Bulletin of the Bingham Oceanographic Collection

BULLETIN

OF

THE BINGHAM OCEANOGRAPHIC COLLECTION

PEABODY MUSEUM OF NATURAL HISTORY
YALE UNIVERSITY

VOLUME IX, ARTICLE 3

STUDIES ON THE MARINE RESOURCES OF SOUTHERN NEW ENGLAND

III. THE POSSIBILITY OF THE UTILIZATION OF THE STARFISH (*ASTERIAS FORBESI* DESOR)

Bingham Oceanographic Laboratory

Issued April, 1946
New Haven, Conn., U. S. A.

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ABSTRACT

This work of composite authorship is a cooperative study. It was undertaken as part of a program at the Bingham Oceanographic Laboratory on the practical aspects of the utilization of marine resources in the belief that it is a vital part of our national economy to manage these resources so as to insure their most efficient utilization and maximum productivity.

Biochemical analyses reported herein gave clear indication that the starfish might be of value in poultry and stockfeeds. The aid of various technological laboratories and experiment stations—federal, state and private—was therefore solicited, and the papers from six separate cooperating agencies are included. These experiments provide evidence that starfish meal may be used satisfactorily as one of the protein concentrates in chick rations. Four additional papers by workers in intimate contact with the oyster industry are also presented. These include accounts of the abundance, control and possible uses of the starfish, and give some indications of the problems involved. A final paper discusses the whole matter of the utilization of starfish, summarizes the pertinent evidence, and indicates the need for additional work in this and related fields; it is concluded that the large-scale utilization of starfish as protein feed or fertilizer seems to be entirely impracticable under present conditions.—D. M.

BIOCHEMICAL OBSERVATIONS ON *ASTERIAS FORBESI*

BY G. E. HUTCHINSON, JANE K. SETLOW AND JOHN L. BROOKS
Osborn Zoological Laboratory, Yale University, New Haven, Conn.

The starfish is one of the commonest marine invertebrates in the coastal waters of the northeastern United States and is particularly well-known as a serious pest of oyster-beds. Our attention has therefore been directed toward this animal, not only on account of its abundance, but because it is already captured in considerable quantities by those engaged in oyster culture. Galtsoff and Loosanoff (1939) indicate that *Asterias forbesi*, ground into meal, has been produced and sold in Virginia as an ingredient of food for farm animals and that it has also been used as fertilizer in the same state. Other species appear to have been employed in similar ways in Europe during the first World War; they were also utilized, mixed with oyster-shells, as fertilizer for acid soils, in France during the last century (Heiden, 1887).

Determinations of certain biologically important elements have been made on *Asterias forbesi*, collected in Long Island Sound in February, 1943.

	In starfish dried at 57° C.	In living starfish
Nitrogen	5.32–5.65 %	1.76–1.87 %
Calcium	16.9 %	5.58 %
Sulphur	0.87 %	0.29 %
Phosphorus	0.438 %	0.145 %
Iron	0.017 %	0.0056 %
Manganese	0.0023%	0.00076%
Fluorine*	0.016 %	0.0053 %
Boron**	0.0034%	0.0011 %

These data are in accord with those previously published for calcium and nitrogen. Accepting the usual convention as to the composi-

* Analysis kindly performed by Miss Anne C. Wollack.

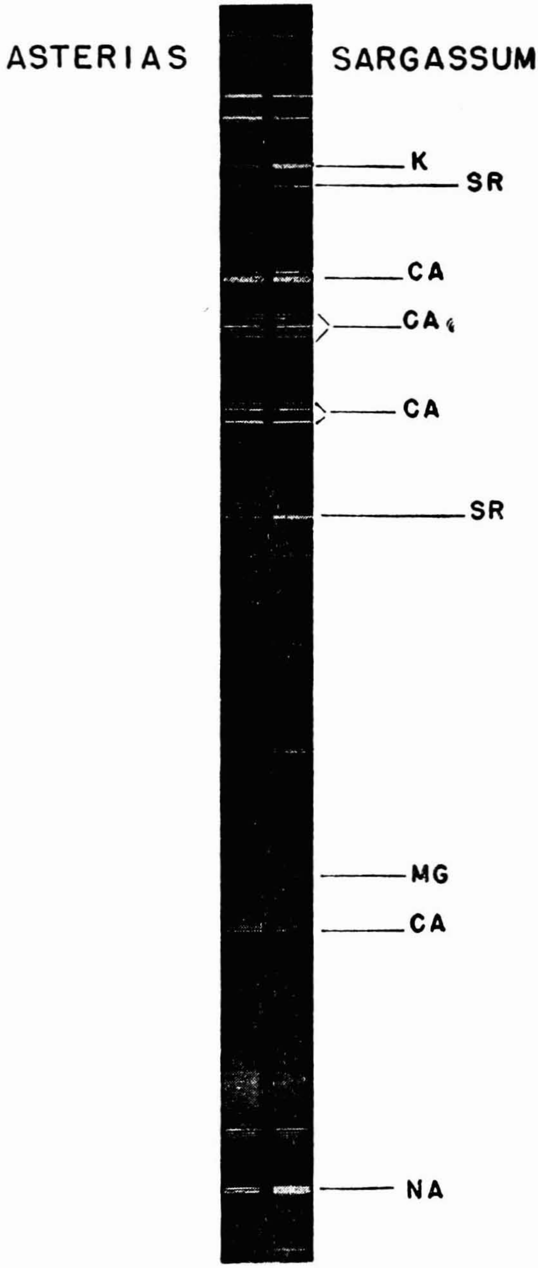
** Analysis kindly performed by Dr. Gordon H. Ellis, U. S. Dept. of Agriculture Laboratory, Ithaca, N. Y.

tion of protein, and assuming the calcium present as $CaCO_3$, we may conclude that the dry material analyzed consists of about 34 per cent protein and 42 per cent calcium carbonate. The quantity of fluorine should not be great enough to cause inconvenience in practical utilization. The iron content is much lower than that previously reported for this and other species; some seasonal variation may be expected. The chief objection to the use of starfish meal in vertebrate nutrition arises from the high $CaO : P_2O_5$ ratio. In view of the large amount of calcium, the high strontium content of sea-water, and the possibility of injurious effects from the ingestion of excess strontium, it seemed worthwhile to examine starfish meal for the latter element. Unfortunately no good gravimetric method is available and the spectrographic equipment at our disposal does not permit more than semiquantitative estimation. The accompanying plate, however, in which a spectrogram of *Asterias* ash is compared with that of the ash of a pelagic *Sargassum* from the subtropical Atlantic, indicates clearly how much greater is the Sr : Ca ratio in the latter than in the former. It appears from the work of Webb (1937) that certain brown algae regularly take strontium from sea water in proportion to calcium in excess of the ratio in the medium. Our observations tend to confirm this conclusion, a fact which may be of practical importance in the utilization of seaweeds for stock feed. It is reasonably certain that in using starfish no danger from excess of strontium need be considered. When liberally applied as a fertilizer, the boron content of starfish meal might make a significant contribution to very boron-deficient soils.

Certain members of the vitamin B complex have been determined microbiologically, under the direction of Dr. Paul R. Burkholder.

Thiamin	1 mgr. per kilo.
Riboflavin	5.5 mgr. per kilo.
Niacin	38 mgr. per kilo.
Pantothenic acid	12 mgr. per kilo.

The low thiamin content of the dried starfish is almost certainly due to post-mortem loss. An analysis by Distillation Products Inc. showed no indication of Vitamin A. Starfish meal incorporated in a Vitamin D deficient diet greatly improved the growth of white rats, but owing to the difficulty of inducing a constant intake, quantitative conclusions can hardly be drawn from the data.


ASTERIAS
SARGASSUM
K
SR
CA
CA
CA
SR
MG
CA
NA

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DEHYDRATED PEA VINES AND STARFISH MEAL IN POULTRY FEEDS[1]

By H. R. Bird

Maryland Agricultural Experiment Station, College Park, Md.

The two entirely unrelated products mentioned in the title were investigated as possible substitutes for alfalfa meal and fish meal, respectively. The dehydrated pea vines were furnished by Charles G. Summers, Jr., Inc., New Freedom, Pennsylvania, and contained 102 p. p. m. of carotene and 23.26 per cent crude fiber as compared with 138 p. p. m. of carotene and 20.36 per cent fiber in the alfalfa meal used in this experiment.[2] The starfish meal was furnished by the Bingham Oceanographic Laboratory of Yale University through the courtesy of Dr. Daniel Merriman.[3] This material has been described in an Interim Report of the Bingham Laboratory (April, 1943). Typical analyses show 34 per cent protein, 16.9 per cent calcium and 0.43 per cent phosphorus. In this experiment the starfish meal was compared with a commercial fish meal (chiefly menhaden) as to its ability to supplement a mash (16) containing no animal protein.

Mash 16 has the following composition: ground yellow corn 29.25, ground heavy oats 10, wheat bran 10, wheat flour middlings 10, soybean oil meal (expeller) 30, alfalfa meal 5, oyster shell flour 1.75, defluorinated superphosphate 1, butyl fermentation residue (80 micrograms riboflavin per gram) 1.5, vitamin A and D oil (85 A. O. A. C. Units of vitamin D per gram) 1, salt 0.5, and manganous sulphate tetrahydrate 0.012. This mash contains approximately 20.5 per cent protein, 1.1 per cent calcium and 0.6 per cent phosphorus.

The plan of the experiment is indicated in Table I, which also gives the results. When additions were made of alfalfa meal or pea vine in

[1] Scientific paper No. A68, Contribution No. 1910 of the Maryland Agricultural Experiment Station (Department of Poultry Husbandry). Also published in *Poultry Science*, XXIII, No. 1, pp. 76-77, 1944.

[2] The crude fiber determinations were made by the Maryland State Inspection Service.

[3] The Bingham Laboratory wishes to acknowledge the generous cooperation of Prof. B. F. Dodge, Dept. of Chemical Engineering, Yale University, who permitted the main supply of dried starfish to be ground in his laboratory.

excess of five per cent, or of fish meal or starfish meal, adjustments of the levels of corn, soybean meal, oyster shell, and defluorinated superphosphate were made in an effort to maintain the protein, calcium, and phosphorus levels approximately the same. This could not be done in the case of the mash fed to group 4; it contained approximately 1.4 per cent calcium.

At the beginning of the experiment each group consisted of 30 New Hampshire chicks. Four chicks were lost during the nine weeks of the experiment, two from group 7 and one each from groups 5 and 8.

The results summarized in Table I show clearly that starfish meal

TABLE I. EFFECT OF FEEDING DEHYDRATED PEA VINES AND STARFISH MEAL ON GROWTH, EFFICIENCY, AND SHANK PIGMENTATION OF CHICKS

Group	*Modification of Mash 16*	*Mean live weights of chicks, 9 weeks, in gms.*			*Efficiency to 9 wks., gms. gain per gm. feed*	*Shank pigment score; 7 wks*
		Male	*Female*	*Mean of Male and Female Means*		
1	*None*	885	807	846	0.336	11.9
2	*Plus 4% fish meal*	1048	902	975	0.354	10.8
3	*Plus 3% starfish meal*	1003	895	949	0.350	12.3
4	*Plus 6% starfish meal*	1012	857	934	0.337	12.2
5	*Plus 5% alfalfa meal (10% total)*	946	801	874	0.312	14.5
6	*Minus alfalfa meal, plus 5% dehy. pea vine*	1009	878	943	0.335	10.6
7	*Minus alfalfa meal, plus 10% dehyd. pea vine*	1003	880	942	0.318	13.4
8	*Minus alfalfa meal, plus 15% dehyd. pea vine*	1001	761	881	0.313	14.5

was comparable to the commercial fish meal in its ability to supplement the basal mash. Excellent growth resulted when either of these supplements was fed. The three per cent level of starfish meal was practically as effective as the four per cent level of commercial fish meal, although it supplied only about half as much protein.

Of even greater interest are the results secured when the alfalfa meal was replaced by dehydrated pea vines in the absence of any animal protein. This change resulted in a growth stimulus almost as great as that induced by the four per cent fish meal supplement.

As would be expected, there was a tendency toward greater efficiency of feed utilization when fish meal was fed, and a tendency toward lower efficiency when the higher levels of alfalfa meal and pea vines were fed. Substitution of pea vines for alfalfa meal had no effect on efficiency; hence the superior growth of the groups fed pea vines was due to greater feed intake. That this was at least partly the result of the greater palatability of the pea vines was indicated by the results of three experiments in which dehydrated pea vines and alfalfa meal were offered to three groups of New Hampshire chicks in separate hoppers for periods of 24 hours. The chicks were five and six weeks old and the groups varied in size. In two trials mash was kept before the birds in additional hoppers but was withheld in the third. The number of grams of alfalfa meal consumed in the three trials was 376, 63, and 192, respectively, and of pea vines 582, 158, and 230, respectively.

The shank pigment scores show that four per cent fish meal had a slight and unimportant adverse effect on pigmentation. The starfish meal did not inhibit pigmentation at the levels fed.

It may be concluded that starfish meal at low levels effectively supplements a chick mash in which soybean oil meal is the only other high-protein feedstuff and that dehydrated pea vines are a good substitute for alfalfa meal and probably have an advantage over alfalfa meal from the standpoint of palatability. Only one sample of each of the products mentioned was used in this experiment. Quality control would be as important for these materials as it is for all feedstuffs, and carotene assays of dehydrated pea vines would be especially important.

STARFISH MEAL IN CHICK RATIONS[1]

By G. F. Heuser and J. McGinnis

Department of Poultry Husbandry, Cornell University, Ithaca, N. Y.

Starfish meal is produced from the starfish, *Asterias forbesi,* which is one of the commonest marine invertebrates in the coastal waters of the northeastern United States. It is particularly well-known as a serious pest of oyster-beds. A typical analysis of the meal shows 34 per cent protein, 16.9 per cent calcium and 0.43 per cent phosphorus.

In this experiment the starfish meal was compared with a commercial fish meal (analyzing 60% protein) as a supplement to a ration containing a high percentage of 44 per cent protein expeller soybean oil meal. The basal mixture common to all of the groups was composed as follows:

Crushed wheat	25
Pulverized oats	10
Dehydrated alfalfa meal	5
Iodized salt	0.5
B-Y feed	0.5
Delsterol	1 lb. per ton
$MnSO_4$	4 oz per ton

The rations and chick weights at eight weeks of age are given in Table I. Twenty-five Single Comb White Leghorn chicks were started in batteries in each lot.

The results show that three per cent of starfish meal is equally as good as three per cent of the commercial fish meal, both of which showed significantly greater growth than the ration containing no animal protein. The average weights of the lot receiving six per cent of starfish meal are somewhat below the weights of the lot receiving only three per cent of starfish meal. The weights of the birds receiving a ration containing 12 per cent of starfish meal were very significantly lower than the weights of the birds receiving six per cent of starfish meal. Two birds (approximately 10%) in this lot showed definite

[1] The starfish meal was furnished by the Bingham Oceanographic Laboratory of Yale University, through the courtesy of Dr. Daniel Merriman.

TABLE I. SUPPLEMENTARY VALUE OF STARFISH MEAL AND FISH MEAL WHEN ADDED TO A SOYBEAN OIL MEAL RATION

	Soybean oil meal		*Fish meal*	*Starfish meal*		
Lot	*1*	*2*	*3*	*4*	*5*	*6*
Ration						
Basal mixture	41.0	41.0	41.0	41.0	41.0	41.0
Soybean oil meal	28.0	28.0	24.0	25.7	23.5	19.0
Starfish meal	....	....	....	3.0	6.0	12.0
Fish meal	....	....	3.0	....	....	....
Steamed bone meal	2.0	2.0	1.2	2.0	2.0	2.0
Ground limestone	2.0	2.0	1.3	....	....	....
Corn meal	27.0	27.0	29.5	28.3	27.5	26.0
Composition (calculated)						
Protein %	20.30	20.30	20.60	20.50	20.40	20.30
Riboflavin μg/100 gm.	356.00	356.00	365.00	368.00	378.00	394.00
Calcium %	1.58	1.58	1.26	1.32	1.82	2.82
Phosphorus %	.70	.70	.69	.70	.70	.69
Ca : P. ratio	2.25 : 1	2.25 : 1	1.83 : 1	1.89 : 1	2.60 : 1	4.09 : 1
Weight at 8 wks. (grams)						
Males	692.0	638.0	769.0	768.0	718.0	467.0
Females	532.0	561.0	628.0	632.0	628.0	414.0
Male and female	612.0	600.0	699.0	700.0	673.0	441.0
Mortality %	16	16	4	0	0	16

perosis at the end of the experiment. It will be noticed also that the mortality was greater in this lot.

Discussion

The results of the rations containing three and six per cent of starfish meal are in agreement with those reported by Bird (1944). The three per cent level of starfish meal was just as effective as the three per cent level of commercial fish meal, although it furnished considerably less of the animal protein. Since the six per cent level of starfish meal shows less growth it would appear that five to six per cent of this product is probably the maximum amount that can be used in a chick starting ration. The very poor results obtained on the 12 per cent level of starfish meal no doubt were due largely to the excess calcium present in the ration which also greatly widened the calcium-phosphorous ratio.

Summary

Three per cent of starfish meal supplemented a mash in which soybean oil meal was the only high-protein feedstuff as effectively as three per cent of commercial fish meal.

The high calcium content of the starfish meal limits the amounts that can be fed to chicks. Six per cent is probably the maximum amount that can be used effectively.

REFERENCE

BIRD, H. R.
1944. Dehydrated pea vines and starfish meal in poultry feeds. Poultry Science. *23:* 76.

PRELIMINARY REPORT ON EIGHT WEEKS OF COMPARATIVE FEEDING OF PROTEIN EQUIVALENT DIETS CONTAINING FISH MEAL, CRAB MEAL, AND STARFISH MEAL TO RHODE ISLAND RED CHICKS[1]

By Roy E. Morse, Francis P. Griffiths, and Raymond T. Parkhurst

Massachusetts State College, Amherst, Mass.

Because of the war conditions there is a shortage of animal and marine protein for use in poultry and stock feeds. New sources and supplies of suitable protein are urgently needed. Starfish are abundant in Long Island Sound and adjacent areas and constitute a serious menace to the oyster industry. Because of the oyster losses they cause, it is frequently necessary for oystermen to spend time and effort removing the starfish from the oyster producing areas and killing them. At present there is no use for these starfish which are collected.

At the suggestion of Mr. J. Richard Nelson of the Warren Oyster Co., Warren, Rhode Island, work was undertaken to determine the composition and availability as a source of protein of a meal made from dried starfish. Mr. Ryan of The Dehydrating Process Co. of Boston very kindly cooperated by dehydrating 8,400 pounds of starfish to 2,100 pounds of starfish meal. This was used as a representative sample of what could be produced by commercial operations. Laboratory samples of starfish meal were also prepared and analysed.

One hundred and sixty, day-old chicks were separated into groups of 40 each and started on chick mash diets which had as a source of animal protein, comparative amounts of commercial fish meal, crab meal and starfish meal. A fourth group having eight per cent starfish meal was also started to act as a check on protein quality and possible toxic effects.

Most commercial feed mixtures contain not more than 2.5 per cent of fish meal, which provides about 1.4 per cent of animal protein in

[1] Also published in "Poultry Science," XXIII, No. 5, pp. 408–412, Sept., 1944.

the diet. The remainder of the protein required is provided by meat scrap and grain products. It is interesting to note that the eight per cent starfish level diet did not contain any meat scrap.

An effort was made to balance the diets with respect to amounts of protein present and calcium-phosphorus ratio. Since starfish contain relatively large amounts of calcium with little phosphorus this was accomplished by the addition of $CaH\ PO_4$ to the starfish diet.

The actual ingredients and amounts used are shown in Table I.

Through the cooperation of Mr. Phillip Smith of the Feed Control Laboratory analyses were made of the completed diet.

Two lots of diets were mixed and the analyses of these diets are designated as one and two in Table I. Diets were quite uniform in composition. The largest variation was 1.4 per cent total protein between the first starfish and the first fish diets.

It is of interest to compare the analyses of the different protein sources, fish meal, crab meal, and starfish meal. Comparative analyses are shown in Table II.

Several samples of starfish meal prepared in the laboratory showed about five per cent higher protein and nearly 20 per cent lower ash. This was due to the unavoidable inclusion of small shells, etc., in the large amount (8400 lbs.) of starfish used for the trial commercial scale dehydration. Extraneous material was not present in the laboratory samples.

Results of Feeding Trials

The average weights of the day-old chicks was 38 grams. At the end of eight weeks the average weights for the different groups was as follows: fish meal 854 grams, 8 per cent starfish meal 816 grams, 4 per cent starfish meal 803 grams, crab meal 803 grams. The eight per cent starfish meal group weighed only four per cent less than the fish meal group and the other two groups were only six per cent under the top group in average weight.

The feed consumed for this period was 207.5 pounds for the fish meal group, 186.6 pounds for the eight per cent starfish meal group, 187.5 pounds for the four per cent starfish meal group, and 188.4 pounds for the crab meal group. The efficiency of feed conversion, pounds of feed fed per pound of weight gained, was 2.89 for fish meal, 2.87 for crab meal, 2.87 for four per cent starfish meal, and 2.86 for eight per cent starfish meal.

TABLE I. COMPONENTS AND ANALYSES OF DIETS USED

Components	*Fish* *lbs. per 100*	*Crab* *lbs. per 100*	*4% Starfish* *lbs. per 100*	*8% Starfish* *lbs. per 100*
Ground corn	25	25	25	25
Ground wheat	15	15	15	15
Ground barley	10	10	10	10
Bran	10	10	10	10
Dried distillers grain plus solubles	7.5	7.5	7.5	7.5
Meat scrap	2.5	2.5	2.5	....
Dried distillers solubles	2.5	2.5	2.5	2.5
Alfalfa leaf meal	6.25	6.25	6.25	6.25
Soy bean meal	15.0	15.0	15.0	15.0
Cod liver oil { *400D* / *1000A* }	0.2	0.2	0.2	0.2
Bone meal	1.5	1.0	1.0	....
Calcium carbonate	1.5	0.50	0.50	....
Salt	0.56	0.56	0.56	0.56
Manganese sulfate	12 grams	12 grams	12 grams	12 grams
Dicalcium phosphate	....	....	....	2
Fish meal	2.50	....	....	....
4 starfish meal	....	....	4.0	....
8 starfish meal	....	....	....	8
Crab meal	....	4.0	....	....

Analyses:	*I*	*II*	*I*	*II*	*I*	*II*	*I*	*II*
Water	7.48	7.63	7.83	7.73	7.53	8.10	7.28	7.33
Protein	22.68	22.07	22.20	22.12	21.32	21.85	21.32	21.89
Fat	4.58	4.10	4.10	3.93	4.00	3.65	4.05	4.15
N.F.E.	52.38	51.80	51.89	51.69	53.85	51.12	51.58	51.42
Fiber	5.93	6.05	6.33	6.73	5.90	6.33	6.23	6.48
Ash	6.95	8.35	7.65	7.80	7.40	8.95	8.53	8.73

Individual examination and scoring of the chicks for feathering, leg color, and toe and foot dermatitis showed them to be approximately equal as to these qualities. Because of the high temperature of the brooder pens all of the chicks showed some retardation of feathering.

During the course of the experiment only four chicks out of the 160 started were lost through accidents and none through disease.

Forty chickens divided in two groups of 20 were continued on fish meal and eight per cent starfish diets until 14 weeks of age. Growth and feathering continued satisfactory and about equal for these groups.

From the results of this experiment it is evident that starfish meal is

TABLE II. COMPARATIVE ANALYSIS OF MEALS AS A SOURCE OF ANIMAL PROTEIN

	Crab Meal	*Starfish Lab. Sample*	*Starfish Commercial Meal*	*Redfish Meal*
	in %	*in %*	*in %*	*in %*
Water	4.35	3.11	2.10	6.5
Protein	31.22	33.63	27.54	56.6
Fat	3.12	7.7	5.3	8.6
Fiber	11.00	0.4	.....	.....
Ash	38.47	41.7	60.13	26.6
Calcium	16.43	15.14	.....	.....
Phosphorus	1.62	0.48	.....	.....
Riboflavin	16.9 ppm	8.9	.....	8.8
Protein Quality	56.6	65.28	58.9	78.9
A	.....	50 i. u.	.....	.....

equal to crab meal as a replacement for fish meal in poultry diets. Because of the higher ash content four pounds of either crab or starfish meal are required to replace 2.5 pounds of fish meal. If it is necessary to use as high as eight per cent starfish meal, allowance should be made for the high calcium and lack of phosphorus. When this was done starfish meal satisfactorily replaced both meat scrap and fish meal in the feed.

STARFISH MEAL FEEDING EXPERIMENT WITH CHICKS

By R. C. Ringrose

Poultry Department, University of New Hampshire, Durham, N. H.

Thirty Barred Plymouth Rock-New Hampshire crossbred chicks were started in each pen on June 15, 1943 and continued for six weeks. Individual chick weights and pen feed consumption records were made at two-week intervals.

Table I presents the percentage composition of the rations used. The analyses presented are based upon calculations from average analyses. However, the protein supplements were analyzed for protein and added on the basis of the actual analysis. Since the protein supplement and corn meal were the only variables in comparable rations, it is believed that the protein level in comparable rations was fairly close.

Growth and mortality results to six weeks of age are presented in Table II. At the lower level of protein feeding, starfish meal gave a growth response which was 83 per cent of that obtained with redfish meal or meat scrap. Growth results for pens 15 and 16 were normal.

The mortality in pen 11 occurred on the eighth and fifteenth days of the experiment and the cause could not be determined. One chick in pen 13 died on the thirty-first day of the experiment. Marked evidence of cannibalism was present but it could not be determined whether this occurred before or after death. No abnormalities were found on autopsy. A total of fifteen chicks in pen 14 died as follows: Sixth day 3; seventh day 6; eighth day 4; thirteenth day 1; fortieth day 1. Autopsy and cultures of various organs and tissues failed to show the cause of death. The one chick which died on the fortieth day exhibited symptoms of rickets before death, and upon examination showed evidence of poor bone formation. During the last two weeks of the experiment marked symptoms of rickets were present in this group.

Due to the high mortality of chicks in pen 14 during the first eight days of the experiment, seven replacement chicks from the same hatch were placed in this pen on the morning of the eighth day. These

TABLE I. PERCENTAGE COMPOSITION OF RATIONS

Pen Number	*11*	*12*	*13*	*14*	*15*	*16*
Ingredient	%	%	%	%	%	%
Yellow Corn Meal	48.25	52.25	51.25	29.25	39.25	37.25
Standard wheat middlings	15.00	15.00	15.00	15.00	15.00	15.00
Wheat bran	10.00	10.00	10.00	10.00	10.00	10.00
Ground oats	10.00	10.00	10.00	10.00	10.00	10.00
Starfish meal	9.00	.....	.....	18.00	.....	.....
Redfish meal	....	4.00	.....	.....	8.00	.....
Meat scrap	....	....	5.00	.....	.....	10.00
Soybean oil meal	....	....	....	10.00	10.00	10.00
Alfalfa leaf meal	5.00	5.00	5.00	5.00	5.00	5.00
Fermentation by-product	1.00	1.00	1.00	1.00	1.00	1.00
Fortified cod-liver oil	.25	.25	.25	.25	.25	.25
Salt and manganese	.50	.50	.50	.50	.50	.50
Steamed bone meal	1.00	....	....	1.00	....	....
Pulverized limestone.	....	2.00	2.00	....	1.00	1.00
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis						
Per cent protein	13.15	13.11	13.15	18.46	18.45	18.53
Per cent calcium	1.92	1.20	1.35	3.39	1.15	1.45
Per cent phosphorus	.61	.59	.67	.67	.79	.93

Starfish meal, redfish meal and meat scrap analyzed for protein and added on basis of actual analyses.

TABLE II. GROWTH AND MORTALITY RESULTS AT STATED INTERVALS

	13% Protein			*18.5% Protein*		
Pen Number	*11*	*12*	*13*	*14*	*15*	*16*
	gms.	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*
Initial weight	40	39	39	39	40	41
2 weeks	67	75	74	56	106	110
4 weeks	123	148	144	105	296	296
6 weeks	209	254	252	170	521	539
Chicks per pen-number	30	30	30	30	30	30
Total mortality-number	2	0	1	15	0	0

chicks had been maintained during the first week on a ration containing a blended fish meal. The ration supplied 13 per cent of total protein. None of the replacement chicks died during the course of the experiment. Thus, beginning on the eighth day pen 14 contained 24 chicks with the loss of one on the thirteenth day and one on the fortieth day.

Table III presents the data from the feed consumption records.

Table III. Feed Consumption in Pounds at Stated Intervals

Pen Number	*11*	*12*	*13*	*14*	*15*	*16*
	lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
0–2 weeks	9.25	9.75	11.25	6.25	12.00	12.25
2–4 weeks	27.75	29.00	28.25	17.50	33.75	36.50
4–6 weeks	22.75	29.00	26.25	16.50	50.75	50.00
Total	59.75	67.75	65.75	40.25	96.50	98.75
Pounds feed per pound of gain	5.84	4.78	4.87	7.14	3.00	3.03

Discussion

The high calcium content of starfish meal offers a special problem which is more troublesome than at first appears. The poor growth results and ricketic condition exhibited by pen 14 was undoubtedly due to the high calcium content and wide calcium : phosphorus ratio of the feed used. Whether the high mortality exhibited during the first week of the experiment was due to the high calcium content and/or the wide calcium : phosphorus ratio is not known. The common phosphorus supplements such as steamed bone meal and tricalcium phosphate are of no value in supplying additional phosphorus since in each case the calcium : phosphorus ratio is about 2 : 1. Monocalcium phosphate or other high phosphorus carrier would be needed to bring the calcium : phosphorus ratio into balance. Such a high phosphorus carrier was not available here at the time of the experiment. Since nothing was known of the availability of the calcium in the meal, although it seemed unlikely that it would be unavailable, it was decided to formulate the ration as shown.

The calcium : phosphorus ratio of the ration of pen 11 is also somewhat wider than is commonly used in practice (2 : 1), although experimental evidence indicates that with adequate vitamin D and reasonable levels of calcium and phosphorus in the ration, the calcium : phosphorus ratio may vary between 1–3 : 1.

Summary

At a level of 13 per cent protein in the total ration, starfish meal gave a growth response which was 83 per cent of that obtained with redfish meal or meat scrap.

STARFISH MEAL AS A PROTEIN SUBSTITUTE IN CHICK RATIONS

BY H. O. STUART AND C. P. HART

R. I. Agricultural Experiment Station,[1] *Kingston, R. I.*

In line with the criticalness of the feed situation during the past year, investigators in many parts of the country have sought to determine the utilizability of many products in poultry feeding which have received scant or no attention in the past. Because of the difficulty of securing adequate quantities of protein concentrates, an effort was made to determine the feasibility of utilizing starfish meal as a substitute for protein concentrates normally found in rations. Furthermore, the lowly starfish has presented a problem of no mean proportions to the oyster industry. Any effort, therefore, looking forward to the utilization of starfish meal is of concern to both the poultry producers and the fishing interests.

Ground, air-dried starfish meal was furnished by the Bingham Oceanographic Laboratory for the purposes of this test. One hundred day-old chicks were divided equally for comparative feeding trials with one group receiving the currently used ration and the other group receiving this ration substituting starfish meal for other protein concentrate and adjusting the ration for calcium content. These adjustments were essential in view of evidence that dried starfish meal contains approximately 34 per cent protein and 42 per cent calcium carbonate. These adjustments are evident in Table I.

TABLE I. COMPOSITION OF RATION

Ingredients	*Check Ration*	*Starfish Meal Ration*
Yellow Corn Meal	170 lbs.	165 lbs.
Ground Barley	60	60
Flaked Wheat	250	250
Ground Oats	250	250
Fish Meal, 60% protein	70	45
Meatscraps, 50% protein	40	40
Starfish Meal	...	40

[1] In co-operation with the Bingham Oceanographic Laboratory, Yale University.

TABLE I. COMPOSITION OF RATION—*Continued*

Ingredients	*Check Ration*	*Starfish Meal Ration*
Dried Yeast	20 lbs.	20 lbs.
Alfalfa Meal, 12% protein	40	40
Soybean Meal, 43% protein	80	80
Cod Liver Oil	4	4
Ground Limestone	10	...
Common Salt	6	6

In view of the fact that the rations above were determined by calculative process, chemical analyses were conducted to determine the analytical comparisons of the rations used based on uniform samples collected from each individual mixture.

TABLE II. ANALYSES OF FEED* (in per cent)

Ingredients	*Check Ration*	*Starfish Meal Ration*
Protein	21.44	21.10
Fat	4.34	4.53
Crude Fiber	4.86	5.19
Nitrogen-free extract	54.40	53.24
Ash	6.53	7.41
Moisture	8.43	8.53
Calcium	1.25	1.49
Phosphorus	0.87	.89

* Analyses by J. B. Smith, R. I. Experiment Station.

Examination of the above table demonstrates that the rations utilized were relatively comparable and that both were sufficiently high in protein content to produce substantial growth.

Growth was determined by weighing each group at two-week intervals throughout the 12-week experimental period. No effort in the beginning was made to segregate male and female weights, but at the completion of the test cockerels and pullets were segregated for this purpose. It will be noted in Table III that while the chicks which were fed the check ration grew at a somewhat faster pace up to and inclusive of 10 weeks of age, this advantage was lost by the time the chicks attained 12 weeks of age. Interestingly enough, the check ration group had a larger percentage of cockerels than was to be found in the starfish meal group. Interesting also is the fact that the cockerels in the check ration group were slightly heavier than those in the starfish meal ration group, and that the reverse was true when the weights of pullet chicks were considered. However, these differences are not necessarily significant when studied on a feed efficiency basis.

TABLE III. GROWTH OF CHICKS (in pounds)

Average Weight	*Check Ration*		*Starfiah Ration*
1st day	.0900		.0900
2nd week	.2812		.2816
4th week	.6500		.6428
6th week	1.2666		1.2183
8th week	1.8668		1.7612
10th week	2.6166		2.4612
12th week	3.0395		3.0877
Average weight of cockerels at 12th week (25 cockerels)	3.4200	*(21 cockerels)*	3.3619
Average weight of pullets at 12th week (23 pullets)	2.6260	*(28 pullets)*	2.8821

Examination of Table IV presenting an over-all picture of total gain in weight and total feed consumption reveals that chickens receiving the check ration utilized feed to a minor degree more efficiently than the test group receiving the starfish meal ration.

TABLE IV. FEED EFFICIENCY

	Check Ration	*Starfish Meal Ration*
Total gain in weight for 12-week period	141.4 lbs.	146.8 lbs.
Total feed consumption for 12-week period	660.0 lbs.	691.5 lbs.
Pounds of feed for one pound of gain in weight	.4667	.4710

In view of the high calcium content of starfish meal and the attendant adjustments in the ration, it was deemed advisable to secure analyses of tibia bones of representative numbers of chickens fed the comparative rations as an indication of physiological utilization.

TABLE V. ANALYSES OF TIBIA BONES*
(Calculated on a fat-free, moisture-free basis)

	Check Ration	*Starfish Meal Ration*
Per cent Calcium	25.70	27.94
Per cent Phosphorus	9.15	9.22
Per cent Ash	48.75	49.80

* Analyses by J. B. Smith, R. I. Experiment Station.

Table V reveals that the chickens fed the starfish meal ration had a higher calcium, phosphorus, and ash content of bone structure as judged on the basis of tibia analyses. This difference may be partially accounted for by a somewhat higher mineral content of the starfish meal ration as quantitatively determined and shown in Table II. However, it does demonstrate that the mineral values of the ration were utilizable by the chickens for bone development.

Conclusions

Under conditions of this test the following conclusions are drawn:

1. Starfish meal may be used satisfactorily as one of the protein concentrates in chick rations.
2. Starfish meal can be utilized in place of fish meal by making appropriate adjustments in the ration.
3. A comparatively satisfactory growth can be secured to 12 weeks of age where starfish meal is used as a protein concentrate.
4. Starfish meal rations carefully compounded will produce weight gains per pound of feed consumed in line with established rations.
5. The starfish, which has consistently presented a problem to the oyster industry, can serve a useful purpose in meeting an important feeding problem.
6. The calcium content of starfish meal is utilizable for bone development.

THE USE OF STARFISH MEAL IN CHICK DIETS

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The shortage of feedstuffs that has resulted from the increase in the production of livestock, has stimulated the recovery and maximum utilization of materials that formerly were discarded or poorly utilized. One such material is starfish. This common marine invertebrate is a serious pest of oysters and is taken in a considerable quantity in the cleaning of oyster beds.

This paper reports the results obtained in three experiments that were conducted between September 1943 and January 1944 for the purpose of ascertaining whether or not starfish meal can be used advantageously in the feeding of growing chicks.

Experimental

The starfish meal used in the experiments here reported was produced experimentally by grinding sun-dried whole starfish and was supplied by Dr. Daniel Merriman, of the Bingham Oceanographic Laboratory, New Haven, Connecticut. The proximate partial composition of the material was:

Moisture	5.5 per cent
Crude protein	30.7 per cent
Fat (ether extract)	4.5 per cent
Crude fiber	1.9 per cent
Ash (900° C.)	30.0 per cent
Calcium	17.6 per cent
Phosphorus	.35 per cent

The basal diet was compounded as follows: ground wheat, 26.9; ground yellow corn, 25.0; soybean meal, 35.0; alfalfa leaf meal, 8.0; B-Y riboflavin supplement (110 micrograms riboflavin per gram), 2.0; steamed bonemeal, 1.0; ground limestone, 1.0; manganized salt, 1.0; and vitamin D powder (1000 A. O. A. C. Units per gram), 0.1.

In diets 1 to 7 various quantities of ground wheat, soybean meal and ground limestone were replaced by starfish meal and sardine fish meal. In diets 8, 9, and 10, a portion of the soybean meal was replaced by corn and wheat in order to have diets that would make possible a more critical study of the quality of the protein. In these experiments, diets 1, 2, 3, 6, and 7, each contained approximately the same quantity of protein, calcium and phosphorus. Diets 4 and 5 contained considerably more calcium because of the high calcium content of the starfish meal. In the third experiment, monocalcium phosphate was used as a phosphorus supplement in order to obtain a satisfactory ratio of calcium to phosphorus in a diet containing a large amount of starfish meal. Thereby, diets 9 and 10 containing three per cent sardine fish meal and 7.5 per cent starfish meal, respectively, were formulated to contain 2.00 per cent calcium and 1.06 per cent phosphorus.

In the first experiment 25-day-old White Leghorn chicks were used per lot and in the second and third experiments 25 day-old Rhode Island Red chicks were used per lot. The chicks were brooded in batteries in air conditioned rooms.

Results

The modifications of the basal diet, and results of the three experiments are summarized in Table I. In the first experiment the average live weight of the chicks in the lot receiving eight per cent of starfish meal was less than that of the other three lots at six weeks. There were no significant differences between the average live weight of the chicks that received the basal diet and that of the chicks that received the diets containing two per cent of sardine fish meal or four per cent of starfish meal, in either the first or second experiments. The chicks receiving the diet containing 12 per cent of starfish meal were significantly smaller than the chicks receiving four per cent of starfish meal or two per cent of sardine fish meal in their diet. These two experiments indicate that the high calcium content of starfish meal limits the quantity of starfish meal that can be utilized in chick diets.

In the third experiment chicks receiving the diet containing 2.5 per cent of starfish meal replacing limestone and wheat were significantly larger than the chicks receiving the diet containing one per cent of sardine fish meal replacing wheat. The chicks receiving diet 8, in which a portion of the soybean meal in the basal diet was replaced by

TABLE I. EFFECT OF STARFISH MEAL ON THE GROWTH OF CHICKS

	Modifications of Basal Diet		*Average 6 Week Live Weights*			
Diet No.	*Material Added*	*Material Replaced*	*First* Experiment*	*Second* Experiment*	*Third* Experiment*	*Av. Mortality*
			Grams	*Grams*	*Grams*	*%*
1	None	None	362.6	374.2	.....	0
2	2% sardine fish meal 1% wheat	3% soybean meal	384.7	400.6	.....	2
3	4% starfish meal	3% soybean meal 1% limestone	376.2	398.7	.....	2
4	8% starfish meal	6% soybean meal 1% limestone 1% wheat	339.9	296.9	.....	6
5	12% starfish meal	6% soybean meal 1% limestone 5% wheat	.....	242.6	.....	16
6	1% sardine fish meal	1% wheat	.....	.....	406.8	4
7	2.5% starfish meal	1% limestone 1.5% wheat	.....	.....	450.2	24
8	9.6% wheat .4% bonemeal 10.0% corn	20% soybean meal	.....	.....	212.1	4
9	3.0% sardine fish meal 2.9% bonemeal .5% monocalcium phosphate 3.6% wheat 10.0% corn	20% soybean meal	.....	.....	343.4	12
10	7.5% starfish meal 3.0% monocalcium phosphate 1.5% wheat 10.0% corn	1% limestone 1% bonemeal 20% soybean meal	.....	.....	350.8	4

* The difference in average live weights between any two lots required for statistical significance (odds of 19.1) was 37.8, 33.2 and 35.9 grams for the first, second and third experiments, respectively.

corn and wheat, attained an average six week weight of about one-half that normally attained by chicks receiving this basal diet. The addition of 7.5 per cent of starfish meal or three per cent of sardine fish meal to the basal mixture in which a portion of the soybean meal was replaced by corn and wheat, increased the average live weight of the chicks receiving those diets by more than 60 per cent, but did not bring the weights up to the normal weights attained on the basal diet.

The use of starfish meal in the diets had no apparent effect on the mortality of the chicks, with the possible exception of diet 5 used in experiment 2, in which the excess calcium supplied by 12 per cent of starfish meal greatly depressed the growth.

Discussion

The results of these three experiments show that starfish meal is a satisfactory feedstuff for supplying calcium and some protein to chickens. The sun-dried starfish meal used in this experiment was of good quality. However, machine drying would be essential for routine commercial production of a starfish meal of similar quality. In these experiments the starfish meal appeared to supply protein of about the same quality as that supplied by sardine fish meal. In addition, the starfish meal when used to supply the same amount of protein appeared to contain the same growth stimulating effect as the sardine fish meal. The growth stimulating action appears to be due to the quantity of certain amino acids or vitamins present. These results confirm those of an experiment reported by Bird (1944), in which starfish meal was found to be comparable to a commercial menhaden fish meal in its ability to supplement a mash containing no animal protein. Since most chick diets contain 1 to 2 per cent calcium carbonate (high calcium limestone or oyster shell) the substitution of 2.5 to 5 per cent of starfish meal would supply the same quantity of calcium and at the same time supply .75 to 1.5 per cent of protein of animal origin. In view of the present shortage of protein supplements of animal origin, the production and use of starfish meal should be encouraged.

Summary

Starfish meal, produced by drying and grinding whole starfish, was found to contain 30.7 per cent protein, 17.6 per cent calcium and .35 per cent phosphorus. In three experiments it was compared with sardine fish meal at the same protein levels as a supplement to a basal diet containing no animal protein. The starfish meal gave as good results as the sardine fish meal when the quantity used did not supply an excess of calcium. The quantity of starfish meal that may be used in practical chick diets is limited to 2.5 to 5.0 per cent of the diet by its high calcium content.

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THE CONTROL AND UTILIZATION OF STARFISH IN RHODE ISLAND WATERS

By Harold N. Gibbs

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The control of starfish is such a vital factor in oyster cultivation, and the two are so intimately connected, that any consideration of one must of necessity include the other.

Rhode Island has a very direct interest in the oyster industry and its related problems. The leasing of grounds for the propagation of oysters has been in effect for about 145 years, the first leases by special acts of the General Assembly.

In 1844 the Legislature created a commission for that purpose and the procedure has continued ever since. In 1935 the duties of several commissions were combined in the present Division of Fish and Game.

In reading the Annual Reports of the Shellfish Commission from 1900 to the present, as well as the earlier manuscript records dating back to 1862, there is one subject that occurs most frequently—the periodic outbreaks of starfish and the time and money expended by the growers in their continuous warfare on these enemies of the oyster.

As a case in point, we read in the Report for the year 1900, "Some growers have kept from one to three steamboats employed all the time in protecting the beds"; and again, in the 1914 Report, "The oyster set was destroyed by Starfish as well as large quantities of one and two year old oysters." The prevalence of starfish is noted in practically every report, and many oyster growers were obliged to cancel much of their holdings following such invasions, which represented the loss of thousands of dollars of state revenue.

Exact figures are difficult to obtain. While it is true that all oyster companies keep accurate records, and although the time spent by boats and men engaged in starfish control is known, the amount of stars destroyed can only be estimated. One concern, The Narragansett Bay Oyster Company, recorded the number of pounds brought in over a period of years. While these figures are important they fail to give a clear picture of conditions, since other factors, such as the number of boats employed and the type of ground worked do not appear in the records. However, the fact that in every year there was an abundance of starfish is most evident.

The reason why more data are not available is explained in part by the nature of the work itself. The objective is to reduce the number of starfish whenever they appear as quickly as possible, and by any method. There are times when the stars invade the beds in such quantities that oyster dredges are used. Scattered individuals, distributed over a large area, are caught with "mops," an iron framework to which thread or twine tangles are attached at regular intervals. In using mops, starfish are either picked off by hand or the mops are immersed in a tub of heated water, the dead stars falling off when the mop goes over. Within the last few years an application of lime has been used to destroy the stars on the beds.

In 1940–41 there was an unusual outbreak of starfish in Narragansett Bay and much of the "public" ground was heavily infested. The oyster growers could not keep ahead of the overflow of stars from adjacent areas.

In 1941 the Legislature appropriated the sum of $12,500 for starfish control and actual work began on April 22 of that year, as soon as the funds were available. Every effort was made to destroy as many stars as possible before the spawning season.

The work was done on a "bounty" basis, the fishermen being paid at the rate of 75 cents per hundred pounds and the stars were offered to local farmers, gratis, for use as fertilizer. All dredging was confined to the public grounds.

From April 22 to May 23, when the funds were exhausted, a total of 1,211,064 pounds of starfish were delivered to the two receiving stations. Approximately 35 boats were licensed to dredge and about half that number were employed continuously. Many of these boats brought in from three to four tons of stars daily. The starfish population was reduced, but there still existed many areas that had not been touched.

In 1933–34 there was a C. W. A. Project to reduce starfish, but the figures are not available to the writer.

In connection with the work in 1941 it is interesting to note that the local farmers who used the raw stars for fertilizer reported excellent results. Analysis of these same stars compared unfavorably even with the poorest grades of commercial fertilizer. We know that in the orchards where starfish were applied the apples were highly colored, probably from the lime content of the stars, but possibly from some additional mineral present. We also know that on other lands where raw stars were placed the grounds continued to produce good crops without any further application of fertilizer. Is it possible that trace elements, too minute to appear in an ordinary analysis, may be responsible? At least the idea is worth further investigation.

There can be no question that we have an ample supply of starfish in our Rhode Island waters and it is equally evident that there must be a rigid control of the population if oyster culture is to be successful. Some means of utilizing the stars should be found. At the moment two methods are suggested—as a fertilizer or as a poultry or animal food.

The ideal solution would be to find a use whereby a price could be paid the fisherman at a level that would induce them to catch them in quantities, to create a demand for the product, and to establish a processing plant near the source of supply.

While the oyster companies do produce an appreciable amount of starfish in the course of a year, it is our opinion that if they are to be utilized to any extent commercially, or if the starfish are to be materially reduced, it will take the combined efforts of both the oyster grower and the fisherman to produce results.

The possibility of exterminating the starfish will be our last concern.

OBSERVATIONS ON THE OCCURRENCE AND POSSIBLE USES OF STARFISH

By J. Richards Nelson

Warren Oyster Company, Warren, R. I.

The starfish is an enemy that must be reckoned with continuously by the oyster planters of New England and New York. Oysters in Delaware Bay are occasionally attacked by this pest and the last serious invasion of the oyster beds occurred in 1930 during a period of dry weather and high salinity. Chesapeake Bay planters report trouble with starfish where they plant nearest the Capes, but they do not experience any difficulty in the lower salinity areas of the Bay and in the several rivers where oysters are produced.

In the North Atlantic area the worst trouble is experienced in Long Island Sound from Norwalk to Branford, Connecticut. This is the main oyster seed producing area of the North and starfish set on practically all of the beds where oyster seed is produced. In general, the starfish set occurs just before the oyster set so that the young stars are just the right size to devour the young oysters. Narragansett Bay and Buzzards Bay have starfish in large numbers and this is an important factor in keeping oyster production low in these two bays.

In Gardiners Bay, Shelter Island Sound and in the Peconic Bays there are some of the best oyster growing and maturing grounds in the North. Oysters do not generally set in these bays but do grow and fatten exceptionally well. Starfish occur throughout this area but are generally not a serious menace except in Great Peconic Bay from Robbins Island to Jamesport. This is contrary to the general rule that starfish are found only where the salinity is highest.

Considerable work has been done in recent years on the control of starfish through the use of lime. This seems to work out well in experiments but has not proved satisfactory so far to the commercial grower. The most effective method for the commercial grower is still the use of mops which are brought up to the deck of the boat and immersed in hot water. Dredging of starfish on vacant bottom is also effective and is commonly done by oyster planters when the presence of this enemy has been discovered.

From the observations of the writer over a period of years, it appears that starfish move quite rapidly under certain conditions and travel to sources of food. Experiments at the Milford Laboratory showed no evidence that stars had any way of determining the location of food, but repeated experience has taught us in the oyster industry that this pest will travel several miles in as many months and find our beds of seed oysters in Long Island Sound. It is difficult to believe that this is the result of mere chance.

The writer's experience in the utilization of starfish has been confined to their use as a fertilizer on various crops. They are particularly suited to the crops that require a high nitrogen fertilizer and that thrive in an alkaline soil. Excellent results have been obtained by spreading the starfish on the ground in March, approximately one layer thick, and plowing these under. The effect is more noticeable the second season, apparently due to the fact that stars plowed under in the spring probably do not become available for at least six weeks or more, and also because plowing usually puts them below the level where most plants can utilize them. Plowing the following year brings them on top and they are thoroughly incorporated in the soil. Such crops as corn, lettuce, cabbage and all leaf crops thrive on stars. Root crops such as beets and carrots do well the second year, but potatoes do not do well with this fertilizer, probably due to the fact that it is unbalanced, being heavier in nitrogen. Also, the lime content tends to promote scab.

Commercial use of starfish depends, in the writer's opinion, on developments which will make it sufficiently profitable to gather them for sale. No industry could be built on the supply received from oyster boats engaged in taking starfish only when they threaten oyster crops. If starfish meal were as valuable as fish meal it is probable that fishing boats could be induced to gather starfish as a business.

In regard to the supply, it appears that this is great enough to support several fish meal plants if the value of the product were great enough to attract commercial fishermen.

STARFISH PREVALENCE AND PRODUCTION PROBLEMS

By H. Gordon Sweet

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INTRODUCTION

Oyster growers have caught immense quantities of starfish over a period of more than one hundred years in their efforts to protect their crops from these animals. This starfish material has served no useful purpose except in a few instances where farmers have been willing to cart it away for fertilizer. In a period of stock feed and fertilizer shortages the possible value of starfish has obvious significance.

The present report is a discussion of some of the production problems to be considered and solved. It is based on data compiled by H. C. Rowe & Company, which propagates oysters in Long Island Sound and produces market oysters in Gardiners Bay and Shelter Island Sound at the eastern end of Long Island.

Abundance of Starfish

The primary concern of the oyster grower is to protect his oysters from the ravages of starfish. The catch of starfish in pounds or tons is of secondary importance. This should be borne in mind in connection with the present report, which is based on operations concerned with the conserving of oyster crops rather than the harvesting of a maximum volume of starfish.

Starfishing is not necessarily carried on in the areas of greatest infestation because the oysterman's first concern is to give maximum protection to his youngest crops.

The preparation of production areas for the planting of dock shells to which the young oysters will attach themselves involves the elimination of all starfish from the beds themselves and from adjacent areas. This operation must be carried out, even though the starfish prevalence is as low as 10 pounds per hour per boat. After the crop of young oysters has appeared, adjacent areas must be constantly watched for the approach of starfish.

These surveys consume many days in every year and are not concerned with a heavy production of starfish, which is the last thing the grower wishes to find on or near his oyster beds.

As crops reach the ages of two, three and four years, they are less vulnerable to destruction by starfish and require less vigilant inspection and care.

It is seldom possible for an oyster grower to send out one of his starring boats with the single objective of finding a maximum concentration of starfish for capture and use as a by-product.

Hence, this report does not indicate the maximum quantity of starfish which might be obtained by vessel units which were released from the necessity of protecting specific ages of oysters and the localities on which they were planted.

The general practice in the oyster industry is to capture starfish with the use of mops or tanglers, as described in a previous paper in this series (Gibbs).

The Rowe Company operates two boats for its starring protection, with occasional assistance from larger units. These two boats are the *RIVAL* and the *SEA GULL*. The *RIVAL* is used for inspection and surveys, while the *SEA GULL*, which is equipped with a steam boiler and tubs containing hot water in which the mops are immersed, is called upon to combat stars in areas which are known to be infested.

The *SEA GULL*, therefore, catches many more starfish than the *RIVAL* in the course of a year, and the figures given relate to the *SEA GULL'S* catch. This vessel is an open-deck Diesel unit of 13 gross tons, 50 feet in length, and equipped with a 40-horsepower Fairbanks-Morse engine. The star frames are raised and lowered with chains operated by hoisters in the hold of the vessel which connect with the main engine. The two iron frames, with their trailing mops of cotton yarn covered with starfish, are hoisted to the deck and dipped in the hot water tubs for approximately two minutes at a temperature of 150° F. The frames are then returned to the water and the cooked starfish, which have become soft, drop off while the gear is being returned to the bottom.

The *SEA GULL* is manned by a Captain and two deckhands. Her operating cost is roughly $30 a day or $750 a month.

The area over which this vessel operates comprises somewhat more than 3,000 acres of oyster grounds located off the Connecticut coast between Branford and Stratford. These areas consist of production beds where young oysters first appear in the summer, extensive growing areas for oysters of different ages, vacant grounds, worthless soft bottom and reefs.

In certain places, such as the vicinity of breakwaters, starfish are always present in appreciable numbers. When an oyster grower is not obliged to fight starfish on the oysters themselves, he first cleans up adjacent areas, and then has a few days or weeks in every year when he can work out from cultivated areas and attack starfish wherever they are concentrated. It is seldom possible to work these areas of maximum abundance because starfish are highly mobile and are constantly threatening to invade the beds where oysters are planted.

The following summary gives a generous estimate of the number of starfish taken each month during the year 1942, based on a 25-day month of 7-hour days. These data were obtained from a live-weight record of pounds per hour caught by the *SEA GULL* in the course of her protection of the Rowe oyster beds.

TOTAL MONTHLY CATCH OF STARFISH BY THE *Sea Gull*

Date	*Lbs. Live Starfish*
January, 1942	3,311
February, 1942	4,452
March, 1942	3,492
April, 1942	3,676
May, 1942	4,232
June, 1942	3,465
July, 1942	2,682
August, 1942	2,575
September, 1942	7,079
October, 1942	33,268
November, 1942	31,597
December, 1942	22,808
January, 1943	8,091
Total	130,728

The above catch of live starfish is estimated to be about five per cent of the total catch from the oyster-producing areas in Long Island Sound between Branford and Bridgeport. From this it appears that the total annual catch for 1942 in this section amounted to roughly 2½ million pounds, live weight.

From January 1942 through August 1942 there were moderate quantities of starfish on or near valuable crops. The quantity and location of these animals was sufficient to justify the use of the *SEA GULL* in these areas, although the total catch was not high.

In September, 1942 the starfish population was very active, and the rise in poundage reflects encroachment upon crops of young oysters.

In October, the Rowe Company encountered the worst general invasion of starfish ever observed, and the *SEA GULL* spent the month working on heavy beds of stars, catching as high as 800 pounds per hour live weight.

In November the situation was still critical but slightly improved, owing to the fact that starfish become inactive during the winter months.

In December there was a noticeable decrease in the total weight, indicating that the *SEA GULL* was in control of the situation. This was further apparent in January, when the catch declined to 8,091 pounds.

Discussion

A few farmers in Connecticut have used starfish on the soil as fertilizer for many years, but have been willing to pay little or nothing for the starfish material.

If these animals are to be used commercially as poultry feed, fertilizer, or otherwise, a careful study of production and handling problems will be necessary before the material can be made available.

The oyster grower would be glad to sell his starfish even though the price received did not cover his cost, since these animals must be caught in any case. With a price of $10 per ton for live starfish, the maximum monthly income from stars taken by the *SEA GULL* in 1942 would have been $166 for October, when the greatest catch was made. This is a small remuneration considering the cost of operating the boat, which was $750 for the month. Moreover, the high catch in this month depended on the use of hot water tubs in which the stars were cooked and then left in the mops for dispersal in the water. If these starfish had been picked off the mops by hand, the catch per hour would have been reduced and the income from starfish in that month would have been less than $166.

A new method of removing the starfish from the mops might be devised, but success in this direction is highly problematical. It is possible that a trawl could be designed for capturing starfish on vacant bottoms. This gear could not be used on oyster beds because of the certain damage which would be inflicted on the growing oysters.

Other types of small fishing vessels might be used to good advantage in this work provided a price commensurate with the effort and cost of operation were received. It is possible that these boats might earn a good living at certain seasons fishing primarily for starfish.

If starfishing were developed in any section, the landing of these animals would be the next consideration. They could be brought to one shore station, or might be delivered to a "buy-boat" out on the water. The establishment, maintenance and operation of a shore plant for receiving and processing starfish for shipment is a separate problem which could be solved without too much difficulty or investment.

In summary, the following considerations are presented:

1. The financial return to an oyster boat in Long Island Sound catching starfish as a by-product of the protection of oyster crops would not be more than a fraction of the operating cost.

2. The financial return to an oyster boat in Long Island Sound operating to catch a maximum tonnage of starfish without regard for the protection of specific oyster beds would not be profitable, although an oyster grower would willingly operate in this manner when his crops were not in danger if he had a convenient place of delivery.

3. The financial return to an oyster boat in Long Island Sound using new methods of starfishing, such as trawling, with the object of making a profit out of the operation, would not be adequate, in the writer's opinion, but should be investigated. In periods when equipment and labor are available, progressive oystermen might be willing to experiment along this line, even though they do not expect the receipts to equal the cost.

4. The use of other small fishing vessels to take starfish commercially depends on an assured market, a receiving station and a stable and adequate price. In view of the fact that prices as high as $14 per ton of live starfish have been quoted recently, it is conceivable that human enterprise may be attracted to the capture, processing and utilization of this marine organism.

STARFISH MENACE IN SOUTHERN MASSACHUSETTS IN 1931

EARNEST W. BARNES

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In 1931 the then newly-created marine fisheries section of the Massachusetts Department of Conservation was suddenly confronted with an alarming menace to the shell fisheries caused by the inroads of immense numbers of starfish which threatened to wipe out the valuable bay scallop, oyster and quahaug fisheries along its entire southern coastline from the Rhode Island State line to Monomoy Point. These shell fisheries were valued in excess of $2,000,000. Upon their success depended the welfare of sixteen coastal towns whose principal income came from these fisheries; they furnished a livelihood for over twelve hundred fishermen. As is not infrequently the case in State fisheries, although a solution of this problem was exceedingly urgent no adequate precedent had been established. The whole problem constituted a direct challenge to the biological staff and was so accepted.

The facts in the situation were these:[1]

A coastline in excess of one hundred miles was affected by starfish with the greatest concentration centered in Buzzards Bay and the neighboring waters of Nantucket and Vineyard Sounds. As evidence of the concentration of stars reported at the time, we may cite the efforts of two or three towns which had attempted individually to suppress them. These efforts are exemplified by the experience in Wareham in March, 1931, where a town appropriation of $1,000 was used up in one day and a second similar appropriation in three and one-half days. One fisherman working alone in this town brought in 88 bushels of starfish in one day, which represented approximately 26,400 stars. This amount, large as it is, was exceeded many times in later work.

The bay scallop public fishery in the general area had dwindled

[1] See Annual Reports of the Division of Fisheries and Game, Department of Conservation of Massachusetts, for 1932–36.

progressively from an estimated $750,000 revenue in 1929 to about $200,000 in 1933; and in the town of Wareham from $200,000 to $1,000.

The oyster fisheries in this area are conducted as private fisheries, and although they were very hard-hit by the menace, the companies were equipped with "cotton mops" or "tangles," and by systematic work were able to reduce, somewhat, the amount of destruction. They were, however, troubled by the migration of stars from neighboring public areas.

Injury to the public quahaug fishery resulted from the smothering effect of concentrated mats of starfish.

The principal ray of hope came from a realization by civic leaders of the seriousness of the situation, but this was also offset by a multiplicity of remedies and a pessimism as to results. Through the support of the affected towns an appropriation of $15,000 was obtained in 1932 from the General Court to be spent under the direction of the State Department and in accord with its rules. Subsequent appropriations amounting in total to $30,000 were made, and by 1936 we considered that the number of starfish had been reduced to such an extent as no longer to be considered a menace. Under the plan adopted each town was required to contribute a certain amount of money toward the project conducted in its waters. This amount was agreed upon in advance on the basis of need as determined by the State but could not be less than one-quarter of the total amount spent. The towns were further asked to adopt a regulation requiring the fishermen to bring ashore all starfish caught in their regular fishing operations under penalty of revocation of all shellfish permits. Later a State law was enacted to that effect.

Late in 1933 the CWA, a Federal relief agency, was induced to accept marine fisheries projects, and during the years 1934, 1935 and 1936 an estimated amount of 95,310 bushels of starfish were collected under CWA, ERA and WPA. The state and towns acted as co-sponsors and contributed certain amounts to the program. While very appreciative of this assistance, it should be remembered that the principal objective of this Federal work was relief to the unemployed, and the main effort therefore was wages and not results. Consequently this contribution should never be considered from the standpoint of practical efficiency. In Federal relief work the reimbursement was on a day basis, and the actual quantity of starfish collected was often estimated by relief foremen, the accuracy varying with their personal ability. The State, as sponsor for the project, endeavored to standardize estimation.

Previous methods were not adequate for such a widespread menace. Cotton mops, such as were in general use by commercial oyster fishermen, could not be used, because the boats of local fishermen were not equipped with them and they were not large enough to handle them, nor could sufficient funds have been obtained to supply them. Furthermore, it was decided that this method was not efficient enough to rapidly and economically reduce the tremendous number of stars. Copper sulphate, an emergency measure advocated by the U. S. Bureau of Fisheries, could not be used, because of its toxic effect upon the food supply of the shellfish as well as for other reasons. The use of lime had not at that time been fully demonstrated, nor is its use even now advocated by this Division for such extensive use. It was therefore decided to use the small scallop dredges, with which most fishermen's boats were equipped. The use of these was supervised and the areas in which they operated were restricted in order to minimize possible damage to seed or adult shellfish.

In state and town work wherever possible (probably in 90% of the work) the fishermen were paid on the bushel basis, the amount of collection being checked daily by State and local fishery officers. At the commencement of the work and until the concentrations were considerably reduced, the fishermen were paid on the basis of the number of bushels collected. Later an hourly wage was paid for work which was strictly supervised.

By 1936 the abundance of starfish had become so reduced as to necessitate a different handling of the problem. No longer did we organize groups of boats and give them a general area in which to collect the starfish, but we actually located the beds of starfish and fished that area with a few selected fishermen under our direct supervision until the starfish were reduced to a nonpaying quantity. Our technique naturally had improved so that even an area in which the stars were scattered could be worked successfully; consequently the per-bushel price was kept low. When the fishermen were paid by the hour, our supervision included such details as the kind of dredge and the number of them to be used, length of dredge line in that area and the boat speed. Collections by State and towns were largely but not exclusively made in the months of April through November.

At the outset we were handicapped in our work by a woeful lack of knowledge as to the migratory habits of starfish. In fact in July, 1932, when the first appropriation became available, the fishermen reported that the starfish had disappeared. Believing that there was no chance of such luck, I personally made a survey of the locality, and after a few days of systematic work located an area of great abundance in the vicinity of Cleveland's ledge in Buzzards Bay, about four square miles in area with an average depth of twenty feet. From this area, in spite of considerable stormy weather, 4,000 bushels of stars were taken in three weeks. It was interesting to note that more than 10 per cent of the starfish collected in this area were still full of spawn, although they were taken in the month of August, and July 1 had been considered as the end of the usual spawning period. In the cooler weather the remnants of these stars and others from smaller areas of concentration moved back into the shoaler waters. The knowledge of this seasonal migration was taken full advantage of in later work.

In the five years of concentrated work, 1932–36, 256,714 bushels were collected, representing more than 3,800 tons, and, at an average of 300 per bushel, more than 77,000,000 individuals. By the end of 1936 the concentrations of starfish had been greatly reduced over the entire area, and the work in 1936 consisted mainly of large-scale mopping-up operations. In areas where at the beginning of the work individual boats had brought in as many as 197 bushels in one day and averaged 100 bushels per day, these same areas yielded from 16 to 20 bushels per day.

The public scallop and quahaug fishery has been on the increase throughout the menaced area in spite of more intensified fishing.

Among other interesting things observed in this campaign was a tendency of the starfish to concentrate in certain definite spots in each area. The reasons for this concentration are very obscure and certainly not directly connected with the abundance of food. This is particularly evidenced by the migration of stars into a newly dredged area. In fact it became a common practice to thoroughly dredge a certain small area and then leave it for two or three weeks. Upon returning it would usually be found that a new concentration of stars had moved in from surrounding areas, even though at times the stars had left beds of seed scallops to do so.

It is not expected that the work done in the suppression of starfish has eliminated them as a menace in the affected areas, but it does demonstrate that something can be done about it. Starfish will continue to be a menace to the shell fisheries and from time to time will be present in great concentrations; but the experience which has been obtained in the suppression of them has left a certain definite assurance that, with careful observation as to the abundance of stars in our shellfish areas, serious trouble can be anticipated and prevented. Since 1936, wherever a concentration of stars was observed in a certain area and we were notified of the fact, or if it was observed by ourselves, we were able to remove the menace rather quickly and inexpensively.

A most important contribution of this work to the Marine Fisheries was that it aroused local interest in protective conservation measures and induced a spirit of cooperation between the towns and the State, which is always a healthy condition for a conservation program. Eventually in Massachusetts this work in the suppression of starfish developed into a permanent policy of shellfish assistance supported by an annual, though modest, appropriation.

TABLE I. STARFISH SUPPRESSION BY MARINE FISHERIES MASSACHUSETTS

	1932 Fiscal Year	*1933 Fiscal Year*	*1934 Fiscal Year*	*1935 Fiscal Year*	*1936 Fiscal Year*
Total Bushels Collected	56,120	53,656	63,567	30,250	53,121
Collected by State	43,127	39,331	10,238	5,250[1]	35,121[1]
Collected by Towns	12,993	14,325	1,016		
Collected by Federal Gov't.	none	none	52,310	25,000 (Est.)	18,000 (Est.)
Paid by State	$8,711	$14,937	$4,924	$1,472	$13,991
Aver. cost to State	20.0c	37.9c	48.0c	[1]	[1]
Paid by Towns	$2,903	$6,059	$8.07	$741	$9,340
Aver. cost to Towns	22.0c	42.3c	79.4c	[1]	[1]
Total cost to State and Towns	$11,614	$20,996	$5,731	$2,213	$23,331
Aver. cost to State and Towns	20.6c	39.1c	50 9c	42.1c	52.9c
Federal Costs	none	none	CWA[2]	ERA[2]	WPA[2]

[1] During these years all starfish projects, except those by the Federal Government, were operated jointly by State and Towns. The only possible separation was in expenditures which were in proportion agreed upon.

[2] Federal costs unknown since total expenditures included many items, allowances and top supervision only remotely connected with collection costs. The major federal effort was directed toward securing wages for the unemployed regardless of the value of their contribution to the project.

TABLE II. AMOUNT OF MASSACHUSETTS STATE EXPENDITURES (IN DOLLARS) CHARGED TO STARFISH, 1932–1942

Area	*Township*	*1932*[1]		*1933*[1]		*1934*	*1935*	*1936*	*1937*	*1938*	*1939*	*1940*	*1941*	*1942*	*Total*
Buzzards Bay	Bourne		4233			554	0	0	0	0	0	6	0	0	4793
	Wareham		7414			1078	42	1736	680	0	0	0	212	424	11586
	Marion		3090			970	102	1541	116	0	0	420	0	0	6239
	Mattapoisett		4269			519	90	1634	55	0	0	237	0	0	6804
	Fairhaven		1047			555	136	899	0	0	0	553	0	0	3190
	New Bedford	0		701		45	688	2257	0	0	0	0	0	0	3691
	Dartmouth	0		1021		49	0	863	0	0	68	234	178	0	2413
	Falmouth[2]	0		0		434	551	145	0	0	0	0	0	0	1130
	Total	8711	+	13064	–	4204	1609	9075	851	0	68	1450	390	424	39846
Vineyard and Nantucket Sound	Chilmark	0		0		0	0	776	260	0	0	0	0	0	1036
	Tisbury[3]	0		233		64	0	240	193	1612	440	382	549	412	4125
	Oak Bluffs[3]	0		3		0	0	373	154	1048	342	911	339	628	3798
	Edgartown	0		1430		640	0	1812	380	1156	633	615	0	0	6666
	Barnstable	0		0		0	0	10	0	900	942	0	0	0	1852
	Nantucket	0		0		0	0	1421	443	0	0	0	0	0	1864
Mount Hope Bay	Swansea	0		208		17	0	224	0	714	0	0	0	0	1163
	Grand Total	$8711	+	$14938	–	$4925	$1609	$13931	$2281	$5430	$2425	$3358	$1278	$1464	$60350

[1] Separate returns for 1932 and 1933 not available for certain towns. Total expenditure listed for the Buzzards Bay region in 1932 does not include Fairhaven, disbursements for which since August, 1932 are included under the 1933 total.

[2] Starfish collected on both Buzzards Bay and Vineyard Sound shores.

[3] Although amounts spent in these towns are charged to starfish, the work consisted largely of dredging and removing accumulated trash which contained quantities of a small starfish species not determined, seldom over 2 inches in diameter.

GENERAL DISCUSSION OF PROBLEMS INVOLVED IN STARFISH UTILIZATION

By Martin D. Burkenroad

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To evaluate the possibility of utilization of starfish requires an examination of the balance existing between the following interdependent factors:

1. The value of and demand for starfish products.
2. The costs of preparing and marketing the products.
3. The quantities of raw material available and the costs of its production and delivery.

The preceding sections of the present volume provide much valuable information upon these factors. However, they are insufficient by themselves to enable any definite conclusions to be drawn as to the possibilities of establishing a starfish industry in southern New England under foreseeable conditions. In order to comply with Dr. Merriman's invitation to prepare a concluding section, it has been necessary to make a variety of further enquiries. Extensive and generous aid in this work has been granted me from many sources; and I should like here, in anticipation of detailed acknowledgment which will appear in a forthcoming report upon the natural history of the starfish, to express my sense of gratitude and deep obligation to all who have helped.

Factor 1. Value of and Demand for Starfish Products

The first six papers of the present publication serve to demonstrate, in a more critical way than has been attempted heretofore, that starfish meal is of value as a foodstuff for domestic animals. The general result obtained by experimental feeding of chicks upon diets containing a proportion of dried and ground starfish is that, in quantity less than six per cent of the ration, starfish is about equivalent weight for weight as a growth-promoter to such standard protein supplements as sardine meal. In view of the relatively low protein content of starfish meal this is a surprising result, which appears to be worth further investigation. In addition, the non-protein content of starfish meal apparently replaces the shell or limestone meal otherwise required by poultry as a source of calcium. Spectrographic and microbiological assays by Hutchinson *et al.*, in addition to defining the quantities of valuable substances contained in starfish, provide assurance that there will be no unexpected after-effects of feeding as a result of detrimental concentrations of the trace-elements fluorine and strontium. In two further papers of the present publication (those of Gibbs and of Nelson), incidental consideration is given to the use of starfish as fertilizer for crops. Although the favorable conclusions presented are not based upon controlled experiment, the information represents an advance over that heretofore available, in providing assurance that no adverse effects accompany the application of starfish to soils.

The maximal price obtainable at present for starfish meal would apparently be set by an O. P. A. ceiling upon materials intended for animal feeding. This ceiling is based upon protein content. Because of its relatively low protein content, starfish meal would not bring more than $42 per ton, in sacks, f. o. b. shipping point. The potential demand at this price under present conditions is apparently very large. Starfish processed like menhaden scrap is reported to have brought a price of about $43 a ton as feed or fertilizer in Virginia in 1937–8.

Should a weight-for-weight equivalence of starfish meal to fish meal as a growth promoter for young chicks be confirmed, a higher price for starfish meal than its gross protein content would justify might be established upon an open market. It is also possible that starfish might prove upon enquiry to be capable of supplying products of greater value than animal feed or fertilizer; for example, the gonads might conceivably serve as human food; or derivatives of special medical or industrial use might be discovered. However, such possible developments are beyond the range of the present evaluation.

The value of starfish captured upon the coast of southern New England is peculiar in having a negative as well as a positive aspect. In addition to its potential usefulness as a raw material, a starfish removed from an oyster-bed has a definite value to the oyster grower, based upon the amount of damage which would otherwise have been caused by it. This negative value is best considered under Factor 3 (Costs of Production).

Factor 2. Costs of Preparing and Marketing the Products

We are informed by Mr. John Ryan, President of Dehydrating Process Company, Boston, that starfish offers no special dehydration problems. It was successfully handled by his company (in preparing the meal used by Morse, Griffiths and Parkhurst, as reported in the present volume) by the same means as for fillet trimmings from non-oily fish (cod and haddock), as follows: the wet weight of batches of material is first reduced by 50 per cent in rotary vacuum dryers, at a 26 inch vacuum with 45 pounds of steam pressure on the dryers. In the second stage, the cooked, semidried scrap is put through a Louisville steam tube dryer and reduced to seven to eight per cent moisture. It is then ground in a hammer mill. The yield of dry meal to raw starfish was 22.5 per cent, slightly lower than for cod and haddock.

The minimal present cost of processing fish meal, by methods such as the above, capable of turning out premium meals, and in a plant producing about 5,000 tons of meal per year, is believed by Mr. Ryan to amount to at least $42.00 per ton exclusive of the costs of raw material. The distribution of this cost would be roughly as follows ($ per ton of meal); Labor, 14.00; Power, 2.00; Heat, 5.50; Sacks, 2.50; Indirect (Building-rental, Office and other supplies, Maintenance, Taxes, Insurance, etc.), 6.00; Transportation and sales, 1.00; Administration, Bank charges, etc., 8.00; Depreciation, 3.00; Total $42.00. In the case of fish meals with a protein content of 50 per cent to 75 per cent, selling at a ceiling of about $1.20 per per cent of protein per ton, the above costs would by no means be prohibitive, and are in fact considerably lower than are now attained in practice.

According to Mr. Ryan, fish meal plants are normally designed with a potential capacity for production more than twice that which they actually achieve; this is because unavoidable irregularities in the delivery of raw material require that the plant be able to handle peak loads when they are available. Actual production at Boston and Gloucester is estimated to be on the order of only 40 per cent of plant capacity, because of seasonal and other fluctuations in the supply of fish. A plant able to handle less than five tons of raw fish per hour is thus not regarded as economical. Under the conditions with which Mr. Ryan is authoritatively familiar, "At $5.00 per ton at the dock (for non-oily fish wastes, amounting to a raw-material cost of about $22 per ton of meal), a production of 3,000 to 5,000 tons of meal (per year, requiring between 13 and 22 thousand tons of fish) would warrant putting in the equipment to process, if you could be assured of getting tonnage year after year. Equipment to process this amount, including Boiler Plant, would be 125 to 150,000 dollars, which would not include building."

Mr. Ryan's remarks are of course not intended as a conclusive statement of the costs of processing starfish, inasmuch as differences between the conditions of operation with fillet trimmings and with starfish (as, for example, in the regularity of delivery of the raw material) might be great. For comparison with the above costs, we are informed by an oyster grower of Mobjack, Virginia, that during the winter of 1937 he was able to sell for a price of about $43 per ton the product of an average daily catch of raw starfish amounting to about 18 tons, processed with steam cooking and steam drying equipment. Since his raw material costs are estimated to have been between $2.50 and $4 per ton wet, or between $11 and $17 per ton of finished product, his processing costs may be presumed to have been less than $32.00 per ton, unless the enterprise was operating at a continuous and obvious loss. This enterprise was discontinued after about a year, upon disappearance of the masses of starfish which had, by their sudden and unique development in Chesapeake Bay, stimulated the initiation of the industry. It has not been possible to determine whether the enterprise could have returned a net profit had the peak level of the local population of starfish been maintained.

It seems possible to say one thing rather definitely about the processing of starfish for feed or fertilizer, namely, that the basic manufacturing costs would apparently be about the same as for other raw materials. In consequence, whatever industrial mode is considered, from one-man sun-drying on up, starfish would have to compete on an equal footing with other materials as regards processing costs. If, therefore, the market value of the finished starfish meal is lower than that of other comparable products, investment in a starfish industry would be unattractive unless the unfavorable differential in the value of the finished product could be balanced by a favorable differential in regard to the supply of raw material.

The cost of non-oily fish wastes to the processor amounts to at least $20 per ton of finished product. Oily fish or wastes generally cost more as raw material (for example, menhaden is obtained not as a by-product but from a primary fishery), but the value of the oil is such that the protein residue may in fact be regarded as a by-product just as much as the non-oily wastes from ground-fish filleting houses. As far as can be learned, the difference in market value between starfish meal and fish meals would be more than $20 per ton at present, which is about the same as the cost of raw non-oily fish wastes sufficient to make a ton of meal. Consequently, even if raw starfish were cost-free, it might not pay to process them.

To summarize, it appears that the manufacture of animal feed or fertilizer from starfish would be unprofitable under present conditions, even if the conditions of supply of raw material were exceptionally favorable (which, as will be shown in the next section, is not the case).

Factor 3. Quantities of Raw Material Available and Costs of Production and Delivery

The sections by Barnes, Gibbs, Nelson and Sweet in the present publication provide information concerning the existent New England fishery for starfish. This fishery is based upon the need to combat this animal as a destructive pest. Starfish caught for this reason, chiefly as a by-product of the oyster industry, might be a possible source of low-cost supply for a starfish processing industry. Put in another way, funds expended by private oyster growers and by public authorities for the protection of economic mollusks from starfish represent a possible contribution to the costs of supplying starfish for processing.

However, it does not appear practicable to found a starfish industry upon the by-product catch alone, quite apart from the question of costs of processing. To judge from available information, the entire catch of starfish in southern New England, from all sources and in years when starfish have been most abundant, has probably never approached 20,000 tons; in fact, Sweet estimates the catch in the whole of Connecticut in 1942 (a year of abundant starfish) to have been no more than about 1,200 tons, capable of producing no more than about 275 tons of meal. Further, this existent production of starfish is scattered along a coast extending from Cape Cod to New York; and in order to utilize it, the scattered catches would have to be collected and delivered at almost daily intervals to a limited number of processing plants. The cost of such delivery would be considerable. Finally, a third difficulty in utilizing the by-product catch of starfish is that the gear most commonly employed for destruction of the pest is the mop-dredge, which can be used for the selective removal of starfish from beds already planted with oysters. The starfish, entangled in and clinging to the mops, are usually killed by immersion of the gear in hot water, after which the mops are cleared for further fishing by being dragged overside. The expense of disentangling the starfish upon deck is (as Sweet points out above) appreciable; and in consequence a large, or the major, part of the existent catch of starfish probably could not be landed except for a price sufficient to cover the added costs of retaining them.

In view of the above difficulties, it seems unlikely that under present conditions any significant amount of starfish could be supplied at low cost to the processor as a by-product of the oyster industry.

The cost of production of starfish by a fishery established primarily for this purpose may now be considered. It will be seen from the remarks of Barnes that the lowest bounty ever paid for starfish by the State of Massachusetts was about $10 per ton, and that the yearly average price ranged from $14 per ton in 1932 to $35 per ton in 1938. The bounty paid in Rhode Island in 1941 amounted to about $15 per ton, according to the account of Gibbs, although the eager response of the fishermen (resulting in a catch of 600 tons in one month) suggests that this price may possibly have been above the minimum required. In contrast to these prohibitive New England prices, we are informed by the Virginia processor referred to above that his two-dredge oyster boat, costing between $45 and $60 a day to operate, made an average daily catch of 500 bushels (estimated to weigh about 18 tons) or more of starfish in the Chesapeake during the winter of 1937. The cost of producing starfish in Virginia, therefore, evidently amounted to between $2.50 and $4 per ton.

The differences between the costs of production of starfish in New England and in the Chesapeake, and between those in Buzzards Bay in 1932 and in 1936, clearly relate, in major part at least, to differences in the abundance of starfish at these times and places. For example, against the average of 18 tons per boat per day in the Chesapeake in 1937, the highest catch in Buzzards Bay between 1932 and 1937 is reported to have been about 2½ tons (a difference far too great to be referred to differences in effectiveness of equipment alone). On the other hand, it seems certain that in 1942–43, much larger catches per boat per day could have been made in New England (where starfish became excessively abundant at this time) than in the Chesapeake (where starfish had become scarce[1]).

That great fluctuations in the amount of trouble with starfish do occur has in fact been recognized for a century by New England oyster growers. Therefore, in order to determine the potential costs of production of starfish, it has been necessary to enquire into the nature and extent of these fluctuations. As a preliminary report on the results of this enquiry is now in press (Burkenroad, 1946, *Science*) and a full report is in preparation, only a brief summary need be given here. Statistics upon the abundance or catch of starfish are lacking, save for a thirty-year record of the annual catch upon its oyster beds by an oyster company in Narragansett Bay, and a similar seven-year record by a company in Connecticut. These records show great changes from year to year (for example, the Narragansett Bay Company caught less than five tons of starfish in 1922, against 650 tons in 1929); but these differences might conceivably refer to changes in fishing effort, or to fluctuations of a merely local sort, balanced by converse changes on neighboring oyster grounds.

In an attempt to determine whether these available limited quantitative records might be representative of general conditions, and whether the changes in magnitude of these recorded catches might correspond with changes in the abundance of the general population of starfish, a method of estimating the relative amounts of trouble with starfish over a long period has been devised. Systematic search of the reports of public commissions, newspapers and trade journals, etc., covering the last hundred years, has yielded a total of 185 items bearing on the abundance of starfish on the oyster beds at various times and in various parts of southern New England. These various

[1] According to personal communications from several sources, confirmed by Mr. R. L. Miles, of J. H. Miles and Co., Norfolk, Va. (Feb., 1945, *in litt.*): "I have been familiar with the oyster business in Maryland and Virginia for sixty years. We never heard of starfish being in Chesapeake Bay until about ten years ago when they came in large quantities in the fall of the year [1936?] . . . twenty-five or thirty miles up the Bay from the Capes was as far as they went. . . They were quite thick here for two years . . . With the exception of those two years [when slight damage to oysters occurred] they have never bothered us very much . . . For the last two years we have not been bothered at all . . . some of the crab boat captains . . . told me [that] for a few years prior to [starfish] . . . coming in Chesapeake Bay so thick, they would catch a few at [or just outside the] mouth of Cape Henry . . . but they [starfish] never came in [to the Bay proper] as far as we know until they did as stated above."

statements have been graded according to whether they seem to indicate that there were very many, many, some, few or very few starfish, and compared. It is found that, in those numerous instances where reports from all parts of southern New England during the same period are available, the relative local abundance of starfish was everywhere much the same at the given time. Therefore, the estimates have been summarized, and plotted as shown in the lower half of Figure I.

The upper half of Figure I is based on the reports of actual catches by the two oyster companies from which adequate records have been obtained. It shows a nearly perfect correspondence as regards the times of peaks and troughs with the indications obtained from the semiquantitative estimates plotted in the lower half of the figure. This correspondence appears sufficient to support the conclusion that the fluctuations in the available catch records are correlated with changes in abundance of starfish on oyster-beds over the whole of southern New England.

The next question to be considered is whether the changes in abundance of starfish upon oyster-beds might result, not from changes in abundance of the general population, but from shifts in the distribution of starfish such as might be caused, for example, by a depletion of wild food resources such as mussels or coot-clams. Enquiry into this question shows that, although the annual catches of the Narragansett Bay Oyster Company cannot be regarded as directly proportional to the magnitude of the general population of starfish, a correlation does exist. For example, analysis of the information supplied by Barnes (present volume) shows that the density of starfish population in Buzzards Bay declined much as did the catches of the Narragansett Company during the same period; and further, that this decline in Buzzards Bay can hardly have been an effect merely of the fishery for starfish. Comparison of the results of the general population survey in Long Island Sound made in 1935–6 by Galtsoff and Loosanoff (Bull. U. S. Bur. Fish. *31:* 75–132, 1939) with informal reports of later surveys by Loosanoff and other information, likewise shows that the great increase in trouble with starfish from 1941 on must have resulted from an increase in magnitude of the general population, and not merely from a change in its distribution.

It is the general practice of the oyster grower (and we are specifically informed that this practice was followed by the Narragansett Bay Oyster Company) to increase the intensity of his efforts at starfish

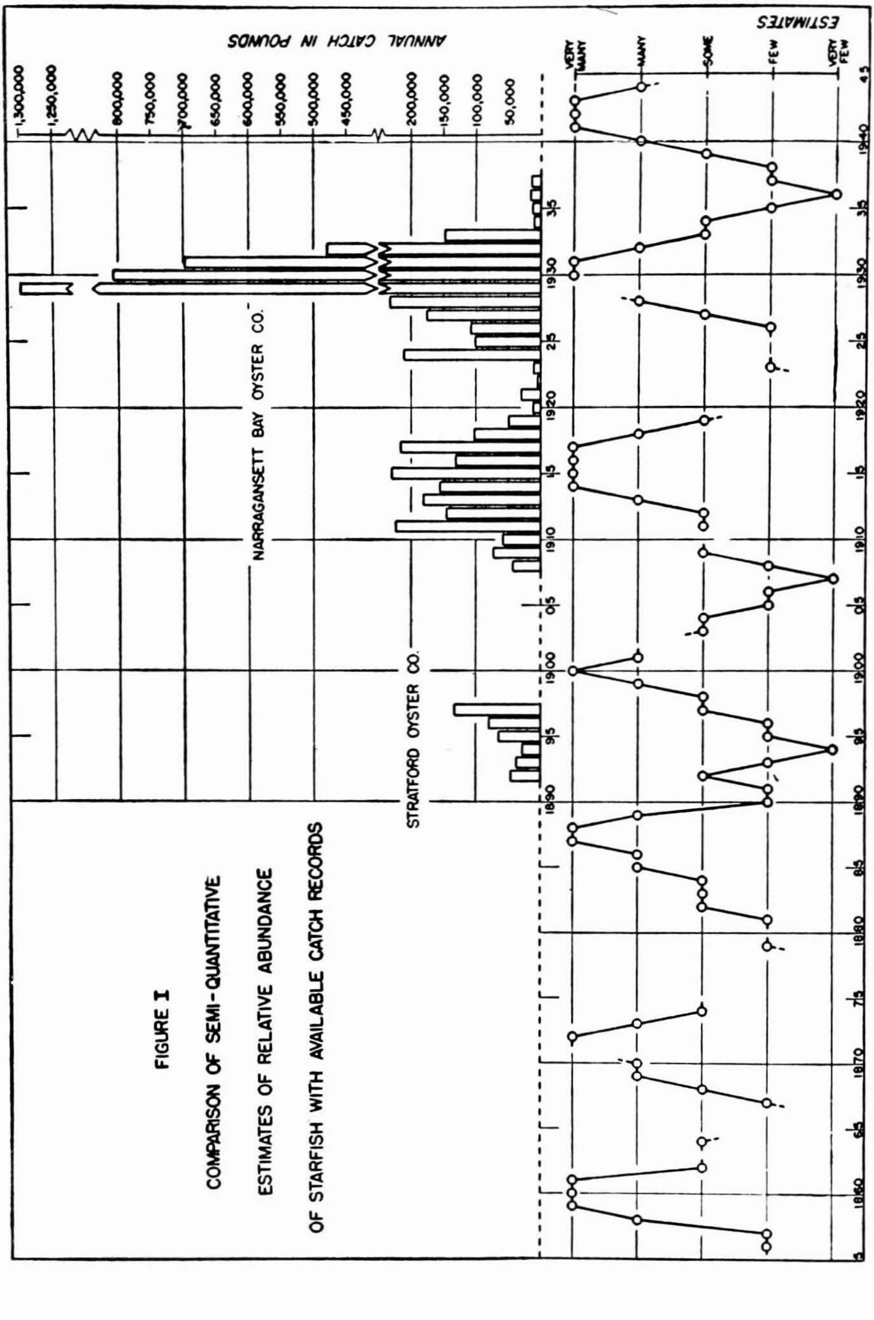

FIGURE I

COMPARISON OF SEMI-QUANTITATIVE ESTIMATES OF RELATIVE ABUNDANCE OF STARFISH WITH AVAILABLE CATCH RECORDS control with increase in the abundance of starfish. In consequence, the catches of the Narragansett Company may be assumed to have varied from year to year not only because of changes in the abundance of starfish but also because of variations in the fishing effort. Making certain reasonable assumptions as to what this change in fishing effort is likely to have been, and correcting the records by this factor, it seems probable that the catch per unit of effort in an average year of peak abundance was of an order 10 to 20 times that in an average trough year.

It will be seen from Figure I that the changes in abundance of starfish have been of a regular sort repeated at intervals of fourteen years. Cyclical changes in abundance, of the great magnitude indicated, would obviously have an enormous effect upon the costs of a fishery. The period in which a bounty of $14 per ton was sufficient to create a fishery primarily for starfish in Buzzards Bay (1932) came about three years after a peak of the cycle; and the period in which a bounty of $15 per ton was highly effective in Narragansett Bay (1941) came a year or two before the time of the next peak of the cycle. It thus seems possible that during the actual peak years themselves the costs of fishing starfish in southern New England might conceivably fall as low as those in Chesapeake Bay in 1937.

To examine this possibility, an analysis has been made of data on the population of starfish in New England in 1935–6 and in the Chesapeake in 1937–8, supplied by Galtsoff and Loosanoff (1939, *op. cit.*). The details of this analysis need not be given here; the results are summarized in Table I. When the estimated density of population per acre in New England in the trough year 1935–6 is corrected by a factor representing the difference between 1935–6 and an average peak year, we arrive at a value of about one-half ton per acre for the average peak density of population on the half-million acres within the common range of *Asterias forbesi* in southern New England. This density is about the same as that estimated for the Chesapeake in 1937–8; and although the estimates rest upon inadequate data and have been reached by way of a network of hypothesis and assumption, it is probably safe to conclude that, for perhaps two years in every fourteen, starfish could profitably be fished in New England at a price as low as $3 to $5 per ton. At other times, however, the cost of production of starfish would undoubtedly rise at least as high as $30 per ton, and the long term average would hardly be less than $15 per ton. At this average price, it would take about $64 worth of raw starfish to make one ton of starfish meal.

A processing industry existing upon other sources of raw material than starfish for eleven or twelve years out of every fourteen, but with equipment to take advantage of the great abundance of starfish available when the peak of the cycle arrives, might conceivably be profitable if the value of the finished starfish product and the costs of processing were in favorable relationship. However, the disparity between the amounts of starfish potentially available during peaks and the amounts of raw materials other than starfish potentially available year after year in the regions where starfish periodically become abundant, is very great, and in consequence, a permanent plant would have to be of highly uneconomic design in order to be able to take advantage of the starfish peaks. For example, even if the Connecticut trawl-fishery could be so organized as to deliver to a processor trash fish and filletting wastes equal in quantity to the tonnage of edible fish annually caught by it, the processing plant would receive only about 6,000 tons of fish per year, equivalent to about 1,400 tons of meal. Thus, even if a Connecticut processing plant were designed with a maximal capacity four times its normal turnover, it would be able to handle no more than 24,000 tons of starfish per year during starfish peaks, so that its *average* production of starfish meal would probably amount to considerably less than 1,000 tons per year.

The only obvious means of coping with the inequalities of the supply of starfish would therefore seem to be a mobile processing plant (comparable with the floating plant currently used in the manufacture of herring meal and oil) able to range from place to place to take advantage of seasonal and periodic gluts of other products as well as of starfish. Such an arrangement would still face the difficulty that, in the case of starfish, periodic availability not only of the processing plant but of the fishing fleet to supply it, would be required. It is unlikely that even under the most favorable circumstances a production of raw material equivalent to 1,000 tons of starfish meal per year per fishing vessel could be obtained, so that a fleet of more than five vessels equivalent to the average oyster dredger would have to be available during starfish peaks to support a processing unit of the dimensions regarded by Mr. Ryan (see under Factor 2 above) as economical. Practicable arrangements for the temporary availability of such a starfishing fleet are somewhat difficult to envisage.

It therefore appears that the factor of supply of raw material is decidedly unfavorable to the utilization of starfish as a source of animal feed, at least as far as immediately foreseeable conditions are concerned.

One remote possibility of reducing the costs of production of starfish remains to be considered. The oyster growers of Connecticut alone are conservatively estimated to spend an average of at least $100,000 per year for the control of starfish. This sum amounts to an expenditure of at least $100 per ton of starfish captured, even in years of peak abundance. Such a cost of production is very much higher than would be attainable if the aim were to catch as many starfish as possible instead of to keep the oyster-beds clear. The question may therefore be raised as to whether or not the expenditure of $100,000 per year to remove as much of the general population of starfish as possible might reduce the damage inflicted by the pest to lower proportions than does the present method of control.

It has been maintained (Galtsoff and Loosanoff, 1939, *op. cit.*) that movements of starfish from place to place on the bottom are of an extremely limited sort, and that the supposed "raids" and "invasions" of oyster beds result merely from growth *in situ* of young starfish settled upon these same beds as larvae. However, re-analysis of the distributional data offered in support of this view does not seem favorable to it. Furthermore, data obtained from reliable commercial sources affords convincing evidence that mass movements of adult starfish do occur. The evidence against mass movement yielded by Loosanoff's ingenious marking experiments in 1935–1936 may reasonably be interpreted as meaning that, during trough years or at other times when food is locally abundant, no stimulus to movement exists. If extensive movements do occur at times of abundance of starfish, it seems possible that the decimation of concentrations of starfish which lie within range of oyster bottoms might greatly reduce the rate of invasion (although use of the mop-dredge to remove starfish which had settled as larvae upon the beds themselves would still be a necessary accessory procedure).

It appears extremely unlikely that fishing operations of practicable magnitude could so reduce the level of the population of starfish during periods of abundance as to make any appreciable difference in the magnitude of the set of young starfish.[2] The same is not necessarily

[2] Without attempting a detailed criticism of current views in the present essay, it

true, however, during trough periods, when, as indicated in Table I, the total population of starfish in Long Island Sound may amount to no more than 30,000 tons. The removal of, say, 10,000 tons of starfish at such a time might conceivably so reduce the set as to interfere with the development of the cycle. Such removal might thus be profitable to the oysterman, although exceedingly costly in terms of price per ton. However, it seems equally possible (for reasons which are too complex to be appropriate for presentation here) that reduction of the spawning stock by even half or more might make little difference as regards the production of a new generation. It is also possible that the balance of life in Long Island Sound is so adjusted that serious interference with the starfish stock by human agency might, if attainable, result in the development of populations of oyster-drills, mussels, Crepidula, etc. of such proportions as to constitute a great menace to the oystermen.[3]

Even should research demonstrate that the support of a fishery intended to capture as many starfish as possible would be profitable to the oyster grower, such a fishery might not be of much assistance in permitting the processing of the catch. The interests of the processor and the oyster grower are in fact opposed; the former wants a steady supply of raw material at a low cost; whereas to the latter, in the words of Gibbs "The possibility of exterminating the starfish will be our last concern." The price which a processor would be able to offer for starfish would not be an appreciable contribution to the costs of fishing during years of scarcity; while the quantity of starfish which could be annually handled by a processor equipped with reference to the regularly available supply would be insignificant in comparison with the amount which the oyster grower would have to dispose of in peak starfish periods. In consequence, little stimulus toward organization of the fishery for delivery of starfish to the processor would exist.

may be stated that the hypothesis that larval starfish settle in the same locality where spawned does not seem to be supported by any critical evidence, and may be regarded as mere analogy from the unproven hypothesis that larval oysters in Connecticut do not move far from the spawning grounds.

[3] Some tentative calculations concerning the energy-budget of Long Island Sound (to be presented elsewhere), based upon Riley's production figures and Petersen's and Lindeman's trophic-dynamic equivalents, do indeed suggest that the starfish may serve as a sort of biological governor, in the absence of which the balance of the ecosystem might shift in unforeseen directions.

TABLE I. ESTIMATED STOCKS OF *Asterias forbesi* (OF DIAMETER MORE THAN 2 CM.) IN SOUTHERN NEW ENGLAND IN 1935–6, COMPARED WITH ESTIMATED STOCKS AT PEAKS OF ABUNDANCE IN SOUTHERN NEW ENGLAND AND IN CHESAPEAKE BAY.[1]

			Average stock in 1935–6					*Average stock during peaks of abundance*			
Region	*Area in Acres*	*No. of Samples*	*No. of Starfish Dredged*	*No. per Sq. Meter*	*Gms. per Sq. Meter*	*Tons per Acre*	*Total Stock in Tons*	*No. per Sq. Meter*[2]	*Gms. per Sq. Meter*	*Tons per Acre*	*Total Stock in Tons*
Buzzards Bay											
Total[3]	190,000	256	1,150	0.13	1.5	0.007	1,250	—	27	0.12	22,500
Bottoms < 41 feet deep[4]	100,000	188	1,121	0.22	2.5	0.011	1,100	—	45	0.20	20,000
Long Island Sound											
Total[3]	1,099,000	323	5,037	0.44	5.6	0.024	27,000	—	100	0.44	486,000
Bottoms < 40 feet deep	333,000	153	4,388	1.07	13.7	0.060	20,000	—	247	1.08	360,000
Connecticut, total populated area	191,000	88	780	0.32	4.1	0.018	3,500	—	74	0.32	63,000
Milford (Bottoms < 40 feet deep)	13,000	260	4,818	0.68	8.7	0.039	500	—	157	0.70	9,000
Chesapeake											
Total populated area	279,000	24	771[5]	—	—	—	—	2.64	120	0.53	148,000

[1] Sampling surveys made by Galtsoff and Loosanoff (Bull. U. S. Bur. Fish. *31:* 75–132, 1939). Narragansett Bay omitted for lack of evaluable data. Constants employed in present calculations are as follows: Acreage per sampling-haul, .0405. Difference between number of starfish taken by sampling-dredge and number present on the area sampled, six times. Average weight of starfish: Buzzards Bay, .025 lb.; Long Island Sound, .028 lb.; Chesapeake, .10 lb. Difference in weight of starfish per unit area in 1935–6 and in average peak periods of cycle of abundance in southern New England, 18 times.

[2] Average number of starfish per square meter during peaks of abundance in New England not estimated, since average size during troughs may be less than that during peaks. The maximal weight indicated, 247 g. per average m² of bottoms at a depth of less than 40 feet in Long Island Sound, would be equivalent to a number per m² of about five large (diameter, 12–15 cm.) starfish.

[3] Total stocks estimated by adding probable percentage of population in deep water to estimated shallow water stock, rather than directly from total acreage multiplied by mean weight per acre of all samples, because of asymmetrical distribution of sampling-hauls.

[4] Several alternative values are available for number of hauls and total catch in shallow water, the records of the sampling survey being ambiguous.

[5] Although the number of starfish actually captured was 771, several of the sampling hauls were not of standard type, and the estimates of the stock are therefore based on a corrected total catch of 1,717 starfish.

Conclusions

Regular large-scale utilization of starfish as protein feed or fertilizer seems to be entirely impracticable under present conditions. However, it is conceivable that future developments of an unpredictable nature, dependent upon researches not yet completed or even begun, might cause this sometimes abundant pest to become a potentially valuable resource. Information included in the present publication may be expected to be contributory to any such development.