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by N. Bourne

FISHERIES RESEARCH BOARD OF CANADA
TECHNICAL REPORT NO. 15

1967

FRB

1867 1967

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TECHNICAL REPORT NO. 15.

DIGGING EFFICIENCY TRIALS WITH A HYDRAULIC CLAM RAKE

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Biological Station, Nanaimo, B. C.

May, 1967

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INTRODUCTION

Landings of butter clams (Saxidomus giganteus Deshayes) in British Columbia have declined steadily in the last 15 years (Fig. 1). This trend is due partly to closure of some areas: the northern part of the province has been closed to shellfish digging since 1963 because of paralytic shellfish poisoning. However the decline is also due to sociological changes among diggers. Digging clams is hard work, and since digging is done at night in the winter it is unpleasant work. In recent years there have been more rewarding jobs available to clam diggers.

An urgent need in the industry is the improvement of the method of digging: i.e., make it more efficient and more rewarding. The present methods have not changed since the white man first came to the coast. Clams are dug with a potato fork, the hack of soil turned over and the clams picked out. This work is back-breaking, slow, and many of the clams are broken in the process of digging.

Recently, mechanical or hydraulic diggers have been used to dig shellfish. Powerful jets of water wash the soil away from the clams, which are then scooped up by an escalator or are easily flicked out of the trench with a rake. Most of the diggers have been designed and built on the east coast and they have proven to be more efficient, faster and cause less breakage to shellfish than the conventional clam fork. Mechanical diggers have been used on the west coast, particularly in the State of Washington.

East coast beaches frequently cover large areas and are relatively free of rock, whereas in British Columbia clam beaches are usually small (sometimes less than one acre) and often very rocky. The escalator harvester (MacPhail, 1961) which was developed and is used commercially on the east coast would not be economical in British Columbia because the beaches are too small to make the operation profitable, and the large rocks would seriously hamper the operation of such a digger. Furthermore, this hydraulic harvester requires an investment of at least $10,000. The type of mechanical digger needed for British Columbia shellfish harvesting should be suitable for a one- or two-man operation, portable, efficient and inexpensive to build.

The hydraulic clam rake, which was perfected at the Biological Station, St. Andrews (MacPhail and Medcof, 1962), appears to be the type of hydraulic digger most suited to British Columbia beaches. MacPhail and Medcof found it was faster, more efficient, and caused less breakage than the conventional clam fork when used to dig soft-shell clams (Mya arenaria L.), and yet it is inexpensive to build and quite portable. We were interested in testing this clam rake on British Columbia beaches and measuring its efficiency for digging butter clams and other species, and undertook the following experiments during the summer of 1966.

GEAR

The hydraulic clam rake or digger used in this work was similar to the one described by MacPhail and Medcof (1962) (Fig. 2). Short 2-inch nozzles were used throughout the work. The only difference between our rake and theirs was in the arrangement of the nozzles on the manifold. Our digger had 7 nozzles on 3-1/2-inch centres. They were joined to the manifold by short 1/2-inch by 11/16-inch couplings.

The pump was a 2-inch by 2-inch centrifugal pump powered by a 4 hp engine and was floated in a small skiff (Fig. 3). The end of the 2-inch intake hose was covered with a 1/4-inch mesh screen and was floated about 1 ft off the bottom to prevent small stones and mud clogging the pump. The hose between the pump and digger consisted of two 100-ft lengths of fire hose, 1-1/2 inches in diameter during the first experiment and 2 inches in diameter in the second.

A pressure gauge was attached to the manifold to measure water pressure at the nozzles.

METHODS

Experimental digging was done during two periods of low water, July 18-22 and August 15-18, 1966, at Seal Island near Comox, B. C. This island, which is covered with water at high tide, is at the northern tip of Denman Island and is actually a bar with a steep slope on the western side. The clam flat has an area of about 10-15 acres and it has supported a very intensive fishery in past years. The soil is mostly clay-mud, gravel and shell with small boulders but no outcrops of large rock. There are numerous oysters and old shell on the surface of the flat (Fig. 4).

Experimental plots were arranged in the same area for both trial periods. The plots were at right angles to the western side of the bar, at a tide level barely exposed at 2.0-ft tides. Each plot was 2 ft wide, the width of the digger, and varied in length from 17-131 ft, although most plots were about 35-45 ft long.

The digging method was similar in both experiments. When the water pressure from the pump reached its maximum, the digger was allowed to "dig in". The digger was pulled slowly across the flat making certain that the water jets penetrated well into the soil (Fig. 5 and 6). Digging speed was not predetermined but was slow enough to keep the digger in the trench and allow the water jets to penetrate the soil and wash out the clams, but fast enough so that the digger did not bury itself in the trench. The distance dug was frequently determined by the length of hose available.

While one person operated the digger the other raked the clams that were washed out and left in the trench (Fig. 6). In the first experiment, garden rakes covered with 1/4-inch mesh screening were used, but these were unsatisfactory. In August, manure forks with 6- to 8-inch tynes bent at right angles to the handle were found to be much more satisfactory.

MacPhail and Medcof used the digger when the flat was covered with 18-36 inches of water. We tried using the digger in similar depths of water but met with only limited success and found retrieving clams under these conditions difficult. We tried the digger when the flat was either dry or covered with no more than 6 inches of water (Fig. 4). Results were much better and most of the trials during both July and August were carried out when the flat was dry.

After the plots were dug the clams were picked up. Butter clams were sorted by eye into commercial and sub-commercial sizes, counted and weighed (commercial size is 2 -1/2 inches in length). Horse clams (Tresus capax Conrad) and little-neck clams (Protothaca staminea Conrad) were also counted and weighed. The number of broken clams, the length of time taken to dig the trench, and the distance dug were also recorded.

The lengths of all butter clams from one plot were measured to obtain a length frequency distribution of clams on the flat.

The width of the trench from verge to verge, as well as the depth and condition of the loose soil in the trench, was noted. Particular attention was given to the location and condition of small clams left in the trenches and in the verges. The fate of the trenches was observed through successive tides.

One or two days after the plots were dug in July, clam holes appeared in the trenches. About half of two trenches were dug by hand to determine the number of clams still in the trenches and missed by the digger. The numbers of clam holes were counted in two small plots. In August most of the plots were re-dug by hand to determine the number of clams missed by the digger.

In August, six plots were dug by hand to obtain an estimate of clam production by hand digging and to compare this rate with that of the digger.

RESULTS

The length-frequency distribution of butter clams dug from Plot 16 on August 18, 1966, is shown in Fig. 7. Although there was a slightly higher percentage of sub-commercial size clams in this plot than in others, it is nevertheless indicative of the size-frequency distribution of clams dug during this work. There was a preponderance of small clams, length 35-55 mm, probably 3-year-olds. Another peak in size distribution occurred at 65-80 mm, probably 7- and 8-year-olds. About 36% of clams in this plot were larger than 2-1/2 inches, the legal limit, while in most other plots the percentage was higher.

Data from the two sets of experiments are shown in Tables I to IV and summarized in Table V. Those plots dug when the flat was dry are considered separately and the data are summarized for total plots and for plots dug when the flat was dry.

In August the total area dug was 33.6% less than in July and 23.6% less when the flat was dry. The digging speed in August was much slower than in July, about half the rate both for total plots and when the flat was dry.

Production of all species of clams was much greater in August than in July. In August, production of commercial-size butter clams was about five times greater than in July, when expressed as numbers or pounds per square yard, and about three times greater when expressed as numbers or pounds per hour. In both July and August the quantities of clams dug, expressed in any terms, were almost always greater when the flat was dry than for the total plots.

The efficiency of the digger, as calculated for the August trials, is shown in Table VI. Most of the clams missed by the digger (both butter and horse clams) were very large; the horse clams weighed about 1 lb each. The efficiency of the digger for commercial-size butter clams was just less than 85% for both numbers and weights when the flat was dry, and slightly less for the total plots. The efficiency was less for horse clams: 68.5% (numbers) and 64% (weight) when the flat was dry and 65.5% (numbers) and 62% (weight) for total plots.

Breakage of all size clams was very low in both experiments: well under 5% for both large and small clams. Many of the plots had no broken clams. Even most of the horse clams were unbroken. Most breakage occurred when the clams were hit by the rake or were tramped on when raking.

The water pressure at the manifold was not recorded in July but in August it was 14-15 lb per sq inch throughout the trials.

The bottoms of the trenches left by the digger were 24 inches in width and were approximately 2 inches below the surface of the flat. The verge-coverage width was 31-32 inches and each verge was built up 1-2 inches above the surface of the flat. However the verges had almost disappeared after a tide (Fig. 8). The soil in the top 6-8 inches of the trench was quite soft and most of the clams dug were in this part of the soil. Many of the small clams observed in the surface of the soil in the trenches were digging back into the soil within 15 min after they had been washed out by the digger. Presumably most clams in this loose soil could dig back in by the end of the following high tide. The trenches remain quite visible for some time and trenches dug in July were quite visible during the August work.

Operating the digger in 12-36 inches of water was quite difficult. The water became so cloudy that it was hard to know if the digger was operating properly. Furthermore, raking was haphazard and undoubtedly many clams were missed. The only advantage to digging under water would be a longer working period; the pump can be kept close to the operator and the water helps float the hose and makes handling the digger slightly easier.

Results of the plots dug by hand are shown in Table VII. One plot had more clams than the others, but the production of commercial-size butter clams for the six plots was 151.8 lb per hr; production of horse clams, 96 lb per hr. Breakage for both butter and horse clams was high, about 25% for butter clams and 50% for horse clams. These plots were small and the digging time short. It is very doubtful if this digging rate could have been maintained for a complete tide.

DISCUSSION

It should be pointed out that although the experimental area at Seal Island was selected at random, it appears it had above normal densities of commercial-size butter clams. In August production for the dry plots varied from 8.4 to 19.4 lb per sq yd, a mean of 13.8 lb per sq yd (Tables III and V). In a population survey of Seal Island in August 1964, Quayle (personal communication) found a mean concentration of 3.5 lb per sq yd, although abundance did range from 0 to 16.6 lb per sq yd for his plots which covered the entire area. Part of this difference may be due to differences in efficiency of the digger and the clam fork. However it is likely that the clam population in this area was above normal and the rate of clam production we experienced in this work would not be found in some other areas of Seal Island or in most parts of the province. These high clam densities should not affect a consideration of the results.

Efficiency

There was a marked difference in clam production in the two trials. The only difference in methods between the two trials was the slower digging speed and greater volume of water through the nozzles in August. (Unfortunately, we have no measure of the amount of water passing through the digger in either experiment but we believe the volume of water was considerably greater in August than in July because the discharge fire hose had a larger diameter and the height of the spray from the nozzles was noticeably greater.) In August the jets of water penetrated deeper into the soil than in July and washed dirt away from those deeply buried clams, freeing them for harvesting. If the volume of water and pressure were further increased to that reported by MacPhail and Medcof (130 gal per min and 25 psi), it is probable that the digger would operate more effectively and the efficiency would be increased over the recorded 85-95%, which was reported by MacPhail and Medcof.

The digging speeds attained in our work, even in July, were much less than those reported by MacPhail and Medcof. With 2-inch nozzles their average speed was 23.1 ft per min, whereas our best speed was 8.0 ft per min (July, Plot 11). This difference in digging speed may be due to several factors: their digger had 8 nozzles and ours had only 7; they had greater water pressure and probably greater flow through the digger; they used the digger in 18 to 36 inches of water whereas our trials were carried out mostly on dry flat. The major reason for the difference in digging speed is probably due to differences in the type of soil. In their work the soil was a silt-sand and very easily washed away. At Seal Island the soil was clay-mud, gravel and old shell, which is more difficult for water jets to penetrate.

Unlike MacPhail and Medcof we had only limited success using the digger in water depths of 18 to 36 inches. It is unlikely that this type of digger can be used to much advantage in water this deep in British Columbia. During the commercial clam season (November 1 to May 31) many of the low tides occur at night. This means that visibility is even further reduced and the efficiency when working under these water depths would probably be low. It would also be rather dangerous working under these conditions, particularly on a bar type flat with a flooding tide. Furthermore, if there is much rock on the beach it is almost impossible to avoid it with the digger when using it under water. The only disadvantage to working on dry flat is that the digger is probably slightly harder to pull and the odd splash strikes the operator when a water jet hits an old shell.

Comparison of hydraulic digger with fork

The hydraulic clam rake digs clams faster and more efficiently than the clam fork.

The rate of digging with a clam fork (16.4 sq yd per hr), as shown in Table VII, is not too realistic and is too fast. The digging period was very brief and we could not have maintained this rate for an entire tide (4 hr). Neave (1945) reports professional clam diggers rarely dig over 25-30 sq yd per tide (certainly a maximum would be 40 sq yd for a 4-hr tide, or 10 sq yd per hr). The digging rate of the hydraulic rake in August was 43.1 sq yd per hr - 4 to 6 times faster than the fork.

Production of commercial-size butter clams with the fork was 151.8 lb per hr but, as was just pointed out, this rate is too high. If we assume a maximum digging rate of 10 sq yd per hr, the mean production with the fork in this work would be 93 lb per hr or 372 lb per 4-hr tide. The hydraulic digger produced 593.4 lb per hr, over 2,000 lb per tide. This production would be for two men so one man could produce over 1,000 lb per tide, at least three times as much as the fork.

We have no measure of the fishing efficiency of the clam fork but MacPhail and Medcof report an efficiency of 50 to 60% for the clam hack which is used to dig soft-shell clams. These and butter clams occur at similar depths and hence the efficiency of the clam fork is probably equal to that found on the east coast. Further evidence of this is seen in our data. The mean production of commercial-size butter clams with the clam fork was 9.3 lb per sq yd and 13.8 lb per sq yd with the hydraulic digger, a difference of 4.5 lb of clams per sq yd.

The hydraulic digger is easy to handle and probably could be operated for an entire tide without interruption. Definite areas could be staked out and dug, and since the digger is efficient there would be no need to re-work dug areas and this would reduce damage to the flat and to small clams. Digging with the hydraulic clam rake reduces breakage considerably. Furthermore the undamaged small clams are returned to the flat in the top soft layers of soil where they quickly re-dig into the soil.

A further advantage of the digger would accrue if all species of clams dug were marketed: butter, horse, Manila, and little-neck clams, and cockles. This would be feasible since all are turned out of the soil unbroken. Horse clams are very fragile and cannot close their valves tightly and hence become quickly desiccated if the shell is broken. However, horse clams are washed out unbroken and could be used with proper care. The cockles might be minced and combined with butter clams; the little-neck and Manila clams could be set aside and sold fresh.

Cost

For the average clam digger the major drawback to the hydraulic digger is cost. However it was designed to be simple, inexpensive and portable, so that the investment would be relatively small. The entire unit can be built for less than $500, not including the skiff. This cost could be as low as $200 if second-hand equipment were used and if one built the digger himself.

Improvements

Further improvements may be made to the digger and would result from experience. The volume of water and pressure could be increased and this would probably increase the speed of digging and the efficiency.

The fire hose does hamper control of the digger to a certain extent. Some arrangement might be made so that it does not drag so much on the flat. The position of the handle may be adjusted, altering the angle of the nozzles. MacPhail and Medcof found the angle of the nozzles didn't matter, but this may not be so in this work.

The size of the manifold, the shape, and number of nozzles would probably have to be altered for use in different types of soil. Where the beaches are very rocky one might want to use a short manifold, perhaps 10-12 inches in length. In soft soil a manifold larger than 24 inches might be more efficient. Probably the best arrangement would be two or three different sized manifolds with nozzles which could be interchanged quickly, depending on the type of soil.

The hydraulic clam rake, as we used it, is quite portable but undoubtedly it could be made even more so, for example, by use of a lighter pump. Any improvements in this direction would be beneficial since an efficient tool would be available to dig clams on even the smallest beaches.

SUMMARY

1. Digging trials with a one-man hydraulic clam rake were carried out in July and August, 1966, to determine its efficiency and digging speed for butter clams.

2. The average rate of digging was 82 sq yd per hr in July and 44 sq yd per hr in August.

3. The average efficiency in the August trials was 85%. The efficiency increased as the speed of digging decreased.

4. Breakage of all species of clams was less than 5%.

5. The digger was more efficient when the flat was dry than when covered with water.

6. The digger is 4-5 times faster, more efficient, and causes less breakage to clams than the clam fork.

7. Several possible improvements to the digger are suggested.

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Table I. Butter and horse clams dug by one-man hydraulic clam rake at Seal Island, B. C., July 19-21, 1966. Numbers in brackets indicate clams which were broken. Asterisk indicates those plots which were covered with water when digging was carried out.

Date (1966)	Plot No.	Description of plot	Distance	Area	Time	Butter clams: Commercial size		Butter clams: Sub Commercial		Horse clams	
						Number	Weight	Number	Weight	Number	Weight
			(ft)	(sq yd)	(min)		(lb)		(lb)		(lb)
July 19	1	Dry	34	7.1	6	130	44	..	..	64 (1)	21
July 20	2	*In 1 foot water	74	16.4	22	16	4.25	89	..	7	2.5
"	3	*In 6-8 inches water	47	10.4	8	108 (1)	37	47	2.5	29 (2)	9
"	4	Dry	41	9.1	6	40	13	17	2.25	6	2.5
"	5	"	42	9.3	6	22	8	15	0.5	6	1.5
"	6	"	42	9.3	6	52	17.5	19	0.5	18	6
"	7	"	45	10.0	6	85	31.5	24	1.5	44 (1)	15
"	8	"	39	8.7	6	39 (1)	14.5	14	1.5	7	1.5
"	9	"	42	9.3	6	19	7.5	6	..	3	2.5
"	10	"	45	10.0	6	12	5	4	..	5	2.25
"	11	"	48	10.7	6	49	22	17	1	15	3.5
July 21	12	*In 8-12 inches water	131	29.1	20	90 (1)	22	116	6	19 (3)	9.5
"	13	Dry	105	23.3	20	257 (2)	93	166	10.5	108 (5)	33
"	14	"	49	12.0	10	148	65	37	2.5	40	18
"	15	"	52	11.6	7	50	26	14	1	18	6
Totals for all plots:			836	185.8	141	1,117	410.25	585+	29.75+	389	133.75
Totals for plots when dry:			584	129.8	91	903	347	333+	21.25+	334	112.75

Table II. Butter and horse clams dug by clam fork, or holes counted in plots which were dug by one-man hydraulic clam rake, at Seal Island, July 19-22, 1966.

Date (1966)	Plot No.	Method of counting	Distance	Time	Butter clams Commercial size Number	Butter clams Commercial size Weight	Horse clams Number	Horse clams Weight	Remarks
			(ft)	(min)		(lb)		(lb)	
July 21	13	Dug by hand	6	..	23	..	35	..	About one-third broken
July 22	12	" " "	11	15	138	56	45	33	25 butter and 20 horse clams broken
July 22	12	" " "	24	25	207	73	50	41	35 butter and 30 horse clams broken
July 22	8	Holes counted	2.5 sq ft	..	..	..	..	..	40 holes; mostly horse clams
July 22	8	" "	1 sq yd	..	..	..	..	..	107 holes; mostly horse clams

Table III. Butter, horse and little-neck clams dug by one-man hydraulic clam rake at Seal Island, B. C., August 15-18, 1966. Numbers in brackets indicate clams which were broken. Asterisk denotes those plots which were covered with water when digging was carried out.

Date (1966)	Plot No.	Description of plot	Distance	Area	Time	Butter clams: Commercial size Number	Butter clams: Commercial size Weight	Butter clams: Sub commercial Number	Butter clams: Sub commercial Weight	Horse clams Number	Horse clams Weight	Little-neck clams Number	Little-neck clams Weight
			(ft)	(sq yd)	(min)		(lb)		(lb)		(lb)		(lb)
Aug. 15	1	Dry	37	8.2	15	337	111	101	7	71 (1)	41	15	..
"	2	"	37	8.2	12	403 (2)	129	127 (1)	8	126 (2)	90	21	..
"	3	"	39	8.7	12	376 (1)	133	237 (2)	17	58 (1)	39	35	..
"	4	"	17	3.8	5	133	47	137	9	9	7	12	..
Aug. 16	5	6 inches water to dry	48	10.7	12	376 (2)	139	434	30	48 (2)	42	76	6
"	6	" " " " "	40	8.9	10	248	96	438 (1)	32	14 (1)	14	83	8
"	7	Dry	36	8.0	10	173	67	392	24	16	12	68	6.5
"	8	"	33	7.3	10	178 (1)	75	287 (2)	20	28 (2)	26	60	8
"	9	"	37	8.2	8	178	70	353	27	28	14	59	7
"	10	"	31	6.9	10	356 (1)	134	292	21	63 (2)	62	69	8
Aug. 17	11	*12 inches of water	42	9.3	10	164	55	340	20	33	14	..	12
"	12	*24 inches of water	38	8.4	10	167	63	168	13	23	14	42	5
"	13	Dry	31	6.9	12	318	126	461	31	32	29	47	3
"	14	"	29	6.4	12	328	124	409	26	51	35	54	4
Aug. 18	15	*18 inches of water	29	6.4	10	39	14	73	5	4	1.5	21	1
"	16	Dry	31	6.9	10	307	114	437	26	74	31.5	42	3
Totals for all plots:			555	123.3	168	4,081	1,497	4,686	316	678	472	704+	71.5+
Totals for plots when dry:			446	99.1	138	3,711	1,365	4,105	278	618	442.5	641	53.5+

Table IV. Butter, horse and little-neck clams dug by clam fork from plots which had been dug by one-man hydraulic clam rake, at Seal Island, August 15-18, 1966. Asterisk denotes plots which were under water when plots were originally dug with hydraulic clam rake.

Date (1966)	Plot number	Distance	Area	Time	Butter clams Commercial size		Horse clams	
					Number	Weight	Number	Weight
		(ft)	(sq yd)	(min)		(lb)		(lb)
August 17	1	37	8.2	35	90	37	54	43
"	2	37	8.2	35	57	28	35	33
"	3	39	8.7	35	69	27	47	43
"	4	17	3.8	12	35	15	7	5
"	7	36	8.0	27	49	24	15	16
"	8	33	7.3	27	39	19	9	9
"	9	37	8.2	20	27	9	11	12
"	10	31	6.9	20	39	28	28	27
August 18	*11	42	9.3	25	74	28	40	25
"	*12	38	8.4	20	32	12	20	11
"	13	31	6.9	20	38	12	7	6
"	14	29	6.4	20	20	8	9	6

Table V. Comparison of production of butter, horse and little-neck clams, and digging speed of one-man hydraulic clam rake at Seal Island, B. C., July 19-21 and August 15-18, 1966.

	July 19-21		August 15-18	
	All plots	Plots dug when flat was dry	All plots	Plots dug when flat was dry
Number of commercial-size butter clams per sq yd	6.0	7.0	33.1	37.6
Pounds of commercial-size butter clams per sq yd	2.3	2.7	12.2	13.8
Number of sub-commercial butter clams per sq yd	3.2	2.6	38.0	41.4
Number of horse clams per sq yd	2.2	2.6	5.5	6.3
Pounds of horse clams per sq yd	0.7	0.9	3.9	9.0
Number of little-neck clams per sq yd	..	..	5.8	6.5
Number of commercial-size butter clams per hr	475.2	595.2	1,457.4	1,613.4
Pounds of commercial-size butter clams per hr	174.6	228.6	534.6	593.4
Number of sub-commercial butter clams per hr	249.0	219.6	1,673.4	1,785.0
Number of horse clams per hr	165.6	219.6	242.4	268.8
Pounds of horse clams per hr	57.0	74.0	168.6	192.6
Number of little-neck clams per hr	..	..	251.4	278.4
Digging speed (sq yd per hr)	79.1	85.6	44.0	43.1

Table VI. Efficiency of the one-man hydraulic clam fork at Seal Island, August 15-18, 1966. Plots marked by an asterisk were dug with a digger when the flat was covered with water.

Plot number	Butter clams						Horse clams					
	Digger		Fork		% efficiency		Digger		Fork		% efficiency	
	Number	Weight (lb)	Number	Weight (lb)	Number	Weight	Number	Weight (lb)	Number	Weight (lb)	Number	Weight
1	337	111	90	37	78.9	75.0	71	41	54	43	56.8	48.8
2	403	129	57	28	87.6	82.2	126	90	35	33	78.3	73.2
3	376	133	69	27	84.5	83.1	58	39	47	43	55.2	47.6
4	133	47	35	15	79.2	75.8	9	7	7	5	56.3	58.3
7	173	67	49	24	77.9	73.6	16	12	15	16	51.6	42.9
8	178	75	39	19	82.0	79.8	28	26	9	9	75.7	74.3
9	178	70	27	9	87.0	86.8	28	14	11	12	72.8	53.8
10	356	134	39	9	90.1	93.7	63	62	28	27	69.2	69.7
11*	164	55	74	28	68.9	66.3	33	14	40	25	45.2	35.9
12*	167	63	32	12	83.9	84.0	23	14	20	11	53.5	56.0
13	318	126	38	12	89.3	91.3	32	29	7	6	82.1	82.9
14	328	124	20	8	94.3	93.9	51	35	9	6	85.0	85.4
Totals for all plots	3,111	1,134	569	228	84.5	83.3	538	383	282	236	65.6	61.9
Totals for plots when dry	2,780	1,016	463	188	85.7	84.4	482	355	222	200	68.5	64.0

Table VII. Commercial-size butter clams and horse clams dug by clam fork at Seal Island, B. C., August 18, 1966.

Plot number	Location of plot	Area	Time	Butter clams		Horse clams		Remarks
				Number	Weight	Number	Weight	
		(sq yd)	(min)		(lb)		(lb)	
17	Above plots 9 and 10	3.0	12	132	49	40	30	About 20% of butter clams and 50% of horse clams were broken
18	Above plots 9 and 10	1.9	12	72	26	27	20	" " "
19	Above plots 9 and 10	2.2	12	73	27	28	23	" " "
20	Above plot 14	3.9	10	43	18	6	6	" " "
21	Between plots 15 and 16	4.4	10	58	24	10	8	" " "
22	Between plots 15 and 16	2.7	10	50	23	22	10	" " "
Totals		18.1	66	428	167	133	97	

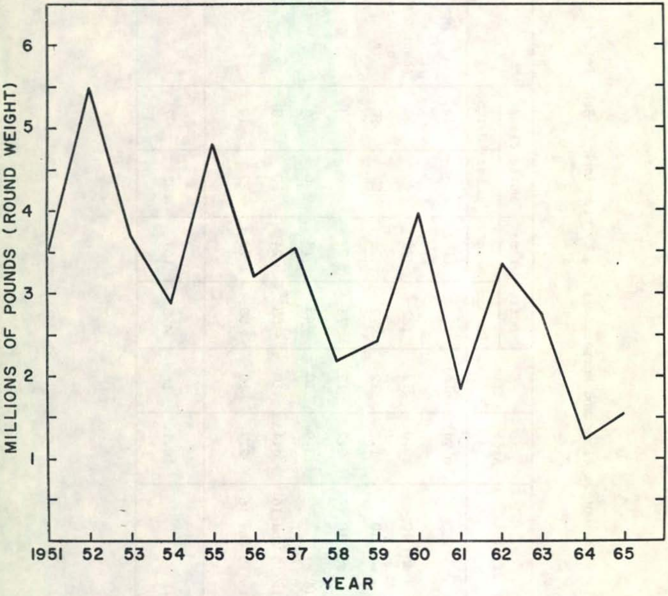

Fig. 1. British Columbia landings of butter clams, 1951-1965.

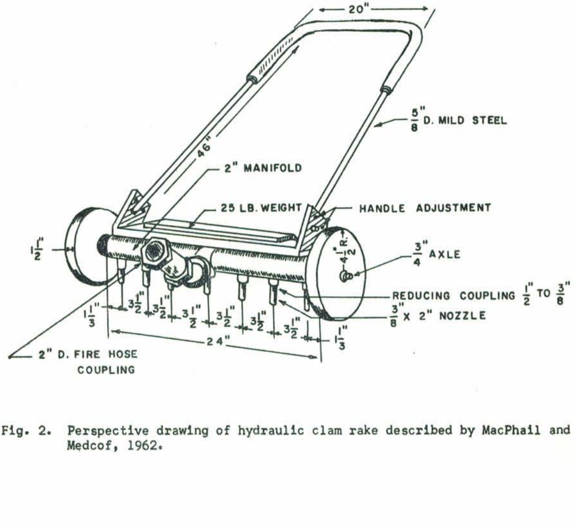

Fig. 2. Perspective drawing of hydraulic clam rake described by MacPhail and Medcof, 1962.

Fig. 3. Pump in skiff at Seal Island, B. C.

Fig. 4. Clam flat at Seal Island, B. C. Figure shows "dry flat" condition during which most of digging was done.

Fig. 5. Hydraulic clam rake in operation on dry flat at Seal Island, July 1966.

Fig. 6. Close-up of hydraulic clam rake in operation, Seal Island, July 1966.

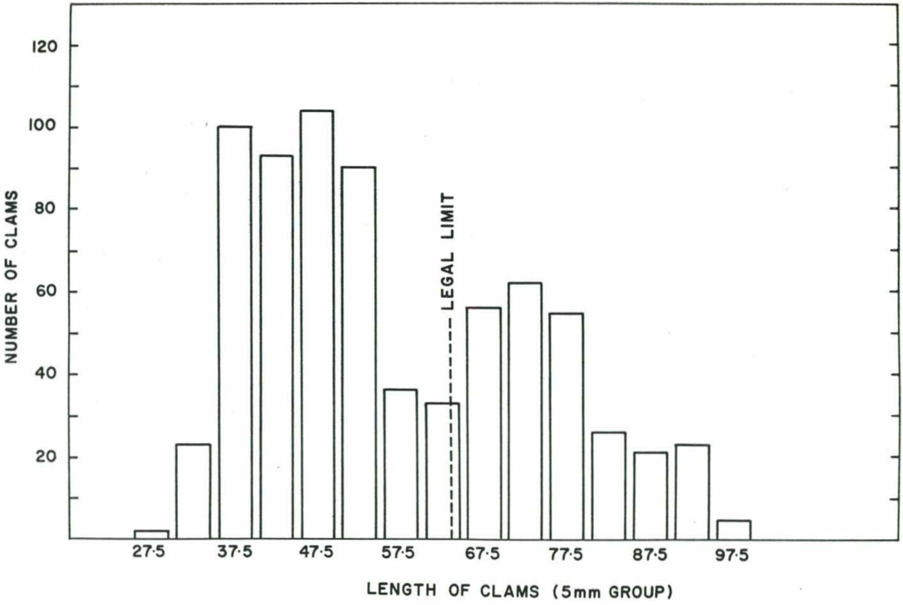

Fig. 7. Size frequency distribution of all butter clams dug from plot 16, on August 18, 1966. Length of clams expressed in 5 mm groups.

Fig. 8. Condition of plot dug by hydraulic clam rake after the plot has been covered for one tide.