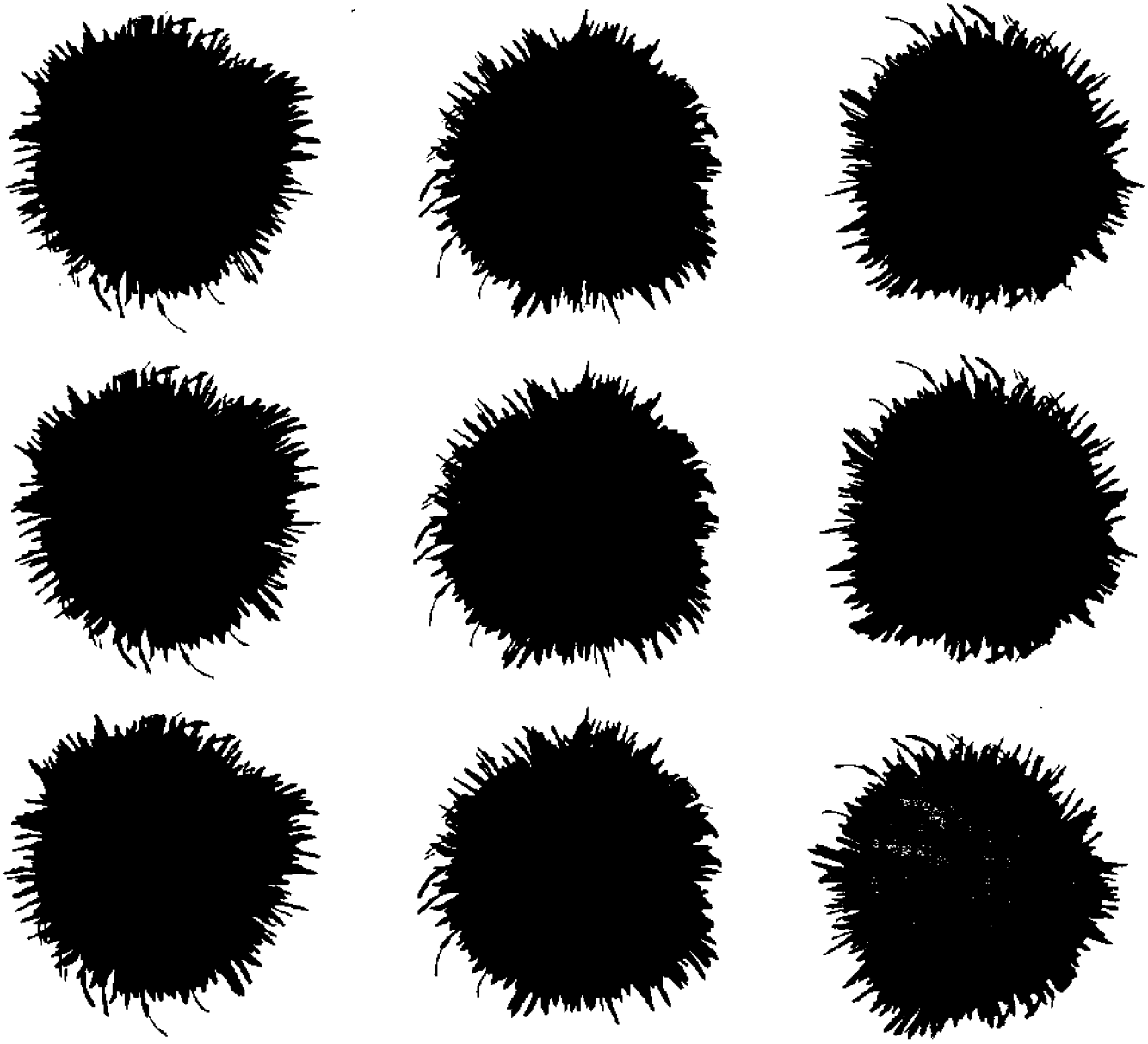
REPRODUCTIVE CYCLE AND GONAD YIELD OF GREEN SEA URCHINS IN LOWER COOK INLET, ALASKA

J.M. Paul and A.J. Paul



University of Alaska

Alaska Sea Grant Report 84-2
April 1984

Alaska Sea Grant College Program
University of Alaska
590 University Avenue, Suite 102
Fairbanks, Alaska 99701

REPRODUCTIVE CYCLE AND GONAD YIELD OF GREEN SEA URCHINS IN LOWER COOK INLET, ALASKA

J.M. Paul and A.J. Paul
University of Alaska
Institute of Marine Science
Seward, Alaska

Alaska Sea Grant Report 84-2
May 1984

ACKNOWLEDGMENTS

The authors wish to thank Russ Gaegel for his assistance in collecting materials and Karen Stomberg for drafting. Facilities at Kasitsna Bay Laboratory and the Seward Marine Science Center were provided by the University of Alaska Sea Grant College Program and Institute of Marine Science, respectively.

This work is the result of research sponsored by NOAA Office of Sea Grant and Extra Mural Programs, NOAA, Department of Commerce under grant number NA82AA-D-00044 and project numbers M/81-01, RR/83-02 and A/75-01; and by the University of Alaska with funds appropriated by the state.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The reproductive cycle of Strongylocentrotus droebachiensis, the green sea urchin, was monitored for one year in southern Kachemak Bay, lower Cook Inlet, Alaska. Gonad yields were relatively high from August through March. The gonads were firm and easily extracted from the test from August through October. In late November, male gonads were soft and leaked sperm when they were removed from the test. Female gonads remained firm and could be removed intact until January. From August through November, gonad weights were approximately 14.5 g for green sea urchins of 50 to 70 mm test diameter. During the study, gonad weights were highest in March, then declined to the lowest values following the annual spawning in April.

The results of this one-year survey suggest that the harvesting period for green sea urchin roe in lower Cook Inlet is from September through November.

INTRODUCTION

The green sea urchin, Strongylocentrotus droebachiensis, supports a commercial fishery in the North Atlantic and has some potential for supporting small local Alaskan fisheries. There is an increasing demand for sea urchin roe in Japan, and S. droebachiensis roe may be suitable for this market. No published information is available on the basic biology of the species in Alaskan waters. This report provides size-weight measurements, including seasonal gonad weights, for green sea urchins from Kachemak Bay, Cook Inlet, Alaska. This work identifies potential roe yields and fishing season for the area.

METHODS

Green sea urchins were collected during selected low tide series from July 1982 to July 1983. Collections were made either at Glacier Spit or near the mouth of Tutka Bay. Both sites are located along the southern shores of Kachemak Bay, Cook Inlet. Sea urchins were collected either with a long-handled dip net, 10 mm mesh, or by picking them up off the beach during minus tides.

Measurements of all individuals included test diameter, test height, live weight, and gonad weight. Drained weights for selected collections were obtained by making an incision around the mouth parts and draining the test for approximately ten minutes. Frequency distribution of test diameters were determined for net-caught sea urchins. Sexing was accomplished for the January 1983 sample, a period when eggs and sperm were easily identified, by examining gonads from individuals under a microscope. A similar examination was made the following June when sexes were more difficult to establish.

RESULTS

The test diameters of green sea urchins that were collected with the long-handled dip net ranged from 39 mm to 65 mm. Three size-classes of test diameters predominated the catch: 46 to 50 mm, 51 to 55 mm, and 56 to 60 mm groups; constituting 27.0, 36.4, and 24.7 percent of the sample, respectively (Table 1; Figure 1).

During this one-year survey, spawning occurred between March 1 and April 15, 1983 (Table 2, Figures 2-9). The water temperature was 7°C during the April collection. Roe yields remained low through August. From September to March, roe yields were similar and relatively high (Table 2, Figures 2-9). Gonads were firm and could be removed intact from animals collected between June and September. From late November until the spring spawning, gonads had a soft texture and oozed gametes when they were removed from the test. Thus, the best period for harvesting green sea urchins in Kachemak Bay during 1982 was from September to November. Gonads constituted from 21 to 27 percent of whole live weight from September through November (Table 3).

The smallest sea urchin collected that had apparently ripe gonads was 36 mm. The seasonal sampling of gonad weight (Table 2, Figures 2-9) suggests that at least some individuals of 35 to 45 mm test diameter spawned. A major change in gonad weight for sea urchins of 46 to 50 mm diameter, and concurrent visual examination of the gonads indicated that all individuals in this size-group participated in the annual spawning event. During September, when gonads began to approach high pre-spawning weights but retained a firm texture, roe yields for 46 to 50 mm sea urchins averaged 8.9 g, while 51 to 55, 56 to 60, 61 to 65 and 66 to 70 mm sea urchins had average gonad weights of 11.3, 14.6, 17.9, and 21.1 g, respectively. Thus, for each 5 mm increase in the average diameter of sea urchins that were processed, the average roe yield increased by approximately 3 g (Figures 3-9).

The equations that describe the various size-weight relationships of green sea urchins from September to January, the potential harvest period, are presented in Table 4. Measurements of drained weight determined that body fluids accounted for approximately 14 to 20 percent of total live weight (Table 5).

Examination of sex ratios in both January and June indicated a slight dominance of males, 65.3 and 56.5 percent respectively, in these collections (Table 6).

DISCUSSION

This survey was conducted through only one spawning period, that of 1983. The Gulf of Alaska sea surface temperature for 1983 was relatively warm. In Kachemak Bay the water temperature at the study site was 7°C in mid-April. April sea surface temperatures for Seldovia, Alaska, typically range from 2° to 5°C with an average near 4°C (U.S. Department of Commerce 1970). Bennett and Giese (1955) found that gonads of Strongylocentrotus purpuratus and S. franciscanus were larger in warmer winters than in cold ones. Thus, some inter-annual roe yield variability is possible. Additional surveys in

Table 1. Size distributions of green sea urchins, Strongylocentrotus droebachiensis, for random dip net collections from Tutka Bay, Cook Inlet, Alaska

Test Diameter (mm)	Number in Sample	Percent of Sample
35 - 40	3	3.5
41 - 45	4	4.7
46 - 50	23	27.1
51 - 55	31	36.5
56 - 60	21	24.7
61 - 65	3	3.5
Total	85	100.0

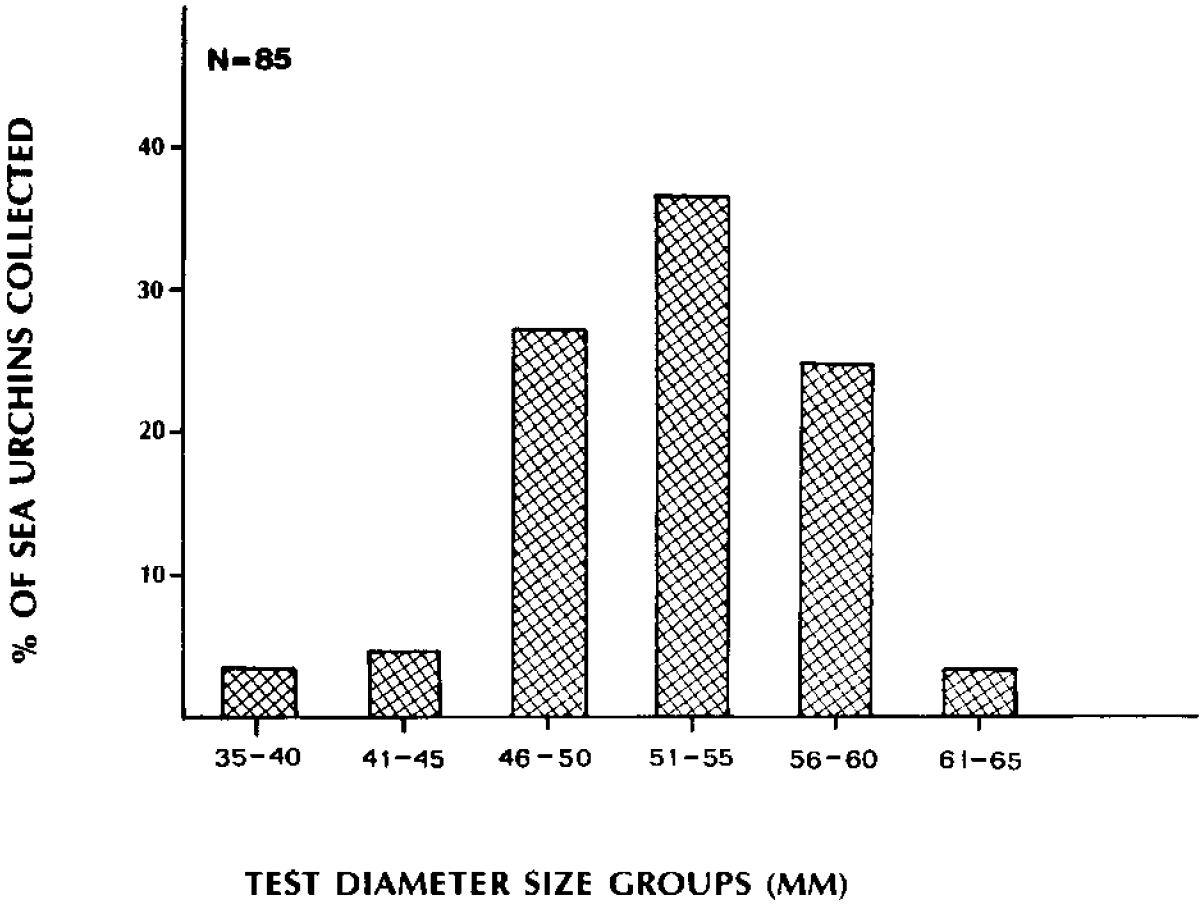


Figure 1. Frequency of test diameters of green sea urchins, Strongylocentrotus droebachiensis, collected by dip net in Kachemak Bay, Cook Inlet, Alaska, in 1983.

Table 2. Seasonal gonad weights and percent of gonad weight to whole live body weight by size groups for green sea urchins, S. droebachiensis, from Kachemak Bay, Cook Inlet, Alaska; %=percent gonad, m=mean gonad weight, sd=standard deviation, and r=range.

Date mo/da/yr	35-40 (mm)	41-45 (mm)	46-50 (mm)	51-55 (mm)	56-60 (mm)	61-65 (mm)	66-70 (mm)
07/23/82							
% gonad		9.4	11.1	11.6	10.5	11.2	10.0
m		2.6	3.9	5.0	6.1	8.4	8.5
sd		0.6	1.6	1.7	1.7	2.4	0.9
r		1.4-	1.9-	3.0-	3.7-	4.7-	7.6-
		3.2	9.9	9.7	9.1	11.7	9.4
09/14/82							
% gonad		22.5	21.3	21.5	21.5	21.2	21.2
m		6.9	8.9	11.3	14.6	17.9	21.1
sd		1.2	1.3	1.8	2.4	3.6	4.7
r		4.6-	6.1-	8.5-	11.1-	13.2-	17.7-
		9.2	10.5	13.3	19.0	23.8	24.4
11/28/82							
% gonad		22.3	23.0	23.6	24.5	16.5	
m		6.1	9.6	13.6	16.5	13.5	
sd		1.1	1.6	2.3	1.8	--	
r		5.1-	7.4-	10.5-	12.9-	--	
		7.2	11.4	18.0	19.3		
01/10/83							
% gonad	14.4	26.9	22.9	25.3	23.8	18.8	
m	3.6	8.2	9.5	13.7	16.5	16.4	
sd	0.8	2.1	1.9	2.1	2.1	0.6	
r	3.0-	6.7-	6.4-	10.4-	13.0-	16.0-	
	4.1	9.6	12.7	17.8	20.2	16.8	
03/01/83							
% gonad	7.5	18.9	25.6	20.6	22.3	21.7	23.6
m	2.8	5.9	11.5	11.7	16.3	17.9	27.0
sd	1.6	2.9	2.5	3.2	5.2	5.4	9.8
r	1.7-	1.1-	7.9-	5.9-	8.9-	12.6-	17.3-
	4.0	10.5	17.1	15.6	28.9	25.1	37.0
04/15/83							
% gonad	3.7	5.0	6.0	7.0	5.8	5.7	5.3
m	0.7	1.6	2.5	3.9	4.2	5.1	5.7
sd	0.3	0.5	0.6	2.9	1.6	1.2	0.7
r	0.3-	1.0-	1.1-	2.2-	1.5-	3.5-	5.1-
	1.2	2.3	3.1	11.9	6.7	7.5	6.5
06/22/83							
% gonad	7.7	10.2	11.0	13.1	11.5	10.5	9.9
m	1.7	3.2	4.6	7.6	8.3	8.7	10.5
sd	0.6	1.5	0.9	1.5	1.5	1.0	0
r	1.0-	1.6-	2.9-	5.5-	6.0-	7.0-	--
	2.6	6.0	5.8	10.0	11.0	10.0	
07/28/83							
% gonad			7.7	8.2	9.1	5.8	
m			3.3	4.8	6.6	5.0	
sd			1.0	1.5	1.8	1.0	
r			2.0-	3.0-	4.0-	4.0-	
			5.0	6.5	9.5	6.0	

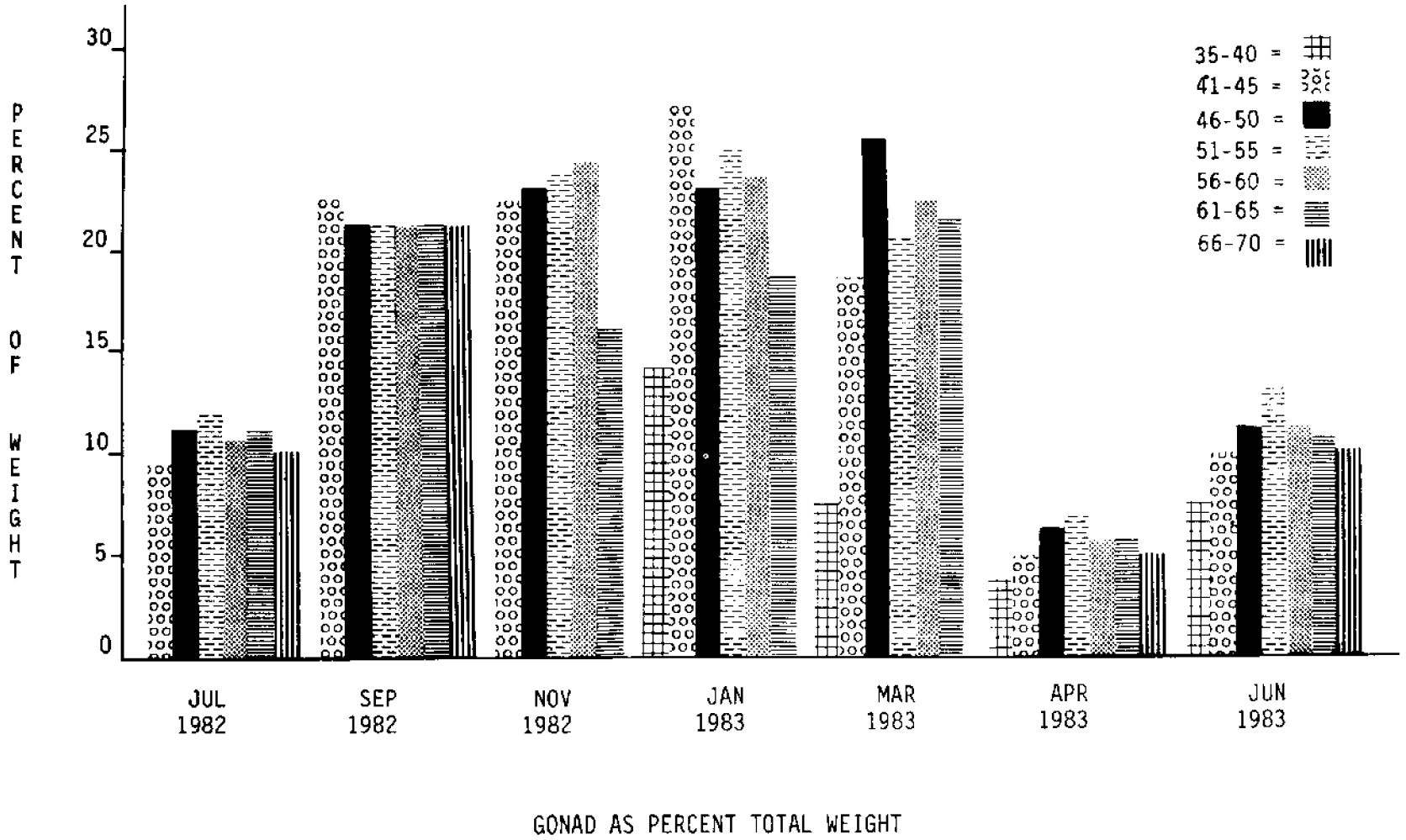


Figure 2. Seasonal gonad weights and percent of gonad weight to whole live body weight by size groups for green sea urchins, S. drobachiensis, from Kachemak Bay, Cook Inlet, Alaska.

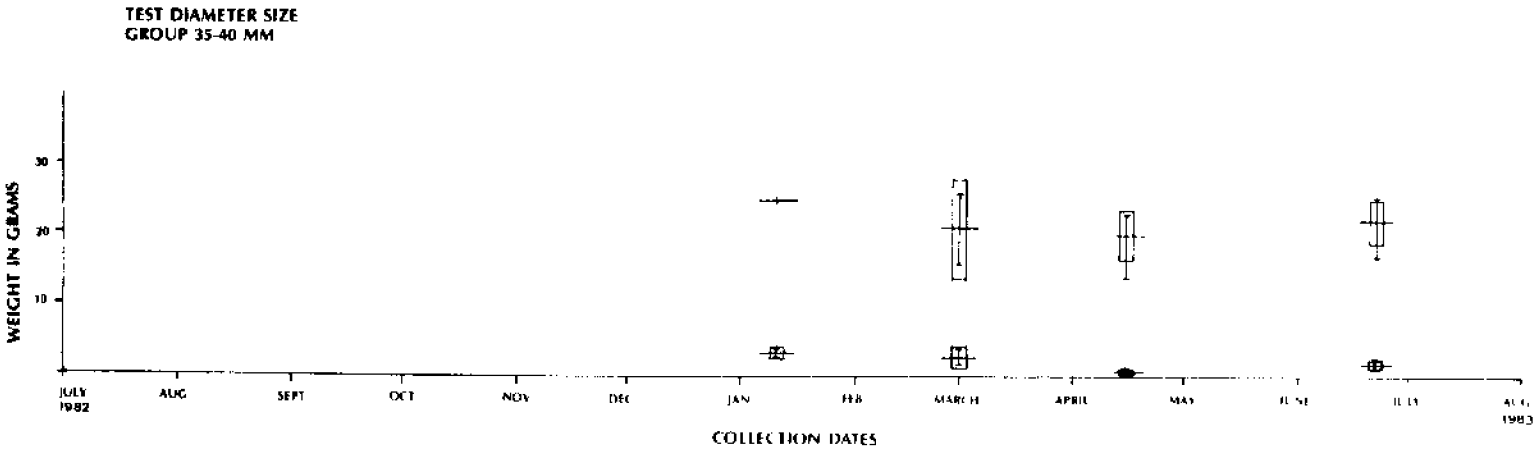


Figure 3. Seasonal whole live weights (upper figures) and gonad weights (lower figures) of test diameters 35 to 40 mm for green sea urchins, S. droebachiensis, from Kachemak Bay, Cook Inlet, Alaska. (Data: horizontal line = mean, box = 2 standard deviations, vertical line = range)

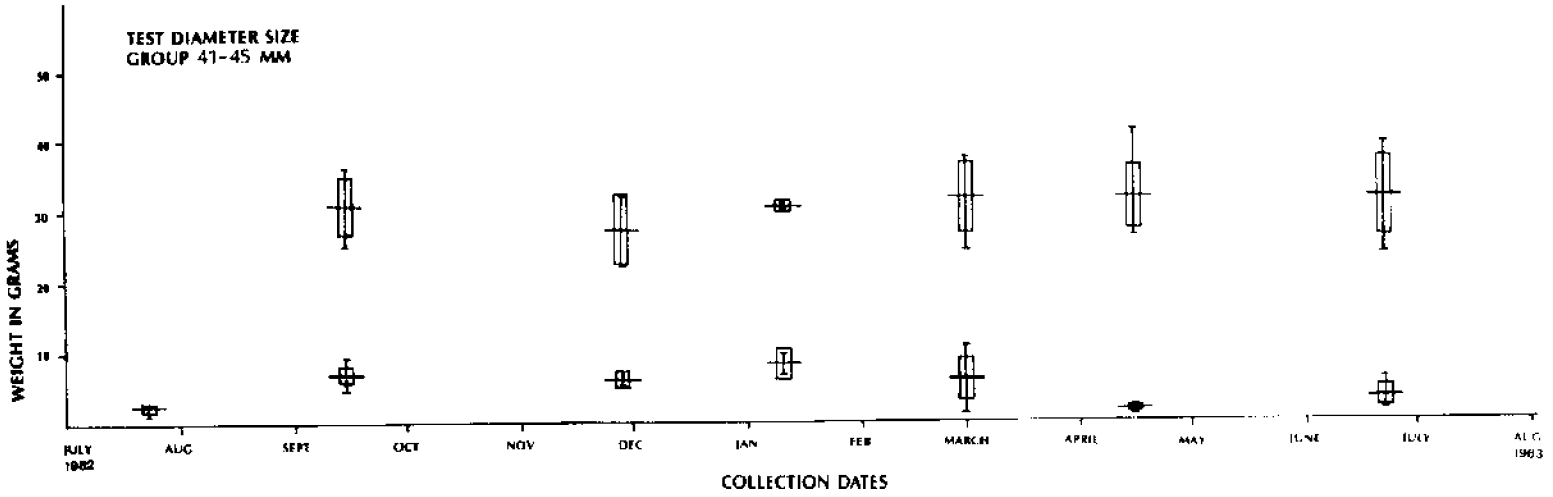


Figure 4. Seasonal whole live weights (upper figures) and gonad weights (lower figures) of test diameters 41 to 45 mm for green sea urchins, S. droebachiensis, from Kachemak Bay, Cook Inlet, Alaska. (Data: horizontal line = mean, box = $\bar{2}$ standard deviations, vertical line = range)

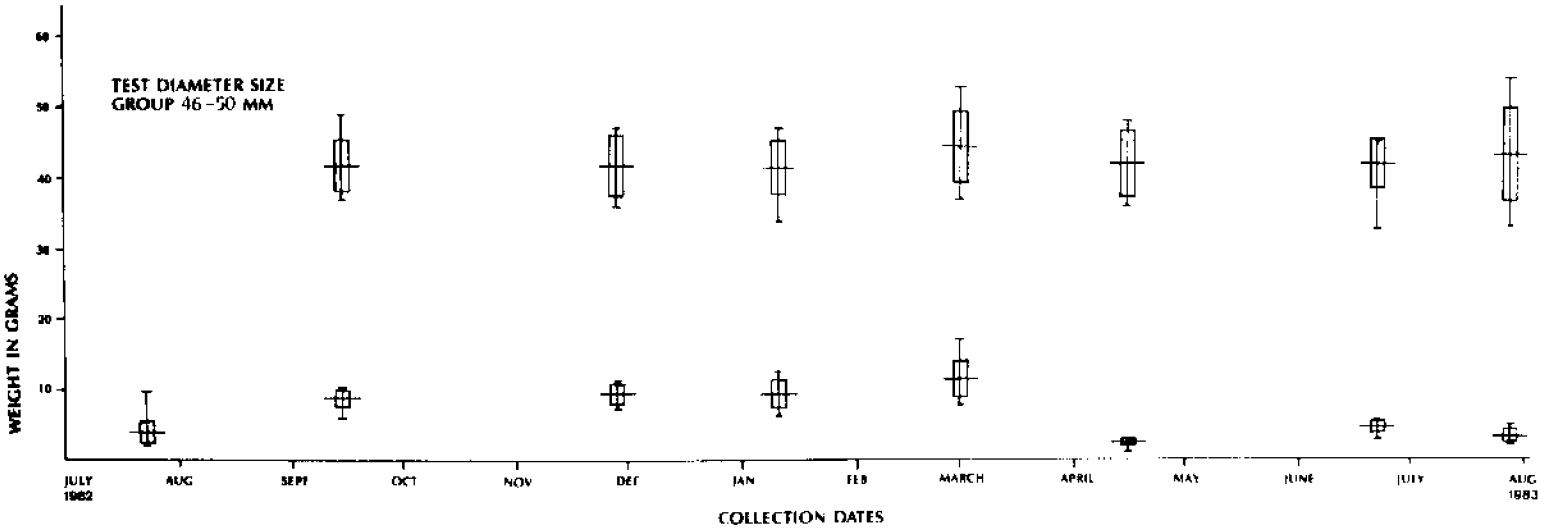


Figure 5. Seasonal whole live weights (upper figures) and gonad weights (lower figures) of test diameters 46 to 50 mm for green sea urchins, S. droebachiensis, from Kachemak Bay, Cook Inlet, Alaska. (Data: horizontal line = mean, box = 2 standard deviations, vertical line = range)

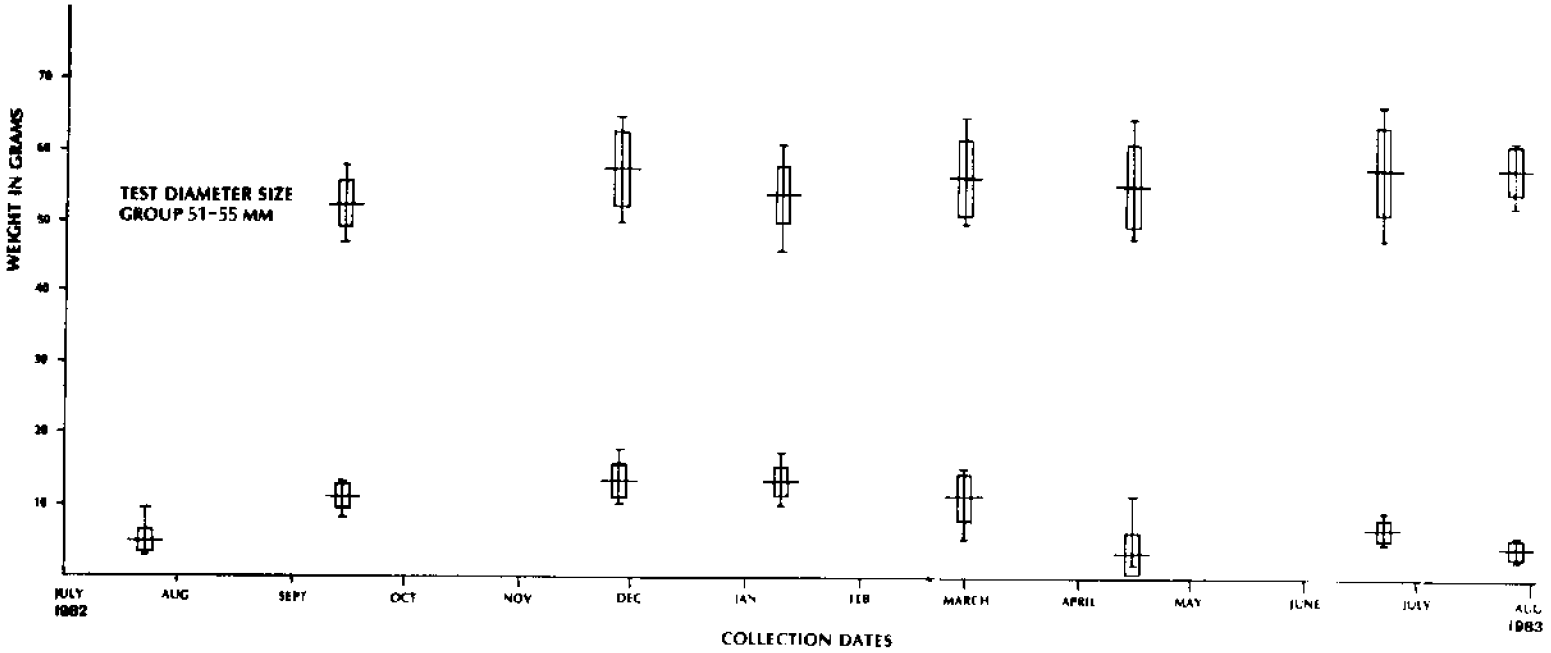


Figure 6. Seasonal whole live weights (upper figures) and gonad weights (lower figures) of test diameters 51 to 55 mm for green sea urchins, S. droebachiensis, from Kachemak Bay, Cook Inlet, Alaska. (Data: horizontal line = mean, box = $\overline{2}$ standard deviations, vertical line = range)

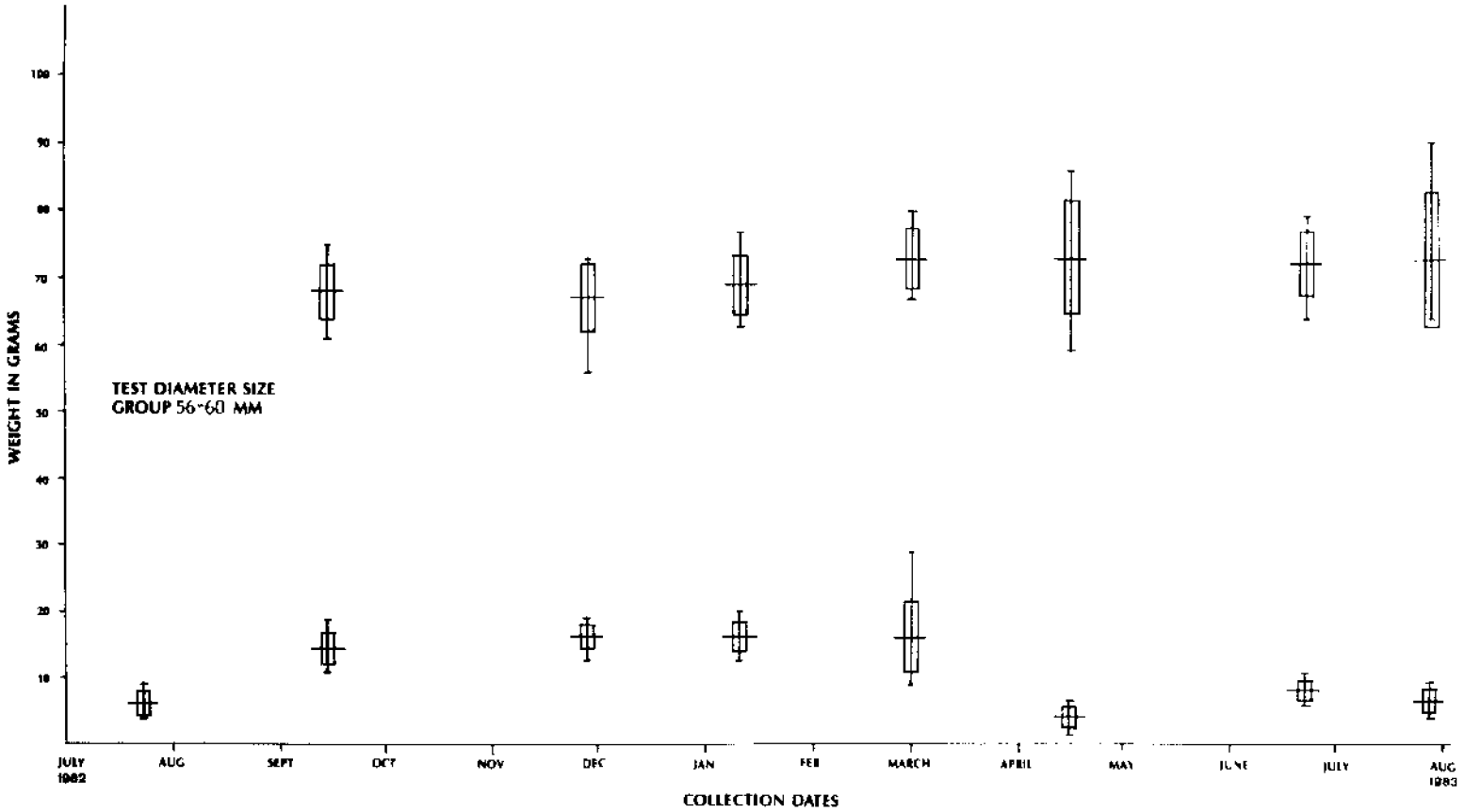


Figure 7. Seasonal whole live weights (upper figures) and gonad weights (lower figures) of test diameters 56 to 60 mm for green sea urchins, S. droebachiensis, from Kachemak Bay, Cook Inlet, Alaska. (Data: horizontal line = mean, box = $\overline{2}$ standard deviations, vertical line = range)

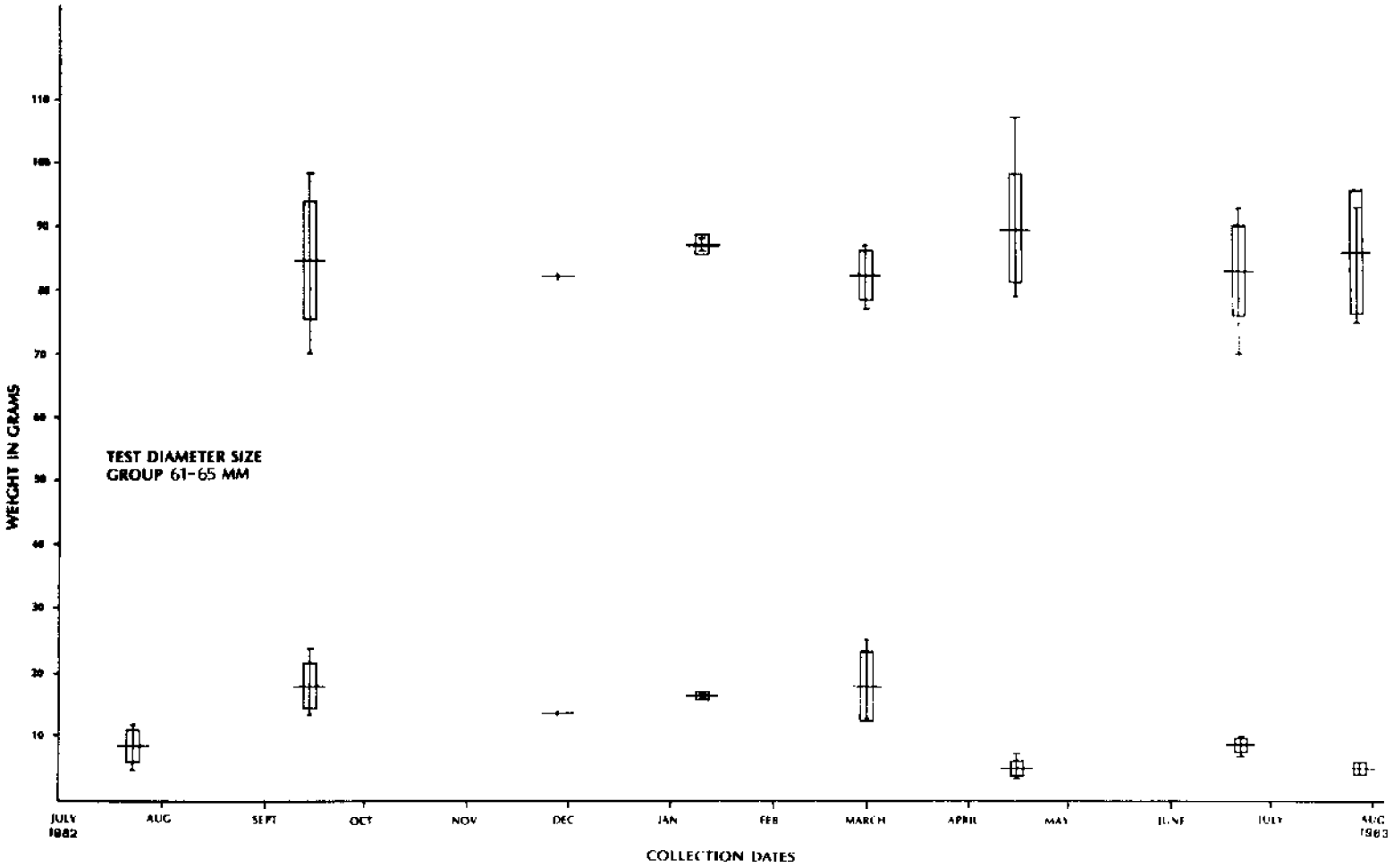


Figure 8. Seasonal whole live weights (upper figures) and gonad weights (lower figures) of test diameters 61 to 65 mm for green sea urchins, S. droebachiensis, from Kachemak Bay, Cook Inlet, Alaska. (Data: horizontal line = mean, box = $\overline{2}$ standard deviations, vertical line = range)

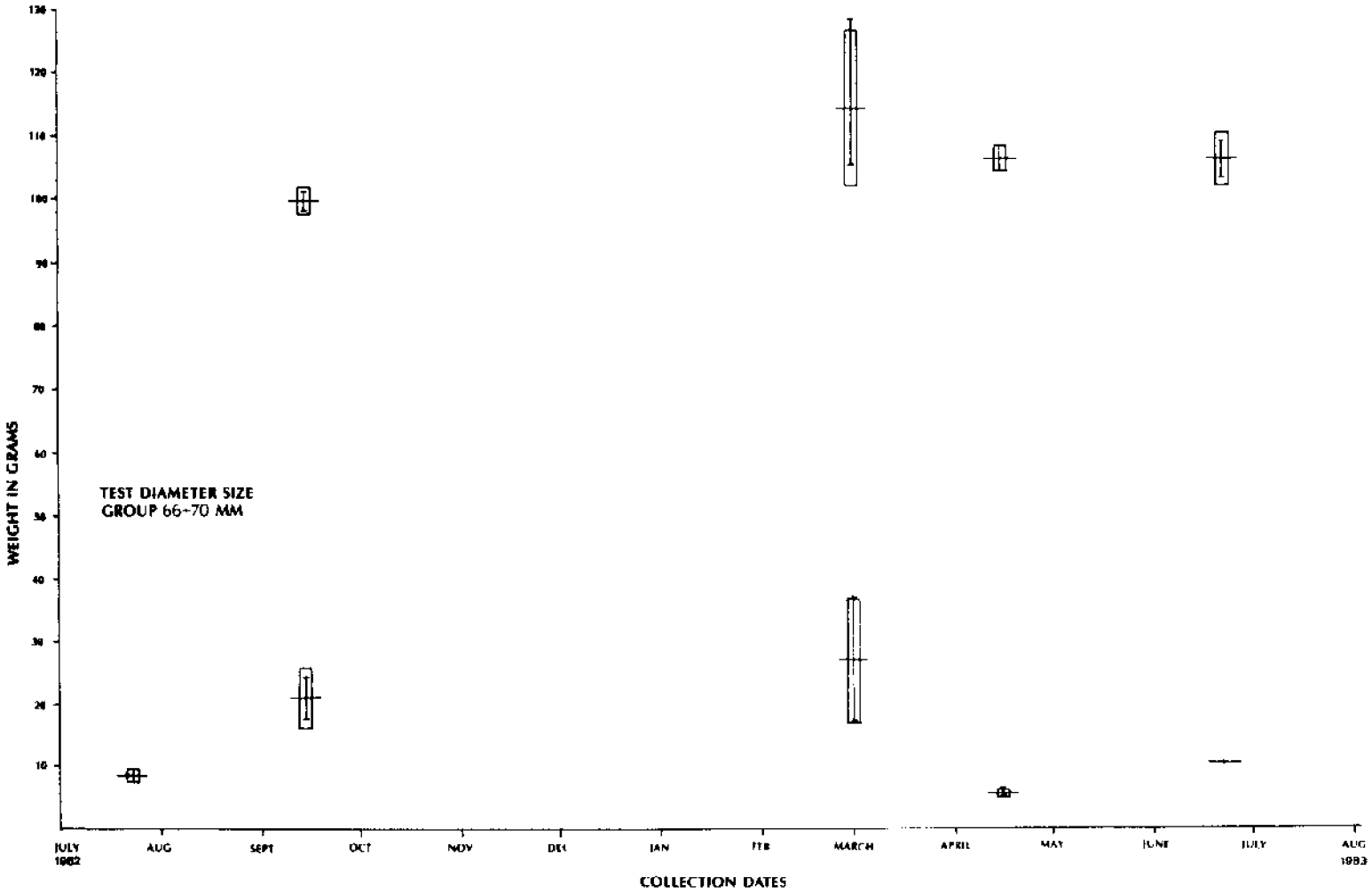


Figure 9. Seasonal whole live weights (upper figures) and gonad weights (lower figures) of test diameters 66 to 70 mm for green sea urchins, S. droebachiensis, from Kachemak Bay, Cook Inlet, Alaska. (Data: horizontal line = mean, box = 2 standard deviations, vertical line = range)

Table 3. Gonad weights of green sea urchins, Strongylocentrotus droebachiensis, from Kachemak Bay, Cook Inlet, Alaska, during September and November 1982

Sea Urchin Test Diameter (mm)	September Gonad Weights (g)	November Gonad Weights (g)
41 - 45	6.9	6.1
46 - 50	8.9	9.6
51 - 55	11.3	13.6
56 - 60	14.6	16.5
61 - 65	17.9	13.5
66 - 70	21.1	--

Table 4. Size-weight relationships for green sea urchins, S. droebachiensis, from Kachemak Bay, Cook Inlet, Alaska

Whole live weight	= -91.1 + 2.8 (test diameter), R^2=0.96
Whole drained weight	= -60.1 + 2.0 (test diameter), R^2=0.92
Whole drained weight	= 7.0 + 0.7 (whole live wt), R^2=0.94
Test height	= 0.8 + 0.5 (test diameter), R^2=0.81

Table 5. The relationships between test diameter to whole live weight and whole drained weight of the green sea urchin Strongylocentrotus droebachiensis collected in Kachemak Bay, Cook Inlet, Alaska; m=mean, sd=standard deviation, and r=range

	TEST DIAMETER									
Date	46-50 mm		51-55 mm		56-60 mm		61-65 mm		66-70 mm	
	Live	Drain	Live	Drain	Live	Drain	Live	Drain	Live	Drain
(mo/da)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)
09/14										
m	41.8	36.5	52.6	43.6	68.0	54.3	84.6	64.8	99.5	76.6
sd	3.6	4.1	3.2	2.4	4.1	3.1	9.2	6.1	2.1	2.8
r	37-49	30-45	47-58	42-48	61-75	48-57	70-98	56-76	98-101	74-78
11/28										
m	41.8	37.3	57.6	49.6	67.3	60.4	82	68		
sd	4.2	2.5	5.3	5.1	5.1	5.1	--	--		
r	36-47	34-41	50-65	44-58	56-73	52-70	--	--		
01/10										
m	41.5	36.5	54.1	47.1	69.3	57.7	87.0	68.0		
sd	3.8	2.7	3.9	2.9	4.4	3.4	1.4	4.2		
r	37-47	31-40	46-61	42-52	63-77	53-65	86-88	65-71		

Table 6. Sex ratios of green sea urchins, S. droebachiensis, from Tutka Bay, Cook Inlet, Alaska for 1983

Date (mo/da)	Test Diameter (mm)	No. Males	No. Females	Total No.
01/10	35 - 40	2	0	2
	41 - 45	1	1	2
	46 - 50	13	4	17
	51 - 55	9	8	17
	56 - 60	5	4	9
	61 - 65	2	0	2
	Totals	32	17	49
	Percent of Sample	65.3%	34.7%	
06/22	35 - 40	6	4	10
	41 - 45	7	3	10
	46 - 50	4	6	10
	51 - 55	6	4	10
	56 - 60	6	3	9
	61 - 65	6	4	10
	66 - 70	0	2	2
	85	0	1	1
	Totals	35	27	62
	Percent of Sample	56.5%	43.5%	

Kachemak Bay and other areas with harvestable populations are necessary to describe the potential yields and best harvest periods for Alaskan green sea urchins.

In the Atlantic off Cape Cod, green sea urchin spawning occurs between December and April, with males maturing about two months earlier than females (Wilson and Gorham 1982). Thus, spring spawning appears to be common throughout the range of S. droebachiensis.

The results of this survey suggest that in 1982, harvests yielding firm gonads with the highest weights would be conducted from September through November. During that period, 50 to 70 mm green sea urchins would have yielded 11 to 21 g of roe per individual processed. The roe yields found from Kachemak Bay green sea urchins, 21 to 25 percent of the whole live weight (Table 2, Figure 2), compares favorably with the previously reported value of 17 percent roe yield (Wilson and Gorham 1982).

There is some information on food and growth of S. droebachiensis for other areas. Himmelman and Steele (1971) report fucoids, Alaria spp., mussels, sand dollars, and other urchins are food sources. Predators include sea stars, sea gulls, crabs, sculpins, flat fishes, and sea otters. Swan (1961) reports 30 mm individuals will grow approximately 23 mm, while 56 mm urchins grew 6 mm per year at Friday Harbor, Washington. Growth rates of green sea urchins in the cold waters of Alaska are probably slower.

Some information on the relative abundance of S. droebachiensis for Cook Inlet is available from other reports. Feder and Paul (1981), collecting subtidal green sea urchins throughout lower Cook Inlet with trawls, found concentrations as high as 0.08 individuals per m^2 and weights of 4.3 g per m^2 (Table 7). Highest concentrations of subtidal sea urchins were reported in Kachemak Bay. Lees and Driskell (1980) operating with scuba gear reported concentrations of 0.5 to 50 individuals per m^2 (Table 8). The average size for green urchins at different sites in the diving survey frequently ranged from 37 to 50 mm test diameter. Highest abundances occurred in rocky habitats. Economic considerations relating to a successful Alaskan sea urchin fishery are reviewed by Wilson and Gorham (1982).

In northern Japan, the urchin Strongylocentrotus intermedius is harvested. It is morphologically similar to S. droebachiensis. However, the thermal regime in northern Japan is 2° to 3°C warmer during the July through December period than is the northeastern Gulf of Alaska. Thus, it is to be expected that growth rates and the reproductive period of S. intermedius would differ from that of Alaskan sea urchins. The following biological characteristics for S. intermedius are provided by Kawamura (1973):

1. Larvae produced by newly-mature females have lower survival rates than those produced by older females.

2. Larvae appear in September and October.

3. Age at maturity is 2 or 3 years, depending on the habitat.

4. Age at harvest is 2 to 4 years.

Table 7. Abundance of green sea urchins, Strongylocentrotus droebachiensis at selected trawl stations in three areas of lower Cook Inlet, Alaska, from Feder and Paul (1981).

Latitude	Longitude	Depth (m)	No./m²	Grams/m²
		Kachemak Bay		
59°36.7'	151°51.6'	31	0.00025	0.01505
59°39.0'	151°51.9'	33	0.00319	0.18526
59°32.1'	151°04.5'	40	0.01327	0.86938
59°28.2'	152°05.2'	49	0.00705	0.51856
59°40.0'	151°59.5'	29	0.08229	4.38976
		Kamishak Bay		
59°15.6'	153°33.8'	32	0.00004	0.00512
59°15.4'	153°40.0'	31	0.00004	0.00374
59°33.0'	152°41.3'	41	0.00424	0.43491
59°46.2'	152°55.0'	26	0.00141	0.19728
59°49.8'	152°52.3'	24	0.00017	0.02258
		Outer Cook Inlet		
59°00.3'	152°42.5'	166	0.00051	0.04743
59°00.3'	153°03.1'	150	0.00014	0.00091
59°00.3'	153°10.6'	121	0.00032	0.01727
59°10.3'	152°47.1'	146	0.00026	0.03922

Table 8. Abundance of green sea urchins, Strongylocentrotus droebachiensis, at selected scuba survey sites from Lees and Driskell (1980) in lower Cook Inlet, Alaska

Location	Number (per m^2)	Depth (m)	Mean Test Diameter (mm)
Kachemak Bay			
Archimandritof Shoals	47.0	4.6	40.0
	137.0	6.7	40.0
	0	15.5	
Bishops Beach	2.9	15.2	51.4
	4.3	15.2	51.4
Bluff Point	7.4	10.1	44.5
	0.2	20	44.5
Troublesome Creek	18.8	8	37.4-47.6
Jakolof Bay (reef)	50	5-10	
(channel)	1.3	5-10	
Barabara Bluff	14.2	10	
Kamishak Bay			
Knoll Head Lagoon	0.04	0	
	0.05	4	

5. Mortality of the zero-age group exceeds 50 percent and thereafter is low.

Currently, there are no other published reports concerning the reproductive cycle and roe yields of Alaskan sea urchins. Likewise, no information is available on growth, size at maturity, variability of annual recruitment, natural mortality, and potential sustainable yields for an Alaskan sea urchin fishery. This biological and environmental information must be obtained if a sustained fishery is desired.

LITERATURE CITED

Bennett, J. and A. Giese. 1955. The annual reproductive and nutritional cycles in two western sea urchins. Bio. Bull. 109:226-237.

Feder, H.M. and A.J. Paul. 1981. Distribution and abundance of some epibenthic invertebrates of Cook Inlet, Alaska. Fairbanks: University of Alaska Institute of Marine Science. IMS report number R80-3.

Himmelman, J.H. and D.H. Steele. 1971. Foods and predators of the green sea urchin Strongylocentrotus droebachiensis in Newfoundland waters. Mar. Biol. 9:315-322.

Kawamura, Kazuhiro. 1973. Fishery biological studies on a sea urchin, Strongylocentrotus intermedius (A. Agassiz). Scientific Repts. Hokkaido Fish. Exp. Sta. 16.

Lees, D. and W.B. Driskell. 1980. Investigations on shallow subtidal habitats and assemblages in lower Cook Inlet. In Distribution, abundance, community structure and trophic relationships of the nearshore benthos, ed. H.M. Feder. OCSEAP final report 15/5.

Swan, E.F. 1961. Some observations on the growth rate of sea urchins in the genus Strongylocentrotus. Bio. Bull. 120:420-427.

U.S. Department of Commerce. 1970. Surface water temperature and density: Pacific coast of North and South America and the Pacific Ocean Islands. Third edition. NOS publication 31-3: 88 pp.

Wilson, J.R. and A.H. Gorham. 1982. Alaska's underutilized species. Vol. III: Sea urchin. Fairbanks: University of Alaska Sea Grant College Program. Report number 82-7.