4.29	8.88	1.31	2.71	0.71	1.48	82.51	0.05	72.66	0.56
	N	10	10	10	10	10	10	10	10	10	10	10	10
Hancock County	Mean	33.0	2.1	11.3	31.7	3.4	9.7	1.9	5.3	640.5	0.78	487.3	10.3
	StdDev	4.12	0.51	10.04	16.42	3.06	5.00	1.67	2.74	320.07	0.31	229.57	1.86
	StdErr	1.14	0.15	2.90	4.74	0.88	1.44	0.48	0.79	88.77	0.09	63.67	0.52
	N	13	12	12	12	12	12	12	12	13	13	13	13
Washington County	Mean	35.8	2.3	25.9	59.8	8.0	18.3	4.4	10.0	511.5	1.08	512.8	14.5
	StdDev	3.57	0.68	31.49	39.06	9.64	11.96	5.27	6.54	406.94	0.33	375.74	4.49
	StdErr	0.45	0.09	4.00	4.96	1.23	1.53	0.68	0.84	51.68	0.04	47.72	0.57
	N	62	62	62	62	61	61	61	61	62	62	62	62
All Combined	Mean	35.1	2.2	22.6	54.8	7.0	16.8	3.8	9.2	526.6	1.01	492.2	13.4
	StdDev	3.74	0.64	28.02	36.47	8.57	11.16	4.69	6.10	378.22	0.34	341.00	4.32
	StdErr	0.40	0.07	3.04	3.96	0.94	1.22	0.51	0.67	40.78	0.04	36.77	0.47
	N	86	85	85	85	84	84	84	84	86	86	86	86

Catch Location		Effort (per Dragger-Day) Width(ft)	Width(M)	Fish Hrs	Mins/Tow	Tows/Hr	Total Tows	Tow Hrs	Man-Hrs	Ft-TowHrs
Lincoln County	Mean	5.0	1.5	8.3	9.0	4.0	33.0	5.0	9.6	24.8
	StdDev	-	-	-	-	-	-	-	-	-
	StdErr	-	-	-	-	-	-	-	-	-
	N	1	1	1	1	1	1	1	1	1
Knox-Waldo Counties	Mean	4.8	1.5	7.1	10.5	3.9	27.9	4.7	16.9	22.5
	StdDev	0.84	0.26	1.39	2.44	1.27	10.95	1.77	4.56	10.78
	StdErr	0.26	0.08	0.44	0.77	0.40	3.46	0.56	1.44	3.41
	N	10	10	10	10	10	10	10	10	10
Hancock County	Mean	4.9	1.5	6.6	7.2	6.6	41.2	4.7	16.8	22.9
	StdDev	0.61	0.19	1.35	2.76	2.52	10.43	1.44	4.92	8.16
	StdErr	0.18	0.05	0.39	0.80	0.73	3.01	0.42	1.42	2.36
	N	12	12	12	12	12	12	12	12	12
Washington County	Mean	5.2	1.6	4.8	6.9	7.0	34.4	3.4	15.1	18.3
	StdDev	0.68	0.21	2.04	3.25	2.82	20.51	2.04	7.59	11.35
	StdErr	0.09	0.03	0.26	0.41	0.36	2.60	0.26	0.96	1.44
	N	62	62	62	62	62	62	62	62	62
All Combined	Mean	5.1	1.6	5.4	7.4	6.6	34.5	3.8	15.5	19.5
	StdDev	0.70	0.21	2.10	3.26	2.80	18.55	1.99	6.95	10.90
	StdErr	0.08	0.02	0.23	0.35	0.30	2.01	0.22	0.75	1.18
	N	85	85	85	85	85	85	85	85	85

Catch Location		Catch/Effort Statistics Lbs/TowHr	Kg/TowHr	Lb/ManHr	Lb/Ft-TowHr	Kg/Ft-TowHr	Kg/M-TowHr	$/TowHr	$/ManHr	$/Ft-TowHr	$/M-TowHr
Lincoln County	Mean	110.3	50.0	57.0	22.1	10.0	32.8	66.2	34.2	13.2	43.4
	StdDev	-	-	-	-	-	-	-	-	-	-
	StdErr	-	-	-	-	-	-	-	-	-	-
	N	1	1	1	1	1	1	1	1	1	1
Knox-Waldo Counties	Mean	114.2	51.8	27.0	23.9	10.8	35.5	90.3	22.2	18.8	61.8
	StdDev	73.34	33.27	11.25	14.75	6.69	21.95	49.12	9.98	9.90	32.49
	StdErr	23.19	10.52	3.56	4.66	2.12	6.94	15.53	3.16	3.13	10.27
	N	10	10	10	10	10	10	10	10	10	10
Hancock County	Mean	152.9	69.3	41.9	32.1	14.6	47.8	122.9	33.7	25.7	84.5
	StdDev	77.56	35.18	17.11	16.76	7.60	24.95	58.34	16.01	12.20	40.03
	StdErr	22.39	10.16	4.94	4.84	2.20	7.20	16.84	4.62	3.52	11.56
	N	12	12	12	12	12	12	12	12	12	12
Washington County	Mean	168.7	76.5	33.2	32.9	14.9	49.0	176.8	34.1	34.3	112.5
	StdDev	121.89	55.29	18.85	24.62	11.17	36.64	143.86	18.65	27.96	91.74
	StdErr	15.48	7.02	2.39	3.13	1.42	4.65	18.27	2.37	3.55	11.65
	N	62	62	62	62	62	62	62	62	62	62
All Combined	Mean	159.4	72.3	34.0	31.6	14.3	47.1	157.7	32.6	31.0	101.8
	StdDev	111.78	50.70	18.20	22.58	10.24	33.60	129.68	17.65	25.12	82.42
	StdErr	12.12	5.50	1.97	2.45	1.11	3.64	14.07	1.91	2.72	8.94
	N	85	85	85	85	85	85	85	85	85	85

Table 3

Diver and dragger CPUE information
by county during 1994/95, 1995/96, and 1996/97 seasons.

Maine Sea Urchin Catch per Unit Effort
1994-95 vs 1995-96 vs 1996-1997

Diver Lbs per Bottom Hour

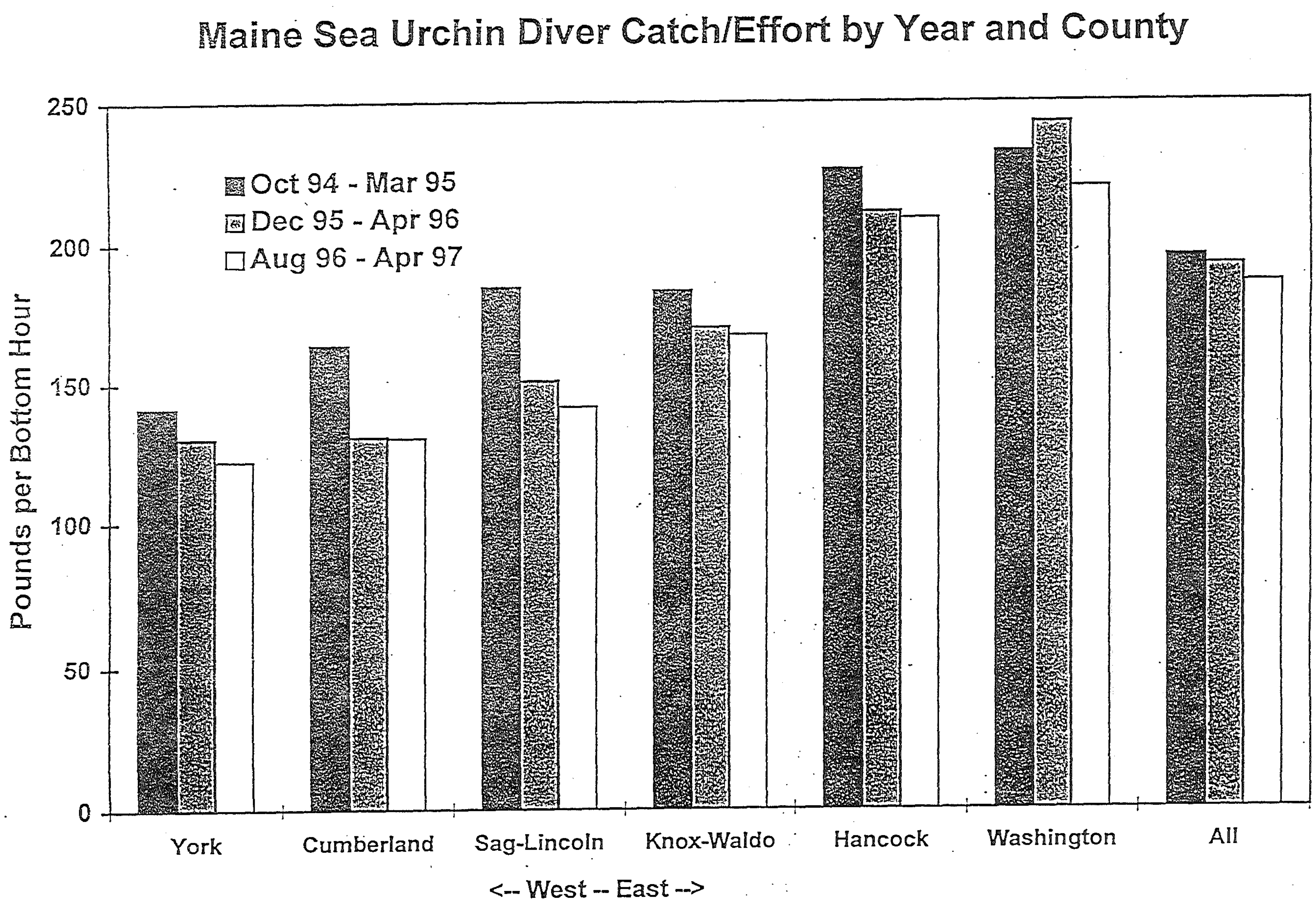
County of Catch	Oct 1994 - Mar 1995			Dec 1995 - Apr 1996			Aug 1996 - Apr 1997		
	Mean	+S.E.	N	Mean	+S.E.	N	Mean	+S.E.	N
York	141.2	9.60	19	130.2	22.14	8	122.0	13.32	18
Cumberland	163.6	13.93	42	130.8	14.03	28	130.4	11.31	27
Sagadahoc-Lincoln	184.7	10.72	76	150.9	11.80	38	141.7	8.14	47
Knox-Waldo	183.4	10.43	88	170.0	13.69	27	167.2	7.27	101
Hancock	226.4	10.47	71	211.2	17.49	29	208.9	7.76	110
Washington	232.7	20.90	42	242.7	13.43	80	220.0	8.17	122
All	195.4	5.54	341	192.4	7.19	213	186.1	4.09	425

Dragger Lbs per Foot Width - Tow Hour

County of Catch	Oct 1994 - Mar 1995			Dec 1995 - Apr 1996			Oct 96 - Apr 97		
	Mean	+S.E.	N	Mean	+S.E.	N	Mean	+S.E.	N
York	-	-	0	-	-	0	-	-	0
Cumberland	-	-	0	43.1	18.85	3	-	-	0
Sagadahoc-Lincoln	-	-	0	-	-	0	22.1	-	1
Knox-Waldo	32.5	4.77	17	20.6	5.19	9	23.9	4.66	10
Hancock	43.6	11.89	24	22.1	3.26	3	32.1	4.84	12
Washington	40.3	6.59	20	36.7	6.74	41	32.9	3.13	62
All	39.1	5.13	63	33.7	5.14	56	31.6	2.45	85

Figure 1

A. Diver CPUE by yearly season and county.



c:\urchin\portsamp\OVERALL.XLS Di456CE Ch 9/12/97

Figure 1

B. Dragger CPUE by yearly season and county.

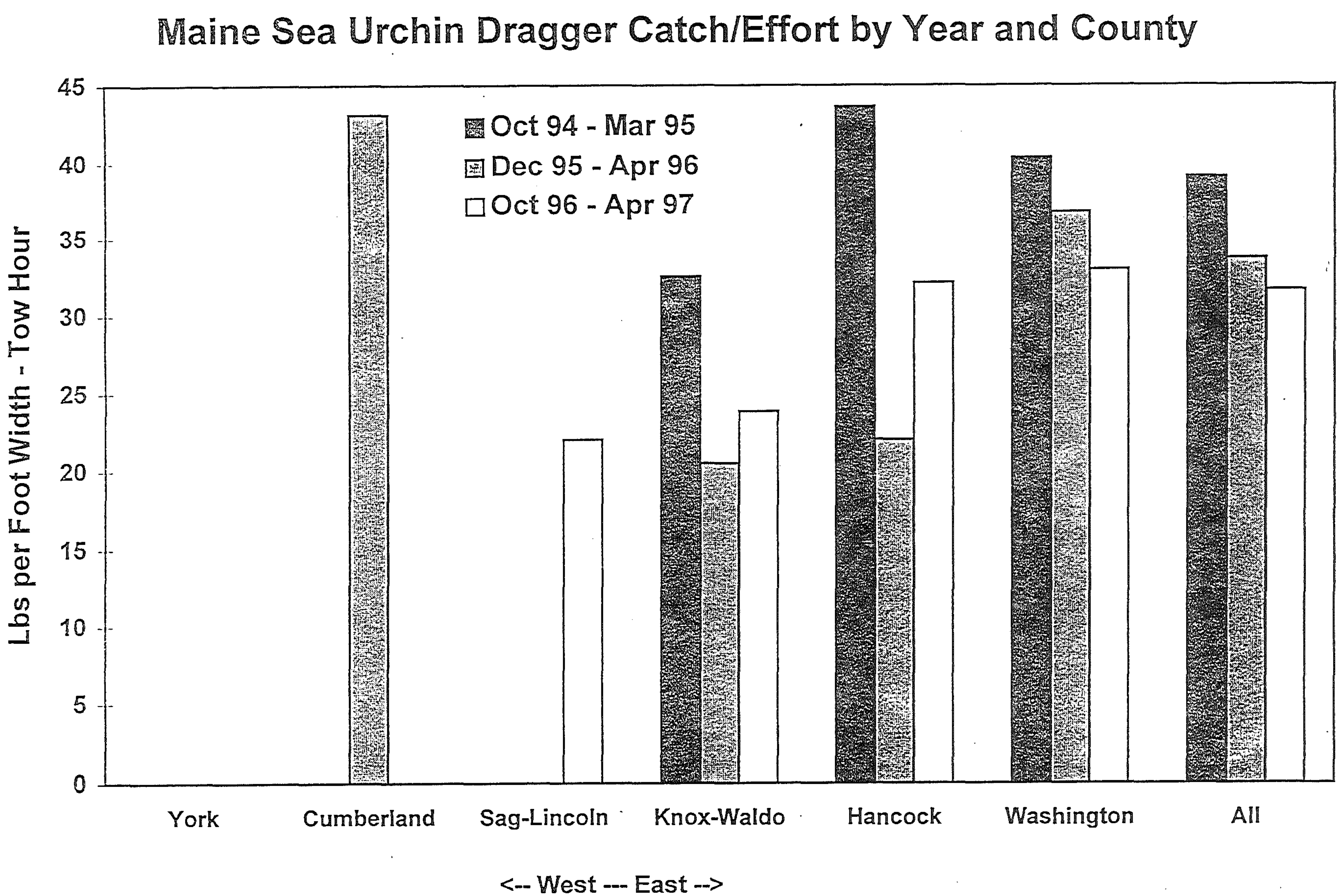
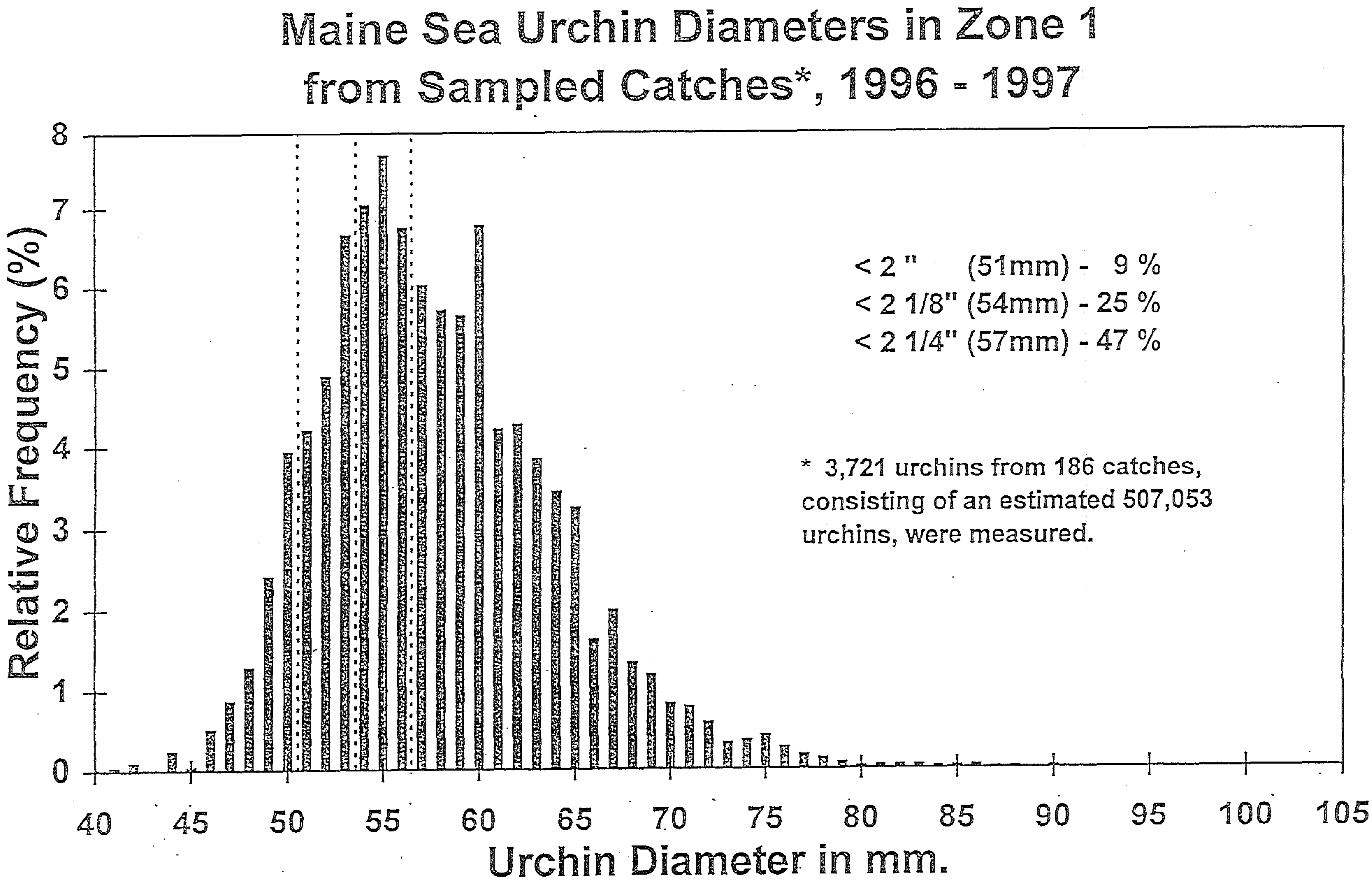
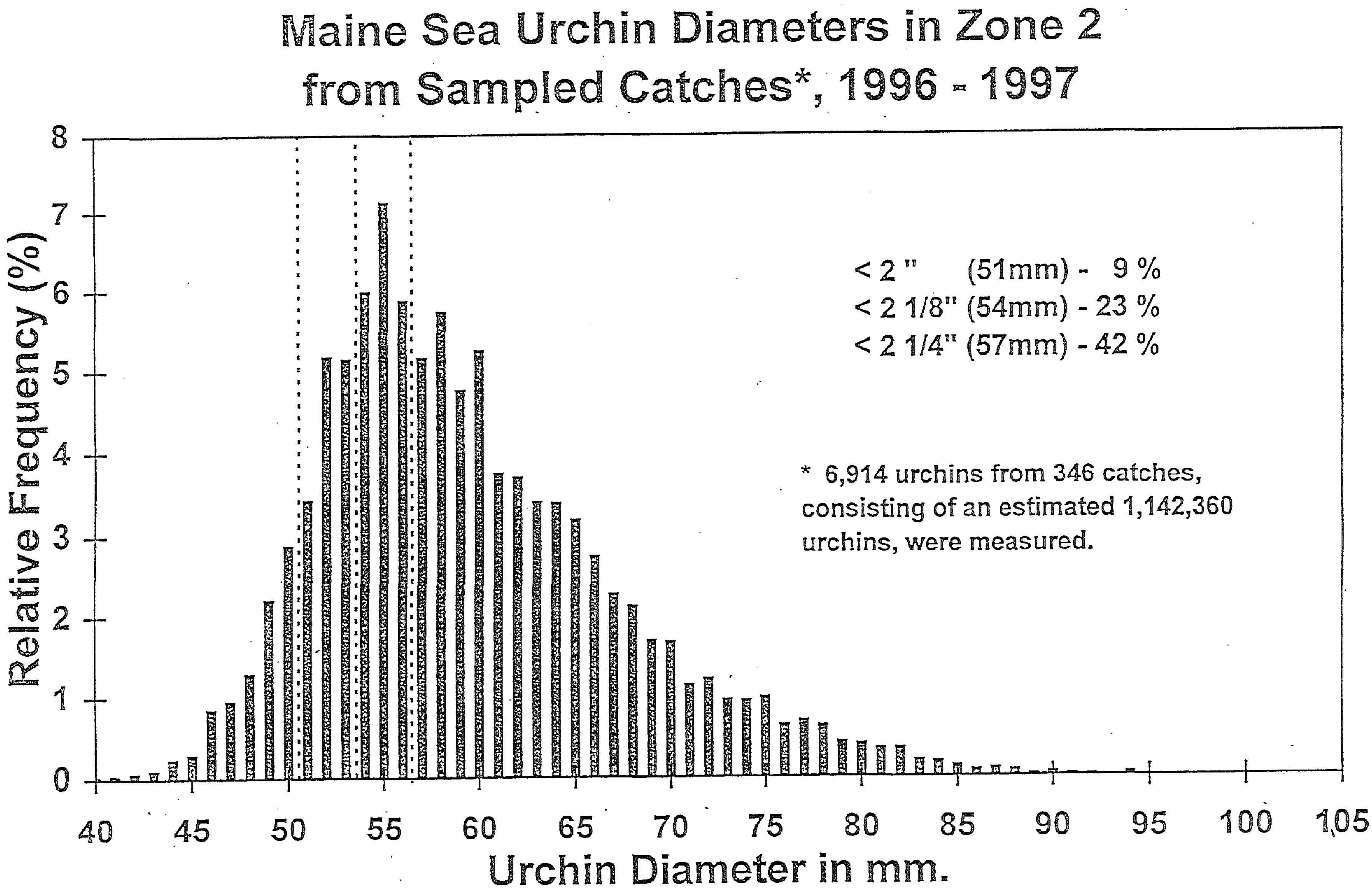


Figure 2

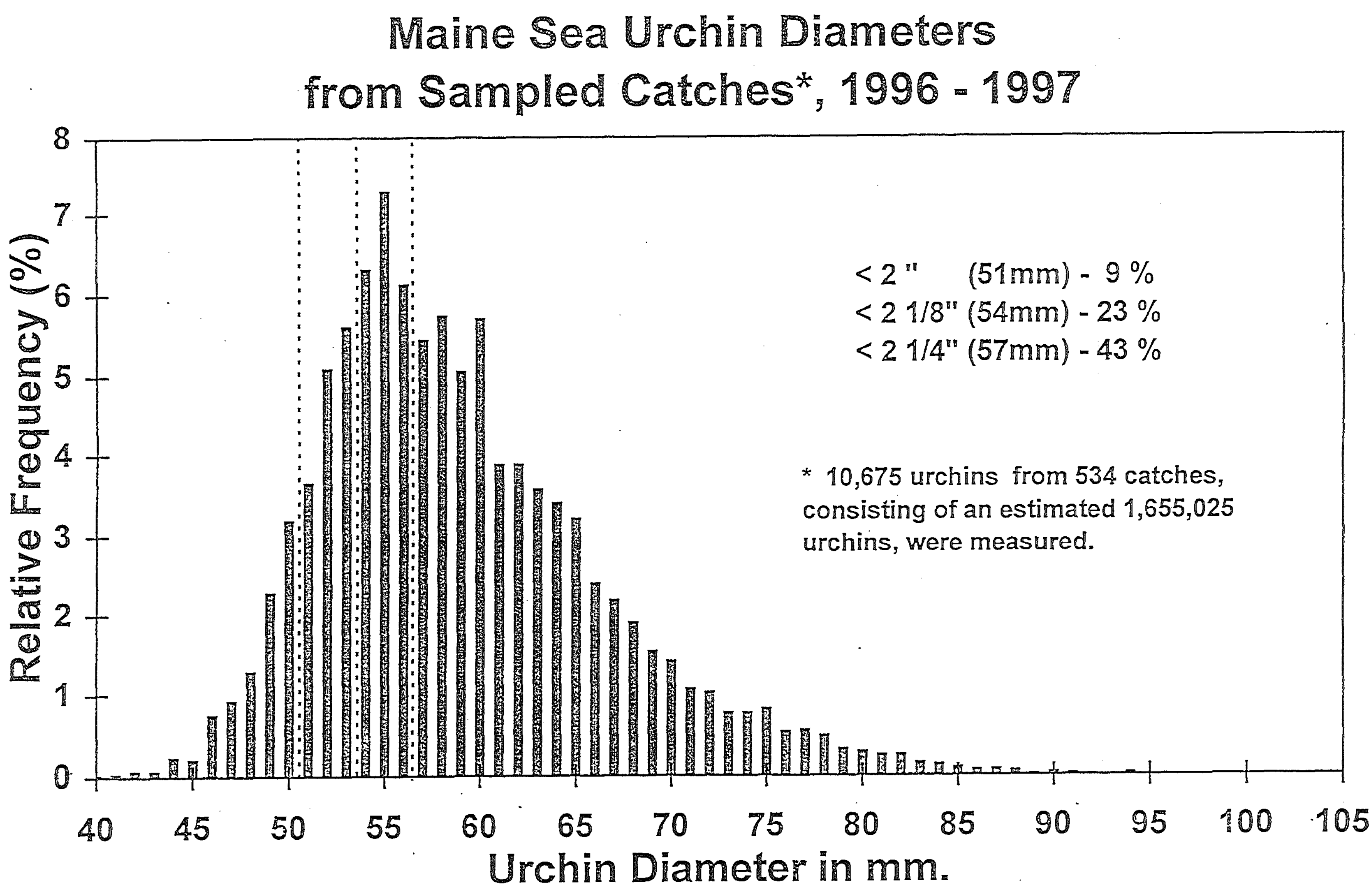
Urchin diameters from catches sampled in Zone 1 (A)
Zone 2 (B) and combined data (C).



C:\URCHIN\PORTSAMP\LENWT671.XLS Raised Diam Freq 9/12/97



C:\URCHIN\PORTSAMP\LENWT672.XLS Raised Diam Freq 9/12/97



C:\URCHIN\PORTSAMP\LENWT967.XLS Raised Diam Freq 9/12/97

Appendix 2

Research to Develop a Management Plan for the Green Sea Urchin

Findings to date from Research

Robert Steneck, Professor
Doug McNaught, Ph.D. student
University of Maine
School of Marine Sciences

GENERAL OVERVIEW:

Surcharge funds from sea urchin harvester's licenses funded our 1996 and 1997 study of sea urchins along the Maine coast. This is the most extensive study of its kind for this species. We have quantified consistent state-wide patterns of larval settlement, settlement success (how many babies survive), and the abundance of larger sea urchins including harvestable sized urchins.

The abundance of harvestable urchins has significantly declined throughout the state primarily as a result of harvesting. The decline today is most striking in western Maine (York County) but our data suggests areas of eastern Maine may decline very rapidly in the foreseeable future. Declines in areas in central Maine from Boothbay to the Mt. Desert region are significant but slower.

Sustainability will hinge on two factors. The abundance of babies that survive on the bottom and their growth rate. Our research shows that regions in western Maine have extremely high natural seeding rates ("settlement rates") but even higher mortality rates due to small predators (mostly crabs half the size of a dime). The abundance of predators appears to be controlled by the abundance of seaweed that has increased in abundance because urchin harvesting has removed their natural grazers. In eastern Maine, natural rates of settlement are low but a much higher percent of the babies survive. Other studies suggest that sea urchins can live to be more than 25 years old. It is possible that much of eastern Maine's landings over recent years has been 'mining' these large old sea urchins. When they are removed, seaweed abundance may shift and babies urchins may suffer high rates of mortality as we have observed in the west.

Details of this overview are given below and full report (for 1996) is on record with DMR. Management is complicated by the ecosystem changes that occur when this grazer is harvested. There is compelling logic in developing rotating closed areas to urchin harvesting so populations of larger individuals can grow (this approach is being used by Washington state). This will not only improve the quality of the product but it may well improve sustainability of the resource because they are likely to graze down seaweed that currently harbors predators of baby sea urchins.

SPECIFIC CONCLUSIONS

Our 1997 results are consistent with patterns we observed in 1996. Therefore we assume settlement and post-settlement survival rates we measured are typical of prime urchin harvesting zones, thus we can make the following conclusions.

1. Natural seeding (i.e., larval settlement to the bottom) throughout the state is high. The lowest recorded seeding density found in Maine averages $24/m^2$ which translates to over 62 **million** settlers per square mile. All other regions in Maine have settlement densities measured in **billions** per square mile.

2. Urchin settlement correlates with larval availability and both decrease from west to east. Low levels of settlement in Jonesport has occurred over several years because relatively low densities of small urchins (ages 1 - 4 years old) are found there.

3. There is no relationship between the local abundance of broodstock urchins and observed patterns of larval abundance or settlement.

4. Natural mortality can be very high. At York, up to 99.9% of newly settled urchins apparently died in the first year. As high as 83% mortality occurred between the first year to harvestable size. Low densities of harvestable urchins in York appear to result from the high rates of mortality there.

5. Kelp-associated predators may be responsible for much of the post-settlement mortality. Experiments showed significantly higher mortality in kelp beds compared to identical adjacent unvegetated habitats. Mortality rates in kelp beds within anti-predator cages were low and not different from outside of kelp beds. These results were confirmed with laboratory experiments. It appears that algal community changes that result from urchin harvesting may reduce subsequent urchin population growth - thereby reducing the number of urchins that can be harvested in area sustainably.

SOME QUANTITATIVE SUMMARY RESULTS:

Note that we have summarized only a small fraction of our results. Quarterly and final reports, reports at the 1997 Fishermen's Forum, 15 minute videos and other information showing our scientific data and experiments are on file with DMR and the University of Maine and will be given to all interested parties. Please contact John Vavrinec directly at 563 - 3146 ext 267 or Doug McNaught (ext 274) or Bob Steneck (ext 233).

One point we wish to stress is how high natural seeding rates are. The following information was obtained in 1996 at 16 sites distributed among 4 regions from York to Jonesport Maine. Note that natural seeding densities range between 62 million and 41 billion per square mile.

Natural Seeding Information

REGIONS	Settlement (#/m2)	Seeding #/acre	Seeding #/sq. mile
York	16,000	64,748,800	41,439,808,000
Pem.-Boothbay	5,000	20,234,000	12,949,940,000
Mt. Desert	1,000	4,046,800	2,589,988,000
Jonesport	24	97,123	62,159,712

In 1997 we found very little change in the above table. At this point, we assume that interannual variation is insignificant and that there are no significant regional differences in growth rates. Growth rate analyses are just being completed by R. Vadas at the University of Maine.

Tentative Conclusion:

1. Artificial seeding from hatcheries may have a low probability of success due to the high natural rates of settlement and high rates of natural mortality.

2. The most sustainable harvests are likely to come from regions where natural settlement is relatively high and natural mortality is relatively low. Regions between Boothbay and Mt. Desert appear to have the best combination of those characteristics of the four regions we studied.

3. Changes in algal vegetation may significantly impact urchin population growth. These preliminary results suggest that an optimum level of harvest may be possible if urchin densities can be maintained at levels where they continue to control macroalgal abundances.

4. A management tool that should be seriously considered given our findings is to set up rotating closed areas that allow sea urchins to grow and graze down sea weed. That should maintain the greatest number and highest quality of the resource. This technique has been successfully used in Washington state.

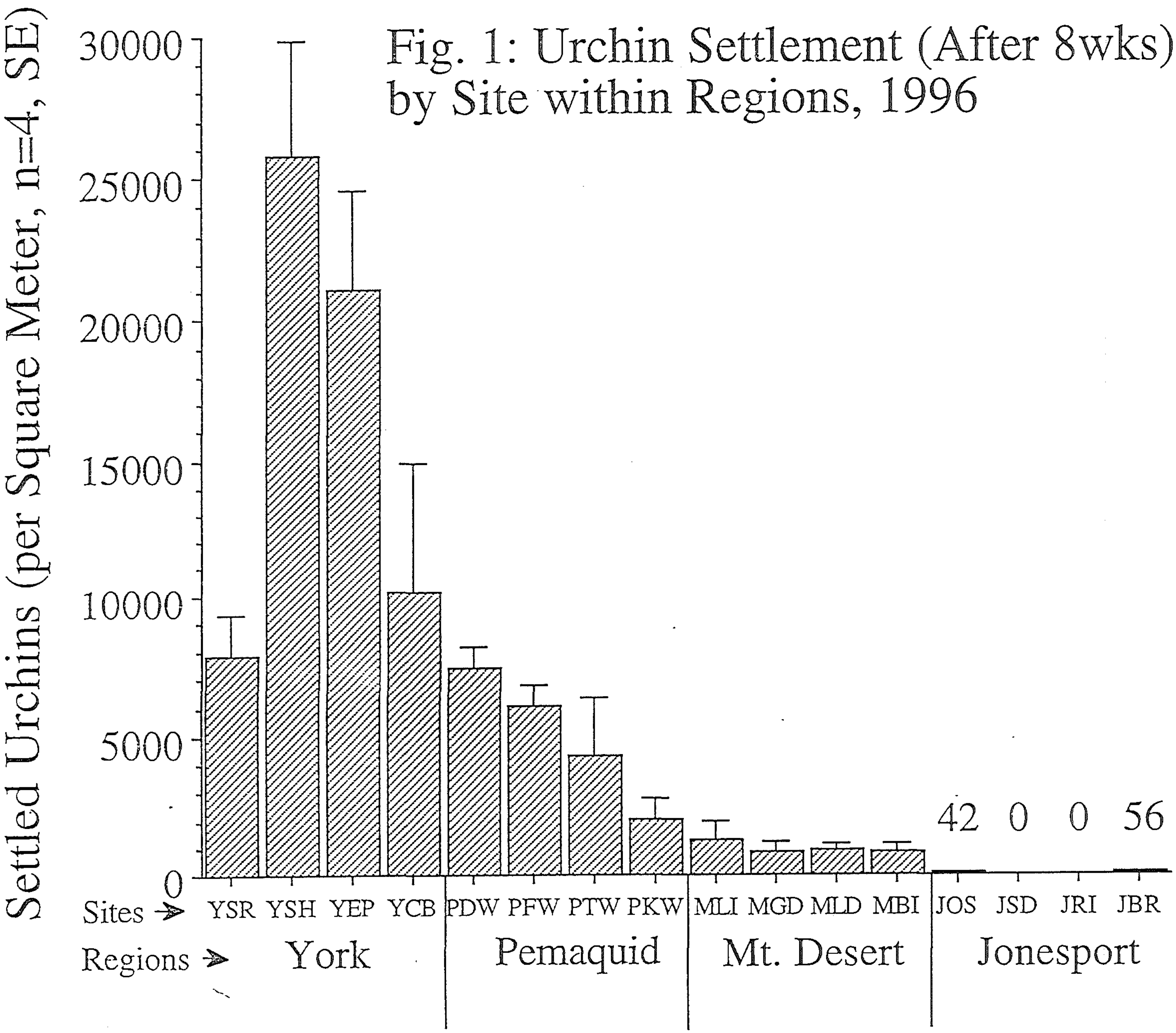
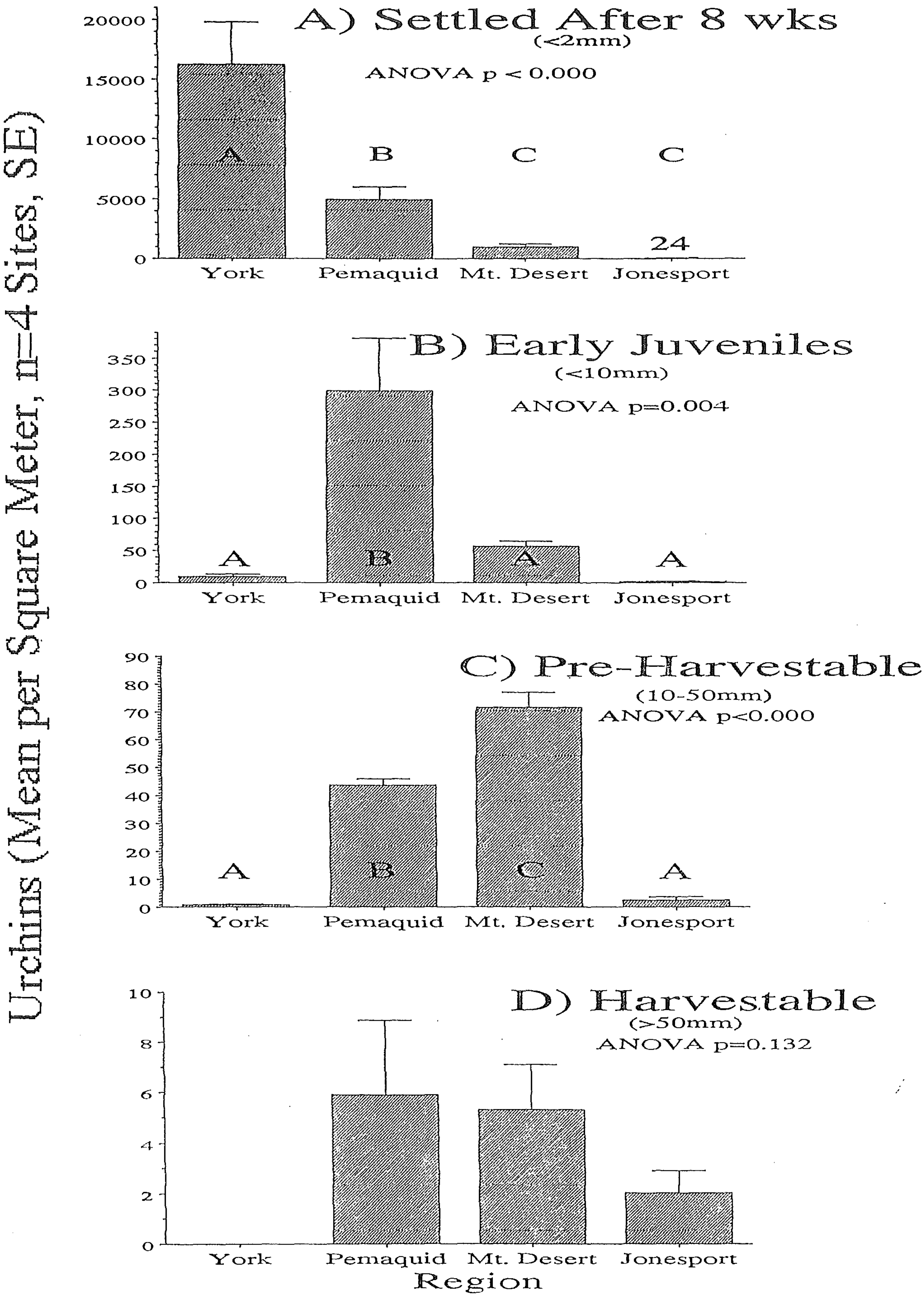


Fig. 1: Urchin Settlement (After 8wks)
by Site within Regions, 1996
Settled Urchins (per Square Meter, n=4, SE)
30000
25000
20000
15000
10000
5000
0
42
0
0
56
Sites
YSR
YSH
YEP
YCB
PDW
PFW
PTW
PKW
MLI
MGD
MLD
MBI
JOS
JSD
JRI
JBR
Regions
York
Pemaquid
Mt. Desert
Jonesport

Fig. 2: Regional Urchin Densities by Size Class, 1996



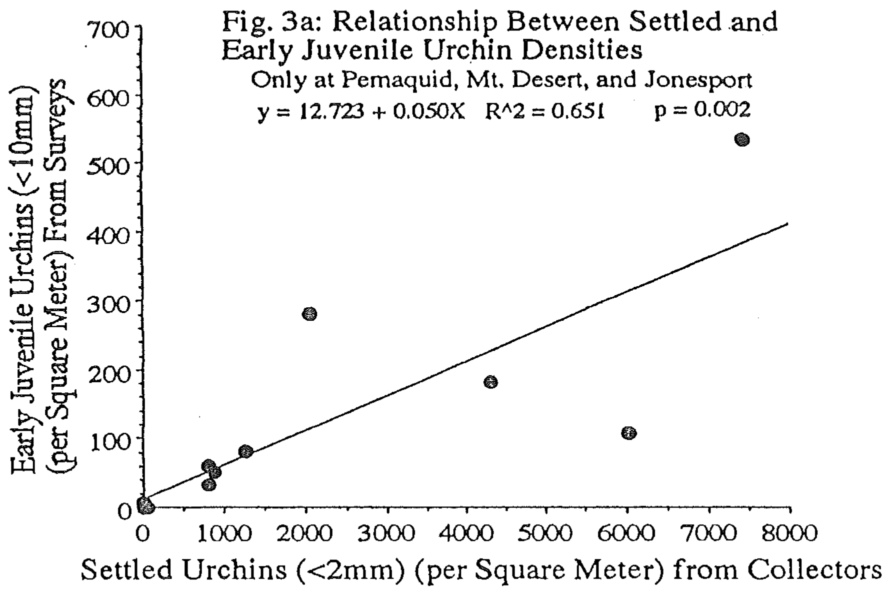


Fig. 3a: Relationship Between Settled and Early Juvenile Urchin Densities
Only at Pemaquid, Mt. Desert, and Jonesport
y = 12.723 + 0.050X R^2 = 0.651 p = 0.002
Early Juvenile Urchins (<10mm) (per Square Meter) From Surveys
0
100
200
300
400
500
600
700
0
1000
2000
3000
4000
5000
6000
7000
8000
Settled Urchins (<2mm) (per Square Meter) from Collectors

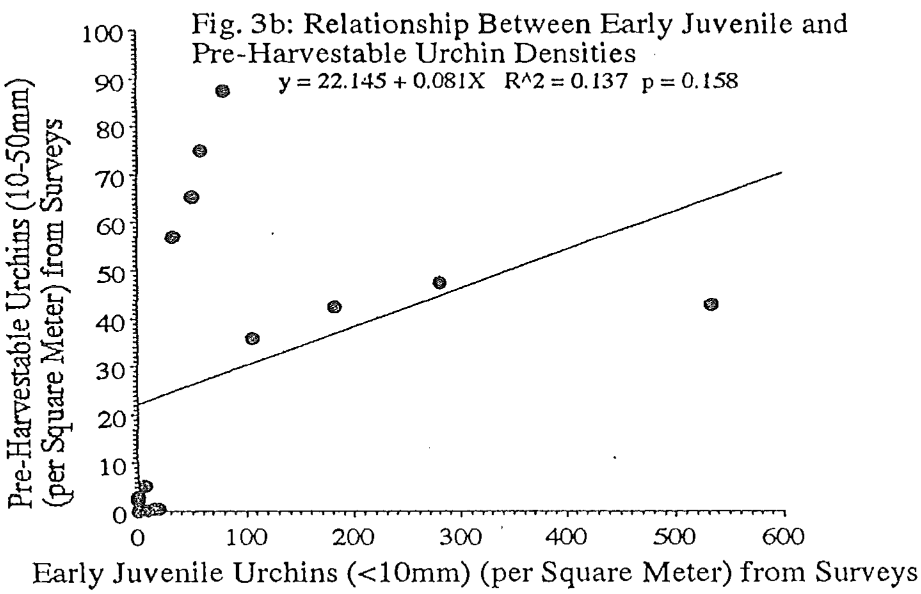


Fig. 3b: Relationship Between Early Juvenile and Pre-Harvestable Urchin Densities
y = 22.145 + 0.081X R^2 = 0.137 p = 0.158
Pre-Harvestable Urchins (10-50mm) (per Square Meter) from Surveys
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
400
500
600
Early Juvenile Urchins (<10mm) (per Square Meter) from Surveys

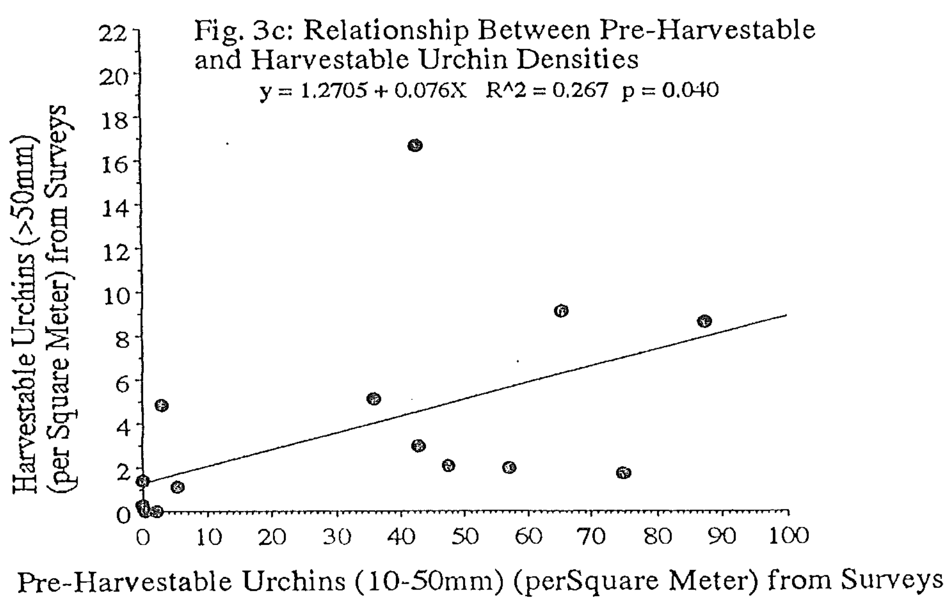
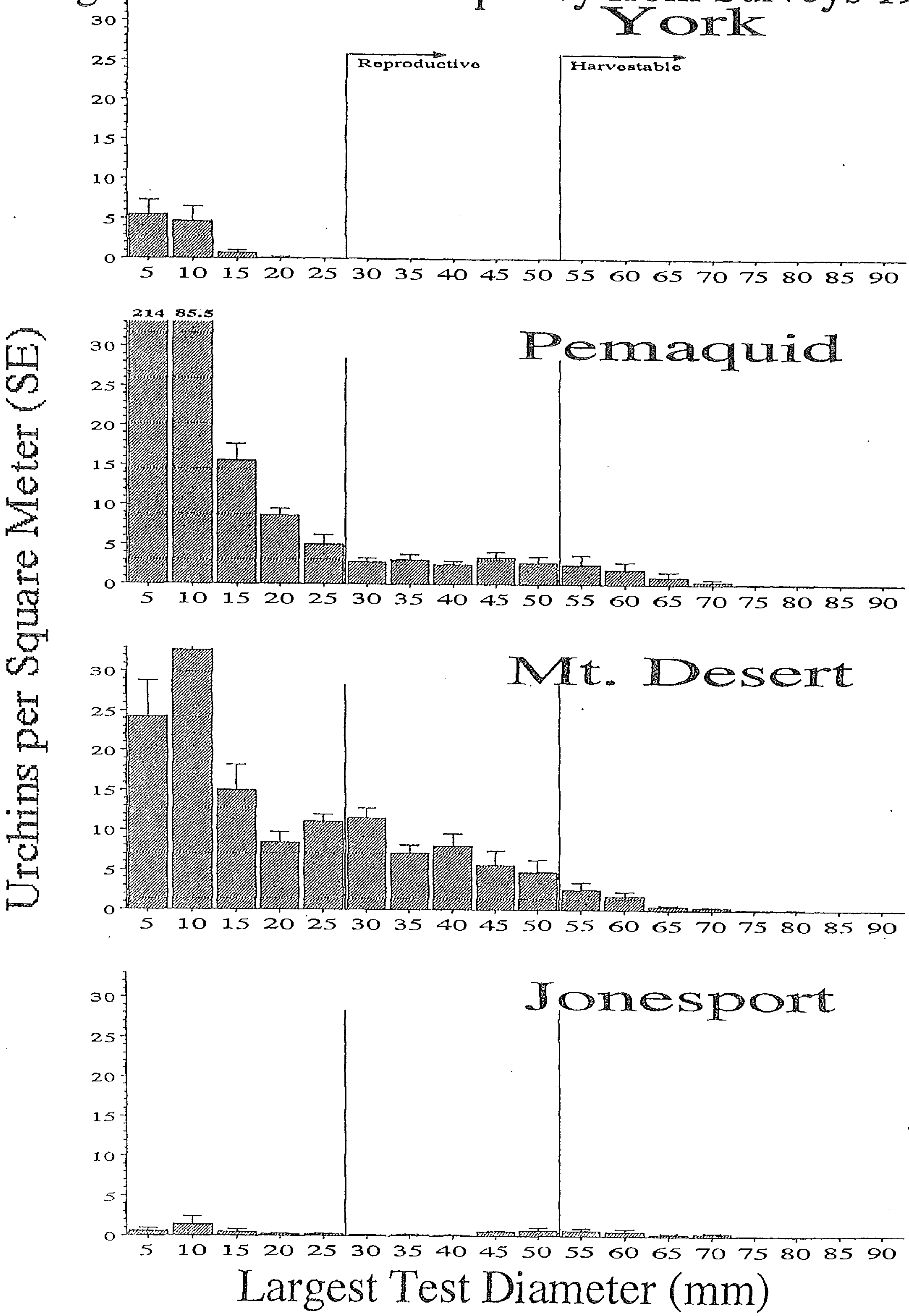


Fig. 3c: Relationship Between Pre-Harvestable and Harvestable Urchin Densities
y = 1.2705 + 0.076X R^2 = 0.267 p = 0.040
Harvestable Urchins (>50mm) (per Square Meter) from Surveys
0
2
4
6
8
10
12
14
16
18
20
22
0
10
20
30
40
50
60
70
80
90
100
Pre-Harvestable Urchins (10-50mm) (perSquare Meter) from Surveys

Fig 4: Urchin Size-Frequency from Surveys 1996



Appendix 3

Density-related Reproductive Trade-offs in the Green Sea Urchin, *Strongylocentrotus droebachiensis*

DRAFT
12/18/97

Richard A. Wahle

&

Hoyt Peckham

Bigelow Laboratory for Ocean Sciences
McKown Point
West Boothbay Harbor, Maine 04575

Tel: 207 633 9600
Fax: 207 633 9641
e-mail: rwahle@bigelow.org

ABSTRACT

Green sea urchin *Strongylocentrotus droebachiensis* (O.F. Müller) populations are being depleted rapidly in the Gulf of Maine and there is justified concern that the potential of this free-spawner to produce larvae may be severely inhibited. Here we evaluate the conflicting effects of varying population-density on gonad development and fertilization success through population surveys and fertilization experiments. We determined gonad indices (gonad mass/body mass) over a range of population densities (0.1 - 250 individuals/ m^2) at seven sites in coastal Maine sampled at two depths (5 and 15 m). At the shallow sites over the observed three-order-of-magnitude difference in density, we found gonad mass to decline by 50%. At the deep locations gonad mass was consistently low and did not vary significantly with density. Patterns of macroalgal abundance suggest urchins at high density and in deeper water are food-limited. Because macroalgal cover co-varies with urchin density we designed field experiments to determine the interaction between urchin density and kelp canopy on fertilization success. On 3 x 3 square arrays we manipulated urchin spacing, but held numbers of simulated urchins constant (5 sperm syringes interspersed with 4 egg containers). These experiments, simulating the range of natural density observed suggest (1) that fertilization rates decline many times faster than individual gamete production increases over the same range in density, (2) that kelp had a mitigating effect on fertilization success at high density when eggs were within 25cm of a sperm source. Additional laboratory fertilization experiments at ambient temperatures (3-5°C) indicate that (1) the sperm concentration at which 50% of the eggs were fertilized (F_{50}) was between 10^3 and 10^4 cell/mL, and (2) that while diluted sperm were viable for <1 hr; egg viability was virtually unchanged for more than 8 hours. In short, the reproductive benefits of aggregating appear to outweigh the costs; and while sperm may be limiting at low population density, eggs have a relatively long window-of-opportunity to become fertilized.

FIGURE LEGENDS

Fig. 1. Map- Necessary?

Fig. 2. Sea urchin, *Strongylocentrotus droebachiensis*, population density, biomass, gonad indices, and macroalgal cover at seven sites surveyed at two depths. Sites ranked by biomass. Error bars = 1SE; absent from biomass estimates because they are calculated from population density. Macroalgal is >100% in some cases because of multiple layer effects. Sites: Thread-of-Life (TOL), Mt. Desert Region (MDR); Thrumcap Island, Johns Island, Ocean Point, Crow Island, White Island. See text for details.

Fig. 3. Least squares regression of gonad index on log(urchin biomass) at seven study sites in Maine. Black circles, 5 m depth; white circles, 15 m. Analysis of variance statistics for the regression, 5m data: F= 16.494, p = 0.0097; 15m data: F = 0.013, p = 0.9129; N=7 for both depths.

Fig. 4. Least squares regression of macroalgal cover on log (urchin biomass) at seven study sites. Black circles, 5 m depth; white circles, 15 m. Analysis of variance statistics for the regression, 5m data: F= 15.845, p = 0.0105; 15m data: F = 26.57, p = 0.0036; N=7 for both depths.

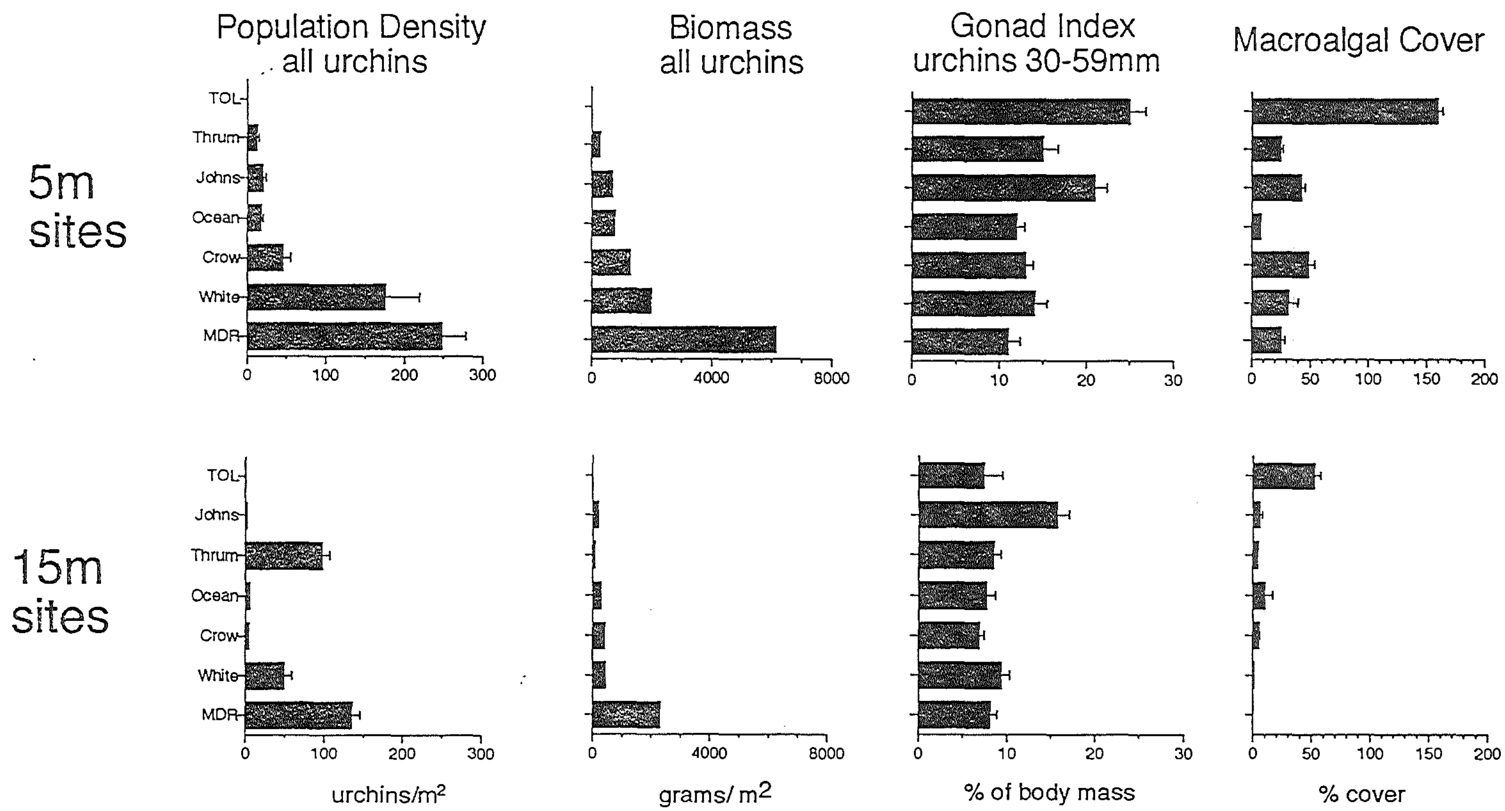
Fig. 5. Density effects on fertilization in weak current. Mean (+1SE) percent of eggs fertilized in egg baskets suspended in three array sizes (n= 3 trials). Four egg baskets interspersed among five sperm sources on square arrays. See Table 1 for statistical analysis.

Fig. 6. Density and kelp cover effects on fertilization in strong current. Mean (+1SE) fertilization rates of n= 5 trials. See Table 2 for statistical analysis.

Fig. 7. Locational differences in fertilization of eggs in baskets on small (1/4 m^2) and large (4 m^2) arrays, with and without a kelp canopy. Shown is the mean of 5 trials. The foreground of the figures represent the upstream edge of the arrays. Sperm syringes were located at the corners and the center of the array. See Table 2 for statistical analysis.

Fig. 8. Effect sperm dilution on fertilization rates. Results of two trials.

Fig. 9. Gamete longevity over 8 hours at 3-5°C. Sperm longevity (line with black diamond symbols): percent of freshly spawned eggs fertilized with dilute sperm of different ages. Egg longevity (line with black circles): percent of eggs of different ages fertilized with fresh sperm. Fresh gameter viability tests (open circles): Freshly spawned eggs exposed to freshly spawned sperm at each time. Blanks (open triangles): freshly spawned eggs exposed to filtered seawater used in the experiment. Points represent mean ±1SE of four trials. Error bars not visible in all cases.


Population Density
all urchins
Biomass
all urchins
Gonad Index
urchins 30-59mm
Macroalgal Cover
5m
sites
15m
sites
TOL
Thrum
Johns
Ocean
Crow
White
MDR
0
100
200
300
4000
8000
10
20
30
50
150
urchins/m2
grams/ m2
% of body mass
% cover

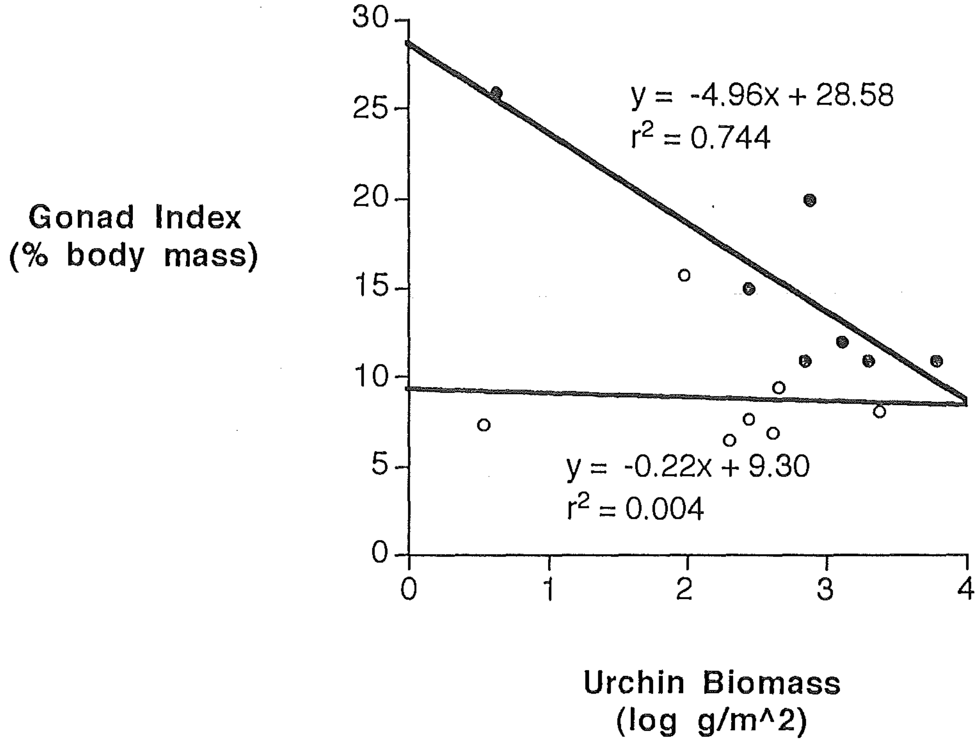


Fig. 3. Least squares regression of gonad index...

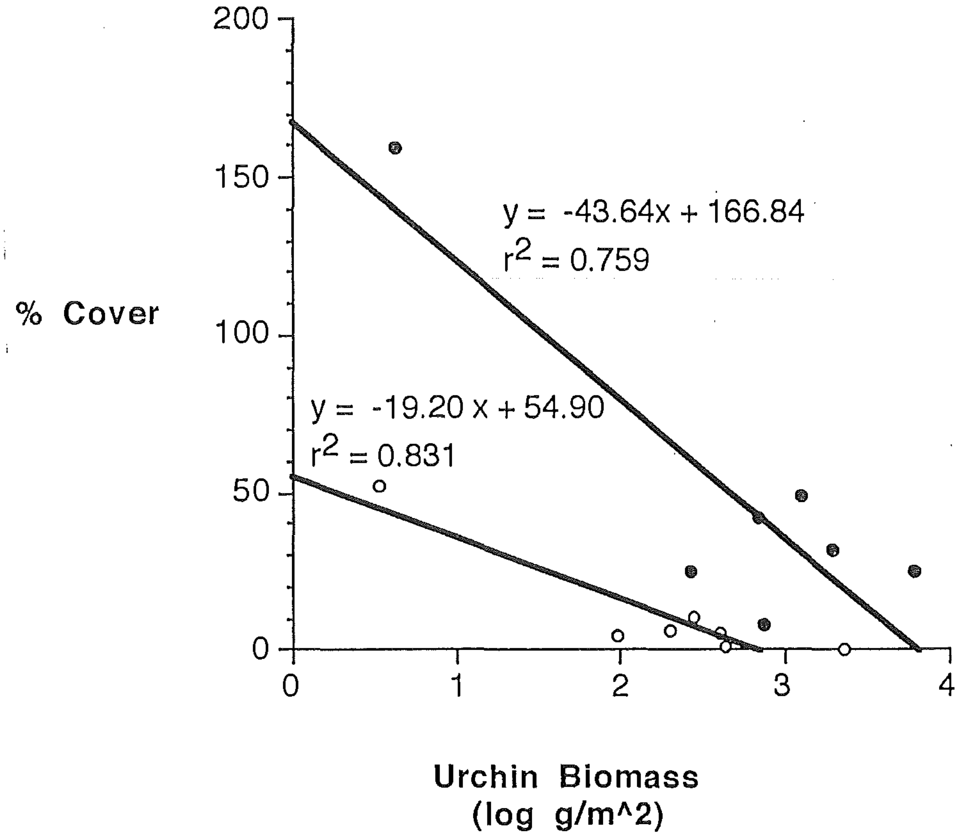


Fig. 4. Least squares regression algal cover...

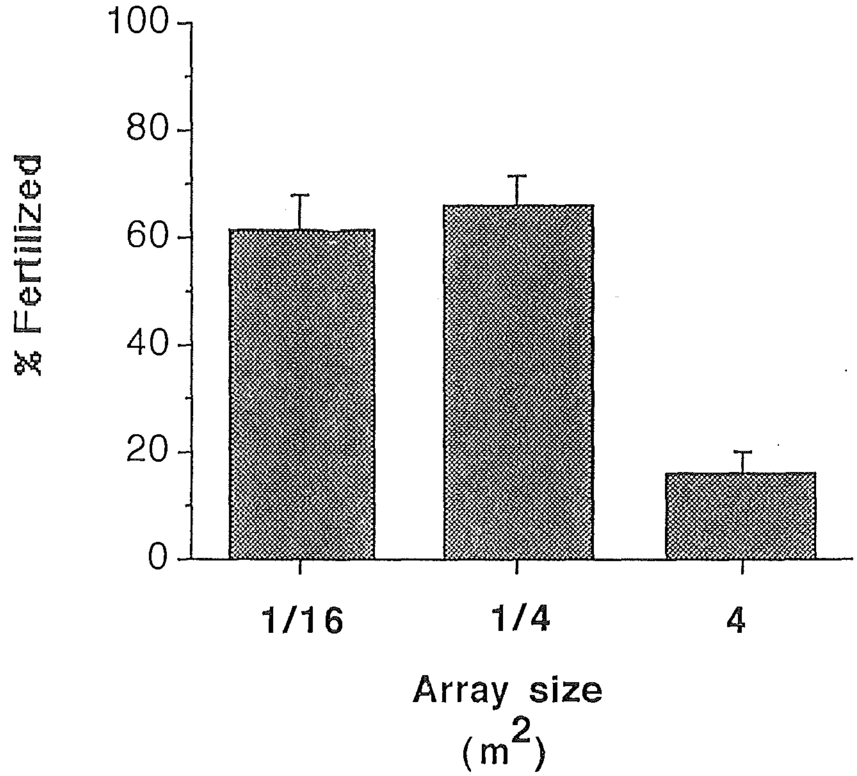


Fig. 5. Density effects on fertilization...

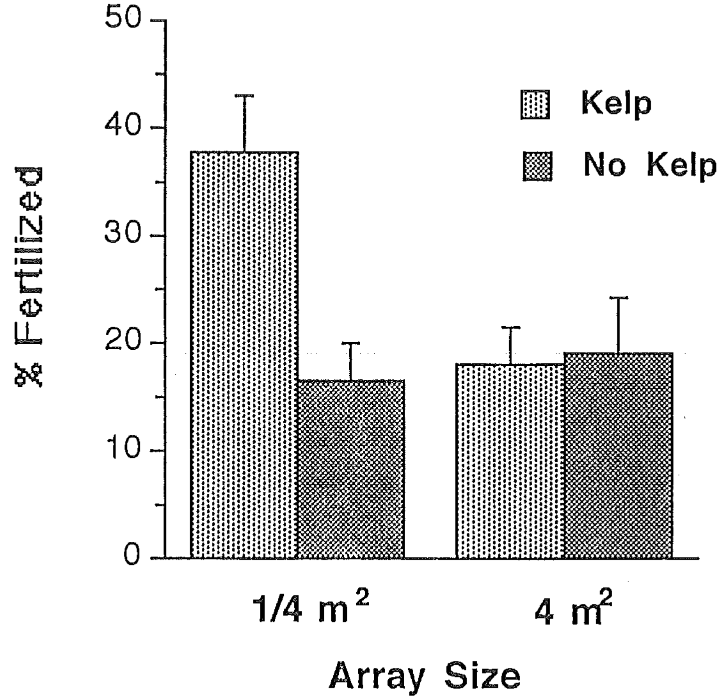


Fig. 6. Density and kelp cover effects...

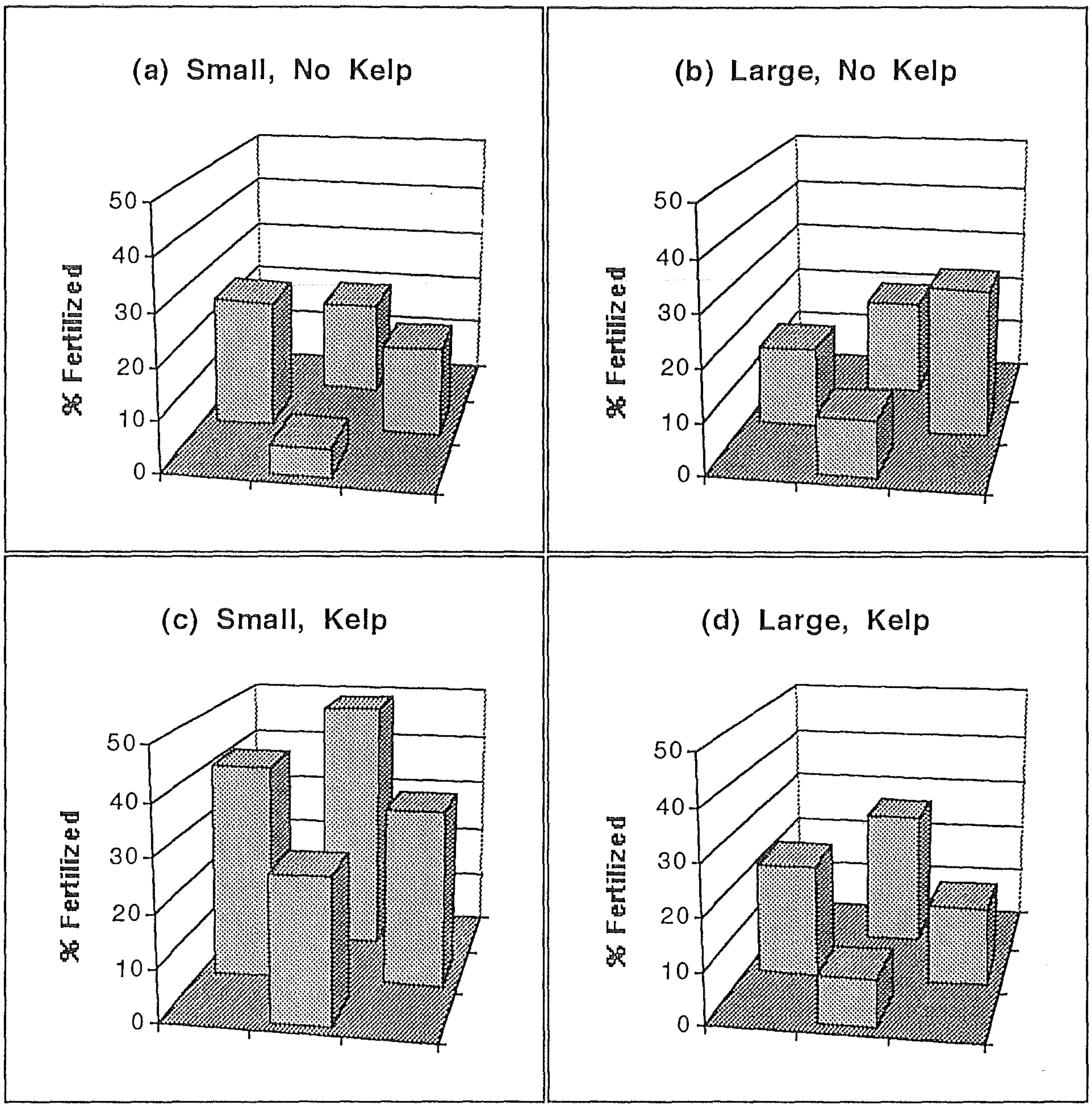


Fig. 7. Locational differences...

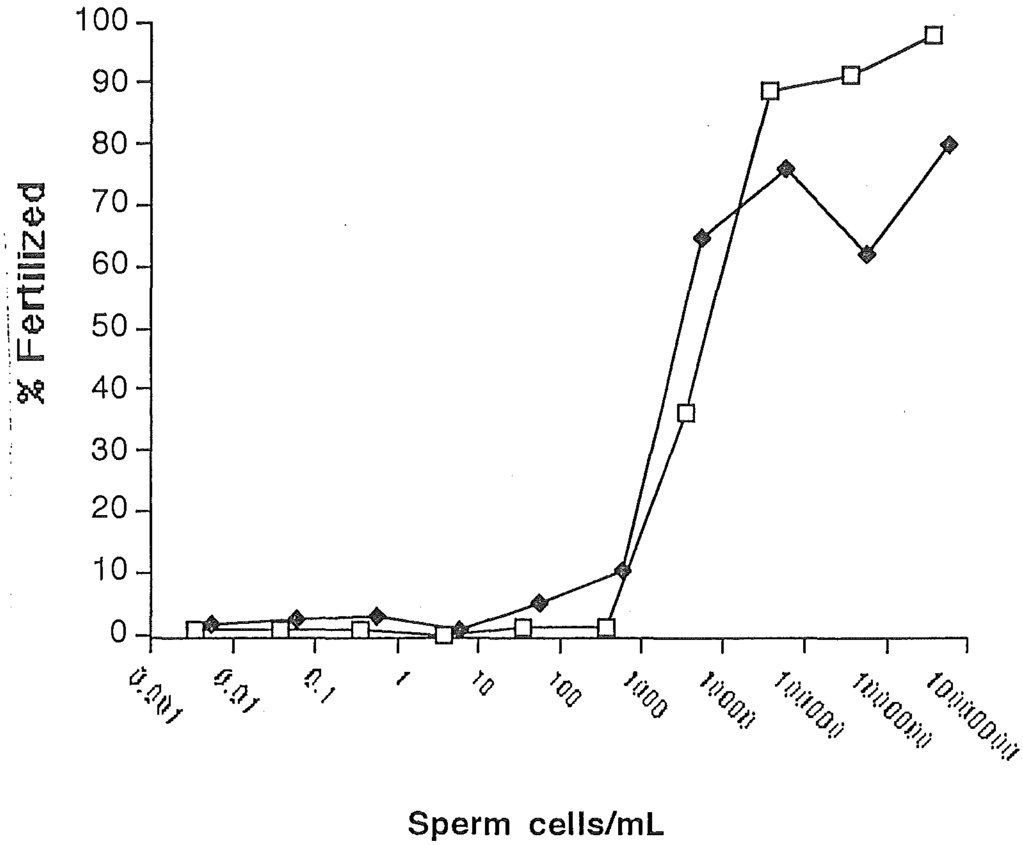


Fig. 8. Effect sperm dilution...

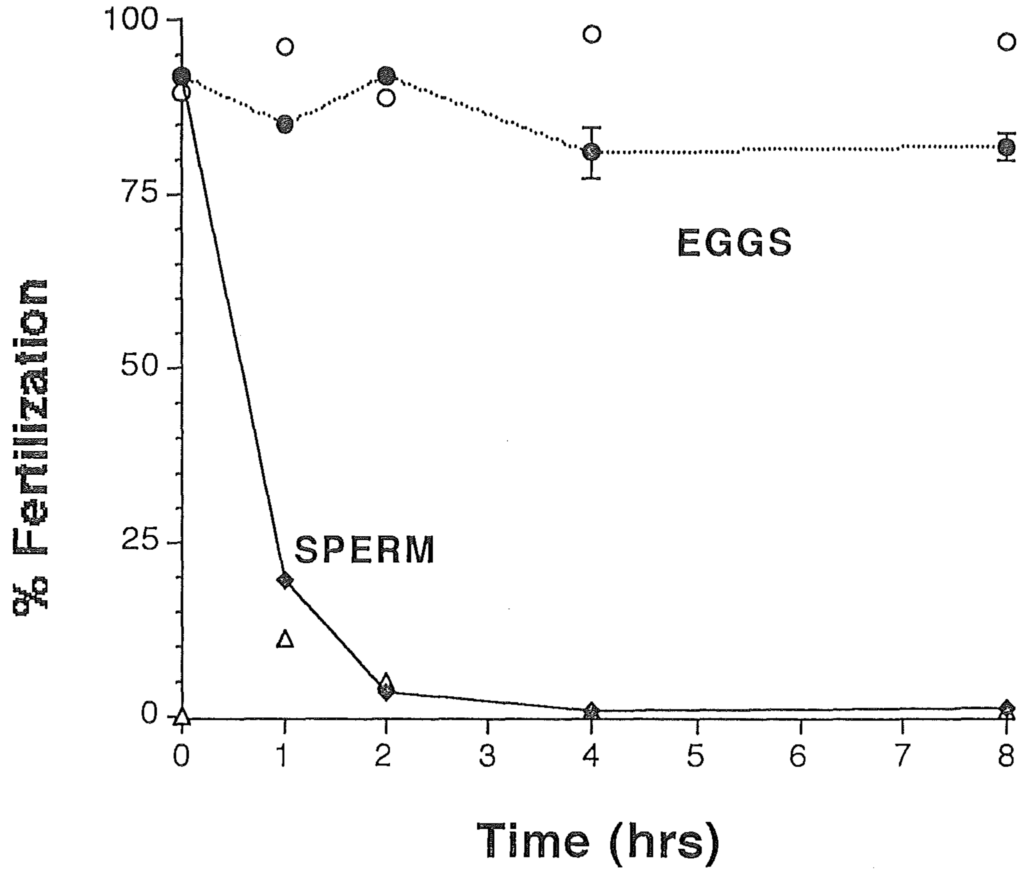


Fig. 9. Gamete longevity ...

Appendix 4

Economic Study Results

The economic study attempted to address questions such as: how might the Maine sea urchin industry position itself to maximize the value of a raw product in this type of market? The findings suggest several things. There are certain fundamental forces which are among the most important determinants of U.S. prices, but which are outside of the control of anyone in the U.S. industry. Exchange rates will always fluctuate and Japanese disposable incomes will also change, reflecting the general health in the economy. Moreover, there is a strong interaction between the supplies of Japanese urchin, their prices, and the prices of imported urchin; when Japanese supplies rise, domestic prices fall, bringing downward pressure on import prices.

With respect to quality, as anyone who has participated in the Japanese fish market can attest, quality has a payoff in higher prices, other things equal. Japanese consume a large proportion of protein in fish products, and the spectrum of products sold and consumed is very wide. While average consumers are not often able to discriminate finely across species, origin, and freshness for ordinary processed products or products bought in food supermarkets, they expect and trust that food consumed in quality settings such as high-end restaurants and sushi bars is indeed high quality. It is the wholesaler segment of the market that grades, sorts, and distributes different qualities of raw product into the various sub-markets according to the willingness to pay of consumers of the final products and Japanese wholesalers who are skilled judges of quality. In the end, higher qualities of raw product, regardless of product type, garner higher wholesale prices, particularly in the Japanese market for fish.

Fresh raw urchin from Japanese sources command the highest prices, on the order of double imported roe. Knowledgeable buyers suggest that there is both an element of quality and also of pure preference for "local" products in this substantial price premium. This has important implications for the maximum prices that non-local suppliers might expect to achieve. If the preference for Japanese products is rigid, then non-Japanese suppliers might never expect to achieve prices close to those garnered for local product, even if they can deliver a virtually identical product. On the other hand, if the price difference is primarily one of quality differences, there may be ways to narrow, if not fully close, the gap. Maine is well-poised in this market since green urchin are similar to those species that command the highest Japanese domestic prices. But there are some logistic limits which ultimately will prevent Maine's roe from competing head to head with the best Japanese roe; it is, after all, essentially impossible to get fresh Maine roe into the Tokyo market as quickly as Japanese roe is delivered. Shipping and handling time drives an irreducible wedge between these products in the end.

Despite the inherent difficulty (and perhaps impossibility) of approaching the market for the highest priced wholesale products in Japan, it is obvious that forces are already operating to improve value-added in Maine's industry. When Maine's industry began several years ago, conditions at both harvesting, processing, and handling were somewhat chaotic as always occurs in any new market. Competitive forces ensure that participants learn, of course, and generally only those who learn and adapt and find niches survive. There has, in fact, been considerable shake out in this industry over the past year or two as urchin densities have begun to thin out and as profit margins have been squeezed from various market forces. During this period, buyers, processors and handlers have learned more about the intricacies of the Japanese market and how to serve various segments of that market. The success of this learning exercise is reflected in the meteoric rise in the unit value of urchin products shipped out of the East Coast. As Figures 17 and 18 show, for example, the value of exports, per pound of product shipped out of Boston and New York, has increased four to five-fold between 1991 and 1995. This equals or surpasses the more mature suppliers' prices, such as those in California. What this shows, quite simply, is that as the industry has matured and as knowledge has accumulated, more value added has accrued as a result of market forces operating in a competitive environment.

Besides quality of the raw product, the other important determinant of the value of earnings from the Maine resource is quantity. Quantity harvested is not independent of quality, of course, and both are inextricably linked up to the biology of the urchin. There are a few general points to be gleaned from our comparison of the workings of urchin fisheries in different regions with what is happening in Maine. Some regions have been successful in maintaining both sustainable supplies and high-valued products. In other areas, there are alarming signs of declines in the fisheries. Important and heated debates have arisen in nearly all areas about when declines in the catch per unit effort reflect over-harvesting and when they simply reflect "fishing down" previously under-exploited stocks. This is an issue of vital importance and efforts need to be made to continue research into not only local conditions but also conditions unfolding elsewhere so that the Maine industry benefits from a broad range of experience.

Among the several urchin fisheries examined, the range of regulations is surprisingly varied. Virtually all impose a minimum size limit; most are larger than Maine's but Japanese fisheries generally harvest smaller urchin in their local fisheries. Some impose an additional maximum size limit, reflecting thinking that larger urchin are more effective spawners and that they may provide canopy protection for juveniles. We did not find any fisheries that attempt to regulate roe content. Instead, most let the market dictate quality by providing recovery bonuses of various types. Most urchin fisheries also have imposed limits on effort, generally through a limited entry program. Most of these limited entry programs have kept the fishery considerably smaller than Maine's program, both absolutely and on a basis relative to the resource size. Most also utilize closed seasons, a two-edged regulation that protects urchin during spawning and also shifts effort into periods when roe condition is higher. A few regions are using or are contemplating experimenting with rotating harvest zones and closed areas.

On the minimum size issue, not too much can be concluded without more quantitative understanding of the bioeconomic implications of changing size limits. It seems reasonable to believe, however, that there is not too much to gain in the market by reducing the minimum size. Most processors believe that, at least for the higher grade roe, processing costs increase substantially as urchin get smaller. Whether minimum sizes should be increased is a more difficult issue, and one not easily addressed without more analysis. It could very well be the case that sustainable landings could be increased with a larger gauge after some reduction in landings during the transition phase. This is a complicated issue, however, and one which can only be addressed by biologists and economists with the best available bioeconomic modeling capabilities. We would expect that the Japanese market could absorb increased supplies from Maine without causing prices to fall to the point that revenues drop, but again, without further quantitative analysis of the market, it is difficult to be definitive about this.

With respect to regulations on roe content, there was little interest in such an idea in other supplier regions. From a biological point of view, it makes no difference whether low content or high content urchin are taken, provided that constraints are established on overall harvest levels to ensure adequate recruitment. Most believe that implementing roe content regulations would be difficult to monitor and enforce. In addition, the evidence from elsewhere is that the market provides incentives to increase roe quality through bonuses and incentives. The extent of these practices vary both from fishery to fishery and often within a fishery by processor. However, there is good evidence that processors will provide the incentives to attract higher quality when it is worth it in terms of wholesale value. In California, divers seem to be shifting diving tactics away from a quantity focus towards a value focus as the resource thins out. Many concentrate on finding patches with smaller numbers of high-value urchins rather than large quantities in poor condition. An issue in Maine is whether it is possible to discover and promote value-oriented behavior among divers. This is partly an issue of science, partly an issue of diver knowledge, and partly one of incentives. Scientists might help, for example, by teaming up with divers to learn about and characterize the conditions under which urchin might be found in uniformly higher quality. Experiments might also be designed which essentially explores how to optimally sample in a setting where quality is unknown.

In sum, there are broad forces operating in the system at large, and many of these are well-exploited already by the industry in Maine. The industry is going through a maturation process that other areas have already gone through, and it is evident that much learning has taken place, over the past couple of years in particular. What fine tuning needs to take place at this point is an open question. Some arenas of further study that would be informative include:

1. More thorough understanding of the intricacies of the first and second tiers of the market in Japan, including product types and final destinations, market size and potential, principle substitute products, other suppliers, marketing chains, and links between and among buyers and sellers, *etc.* This might be handled with a "trade mission" type of visit to Japan, perhaps including representatives from different parts of the industry, managers and fisheries market analysts.

2. Quantitative analysis of the nature of seasonality in prices and interrelationships between local product and import prices. A basic wholesale demand analysis (of the type done by Wessells and Wilen 1994) would be useful, for example. This would clarify whether there are significant marketing opportunities that might exist that could be earned by simply shifting the pattern of Maine's harvest over the season. It might also explore the relationship between the need to have continuous market presence and the benefits of fitting peak periods.

3. Exploration of the nature of the market bias against imported products. Is the price differential between Japanese and imported urchin something that can be reduced by better quality or is it immutable? Some analysis such as Kusakabe and Anderson's 1994 conjoint analysis might be helpful here. Is there anything that can be done to improve

and speed delivery of Maine's product and would it ultimately pay?

4. Understanding whether there are more effective ways of sorting at-sea for higher quality would be helpful. Are green urchins of uniform quality in each patch? Is there a way to sample efficiently (on the seabed or on board?) in order to improve landed quality? Would scientific sampling and diver education programs help?

5. Determining the optimal minimum size needs to be pursued, perhaps with a long term sampling and modeling program. The current size may not be resulting in large amounts of foregone revenues, although one could not be certain without quantifying various dimensions of quality and the sorting through exactly how important size is. Casual observations suggests that Maine urchins are already the most similar to Japanese urchins. While there may be no compelling justifications for reducing the minimum size, there may be gains from increasing it. This could be investigated by examining processing cost differences associated with large urchins; perhaps a comparison of packing, sorting, and handling productivity per laborer with other areas. An attendant issue is whether there are gains in the spawning biomass to be earned as a result of gauge increases, and how large these might be.

Appendix 5

Department of Marine Resources
Bureau of Resource Management - Sea Urchin Fund
Revenues & Expenditures
Inception through December 31, 1997

REVENUES

	Collected
STATE FISCAL 1995	322,775.00
STATE FISCAL 1996	360,899.50
STATE FISCAL 1997	308,764.56
STATE FISCAL 1998	91,445.00
Total Revenues	1,083,884.06

EXPENDITURES

	Actual	Encumbered	Total
PERSONAL SERVICES			
SALARIES & WAGES	55,950.17	0.00	55,950.17
FRINGE BENEFITS	28,895.02	0.00	28,895.02
Total Personal Services	84,845.19	0.00	84,845.19
ALL OTHER			
40 PROF. SERVICES, NOT BY STATE	267,031.04	166,156.78	433,187.82
41 PROF. SERVICES, BY STATE	13,996.80	0.00	13,996.80
42 TRAVEL EXPENSES, IN STATE	406.18	0.00	406.18
43 TRAVEL EXPENSES, OUT OF STATE	1,604.00	0.00	1,604.00
44 STATE VEHICLE OPERATIONS	7.81	0.00	7.81
45 UTILITY SERVICES	458.18	0.00	458.18
46 RENTS	6,774.27	0.00	6,774.27
47 REPAIRS	533.75	0.00	533.75
48 INSURANCE	38.86	0.00	38.86
49 GENERAL OPERATIONS	5,680.40	0.00	5,680.40
53 OFFICE SUPPLIES	12.36	0.00	12.36
54 CLOTHING	2,483.68	0.00	2,483.68
56 OTHER SUPPLIES	4,044.22	0.00	4,044.22
85 TRANSFERS	7,531.19	0.00	7,531.19
Total All Other	310,602.74	166,156.78	476,759.52
CAPITAL			
72 EQUIPMENT	0.00	0.00	0.00
Total Capital	0.00	0.00	0.00
Total All Lines	395,447.93	166,156.78	561,604.71

Beginning Cash, July 1, 1995:	0.00
Add Revenues	1,083,884.06
Less Expenditures/Encumbrances	(561,604.71)
Available Cash, December 31, 1997:	522,279.35