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Title

Fluctuations in Abundance of the Giant Scallop *Placopecten magellanicus* (Gmelin), in the Digby area of the Bay of Fundy

Author

Lloyd M. Dickie

A thesis submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
in the
University of Toronto

April 1953

ERRATA

Page	Paragraph	Line	
3	3	10	Read "geographic and ecological" not "geographic"
16	2	6	Insert "the length of" before "fishing season"
21	1	6	Read "hour of fishing" not "unit of effort"
28	2	8	Add "or vice versa" after "landings"
41	1	9	Read "to the average number present during" not "to the number present at the beginning of"
46	2	2	Read "fraction of the stock taken" not "catch"
65	1	19	Insert "necessarily" before "indicate"
102	2	7	Insert "scarcity of" before "food"
102	2	9	Read "Food supply," not "Food,"
104	Fig. 17, legend	3	Read "--April 1940" not "--1939"
104	"	4	Insert "November" before "1940"
104	1	5	Read "April 1940" not "1939"
116	2	13	Read "except 1931, for which no data are available" in brackets

" not

Appendix VII, page 1 -
Heading for next to last column under Method 1 should read:

no
pages

$$k = \left(\hat{f} - \frac{k''a''}{e}\right)\left(\frac{1}{1 + \frac{k'a'}{ke}}\right)$$

not

$$k = \left(kr - \frac{k''a''}{e}\right)\left(\frac{1}{1 + \frac{k''a''}{ke}}\right)$$

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I INTRODUCTION

Fluctuations in the abundance of animals have for some years been recognized as common and important phenomena. Kemp (1938) showed that fluctuations in abundance are an important feature of life in the sea. It was his belief that, although fluctuations in abundance of [redacted] animals may not be greater, they are of more general occurrence in the sea than on land. Dymond (1947) in a review of much of the information that has appeared since Kemp's statement, with particular reference to mammal and bird populations in North America, pointed out that the accumulating evidence suggests fluctuations in abundance to be the rule in animal populations generally, rather than the exception.

The present contribution is concerned with fluctuations in a population of the giant scallop, *Placopecten magellanicus* (Gmelin), in the Bay of Fundy. It maintains that great changes in the landings by the fishery of this area reflect fluctuations in the abundance of the stocks which are controlled by the effects of water temperature and circulation. Specifically, it shows that high water temperatures at the time scallops spawn lead to rapid development and short pelagic life of the vulnerable larvae, and are indicative of conditions of water circulation which retain the larvae on the parent beds. The resulting successful sets lead to strong year-classes and high catches when the scallops grow large enough to be taken by the fishery. Low temperatures prolong the length of the pelagic larval life and are indicative of conditions of water circulation which increase the chances for the larvae to be swept away from the beds. Poor sets result, leading to weak year-classes and low catches when they grew large enough to be fished.

II THE GIANT SCALLOP OF THE BAY OF FUNDY

A SYNONYMY

The scallop of the Bay of Fundy is know commonly as the giant or deep sea scallop, to distinguish it from the Bay scallop (Pecten irradians) of commercial importance along some parts of the New England coast. The giant scallop has been known by at least three scientific names in the literature. Gould (1870), Ganong (1885), and Drew (1906) called it Pecten tenuicostatus, Mighels and Adams (Boston Jour. Nat. Hist. 4: p. 41, 1842). Stafford (1909) and Proctor (1933) use the name Pecten magellanicus, Gmelin (Syst. Nat. p. 3317, 1788). Johnson (1934) and several other recent authors have used Pecten grandis, Solander.

The fixing of priority among these names is complicated (letter from W. J. Clench, Harvard Museum of Comparative Zoology, on file at the Atlantic Biological Station, St. Andrews, N.B.). Solander first used the specific name "grandis" in the auction sale catalogue of the Portland Museum of Natural History, 1786, copies of which were deposited at the British Museum of Natural History. Arguments for adoption of this catalogue for fixing priority were advanced by Iredale (1916), but recent opinion does not regard the list as a valid publication of the name, and Gmelin's claim is recognized by taxonomists in the Harvard Museum of Comparative Zoology.

Verrill (1897) established the subgenus Placopecten, which is recognized by later workers. Conforming to this usage, it seems best to refer to the scallop as Pecten (Placopecten) magellanicus (Gmelin).

B GEOGRAPHIC RANGE

Placopecten magellanicus is restricted to the Northwest Atlantic coast of North America from Newfoundland to Cape Hatteras, where it is found in depths of from about 10 to 100 fathoms. Concentrations of the animals are fished commercially in Newfoundland, the Northumberland Strait, at various points along the south coast of Nova Scotia, in the Bay of Fundy, on Georges Bank, and in bays along the American coast from Maine to Cape Cod. The depths at which these concentrations are found vary from 10 to 15 fathoms in northern regions to 30 to 50 fathoms in southern regions. South of Cape Cod they are found only at great depths. This geographic distribution identifies the scallop as primarily a cold water species.

C LIFE HISTORY

Some knowledge of the life history of P. magellanicus is necessary for an understanding of fluctuations of the population of the Bay of Fundy. It has been studied in some detail by Drew (1906) and Stafford (1909), and more recently by Borden (1928), Stevenson (1934, 1935, 1936) and Welsh (1950). The life history appears to be much the same as for other pelecypod molluscs, although certain features are not known except by indirect observation and comparison with other, closely related, species.

Scallops live on the bottom. When young they are often attached to rocks and other objects by byssus threads, but can detach themselves and when older are mostly free living. They retain powers of swimming throughout life. Maturation of the gonads occurs at about four or five years of age (Stevenson, 1935). The eggs and sperms are shed into the water during late summer or autumn, and fertilization takes place there. Development goes through quite typical free-swimming trochophore and veliger stages (Drew and Stafford) which tend to stay close to bottom (Drew and Stevenson). These stages appear to last at least one or two weeks (Drew and Stevenson), depending upon water temperatures. When the prodissoconch shell is from 0.5 to 1.0 mm. in diameter, the veliger settles to the bottom and attaches itself to sand particles, bryozoan growth and occasionally shells (Drew 1906 and collections by Baird - see sect. VI). In the Bay of Fundy growth is quite rapid at first but slow in later life and varies somewhat from place to place and time to time. Maximum size is 10 to 11 inches shell diameter, and maximum age about 20 years, although few old shells exceed eight inches, and most "old" scallops do not appear to be older than 12 to 15 years of age.

B DISTRIBUTION OF SCALLOPS IN THE BAY OF FUNDY

Scallops are found in several parts of the Bay of

Fig. 1 Digby Area of the Bay of Fundy showing the principal scallop beds. Shading represents censused areas. Solid outlines represent areas surveyed but not regularly censused. Dashed outlines mark supposed limits of main scallop concentrations.

Fundy. The most important beds exist in the south-western Bay from Yarmouth to Digby, N. S. with the greatest concentrations in the Digby area. Others are found near Grand Manan, N. B. Both these areas have been intensively fished for a number of years. A smaller bed is known to exist in the south-western part of Minas Basin but has never been considered worthy of commercial exploitation. Another small bed is also said to have once existed at the head of the Bay proper, near Cape Spencer and Ile Haute, but was not found during a survey of the Bay in 1934 (Stevenson 1935). No beds are found along the north shore, except those already mentioned for the Grand Manan area.

B. ARRANGEMENT OF THE DIGBY SCALLOP BEDS

The concentrations of scallops in the Digby area are the largest known in eastern Canadian waters. Major concentrations occur in several parallel rows, stretching along the coast in the neighbourhood of Digby Gut (see fig. 1). The beds now fished are found within an area stretching from 15 miles west to five or six miles east of the Gut, and within about 12 miles of the shore line. Some scallops occur outside this area, but are not attractive to fishermen, partly because they appear to be scattered and partly because it is expensive, time-consuming, and dangerous to fish far from the only safe harbour - Digby - during the winter fishing season.

Fig. 1 shows that within the fished area the beds are arranged in four more or less distinct rows, parallel to the coast. These beds are classified by the fishermen as "inshore" and "offshore" beds. The inshore group includes several distinct beds arranged in the east in a single row 3½ to 4 miles from the shore, and in the west split into two rows, 2½ to 3 and 3½ to 4 miles from shore. The separate beds represent areas where there are concentrations of scallops on bottom which is sufficiently smooth for successful dragging. A few scallops are found between these areas but they are scarce and occur on rough bottom where dragging is difficult. A second row of beds six to seven miles from shore, and known as the Snow Ground or 40-Minute Ground, is sometimes classed as an inshore bed. This area was of commercial importance during the early period of the fishery but except for its western extremity is not often fished today. This smaller western extremity supports a valuable concentration of scallops and in consequence the younger fishermen reserve the name 40-Minute Ground for it alone. Older men distinguish it as the 40-Minute Ground "Below the Head" (i.e. west of Gulliver's Head).

The offshore beds are arranged in two long, wide rows 8 to 9 and 11 to 12 miles offshore. The bottom there is smooth and it is possible to fish scallops in most places along these beds. However, at the present time offshore fishing is concentrated on that part of the offshore beds nearest Digby Gut.

Table I. Catch Statistics and Fleet Size of the Digby Scallop Fishery.

1	2	3	4	5	6	7	8
Year	Total Landings Oct.-Apr., Inc.	Fleet Size Estimated from:				Fleet Size (Best Estimate)	Av. Seasonal Catch per Boat.
		Fisheries Statistics	Additional* Statistics	Customs Clearance	Actual Count		
1920 - 21	34,600	-					
1921 - 22	[illegible],400	-					
1922 - 23	79,100	(22)				22	3,600
1923 - 24	57,900	48				48	1,200
1924 - 25	69,200	48				48	1,400
1925 - 26	131,500	48				48	2,700
1926 - 27	329,600	90				90	3,700
1927 - 28	535,800	78				78	6,900
1928 - 29	249,400	45				45	5,500
1929 - 30	199,100	35				35	5,700
1930 - 31	225,400	43				43	5,200
1931 - 32	122,700	23				23	5,300
1932 - 33	411,600	-	23			23	17,900
1933 - 34	511,000	-	46			46	11,100
1934 - 35	766,000	-	52			52	14,700
1935 - 36	1,066,500	-	63			63	16,900
1936 - 37	1,834,300	69	78			78	23,800
1937 - 38	1,276,700	70	82			82	15,600
1938 - 39	506,700	66				66	7,700
1939 - 40	308,800	34				34	9,100
1940 - 41	447,100	50				50	9,000
1941 - 42	682,100	47				47	14,500
1942 - 43	552,200	39				39	14,200
1943 - 44	493,500	38				38	13,000
1944 - 45	694,300	39				39	17,800
1945 - 46	842,300	46				46	18,300
1946 - 47	535,100	46	48	49		49	10,900
1947 - 48	449,200	40		47		47	9,600
1948 - 49	275,800	35	33	26		26	10,600
1949 - 50	179,400	25	27	17		17	10,600
1950 - 51	333,200		33	27		27	12,300
1951 - 52	169,400		31	16	18	18	9,400
1952 - 53					18	18	

* Supplied by Mr. E. D. Fraser, Chief Supervisor of Fisheries, Eastern Division

III THE HISTORY OF THE DIGBY SCALLOP FISHERY

A review of the history of the Digby scallop fishery shows that after its small beginning in 1920, methods of fishing were developed and new beds discovered which led to the establishment of a valuable industry. However, after a period of development and initial prosperity, there was a sharp drop in landings which have since fluctuated about a lower level. In this section it will be shown that these changes in landings have resulted only in part from changes in total fleet size, efficiency of fishing gear, fishing practice or economic conditions. It is concluded that major changes in the abundance of the stocks must also be involved.

A. FLUCTUATIONS IN TOTAL LANDINGS

Fig. 2A and Table 1 show the landings of scallops from the Digby area during each Oct. 1 to April 30 period since fishing began in 1920. These data are taken from the monthly reports of fisheries officers (F.S. - 1's) for the districts of Digby Neck, Digby and Annapolis, N.S., the only districts where Digby scallops are landed (Appendix I). The data do not show total landings for each fishing season. Up to 1936 fishing was allowed from October 16 to May 31 and in April 1936 this season was extended to cover the period October 1 to May 31. Not until April 1938 was fishing restricted to the period October 1 to April 30. The data considered here are limited to the latter period to show the great changes in landings which have taken place despite changes in the length of fishing season.

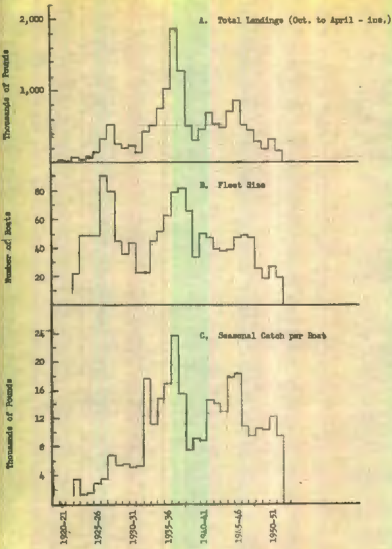


Fig. 2. Statistics of the Digby Scallop Fishery.

Fig. 2A shows that there have been remarkable fluctuations in Digby scallop landings. At least three distinct periods of high catches are evident and are centered about the 1927-28, 1936-37 and 1946-47 fishing seasons, with an additional small peak in 1941-42. Alternating with the peak years were periods of low catch. These occurred in 1931-32, 1939-40 and 1949-50.

It is to be expected that some variation in total catch will result from changes in the amount of fishing done, particularly changes in the size of the scallop fleet, therefore changes in total landings may be compared with changes in total fleet size.

B. FLEET SIZE

Fig. 2B shows the best estimates of fleet size that can be made from the available data. In preparing these estimates, several different sources were consulted and the data from each are given in Table 1, columns 3 to 6. There is uniformity in the general trend expressed by each of these sources, but there are differences in the actual numerical estimates. For this reason a consideration of possible errors in each, and selection of most reliable data was necessary.

The longest series of estimates, in column 3, Table I, is derived from Fisheries Statistics of Canada (Appendix II). Fishing gear is reported in the statistics in two ways: (1) scallop drags in use and (2) fishing craft. "Scallop drags in use" is a confusing category as scallop boats at Digby tow a gang of six or seven scallop drags suspended from a drag-bar. Some officers consider each drag as a unit of gear while others report each gang as a unit. Fortunately, the total value of the gear is also reported and from it, value per unit of gear was calculated. Since in recent years a gang of drags has cost between $100 and $200, those reports which value drags at about $100 refer to gangs of drags, while valuations of $10 to $20 per drag refer to the individual drags of a gang. Using this price information, all reports of gear could be converted to "gangs of drags".

Each scallop fishing boat at Digby N.S. uses a single gang of drags so that the relationship between gangs of drags and fleet size reported in Fisheries Statistics provides a useful check of the reliability of the Statistics. From this ratio it was concluded that the reports from 1923 to about 1931 are likely to be accurate and complete. However, the Digby Co. reports are confusing from about 1932 to 1940 or 1941. For example in 1937, 145 drags, 14 vessels, and 24 boats were reported, but in 1936, 146 drags and only 14 vessels, while in 1935, 143 drags and 24 boats are reported. It appears likely that at least 25 boats were omitted from the 1936 report and 14 vessels from the 1938 report. But since Digby Co. reports of the ratio between gear and fleet size show no consistent relationship, fleet size estimates based on them must be used with caution.

Fortunately, in addition to the published data estimates of fleet size for 1922-23 are given by Stevenson (op. cit.), and data for 1932-33 to 1937-38 and 1947-48 to 1949-50 have been supplied by Mr. E. D. Fraser, Chief Supervisor of Fisheries, Eastern Division who obtained them from personal records kept by one of his officers. Where data other than Fisheries Statistics are available it has seemed advisable to disregard the latter in making up the fleet size estimates given in column 7, Table I.

The figures appearing in column 3 and 4, Table I are based on the number of scallop licenses issued. These licenses are issued for the government fiscal year April 1 to March 31, but the scallop season extends from October 1 to April 30, so that licenses are required to be renewed one month before the close of the season. If the fishermen do this, but do not fish during the following season, fleet size, based on license issues for the most nearly corresponding fiscal year, will be over-estimated. Such over-estimates will always result when fleet size is decreasing. Part of the difficulty may be overcome by judging fleet size from licenses for the following fiscal year, but in this case over-estimates will result when fleet size is increasing. Therefore, estimates given in column 3 and 4 tend to be too large, especially during periods when fleet size is decreasing from year to year.

The figures appearing in column 5 of Table I represent the number of scallop boats clearing customs at Digby and Annapolis from 1946-47 to 1951-52. They are more likely to be reliable estimates of fleet size than are Fisheries Statistics because fishing boats are required to "clear" once each season if the crew is to be eligible for "sick-mariner's" and other benefits. Almost all boats regularly do this and customs records are a nearly complete set of records compiled for the fishing season rather than the overlapping fiscal year. These records do, however, tend to be underestimates of fleet size because some of the fishing boats, regularly based at ports outside Digby and Annapolis, may only clear with their home port. This happened in 1951-52 when an actual count of the fleet, supplied by Mr. J. S. MacPhail of the Atlantic Biological Station, shows that 18 boats were fishing although only 16 are reported by the customs records.

Final estimates of fleet size are shown in column 7 of Table I. From 1920 to 1932 and 1938 to 1946 only Fisheries Statistics are available. From 1932 to 1938 special statistics, and after 1945 customs clearance records are used, except in 1951-52 when an actual count was made. Where information on total scallop fleet size is required, these estimates must be used as the best available, despite their acknowledged weaknesses.

C. CHANGES IN LANDINGS RELATED TO CHANGES IN FLEET SIZE

Comparison of changes in the size of the scallop fleet with changes in landings indicates that changes in the total amount of fishing are partially responsible for changes in total landings at Digby. However, it also shows that changes in fleet size have not been of major importance in causing fluctuations in Digby scallop landings. This is indicated most clearly by a comparison of fig. 2C, showing annual catch per boat, with records of total landings (fig. 2A) and fleet size (fig. 2B).

Catch per boat was high in 1936-37, 1941-42, and 1945-46, and was low in the intervening years. These changes in catch per boat parallel changes in total landings very closely (correlation of 0.815 over a period of 30 years). This surprising result shows that changes in total scallop landings have not resulted simply from changes in the amount of fishing done, but primarily from changes in the amount of scallops caught by each boat. An examination of the history of changes in gear efficiency and fishing practice show that such factors do influence a boat's seasonal catch, but that some other factors, such as abundance changes, are of far greater importance.

D. CHANGES IN TOTAL LANDINGS AND CATCH PER BOAT RELATED TO FISHING PRACTICES

According to Stevenson (1936), when scallop fishing began at Digby in 1920, only a small concentration of the animals was known in the sheltered waters of Annapolis Basin. This bed was fished by a large number of small row boats and open lobster boats using light dredges which were hauled by hand. Very soon, however, scallop beds were discovered in the Bay of Fundy and by 1925-26 these were fished by the larger boats which could handle heavy gear and fish in the deep water of the Bay.

During the early stages of the fishery certain regulations were established. Fishing was allowed only from Oct. 16 to May 30 and a minimum size limit of 4 inches shell diameter was set. Since scallops are shucked before the boats land, making enforcement of the size limit difficult, a minimum diameter of four inches for the metal rings used in making up scallop drags was also enforced. At this time, the boats were mostly small and converted from the types used in lobster fishing and line-trawling. Some of them were equipped with power haulers and were able to use two or three drags simultaneously. Under these regulations, and with this type of gear, the fishing fleet increased rapidly to about 90 boats and catches rose to a peak of over 500,000 pounds in 1927-28. But the average efficiency of the boats fishing in these years was low. This is indicated by the low catch per boat in the period 1920 to 1931, relative to later years.

Subsequent to 1927-28, total scallop landings dropped as did fleet size, however, catch per boat remained relatively stable, indicating no important change in the number of scallops available. According to Stevenson, the fishermen ascribed this drop in total catch to a glut on their principal market at Boston by increased landings of American trawlers from beds newly discovered on George's Bank in 1928. According to statistics of the American fishery, kindly supplied by Mr. J. A. Posgay of the U.S. Fish and Wildlife Service at Woods Hole, American landings jumped from 119,000 pounds in 1928 to 466,000 pounds in 1929. This increase of about 350,000 pounds is small compared with landings of later years but it represents the difference between the two highest American catches up to that time, and corresponds to a decrease in Canadian landings of about 300,000 pounds. It may be concluded that American landings supplied the limited demand formerly satisfied by Canadians, and that this first depression in the Digby scallop industry was caused by economic conditions.

Despite this initial setback, the fishery continued and improvements in gear were made. During the early 1930's a special type of decked-in boat of approximately 45 ft. in length, registered at 10 to 15 tons and equipped with powerful engines and hoisting gear was built exclusively for scallop fishing. It could handle heavy gear, and towed a gang of seven or eight drags suspended from a long drag-bar, but was so powerful and made such heavy catches that it quickly stretched the large four-inch rings out of shape. For this reason fishermen adopted a smaller ring with an inside diameter of 2 5/8 inches. This ring was in general use by 1934. In addition to these improvements, the new boats were safer for venturing into the Bay of Fundy - notorious for rough water and sudden storms - so that with this development, new beds were discovered and fished.

The rise in landings beginning about 1932-33 marks the beginning of this improvement in fishing practice. Fleet size also increased rapidly and landings rose steadily for four years as boats became bigger, gear more efficient, and new beds were discovered. By 1936 some of the largest boats were towing gangs of drags spanning over 20 feet. All were making large catches. In addition, in April 1936 the fishing season was lengthened 15 days to October 1 to May 30. Fig. 2A, which shows the landings for October 1 to April 30 only, indicates a rapid rise in catch and fig. 2C a rise in catch per boat to the banner year of the fishery in 1936-37.

In 1937 fishermen became apprehensive about the effects of this large effort on the stocks, and agitated for stricter controls. As a result, in April 1938 the season was shortened by a month to the period October 1 to April 30. Fig. 2A, which reports only landings for these months, shows that landings were lower than the previous year, and fig. 2C that catch per boat also dropped sharply.

In addition to the shortening of the fishing season, another regulation, enforced from the beginning of the 1938-39 season, made it illegal for any boat to use a gang of drags which spanned over 18 ft. As a result, a number of the largest fishing vessels no longer considered scallop fishing worthwhile and fig. 2A shows a sharp drop in total landings. According to fig. 2B there was only a slight drop in fleet size, however, it has already been pointed out that during periods of decreasing fleet size, the number of boats actually fishing is overestimated. From this, and from stories told the writer by the fishermen, it appears that fleet size dropped more than is indicated by fig. 2B, and although catch per boat also dropped, it is doubtful that the decrease was as great as is indicated in fig. 2C.

This record of the early history of the fishery, shows that the great increase in total landings and in catch per boat up to 1936-37 and the drop in 1938 and 1939 was accompanied by changes in fleet size, gear efficiency, and fishing season, and may have been partly produced by them. Since 1938, however, no changes have been made in either efficiency of gear or fishing season, yet fluctuations in both total landings and in catch per boat have persisted. Furthermore, October 1 to April 30 landings within the period 1936-37 to 1937-38 decreased sharply despite an almost constant fleet size and no change in fishing practice. This indicates that great changes in catch occur which are independent of changes in fleet size and fishing practice. It must be supposed that such changes in total catch and catch per boat have resulted from fluctuations in the actual numbers of scallops available to the boats. An analysis of the factors which affect the catch, supports this supposition and indicates that fluctuations in abundance are of primary importance in producing these changes in catch.

IV CAUSES OF FLUCTUATIONS IN CATCH

Average catch per boat may be used as an index of relative abundance because *ceteris paribus*, the average catch made by a boat will go up or down depending on whether the population being fished is large or small. Using average catch per boat per season in this sense, fig. 2C, indicates that there have been major changes in the abundance of scallops during the course of the fishery. The correspondence between catch per boat and total landings would indicate further that these changes in abundance have been of major importance in producing changes in total landings since the time the industry reached its full development in the mid 1930s. However, seasonal catch per boat may not be a precise measure of relative abundance because it can be influenced by other factors, including changes in efficiency of fishing gear, in beds fished, movements of the stocks, changes in weather, and in prices paid for scallops. In this section the effects of such factors on catch are assessed and estimates of catch obtained which are better reflections of abundance changes. The results show that fluctuations in abundance are of primary importance in producing changes in catch from year to year.

A. CHANGES IN EFFICIENCY OF THE FISHING FLEET

It was shown in the last section that fluctuations in catch are not primarily produced by gear changes. However this does not exclude the possibility that catch per boat is dependent on changes in efficiency. For example, during the history of the fishery there have been great changes in total fleet size. Since there are also differences in efficiency among fishing boats, depending on the abilities of the skippers and peculiarities of the boats, it may be expected that with changes in fleet size the ratio of good to poor boats in a fishing fleet will also change. In years of high catch and a large fleet, almost all boats will be able to make fishing pay, but in poorer years some of the poorer boats may be forced to stop fishing, leaving a greater proportion of efficient fishermen in a small fleet. As a result, average catch per boat will be higher relative to the stocks available when catches are low than when catches are high. This will tend to obscure the effects of changes in abundance of the stocks and make catch a less reliable index of abundance than if fleet size is constant. Such effects of changes in the character of the fleet on the catch per boat may be largely eliminated by considering the catches of a sample fleet of known boats. Detailed data for a sample fleet of this kind are available, and are analysed in subsection D.

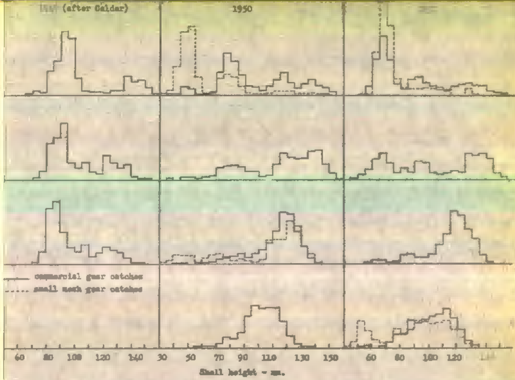
B. CHANGES IN BEDS FISHED

Catch may also be influenced by differences in the intensity of fishing of different parts of a population, which in the scallop fishery means changes in the beds fished. That is, changes in catch may reflect local differences in character or abundance of different parts of the population, if these exist. All scallop beds known and fished today at Digby were discovered during the expansion of the industry in the early 1930s, so that all changes in catch since then have involved the same beds. However, there are differences among the beds which raise a possible objection to the use of catch per boat as an index of relative abundance.

Fishermen make a broad distinction between inshore and offshore beds (see section II G). This distinction is made partly on practical grounds. The Bay of Fundy is notorious for its rough waters and strong tides and in winter the southern part is particularly dangerous as a fishing area because the only sheltered harbour - Digby - is reached through a narrow gap in a straight rocky coast line. Through this gap run tidal currents of over five knots, accompanied by whirlpools and tide rips. The difficulty of reaching and entering this gap with an adverse tide and in snow storms is hard to imagine. Fishermen have had too much experience with such conditions to make them go far offshore during winter.

With judicious planning, however, the tides may be used to aid the boats in reaching the inshore fishing grounds quickly and in ensuring rapid and safe returns if storms threaten. For example, the ebb tide flows out of Annapolis Basin, through Digby Gut, and westward along the shore. If the boats leave port with the ebb tide, they can reach beds far to the westward of the Gut in about 1½ to 2 hours. After a few hours fishing, they have a flood tide which expedites the return trip. Scallop skippers regularly take advantage of the tides and beds up to 15 miles west of the Gut and close to shore are easily reached and extensively fished while beds only 8 or 10 miles offshore are considered more dangerous and fished much less often.

There are also biological differences between inshore and offshore scallops. These differences will be described more



3. The percentage size distribution of scallop samples taken from different beds in the Digby area in 1940, 1950 and 1952.

fully in the next section, but in general, scallops on the inshore beds grow to larger sizes than do those offshore and have larger "meats" (adductor muscles) relative to shell size than do offshore scallops (see fig. 15 and 16). This means greater weight of catch per scallop caught inshore but this advantage is partly offset by the fact that on the offshore areas dragging is easier, the gear more efficient (see section V C, 2b - pp. 74), and greater numbers of scallops are usually taken per tow. However, it is generally agreed by fishermen that, except when inshore catches are very low, it does not pay to fish offshore, and few do.

Log-book records do not extend over a sufficiently long period to show how much fishing is actually done on different beds but various fishermen estimate that from 70 to 90% of the total season's landings "normally" come from the inshore beds alone. Exceptions to this occurred in 1935 to 1937 when some large vessels are said to have fished exclusively offshore, and in recent years, particularly 1950-51, when inshore catches were very small, most of the winter landings came from the offshore areas.

Within the inshore area, which yields the bulk of the catch, the characteristics of the stocks are similar. This is illustrated by the coincidence in position of the size modes in the size composition of stocks on the most important beds (fig. 5). It is, however, almost axiomatic in any fishery that if a given number of beds are open to exploitation by a fleet of boats, the fleet will search out and exploit those beds which give the highest "economic" yield. That is, fishing during any season will be carried out in a more or less systematic fashion with the beds nearest port being fished most intensively and at relatively low levels of catch while those farther away will be fished less intensively and at only higher levels of catch. If catch per unit of effort is measured on several beds, it will tend to be higher, the greater the distance from port, provided that fishing conditions are similar on each bed and the fishing fleet is relatively homogeneous. That this is true for the Digby scallop fishery is shown by the relatively stronger large size-classes on Shelburne Cove and offshore (fig. 3). That is, average catch per unit of effort does not represent a uniform abundance on all beds, but it almost always represents a uniform ratio of abundance among beds. Seasonal catch per unit of effort in the Digby fishing area may then be said to represent the average abundance of scallops on the beds fished.

It may be concluded, that since, with certain known exceptions, the bulk of Digby scallop landings comes from the inshore fishing areas, changes in total catch and catch per boat are a reflection of changes in average fishing conditions on the inshore scallop beds, rather than shifts in fishing from one bed to another.

C. MIGRATIONS OF SCALLOPS

The possibility that some changes in catch may be the result of migration cannot be ignored. Verrill (1897) and Drew (1906) remark upon the swimming ability of the scallop and express the belief that migrations may occur. Some fishermen at Digby believe that whole stocks of scallops move and explain some seasonal and year to year changes in the catch from a given area in this way. Similar reports of migrations have reached the writer from areas along the Maine coast and in Passamaquoddy Bay. A further supposed case of a spawning migration off Boughton Island in Northumberland Strait was reported to, and examined by the writer in 1946. In this case it was concluded that no migration had occurred but that the change in catch, which formed the evidence for the migration hypothesis, was the result of a peculiar mass mortality of scallops (Dickie, 1951). It appears that many other supposed cases of migration may be equally satisfactorily explained by alternative hypotheses.

Few experiments have ever been designed solely to test the validity of the migration hypothesis in the Digby area, but some results of an extensive tagging experiment, carried out during 1947 and 1948 in the Bay of Fundy by Dr. J. C. Medcof and Mr. J. S. MacPhail of the Atlantic Biological Station, cast doubt on it. In September 1947, 1,150 marked scallops and in September 1948, 2,518 tagged scallops were released on several different beds. Up to December 1950 about 15% of the 1947 and about 6% of the 1948 releases had been returned. Although about half of the 1947 returns were not made until April 1948, and two of them were not made until 1950, in no case was a tagged or marked scallop recovered from a bed other than that on which it was released. Similarly, the writer carried out intensive marking programmes on small areas during the summers of 1949 and 1950 (see section V G 2). In each case about 10,000 scallops were marked and distributed over a 12-acre area. Tows were then made on and around the areas, but although considerable numbers of recaptures were made, no marked scallops were found outside the small areas where they were deposited. In the summer of 1951 a few tows were made on and near the area so tagged in 1950. Several marked, living scallops were recovered from the release area. These data fail to show any movements of scallops from even restricted heavily fished areas over a considerable period of time.

Further doubt is cast on the migration hypothesis by the characteristics of scallop beds. Scallop beds have not shifted in position since they were first discovered. Furthermore scallop shells from neighbouring beds have distinctive appearances. Sub-areas within Buoy Ground yield scallops covered with a characteristic brown encrusting sponge, while on others the scallops are so uniformly covered with barnacles that the beds are known as barnacle beds. These special features of scallops from certain areas have long been recognized by the fishermen and seem to preclude any but a very limited exchange of animals between areas.

It may be concluded that if long range movements of scallops do take place at Digby at all, they are not common occurrences, and that during the period under consideration it is extremely unlikely that concerted stock movements which would affect the catch have [redacted] occurred. Changes in catch per boat are, therefore, a reflection of changes in abundance rather than changes in availability resulting from scallop migrations.

D. CHANGES IN FISHING EFFORT

The foregoing paragraphs of this section show that since the late 1930s, seasonal catch per boat has not been influenced by changes in the efficiency of the types of boats or gear used, major changes in beds fished (except 1950-51), or by migrations of the stocks. Change in average catch per boat is therefore a measure of change in the average abundance of the fishable stocks, unless catch is also influenced by changes in the amount of fishing the boats do, or in the average efficiency of the fleet. Among the most important factors which influence the amount of fishing (i.e. fishing effort) are weather, which may limit the total number, or the lengths of fishing days, and price, which may influence the length of fishing days, the size of scallops taken, or the total fleet size. Changes in average efficiency of the fleet may be caused by changing fleet size, as explained in sub-section A above.

The effects of weather and price on catch may be assessed and accounted for by an analysis of detailed special statistics of a sample fleet of boats. The use of statistics of a known sample fleet also eliminates the possible influence of average efficiency changes resulting from differences in fleet size.

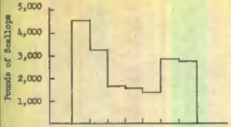
1. Source of the Special Catch Records

The detailed statistics, on which the following analysis of factors influencing catch is based, were made available to the writer through the Fisheries Research Board of Canada by Mr. E. B. Richardson, manager of Maritime National Fish Division of National Sea Products, at Digby, N. S. He has kept a careful account of the individual landings made by each boat that sold to him since 1941-42, as well as the wharf price paid for scallops. From this unique set of records it has been possible to select a sample fleet which sold exclusively to Mr. Richardson from 1941-42 to 1950-51, inclusive. The landings of this sample fleet are given in Appendix III A, and summarised in Appendix III B.

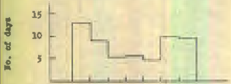
The sample fleet is composed of five boats, all of which are among the best or "high-line" boats of the fleet, but the sample selected is not composed of the same five boats throughout the whole ten year period. Occasional substitutions have been necessary when one of the boats initially used stopped fishing, for a short time, or permanently. In such cases, another boat of similar performance was used as part of the sample and the substitution has been noted in the Appendix.

2. Analysis of the Special Catch Records

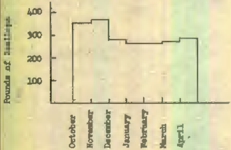
The special catch records may be arranged to show the average monthly catch per boat, the average number of trips per boat per month, and the average catch per boat per trip in each month of



A. Average monthly catch per boat.



B. Average number fishing days per boat per month.



C. Average monthly catch per boat per day.

Fig. 4. Month to month variations in the Digby scallop fishery.

the 10 seasons. Digby fishermen usually land their catch at the end of each fishing day so that catch per trip is almost the same as catch per day. This arrangement of the information permits an analysis of the principal factors which influence catch from month to month during an average season, and from year to year.

a. Month to Month Variations

Fig. 4 A combines the ten seasons' records of landings by the sample fleet into monthly averages. It shows that within the seven-month season from October 1 to April 30 there are regular variations in the average monthly landings. The total seasonal catch per boat of the sample fleet averaged 17,700 lbs. of which 7,500 lbs. (42%) were taken in the first two months combined, 4,500 lbs. (25%) were taken in the three mid-winter months, and 5,700 lbs. (33%) in the last two months.

These variations can be explained as resulting from changes in weather conditions, wharf price, and abundance of scallops.

(1) Influence of Weather:

There are 212 or 213 days in the seven-month fishing season, but even although the boats go out whenever the weather is fit (except Sundays), an average of only 57 actual fishing days per season was realized. Fig. 4B shows that 22 of these days (39%) occurred in the first two months, 16 days (28%) in the three mid-winter months, and 19 days (33%) in the last two. The shapes of fig. 4A and B correspond closely indicating that changes in the number of days fished were responsible for most of the month to month variation.

(2) Influence of Abundance of Scallops:

Fig. 4C shows average catch per boat trip. It is a better index of abundance than is monthly catch because unless the lengths of fishing days change greatly it will go up or down depending on whether the beds are well or poorly stocked. Fig. 4C suggests, therefore, that there were changes in abundance during the season. There was a mid-winter depression in catch which is believed to be attributable to the shortness of winter fishing days (fewer hours of daylight and unstable weather) rather than changes in abundance, but the important feature is a drop in catch per trip in March and April to only three-quarters of that in October and November, although lengths of fishing days in these two periods are about the same. It may be concluded that catch per boat in March and April were one-fourth lower because scallops were less abundant. This reduction in abundance must be the result of fishing and natural mortality removing about one-quarter of the catchable stocks each season. Abundance of scallops, therefore, affected the landings during the course of each season, but less than did weather.

(3) Influence of Price:

Mr. Richardson's records include the wharf prices paid to fishermen for their scallops. Average prices were low (43 cents per lb.) at the beginning of the season when landings were large, rose slowly during the winter to a maximum in February (52 cents per lb.) as landings decreased, and then dropped in March and April (49 and 47 cents per lb. respectively) as landings recovered.

This variation is what would be expected from the law of supply and demand. However, the winter rise and spring drop in price were small and the times at which they occurred do not correspond well with changes in landings to which they might be assumed to be related. Furthermore, when the records for any single year are considered, the relationship just described is often obscured or lacking. This shows that price changes during any one season had only minor effects on landings. The explanation lies in the fact that Digby shipments formed only a small part of the total supply on the principal market at Boston; a greater part was contributed by the American draggers from George's Bank.

(4) Conclusions:

It may be concluded that month to month changes in total landings by each boat are influenced by seasonal changes in abundance, but the influence of these abundance changes is largely obscured by the effects of great changes in weather. Price changes have little influence on landings during the season.

Catch per boat per fishing day which is a reliable index of abundance changes during October, November, March and

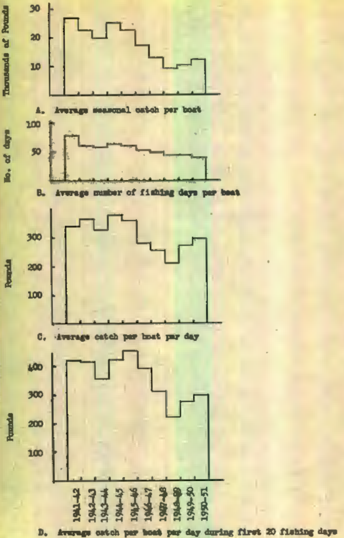


Fig. 5. Year to year variations in the Digby scallop fishery.

April, shows an average seasonal decrease of about 25% and indicates that, on the average, one quarter of the catchable stocks is removed by the combined effects of fishing and natural mortality each season.

b. Year to Year Variations

Annual catch per boat of the sample fleet from 1941-42 to 1950-51 is shown in fig. 5A. It was high in 1941-42, declined during the next two years, then increased sharply in 1944-45. Subsequently there was a sustained decrease to a minimum for the period in 1948-49, followed by a slight increase. It is to be expected that these year to year changes in catch may be influenced by the same factors - weather, price, and abundance - as were catches within any one season. The relative importance of these factors to changes in catch from year to year is assessed in the following analysis.

(1) Influence of Weather:

Fig. 5B shows the average number of fishing days realized by each boat in each season of the ten year period. The average was 57, the first five years being above average and the last five below. The highest number, 80 days, was realized in 1941-42; for four years after this it remained fairly constant between 60 and 65 days, then dropped almost steadily until there were only 42 fishing days in 1950-51. A comparison between figs. 5A and 5B shows that the especially high catch per boat in 1941-42 was in part a result of the unusually large number of days fished, and that the steady decrease in numbers of fishing days from 1945-46 to 1948-49 may have contributed to the drop in catch during the same period. This influence of differences in the number of fishing days on catch changes is largely removed by considering catch per boat per day (i.e. per trip).

Average catch per boat per day in each season is shown in fig. 50. Comparison with total catch per boat in each season, fig. 5A, shows that the trends of the two histograms are very similar, except that 1941-42 daily catch per boat is lower relative to the other seasons than was seasonal catch. It may be concluded that, except in 1941-42, weather changes have had little influence on year to year changes in catch, relative to the influence of other factors.

(2) Influence of Price:

Price may influence catch through its effects on fishing effort by inducing:

(1) boats to fish more or fewer days per season, or longer or shorter hours each day.

(2) changes in the number of boats fishing for scallops.

(3) fishermen to take small scallops (which are laborious to shuck) or to return to the beds.

It is unlikely that (1) is of any importance, because as was shown in the analysis of month to month catch changes, the numbers of days, and hours fished per day are largely controlled by weather. But prices do appear to have some effects on fleet size and on the size composition of the landings.

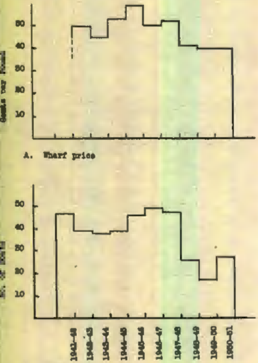


Fig. 6. The effect of wharf prices on the number of boats fishing for scallops at Digby, N. S.

1 Effects of Price & Value Landed on Fleet Size: No records of price are available for 1941-42, but fig. 64 shows that average wharf price rose rapidly from 1943-44 to a maximum in 1945-46, and fig. 68 indicates that this stimulated an increase in total fleet size. In 1943-44 price was low and the fleet totalled 38 boats. But in 1944-45 prices improved and catches were high so that seven new boats joined the fleet in 1945-46. That year price rose sharply again and although catch dropped slightly the total value of scallops landed by each boat was greater than previously and in 1946-47 there was a further three-boat increase in fleet size. That year, however, catch continued to drop and price dropped sharply leading to a decrease in value landed and a decrease in fleet size in 1947-48. In 1947-48 price was about the same as the year before but catch dropped still further, leading to a sharp decrease in fleet size in 1948-49. This continued in 1949-50 because of a continued decrease in both price and catch in 1948-49. In 1950-51 there was a rise in fleet size which resulted from the opening of an offshore summer fishery in 1950, attracting additional boats to the fishery which remained to fish during the winter season. This last change in fleet size was independent of any price change.

It may be concluded that if in any one season the total value of scallops landed by each boat is high, fleet size will increase in the following season. If however, the value landed is low, fleet size will decrease in the following season.

Table II. Seasonal decrease in catch per boat per day and its relationship to fleet size

Year	Average catch per boat per day		Difference	% Reduction*	Fleet Size	Log 10 Fleet
	Oct. & Nov.	Mar. & Apr.				
1941 - 42	369	301	68	18.4	47	1.67
42 - 43	433	336	97	22.4	39	1.59
43 - 44	337	313	24	7.1	38	1.58
44 - 45	444	338	106	23.9	39	1.59
45 - 46	462	344	118	25.5	46	1.66
46 - 47	368	200	168	45.7	49	1.69
47 - 48	320	231	89	27.8	47	1.67
48 - 49	244	235	9	3.7	26	1.42
49 - 50	276	273	3	1.1	17	1.23
50 - 51	331	300	31	9.4	27	1.43

* % Reduction = $\frac{\text{Difference}}{\text{Oct. and Nov.}} \times 100$

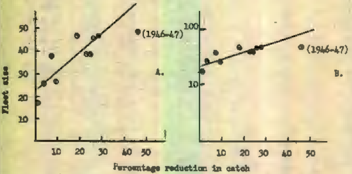


Fig. 7. Relationship between fleet size and percentage reduction in average catch per boat per day for October and November to March and April of 1941-42 to 1950-51 inclusive.

ii Effect of Changes in Fleet Size on Catch: The effects of changes in fleet size on catch are well known. Given a certain size of fishing stock at the beginning of a season, a larger fleet will remove a larger proportion of the stock per unit time than will a small fleet. Therefore, catch per boat at the end of a season will be lower relative to initial catch per boat if the fleet is large than if it is small. This is illustrated for the scallop fishery by Table II and fig. 7. Ricker (1940) has shown that a logarithmic relationship theoretically exists between catch and effort. For this reason percentage reduction in catch has been plotted against an arithmetic (fig. 7A) and a logarithmic scale (fig. 7B) of fleet size. The straight line fitted to the points in fig. 7 indicates that as fleet size increases percentage reduction in catch per boat per day from the beginning to the end of the season increases in proportion, although the scatter of the points about the line shows that factors other than fleet size also influence seasonal reduction in catch.

Since differences in fleet size will give rise to differences in the amount by which the catch is reduced during the season, seasonal average catch per boat per day from a given initial stock of scallops will be lower if fleet size is large than if it is small, and this influence of fleet size will be more marked the greater the inroads on the stock. However, changes in fleet size will have little influence on catch if only a small part of the stock is removed, such as during a short period at the beginning of the season. That is, average catch per boat per day during the first few days of each season will be high or low depending upon whether the beds are well or poorly stocked and gives an index of relative abundance changes from season to season.

Average catch per boat per day during the first 20 days of each fishing season is given in fig. 5D and shows that abundance was high at the beginning of the 1941-42 and 1942-43 seasons. Abundance was lower in 1943-44 but rose subsequently to a maximum in 1945-46. Thereafter, there was a sustained decrease to a minimum in 1948-49, with a progressive small increase during 1949-50 and 1950-51. However, certain reservations must be made in comparing these changes from year to year because price changes have also brought about changes in the size composition of the stocks taken by the fishery, and changes in size composition of the catch may influence the catch statistics on which these relative abundance estimates are based.

iii Effect of Price on the Size Composition of the Catch: In almost every year, the scallops captured by commercial scallop drags range in size from about 60 mm. to 160 mm., shell diameter and in some years the proportion of small scallops in the total catch may be quite high. Under ordinary conditions fishermen do not consider it worthwhile to shuck scallops smaller than about 80 mm. because the meats are very small and it requires up to five times as much labour for a pound of meats from them as from larger scallops. If, however, prices rise and at the same time the abundance of large scallops is low, fishermen will shuck out small scallops.

ix Effect of Changing Size Composition on Abundance Estimates: Conditions leading to shucking of small scallops apparently prevailed from 1945-46 to 1947-48 inclusive, and fishermen report that large numbers of small scallops were taken, particularly in 1946-47. The change in the size composition of scallops taken by the fishery is reflected in the catch statistics of both the whole and the sample fleet and gives a false impression of abundance relative to other years. This is illustrated by a comparison of changes in size composition of the catch, with changes in the reported total catch, and catch per boat.

In 1944-45, initial catch per boat of the sample fleet per day was high and average seasonal catch per boat of the sample fleet per day was the highest of the ten year period (fig. 5D and C). At that time, however, fleet size and price began to increase. In the next year initial abundance was slightly higher than the year before, but fleet size and price had increased sharply leading to rapid removals of the stocks and the sample fleet's average seasonal catch per boat per day that year was lower than before.

The rapid decrease in the catch of larger animals was apparently experienced by all the boats and for some of the poorer of them meant seriously decreasing catches at a time when prices were unusually high. Fishermen report that these poorer boats began to take small scallops. The long term effects of such a practice are in doubt, but the short term effects are obvious. There was an unprecedented high average catch per boat of the whole fleet in March 1946 (Appendix I) and the 1945-46 average <u>seasonal</u> catch per boat of the whole fleet was higher than the year before (fig. 1C).

It must be concluded that the difference in the trend of seasonal catch per boat by the whole and the sample fleet from 1944-45 to 1945-46 resulted from the change in the size composition of the catch taken by some of the unsampled fleet. That is, seasonal catch per boat of the whole fleet in 1945-46 is high relative to the catch of the sample fleet, because some of the boats had begun to fish a part of the scallop population which ordinarily was not fished.

Fishermen report that by 1946-47 the abundance of large scallops had fallen. The sample fleet's initial catch per boat per day was lower that season than in 1945-46. But fleet size was even greater than the previous year, meaning that the small stock of the larger scallops would be reduced even more quickly than before and catches would fall in proportion. In an attempt to improve their catches all fishermen began ~~to concentrate on~~ shucking small scallops and by the end of the season most of the catch was composed of them.

No data on size composition in 1946-47 are available but fishermen report that by making two or three hauls in the morning they could catch enough small scallops to keep them busy shucking all day. Since it requires four or five times as much work to shuck a given weight of small scallops as of large, daily catches made up of a high proportion of small scallops must be lower than catches of the same number of large. If the working day at the time small scallops were taken had been the same as before, catches might have been only 1/4 to 1/3 of previous catches. However, this potential drop was partially checked by a change in the pattern of the working day. Fishing was confined to a short period during the day so that landings became less dependent on weather. The whole crew then devoted the rest of the day to shucking scallops rather than handling drags so that each man would shuck more scallops per day. In addition to this, crews report that they worked particularly long hours and some enterprising skippers hired extra "hands" as shuckers. The combined effect was to raise catch above what might have been expected if fishing for small scallops had followed the usual fishing routine, but even so, from a drop in initial catch per boat per day of only 14% below the previous year, seasonal average catch per boat per day of the sample fleet was 22% less than before (fig. 5) and the whole fleet's average catch per boat was 40% less than the year before (fig. 10). fig. 7 indicates that the reduction in catch during that season was greater than would have been expected from fleet size alone, on the basis of the relationship between percentage reduction in catch and fleet size of other years.

It may be concluded that initial catch per boat of the sample fleet per day was unusually high in 1946-47 because fishermen started fishing small scallops early in the season. However, by taking small scallops they reduced their catches during the season to a greater extent than would have been expected on the basis of removals of large scallops so that average catch per boat per season was unusually low. That is, the practice of taking small scallops gave a falsely high index of relative abundance of scallops at the first of the season and a falsely low impression of the average abundance during the season.

(3) Effect of Abundance Changes:

From the foregoing analysis it appears that average catch per boat per day during the first twenty days of the fishing season, may be regarded as an index of the relative initial abundance of catchable scallops from 1941 to 1951, except in 1946-47 when there was a great change in the average size of scallops taken. The initial catch per boat per day is shown in fig. 5D which indicates that the abundance of the scallop stocks ordinarily taken by the Digby scallop fishery decreased from 1941-42 through 1942-43, increased afterwards to a maximum in 1945-46, then decreased rapidly to a minimum in 1948-49. A slight increase in 1949-50 and 1950-51 is also indicated but in 1950-51 it is known that much of the fishing was done on offshore beds, so that this catch refers to a different part of the population. It may be concluded in this case, however, that the abundance of the population of inshore scallops was lower than is indicated by relative initial catch in that year or it would not have paid fishermen to risk offshore fishing.

A comparison of initial catch per boat of the sample fleet (fig. 5D) with seasonal catch per boat of the sample fleet (fig. 5A) shows that the shapes of the two correspond closely. The same is true of a comparison of initial catch of the sample fleet with seasonal catch of the whole fleet (fig. 1C). Since initial catch per boat of the sample fleet may be considered as a measure of relative abundance this correspondence indicates that abundance changes are primarily responsible for changes in the landings by the Digby scallop fishery.

E SUMMARY AND CONCLUSIONS

A consideration of the available information about the Digby scallop fishery indicates that no changes in catch have resulted from changes in efficiency of gear or types of boats since the late 1930s and that the inshore areas have contributed by far the greatest, and a nearly constant proportion of the total landings from about 1938 to 1950. Therefore since 1938 no major changes in catches of Digby scallops have resulted from changes in beds fished. It was also concluded that scallop migrations are of no importance to catch changes in the Digby area.

An analysis of special catch statistics indicated that significant changes in catch from month to month are produced by weather, and that both weather and price may be partly responsible for changes in catch from one year to another. However, the influence of these factors is of minor importance compared with the influence of abundance changes. Fluctuations in abundance are primarily responsible for changes in catches of individual boats and in total landings from one year to another.

Since abundance changes are primarily responsible for changes in catch it may be concluded that fluctuations from year to year since the mid 1930's, when the Digby fishery developed efficient fishing methods, reflect changes in the abundance of the stocks. It remains to estimate abundance in different years and explain changes in it.

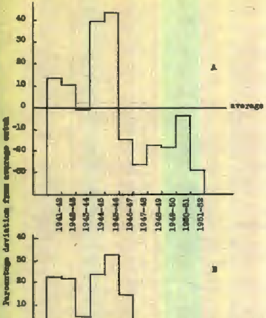


Fig. 8 Relative abundance changes.
A. From average catch per boat per season - whole fleet.
B. From average catch per boat per day during first 20 fishing days of each season - sample fleet.

V CALCULATIONS OF ABUNDANCE CHANGES

The foregoing analysis shows that changes in relative abundance are primarily responsible for year to year changes in catch, therefore an appropriate measure of catch may be used to describe actual changes in abundance of the catchable scallop stocks. An accurate description of these abundance changes is necessary before they can be understood or explained. In this section estimates of relative and actual abundance changes will be made from the indirect evidence of catch statistics. These will be checked by more direct estimates from tagging programmes, special fishing techniques, and submarine photography.

A. RELATIVE ABUNDANCE

Relative abundance changes in the catchable scallop population were estimated from initial catch per boat of the sample fleet per day for each season from 1941-42 to 1950-51. A second estimate of relative abundance may be obtained from seasonal average catch per boat of the whole fleet. These are shown in fig. 8, and although both are subject to certain errors, they give a similar picture of relative abundance changes throughout the period under consideration (correlation of 0.838 over the 10 year period).

In the following analysis several techniques are employed to make estimates of the actual abundance of the fishing stocks. Comparison of the results with the relative abundance estimates indicates that the latter describe abundance changes accurately, and permits use of the data in explaining fluctuations in abundance.

B. ABUNDANCE ESTIMATES FROM CATCH DATA

The technique for estimation of population size from catch or sampling and removal data has been described by DeLury (1947, 1951) who used the scheme for calculating populations of trout and lobsters. Similar methods have been applied to the analysis of creel census data by Mottley (1946) and for the estimation of populations of small mammals by Haynes (1949). These methods are based on the assumption, [redacted], that the number of animals captured by a given unit of effort is proportional to the number present at the beginning of the period of capture. From this assumption it follows that if successive short sampling periods are considered, the average difference between successive catches is related to changes in the population and, with certain restrictions, the total catch up to the time of each successive drop in catch per unit of effort can be related to actual populations. Specifically, if a certain population is fished over a long period of time and no other additions or subtractions are made, the catch per unit of effort will decrease as the total amount of fish caught increases. If fishing is continued long enough, the catch per unit effort must eventually become zero when all the population is caught. At this point the accumulated catch equals the population which was initially present.

In practice, natural populations are never fished to extinction by the commercial fishery but if a considerable proportion is caught during a fishing season, the rate of decrease of catch per unit effort may be established and from the catch records it may be possible to calculate how much will have to be caught before catch becomes zero. This gives an estimate of the population initially present.

1. Methods of Calculating Abundance From Catch Records

DeLury has shown that if a population is subjected only to fishing, if the units of fishing gear do not complete at any one instant, and if catchability (defined as the fraction of the population removed by a unit of effort) is constant, then the change in catch per unit effort can be used to calculate actual initial population. Using his symbols, by definition: $C(t) = kN(t)$ where $C(t)$ is the catch per unit of effort during any short interval of time, k is the constant catchability, and $N(t)$ is the population present at the beginning of the catching interval. That is, catch per unit of effort is proportional to population present. If decreases in this population are the result of fishing alone, the population present at any time - "$N(t)$" - is equal to the original population - "N" - less the total catch - "$K(t)$". That is:

$$N(t) = N - K(t)$$

Substituting this equation in the first:

$$C(t) = k\left\{N - K(t)\right\}$$

that is, $C(t) = kN - kK(t)$ - - - - - - (1)

Fig. 9 illustrates equation (1) in graphic form and shows that if the catch per unit effort during successive short intervals is plotted against the accumulated catch up to each

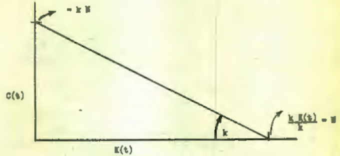


Fig. 9. Graph of the function $C(t) = kN - k\,K(t)$

interval the resulting straight line has a slope equal to the catchability. This line has the important property that when

$C(t) = 0$, $\quad k\,N = k\,K(t)$

whence $\quad N = K(t)$ That is,

the intercept of the line on the abscissa gives an immediate graphic estimate of the population initially present.

The conditions required for fitting this equation are rarely met in natural populatines. It is not uncommon to find changes in the efficiency or kind of gear used, or in the ways fishermen fish so that catchability may change during the season. Furthermore the stocks may be growing and young animals be recruited into the stocks. However, in the scallop fishery any systematic catchability changes may be eliminated from the data, and only the end of the growing season for scallops overlaps with the fishing season. Therefore, these objections do not appear to be obstacles to the application of DeLury's method to the estimation of abundance of scallops present at the beginning of each fishing season.

It cannot safely be assumed that the scallop population is closed to natural mortality, and DeLury's basic equations require detailed records of all fishing, although detailed scallop fishing records are available for only a sample of the total fleet fishing for scallops. However, DeLury (1951) has shown how the basic equations may be expanded to take some of these situations into account. For example, if two kinds of fishing gear fish a population, but records for only one of them are available, the equation fitted is approximately *

$$C(t) = kN - \left(k + \frac{k'e'}{e}\right) K(t) \quad \text{-------- (2)}$$

where k and e are the catchability and effort for the type of gear or fleet for which records are available, and k' and e' are corresponding quantities for the other. That is, if catch per unit

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* This is only an approximation because if two kinds of effort are acting, the total decrease is not the sum of the effect each would have alone. For example if one type of gear removes 10% of the stock per unit of effort ($k = .10$) and the second 25% ($k' = .25$) their combined effect $\hat{k}$ will equal
$$.25 + .10 - (.25 \times .10)$$
whence $\hat{k} = .35 - .025 = .325$. Here the actual rate of decrease differs from the sum of the two by .025. Such small differences are usually so far within the limits of "experimental error", especially if one of the efforts is small, that refined treatments to take the product term into account are rather pointless.

of effort - $C(t)$ - of a sample fleet is plotted against accumulated catch of this sample - $K(t)$ - the resulting, observed, straight line has a slope $\hat{k}$ which reflects not only the drain of the sample fleet on the population but also the effects of the drain imposed by the unsampled fleet. The observed slope,

$$\hat{k} = k + k'\frac{e'}{e}$$

$$= k\,(1 + \frac{k'e'}{k\,e})$$

from which the catchability of the sample fleet alone $k = \hat{k} \cdot \frac{1}{1 + \frac{k'e'}{k\,e}}$

If the ratios of the two catchabilities $\frac{k'}{k}$ and of the efforts $\frac{e'}{e}$ are known, the true catchability of the sample fleet may be calculated and the initial population found from the identity $\frac{kN}{k} = N$, where the numerator kN is given by the intercept of the line on the ordinate.

If more than two kinds of effort are involved the equation becomes $C(t) = kN - (k + \frac{k'e'}{e} + \frac{k''e''}{e})\,K(t)$ - - - - (3) where k'' and e'' are the catchability and effort of the third kind of effort. If they are identified with natural mortality, k'' is the instantaneous natural mortality rate and e'' is the number of days for which it operates. The product - $k''e''$ - is therefore the natural mortality rate applying over the fishing season. This equation may be solved for k, and adjusted estimates of population size obtained as before.

2. Estimates of Abundance from Catch Statistics Disregarding Effects of Natural Mortality

a. From Statistics of the Sample Fleet

The daily catch per boat of the sample fleet may be used to estimate abundance of the stocks. The records for 1941-42 to 1950-51 were obtained from Mr. Richardson, and to them have been added similar records for a different set of boats for 1951-52, supplied by Mr. Archer-Shee, Manager of the Digby Packing Co. These records, which are summarized in Appendix III, include all landings made by the sample fleet over the 11 year period.

(1) Calculation of Catch per Unit of Effort - C(t)

One of the primary conditions for calculating abundance from DeLury's formulae is that catch per unit of effort does not change during the season (i.e. catchability must be constant). But it is known that weather may influence the catch. It is virtually impossible to fish when wind velocities exceed 15 m.p.h., and when they are between 10 and 15 m.p.h. catches will be small because handling the drags is difficult and dangerous, and fishermen believe that they make lower catches because the drags skip over the bottom. Calm weather is necessary for effective fishing. Therefore, if average catch per boat per day is used as a unit of effort, weather changes will lead to changes in catchability from day to day throughout the season. Such changes in catchability must be eliminated before estimates of abundance can be made.

Fine and poor fishing days can be determined with some accuracy from records of wind velocity kept by the Meteorological Observation Station at Greenwood, N. S. They show the wind velocity at one hour intervals each day throughout the period under consideration. For purposes of determining good, fair, or poor fishing days, the wind velocity for each day was obtained from the original records and classified as less than 10 m.p.h., between 10 and 15 m.p.h., over 15 but under 30, and over 30 m.p.h. during each 1/2 day. These data are given in Appendix IV. From a knowledge of the habits of the fishermen, it was decided that a good fishing day might be defined as one on which from midnight to noon the wind velocity did not exceed 10 m.p.h. and either remained calm or did not exceed 15 m.p.h. until the succeeding midnight. To eliminate variations in catch due to changes in weather, only catches made on fine days are used for calculating catch per unit of effort.

Fine days, classified in this way, were compared with the catch records of the sample fleet. (They are included in the tables of catch records - Appendix III). It was found that on a few occasions no fishing was done although the wind records show low wind velocities, and sometimes high catches were made on apparently windy days. The reason is that wind velocities were observed by a Station about twelve miles from the coast of the Bay of Fundy and separated from it by a low range of hills. Thus, local weather disturbances may have occurred at either place which were not felt at the other. However, general weather conditions are the same in both areas, and this is reflected in the fact that very few high catches were made when wind records show poor fishing weather or vice-versa.

To eliminate bias in analysis of the records, only catches made on days which could be defined as fine from meterological records were used in calculating catch per unit of effort, and all others were disregarded, with two exceptions. The first exception was made if on an apparently fine day one or more of the boats failed to land but reported on the succeeding day. The late report probably indicates that the boat arrived at the wharf after the plants closed so that these catches were counted as fine day catches regardless of weather the second day. If, however, the weather on the second day was also fine and the catch of the formerly missing boat was double, or nearly double, that of boats landing on either or both days, its catch was counted as two days' catch. The second exception was made if the catch of one of the boats, on an apparently fine day, was very much lower than catches made by other boats on that day, or was at least much lower than that boat's usual preformance would indicate it could have made. Such low catches were assumed to have resulted from engine or similar trouble. An examination of the records indicated that for the sample fleet boats all daily catches less than 150 pounds might be regarded as abnormally low catches and this was taken as the lower limit of catches used in calculating average catch per boat per fine day.

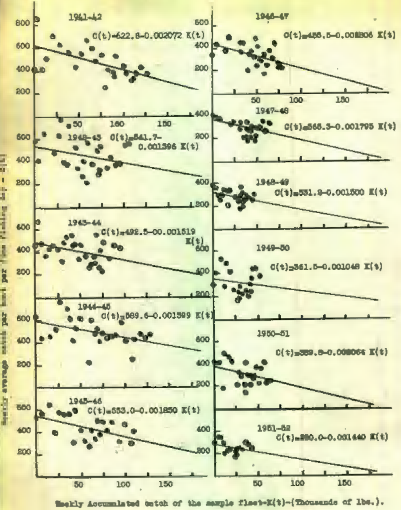


Fig. 10 Relationship between average catch per boat of the sample fleet on fine fishing days in each week-C(t)-and the accumulated catch of the sample fleet at the beginning of that week-K(t)-from 1941-42 to 1951-52 inclusive.

Using the weather data to define fine fishing days, the average catch per boat per fine day was determined for each week of each season. A week was chosen as the most natural interval into which a season may be divided as scallop fishing, like many other human activities, is based on a weekly cycle. Very few scallop fishermen fish on Sunday, and Saturday nights are generally regarded as a time for relaxation and recreation whether fishing has been good during the preceeding week or not. Therefore the catch per unit effort for the scallop fleet is defined as weekly average catch per boat per fine day.

(2) Calculation of Abundance

Catch per unit effort - $C(t)$ - for each season, has been plotted against the appropriate $K(t)$ and straight lines have been fitted to the points by the method of Least Squares (fig. 10). These $C(t)$ and $K(t)$ values, and the equation of the line for each season, are given in Appendix V. From the discussion on methods, each of these lines are of the form

$$C(t) = kN - \hat{k}\,K(t)$$

and the abscissal intercept and slope give estimates of kN and $\hat{k}$ respectively. Since the sample fleet statistics alone have been used to calculate these lines, the observed slope is a compound, including the effects of both the sampled and unsampled fleets. That is

$$\hat{k} = k + \frac{k'e'}{e}$$

$$= k\left(1 + \frac{k'e'}{k\,e}\right)$$

where k and e refer to the sample fleet and k' and e' to the unsampled fleet. From this the catchability of the sample fleet alone

$$k = \hat{k}\left(\frac{1}{1 + \frac{k'e'}{k\,e}}\right)$$

The ratios $\frac{k'}{k}$ and $\frac{e'}{e}$ may be obtained from the ratios of the catches of the two fleets. Since catch per unit effort of the sample fleet = $C(t) = kN$, and catch per unit effort of the whole fleet $C'(t) = k'N$ the ratios of the two

$$\frac{C'(t)}{C(t)} = \frac{k'N}{kN} = \frac{k'}{k}$$

That is, the ratios of the catchabilities is the same as the ratios of catch per unit of effort. e and e' are the efforts of the two fleets, and if it is assumed that the ratio of the effort of the sampled and unsampled portions of the fleet was constant throughout the season

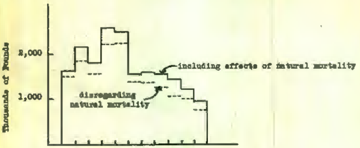
$$\frac{e'}{e} = \frac{\text{size of the unsampled fleet}}{\text{size of the sampled fleet}} = \frac{\text{Fleet}_{u}}{\text{Fleet}_{s}}.$$

Combining these ratios to give the denominator of the correction factor

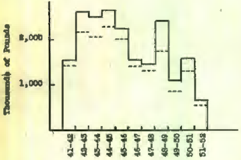
$$\frac{k'e'}{k\,e} = \frac{\dfrac{\text{Total } K'(t)}{\text{Fleet}_{u}}}{\dfrac{\text{Total } K(t)}{\text{Fleet}_{s}}} \times \frac{\text{Fleet}_{u}}{\text{Fleet}_{s}} = \frac{\text{Total } K'(t)}{\text{Total } K(t)}$$

$$= \frac{\text{Total catch of the unsampled fleet}}{\text{Total catch of the sampled fleet}}$$

That is, the correction factor is dependent only upon the ratio of the catches of the two parts of the fleet and is equivalent to considering the accumulated catch of the sample fleet as a given and constant fraction of the accumulated catch made by the whole fleet at the same time. Total catch data for the whole and sampled fleet are given in Appendix I and III and the correction factor for each season is calcu-



A. Initial Abundance from C(t) on E(t)–see fig. 10



B. Initial Abundance from C(t) on Ex(t)–see fig. 12

Fig. 11 Estimates of Abundance from Catch Statistics.

lated in Appendix VI.

Given the values of kN and $\hat{N}$ from the regression lines, and the corrected k values, a first estimate may be made of the abundance (weight of meats) of the stocks available to the fishery at the beginning of each season. The calculations are shown in Appendix VII under the column head $\hat{N}$ and the estimates are shown in fig. 11A.

First estimates of population size (fig. 11) show that a catchable population of scallops with meats weighing about 1.5 million lbs. was present before fishing began in 1941-42. The population was larger - 1.9 million lbs. at the beginning of the next season but dropped to 1.6 million in 1943. It was larger again at the beginning of the 1944-45 and 1945-46 seasons, but subsequently dropped rapidly until at the beginning of the 1951-52 season it appears that less than one million lbs. of scallop meats were present in the fished population.

b. From Statistics of the Sample and Whole Fleet Combined

Estimates of abundance using only sample fleet statistics may be checked by estimates made from catch per unit effort of the sample fleet combined with records of total landings of the whole fleet. Detailed landings by the whole fleet are not available but officers of the Department of Fisheries submit monthly reports of total landings which are summarized in Appendix I. These may be combined with monthly catch per unit effort of the sample fleet and abundance calculated as before.

It was shown in the previous section that if catch per unit effort of the sample fleet - C(t) - is plotted against the accumulated catch of the same boats, the result is a straight line of the form

$$C(t) = kN - (k + k'\frac{e'}{e})\ K(t) - - - - - - (2)$$

$$= kN - k(k + \frac{k'e'}{k\ e})\ K(t)$$

If k' and e', and k and e, are the catchabilities and efforts of the unsampled and sampled fleets respectively, then from the definition of terms, the total effect of the whole fleet on the population is approximately * equal to the sum $k'e' + k\ e$ over a given interval of time. The proportion of this total which may be assigned to the sample fleet is then: $\dfrac{k\ e}{k'e' + k\ e}$.

The proportion of the catch of the whole fleet - Kw(t) - which is taken by the sample fleet

$$K(t) = \frac{k\ e}{k'e' + k\ e}\ Kw(t).$$ From this relationship

$$Kw(t) = \frac{k'e' + k\ e}{k\ e}\ K(t)$$

$$= (1 + \frac{k'e'}{k\ e})\ K(t)$$

Substituting in equation (2)

$$C(t) = kN - k\ Kw(t) - - - - - - (4)$$

Therefore if the catch per unit effort of the sample fleet, - C(t) - is plotted against the accumulated catch of the whole fleet - Kw(t) - the slope of the resulting regression line gives an immediate estimate of the catchability of the sample fleet alone. Total population available may, therefore, be directly estimated from the fitted line

* See footnote page 44.

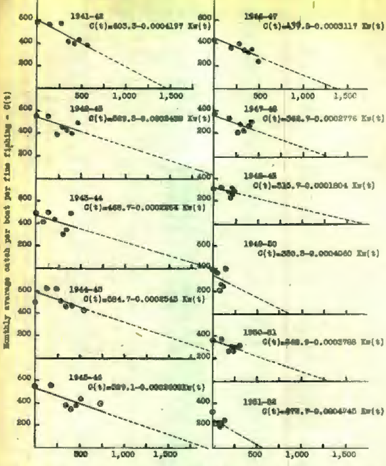


Fig. 12 Relationship between average catch per boat of the sample fleet on fine fishing days in each month-C(t)-and the accumulated monthly catch of the whole Digby scallop fleet up to the beginning of that month-Kw(t)-from 1941-42 to 1951-52 inclusive.

as $\frac{kN}{k} = N$, or is given graphically by the intercept on the abscissa, i.e.

$$\text{where } C(t) = 0 \qquad kN = k\ Ew(t)$$

$$N = Ew(t)$$

Since the catches for the whole fleet are given only in monthly intervals, C(t) has been recalculated over monthly periods for each season rather than weekly periods as before. These have been plotted against the appropriate Ew(t) values and lines fitted to them by Least Squares. The details of the calculation and fitting have been included in Appendix V and are present graphically in fig. 12.

The estimates of initial abundance of scallops as judged from the combined sample and whole fleet records, are shown in the second part of Appendix VII and graphically in fig. 11. It appears that about 1.4 million lbs. were available on the beds at the beginning of the 1941-42 season. Abundance was greater at the beginning of the next season - 2.1 million lbs. - dropped slightly in 1943, and rose again to a maximum of 2.3 million lbs. in 1944. Thereafter there was a decrease, slight at first, then more rapid to about 1.3 million lbs. in 1947. These estimates of abundance indicate a very variable population subsequent to 1947: high in 1948, lower in 1949, high again in 1950, then very low in 1951.

The estimates of relative abundance in fig. 8, and estimates of actual abundance, fig. 11, show close agreement in trend for the first seven years of the eleven year period under consideration, but considerable disparity in the last four years. This disparity is particularly marked between the estimates of actual abundance. However, each of the estimates are subject to errors, among which is the fact that natural mortality has been neglected. Estimates of natural mortality rate may be made and revised estimates of actual initial abundance calculated, taking the natural mortality factor into consideration.

3. Natural Mortality

Many scallops die from causes other than fishing. Tank observations indicate that they are attacked by starfish (Welsh 1950) and large gastropods. There is also evidence that extensive erosion of the shells by boring sponges seriously weakens the scallops (Medcof 1949) and may kill them or lower their resistance to other factors. The fact that appreciable natural mortality occurs is attested by quantities of empty shells which are brought up in the drags. Natural mortality must therefore be taken into account in making estimates of population size from the rate of decrease of the catch.

Shells of scallops which have recently died from natural causes can be distinguished from those killed by the fishery. In shucking the two valves of the shell are always separated before the adductor muscle or meat is removed and the shells are discarded on the bed. Natural mortality, on the other hand leads to decomposition or removal of the soft body parts and leaves the two valves firmly attached by the hinge ligament. These empty shells persist for some time before the hinge ligament decomposes and the valves separate. Numbers of the empty shells, called "cluckers" by the fishermen, are brought up in the drags along with living scallops, single shells, and detritus.

The rate of natural mortality can be estimated from the relative size of the populations of living scallops and cluckers if the time from death of the scallop to separation of the clucker is known, and the population size of the cluckers is not changing at the time the estimates are made. That is, the population of cluckers may be regarded as a "pool" of dead animals to which newly dead animals are constantly added and from which the separating cluckers are removed. If, over a given period of time the size of this dynamic pool remains constant, the number of scallops dying must be just balanced by the decomposition of cluckers and the numbers of living scallops which die per unit time may be determined from the rate of decomposition of cluckers. The number dying per unit time, expressed as a fraction of the average population of living present at the same time, gives an estimate of the natural mortality rate.

a. Relative Population Size of Living and Clucker Scallops

The size of the population of living scallops and cluckers may be judged from the catches of each made in a series of tows of standard length on each of several beds during the summers

TABLE III

Relative Populations of Living and Clucker Scallops and calculation of Natural Mortality from the relationship between them.

Scallop Bed		Year	No. of hauls	D= no. of cluckers/haul	P= no. of living/haul	L = no. of days cluckers persist	$i = \frac{D}{L} \times \frac{1}{P}$	− it where t=365 days	e^{-it}	seasonal natural mortality rate $a = 1 - e^{-it}$
Part 1 – 96 to 155 mm. scallops										
Buoy Ground		1950	8	1.375	75.88	100	.0001812	.0661	.9361	.0639
		1951	4	0.375	141.46	"	.0000619	.0226	.9775	.0227
		1952	11	1.591	91.75	"	.0001735	.0633	.9390	.0610
Broad Cove		1951	5	1.167	108.27	100	.0001080	.0394	.9628	.0372
		1952	6	.972	96.64	"	.0001006	.0367	.9637	.0363
Shelburne Cove	1st Ridge	1950	9	6.333	131.56	100	.0004814	.1757	.8386	.1614
	2nd Ridge	"	4	9.600	163.30	"	.0005879	.2146	.8069	.1931
	2nd Ridge	1952	4	3.792	164.50	"	.0002306	.0841	.9194	.0806
40-Minute Ground	Aug. 14	1950	10	10.600	247.40	100	.0004285	.1564	.8556	.1444
	" 23	"	9	10.111	332.56	"	.0003040	.1110	.8949	.1051
	" 24	"	9	15.111	344.33	"	.0003808	.1390	.8705	.1295
	Sept. 4	"	3	15.667	269.67	"	.0005810	.2121	.8090	.1910
	" 6	"	8	11.875	328.13	"	.0003619	.1321	.8763	.1237
	" 8	"	11	11.000	271.18	"	.0004056	.1480	.8624	.1376
	" 9	"	3	13.000	252.67	"	.0005145	.1878	.8286	.1714
		1951	9	10.650	280.51	"	.0003789	.1383	.8711	.1289
		1952	11	10.394	194.51	"	.0005349	.1952	.8229	.1771
Offshore	Inner	1950	9	42.000	602.00	100	.0006977	.2547	.7749	.2251
	Outer	1950	6	29.750	610.75	"	.0004871	.1778	.8370	.1630
	Inner	1951	4	10.500	277.96	"	.0003778	.1379	.8711	.1289
	"	1952	6	8.063	234.57	"	.0003463	.1264	.8816	.1184
Part 2 – Scallops 0 – 95 mm.										
Buoy Ground		1952	11	1.890	195.69	60	.0001420	.0518	.9493	.0507
Offshore	Inner	1950	9	4.376	220.15	60	.0003975	.1451	.8650	.1350
	Outer	"	6	4.469	180.85	"	.0005163	.1885	.8278	.1722

Av. Buoy Gr. and Broad Cove = 0.0455 = 4.6%

Av. Shelburne Cove and 40-Minute Ground = .1577 = 15.8%

Offshore = .1571 = 15.7%

of 1950, 1951 and 1952. Since few cluckers less than 96 mm. shell height were taken, natural mortality rate is determined principally from the larger size groups. Part I of Table III shows the average number per tow of living and cluckers of 96 to 155 mm. shell height. Part II shows the records of the hauls in which numbers of both less than 96 mm. were taken. If living scallops and cluckers are equally liable to capture by scallop gear, the average number of each taken per tow is a reflection of the relative population size.

There is a certain amount of day to day variability in catches which represents sampling errors. This is illustrated by the variation in number of cluckers and living taken per haul on 40-Minute Ground in a six day period from Sept. 4 to Sept. 9, 1950. (Table III). But within the limits of this sampling variation, the populations appear to have remained constant over a period of almost a month. Furthermore, the relative numbers of living and dead per tow on Buoy Ground, Broad Cove and 40-Minute Ground remained about the same throughout the sampling period of two years. The Shelburne Cove and Offshore Ground show more variation although the latter was much the same in 1951 and 1952. From these samplings it may be tentatively concluded that throughout the period of observations, additions to the clucker population through natural death of scallops have been balanced by decomposition of the cluckers.

b. Rate of Separation of Cluckers

A preliminary tank experiment to determine the rate of separation of clucker shells of different sizes was reported

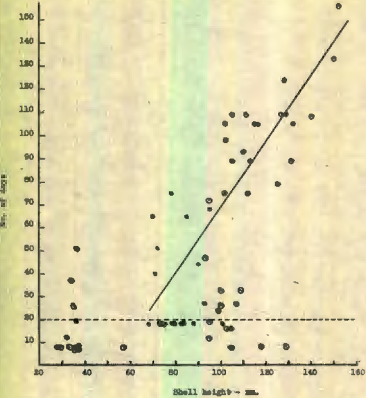


Fig. 18. Number of days from death of different sizes of scallops to separation of valves of the "clucker" (after Medcof and MacPhail 1951).

by Medcof and MacPhail (1951). Their results are summarized in fig. 13 which shows that a number of shells of assorted sizes parted within 20 days, but that there is a sharp distinction between these and later separations, suggesting that the ligaments of those which separated early may have been damaged in some way when the animals were killed. If the group of early separations is disregarded, the remaining observations fall along a straight line, indicating that the time to separation of the valves is proportional to shell size. However, with so few observations it is almost impossible to specify the exact relationship and for the purposes of estimating natural mortality the results have been grouped to give average time from death of scallops to separation of valves of cluckers less than 96 mm., and those between 96 and 155 mm. in shell height. Average time to separation in the smaller cluckers was 51.4 days and for the larger was 103.4, or about 50 and 100 days. The daily rate of separation of cluckers is, therefore, 1/50 and 1/100 for small and large respectively.

e. Calculation of Natural Mortality Rate

Natural mortality rate may be calculated as follows: On Bacy Ground in 1950 an average of 1.375 large cluckers was taken per tow. The rate of separation of cluckers was therefore 1.375 x $\frac{1}{100}$ =0.01375 cluckers per day. The average living population of large scallops present at the same time is represented by 75.88 taken per tow. From this $\frac{0.01375}{75.88}$ = .0001812 of the scallops die from natural causes each day. Ricker (1944) has shown that the daily natural mortality rate may be converted to an annual mortality rate from the relationship

$a = 1-e^{-it}$ where "a" is the annual mortality rate, "e" is the natural base of logarithms, "i" is the instantaneous (i.e. daily) natural mortality rate, and "t" is the number of days. If "a" is to be determined over a year, then t = 365 days, and the annual natural mortality rate for Buoy Ground in 1950 is

$$a = 1-e^{-(0.0001812)(365)}$$

$$= 1-e^{-0.0661}$$

$$= 1 - 0.9361 = 0.0639$$

Natural mortality rate was calculated in this way for each scallop bed in each season (Table III).

The results of the calculations show that natural mortality rate is relatively constant for the same bed from year to year, but the beds appear to fall into three quite distinct groups. The first, including Buoy Ground and Broad Cove Ground, two beds in 40-45 fathoms of water close to Digby Gut, have a low natural annual mortality rate of only about 4.5%. The Shelburne Cove and 40-Minute Ground, two areas situated near the western end of the scallop area in about 50 fathoms of water suffer annual natural mortalities of about 13.6%, while the offshore beds in 55 fathoms, have an annual natural mortality of about 15.7%.

The catches of scallops landed at Digby, N. S. do not come equally from the areas which exhibit these different natural mortality rates, so that no one rate is appropriate as a correction factor in calculations of abundance. However, what is known of the fishery indicates that roughly half of the total catch regularly comes from Bucy Ground and Broad Cove combined, about one-third from the rest of the inshore areas and the remainder from offshore (until very recently when a greater proportion came from offshore). On this basis, the natural mortality of the fished population is:

.50 x .045	=	.0225			
.30 x .138	=	.0414			
.20 x .157	=	.0315			
		.0953		or about 10% per year.	

This estimate of annual natural mortality is obviously subject to considerable error. It is based on sampling data which show considerable variation, and on estimates of separation of shells made from rough, preliminary experiments. More important than these, however, are some field observations reported by Chiasson (1952). He observed a mass mortality of scallops in Northumberland Strait in 1950, and his measurements of cluckers and living, showed that the modes in the size distribution of the two corresponded. But on re-examination of the same bed in 1951 he found large numbers of cluckers which had a size distribution corresponding with that of the previous year while the modes in the size distribution of the living were greater by an amount that would be expected on the basis of annual growth. His conclusion that the 1951 cluckers represent 1950 deaths seems fully justified and shows that cluckers in Northumberland Strait may persist much longer than did shells held in the tanks at St. Andrews. In the Digby collections the modes of the size distribution of living scallops and cluckers correspond with each other, indicating that cluckers do not persist as long in the Bay of Fundy as in Northumberland Strait. However, there remains the possibility that they persist longer in the Bay of Fundy than they did in the tank experiments. If this should prove true, the rate of natural mortality estimated above is too high.

It must be noted further that although an average annual 10% mortality rate has been assigned to the stocks, observations on which this is based were made during the mid and late summer (July to September). If natural mortality results from depredations by starfish and gastropods (which are common on and around the Digby scallop beds), one would expect it to be highest in September and October when the water of the Bay of Fundy is warmest and predators are most active. Therefore, the mortality rate, calculated from observations made in August and September, is likely to be near the annual maximum.

It may be concluded that the annual natural mortality rate of the fished population of Digby scallops is of the order of 10% and is not likely to greatly exceed this value.

4. <u>Revised Estimates of Abundance from Catch Statistics Taking the Effects of Natural Mortality into Account.</u>

a. Revised Estimates from Statistics of the Sample Fleet

Revised estimates of abundance may be made taking natural mortality into account.

The annual natural mortality rate of 10% corresponds to an instantaneous daily rate of $.10 = 1-e^{-(i)(365)}$

whence $i = 0.0003014$. Since the scallop season lasts for 212 days, seasonal natural mortality rate

$$n = 1-e^{-(0.0003014)(212)}$$

$$= .0620 = 6.2\%$$

From the discussion of methods it was shown that when the sampled and unsampled fleet and natural mortality are all acting on the population, catch per unit effort of the sample fleet plotted against the sample fleet's accumulated catch gives a straight line with observed slope $\hat{k} = k + \frac{k'e'}{e} + \frac{k''e''}{e}$ where the product k"e" is the seasonal rate of natural mortality, or 0.0620. The denominator of the fraction $\frac{k''e''}{e}$ is the effort expended by the sample fleet during the same time. Since the sample fleet is composed of five boats, it is five times the number of units of effort by each boat - i.e. five x average number of days fished per boat. The calculation of the correction term for natural mortality in each season is shown in Appendix VI. The revised estimates of population present at the beginning of each season are given in Appendix VII and in fig. 11.

These revised abundance estimates show that the abundance of scallop "meats" present before fishing in 1941-42 weighed 1.7 million lbs., increased in 1942, but dropped to 1.8 million lbs. in 1943 and rose to a maximum of 2.6 and 2.5 million lbs. in 1945 and 1946. Abundance appears to have been lower, of the order of 1.6 million in the next 3 years but dropped rapidly thereafter. These estimates may be compared with estimates from the sample and whole fleet statistics combined.

b. Revised Estimates from Statistics of Sample and Whole Fleet Combined

Initial abundance of scallops, taking natural mortality into consideration, can be estimated from the combined sample and whole fleet statistics using DeLury's formula

$$C(t) = k\,N - \left(k + k'\frac{g'}{e} + k''\frac{g''}{e}\right) K\,(t) \text{ - - - - - } (3)$$

from which $$C(t) = k\,N - k\left(1 + \frac{k'g'}{k\,e}\right) K(t) - k''\frac{g''}{e} K\,(t)$$

However, it was shown in section b(2), p. 52, that

$$K_w(t) = \left(1 + \frac{k'g'}{k\,e}\right) K(t)$$

so that by substitution

$$C(t) = k\,N - k\,K_w(t) - k''\frac{g''}{e} K(t)\ .$$

But since $$K(t) = \frac{1}{1 + \frac{k'g'}{k\,e}}\; K_w(t)\ ,$$

then by further substitution

$$C(t) = k\,N - k\,K_w(t) - k''\frac{g''}{e}\; \frac{1}{1 + \frac{k'g'}{k\,e}}\; K_w(t)$$

$$= k\,N - \left\{k + \left(\frac{k''g''}{e}\right)\left(\frac{1}{1 + \frac{k'g'}{k\,e}}\right)\right\} K_w(t)$$

Solving the observed slope- k_f - of this equation for k, the catchability of the sample boat, $k = k_f - \left(\frac{k''g''}{e}\right)\left(1 + \frac{1}{\frac{k'g'}{k\,e}}\right)$

Both of the correction terms have already been calculated (Appendix VI). The revised estimates of abundance, using this method, are given in the second part of Appendix VII and the results are shown in fig. 11.

The estimates of actual abundance given in fig. 11 may be compared with one another. This comparison reveals some of the weaknesses of each and permits an evaluation of the results.

9. Comparison of Estimates of Actual Abundance

The estimates of actual initial abundance (fig. 11) show general agreement in trend for the first seven years of the eleven year period under consideration but for the last four years there are considerable disparities. An examination of fig. 10 and 12, on which they are based, shows the relative degrees of error to which each is liable, and indicates which of them are most reliable.

The estimates of abundance are based on the position and slope of each of the "lines of best fit" shown in fig. 10 and 12. Since the reliability of the determination of the position and slope of these lines depends on the number of points used, their spread along the line, and their scatter about it, these features are indicative of the relative reliability of the abundance estimates. From considerations of this kind it appears that the sample fleet statistics give more reliable abundance estimates than do records of the whole and sample fleet combined. It also appears that estimates of abundance for the last four seasons are less reliable than are estimates for the first seven. However, both sets of data agree well in the order of reliability of estimates from season to season as follows:

	fig. 10 (sample fleet)	fig. 12 (sample & whole fleet)
most reliable:	1941-42	1945-46
	44-45	41-42
	45-46	44-45
	42-43	46-47
	43-44	42-43
	46-47	47-48
	47-48	43-44
	50-51	50-51
	49-50	48-49
	48-49	51-52
least reliable:	51-52	49-50

It is to be noted that in both lists the four lines whose positions are least reliably determined represent the four seasons among which the abundance estimates of fig. 11 show least agreement.

One of the main requirements for using Delury's method to estimate abundance from catch data is that catchability remain constant throughout the season. That is, besides requiring as little scatter and as much spread along the lines as possible, it is necessary that no systematic trend of catchability be present. However, in certain of the plotted lines there is a tendency for the first and last points to be above the line and the middle points below it. This is particularly marked in fig. 10 for 1949-50 and 1951-52, and in fig. 12 for 1945-46, 1949-50 and 1951-52. The low points in the middle of each of these lines may be identified with mid-winter catches, and the regular pattern of the points indicates systematic lowering of catchability in the mid-winter months (see page 46). However in each of the years showing low mid-winter catch a number of substitutions were made in the sample fleet statistics because boats regularly used had stopped fishing, and in 1949-50, only incomplete data are available. It has also been noted above (p. 46) that the sample fleet for 1951-52 was entirely different from the regular sample. It appears, therefore, that part of the unreliability of the abundance estimates in these years may be ascribed to a mid-season change in catchability which resulted from a change in the boats used for a sample fleet. It does not indicate a seasonal change in catchability of any one boat.

It may be concluded that estimates of abundance based on statistics of the sample fleet alone, are more reliable than are those of the sample and whole fleets combined. The first seven years data yield more reliable abundance estimates than do those for later years, with estimates for 1949-50 being poorest.

In view of the errors involved in estimating abundance from catch statistics, and especially because of the possibility of systematic variation, which by producing changes in catchability may lead to large errors in the estimates, the final divisions of this section are devoted to an analysis of more direct methods for estimating abundance. Agreement between the results given by the different techniques substantiates the belief that these abundance estimates from catch statistics are of the right order of magnitude.

C. ESTIMATES OF ABUNDANCE FROM SPECIAL FISHING TECHNIQUES

During the summer of 1949 a method of "strip-fishing" of the scallop population was instituted. The method is an adaptation of the "strip-census" employed by timber cruisers in estimating potential cuts on forest plots. The relative size of the scallop population was assessed by catches made in standardized hauls at regular intervals across the beds. Special intensive marking experiments gave estimates of the efficiency of the drags for taking scallops of different sizes, and these results were used to convert the strip-fishing catches to represent numbers of scallops per square yard of bed. Estimates of the size of each of the beds were also made, and from them the numbers of scallops present on each of the beds were calculated. These estimates of numbers of scallops were then expressed as pounds of "meats" present on the beds, so that the estimates of abundance from this series of special fishing techniques could be compared with estimates from catch statistics.

1. Strip Fishing of the Stocks

The strip-fishing method for estimating relative scallop population size was begun in 1949 on three of the main beds, two inshore (Buoy Ground and Broad Cove) and one offshore (Hour Ground). In 1950 it was extended to cover most of the inshore areas, particularly the more heavily fished beds to the extreme west of the Digby scallop area (see fig. 1). In 1951 and 1952, it was necessary to confine the fishing to three inshore areas: Buoy Ground, Broad Cove, and Shelburne Cove Second Ridge, and to 40-Minute Ground and Hour Ground.

In strip-fishing, timed tows were made at intervals across the selected beds. The scallop boat was run to the bed and the position of the start of the first tow determined as accurately as possible by timed runs from a given land mark and by cross bearings to determine final position.

Once the initial position was determined, a 15-minute tow was made in the direction of the tide, which during full flood and ebb parallels the long straight coast line. At the end of this tow the drags were hauled and the boat run back at normal cruising speed to the starting marks. A timed run was then made to one side of the original tow to the starting position of the second. The spacing of the tows varied with the width of the bed, the variability in the density of the population as shown by variations in the catch per haul, and the time available for censusing each bed. The spacing of strip-fishing of the Digby scallop beds, showing average total catch

composition of catch per standard* tow.

	1949				1950				1951				1952			
	Total Catch	size comp. (mm) >100	<100 >75	<75	Total Catch	size comp. (mm) >100	<100 >75	<75	Total Catch	size comp. (mm) >100	<100 >75	<75	Total Catch	size comp. (mm) >100	<100 >75	<7
	298	192	11	25	168	81	61	26	459	172	211	76	544	115	95	334
	165	135	11	19	150	98	36	15	256	146	78	32	341	108	86	149
					204	172	28	4					330	210	59	1
					307	236	56	15	465	295	152	18	519	368	149	2
shore)	357	345	184	8	1,078	686	485	27	785	494	275	26	646	379	251	16
	306	223	69	17	391	242	133	16	494	277	179	38	460	206	154	100

haul is defined as a 15-minute tow with a gang of seven commercial-type drags.

run was usually one or two minutes long. The series of tows was continued until one edge of the bed was reached, then a similar series was made between the first line of tows and the other edge of the bed. If the bed was long, additional series were made at other points across it. This procedure was followed on each of the inshore fishing areas and 40-Minute Ground during the summers of 1950, 1951, and 1952.

The offshore beds are large so that no exhaustive strip-fishing was feasible. However, the distribution of scallops offshore is more uniform and catches less variable than on the smaller, more irregular, rough bottom, inshore areas so that one line of tows from one end of the most heavily fished portion to the other was considered to give an estimate of relative density of the offshore population.

The strip-fishing results are summarized in Table IV. As is to be expected some of the tows were slightly shorter or longer than the standard. Furthermore some were made with a six-drag gang while others employed the more commonly used seven-drag gang. The results reported in the table have been corrected to show the catch of a conventional seven-drag gang in a standard, 15-minute tow. They show that on the inshore areas (no. 1-3) the total catch per tow decreased from 1949 to 1950, but has increased steadily since. This has been accompanied by striking changes in the size composition of the catches so that the great increase in 1952 on Buoy Ground and Broad Cove was due to the increase of small scallops; the large scallops decreased slightly in number. The average number of all sizes on all inshore areas shows a decided increase. The 40-Minute Ground was not sampled in 1949 but its population increased steadily from 1950 to 1952. The trend of population size on the offshore area was opposite to that of the inshore beds. It reached a peak in 1950 and decreased thereafter, although the 1949 results for this area may not have been as accurate as later results. The average population present on the sampled areas increased to 1951 but dropped slightly in 1952 because of the large decrease in the offshore population.

During the strip-fishing a series of timed runs were made over a marked off course. From them it was found that a 15-minute tow with a seven-drag gang covers, on the average, a distance of 900 yards. Since the width of the drag is six yards, each standard tow covers an area of 5,400 sq. yd. This information permits a calculation of the relative density of scallops of each size taken in the strip-fishing from year to year. The relative density estimates may be converted to estimates of actual density of the population, from the results of experiments on the efficiency of scallop drags.

2. Tests to Determine Efficiency of Drags

During the summers of 1949 and 1950 intensive marking programmes were carried out on small areas to determine the efficiency of scallop gear, i.e. the percent of scallops present in their path which are actually captured by the drags. In each year an area of about 12 acres was marked off by buoys and about 10,000

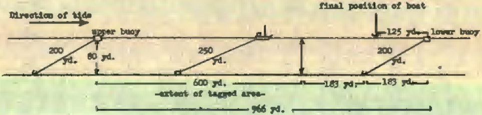


Fig. 14. Schematic longitudinal section of 1949 plot on which marked scallops were placed, showing position of buoys relative to borders of the plot (vertical scale = 1½ horizontal).

living scallops were marked and placed on it. This area was sampled by making drags from one end of the area to the other. A record was kept of the number and size of marked and unmarked animals recovered in each tow and the samples were replaced on the bed. From the ratio of marked to unmarked in each haul estimates were made of the total number of scallops and their average density on the area. Since the area covered by each tow was known, it was possible to determine the number of scallops taken per unit area dragged. Efficiency of drags is the ratio of number taken to number present per square yard.

The actual preformance of the experiments to determine efficiency was beset by many practical difficulties. For example, the size of the marked area was difficult to control because the positions of the buoys marking the boundaries changed with the tide. In practice large metal drums were anchored at the corners of the beds by 3/8 inch wire cable 100 fathoms (200 yards) long. The area was arranged with its long axis parallel to the direction of the tide and the buoys placed so that when the tide was running at full strength those at the "upstream" end were over the upper border of the bed. In this case the other buoys were some distance "downstream" from the opposite border. This is illustrated by fig. 14 which shows a diagrammatic longitudinal section through the water over a marked bed such as that used in 1949. As this diagram shows, to mark off a bed 600 yards long using buoys anchored by 200 yard cables, and in a tide which reverses direction, the buoys must theoretically be placed 966 yards apart. Actually they were placed about 950 yards apart, this distance being closer to that required to mark the area because the buoy cables are catenaries rather than straight lines.

In dragging, a towing cable of about 125 fathoms (250 yards) was used. The drags were let down when the boat was abreast the upper buoys and the tow made in a line parallel to the long axis of the bed. The drags were hauled when the boat was judged to be 125 yards from the buoys at the lower end, by which time the drags were presumed to have towed the whole length of the area.

For the marked population scallops were dragged from areas outside the experimental plots, marked with Volger's Red Ink (a carbolic acid penetrating ink) and scattered as evenly as possible over the area at slack water to prevent tidal currents from carrying them away from the area during their descent through the water. Some of the marked animals may have drifted outside the area, but a number of drags were made around it from time to time and no marked animals were ever recovered in them, indicating that the number of misplaced animals must have been small.

In each of the drags made on the marked off area, numbers of marked and unmarked scallops were recovered. A large proportion had died as a result of the marking so that total mark recoveries are composed of living, cluckers and single shells. The

TABLE V

Efficiency of capture of different sized scallops by commercial gear. Estimated from marking experiment of September 1949 on Buoy Ground.

Size Class (mm)	No. marked released X	Catches marked x	Catches unmarked n	Catches Total n + x	Calculated* No. per 60,000 sq. yd.	Density = No. per sq. yd.	No. encountered per tow 5 drags	No. encountered per tow 7 drags	No. caught per tow 5 drags	No. caught per tow 7 drags	% efficiency 5 drags	% efficiency 7 drags
30-40	1	0	0									
40-50	7	0	1	1								
50-60	27	0	3	3								
60-70	68	0	1	1								
70-80	197	1	29	30	5,910	.098	241	353	1.9	1.3	0.8	0.4
80-90	369	13	19	32	710	.012	30	48	1.2	2.3	4.1	5.2
90-100	1261	40	11	51	1,633	.027	64	97	2.5	4.6	3.7	4.9
100-110	2047	93	110	203	4,495	.075	186	270	11.6	12.3	6.4	4.6
110-120	2466	89	177	266	7,367	.123	303	455	14.0	21.0	4.6	4.7
120-130	2024	77	317	394	10,356	.173	426	623	21.3	29.3	5.0	4.7
130-140	1261	54	500	554	12,937	.217	534	781	28.0	47.3	5.2	6.1
140-150	616	13	208	221	5,406	.090	221	324	12.1	16.0	5.5	5.0
150-160	18	2	8	10	60	.001	3	4	0.4	1.3	13.0	34.7
160-170	1	0	0	0								
Total	10,068	381	1,377	1,758		.816						

Av. efficiency: 5 drag gang = 4.9 ± 0.8%
(omitting 70-80 & 150-160 mm) 7 " " = 5.0 ± 0.5%

*No. per 60,000 sq. yd. = $\frac{nX}{x}$

accuracy of the estimate of population present on the area depends upon the validity of the assumption that all are equally catchable.

a. The Buoy Ground Marking Experiment

Results of the 1949 marking experiment on Buoy Ground are summarized in Table V. A total of 10,068 scallops of different sizes were marked and scattered over an area 600 yards long and 100 yards wide. 17 tows were made on this area, 13 with a gang of five commercial-mesh-size drags and four with the standard commercial gang of seven drags. A total of 1,758 scallops of different sizes was taken in these hauls, of which 381 were marked and 1,377 were unmarked. The captures are divided into 10 mm. size groups in the table.

The actual number of scallops of each size group originally present on the beds may be calculated from the relationship $\frac{N}{n} = \frac{X}{x}$ where N and X are total numbers of unmarked and marked present in the beds and n and x are the numbers of unmarked and marked caught. Since the total area over which the scallops were scattered was 60,000 sq. yd., the average number of scallops of each size present per square yard of area could be determined directly.

Each tow extended the full 600 yd. length of the area. Since the five drag gang has a spread of 4.1 yd. and the seven drag gang a spread of 6 yd., tows by the two types of gear covered 2,460 and 3,600 sq. yd. respectively. The area towed times the number of scallops per unit area gives estimates of the average number of scallops encountered during each tow. Efficiency of the gear was determined directly from the ratio of the number taken to the calculated number encountered per unit area and percentage efficiency of both types of scallop gear is shown in the last two columns of the table.

The results of this marking experiment show that the efficiency of the gear for taking the smallest, 70-80 mm. scallops, is very low, and for taking 150-160 mm. scallops is very high. But these estimates are based on recaptures of only one and two marked individuals respectively and cannot be considered as meaningful results. Estimates of efficiency of capture of size-classes from 80 to 150 mm. are based on recaptures of from 13 to 92 marks each. From these recoveries average efficiency of the five drag gang is 4.9 ± 0.8% and for the seven drag gang 5.0 ± 0.5%.

Estimates of scallop gear efficiency from this experiment may be presumed to apply to all inshore beds since they are all similar in nature to Buoy Ground where the experiment was preformed. These inshore areas are characterized by an irregular bottom on which are found many large rocks. The drags regularly bring up rocks ranging in size from a man's fist to twice the size of a head. Under such dragging conditions it is not surprising that drag efficiency for taking small, flat scallops should be as low as is indicated by the experiments.

However, the offshore area and 40-Minute Ground are, on the average, smoother and large rocks are uncommon, most of them being the size of a man's fist. Efficiency of scallop gear

TABLE [illegible]

Efficiency of capture of different sized scallops by commercial year; Estimated from marking experiment of September 1950 on 40-Minute Ground.

Size Class (mm)	No. marked released X	Catches# marked x	unmarked n	Total	No. per 67,500 sq. yd.	Density No. per sq. yd.	No. encountered per tow	No. taken per tow	% efficiency
40-50	2	0	8	8	-	-	?	.5	-
50-60	3	0	11	11	-	-	?	.5	-
60-70	50	1	111	112	5,550	.082	445.9	4.5	1.0
70-80	445	18	682	700	16,861	.250	1348.4	28.4	2.1
80-90	491	83	738	821	4,366	.065	349.4	30.8	8.8
90-100	499	121	792	913	3,921	.058	313.7	33.0	10.5
100-110	1163	294	1354	1648	5,354	.079	428.8	54.4	13.2
110-120	2350	744	2835	3579	8,878	.132	710.1	118.1	16.6
120-130	3636	883	3008	3891	12,018	.178	961.2	125.3	13.0
130-140	972	181	519	700	2,787	.041	223.0	21.6	9.7
140-150	51	15	12	25	47	.001	3.8	.5	13.2
150-160	1	1	0	1	-	-	-	-	-
Total	9,635	2,339	10,070			.845			

(Total 80 + mm = .554)

Av. efficiency (omitting 60-80 mm) = 12.2 ± 2.47%.

Adjusted to conform with totals in standard hauls on the marked area - see text p. 74-75 and Appendix VIII

under such conditions seems likely to be higher than inshore, a difference which would explain the consistently higher catches per standard haul on offshore areas. To test this hypothesis a second intensive marking experiment was carried out on 40-Minute Ground during the summer of 1950.

b. The 40-Minute Ground Marking Experiment

Results of the 40-Minute Ground marking experiment are summarized in Table VI. A total of 9,635 scallops was marked as before and scattered as evenly as possible over an area 900 yards long and 75 yards wide. A total of 25 tows was made with seven-drag commercial gear to recapture them.

During the course of this experiment considerable difficulty was experienced in keeping the tows confined to the marked area. It was made longer so that tows would correspond more closely in length to those made by fishermen under similar circumstances. However, weather conditions confined dragging to a period of neap tides so that towing speed was reduced and cross winds often carried the boat outside the borders of the area. This happened in 15 out of 25 tows. Of these one was discarded and the catches of the remaining 14 were adjusted to show the catch of both marked and unmarked which should have been made had the tow covered the full 900 yd. length on the marked area. Of this 14, six drags were 900 yards long but were partly outside the marked area so that only numbers of marked recoveries were adjusted in these cases. The remaining eight were shorter than 900 yards and part of the tow was outside the area so that captures of both marked and unmarked have been adjusted. (See Appendix VIII) A total of 1,583 marked and 8,641 unmarked were actually captured but the adjusted totals are 2,339 marked and 10,070 unmarked in 24 tows. The number of marked scallops released and the adjusted numbers of marked and unmarked captured are given in Table VI, grouped into 10 mm. size-classes.

Efficiency of the drags on 40-Minute Ground was calculated from the ratio of numbers taken per standardized haul to calculated number encountered and is given in the last column of Table VI. The results show that only 1.6% of scallops between 60 and 80 mm. present in the path of the drags are retained by the gear, but efficiency of capture of the large animals is 12.2 ± 2.5%. It appears from this that efficiency of capture of large scallops is considerably higher on the smooth offshore areas than on the rough inshore areas.

c. Efficiency of the Drags for Capturing Small Scallops

Both marking experiments indicate that small scallops are taken less efficiently than are the larger. This is to be expected since scallops smaller than 2 5/8 inches can escape through the meshes of the bags. Medcof (1952) has shown further that the proportion of small scallops escaping becomes higher the greater the mesh size. However, on Buoy Ground the efficiency of the drags for taking small scallops cannot be well established from the marking

TABLE VII

Calculation of efficiency of commercial mesh drags for taking small scallops from Buoy Ground - by comparing catches made simultaneously with commercial and special small mesh drags.

Size Group	Average number scallops taken per tow with 6 drag gang: commercial mesh	Average number scallops taken per tow with 6 drag gang: small mesh	Totals above 80 mm (at highest efficiency of commercial mesh): comm.	Totals above 80 mm (at highest efficiency of commercial mesh): small	Number of small scallops available to large mesh if efficient over same size range as small mesh	% small scallops retained by commercial mesh	% efficiency of capture of scallops by commercial mesh
0-10							
10-20							
20-30							
30-40		15			15.1	0	
40-50	6.5	215			198.4	3.4	0.2
50-60	4.7	208			182.3	2.6	0.1
60-70	5.9	11			9.6	51.0	1.6
70-80	49.5	92			80.6	61.4	3.1
80-90	41.7	66					
90-100	11.5	8					
100-110	5.6	7	103.4	118		100	5.0% (estimated from marking experiments)
110-120	26.5	20					
120-130	10.3	15					
130-140	2.8	2					
140-150							

experiments as too few of them were recaptured. The relationship can, however, be judged from the difference in catch between a series of tows using commercial drags with the regular 2 5/8 inch inside mesh diameter and a special drag with a mesh diameter of 1 1/2 inches.

Catches of six Buoy Ground hauls using the two types of gear are shown in Table VII. Six commercial mesh drags caught an average of 103.4 scallops larger than 80 mm. per haul, while the small mesh drags took 118, but commercial drags took only 49.5 of 70-80 mm. scallops while the small mesh drag took 92. According to the marking experiments, the commercial drags take all scallops larger than 80 mm. with about equal efficiency while smaller animals escape. The small mesh drag may be assumed to retain all scallops down to about 40 mm. shell diameter. If the commercial drag had retained small scallops as well as the small drags did, it should have taken $92 \times \frac{103.4}{118.0} = 80.6$ scallops from 70-80 mm. Since it captured only 49.5, it follows that commercial gear retains only $\frac{49.5}{80.6} = 61.4\%$ of this size which enter the drag. The efficiency of commercial drags for taking large scallops on Buoy Ground was 5%, therefore, commercial drags capture $5.0 \times 0.614 = 3.1\%$ of 70-80 mm. scallops present on the beds. These calculations are given in the table which also shows that commercial gear takes 1.6% of 60-70 mm. scallops and only about 0.2% of those between 40 and 60 mm.

These results together with the data from the marking experiments may be used to interpret the results of the strip-fishing.

3. Density of Scallops on the Sampled Areas

Results of the drag efficiency experiments, permit calculation of the density of scallops from samples shown by the strip fishing catches. The strip fishing catches for each bed in each season are summarized in Table IV which shows total numbers caught per haul, and the size-frequency distribution of this catch according to whether the scallops were larger than 100 mm. shell height, between 100 and 75 mm. or less than 75 mm. From these data the number of scallops present per square yard of each bed in each season was calculated as follows: The strip fishing of Buoy Ground in 1950 captured an average of 188 scallops per standard tow. Of these, 81 had shells greater than 100 mm., 81 were between 100 and 75 mm., and 26 were less than 75 mm. Average size of scallops in each of these size classes ~~has been determined and~~ was 121, 89, and 66 mm. respectively. The drag efficiency experiments on Buoy Ground showed that scallops over 80 mm. shell height were taken with 5% efficiency. Each tow is also known to have covered 5,400 sq. yd. Therefore, one scallop greater than 80 mm. taken per standard tow on Buoy Ground represents $\frac{1}{5,400 \times 0.05}$ = 0.0037 scallops per sq. yd. Similarly scallops between 60 and 70 mm. were taken with 1.6% efficiency (Table XII) so that one scallop between 60 and 70 mm. taken per standard haul on Buoy Ground represents $\frac{1}{5,400 \times 0.016}$ = 0.0116 scallops per sq. yd. The drags took 162 scallops greater than 80 mm. and 26 between 60 and 70 mm. therefore the density of scallops greater than 60 mm. present on Buoy Ground in 1950

$$= (162 \times 0.0037) + (26 \times 0.0116) = 0.901 \text{ per sq. yd.}$$

TABLE VIII Calculations of Abundance from strip-fishing and drag efficiency experiments.

Column #1	2	3			4			5			6		
Scallop Bed	Total Area (sq. yd.)	Density = No yard^2			Popul'n-Thousands/Bed			Av. wt. per scallop (lbs.)			Abundance (Thousands of pounds)		
		1950	1951	1952	1950	1951	1952	1950	1951	1952	1950	1951	1952
Regularly Surveyed Areas:													
Buoy Ground	1,560,000	.901	2.899	4.651	1,406	3,586	7,256	.0285	.0266	.0192	40.1	95.4	139.5
Broad Cove	1,620,000	.587	1.200	3.459	951	1,944	5,951	.0459	.0391	.0249	44.6	76.0	98.4
Shelburne Cove (Second Ridge)	1,620,000	.786	(1.045)[1]	1.303	1,273	(1,693)[1]	2,111	.0432	(.0446)[1]	.0459	53.9	(75.5)[1]	96.9
40-Minute Ground	3,780,000	.682	1.004	.813	2,578	3,795	3,073	.0269	.0220	.0232	69.3	83.5	71.5
Hour Ground	31,500,000	2.076	1.636	1.278	65,394	51,503	40,257	.0186	.0186	.0190	1,216.3	958.0	764.9
Total					71,602	62,521	56,648				1,424.2	1283.4	1,170.6
Surveyed in 1950 only:													
Shelburne Cove (First Ridge)	2,450,000	.826			2,006			.0385			77.2	(106.0)[2]	(139.0)[2]
Centreville (Inshore)	1,580,000	1.253			1,981			.0400			79.2	(110.9)[2]	(142.6)[2]
Total All Areas											1,580.5	1507.4	1,452.4

1 Shelburne Cove Second Ridge was not included in the 1951 census, but some estimate of its population can be made from the average of results for 1950 and 1952.

2 At rate of increase the same as Shelburne Cove Second Ridge.

Similarly the density of scallops on Buoy Ground in 1951 was

$(383 \times 0.0037) + (76 \times 0.0116) = 2.299$ per sq. yd.

The density of scallops on all surveyed inshore areas was calculated in this way and the results are shown in Table VIII. A similar method was used for 40-Minute Ground and Hour Ground, using the drag efficiency estimates of Table VI to correct the strip fishing catches. Results of these calculations are also shown in Table VIII.

4. Area of the Scallop Beds

The area of that part of each scallop bed sampled can be determined from the length of each tow and the distance between those tows which determined the edges of the bed. The surveyed areas are listed in Table IX and have been marked on fig. 1. In every case except Hour Ground, the width of the surveyed area is also the actual width of the bed. The beds, however, are long and it was not possible to survey the whole of any one. For example, in 1950 two series of strips on Buoy Ground covered the main fishing area. Each tow was about 650 yards long and the inside and outside edge tows about 600 yards apart. The total sampled area was then 780,000 sq. yd. However, fishermen estimate that there is an additional profitable dragging area about the same size as the surveyed area but to the west of it. Therefore, 2 x 780,000 = 1,560,000 sq. yd. has been taken as the total area of Buoy Ground.

The dimensions of that part of each bed sampled during the 1950 "exploratory" dragging and strip-fishing and the [illegible]

TABLE IX

Dimensions of the principal Digby Scallop beds.

Column 1	2			3	
Name of Bed	Surveyed Area			Total Area	
	Length yds.	Width yds.	Area - sq.yd.	Relative to surveyed and direction of extention	Dimensions sq. yd.
Regularly Surveyed Areas:					
Buoy Ground	1,300	600	780,000	2 x surveyed, extending to westward	1,560,000
Broad Cove	900	900	810,000	2 x surveyed, to west and north	1,620,000
Shelburne Cove Second Ridge	900	600	540,000	3 x surveyed, to east and west	1,620,000
40 Minute Ground	1,800	1,400	2,520,000	1½ x surveyed, to east	3,780,000
Hour Ground	5,000	3,150	15,750,000	2 x surveyed, to east and west	31,500,000
Additional Areas Surveyed in 1956					
Shelburne Cove First Ridge	900	900	810,000	3 x surveyed, to east and west	2,430,000
Centreville (Inshore)	900	1,200	1,080,000	1½ x surveyed, to north	1,620,000

of the whole of each scallop bed is shown in Table IX and fig. 1. The sizes and positions of these have been determined from talks with scallops skippers* and from results of exploratory dragging during 1949 and 1950.

5. Population of the Scallop Beds

From the density of catchable scallops present on each bed in each year, and the total area of each bed, estimates have been made of the total "catchable" population. This is entered in column 4 of Table VIII.

The calculated numerical abundance of the population of the inshore beds was very low in 1950 about 1.41, 0.95, and 1.27 million scallops on Buoy Ground, Broad Cove and Shelburne Cove Second Ridge respectively. The population of 40-Minute Ground was higher - 2.6 million - and on Hour Ground there were 65 million scallops. During 1951 and 1952 the numbers present on the inshore areas increased rapidly, especially on Buoy Ground where there was a five fold increase. On 40-Minute Ground there was an increase from 1950 to 1951 but a slight decrease in 1952. The offshore population decreased by nearly 40% from 1950 to 1952.

In addition to these regularly surveyed areas, two fished inshore areas were surveyed in 1950 but could not be included in the 1951 or 1952 surveys. Estimates of population present on them are available for 1950 and are included in Table VIII. Since they are

* The writer has particularly depended on the assistance and advice of Messrs. Lewis Hudson, Jesse Magarvey, and Robert Longmire in determining the position and size of the scallop beds.

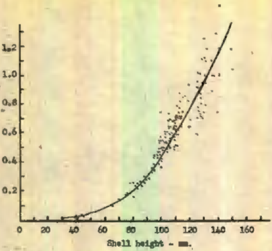


Fig. 15. Meat yield from scallops of different shell sizes from Buoy Ground.

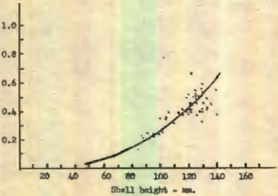


Fig. 16. Meat yield from scallops of different shell sizes from Hour Ground

similar in characteristics to Shelburne Cove Second Ridge, they are assumed to have changed by the same proportion as it did in 1951 and 1952.

These estimates of numerical strength of the scallop population may be converted to weight of scallop meats for comparison with abundance estimates based on catch statistics.

6. Relationship Between Shell Height and Meat Weight

The relationship between the diameter of the shell (shell height) and the meat yield of scallops has been determined. Fig. 15 shows this relationship for scallops from Buoy Ground, and is based on a series of 86 measurements made in September 1948 by Medcof (1949), and an additional series of 80 measurements made by the writer in September 1950. The curve, fitted to these points by inspection, shows a slow increase in meat weight relative to increase in shell size when scallops are small, becoming more rapid between 80 and 100 mm., but remaining almost constant and high thereafter. Fig. 16 shows the shell height to meat weight relationship for scallops from Hour Ground and is based on 46 measurements made by the writer in July 1949. It shows that the meat yield of an offshore scallop is much less than for a similar size of scallop from Buoy Ground, and that this difference becomes more marked with larger shell sizes.

According to fishermen, meat yield from a given size of scallop is about the same on all inshore areas, and although there are no records of the exact relationship available, personal observations confirm this. Therefore, the Buoy Ground measurements are considered to represent all the inshore areas. 40-Minute Ground scallops do not have as high a meat yield as do inshore scallops, and although they are not as poorly meated as are Hour Ground scallops, they are more like them than like inshore scallops. For present purposes the Hour Ground measurements are assumed to be typical of scallops from both the Hour and 40-Minute Ground.

7. Abundance by Weight from Strip Fishing Catches

The relationship between shell height and meat weight may be used to convert numerical abundance of scallops to abundance by weight. The procedure is illustrated by the following example: The 1950 strip-fishing of Buoy Ground showed 26, 81 and 81 scallops having an average shell size of 66, 83 and 121 mm. respectively. Scallops of these sizes have meats weighing 0.0075, 0.0144, and 0.0494 lbs. each (fig. 15). Average weight of scallop meats on Buoy Ground in 1950 was therefore:

$$\frac{(81 \times 0.0494) + (81 \times 0.0144) + (26 \times 0.0075)}{188} = 0.0285 \text{ lbs.}$$

This is entered in column 5 of Table VIII, as is average weight of meats on each other bed in each year. Abundance of scallops by weight of meats is then total numbers times average weight, which in 1950 on Buoy Ground was 1,406 x 0.0285 = 40.1 thousand lbs. Abundance by weight of scallop meats, on each of the beds is given in column 6, Table VIII.

The data of Table VIII show that during the summer of 1950 there was a total of 1,581 thousand lbs. of scallop meats present in the Digby area. Of this total over 1,216 thousand lbs. were present on Hour Ground alone, the remaining 365 thousand being distributed among the inshore and 40-Minute Ground areas. During the subsequent two years the stocks on the regularly strip-fished areas decreased slightly although the total stock appears to have remained almost constant. This steady population has, however, been accompanied by great changes in the size composition of the stocks. In two years the inshore population has increased rapidly, three fold on Busy Ground, double on Broad Cove and nearly so on Shelburne Cove Second Ridge and presumably by an equal amount of the other western beds. The 40-Minute Ground population increased slightly in this time and the offshore population decreased sharply. By 1952 the inshore beds and 40-Minute Ground supported 687 thousand pounds or 46% of the total in contrast to only 23% in 1950.

As has been pointed out above, these estimates of abundance are subject to errors. It is difficult in studies of this kind to detect all sources of errors or to know whether they are more likely to yield overestimates or underestimates of population size. However, the preliminary results of underwater photographic surveys provide a check of the weakest step in the experiments just described: the estimation of population density.

D. CHECKS OF ABUNDANCE ESTIMATES BY SUBMARINE PHOTOGRAPHY

During the summer of 1950 and again in 1952 an underwater photographic survey was made to determine the density of the scallop population of some of the areas sampled in the strip fishing and drag efficiency experiments. Underwater photography was developed initially for use in salvage operations, but has since been adapted for use in marine biology as a technique for "sampling" the epifauna of the sea bottom. Ewing, Vine, and Worzel (1946) described several modifications of an underwater photographic apparatus for taking pictures in deep water. Vevers (1951, 1952) has used a similar apparatus for detailed studies of the bottom fauna in the Plymouth area of the English Channel.

The apparatus used in the present study is described in detail by Ewing, et. al. and was built at the Woods Hole Oceanographic Institute. It consists of a Robot II camera in a water-tight case, mounted near the top of a long pole. Near the bottom of this pole is mounted a reflector for a #5 flash-bulb. The bulb is activated by dry-cells placed in the water-tight camera case, and is synchronized with the camera shutter. From a trigger handle, which projects from the side of the water-tight case, is suspended a heavy weight which hangs below the foot of the pole. In taking photographs of the sea bottom, the whole apparatus is lowered through the water vertically. When the weight hits bottom, it releases the trigger handle, which pushes the shutter release of the camera, sets off the flash bulb and exposes the film. As the apparatus is hauled, the weight again depresses the trigger handle and the camera-spring mechanism automatically rolls the film into position for the second picture, however, it is necessary to haul the apparatus, replace the flash bulb, and lower again before making another exposure.

A systematic census of the scallop beds, like that described by Vevers (1951) was found to be impossible because of technical difficulties with the operation of the photographic apparatus. The adverse effects of the deep water over the beds (40 to 60 fathoms), strong tides, and apparent irregularities in the transparency of the turbid bottom water caused many misfires, exposure failures, and fogged or blurred negatives. Despite these difficulties, however, a number of satisfactory pictures were obtained.

In September 1950 a total of 97 exposures were made on, and immediately surrounding, the 40-Minute Ground marked area. Of these 27 were blurred, fogged or out of focus too badly to be useful for identifying objects on the bottom. Of the remainder, 53 permitted reliable identification of scallops larger than about three inches in shell diameter. A further 17 were clear photographs comparing favourably with those published. In May 1952, 221 exposures were made on Hour Ground and on Shelburne Cove Second Ridge. 36 reliable prints were obtained and another 78 permitted positive identification of scallops larger than about three inches shell diameter. The remainder were too badly blurred or fogged to permit interpretation.

The average density of scallops was determined directly from the average number shown in the successful exposures. The area represented by each negative was known from the size of the reflector and its apparent size in each photograph, from photographs of a calibrated stick affixed to the bottom of the pole and from camera to bottom

TABLE X

Calculations of scallop population density as shown by submarine photography.

Date	Roll No.	Number Readable Exposures	Area photo-graphed sq. yd.	Number Scall-ops	Density No. per sq. yd.	Average Density	Standard Error of Density
1950 - 40 Minute Ground							
[illegible]	1	4	6	8	1.33		
	2	1	1.5	1	.67		
[illegible]	1	6	9	2	.22		
Sept. 18	1	18	27	12	.44	0.52	± 0.54
	2	10	18	6	.33		
Sept. 20	1	12	18	9	.50		
	2	32	48	24	.50		
	3	13	19.5	9	.46		
Sept. 25	1	13	19.5	13	.67		
Total		109	163.5	85			
1952 - Hour Ground							
May 7	1	4	6.4	6	.94		
	2	4	6.0	4	.67		
	3	5	7.5	6	.80		
May 9	4	4	6.0	5	.83		
	5	9	13.5	8	.59		
	6	13	19.5	17	.87	0.72	± 0.14
	7	6	9.0	8	.89		
May 10	9	7	10.5	7	.67		
	10	11	16.5	13	.79		
May 11	11	6	9.0	5	.56		
	12	6	9.0	4	.44		
	12a	9	13.5	4	.30		
May 15	16	7	10.5	12	1.14		
Total		91	134.9	99			
1952 - Shelburne Cove End Ridge							
[illegible]	13	9	12.8	9	.67		
	14	6	9.0	9	1.00	0.81	± 0.41
	15	8	12.0	10	.83		
Total		23	24.5	28			

and reflector to bottom distances. One point five sq. yd. were included in each negative with a camera-to-bottom distance of nine ft., and 1.4 and 1.6 sq. yd. with camera to bottom distances of 8 and 10 ft. respectively.

Numbers of successful exposures per roll of film, total area photographed, numbers of scallops detected, and scallop population density, are given in Table X. The photographs on 40-Minute Ground showed an average population density of 0.52 ± 0.24 scallops per sq. yd. It was pointed out above that in this survey only 17 photographs were clear enough to permit positive identification of small scallops. 53 were so blurred that scallops less than about 80 mm. shell diameter might be confused with other objects. Therefore, this density figure applies only to that part of the population greater than 80 mm.

From the marking experiment on 40-Minute Ground, the density of scallops larger than 60 mm. was 0.85 per sq. yd. Of this total catchable population, the density of that part of it greater than 80 mm. was 0.55 per sq. yd. This shows excellent agreement with the photographic survey result of 0.52 scallops per sq. yd.

The 1952 Bear Ground photographic survey showed an average density of scallops larger than 80 mm. of 0.72 ± 0.14 per sq. yd. The combined drag efficiency experiments and 1952 strip-fishing data, indicate a density of these sizes of 0.76 per sq. yd. which again agrees well with the results of the photographic survey.

The photographic survey of Shelburne Cove Second Ridge in 1952 showed 0.81 ± 0.41 scallops larger than 80 mm. per sq. yd. compared with the strip census result of 1.15. The agreement is not as good here as in the other two cases, but this part of the photographic survey included only 3 rolls, or a total of 34.5 sq. yd. on 23 negatives.

For the close agreement between estimates of population density from the direct photographic survey, and the combined results of strip-fishing and drag efficiency experiments, it may be concluded that the latter, potentially liable to errors arising from several sources have, in fact, given reliable estimates of population density. This indicates that abundance estimates are likely to be of the correct order of magnitude. The greatest sources of error are in the estimation of sizes of the fishing areas and in the estimates of average weight of catchable scallops, but these sources of error seem likely to be small, and are of little or no importance in comparing population changes from year to year.

E. ABUNDANCE ESTIMATES FROM COMMERCIAL RETURNS OF MARKED SCALLOPS

The size of the Digby scallop population may also be judged from the results of a marking programme. In September 1947 and 1948 numbers of scallops were marked or tagged and released by Dr. J. C. Medcof, of the Atlantic Biological Station, assisted by Mr. J. S. MacPhail. Rewards were offered for these and a large proportion of the 1947 marked scallops were returned. Returns of the 1948 tagging were small and of no value in calculating population size.

The September 1947 experiment may be summarised as follows:

		Buoy Ground	Shelburne Cove Area
No. released:	Sept. 1947	150	1,000
Recoveries:	Oct. 1947	47	2
	Feb. 1948	1	18
	April 1948	-	103
Total		48	123
Percent Recovery		32%	12.3%

It is interesting to note that recoveries during the first month of the season were high from Buoy Ground but low from the Shelburne Cove area, and that this situation was reversed towards the end of the season. This shift is indicative of the systematic exploitation of the beds noted in sub-section IVB (p. 21) and shows that the beds nearest harbour are exploited first until catch per unit effort becomes less profitable than fishing on more distant beds. That is, change in catch per unit effort may often represent a change in area fished, but this in turn is determined by the average abundance of the population present on the fishing areas.

It is difficult to interpret the marked scallop returns to make abundance estimates. Many of the returns are of single shells or cluckers, indicating high mortalities despite precautions taken to avoid them. Furthermore the writer, during drag efficiency experiments, found that fishermen, accustomed for years to sorting living scallops from the debris of the catch as quickly as possible, miss the marks on cluckers and single shells unless special precautions are taken to sort all shells very carefully. In addition to this, in the monotonous, mechanical, but extremely rapid shucking process, many fishermen will shuck out a meat and throw the shell overboard before they realize it was marked. Therefore, the ratio of living to dead marked scallops actually caught and that returned is likely to be different, and returns are likely to be low relative to the capture of living scallops. Interpretation of returns is made more difficult because it is not known how much fishing was done on different areas, or how much of the total catch came from the populations into which marked animals had been introduced. All these factors tend to make estimates of population size from marked scallop returns too large. However, calculations may be made and the results regarded in this light.

It is known from monthly reports of officers of the Department of Fisheries that a total of 449 thousand lbs. of scallops were captured in 1947-48. Of this total, 342 thousand lbs. were caught from October to February inclusive, and 107 thousand in March and April. If it is assumed that the first period of capture was confined largely to Buoy Ground and environs, then the population from which this catch was taken was:

$$\frac{342}{N} = \frac{48}{150}$$

from which $N = \frac{342}{0.32} = 1{,}069$ thousand lbs. Similarly if the remaining catch came from Shelburne Cove at its rate of exploitation, population was: $$\frac{107}{N} = \frac{123}{1000}$$

whence $N = \frac{107}{0.123} = 870$ thousand lbs. Total population from which the catch was taken is the sum of these, or approximately 1,900 thousand lbs.

This population "estimate" of 1,900 thousand lbs. is almost certainly too large, but may be compared with the 1947 population estimate made by using DeLury's formula - 1,600 thousand lbs. (fig. 11). The fact that this estimate is lower than the estimate from the tag returns supports the conclusion that abundance estimates based on the DeLury formula are of the right order of magnitude.

F. DISCUSSION OF ABUNDANCE ESTIMATES

The estimates of abundance from catch statistics and special fishing techniques, may be compared.

For 1941-42 the two estimates of relative abundance based on average catch per unit effort are shown in fig. 8. They indicate high abundance that year relative to other years. But estimates based on DeLury's method (fig. 11) indicate that actual abundance that year was lower than average. It appears that price changes may be responsible for this disagreement.

Fisheries Statistics of Canada show that previous to 1940 market price of scallops was low (16¢ to 23¢ per lb.) but in 1941 and 1942 rose sharply (28¢ and 41¢ respectively). Statistics of the American fishery show a similar sharp rise in price. These reports are averages for the calendar year, but the 1941-42 scallop fishing season has three months in 1941 and four in 1942, overlapping the statistical reports, so that the price rise of 1941 and 1942 came into effect during the 1941-42 season. The previous discussion of the seasonal effects of price did not show any direct effect of price on effort from 1943 to 1951 but it seems likely that the rise in price in 1941-42 to nearly twice that to which fishermen had been previously accustomed, may well have influenced their effort. This is indicated by the unusually high number of days which were fished by the sample fleet in that year (fig. 5B).

When extra effort is being put forth by each boat, catch per boat per day during the first part of the season would be expected to be higher than usual relative to the actual population. Seasonal average catch would be lower than initial catch, but may still be high relative to more normal years, depending on how large a proportion of the total population was caught. But the decrease in catch per unit effort, compared with total landings, will depend simply upon the proportion of the stock removed by the effort, so that DeLury's method should give a true estimate of initial abundance whether effort is high or is low, so long as it does not change appreciably during the season. In 1941-42 daily catch per boat at the first of the season was 22% above average, seasonal catch per boat was 13% above average, but actual abundance was 8% below average. It may be concluded, therefore, that 1941-42 estimates of relative abundance were falsely high because price induced greater effort, but that the actual abundance of the population was less than the average for the 11 year period, and is accurately estimated from the DeLury formula.

From 1942-43 to 1949-50 estimates of relative and actual abundance correspond closely but there is consistently closer agreement between the relative abundance estimate based on seasonal catch per boat of the whole fleet and the DeLury estimates (correlation coefficient 0.975), than between relative abundance based on initial daily catch per boat of the sample fleet and the DeLury estimates (correlation coefficient 0.792), despite the fact that both the latter estimates are based on the statistics of the sample fleet. The explanation for this poor agreement between the two sample fleet estimates appears to lie in the fact that the relative abundance estimate was based on catches made at the first of the season and is subject to errors arising from special conditions which held during the first part of the season. For example the 1947-48 tag returns showed that the boats fished principally on Ruby Ground during the first part of the season, and only moved to more distant beds as this population became depleted. This is known to be common practice at Digby, therefore, change in catch per boat at the first of the season may reflect only changes in readily accessible beds close to port. The close agreement between relative abundance estimates based on seasonal catch per boat of the whole fleet and Dalury estimates from the sample fleet must, therefore, reflect the fact that both of these are based on the entire season's catch. It may be concluded that the catches for the whole season must be used if estimates of average abundance of the whole area are to be obtained.

In 1950-51 and 1951-52 there is again a considerable difference between the trend of relative abundance and actual abundance estimates. It was pointed out earlier (page 65) that estimates for these more recent years are not as reliable as estimates for previous years, and so some difference between them should probably be expected on account of sampling errors. However, there appears to be a fundamental reason for this difference, over and above the effects of possible sampling error, which makes examination of estimates for these two years important.

In "normal" years 70 to 90% of the total catch comes from the inshore beds, so that estimates of abundance for the earlier years apply principally to the inshore areas. However, beginning in 1945-46 there was a marked decrease in inshore abundance. At first the fleet continued to fish the inshore beds at the beginning of each season, moving offshore only when it became apparent that profitable catches could not be made otherwise. But in the summer of 1950, the offshore areas were opened to a summer fishery. The result was an increase in fleet size and thorough exploration of the offshore areas, so that when the 1950-51 winter season began the boats continued to fish [illegible] on the offshore areas. Extensive offshore fishing continued in 1951-52, although in the spring of that season it is known that some fishing resumed inshore. It appears, therefore, that abundance estimates which in former years have represented inshore areas, in 1950-51 and 1951-52 represent principally the offshore areas, a distinct change in the average population fished.

It was shown earlier that the efficiency of offshore fishing is over twice that of inshore (12.6% compared with 5.0%). Therefore, offshore catch per boat per day from 1950 to 1952, which is the basis for relative abundance estimates, will be higher than it would be for the same population inshore, although the difference is not as great as indicated by drag efficiency alone because offshore meat weight per scallop is less, and scallops are smaller than inshore. On the other hand, actual abundance estimates based on decrease in catch per unit effort as total catch increases will still depend simply on the proportion of the total population removed whether inshore or offshore populations are fished. It is to be expected, then, that if the fleet shifts from combined offshore and inshore to exclusive offshore fishing, actual abundance of the fished population will be lower than usual, but catch per unit effort will be high relative to the same sized inshore population. The difference in efficiency of fishing on the two areas appears, therefore, to account for the disagreement between the abundance estimates from 1950 to 1952.

This explanation for the change in the relationship between relative and actual abundance estimates in 1950-51 and 1951-52 may be checked by the estimates of abundance based on the strip-fishing experiments. They showed that total population present in the Digby area in 1950 was of the order of 1,580 thousand lbs. (Table VIII), but that the offshore population was 1,216 thousand lbs. of this. The 1950 estimate of actual abundance of fished population from the DeLury formula was 1,230 thousand lbs., (fig. 11) which corresponds closely with this offshore population. Similarly in 1951 the strip fishing showed a total population of about 1,500 thousand lbs. of which 958 thousand were offshore scallops. The total fished population for that year was 969 thousand lbs. From the close agreement between these estimates of offshore and total fished population it can be only concluded that the low abundance estimates for 1950 and 1951 resulted largely from a change in the part of the population fished. That is, relative abundance appeared to be higher than previously because of greater efficiency of dragging offshore, but actual abundance was lower because the fishery was exploiting only that part of the population present on the offshore areas.

It may be concluded from these comparisons that during the period 1941-42 to 1951-52, there have been ~~great~~ moderate fluctuations in the abundance of the stocks fished on the Digby scallop beds. Abundance appears to have fluctuated from about 1.6 million lbs. in 1941 to a high of from 2.6 to 2.5 million lbs. in 1944 and 1945. In 1946 there was a sharp drop in abundance, to about 1.6 million lbs., and the population has remained at about this level ever since. However, during this period of relatively stable total abundance there have been continued changes in the constitution of the population of the beds. The early years of fishing were confined principally to the inshore areas which supplied at least 70 to 75% of the total catch and the drop in 1946 represents mainly a drop in abundance of the inshore population. This inshore population was reduced to such a low level, that in 1950-51 fishing was confined to the offshore area. Detailed data from strip fishing of the stocks indicates that that year the inshore population was only about 20% of the total. In 1950, however, the trend toward decreased inshore abundance was reversed and by 1952 it was more than double its 1950 level, and made up over 45% of the total stocks.

Actual abundance of the stocks was estimated from the DeLury formula for the eleven-year period beginning in 1941. Previous to this the only measure of abundance changes is relative abundance based on seasonal catch per boat. But the above analysis has shown that throughout the eleven-year period the relative abundance estimate corresponds closely with actual abundance with three exceptions which were indicative of special circumstances. Barring similar exceptional circumstances previous to 1941, seasonal catch per boat may be used to show abundance changes back to about 1936. Previous to 1936 it is known that changes in methods of fishing were taking place so that seasonal catch per boat can only be used to show relative abundance from this time to the present.

It remains to discover the factors responsible for abundance changes.

VI CAUSES OF CHANGES IN ABUNDANCE

In common with Digby scallops many species of marine animals have been shown to undergo fluctuations in abundance . In some cases the mechanisms which produce these changes, have been demonstrated. In this section the development of thought concerning these fluctuations, and the volume of evidence which has accumulated to explain them will be briefly reviewed. This background is important for an understanding and interpretation of the evidence which is then presented to show the factors controlling fluctuations in the scallop population.

A. PREVIOUS STUDIES OF FLUCTUATIONS IN ABUNDANCE OF MARINE ANIMALS

The now classic work of Hjort and his co-workers was the first to demonstrate clearly that changes in year-class strength are primarily responsible for fluctuations in abundance of fish populations. They showed that a single exceedingly strong year-class of herring may sometimes dominate the Norwegian herring fishery for several years, resulting in an abundant fishing stock and high catches, while poor broods lead to low abundance and poor catches. Subsequent studies have confirmed that fluctuations in year-class strength are primarily responsible for fluctuations in abundance and have also shown that they can often be correlated with hydrographic conditions during some "critical" stage in the early life history of the year-classes.

Johansen (1927) found a correlation between year-class strength of plaice in the Beltsee and southern Kattegat, and the surface salinity and volume of plankton when the fry were developing. He concluded that in years of high outflow of fresh water from the Baltic the young plaice fry were deprived of nourishment and died en masse. His findings were supported by Jensen (1931, 1933) who found a significant correlation between the strength of year-classes of plaice and the amount of south-west or north-west winds at the time the fry were in the pelagic stages. Buckmann (1936), working on the plaice stocks on the west side of Denmark, could find no evidence for the influence of the availability of food but concluded that success of year-classes there depended upon transport of the early development stages into regions along the coast which would favour further development. Hlegvad (vide Jensen 1937) found that abundance of cod in the Beltsee is correlated with temperature at the time the eggs and larvae are drifting in the water. Hickling (1935, 1946) showed that fluctuations in year-class strength of five-year-old hake off the west and south coasts of Ireland could be correlated directly with surface water temperatures and circulation five years previously. He concluded that high temperatures lead to strong year-classes because they speed development past the "critical" pelagic stage, but that the temperature correlation breaks down if the water circulation which is itself usually correlated with temperature does not carry the rapidly developing larvae into favourable feeding areas. Walford (1938) showed that year-class strength in George's Bank haddock appears to be a function of ocean currents which either keep the drifting eggs and larvae within the main George's Bank circulation leading to strong year-classes and high abundance, or carry them away from the bank leading to impoverished year-classes and low abundance. Walford (1946), working on the Pacific sardine, found that year-class strength in these fishes is correlated with salinity of the water during the summer after they are spawned, and concluded that since salinity is a measure of the upwelling of deep waters rich in nutrient salts, the success of the year-classes probably depends upon abundance of food during some "critical" stage. However, in the same paper he quotes the opinion of Sverdrup that during greatest upwelling, indicated by high salinity, shore eddies are most strongly developed and these may play an important part in enhancing larval survival. The implication seems to be that eddies may hold the larvae in suitable environments and increase their survival, without invoking the vastly complicated problem of changes in the abundance of food.

These examples illustrate the apparently overwhelming importance of conditions during some early period of the life history of fish on year-class strength and abundance. In at least three of the quoted cases available food has been postulated as the mechanism controlling abundance, but in every case water circulation also appears to be involved, and may provide a more satisfactory explanation. This view has many recent proponents, among the most vigorous of whom is Carruthers (1951). He has found that year-class strength and abundance of various food fishes show remarkable correlations with water currents at the time the young fish are present as pelagic larvae.

Before so much evidence was accumulated to show the importance of hydrographic conditions on fluctuations in abundance of marine animals the idea was widely held that the size of the spawning stock was of importance in determining population numbers. It led to the establishment of marine fish hatcheries which have since been largely abandoned, but still persists in regulations governing many sea fisheries of which the Pacific halibut fishery is a well known example. In addition Herrington (1944, 1947, 1948) has maintained that the size of the spawning stock is important in determining the strength of year-classes of Georges Bank haddock below certain population density levels. However, the validity of the evidence that the spawning stock is of any importance to existing population levels of the Pacific halibut has been questioned by Burkenroad (1948), or to the haddock has been questioned by Burkenroad (in discussion of Herrington 1948) and by Kesteven (1950). It seems reasonable to conclude with Huntsman (1944, 1949) that the importance of a spawning stock in causing fluctuations in year-class strength or abundance in North American marine fish has yet to be convincingly demonstrated.

Evidence of the precise mechanisms governing fluctuations in year-class strength and abundance may be obtained from the literature dealing with the oyster and other shallow water lamellibranchs. Spärck (1927, 1949, 1950) showed that remarkable fluctuations in year-class strength of the European oyster (Ostrea edulis) in Limfjord were correlated with summer water temperatures although he concluded that increase in the stocks depended upon a series of warm water years because of the "gregarious" habits of the spat. (see also Knight-Jones 1952). He maintained (vide Korringa 1952) that the height of summer water temperatures control the abundance of oysters because of their effect on several phases of the life history, including: the amount of spawn produced, the survival of pelagic larvae, and the success of sets. Most recent investigations have concluded that only certain of these stages of the early life history are of real importance.

Several investigators have studied the effects of temperature and other factors on egg production and abundance. Loosanoff and Engel (1940), and Loosanoff and Davis (1952) showed that the American oyster (Ostrea virginica) develops normal gametes and spawns within the range of temperatures in which oysters are normally found, but that, if the oysters spawn, the amount of spawn produced depends on the size of the oyster, the depth at which it was found, and possibly on food, but is independent of temperature. Similar results have been obtained with the European oyster (Korringa 1947).

From these observations it appears that if abundance is correlated with temperature, it is likely to be independent of egg production. This conclusion is supported by results of other investigations, which have shown that the number of eggs and larvae produced by molluscs depends upon the size of the parent stock, but that the size of the parent stock or the number of eggs produced bears little or no relationship to the success of the sets or to the strength of the surviving year-class. From such observations, together with those of fish populations reviewed earlier, it may be concluded that abundance depends upon factors which affect the survival of the pelagic larvae. The results of several investigations show that conditions for survival of the larvae are related to water temperature and elucidate the mechanism responsible for the relationship.

Zeuthen (1947) showed that metamorphosis in Asterias and Nassa is not connected with any essential physiological change which would make this period of life a particularly sensitive one. His findings are supported by Cole and Knight-Jones (1949) who regard the larva previous to settlement as especially resistant and vigorous, and by the observations of Thorson (1946) who found that pelagic lamellibranch larvae can postpone metamorphosis for long periods of time until suitable bottom is found. Therefore, great changes in survival of larvae do not depend upon the direct limiting effects of temperature.

The most important action of temperature appears to be its effect upon the length of the vulnerable larval life. Medcof (1939), Needler (1941), Korringa (1942), and Loosanoff, Miller and Smith (1951) have shown that small differences in temperature lead to great differences in the length of the pelagic life of oyster and quahaug larvae. Temperatures only a few degrees below those which produce successful year-classes may slow up development of the pelagic stages so much that most of the larvae are devoured by the myriads of filter feeders in the water, or are dispersed by water currents before they begin to metamorphose and settle. Thorson (1946) has calculated that a single *Mytilus edulis*, filtering 1.4 liters of water per hour may kill 100,000 pelagic lamellibranch larvae in twenty-four hours at maximum breeding season in a Danish fjord. Korringa (1941) stressed the importance of various filter feeders as predators of oyster larvae, but also showed that failures of sets in the Oosterschelde result from the fact that low temperatures retard larval development and permit a large proportion of the veligers to be carried away by water currents.

Food has also been frequently mentioned as an important factor in year-class survival. Thorson (1950) has indicated that pelagic larvae may go for long periods of time without food and survive, but that starvation arrests development as does low temperature so that both are likely to contribute to increased exposure to dispersal and enemies. Loosanoff and Engel also stressed the possible importance of food in prolonging larval life but the experiments of Loosanoff, Miller, and Smith showed that quahaug development is arrested by low temperatures even in the presence of food. Food, is therefore, not necessarily involved in year-class survival but may be, in which case its action appears to be similar to that of temperature alone.

On the basis of this evidence the conclusion seems fully justified that changes in the length of exposure of pelagic larvae to predators and dispersal by currents which follow from changes in temperature alone, or in some cases possibly temperature and food, are the effective mechanisms controlling the strength of year-classes and abundance of lamellibranchs, and fish. An examination of the available evidence indicates that a similar mechanism controls fluctuations in abundance of the giant scallop in the Bay of Fundy.

B. CAUSES OF CHANGES IN ABUNDANCE OF SCALLOPS

The previous section of this contribution demonstrated great changes in the abundance, by weight, of the catchable scallop population. In this section it will be shown that periods of high abundance correspond with periods of recruitment of strong year-classes of scallops into the catchable population, while low abundance results from periods of recruitment of weak year-classes. It will then be demonstrated that the relative strength of these year-classes depends upon the action of water temperature and water circulation on the rate of development and rate of dispersal of the pelagic larvae .

1. Size Composition of Catches in Good and Poor Years.

Samples of the scallop stocks have been taken from time to time since 1937 and show the size composition of the stocks in both good and poor years. Two series of such records are pre-

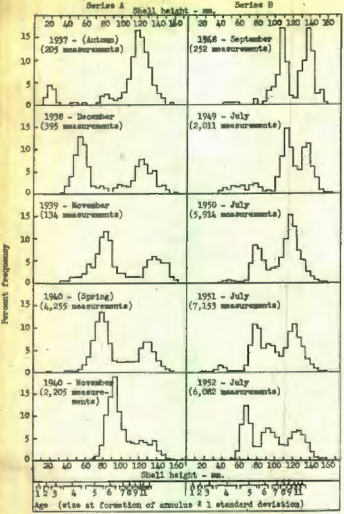


Fig. 17. Percentage size-frequency distribution of catches of scallops from inshore beds off Digby, N.S.

(Catches with small mesh drags from 1937-1939, and with commercial mesh drags in 1940 and from 1948-1952).

sented in fig. 17. Series A shows changes in size composition of the stocks present on inshore beds from 1937 to 1940, a period of rapidly decreasing abundance after the peak year of 1936 and just previous to a slight increase in abundance in 1941. Samples were taken at several inshore stations during the autumns of 1937 to 1939 by Capt. A. E. Calder of the Atlantic Biological Station, using a special small mesh drag. ~~The sample for April 1940 represents measurements of all scallops taken in several hauls using commercial drags~~. The autumn 1940 sample represents measurements of shells of those scallops making up commercial landings.

In 1936 the abundance (by weight) of the catchable scallop population appears to have been the highest on record and samples taken one year later, in November 1937, show that the stocks on the inshore beds were composed principally of scallops ranging in size from 110-130 mm. total shell height, with a size mode of 115-120 mm. A few 15-20 mm. scallops were also present on the beds, but these were much too small to be captured by commercial gear.

The abundance of catchable scallops appears to have been very low in 1938, although there is some reason to believe that it was not as low as is indicated by the relative abundance estimates. December 1938 samples indicate that the modal size of catchable scallops was about 5 mm. larger than in 1937 but that the whole group was relatively much weaker than before. The samples also indicate that a strong size-class of about 45-65 mm. scallops with a mode of 50-55 mm. was present on the beds but these scallops were still too small to be part of the catchable population.

Abundance in 1939 increased slightly over 1938 and the November 1939 samples show that the largest size-class was nearly 10 mm. larger than in 1935 - about 135-150 mm. - but that their numbers were smaller than 1938. However, there was a relatively more abundant class at 70 - 90 mm. with a mode 80 - 85. These were just large enough to form part of the catchable population but still not large enough to be captured with the full efficiency of commercial gear. Also present were a few small scallops between 50 and 70 mm. Samples taken during the spring of 1940 show prominent size-groups at 75-80 mm. and 124-135 mm.; smaller than the previous autumn, indicating that many of the larger scallops had been caught during the winter fishing season.

Abundance in 1940 was about equal to that of 1939 and commercial catches of November 1940 indicate that relatively few large scallops were left in the population. The fishery was, therefore, dependent upon the extremely abundant 80-100 mm. scallops. The unchanged abundance by weight with a slightly reduced stock of large scallops but a much increased stock of small ones is a reflection of the fact illustrated by fig. 15, that meats from 80-100 mm. scallops weigh only about 1/3 those of 125-135 mm. scallops so that the increase of the stock of small scallops did not quite compensate for reduction in the larger animals.

No size composition data are available for 1941 but abundance by weight of scallops was nearly twice as high as in 1940. It appears certain that the increase in weight of the smallest size-classes must be partly responsible for it, however, the discussion of abundance changes indicated that a sharp price rise led to an overestimate of the extent of the actual abundance increase that year.

Series B shows the size composition of inshore catches taken with commercial gear during the summers of 1948 to 1952. Previous to 1948, abundance was rapidly decreasing after a maximum in 1944 and 1945. The first histogram of Series B represents the stock remaining in 1948. Two size groups are clearly distinguishable with modes at 105-110 and 135-140 mm.

In 1949 abundance appears to have been lower than at any time since 1938. The samples taken that year show two size-modes still present, with the smaller shifted to the right but the larger reduced and shifted to the left indicating removal of the largest of the scallops. Only a very few small scallops were added to the catchable population.

The total catchable population in 1950 appears to have been about the same as in 1949 but the strip-fishing indicates that the inshore population probably decreased slightly. The July 1950 samples show a weak stock of larger animals which was reduced to the point where the largest size mode had disappeared. However, a number of small scallops were present on the beds and were just beginning to enter the catchable population.

In 1951, total abundance was still about the same as in 1950 but the abundance of the inshore population was almost double that of 1950. The July 1951 samples show three modes, two of small scallops at 75-80 mm. and 90-95 mm. each of which appear to have been equally as strong as the mode at 120-125 mm. The increase in abundance reflects the addition of these small size-classes to the catchable population.

Finally, in 1952, the results of the strip fishing indicate another great increase in inshore abundance, on Busy Ground nearly double that of 1951, although less spectacular on the remaining inshore beds and with a decrease on 40-Minute Ground and Hour Ground. The samples taken on the inshore beds in July 1952 show three modes, a new and strongest one at 65-75 mm. which was not yet fully catchable and two fully catchable and of approximately equal strength at 85-105 and 120- 135 mm. respectively. Increase in abundance probably reflects the combined growth of the fully catchable and addition of the new, small, but strong size-classes to the population.

These two series of size composition data indicate clearly that when the stocks are composed for a number of seasons of large scallops alone, abundance becomes progressively lower, due undoubtedly to the excess of removals of scallops by fishing and natural mortality over growth. But as new size-classes appear, abundance increases, at first slowly because the meat yield and efficiency of capture of small scallops is low, then rapidly as with growth they become heavier and fully enter the catchable population.

There can be little doubt that the distinctive size-classes in the samples of the scallop population represent age-classes which appear in the population, grow to catchable sizes over a period of years to gradually merge with the larger sized stocks and diminish in numbers as they are fished and die from natural causes. A study of growth rates of Digby scallops confirms this and provides information which can be used to indentify the year-classes to which they belong.

2. Growth Rate of Digby Scallops

The age and growth rate of scallops from the Bay of Fundy can be determined from the number and spacing of the ring markings on the shells. Lines of growth are present as fine concentric striae on the surface of the shell. At intervals the striae are close together giving the appearance of a slightly roughened or thickened ring. Experiments by Stevenson (1936) showed that these conspicuous rings are only formed during the winter when low water temperatures from December to April lead to a slowing or virtual cessation of growth. They therefore represent true annuli and may be used in determining the age and growth rate of scallops.

The annuli of scallops are plainer on the upper or left valve so that it has been used for the growth studies. However, other concentric markings are also present on the shells in the form of "shock" rings, and these must be carefully distinguished from the true annuli. Shock rings become especially common as growth slows during old age, so that annuli past the ninth or tenth are often difficult to detect. The first annuli are also less distinct than later ones, as the winter cessation of growth does not appear to be as sharp in the first year or two of life, and on older shells the part of the shells on which the first annulus is deposited may be badly eroded. In the majority of small and intermediate sized shells it is possible to determine age and size at different ages accurately from the annuli.

a. Establishment of Position of the First Growth Ring

The establishment of the position of the first annulus is of primary importance for the identification of year-classes. Stevenson, from an examination of annuli on shells ranging from 50 to 150 mm. shell height concluded that the first is formed on Digby scallop shells 15 to 20 mm. from the umbo. Welsh (1950), following Stevenson, concluded that scallops along the coast of Maine form their first at about 20 mm. However, from an examination of a number of scallops smaller than were available to these investigators the writer has concluded that they missed the first true annulus.

The size of P. magellanicus at the time of formation of the first annulus can be established from collections of young scallops made by the writer during the summer of 1950 in the Bay of Fundy, and two collections made in Penobscot Bay in 1951 by Mr. Fred Baird of the Maine Sea and Shore Fisheries Laboratory, Boothbay Harbour, Me. The latter generously made his collections available to the writer for study and comparison with the Bay of Fundy Collections.

On September 26, 1950, 53 small scallops were collected from Buoy Ground. These were between 8 and 30 mm. total shell height (i.e. measured along the longest shell diameter passing through the umbo of the left valve -see Appendix IX). Since scallops do not spawn until late autumn, it was believed that these must have represented survivors from the 1949 or earlier year-classes.

Mr. Baird's first collection of small scallops was made in March 1951. He collected detritus consisting of bryozoan and algal growth to which lamellibranch larvae were attached and placed it in an aquarium. It was not examined closely again until the summer of 1951 at which time a large number of small scallops were found clinging to the sides of the tank. The writer examined these in September 1951, retaining 24 of them as a sample. They ranged in height from 7 to 15 mm. (see Appendix IX) and so correspond in size with the Digby collections. The time of their collection excludes the possibility that they resulted from an undetected early summer 1951 spawning, and by comparison confirms the Digby collection as the 1949 or earlier year-classes.

All the examined shells of Mr. Baird's collection show a distinct shock mark at 1 to 4 mm. from the umbo. This mark is in the form of a thin, narrow band of shell overlying the main surface. It is interpreted by the writer as representing the edge of the shell at the time the collection was made in March 1951. It appears that when the animals were collected, the mantle edge, which secretes the outer layer of the shell (Drew, op. cit.) was withdrawn, and when growth was resumed in the tanks the new shell was added from a point behind the former edge. The experiments by Stevenson, showed that annuli are formed primarily during the period January to April so that this shock mark must indicate the position of the first annulus. By comparison, close spacing of striae at about this position on the Digby shells represents their first annulus.

This interpretation of shell growth is confirmed by Baird's December 1951 collection which consisted of small scallop larvae found clinging to bryozoan growth. A large number of shells was collected, varying in height from 0.75 mm. to about 2.0 mm. None of these show markings similar to those interpreted as denoting the first annulus. Drew's findings that scallop veliger larvae average about 1.0 mm. previous to settling, combined with the information from these collections of small scallops, definitely establishes that the first annual growth ring of the 1950 Digby and 1951 Penobscot Bay collections must have been deposited when the shells were at least 1.0 mm. in height and before they were about 15 mm.

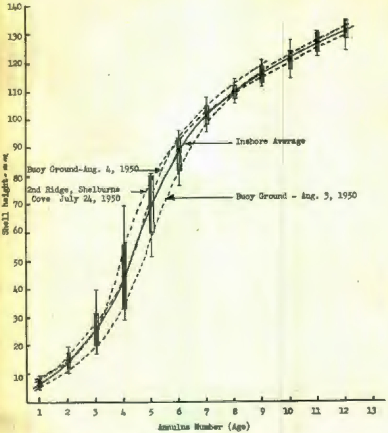


Fig. 18. The growth of inshore scallops.

(Vertical boxes represent ± / standard deviation in size, and the vertical lines the range of total variation in size at formation of each annulus about the general mean).

Examination of the Digby shells shows that it is actually formed at a shell height of from one to seven mm.

b. Growth Rate

2,738 measurements of annuli were made on a number of shells collected from different scallop beds at Digby, N. S. during the summer of 1950 (Appendix X). From these measurements a growth curve for each sample and an average growth curve for the three samples has been calculated and is shown in fig. 18.

The growth curve shows a typical sigmoid pattern with growth rate increasing up to an inflection point which is reached at about 4 years of age, or at about 55 mm. shell height. Thereafter growth rate decreases, and tends toward the upper asymptote, probably between 150 and 160 mm. However, there is considerable variation in size attained at each age. The amount of variation has been measured as the standard deviation of the mean size at formation of the annulus of each year-class about the general mean size at that annulus, and has been marked on the growth curve of fig. 18. Also shown on the figure is the total range of variation in size at each annulus.

The amount of variation in size of scallops at any age appears to be small at first but increases rapidly during the first four years of the scallop's life, when the animals are growing rapidly. Thereafter, the amount of variation decreases as scallops more fully realise the growth potential for the species under growing conditions prevailing in the Bay of Fundy. The range in size, defined by one standard deviation above and below the general mean, does not overlap from one age group to another until scallops are about eight years of age or about 110 mm. in diameter. Therefore, year-classes may be reliably identified for size-modes up to about 110 mm.

3. Correspondence Between Size-Modes and Age-Classes

The average size at formation of each annulus and its variation has been entered as an abcissa on fig. 17, and may be used to identify the modes shown in the percentage size frequency polygons as year-classes.

In series A the 1937 sample shows modes in the size distribution from 15-20 mm., 80-85 mm. and 115-120 mm. Since these were collected in late fall the scallops represented would, according to Stevenson and Welsh, have completed about 75% of the annual growth. From the growth curve of fig. 18 the first mode would be expected to increase 2.5 mm. during the remaining quarter of the growing season, the second 5 mm., and the third 1.5 mm. Therefore, during the 1937-38 winter growth stoppage the scallops represented by these modes would form the 3rd, 6th and 8 to 10th annuli respectively. They are, therefore, 2, 5, and 7 to 9 year-olds, and belong to the 1935, 1932, and 1928 to 1930 year-classes.

Polygons representing the remaining samples of series A, taken from 1938 to 1940 also indicate that the first size-mode

TABLE XI

Seasonal growth of scallops as shown by three hauls from Buoy Ground at different times of the year.

Size Class (mm)	No. of Scallops per tow – 1958 – March 10	July 18	Nov. 15	Average size and variation about it at formation of annulus No.	Proportion of annual growth completed
35-40					
40-45					
45-50	1			4th annulus	
50-55	4				
55-60	19	5			March =
60-65	21	59			$\frac{0}{22.5} = 0$
65-70	9	93	1	5th annulus	
70-75	6	51	16		July =
75-80	2	16	60		$\frac{8}{22.5} = 35\%$
80-85	7	9	37		Nov. =
85-90	21	34	10	6th annulus	$\frac{20}{22.5} = 89\%$
90-95	7	45	5		
95-100	4	25	2		
100-105	5	28	–		
105-110	2	9	1		
110-115	2	6	–		
115-120	5	8	1		
120-125	3	4	1		
125-130	1	6	1		
130-135	3	1	1		
135-140					
140-145					
145-150					

Changing position of modes shows that about 35% of annual growth takes place between March and July but about 90% is completed by the middle of November. (Size frequency composition data kindly supplied by Dr. J. C. Medcof and Mr. J. S. MacPhail) to appear in each may be interpreted as the 1935 year-class while the 1932 year-class becomes merged with the 1928 to 1930 year-classes whose numbers become progressively diminished from year to year.

The first polygon of series B represents a sample of scallops taken in September 1948 and shows three distinct modes at 40-60, 105-115, and 130-145 mm. Comparison of the size modes with the growth abcissa shows that the year-classes in this sample represent animals which would already have deposited their 4th, 8 or 9th and 10th or later annuli, and belong, therefore, to the 1944, 1940, or 1939, and 1938 or older year-classes.

The remaining polygons of series B represent samples taken from the inshore beds during July of each summer. A series of hauls made at different times during 1952 (Table XI) show that by July scallops have completed the annual ring and realised about 1/3 of their annual growth. Therefore, in the 1949 samples, modes at 40-60 and 70-80 mm. are four and five year-olds or the 1945 and 1944 year-classes respectively, while modes at 110-115 and 130-140 mm. represent remnants of the 9 or 10 and 11 or older ages, that is, the 1940 or 1939, 1938 and older year-classes.

The 1950 samples are the first of series B to show a prominent mode as small as 60-80 mm., representing the 1945 year-class. Also present were a few scallops at 40-50 mm. representing the 1946 year-class and the 1939 or 1940 year-classes. The 1938 and older year-classes had largely disappeared.

The 1951 samples show the 1945 year-class as six year-olds, and a new set of five year-olds belonging to the 1946 year-class. Also present were a few of the 1947, and remnants of the 1939 and 1940 year-classes.

The 1952 samples show the 1945 and 1946 year-classes entering the fishery at 85 to 105 mm., another group of five year-olds representing the 1947 year-class, and a few of the 1939 or 1940 year-classes. No small scallops of the 20-40 mm. group, or 1948 year-class were present in the 1952 samples.

Since it was shown earlier that abundance depends upon recruitment of new size-classes into the catchable population, it must be concluded from the correspondence of size and year-classes, that fluctuations in abundance result from differences in the strength of the recruited year-classes. A further analysis supports this conclusion and shows what factors are responsible for differences in strength of scallop year-classes.

4. Correlation Between Temperature and Abundance

Since high abundance depends on recruitment of strong year-classes into the catchable population, while low abundance follow periods of weak recruitment, abundance depends primarily upon factors which determine the abundance of the recruits. Scallops do not become fully catchable until they are larger than 80 mm., therefore, newly recruited year-classes make

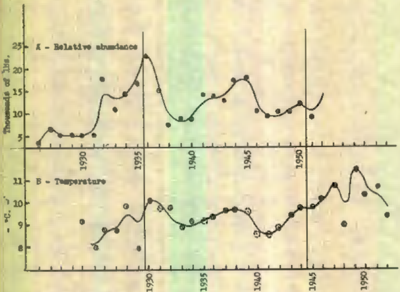


Fig. 19. A. Abundance of scallops as shown by seasonal catch per boat.
B. Average September-October-November water temperatures 90 meters, Prince Station 5, 6 years previously.

(Broken circles indicate that temperature records are incomplete so that the averages are calculated from September observations - see text) their first full, and presumably greatest contribution to the population at the time they pass 80 mm. shell height or at about the time they have deposited their sixth annulus. If, as has been found in previous studies, the size of a year-class is determined at about the time the animals are spawned, then average abundance in any year will be determined by conditions affecting scallop year-classes six years prior to the time they enter the fishery in numbers.

Fig. 19A shows the seasonal scallop catch per boat since the beginning of the fishery. This was shown earlier to be a measure of relative abundance of the catchable scallop population from 1936 to 1950 or 1951. In fig. 19B is shown average temperature of the bottom water of the Bay of Fundy during September, October and November from 1928 to the present, based on monthly observations at 90 meters at Prince Station 5 off the entrance to Passamoquoddy Bay. Conditions at this station are representative of conditions in the Bay of Fundy as a whole (Bachey 1934). Comparison of abundance with temperature shows that high abundance occurs when temperatures were high, and low abundance when temperatures were low six years previously. The correlation between abundance from 1936 to 1951 and water temperatures from 1930 to 1944 (except 1931) is high (0.608 for the 14 years data) and is statistically significant at the 2% level.

The correspondence between abundance and water temperature is so close that it is believed to signify an actual

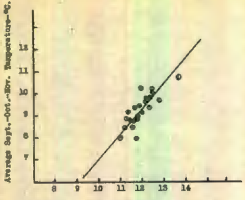


Fig. 20 A. Relationship between St. Andrews July to Oct. surface water and Sept. to Nov. 90-meter water temperatures, Prince Station 5.

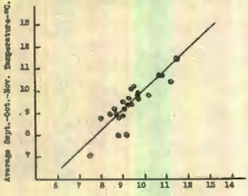


Fig. 20 B. Relationship between September and average Sept. to Nov. water temperatures at 90 meters, Prince Station 5.

influence of temperature conditions on the population. The degree to which this influence is important is emphasized even more if certain deficiencies in the original data are considered. For example it was shown earlier that fleet size for 1938-39 was overestimated so that that relative abundance for 1938 was not as low as is indicated in fig. 19. Furthermore, in 1938 a new regulation was introduced limiting the size of the drags, with the result that the largest boats, which had caught the most scallops, were forced to stop fishing. Therefore, the drop in abundance from 1937 to 1938 was probably not as sharp as is indicated by the abundance estimates, and so agrees better with the trend in temperatures. Furthermore, abundance estimates for 1941 and 1945 were shown to be high relative to other years, as were 1950 and 1951 estimates.

In addition to these errors in estimated abundance no records of temperature are available for Prince Station 5 (P.5) for 1931 and no observations were made there in some of the late fall and winter months during the war years from 1939 through 1945. However, records of surface water temperatures are taken twice daily at the Atlantic Biological Station at St. Andrews, N. B., and fig. 20A show that there is close correlation between temperatures there from July to October and P.5 temperatures for September to November. From this relationship it appears that average September-November temperature at P5 in 1931 was about 9.7°C. and this value has been entered on fig. 19. For those years in which series of monthly observations are incomplete, replacing values were calculated as is illustrated by the following example: No observations were made in October 1939, but the mean of all other October observations was 9.95°C. In 1939 the observed September temperature was 10.10°C., but the September mean was only 9.35°C. The October 1939 temperature was then calculated as $9.95 \times \frac{10.10}{9.35} = 10.05$°C. and the mean for September to November of that year was determined using this value for October. Other missing values were similarly replaced using September records as the indication of average temperature and all such cases of replacement are indicated in fig. 19. That this method of calculating average temperatures gives an accurate indication of the actual average is indicated by the close correlation between the September and average September-November temperatures in fig. 20B.

If the relative abundance estimate for 1938 is disregarded but the estimated temperature for 1931 is included in the comparison, the correlation between abundance and temperature becomes 0.733 compared with the original 0.608. This indicates that if the errors and deficiencies in the data are accounted for the correspondence between trends in abundance and temperature will be even better than is indicated by fig. 19. It may be concluded that conditions controlling the size of year-classes at the time they are spawned, are primarily responsible for fluctuations in abundance of the stocks. This conclusion is supported by a more detailed examination of the scallop stocks in recent years.

5. Year-Class Strength and Water Temperatures.

The strength of recent year-classes may be judged from catches made in standardized hauls during the strip fishing, and the strength of individual year-classes compared with water temperatures at the time they were spawned. Fig. 21 shows the size composition of the catches made in a series of hauls on Buoy Ground from 1949 to 1952 inclusive, by commercial and small mesh drags. Since these size frequency polygons show the average catch of different size-classes per standard haul, the number of scallops in each fully catchable size-class is a direct measure of its relative strength in the catchable population. The commercial catch polygons are each based on a large number of measurements from different parts of the bed, as is the small mesh catch for 1950, so that these may be taken as accurate representations of the size-frequency composition of the stock. The 1951 and 1952 small mesh catches are not as accurate, as they are based on only a few measurements. No small mesh catches were made in 1949.

The 1950 commercial drag catches from Buoy Ground, fig. 21, show a low relative abundance of large size-classes in the catchable population, but a strong 70-90 mm. and a weak 45-55 mm. size-class. The small mesh drag catches which include almost all scallops captured down to about 40 mm. also show the weak larger sizes but indicate that both the 70-90 mm. and 45-55 mm. size-classes are strong. These strong small size-classes represent the 1946 and 1945 year-classes.

The 1950 samples may be compared with the 1949 commercial samples. It appears from them that the 1945 year-class was present in 1949 as 40-60 mm. scallops, and in addition that the 1944 year-class was represented by a weak mode at 60-80 mm. From the small numbers of the 1944 year-class relative to the strength of the same size-class in later years, it must be concluded that it was weaker than the 1945 or 1946 classes and by 1950 was completely overshadowed by them.

The 1951 commercial samples show the 1945 and 1946 year-classes present in some numbers. The 1945 year-class was about equal in strength to the old scallops, but the 1946 class was nearly three times stronger than the older scallops despite the fact the scallops composing it were still not large enough to be captured with the full efficiency of commercial drags. The 1947 year-class was also present as a weak mode. From the 1951 small mesh catches, the 1946 year-class is seen to have been very much stronger than was the 1945 class in 1950. The 1945 class still appears as a strong mode from 95-100, and the 1947 year-class is also strongly represented although it was not yet fully catchable even in the small mesh drags.

The polygon representing the 1952 commercial samples shows that the 1945 year-class which should be about 90-100 mm. is present only as one side of the larger mode at 85-95, but is still about equal in strength to any one size-class of older animals. It is overshadowed by the larger 1946 class, which is still distinct from the exceptionally strong 1947 year-class. The small mesh catch from this year shows that the 1947 year-class was completely dominant in the population. However, only one tow was made with this small mesh drag so that the relative strength of the larger size-classes cannot be accurately judged from its catch. An important feature of the 1952 samples is the complete lack of any indication of the 1948 year-classes.

The samples represented in fig. 21 are all taken from Buoy Ground which has been used to illustrate relative year-class strength because it is the most heavily fished bed, and as a result fluctuations there are more marked and of more importance to the fishery than are fluctuations on other areas. However, fig. 3, which gives the percentage size-distribution of scallops on a number of beds shows that similar strong year-classes are appearing on all the scallop areas sampled. On Broad Cove as on Buoy Ground, they have already entered the catchable population in considerable numbers. Small mesh catches on Hour Ground indicate that they are present in strength there as well, although offshore scallops appear to be slower growing, so that this recruitment is slower to affect the commercial drag catches. The same is true for Shelburne Cove where there has been only a slight increase of small scallops in the commercial catch. Comparison with 1950 catches by small and commercial mesh in Shelburne Cove shows that this slight increase is indicative of strong year-classes which are still too small to be fully catchable.

The relative strengths of these recent year-classes may be compared with the average temperatures at the time they were spawned. Average water temperatures during September, October and November were less than 9°C. from 1940 to 1942 and only 9.5°C. in 1943, and no year-class for 1943 appears in the small mesh samples of fig. 21. However, 1944, with temperatures of 9.8°C., apparently produced a weak year-class which was present in the 1949 samples. In 1945 average temperature was still 9.8°C. and a stronger set of scallops was produced. In 1946, with an average temperature of 10.2°C. the set appears to have been highly successful and in 1947, an average temperature of 10.8°C. seems to have produced one of the most successful year-classes on record. In 1948, average temperature fell sharply to 9.0°C. and no 1948 year-class has yet been represented in any of the commercial or small mesh catches. It appears that this year-class, ~~if present in the population,~~ is very weak. This comparison shows directly that the strength of year-classes is related to temperature at the time they are spawned.

The same correspondance between year-class strength and temperature may be shown for earlier years. The analysis of the percentage size-frequency polygons in fig. 17, Series A, indicated that scallops representing the 1928 to 1931 or 1932 year-classes were plentiful while the 1933 to 1934 year-classes were scarce, corresponding respectively with the high temperature years of 1928 to 1932 and the low temperature years of 1933 and 1934.

1935 also appears to have produced a good year-class but unfortunately temperature records are incomplete for this year. The calculated average shown in fig. 19B indicates an average temperature about the same as for 1934 which did not produce a strong year-class. Possibly the calculated September-November average for 1935 is too low.

It must be concluded from the generally good agreement between relative strengths of year-classes and temperature conditions of the water in the year they were spawned that the success of sets of scallops is dependent upon the influence of water temperature or upon environmental conditions related to temperature at the time of spawning and early life of the scallops. As was pointed out in the review of previous studies, some investigators have maintained that egg production is the important factor which determines year-class strength. Others have found that survival of pelagic larvae is important, while yet others believe that both are important. Therefore, before the mode of action of temperature on scallop abundance can be determined it is necessary to know when spawning takes place and whether temperatures before are after spawning are correlated with year-class strength and abundance.

6. The Time of Scallop Spawning

Stafford (1909) reported that P. magellanicus veliger larvae may be found in the waters of the Maritimes from late July until September, although observations by Stevenson

(1936) indicate that in the shallow water of Annapolis Basin spawning may begin in mid July. Drew (1906) working with scallops off the coast of Maine, found that scallops are generally late spawners and did not observe any important spawning until after August 20 in 1901.

Stevenson (1936) and Welsh (1950) have shown that spawning may be readily detected in scallops by macroscopic examination of the gonads. By this method Stevenson found that spawning in the deep water of the Bay of Fundy in 1934 and 1935 took place in August. Welsh found that on the coast of Maine in 1948 it occurred in late August and early September. The writer has found a few scallops on Georges Bank that had started to spawn as early as June 15 and has similarly found an occasional spawning or spawned scallop in the Bay of Fundy in mid summer. However, in agreement with the observations of other workers, he found that in 1949, 1950 and 1952 the main spawning in the Bay of Fundy occurred during the latter part of August and early September.

On August 24, 1949, scallops in the Bay of Fundy were fully mature and appeared ready to spawn, but examination of the gonads indicated that few of them had done so. No more observations were made until August 27 because of stormy weather, but on that date examination of a large number of gonads showed slightly over 50 per cent. of females and just under 50 per cent of males were completely spawned. By September 13, about 75 per cent of the scallops were completely spawned. This sudden initiation of spawning coincided with the occurrence of the first spring tides of the warm water season (27 foot amplitude at St. John Harbour, N. B.). No temperature records were obtained.

In 1950 scallops in the Bay of Fundy again showed the first signs of spawning following the full 27 foot tides on August 27. Counts on September 6 and September 8 showed between 45 and 50 percent of both males and females had completely spawned and by September 18 only one unspawned scallop was found in over 100 examined. Since water temperature had been at 10. 8°C. from top to bottom since at least August 18 and was the same in early September, it seems unlikely that spawning was initiated by any temperature change during late August or in September.

No further observations of spawning were made until 1952 when the writer made a short trip to Digby on August 19 to find out if spawning had followed the 27 foot tides which occurred the first week in August. It was found that 50% of the scallops had completely spawned and nearly all the remainder showed signs of partial spawning. The fishermen who took the writer to the scallop beds told him that if he had wanted to see the scallops spawning he should have come two weeks earlier when almost all scallops brought on decks were spawning.

Amirthalingam (1928) reported a lunar periodicity in spawning in the Queen scallop, Pecten opercularis, of the

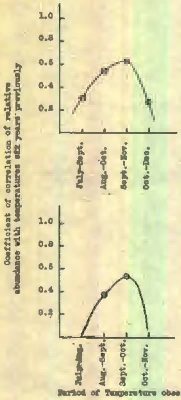


Fig. 22 Correlation between relative abundance of the scallop stocks and running average temperatures for three and two month periods six years previously.

Plymouth region of the English Channel, with maxima occurring on the full moon spring tides. Another possible case of "lunar periodicity" in spawning was reported by Tang (1941) for Pecten maximus off the Isle of Man. A large number of similar cases of relationships between spawning in marine animals and tidal or lunar cycles are reported by Korringa (1947). However, Yamamoto (1951, 1952) could find no correlation between spawning in the Japanese scallop, Pecten yessoensis, and tidal cycles and concluded that spawning was induced by a sudden temperature rise of about 0.8°C, above a critical temperature of 9.0°C. The scanty observations made in the Bay of Fundy suggest that spawning there may be related to tidal cycles and is not related to any changes in water temperature.

From these observations it appears that scallop spawning in the Bay of Fundy usually occurs late in the summer, from early August to early September, that it does not appear to be initiated by temperature changes, and may be related to tidal cycles.

7. Relationship between Time of Spawning, Success of Year-Classes and Temperature

Fig. 22A and B show the coefficient of correlation between abundance of scallops and a series of averages of water temperatures six years previously. It shows that the coefficient of correlation between abundance and average water temperature for July, August, and September is very low (0.303), is higher (0.542) for the three month period August - October, and is at a maximum (0.608) if average temperatures for September - November are used. Correlation between abundance and October - December temperature is again very low.

The period during which temperatures have the greatest effect on abundance can be still better defined if two month temperature averages are considered although the correlations with two month temperature averages are lower because time of spawning may vary by more than a month from year to year. The coefficient of correlation between abundance and average temperature for July and August and October and November six year previously is practically zero but for August and September is 0.377 and for September and October is 0.537. These results clearly indicate that conditions following the August and early September spawning are of more importance for successful year-classes of scallops than conditions previous to spawning. From this it may be inferred that total egg production is of little significance in determining the abundance of scallops and that survival of the pelagic larvae is of great importance. It remains to be shown how temperature may influence survival of pelagic larvae and the size of year-classes of Digby scallops.

8. Relationship between Temperature and Survival of Scallop Larvae.

A number of laboratory observations have been made on the scallops and related lamellibranchs, particularly the oyster, which show the general pattern of events of the early life history and the factors which influence it. These indicate the way in which temperature controls larval survival.

Drew (1906) described stages in the development of the giant scallop larvae. He obtained a large number of fertilized eggs from a suspension of eggs and spermatozoa released by mature scallops into the bottom of a dory. He was successful in rearing them to veliger larvae which remained alive for five days. According to his observations the fertilized eggs settled to the bottom of his container where segmentation was initiated in less than an hour. Gastrulae were formed in 12 to 14 hours, actively swimming trochophores in 16 to 20 hours and veligers in 30 hours. Upon formation of the apical tuft of cilia the trochophores begin to move and the trochophores and veligers swim actively up into the water. According to him, the veligers "swim about actively through the water ... but each individual occasionally retracts its velum between the valves of its shell, closes its shell and slowly settles to the bottom. This is almost always the case whenever the animal is disturbed, as by jarring the dish ... or when the animal runs into anything or is run into by another animal," (page 58). The veligers died after about five days, Drew supposes, of starvation. It is unfortunate that there are no records of the temperatures at which the larvae were kept.

Stevenson (1936) reared a number of scallop larvae at different temperatures and although none survived past the trochophore stage, his observations show very clearly that temperatures may influence the rate of development and survival of the larvae. He found that at 2.2°C. no development took place and that at about 5°C. active trochophores are not formed until the 6th and 7th days after fertilization. Development and survival at this temperature was low. About 33% of the eggs had become trochophores by the seventh day but there was severe mortality after that. At 10°C. 12% of the fertilized eggs had become trochophores in three days and a maximum of 37% was reached in five. Percentage formation of trochophores at this temperature was the highest of the four temperatures used and the trochophores survived for the longest time. At 15.5°C. trochophores were formed by the second day (actually after 43 hours) but only 17% of the fertilized eggs become trochophores and these survived only about one day. It is clear from these observations that rate of development, percentage of eggs developing, and length of survival of trochophores was enhanced by increasing temperatures up to about 10.0°C. Above this, at 15°C, rate of development was more rapid but survival poor.

It may be concluded that temperature may have some direct effect on the survival of scallop larvae to, at least, the trochophore stage. However, according to Stevenson's results, the variations in survival between 5.0°C. and 10.0°C. were not great. It seems unlikely, therefore, that the striking changes in year-class strength which occur regularly at Digby could be produced by the direct effects of temperature on the pelagic larvae. This conclusion is in agreement with the findings of other investigators working on oyster and quahaug larvae.

Of more importance than the direct effect of temperature on survival may be its indirect effect on the length of the pelagic larval stages. The review of the literature showed that heavy losses of oyster larvae are usually attributed to the actions of predators and dispersal by currents. Stevenson's observations that temperature has a decided effect on the rate of early development of the trochophores is undoubtedly true also for the veliger stages. Low temperatures, then, must prolong the pelagic larval life, at which time Drew found them to be actively swimming about in the water, and must increase the length of their exposure to plankton feeders and to dispersal by water currents.

Hachey (1934 and personal communication), and Fish and Johnson (1937) have described the predominant circulation of waters in the Bay of Fundy. There is a current into the Bay on the Nova Scotian side in the Digby area, a north-west flow across it and an outflow along the New Brunswick shore. In some years this circulation is closed and almost wholly within the Bay, and in other years is almost wholly in and out of the Bay. The outside waters from the Gulf of Maine and Scotian Shelf which are available to the Bay circulation are of approximately the same temperature from year to year and therefore differences in temperature of water in the Bay are principally a reflection of the amount of irradiation of the surface, and of the resultant interplay of horizontal transport and vertical mixing. If the circulation of water in the Bay is closed, the surface waters warmed by the sun will be thoroughly mixed and the whole water mass will be warmed. If, on the other hand, the circulation is open, the warmed surface waters will be carried away and the average temperature of the water mass will be low. That is, high temperatures reflect a closed circulation and low temperatures an open one.

The part that such circulation and temperature conditions of the waters of the Bay must play in the success of year-classes of scallops is obvious. Not only will warm waters hasten development of the larvae to the settling stage thereby lessening the chances for them to be swept away by the rapid tidal flow, but warm waters are also indicative of a closed circulation so that dilution of the larvae in the water is confined to the Bay circulation, increasing the chances that they may settle on the beds. On the other hand, cold waters reduce the rate of development of the larvae and are also indicative of an open circulation. This means that at low temperature the pelagic stages persist for a long time and during this time are more likely to be carried outside the Bay and to be lost to the population. It can only be concluded that this combined action of water circulation and temperature is the mechanism responsible for success of year-classes of scallops, and for the correlation between fluctuations in abundance and average water temperatures six years previously.

C. <u>CONCLUSIONS</u>

Fluctuations in average seasonal catch per boat reflect changes in the abundance of scallops. Abundance increases during periods of recruitment of new strong year-classes into the catchable population, and decreases when the stocks are composed of old scallops and recruitment is weak. Abundance and the strength of year-classes entering the fishery is seen to be correlated with average water temperatures during the time when the year-classes are present in the water as pelagic larvae. This indicates that the influence of temperature on the survival of the pelagic larvae is of primary importance in determining year-class success. It is known that low temperatures retard pelagic larval development and are also indicative of periods of greatest exchange of Bay of Fundy water with other water masses, while high temperatures speed pelagic larval development and are indicative of a closed Fundy circulation. It is concluded that fluctuations in abundance and year-class strength are correlated with water temperature because low temperatures expose the pelagic larvae to long periods of dispersal while high temperatures speed development to metamorphosis and are indicative of conditions which increase the opportunity for the larvae to settle on the parent beds.

VII SUMMARY

Great fluctuations in total landings have characterized the scallop fishery in the Digby area of the Bay of Fundy since it began in 1920. Landings were high during the 1927-28, 1936-37, 1941-42, and 1945-46 winter fishing seasons, were low in the intervening periods, and have been low since 1946.

Fluctuations in total landings correspond closely with changes in catch by each boat, indicating that changes in the number of scallops available are primarily responsible for them.

Early fluctuations in total landings were accompanied by changes in fishing methods, and may have been partly produced by them. However, fluctuations are greater than can be accounted for by the influence of these factors, and have persisted since 1938 when the last major changes were made in fishing methods.

Within any one season weather is responsible for much of the variation in catch, but an average seasonal 25% decrease in catch is produced by abundance changes.

Catches from season to season are influenced by weather and price, but these factors are of minor importance compared with the great effects of abundance changes.

It is concluded that abundance changes are primarily responsible for fluctuations in catch per boat and in total landings.

Several different methods for assessing the abundance of the stocks are described and discussed, viz. changes in commercial catches, special "census-fishing" techniques combined with marking tests to determine efficiency of fishing gear, submarine photographic surveys, and a preliminary tagging programme. Abundance estimates from the different methods correspond. The results show that abundance was high in 1936, 1944 and 1945, and is presently increasing, and that abundance was low just previous to 1936, in 1939 and 1940, and from 1946 to 1950.

Abundance is high when strong size-classes, representing strong six-year-old year-classes, are being recruited into the catchable population, and is low when recruitment is weak.

Abundance is correlated with average water temperatures six years prior to the time that year-classes enter the fishery in numbers indicating that abundance and year-class strength are determined by conditions related to water temperature during the early life history of scallops.

Abundance of the stocks and the strength of year-classes are correlated with water temperatures in the months following the time of spawning, indicating that they are determined by conditions related to water temperatures at the time the scallops are present in the water as pelagic larvae.

Rate of development of the pelagic larvae is known to be influenced by water temperatures and is high at the temperatures which have produced strong year-classes. Water temperatures are also known to be related to the circulation of Bay of Fundy waters. Low temperatures are indicative of exchange with outside water masses which may disperse the pelagic larvae, but high temperatures are indicative of a closed Fundy circulation which would retain the larvae in the vicinity of the parent beds.

It is concluded that great changes in abundance of the scallop stocks, which are reflected in the fishery, are the result of the combined action of water temperature and circulation on the success of year-classes. Low temperatures retard development of the pelagic larvae, and water currents at such times disperse them, leading to poor sets, weak year-classes and low abundance of the catchable stocks six years later. High temperatures speed development of the pelagic larvae, and water currents at such times retain them over the parent beds, leading to successful sets, strong-year classes and high abundance of the catchable stocks six years later.

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APPENDICES

Appendix I

Summary of Monthly Total Scallop Landings (lbs.) for Digby and Annapolis Co., N.S.
(Abstracted from monthly reports of the Department of Fisheries - F.S.-ls.)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
1920-21	40	360	1,700	6,820	13,000	7,240	5,400	34,560
1921-22	780	4,440	2,000	720	60	5,080	15,580	28,620
1922-23	17,860	15,000	9,740	6,820	820	11,660	17,120	79,120
1923-24	19,040	12,060	7,420	2,140	2,200	5,400	9,600	57,860
1924-25	9,560	10,440	7,960	3,160	10,000	18,240	9,880	69,240
1925-26	27,720	20,000	11,120	17,140	1,160	18,200	36,160	131,500
1926-27	46,060	52,480	33,820	22,860	25,500	71,720	77,140	329,560
1927-28	110,100	112,560	74,440	50,320	32,900	89,260	66,220	535,800
1928-29	19,580	51,840	46,360	12,600	37,540	46,020	35,460	249,400
1929-30	12,560	55,000	21,980	24,800	34,600	26,040	24,080	199,060
1930-31	9,320	45,140	63,620	83,900	25,660	31,980	25,760	225,380
1931-32	13,980	6,240	13,140	15,940	9,840	20,920	42,600	122,660
1932-33	22,360	44,800	90,060	75,080	49,540	62,060	67,680	411,580
1933-34	45,240	83,320	80,760	53,020	24,000	132,140	92,520	511,000
1934-35	47,640	149,640	77,340	78,490	74,330	134,430	204,080	765,950
1935-36	232,040	114,720	117,260	79,960	126,230	261,950	134,300	1,066,460

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
1936-37	322,010	282,000	227,710	159,600	227,380	272,200	363,400	1,854,300
1937-38	157,930	240,370	232,800	179,740	128,100	198,140	139,650	1,276,730
1938-39	47,200	102,200	101,500	64,590	43,500	49,500	98,250	506,700
1939-40	25,800	57,300	58,150	54,100	46,200	54,350	128,900	308,790
1940-41	47,900	86,550	65,600	53,150	54,100	56,750	83,400	447,650
1941-42	130,000	130,300	81,250	66,250	48,750	103,650	121,850	682,050
1942-43	125,200	100,600	52,800	52,000	62,200	70,850	88,500	552,150
1943-44	72,150	61,100	76,800	85,800	39,000	42,300	116,350	493,500
1944-45	123,500	107,370	42,250	53,600	62,840	146,900	157,800	694,260
1945-46	177,500	163,200	59,900	63,750	44,800	220,600	112,500	842,250
1946-47	178,200	92,400	55,700	49,600	35,700	86,300	37,200	535,100
1947-48	172,500	90,000	37,000	32,500	9,800	64,800	42,600	449,200
1948-49	77,500	85,100	24,500	9,500	3,000	26,200	50,000	275,800
1949-50	45,500	26,600	14,100	14,300	10,800	21,400	46,700	179,400
1950-51	100,200	82,400	28,600	21,000	21,000	53,500	26,500	333,200
1951-52	41,900	21,700	14,400	19,900	4,000	28,500	39,000	169,400

APPENDIX II

Calculations of Fleet Size from Fisheries Statistics of Canada Reports

Report for Statistical Year	County	Fishing Gear: Reported: Total Drags	Fishing Gear: Reported: Total Value $	Fishing Gear: Calculated: Value/Unit Reports $	Fishing Gear: Calculated: No. Sets of Drags	Fishing Gear: Calculated: No. Sets per Boat	Fishing Craft: Reported: Vessels	Fishing Craft: Reported: Boats	Fishing Craft: Additional Calculated: Vessels	Fishing Craft: Additional Calculated: Boats	Reported Fleet Size	Calculated Actual Fleet Size
1923	D	48	4,360	91	48	1						
1924	D	48	4,360	"	48	1						
1925	D	48	4,360	"	48	1						
1926	D	90	3,420	38	90(?)	1						
	D	60	6,108	103	60	1						
1927	A	16	1,890	115	16	1						
	Y	2	150	75	2	1						
1928	D	36	5,400	150	36	1.3	-	27			45	45
	A	18	2,070	115	18	1	18	-				
1929	D	36	5,400	150	36	2	-	18			35	35
	A	17	1,955	115	17	1	17	-				
	D	28	3,500	125	22	2	-	14				
1930	A	14	1,610	115	14	1	14	-			43	43
	Y	-	-	-	-	-	15					
1931	D	28	3,360	120	28	2		14			23	23
	A	9	1,035	115	9	1	9					
1932	D	36	3,600	100	36	(?)	-	-			8	?
	A	8	920	115	8	1	8	-				
1933	D	110	11,000	100	110		-	-			13	?
	A	13	1,700	130	13	1	13	-				
1934	D	118	11,800	100	118		-	-			16	?
	A	16	2,114	132	16	1	16	-				
	D	123	12,300	100	123		-	-				
1935	A	25	3,300	132	25	?	-	-	25		2	27+ ?
	Y	2	250	125	2	1	2					
	D	146	14,150	97	146		14	-	-	25		
1936	A	28	3,696	132	28	1	-	-	28		16	69+ ?
	Y	2	250	125	2	1	2	-				
	D	145	14,500	100	145	4.3	14	24				
1937	A	216	2,592	12	30	1	2	28			70	70
	Y	2	250	125	2	1	2	-				
1938	D	145	14,500	100	145		-	25	14		52	66
	A	168	2,016	12	28	1	28					
1939	D	50	4,000	80	50	2.94	11	6			34	34
	A	102	1,224	12	17	1	17	-				
1940	D	50	4,000	80	50	1.63	25	6			50	50
	A	48	575	12	(8) ?	?	19	-				
1941	D	50	5,750	115	50	1.8	25	3			47	47
	A	48	576	12	(8) ?	?	19	-				
1942	D	40	5,600	115	40	1.3	28	3			39	39
	A	48	576	12	8	1	8	-				
1943	D	38	5,320	140	38	1.3	27	3			38	38
	A	48	576	12	8	1	8	-				
1944	D	35	5,250	150	35	1.2	27	3			39	39
	A	54	648	12	[illegible]	1	9	-				
1945	D	48	7,200	150	[illegible]	1.3	34	3			46	46
	A	9	648	72	9	1	9	-				
1946	D	64	10,800	200	64	1.7	34	3			46	46
	A	9	648	72	9	1	9	-				

Appendix III A

Special statistics of landings and wharf price for a sample fleet of five boats of the Digby scallop fishery - from records supplied by Mr. E. B. Richardson, Manager Maritime National Fish Division of National Sea Products, Digby, N. S.

October 1941-42

Boat No.	1	2	3*	4	5*	6	7*	8	9	10*	11	12	13	14*	15*	16	17	18	19	20	21*	22	23	24	25	26	27	28	30*	31
1			252	336		173		819			583				645	345	54	96		271	516	32	332		392				659	180
2			463	442		140		781			170			196	283	410		18		116	535	44	120		405				779	
3			590	607		153		1017			945			264	381	535	117	204		140	667	84	290		584				851	
4			365	359		95		718			436			187	297	387	45	64		43	336	140	137		370				500	295
5																				294	490	42	323		452		145		605	265

November 1941-42

Boat No.	1*	2	3	4*	5*	6*	7	8	9	10*	11*	12	13	14	15	16	17	18*	19*	20	21	22	23	24	25	26	27	28	29	30
1	638		927		658	656				628	102	70		59											103			322	120	
2	678		400	842						400	500	25		178	271			333	460	90					85			262	51	
3	903		250	680	910					714	723	3		247	402			137	730	164					152			295	164	
4	654		390	712	254	526				505	446	30		185	310			220	293						82			265	118	
5	667		698	534	405	794	310			400	764	225		260	261			530	542	135					167			315	171	

December 1941-42

Boat No.	1	2	3*	4*	5*	6*	7	8	9	10-12	13*	14	15	16	17	18	19	20	21	22	23*	24	25	26	27	28	29*	30	31*
1			865		252						808									230	524								536
2			655		205				66		617				110	246		190			465	50			237		32		778
3			1133		285				119		809				114	310		144			583	95			307		428		
4			816		280						630				83	260		232			460				190		274		380
5			800		305						507				146	160		195				945			345		350		

January 1941-42

Boat No.	1	2	3	4*	5	6	7	8	9*	10*	11	12	13	14	15	16	17	18	19	20	21	22*	23	24	25	26*	27	28	29	30	31*
1	459				90	200										100	225						572	90		325		300			
2	360					130	10										45						482	40		233		220			
3	1165					335	13										87						580	49		158		405			
4	455					245	10										105						423	35		210		360			
5	1025																76						665	80		380		535			

February 1941-42

Boat No.	1	2	3	4	5*	6*	7	8	9	10	11	12	13	14	15	16	17	18	19*	20	21	22	23	24*	25*	26	27	28
1		550			775														319						766			
2		263			918														412					310	14			
3		235			935														477					465	17			
4		184			810														425					280	21			
5		200			685														305						677			

March 1941-42

Boat No.	1*	2*	3	4	5	6	7	8*	9	10	11	12	13	14*	15*	16*	17	18*	19	20	21	22	23*	24	25	26	27	28	29*	30*	31
1		790	41	205	206	322						47		655		500	395	390	200				82	300						518	17
2	40	378	13	170	98	230						62		310		260	345	220	260					225						385	
3	47	510	75	290	265	375						122		575		565	520	325					110	300						297	
4	49	370	50	257	158	140						55		382		442	235	283	180				255	107						265	
5	394	605	132	302	130	420						148		305			260	445	604				380	350						490	89

April 1941-42

Boat No.	1	2	3	4*	5*	6*	7*	8	9	10*	11	12	13	14*	15	16	17*	18*	19	20*	21	22	23*	24*	25*	26	27	28	29	30
1	261 ——→					472	375	22		250				360	120		635			510	230		475	265	260			150		
2	230 ——→					395	372			275				330			444	130		405	140		400	310	240			34		
3	252 ——→					330	305	71		390				410			680	135		400	182		510	400	350			43		
4	200 ——→					170	433	55		310				322			420	150		170	173		422	270	260			33		
5	470 ——→					570	450			400				505	230			870		500	250		495	410	350			185		395

October 1942-43

Boat No.	1*	2	3	4*	5*	6	7	8*	9	10	11*	12	13*	14*	15*	16	17*	18	19	20	21*	22	23*	24*	25*	26	27	28	29*	30	31*
1	610				230	164	375	575	129	45			518	430	800		840				470		435	540					675		
2	593				325	71	240	450	113	110			810		700		623				412		550	400					600		
3	684				403	130	295	565	163	129			1050		860		750				730		600	420					730		
4	428				160	60	195	390	155	102			590		530		525				455		353	125					500		
5	655				102	145	270	545	160	65			550	275	610		590				585		325								

November 1942-43

Boat No.	1*	2	3*	4	5*	6*	7*	8*	9*	10	11	12*	13	14*	15	16*	17*	18*	19*	20*	21	22*	23	24*	25	26	27*	28	29	30*
1			920	530					155	250		675						1110		305			133	1013			770	100		
2																		205		420			110	650			750			
3			875	525						210		250					175	298		305			120	990			780			
4			540	375						142		250					440	275		294				470			540			
5																											515			

December 1942-43

Boat No.	1*	2	3	4	5	6	7	8	9*	10*	13*	12*	13*	14	15	16*	17	18	19	20	21*	22*	23*	24*	25*	26	27	28*	29*	30*	31*
1	690									865		294										32						544		395	37
2	470								127	368		255										21		174				440		395	88
3	525								380	318	370													425				490		410	
4	405								125	305		224												257				375		348	
5	540								265	274														234				410		275	280

January 1942-43

Boat No.	1	2	3	4	5	6	7	8	9*	10*	11*	12	13	14	15	16	17	18*	19	20	21	22	23	24	25	26*	27	28*	29	30*	31*
1				145							1324			670				589												850	
2									14					257				255								51		38			
3				138					129		640			180				260								25		55			
4				95					224		462			175				320								25				330	
5				130					218		405			262				491												340	

February 1942-43

Boat No.	1	2	3	4	5	6*	7	8	9	10	11	12	13*	14	14	15	16	17	18	19*	20	21*	22*	23*	24	25	26	27	28
1	558			213									397										515	619				632	
2						323				148			354										620	510			355		
3				241		153				294			408										831	686				457	
4	84			174		235				157			260										375	390				315	
5	385			163		435					31		241										139	300				461	

March 1942-43

Boat No.	1	2	3	4	5	6	7	8	9	10	11*	12*	13*	14	15*	16	17	18	19	20*	21	22*	23	24	25	26	27	28	29	30	31
1	37	403								960		644			285			254		1363		450				623			96	540	
2	45	221								642		249			128			162	338			296			465				62	348	
3	47	300								775		204			215			299	600			543			465				60	411	
4		103								551		112					127	124	359			211			295					236	
5	41	150								584		322			249			197	570			332			390	246				195	

April 1942-43

Boat No.	1	2*	3	4	5	6	7	8*	9	10	11	12	13	14	15	16	17	18	19	20	21*	22*	23*	24*	25*	26	27	28	29	30
1	186	489			151			390	460							102			767				556					27		
2	122	376	~~90~~		183			720								410			654				480					30		360
3	132	~~440~~	69		142			743	370							539			774				748					71		535
4	190	~~399~~	212		55			372	284							211			562				450					30		425
5	154	265	181		144			525	260							337			245											

October 1943-44

Boat No.	1*	2*	3	4*	5	6	7*	8*	9	10	11*	12*	13*	14*	15*	16	17	18*	19*	20	21	22*	23	24	25	26	27*	28*	29	30	31
1																				317			337			448					
2	576	513		51				688	121		505		635					430	71							30		50			
3	700	406		70				930	132		540	54	700	260				421	66							102		40			
4	350	275						475			269	52	570	232				302	20							70		73			
5	375	146		74				638			331	130		789				310										28			

November 1943-44

Boat No.	1	2*	3*	4*	5*	6*	7*	8*	9	10*	11	12	13*	14	15	16*	17	18*	19*	20*	21*	22	23	24*	25*	26*	27	28	29	30
1						700		979		480			371					430	356	964					1016				611	
2	462 →		300			357		566		443								127	140					219	280	333				
3	247 →		402			544		518		485			139					150	287	304				199	290	410				
4	230 →		136			368		429		450			151					69	270	302				205		405				
5	236 →		278			494		286		393			77					139						142	200					

December 1943-44

Boat No.	1	2	3*	4*	5	6	7	8*	9*	10	11	12	13	14	15	16*	17	18*	19*	20	21	22	23	24	25*	26*	27*	28	29	30*	31*
1	138					1125			-860		367					140		562									346				
2			435					367	84		129																95				445
3			590					608	135		131																389			405	610
4			428					518			69																				
5			495					324																			154				697

January 1943-44

Boat No.	1*	2	3*	4*	5*	6*	7	8	9	10	11*	12	13	14	15	16	17*	18*	19*	20*	21*	22	23	24	25	26*	27	28	29*	30	31
1	704		252		1005		560				375		133				208		560	417	1033					552			380		
2				479							334	30					80	630	140		430					549			245		
3				800							314	17					113		1045	84	500					623			160		
4	115			144			321					125						500			161					263			272		
5	676 →										77							193			48					290			270		

February 1943-44

Boat No.	1	2	3	4	5*	6	7*	8	9*	10	11*	12	13	14	15	16	17*	18*	19	20	21	22*	23	24*	25	26	27*	28*	29*
1	107				243		400		250	364				345			415					400							
2					288		467		179		250											63						90	667
3					305		443		223		276						306					122							540
4					255		326		170		279						48					112							695
5					118		225		150		243											198							339

March 1943-44

Boat No.	1	2	3	4	5	6	7	8	9	10	12*	13*	14	15	16*	17*	18	19	20*	21	22*	23	24	25	26*	27	28	29	30*	31
1			650				357					115			270	278			407	130	132	111					291			256
2							97					130			255					268	55					88	133		201	
3							100					113			193					290	74					90	94		244	
4							73					75			285						38					52	52		160	
5															91					129	81								73	

April 1943-44

Boat No.	1	2*	3*	4	5*	6	7	8*	9*	10*	11*	12*	13	14	15	16	17*	18*	19*	20	21*	22*	23*	24*	25	26	27	28	29	30
1			411	265	845			570		422		420						434			782	415		421			533			
2	36		16	328	445	114		532		295	524	249							609		767	755		828			515			
3			13	370	560	147		529		228	539	221							547		1050	802		650			587			
4				113	254	43		400		74		87							270		386	330		122			500			
5			551	122	328			71		129	289								267		444	608					390			

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October 1944-45

Boat No.	1	2	3	4	5*	6*	7	8*	9*	10*	11*	12*	13*	14	15	16	17	18*	19	20	21*	22	23	24*	25	26	27	28*	29	30	31
1					544	794	409		664	670	541	679	279	420			272	720		555	397				835	643					
2					894	752			522	530	474		275	110			76	718		241	266			622	19	387					245
3					906	682			518	510	520	538	274	110			108	757		291	160			569	682	21					240
4					716				325	406	474	378	56	188			40	470		198	144			379	448	42					
5					200	249						426	182	43			38	193		282	141				408						225

November 1944-45

Boat No.	1	2*	3*	4*	5*	6	7	8	9*	10*	11	12*	13*	14*	15*	16*	17	18	19	20*	21	22	23	24*	25	26	27*	28	29	30
1	265	~~686~~	1200	530						1111				928		697				552	483			588			643		856	
2																								240			560	52		
3		~~783~~	~~685~~	649						791				622	528	262				94				308			661	111		
4																								192			315	121		
5		147		872						956																				

December 1944-45

Boat No.	1	2	3*	4	5*	6*	7*	8*	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23*	24*	25*	26	27	28	29	30	31*
1						1384			620		789									126											
2					533	128		516											7												
3					500	148		872											65									59			
4						783		671			189								54												
6					678	250	97	665											70									90			

January 1944-45

Boat No.	1	2	3	4	5	6	7	8	9*	10*	11*	12	13	14	15	16	17	18	19	20	21*	22*	23	24	25	26	27	28*	29*	30	31
1	280			692						230			842						271			812	800						868		
2			498	135								86	273		47	125						617							435		
3			332	217								217	222			104						772							290		
4			257	170								112	136			249						640							430		
5			50									117	185			57						164							355		

February 1944-45

Boat No.	1	2	3	4	5*	6*	7*	8	9	10*	11	12*	13	14*	15*	16*	17	18*	19	20*	21*	22*	23*	24*	25*	26*	27	28
1					1052					1925						1075			620			960				696		
3					129		180							39		414				526		236				686		
2					252		135							31		268				375		409				588		
5							98										366											
4							335			246				170		503				444		269				536		

March 1944-45

Boat No.	1*	2*	3*	4	5	6	7	8*	9*	10*	11*	12*	13*	14*	15	16*	17*	18	19	20*	21	22	23	24	25	26	27*	28*	29	30*	31*
1		1078	352		250				874	346		855		380		687	655		667	755						281	483	613	254	640	524
2			302		120			413	31			615		320		217			112	500						83		278		517	370
3	395	160	350		138			642	477			710		500		260			136	650						381	272	217		466	387
4	425		497					459	394					391		165	400			648						310		311		536	
5	305	182	49		17			288	259			400		27		100				360						170		6		325	

April 1944-45

Boat No.	1	2	3	4*	5	6	7	8	9*	10*	11	12*	13*	14	15	16*	17*	18	19	20	21*	22	23	24	25*	26*	27	28	29	30*
1		236		412			50		512	532	252	509	305			636			356	396	645			272		1250	252			1024
2				100			160		405	361		413				504			200		125									500
3				160			228		318	397		372	534			590			327	130	174				685	158	105			445
4				140			138			785		430				506			280	93					262	249	66			
6		143		203			211		395	381		400	207			298			267	134	137				667	270	88			386

October 1945-46

Boat No.	1*	2	3	4	5	6	7	8	9	10*	11*	12*	13*	14	15	16*	17*	18*	19*	20	21*	22*	23	24	25*	26*	27	28	29	30	31
1	529					1025			444	375	795				640	189		617	390			645			389	381			321		
2		301			27	613			538	137	780				69			376	1202			365			317				232		
3		510			48	779			618	420	908					98		913	846			503			248				406		141
4		338				545			489	318	477					37		534	1003			540			108				201		48
5		317				712			518	252	812					49		640	451			559			226	203			268		

November 1945-46

Boat No.	1	2*	3	4	5	6	7*	8*	9*	10*	11*	12*	13*	14	15	16	17	18*	19	20	21	22	23	24*	25*	26*	27*	28	29	30
1		678	359				976	360				1499					200					367		307		836		789		
2		482	131				603	265				518										202				652		366		
3		728	477				790	374				376		104								356				770	204	416		
4		557	230				658	481				696		380								303				543		505		
5		441	405				766	178				1120		320								300		131		595		442		

December 1945-46

Boat No.	1	2	3*	4*	5	6*	7	8	9	10*	11	12	13	14	15*	16*	17	18	19*	20	21	22	23*	24	25	26	27	28	29	30	31
1			879			420				410				498	395						60								922		
2			335			365				220				60	353														177		
3			460			456				385				83	356														262		
4			325			263				300				106	170														264		
5			332			277									351																

January 1945-46

Boat No.	1	2	3	4	5*	6	7	8	9*	10*	11	12*	13	14	15*	16	17*	18*	19	20	21	22	23	24	25	26	27	28*	29	30	31
1			191						445	108		190			660			985			327							300			
2									248			214					218	181	41												
3									240			120					134	202	47												
4									347	83		114						254	51				116	25							
5									118	261		92						143						28							

February 1945-46

Boat No.	1	2	3	4	5	6*	7	8	9*	10	11	12	13	14	15	16	17	18	19	20	21	22	23*	24	25	26	27	28*
1	118	282				461			410							125							644					
2						177			323			77	40			79							99					
3									442			157	61			102							170					
4							128		303			99	69			99							112					
5						127			233			304																

March 1945-46

Boat No.	1	2*	3	4	5*	6*	7*	8*	9	10	11*	12	13	14	15	16*	17*	18*	19*	20*	21*	22	23	24	25*	26*	27*	28	29	30	31
1	660	-272				-952		922			421					778		653	528		867				530	500		266	667		
2	247	378			112	217		559			173			505	197	575		500	116		635					220			563		
3	358	435			71	216		788			245			44	215	639		608	115	345	627				323	392			582		
4	390	-293			-196	175		530			165			401		446		450	240	265	467				218	160			376		
5		519				156		378			220			380		418			438	124	265				249	199			275		

April 1945-46

Boat No.	1*	2	3	4	5	6	7*	8*	9*	10	11	12	13	14*	15	16	17	18	19	20	21	22	23	24*	25*	26*	27	28	29	30*
1		400	103						990						184			371		672			450	657	302				670	400
2		-81		150				372	438						143			229		267				327	135				414	150
3				176				262	487						134			242		314				255	175					65
4		-65		199				270	390						98			231		213				167	111				286	70
5								553										150		176				226	77				173	127

October 1946-47

Boat No.	1	2*	3	4*	5*	6*	7	8	9*	10*	11*	12*	13	14	15*	16*	17	18	19	20*	21*	22*	23*	24*	25*	26	27*	28*	29	30	31
1		-230		554			684		470	777	485	390			605	382					766	638	766	375	510			532			
2	1	173		307	398		266		187	63	525	218			224	302					572	521	518		346						
3		293		468	619		625		371	491	660	241			558	330					687	598	525	210	486						
4	6	242		226	389		396		206	381	256	196			434	154					-530	437	410	161	317						
5		194		290	326	615	380		190	388	784				580	225					1062		260	738	355						

November 1946-47

Boat No.	1	2	3*	4*	5	6	7	8*	9	10	11*	12*	13*	14*	15	16	17*	18	19*	20*	21*	22	23	24	25	26*	27	28	29*	30*
1		535		396				774			439			1057					131							150			53	
2				158				278			21	69		419					110		206					150				
3		257		356				379			390	118		584					166		159	565				360				139
4				189				318			298	96		500					138		240					294				70
5				288				290			270			442					186							376				

December 1946-47

Boat No.	1*	2	3	4	5	6*	7	8*	9*	10*	11	12	13	14	15	16	17	18*	19*	20*	21	22	23	24	25*	26	27	28	29*	30	31*
1		267			314		663			500										560											
2		31			183		145																								
3					332	510	100		26	255		259					94			588											
4					250	254	62		31	193		90					114			390											
5					180	347														331											

January 1946-47

Boat No.	1	2*	3*	4*	5	6	7	8	9	10	11	12	13	14*	15*	16*	17	18	19	20*	21	22	23	24	25*	26*	27*	28	29	30*	31
1	184			255							118			638		466									510		505	264		406	
5														332		222											110			192	
6																												98		246	
7														500		471				64										198	
8											29			382		255				15					288		57	112		256	

February 1946-47

Boat No.	1*	2	3	4*	5	6*	7*	8	9	10	11	12	13	14*	15*	16*	17	18	19	20	21	22	23*	24*	25*	26	27*	28*
1															801										152			
3																									286		258	
4																									225		190	
5															254	174												
6				75											296										231		75	

March 1946-47

Boat No.	1*	2	3	4*	5*	6*	7	8	9	10	11	12*	13*	14	15	16	17*	18	19	20	21	22	23	24*	25	26	27	28	29	30	31*
1	795				250							436	252				436			366	184			650					163		
3	108				286	203						500	546				522			259	128			441	110				380		
4	67				244							488	289				260			231				505	45				236		
5	395				94								156				181							166					117	67	
6	275				298	195						410	367				322			266	152			451	106				380		

April 1946-47

Boat No.	1	2	3	4	5*	6*	7	8	9*	10*	11	12	13	14*	15*	16*	17	18	19	20*	21	22	23*	24	25*	26	27	28	29*	30
1					211													122				360	235							284
3					73									251		250	44	127					22							
4					28									165		185	24	153				50	180							
5					562				272	150				367	74		52	159				40	263							17
6					296				165	63				262	165	74	40	97		131			141							97

October 1947-48

Boat No.	1	2	3*	4*	5	6*	7	8	9	10*	11*	12*	13*	14	15*	16*	17*	18*	19*	20	21	22	23	24	25	26*	27*	28*	29*	30	31
1		238		309	241			17		599	555		218		781	239		234		179			40				386	153			
3		560	617	230			78	80		915	504		492		657	397	587	307		520			110		49		494	255	86		
4				158						522	215		206		258	250	231	245		120			64		14		151	189	58		
5		510	463	584			40			680	384		330		478	728	195	276		669			239		21		509	347	170		
6		560	545	248			50			197					470	441	313	389		462			304		59		445	365	42		

November 1947-48

Boat No.	1	2*	3*	4*	5	6*	7*	8*	10	11	12	13	14	15	16	17	18	19	20*	21	22*	23*	24*	25	26*	27*	28*	29*	30
1			335	500			240	354													240		115				190		
3			522	410				369		344											386		315		376		484		
4			249	250				224		121											295		237		274		395		
5			367	471				218															205		386		496		
6			440	520				304		300											249		364		408		494		

December 1947-48

Boat No.	1	2	3*	4	5	6	7	8*	9	10	11*	12	13	14	15	16	17	18	19	20*	21*	22*	23*	24	25	26*	27	28	29	30	31
1	50		340								241				170											350					
3	87		180																												
4	60		215								150				104																
5	38		162								191																				
6	80		225								284				179																

January 1947-48

Boat No.	1	2	3	4	5*	6	7*	8	9*	10	11	12	13	14*	15*	16*	17	18	19	20	21	22*	23	24	25	26	27	28	29*	30	31
1						182				205		168		236			406													185	
2												122		122															70		
7									56			48		88																	
9						368				112		156		176			286														
10						402						65					52														

February 1947-48

Boat No.	1*	2*	3	4*	5*	6*	7	8	9	10*	11*	12	13	14	15	16	17	18	19	20	21	22	23	24*	25*	26	27	28*	29
1						260				224	193						24		170										
2		98			57																			185					
3																								126					
4																								100					
6																								120					

March 1947-48

Boat No.	1	2*	3	4*	5	6	7	8	9	10*	11*	12	13*	14*	15	16	17	18*	19	20	21*	22	23*	24*	25	26	27	28	29	30	31*
1		400								160								234	190				282								280
3		94		352						200	29							240	134			81	296			250					335
4		336		285						110	13							160				93	210			185					255
5		274		280						154	60							228				61	310			240					317
6		337		290						210	47							256	180			106	402			240					382

April 1947-48

Boat No.	1	2	3	4	5	6*	7*	8	9*	10	11	12	13	14*	15	16	17	18	19*	20*	21*	22*	23	24*	25	26	27	28	29*	30*	31
1					95		248									251			98			346	360	255					295		
3					234	96																									
4						425		25			21		256	362		135			40			105	44	191					302	135	
5					340	360	443		50				512	418		423			265			389	152	235					341	308	
6					204	186	230	46					305	357		348			235			368		255					233		

October 1948-49

Boat No.	1*	2	3	4	5	6*	7*	8*	9	10*	11*	12	13	14*	15	16*	17*	18	19	20	21*	22*	23*	24*	25	26	27	28*	29*	30	31*
2							338	255			156		109			55						105						263	15		
4	477				148		406	501			240		107	90		323						341	243					329	14		
5	372					609	399	442			406		134			304						345	195					321	33		
6					280	253	457	342			301		104	104		346						365	190					358	10		
11	310				152		104	292			240		58	61		317						187	209					252			

November 1948-49

Boat No.	1	2*	3*	4*	5	6	7	8	9*	10*	11	13*	14	15*	16	17*	18	19	20	21	22*	23*	24*	25*	26*	27	28	29*	30*
2		453	131	19		31			301			37		78		206					291	205	270		295				
4		389	159	848		59			398			18		216		228					395	282	397		452				
5			721			159			365					206		176					246	375	328		334				
6		140	330	300					410					17		95		14			361	382	487		366				
11		49	120	101		44			251			9		98		65		15			345	318	298		345				

__December__ 1948-49

Boat No.	1*	2*	3*	4*	5*	6	7	8*	9	10*	11	12*	13	14	15	16*	17*	18	19	20	21	22*	23*	24*	25*	26	27*	28*	29*	30	31
2	175			55		118				16							82														
4	299			390		139				45																					
5	348			116		201				68																					
4				270		158				37							7														
11						99				38							21														

__January__ 1948-49

Boat No.	1*	2*	3*	4	5*	6	7*	8*	9*	10*	11*	12*	13	14*	15	16	17	18	19*	20*	21	22	23	24*	25	26*	27*	28*	29*	30	31
8								34		304		201												100			176				
9					85				70		174																				
12										146		140																			
13									230	303							178														
14									192	315																					

__February__ 1948-49

Boat No.	1	2	3	4*	5	6*	7	8	9*	10	11	12	13*	14*	15*	16	17	18	19	20	21	22*	23*	24	25*	26	27	28*
5	94						45																		193			
8	95					566																						
9															147										400			
14		92																										

March 1948-49

Boat No.	1	2	3*	4*	5*	6*	7	8	9*	10	11*	12	13	14	15*	16	17	18*	19	20	21	22*	23	24*	25*	26*	27*	28*	29	30	31
4																		148						156	285			154		195	
8	81			400																	47			217	244			105		177	
4																		126			74			322	255			114		25	
9	175			401															47			25					529				
11																		197			46			79	220			106		187	

April 1948-49

Boat No.	1*	2*	3*	4*	5	6	7	8*	9*	10*	11*	12	13	14*	15*	16*	17*	18*	19	20	21*	22*	23*	24	25	26	27*	28*	29	30
4				429		566		115			394	165			162			169				451					284	60		
5				397		362																								
6				235		150																								
9				395		508		500			510	596						206				260								
11				301		641		322	158		354	125			169			160				482					350	50		

October 1949-50

Boat No.	1	2	3*	4*	5	6	7*	8*	9*	10	11*	12*	13	14*	15*	16	17*	18*	19	20	21*	22*	23	24*	25*	26*	27	28	29*	30*	31
3			58				318	128		261	134			404	556		708	285				115			141				348		46
4			54				334	109		192	308			421	460		699					58			105						116
5			78				218	270		286	185			457	356		590	518				86			19				240		184
11			5				281	90		200	54			108								79			188				317		113
15			109				451	325		325	561			681	580		786	368				186			84				241		147

November 1949-50

Boat No.	1	2	3*	4	5*	6*	7	8*	9	10	11	12	13*	14	15*	16*	17	18	19	20	21	22	23	24	25	26	27	28*	29*	30
3			509							540					395	506	72											98	286	
4			475							308					298	410	155											148	294	
8			384							199					264	458	115												60	
11			550							500					301	450	56											150	315	
15			646							674					611	575	48											100		

December 1949-50

Boat No.	1*	2*	3	4	5*	6	7	8*	9	10	11*	12	13	14*	15*	16*	17*	18*	19*	20*	21	22*	23	24	25	26	27*	28	29	30	31
3	241	175					81			158																					
4	292	249			165		54	29								240					179										
5	188																														
11	344	190					172	50							245																
15	674	68					49														189										

January 1949-50

Boat No.	1*	2*	3*	4*	5	6*	7	8	9*	10*	11	12	13*	14	15	16	17	18	19	20	21*	22*	23*	24	25	26*	27	28	29	30	31
3					127	354							220																		
4		425	210			345							308																		
11					145	387							249																		
16		563	95		84	261							257																		
17		178	69			195																									

No scallops purchased from January 14 to March 6

March 1949-50

Boat No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17*	18	19	20	21*	22*	23	24*	25*	26	27*	28	*29*	30	31
3													161				238					168	165								
4								35									209	54				158									
6													130				273	153				245	254				418		162		
11																	270	185				107	204								
15													89				288	110			288	190	259	130			347		94		

April 1949-50

Boat No.	1	2	3*	4*	5	6	7	8	9	10	11	12	13*	14*	15	16*	17*	18*	19*	20	21	22	23	24	25	26*	27*	28*	29*	30
3						351								17			362	348	393								507	169		
5						213						456						329	375							513	477	216		
6			408			288					164			28			394	414	443							320	321	183		
11			283			224					133			30			363	351	189							313		300		
15			428	150		282					46	408	305	66			336		423											

October 1950-51

Boat No.	1*	2*	3*	4*	5*	6*	7*	8*	9*	10	11	12*	13	14*	15	16*	17*	18	19*	20	21	22*	23*	24	25	26	27	28*	29*	30*	31*
1		446		180	582	599	575	512					321			197	175		155						440			365			
3		354		65		463	630	364				277				233	202		160						364			634		499	
4		396		117		510	360	473				301				210	163		124						340			669		514	
5		204		55		221	674	564								273	114		169						241			332			
11		438		60		63	465	345				156				190	124		115									380		439	

November 1950–51

Boat No.	1*	2*	3	4*	5	6	7*	8*	9*	10	11	12*	13*	14*	15*	16*	17	18	19	20*	21	22	23*	24	25	26	27	28	29	30
1		580					556	464	503				140	204	194		48						515							
3	74	460	60				506	445	95					177	262	255							200							
4		665					524	565	155					150	175	216							261							
5	257	566					427	435	278				39	254	236															
11	125	130					277	513	130					186	182								141						23	

December 1950–51

Boat No.	1*	2	3*	4	5	6	7	8*	9	10	11	12*	13*	14*	15*	16	17	18	19*	20*	21	22	23	24	25	26	27	28*	29	30*	31*
1										148				388	312					310		35									
3			200								27				238	12		200		206											
4	61		183								132			308	250			146		158											
5	14												39	219	358					254		65							108		
11	51		166								80	57			373	57		126		179											

January 1950–51

Boat No.	1	2*	3	4*	5	6*	7	8	9	10*	11*	12	13	14*	15	16	17	18*	19*	20*	21	22	23	24	25*	26*	27	28	29*	30	31*
1	153											628							693	320			346								
3																							205		106						
5	114	73				153					148							255	212	288					118						
11														59									154		121						
16						109					158								296	367			296								

February 1950-51

Boat No.	1	2	3	4	5*	6*	7	8	9	10*	11*	12*	13*	14	15	16*	17*	18*	19	20	21	22	23	24	25*	26	27*	28
1																		154		171								
3					305	115						122	256				300					301						
4																												251
5					261							119	256			332	92	104										271
11					304	45							58				348					200						300

March 1950-51

Boat No.	1	2	3	4*	5*	6	7*	8*	9	10	11	12	13	14*	15	16*	17*	18	19	20	21	22*	23*	24*	25	26*	27	28*	29	30*	31*
1					313		251							320		169														379	278
3					407		261							209		575						226	255					498		384	145
4					377		207							205		475						316	164					380		266	122
5					390		370									471						318	173					373			
11					219		174	27						217		406				117		182	192					475		339	

April 1950-51

Boat No.	1	2*	3	4	5*	6	7	8	9*	10	11	12	13	14*	15*	16	17*	18	19	20	21	22*	23	24	25*	26	27	28	29	30
1		400				250								95																
3		552			47									150			212		150					56						
4		398			480								56	269			179		118											
5		61			318								53	218			444		142						250					
11														151			155		74	15										

<u>October</u> 1951-52

Boat No.	1	2*	3	4*	5*	6	7	8	9	10*	11*	12	13	14*	15	16*	17*	18*	19*	20	21	22*	23*	24*	25	26	27	28	29	30	31
15	380	455		404	215						423	98				481	242	341	150			436		265							
16	131	224			164						294					246		283	95			290									
18	256	279			234						356	203				365		354	156			292	223								
19	270	294		419	305						352						734	319	438	363											
20	145	304		264	160																										

<u>November</u> 1951-52

Boat No.	1	2	3	4	5*	6	7	8	9	10*	11*	12	13*	14	15	16*	17	18	19*	20*	21	22*	23	24*	25	26	27	28	29*	30*
15					210					186			165									249								380
16					234					117			232			159						184								165
18					319					319			380			208						280								211
19					349					343			310	65	155		190													
20					200					154			154			164						209								245

<u>December</u> 1951-52

Boat No.	1*	2	3	4*	5*	6*	7*	8	9	10	11	12	13	14	15	16	17	18*	19	20	21	22*	23	24	25	26*	27	28*	29	30*	31
15				491	279	79					219																				
16			106	176			102				92																				
18			143	111	240	70	224				106																				
19				752	170		204				100																				
20			144		160																										

January 1951-52

Boat No.	1	2	3*	4	5	6	7	8	9	10*	11	12	13	14	15	16	17	18	19	20	21	22	23	24*	25	26	27	28*	29	30	31*
15																								99				155			
16																								61				65			
18		125								101																		204			
19																								116				174			
20																								77				133			

February 1951-52

Boat No.	1*	2*	3	4	5	6	7	8	9	10	11*	12	13	14	15	16	17*	18	19	20	21	22	23	24	25*	26*	27*	28	29
15	63																												
16	36																										181		
18	96																										252		
19																													
20																											152		

March 1951-52

Boat No.	1	2	3	4	5*	6	7	8	9	10*	11	12	13	14	15	16	17*	18	19	20*	21*	22*	23*	24	25*	26*	27	28*	29*	30*	31*
15										296	118						180				295					284	228		333		
16											111						67				184					190	130	66	255		164
18											192						115				263				101	228		151	420		446
19										194	149						77				352					455	108	120	298		241
20										188	157										206					118	92		371		150

April 1951-52

Beat No.	1*	2*	3	4*	5*	6	7	8	9*	10*	11	12	13	14*	15	16	17*	18*	19	20	21	22*	23	24	25	26	27*	28*	29	30
15	270	165	240	195	131					280				146		239	85	316	190			248			309			56		
16	186		95	64	105					227				140			171	340	125						80					
18		39		82	270					290				241		265	240	394	222			260			142					
19	290			108						447	270			204		107	407		220			237			336					
20	275			90	171					232				155	30		357	227	178						75					

Appendix III B

A summary of daily landing and other statistics for a sample of five boats of the Digby Scallop Fleet during the regular winter season from 1941-42 to 1950-51.

		1941-42	1942-43	1943-44	1944-45	1945-46	1946-47	1947-48	1948-49	1949-50	1950-51	Average
Oct.	Av.catch/boat	5125	5967	2938	5638	5555	6255	4906	2611 (*2)	3032	3901	4575
	Av.no.days fished	14.4	14.0	9.4	14.2	12.4	15.0	15.6	10.2	12.0	10.7	12.8
	Av.catch/boat/day Price	356	426 31	313 40	397 43	448 49	417 55	314 48	256 48	254 31	365 45	355 43
Nov.	"	5511	3291	3672	3498	4523	2431	2451	2663	2085	2458	3258
		14.4	7.4	10.2	6.4	9.4	8.6	7.4	11.4	6.6	8.5	9.0
		383	445 31	360 43	547 52	481 54	283 57	331 51	234 42	316 31	289 40	367 45
Dec.	"	3710	2451	2132	1859 (*1)	1905	1326	583	519	754	1072	1631
		9.6	7.4	5.4	4.6	5.6	5.2	3.6	4.0	4.2	4.9	5.5
		386	331 45	395 43	404 55	340 58	255 54	162 51	130 41	180 37	219 40	280 47
Jan.	"	2255	1819	3241	2365	1432	1379 (*1)	673 (*1)	534 (*1)	814 (*3)	1069	1558
		7.8	6.0	8.8	7.2	6.0	5.4	4.0	3.0	3.6	3.8	5.6
		289	303 54	368 43	328 55	239 58	255 52	168 58	178 43	226 41	281 41	264 50
Feb.	"	2009	2496	1949	2713	1088	535 (*1)	299 (*1)	358 (*1)	(*3)	851	1366
		5.0	7.0	7.0	6.4	5.2	2.2	2.2	4.0		3.5	4.7
		402	357 57	278 48	424 55	209 66	243 50	136 54	80 43		243 42	265 52
Mar.	"	4077	3577	1308	5352	5468	2650 (*2)	1903	1027 (*1)	1054 (*3)	2396	2881
		14.6	10.6	7.8	14.0	14.0	9.4	8.8	5.8	5.6	7.6	9.8
		279	338 63	133 48	375 55	391 65	282 44	216 51	177 36	188 42	315 37	269 49
April	"	4467	3278	4830	3694 (*1)	2723	1182 (*1)	2250	1835 (*1)	2766	815	2784
		13.8	9.8	11.8	12.8	9.8	9.8	9.2	6.4	8.4	3.1	9.5
		324	334 53	409 48	289 55	278 65	121 41	245 45	287 31	329 53	263 33	288 47
Annual catch/boat		27,154	22,879	20,070	25,119	22,694	15,758	13,065	9,547	10,525	12,562	
Annual catch/boat/day		341	368	332	383	364	283	257	213	275	298	
catch/boat/day 1st 20 days		422	418	357	425	455	393	314	223	277	302	
No. fishing days/year		79.6	62.2	60.4	65.6	62.4	55.6	50.8	44.8	45.3	42.1	
Av. wharf price		-	49.7	44.6	52.8	58.8	50.4	51.2	40.5	39.6	39.7	

(*1) Some of regular sample not fishing - others substituted in this month.

(*2) One of boats of regular sample no longer fishing - another of approximately same performance substituted in rest of table.

(*3) Richardson not buying scallops all or part of this month.

Appendix IV

Daily average wind velocity.

Abstracted from records of hourly observations made at the weather observation post at Greenwood, N.S., (original data supplied by Climatology Branch of Meterological Service of Canada, Toronto, Ont.)

C = calm i.e. wind velocity less than 10 m.p.h. for whole day.
L = light breeze i.e. wind velocity less than 10 m.p.h. for first half of day but increasing up to 15 m.p.h. for remainder.
B = breeze — wind velocities between 10 and 15 m.p.h. during morning or whole day.
S = strong winds - between 15-30 m.p.h. during day.
G = winds exceeding 30 m.p.h. during day.

1941-42

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Oct.	S	B	L	B	L	B	C	S	S-C	C-S	S	B	B	L	L	S	S	S	S	S	C	B	G	G	B	S	S	S	S	C	B
Nov.	L	S	B	C	C	C	S	B	B	C	C	S	S	S	B	B	S	C	C	S	S	S	S	G	S	S	S	S	B	S	
Dec.	S	S	C	C	C	C	G	G	S	S	G	B	C	S	S	B	B	B	S	S	S	S	C	S	S	S	S	B	L	B	C
Jan.	B	S	S	L	B	S	S	S	C	L	B	B	S	S	S	S	S	B	B	S	B	C	S	S	S	L	B	B	S	S	C
Feb.	S	B	S	B	C	C	S	S	S	S	S	B	S	S	S	B	S	G	L	S	S	B	S	C	C	S	S	B			
Mar.	C	C	G	S	S	S	G	C	S	S	S	S	S	C	C	C	S	C	S	S	S	G	L	S	S	S	B	B	C	L	B
Apr.	S	S	S	C	C	C	C	S	S	L	B	S	B	L	B	S	C	C	B	C	S	S	L	C	C	S	B	B	B	S	

1942-43

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Oct.	C	B	S	C	L	S	S	L	B	B	C	S	L	C	C	B	C	B	S	S	C	S	L	C	C	B	S	S	C	S	C
Nov.	L	B	C	S	C	C	L	C	C	S	S	C	S	L	S	C	C	C	C	C	B	L	B	C	B	S	C	G	S	C	
Dec.	C	S	S	S	S	S	S	S	C	C	C	C	C	S	S	C	S	B	S	S	C	C	C	C	C	S	B	C	C	C	C
Jan.	S	S	S	S	S	S	S	S	C	C	C	S	S	S	S	B	B	C	S	G	G	S	B	S	B	L	B	C	B	C	C
Feb.	S	S	S	S	S	L	S	S	S	S	S	S	C	S	S	B	S	B	C	B	C	C	C	B	S	S	S	S			
Mar.	B	S	S	S	S	S	S	S	B	B	C	C	C	S	C	S	S	S	S	L	S	C	S	S	S	S	S	S	S	B	B
Apr.	B	C	S	S	S	S	S	C	S	S	S	B	S	S	S	S	B	S	B	S	C	C	C	C	L	S	S	S	S	B	

1943-44

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Oct.	C	C	B	L	B	B	C	C	S	S	L	C	C	C	C	S	S	C	C	B	S	C	B	B	S	S	C	C	B	S	S
Nov.	S	C	L	C	C	C	C	C	S	C	B	B	C	S	B	C	B	C	L	C	C	S	S	C	C	C	B	S	B	S	
Dec.	S	B	C	C	B	S	B	C	L	S	B	B	S	B	B	C	B	C	C	B	S	S	S	B	C	C	C	S	S	C	C
Jan.	C	B	C	C	C	C	S	B	B	B	C	B	S	S	S	B	L	C	C	C	C	B	S	G	B	C	S	S	C	S	S
Feb.	S	S	S	S	L	S	C	S	C	B	C	S	S	S	O	S	C	C	S	S	S	C	S	C	B	S	C	C	C		
Mar.	S	S	S	S	S	B	S	B	S	S	B	C	C	S	B	C	C	S	S	L	B	C	B	G	S	L	B	S	S	C	S
Apr.	S	C	C	B	C	B	S	C	C	C	C	L	S	S	S	S	C	L	L	B	C	C	C	C	S	B	B	S	B	S	

1944-45

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Oct.	B	S	S	B	C	C	B	L	C	C	C	C	C	B	S	S	S	C	S	S	L	B	S	C	B	S	B	L	S	S	B
Nov.	B	C	L	C	L	S	S	S	L	L	S	C	C	C	C	L	S	S	B	C	S	S	S	L	S	S	C	S	B	O	
Dec.	S	B	C	S	C	C	C	C	B	S	B	S	S	B	S	B	B	B	S	B	S	B	C	C	C	S	S	G	S	S	C
Jan.	S	G	B	B	S	S	B	S	C	L	C	S	S	S	B	B	B	B	S	S	C	C	S	S	S	G	S	B	L	S	S
Feb.	S	S	B	B	C	C	C	S	O	L	S	L	[illegible]	L	C	L	B	C	B	C	C	C	C	C	L	C	S	S			
Mar.	C	C	C	S	B	S	S	C	C	C	C	C	L	C	B	C	C	S	S	C	B	S	B	S	B	B	L	L	S	C	C
Apr.	S	S	S	C	S	S	S	S	C	C	B	C	C	S	S	C	L	B	S	S	C	S	S	S	L	L	S	S	S	C	

1945-46

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Oct.	C	B	B	S	S	B	S	S	B	C	C	C	C	B	B	L	L	L	C	B	L	C	B	S	L	C	S	S	B	S	S
Nov.	B	C	S	B	S	S	C	C	C	L	C	C	C	S	O	S	S	C	S	S	S	S	S	C	C	C	C	S	S	O	
Dec.	S	S	C	L	B	L	S	S	B	C	S	S	S	S	C	C	B	B	C	S	B	B	C	G	B	S	S	S	S	S	B
Jan.	S	B	B	B	L	S	B	S	C	C	S	C	S	S	C	S	C	C	S	S	S	S	S	S	G	S	S	C	O	S	S
Feb.	S	S	S	S	B	L	S	B	C	S	B	S	S	S	S	G	S	B	B	S	G	S	C	S	S	S	B	L			
Mar.	S	L	B	S	L	C	L	C	S	S	L	B	B	B	B	C	C	C	C	O	L	B	S	B	L	L	L	S	B	B	S
Apr.	C	B	S	B	B	B	C	C	C	S	S	S	S	C	S	S	S	S	S	S	S	S	S	C	C	L	S	S	S	C	

1946-47

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Oct.	S	C	S	C	C	C	S	S	C	C	C	L	B	B	C	L	B	B	S	C	C	C	C	C	C	B	C	C	S	S	S
Nov.	S	B	C	L	S	S	S	C	B	B	C	C	C	C	B	B	L	S	C	C	C	S	S	S	S	C	S	S	L	C	
Dec.	L	S	S	S	B	C	C	C	C	C	C	S	S	S	S	B	B	C	C	C	B	S	S	S	C	B	S	B	C	S	L
Jan.	S	L	L	C	S	B	L	S	S	S	S	S	S	C	C	C	S	S	S	L	S	S	S	S	C	C	C	B	S	C	S
Feb.	L	B	S	C	S	C	C	S	S	S	S	S	B	C	C	L	S	S	S	S	S	B	C	C	C	B	C	L			
Mar.	C	B	G	C	C	C	B	B	B	B	B	C	C	S	B	S	C	B	B	S	S	S	S	L	S	S	S	B	B	S	L
Apr.	S	B	S	B	C	C	S	B	C	C	S	B	S	L	L	L	B	B	S	C	B	B	C	S	C	S	S	S	C	S	

1947-48

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Oct.	S	B	C	C	B	L	B	S	B	C	C	C	L	B	C	L	L	C	C	B	S	S	S	S	S	C	C	C	C	B	S
Nov.	S	C	C	C	B	L	C	L	S	S	S	S	S	S	S	B	S	S	B	C	S	C	L	L	S	C	C	C	L	B	
Dec.	B	B	C	S	S	S	S	C	S	S	C	S	S	S	B	S	S	S	S	C	C	C	C	S	S	L	S	B	S	S	B
Jan.	B	S	S	B	L	G	L	S	L	S	S	S	B	C	C	C	S	S	S	S	S	L	S	S	B	S	S	B	C	S	B
Feb.	C	C	S	C	C	C	B	S	S	C	L	S	B	S	S	S	S	S	B	B	B	B	S	C	L	B	S	C	B		
Mar.	S	L	B	C	S	B	B	S	B	C	L	B	L	C	S	S	S	C	B	S	C	S	C	C	S	B	B	S	B	S	C
Apr.	S	B	S	S	S	C	C	S	L	S	S	B	S	L	B	B	S	S	C	C	C	C	B	C	S	S	S	B	C	L	

1948-49

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Oct.	L	B	B	S	B	C	L	C	S	C	C	S	S	C	S	C	L	B	B	B	C	C	C	C	S	S	S	C	L	B	L
Nov.	S	C	C	L	B	B	S	S	C	L	S	L	L	S	C	B	L	S	B	S	B	C	C	C	C	C	S	S	C	C	
Dec.	C	C	C	C	C	S	S	C	B	L	S	C	S	S	S	C	C	S	S	S	B	C	C	C	C	S	C	C	L	S	S
Jan.	C	C	C	B	C	S	C	C	C	C	C	C	B	L	S	B	B	B	C	L	S	B	S	C	B	C	C	L	L	S	B
Feb.	S	S	S	C	B	C	S	S	L	B	S	B	C	C	C	B	S	B	B	B	S	C	C	S	C	S	S	C			
Mar.	B	S	C	C	C	C	B	B	C	B	C	B	B	B	C	S	B	C	S	S	B	C	S	C	C	C	C	C	S	S	S
Apr.	C	C	C	C	B	S	S	C	C	C	C	S	B	L	C	C	L	C	S	S	C	C	L	S	S	B	C	L	B	C	

1949-50

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Oct.	B	B	C	C	B	B	C	C	C	B	C	C	B	C	C	B	C	C	S	S	C	C	S	C	C	C	S	B	C	C	B
Nov.	B	B	C	S	C	C	C	C	S	B	B	B	C	S	C	C	S	S	B	B	B	S	S	S	S	S	B	C	C	B	
Dec.	C	C	S	S	L	B	B	C	B	B	C	B	B	C	C	C	C	C	C	L	S	L	B	B	B	L	C	S	S	S	B
Jan.	C	C	L	C	S	C	B	S	C	C	S	S	C	S	S	S	S	S	S	B	C	C	C	B	B	C	S	B	B	S	B
Feb.	C	C	S	S	S	C	S	B	S	B	B	C	B	C	S	S	B	C	S	S	S	C	B	S	S	S	B	B			
Mar.	B	S	S	S	S	S	S	B	S	S	S	S	B	B	S	S	C	S	S	S	C	C	S	C	C	B	C	C	C	S	B
Apr.	S	B	C	C	B	B	S	S	S	S	S	C	C	L	B	C	C	C	C	S	S	S	S	S	S	C	C	C	L	B	

1950-51

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Oct.	C	C	C	C	C	C	C	C	C	B	C	L	S	L	B	C	C	B	C	S	S	C	C	B	S	S	B	C	C	C	C
Nov.	C	C	B	L	S	B	C	L	C	S	B	C	C	L	C	C	S	S	S	L	S	B	C	B	S	C	C	S	S	B	
Dec.	L	S	C	B	B	S	S	L	S	B	S	L	C	C	L	B	S	S	C	L	B	B	B	S	B	S	B	L	S	C	C
Jan.	B	C	L	L	S	C	B	S	B	C	C	C	S	C	S	S	S	C	C	C	S	S	B	C	C	L	S	S	C	B	C
Feb.	S	S	S	S	C	C	S	C	S	C	C	C	C	S	B	C	L	C	B	B	B	B	B	S	L	S	L	S			
Mar.	S	S	S	C	C	S	C	L	B	B	S	S	B	L	S	C	L	B	B	S	S	L	L	L	S	C	B	C	B	C	L
Apr.	B	C	S	S	L	S	B	B	C	B	B	B	S	C	C	S	C	S	S	S	B	C	S	S	L	S	B	S	S	A	

1951-52

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Oct.	B	C	B	C	L	S	S	S	S	C	C	S	S	L	B	C	C	L	L	B	B	C	L	L	S	S	B	B	S	S	L
Nov.	B	B	S	B	C	B	S	S	B	C	C	B	C	B	S	L	B	B	C	L	S	L	S	L	S	S	S	S	L	C	
Dec.	C	S	S	C	C	L	C	S	S	S	B	B	S	S	S	S	S	L	C	B	C	C	S	B	B	C	B	L	S	L	S
Jan.	B	S	L	S	B	B	B	C	S	C	C	S	B	B	B	S	S	S	S	S	S	S	C	C	S	S	S	C	S	B	C
Feb.	C	C	B	S	C	S	S	S	S	S	L	C	S	S	S	B	L	C	S	S	S	S	B	B	C	C	L	C	S		
Mar.	B	C	S	S	L	B	B	B	B	C	B	S	S	S	S	B	L	S	S	L	C	L	L	B	L	C	S	C	C	L	L
Apr.	C	L	B	L	C	S	B	B	C	C	S	C	S	C	S	S	L	C	S	S	S	S	S	S	S	C	L	L	B	S	

Calculated Catch per unit effort - C (t) - and accumulated catch - K (t) - of the sample fleet, and regression lines for abundance estimate

$x = \frac{K\ (t)}{1500}$ and $y = \frac{C\ (t)}{10}$

(data from Appendix III) 1941 - 42

Week ending on	Accumulated weekly catch - 5 boats - K (t)	Weekly total catch - 5 boats -	No. days fished	No. fine fishing days	Weekly catch on fine days - 5 boats -	Catch per boat per fine day C (t)
Oct. 4	0	3414	8	4	1670	418.5
11	3414	6030	12	4	3437	859.3
18	9444	4548	18	6	3865	410.4
25	13992	7155	25	5	2544	508.8
Nov. 1	21147	8019	14	10	7134	713.4
8	29166	9946	17	11	6971	633.6
15	39112	7762	24	9	5134	570.4
22	46874	3634	11	7	3108	444.0
29	50508	2672	15	-	-	-
Dec. 6	53180	5596	10	10	5596	559.6
13	58776	3554	7	5	3369	673.8
20	62330	2190	12	-	-	-
27	64520	4431	12	5	2977	595.4
Jan. 3	68951	6170	14	8	3936	492.0
10	75121	910	8	-	-	-
17	76031	100	1	-	-	-
24	76131	3554	10	5	2722	544.4
31	79685	3126	10	5	1506	301.2
Feb. 7	82811	5555	10	10	4123	412.3
14		-	-	-	-	-
21	88366	1938	5	5	1938	387.6
28	90304	2550	8	5	1058	351.7
Mar. 7	92854	7062	29	5	2653	530.6
14	99916	2661	10	5	2227	445.4
21	102577	6529	18	9	3430	381.1
28	109106	2169	9	2	635	317.5
Apr. 4	111275	3474	12	10	3368	336.8
11	114749	5965	12	15	5817	387.8
18	120714	5741	16	11	4726	429.6
25	126455	8387	25	20	7408	370.1
30	134842	-	-	-	-	-

N = 25

$\Sigma x = 1704$ $\bar{x} = 68.16$ $\Sigma x^2 = 152938.00$ $\bar{x}\Sigma x = 116144.64$

$\Sigma xy = 74440.00$ $\frac{\Sigma x \Sigma y}{N} = 82064.80$

$\Sigma y = 1204$ $\bar{y} = 48.16$ $\Sigma y^2 = 62554.00$ $\bar{y}\Sigma y = 57984.64$

$Y = 62.28 - 0.2072X$ or $C(t) = 622.8 - 0.002072\ K(t)$

Calculated Catch per unit effort – C (t) – and accumulated catch – K (t) – of the sample fleet, and regression lines for abundance estimate

$$x = \frac{K(t)}{1000} \quad \text{and} \quad y = \frac{C(t)}{10}$$

(data from Appendix III) 1948 – 49

Week ending on		Accumulated weekly catch – 5 boats – K (t)	Weekly total catch – 5 boats –	No. days fished	No. fine fishing days	Weekly catch on fine days – 5 boats –	Catch per boat per fine day C (t)
Oct.	3	0	2970	5	5	2970	594.0
	10	2970	6909	30	9	3651	405.7
	17	9879	11051	17	17	11051	650.1
	24	20930	6400	14	13	6276	482.7
	31	27330	2505	4	4	2506	626.5
Nov.	7	29835	2755	4	3	2325	775.0
	14	33590	1932	7	3	1175	391.7
	21	35522	5827	10	10	5827	582.7
	28	39349	6941	13	9	6478	719.8
Dec.	5	46290	2630	5	6	3630	626.0
	12	48920	3787	14	11	3906	355.0
	19	52707	-	-	-	-	-
	26	52707	1143	6	4	1090	272.5
Jan.	2	53850	4325	13	10	4076	407.6
	9	58175	1093	8	2	442	221.0
	16	59268	4375	10	5	2831	566.2
	23	63643	1915	5	5	1915	383.0
	30	65558	1714	8	3	1520	506.7
Feb.	6	67272	2964	11	4	1146	286.5
	13	70236	2310	9	5	1660	332.0
	20		-	-	-	-	-
	27	78546	7202	13	9	4835	538.4
Mar.	6	79748	1347	9	-	-	-
	13	81095	5643	10	4	1419	354.8
	20	86138	5232	13	9	3981	442.3
	27	91370	4316	11	5	1832	366.4
Apr.	3	95686	5233	22	5	1949	389.8
	10	100919	4799	14	5	2750	550.0
	17	105718	1593	5	-	-	-
	24	107311	5236	9	4	2234	558.5
	30	112547	1476	7	-	-	-
		114023	-	-	-	-	-

$N = 26$

$Sx = 1421$ $\bar{x} = 54.65$ $Sx^2 = 99518.00$ $\bar{x}Sx = 77657.65$

$Sxy = 63080.00$ $\frac{SxSy}{N} = 66131.50$

$Sy = 1210$ $\bar{y} = 46.54$ $Sy^2 = 61844.00$ $\bar{y}Sy = 56313.40$

$Y = 54.17 - 0.1596\,X$

$C(t) = 541.7 - 0.001596\,K(t)$

1943 - 44

Week ending on	Accumulated weekly catch - 5 boats - K (t)	Weekly total catch - 5 boats -	No. days fished	No. fine fishing days	Weekly catch on fine days - 5 Boats -	Catch per boat per fine day C (t)
Oct. 2	0	3341	8	7	3195	456.4
9	3341	3179	9	4	2731	682.8
16	6520	5057	15	10	4631	463.1
23	11577	2274	9	4	1463	365.8
30	13851	841	8	-	-	-
Nov. 6	14692	4744	13	8	3443	430.4
13	19436	5773	14	12	5551	462.6
20	25209	3438	13	7	2913	416.1
27	28647	3699	12	11	3557	323.4
Dec. 4	32346	2697	6	4	1948	487.0
11	35043	4729	15	7	3814	544.9
18	39772	702	2	1	562	562.0
25		-	-	-	-	-
Jan. 1	40474	3960	10	8	3750	468.8
8	44434	4237	9	7	3356	479.4
15	48671	1405	8	3	1023	341.0
22	50076	6142	17	12	5677	473.1
29	56218	3604	10	10	3604	360.4
Feb. 5	59822	1316	6	4	1091	272.8
12	61138	4225	16	14	4095	292.5
19	65363	1114	4	2	721	360.5
26	66477	895	5	2	598	299.0
Mar. 4	67372	2981	6	4	2241	560.3
11	70373	627	4	-	-	-
18	71000	1805	10	5	1281	256.2
25	72805	1715	11	1	407	407.0
Apr. 1	74520	1770	15	4	861	215.3
8	76290	7057	22	11	5416	492.4
15	83347	3477	12	9	3187	354.1
22	86824	8466	18	18	8466	470.3
29	95290	5146	9	6	2621	436.8
30	100436	-	-	-	-	-

N = 28

$Sx = 1337$ $\bar{x} = 47.75$ $Sx^2 = 63855.00$ $\bar{x}Sx = 63841.75$

$Sxy = 55163.00$ $\frac{SxSy}{N} = 56154.00$

$Sy = 1176$ $\bar{y} = 42.00$ $Sy^2 = 53416.00$ $\bar{y}Sy = 49392.00$

$Y = 49.25 - 0.1519\ X$ $C(t) = 492.5 - 0.001519\ K(t)$

1944 - 45

Week ending on	Accumulated weekly catch - 5 Boats - X (t)	Weekly total catch - 5 Boats -	No. days fished	No. fine fishing days	Weekly catch on fine days - 5 Boats -	Catch per boat per fine day C (t)
Oct. 7	0	6146	10	9	5737	637.4
14	6146	10222	22	21	9351	445.3
21	16368	6067	20	8	3681	460.1
28	22435	5058	12	3	1570	523.3
Nov. 4	27483	8190	14	7	5405	772.1
11	35683	2858	5	4	2858	714.5
18	38541	3037	5	5	3037	607.4
25	41578	2265	6	4	1689	422.0
Dec. 2	43843	3319	6	4	2129	532.3
9	47162	7809	15	12	7436	619.7
16	54971	978	2	-	-	-
23	55949	322	4	-	-	-
30	56271	149	2	-	-	-
Jan. 6	56420	2371	9	-	-	-
13	58791	2420	10	1	250	250.0
20	61211	853	6	-	-	-
27	62064	3805	6	5	3005	601.0
Feb. 3	65869	2578	5	5	2378	475.6
10	68447	4106	16	7	3744	534.9
17	72553	2666	9	6	2430	405.0
24	75219	3839	8	8	3839	479.9
Mar. 3	79058	6601	16	15	6552	436.8
10	85659	4708	14	9	4152	461.3
17	90367	6682	16	14	6555	468.2
24	97049	3828	6	5	2913	582.6
31	100877	7424	21	14	5939	424.2
Apr. 7	108301	4181	12	3	775	258.3
14	112482	7518	18	17	7254	426.6
21	120000	5798	15	7	3353	479.0
28	125798	4384	12	8	3541	442.6
30	128122	2355	5	5	2355	471.0
	130477	-	-	-	-	-

N = 26

$\Sigma x = 1724$ $\bar{x} = 66.31$ $\Sigma x^2 = 140418.00$ $\bar{x}\Sigma x = 114318.44$

$\Sigma xy = 80967.00$ $\frac{\Sigma x \Sigma y}{N} = 85738.85$

$\Sigma y = 1292$ $\bar{y} = 49.69$ $\Sigma y^2 = 67748.00$ $\bar{y}\Sigma y = 64200.88$

$Y = 56.96 - 0.1599\ X$

$C(t) = 569.6 - 0.001599\ X(t)$

1945 - 46

Week ending on		Accumulated weekly catch - 5 boats - K (t)	Weekly total catch - 5 boats -	No. days fished	No. fine fishing days	Weekly catch on fine days - 5 boats -	Catch per boat per fine day C (t)
Oct.	6	0	5734	13	1	529	529.0
	13	5734	7881	13	9	5137	570.8
	20	13615	7388	13	12	7775	647.9
	27	21003	4484	12	11	4376	397.8
Nov.	3	25487	6105	17	5	2886	577.5
	10	31592	5568	10	10	5568	556.8
	17	37160	4795	10	7	3989	569.9
	24	41955	1664	7	1	307	307.0
Dec.	1	43619	6118	11	6	3600	600.0
	8	49737	4112	10	10	4112	411.2
	15	53849	3707	13	9	2940	326.7
	22	57556	80	1	-	-	-
	29	57636	1625	4	-	-	-
Jan.	5	59261	191	1	-	-	-
	12	59452	2580	13	7	1945	277.9
	19	62032	2916	11	6	2500	416.7
	26	64948	469	4	-	-	-
Feb.	2	65417	400	2	-	-	-
	9	65817	2604	9	7	2349	335.6
	16	68421	807	7	-	-	-
	23	69228	1630	8	2	1014	507.0
Mar.	2	70858	3552	9	5	1897	379.4
	9	74410	5232	13	10	4915	491.5
	16	79642	5781	16	10	4060	406.0
	23	85423	7243	17	14	6888	492.0
	30	92666	5520	15	9	2791	310.1
Apr.	6	98186	1174	7	-	-	-
	13	99360	3762	8	8	3762	470.3
	20	103122	3424	14	-	-	-
	27	106546	2452	10	7	2129	304.1
	30	108998	2355	9	1	400	400.0
		111353	-	-	-	-	-

N = 25

Sx = 1801 $\bar{x}$ = 56.57 Sx^2 = 95341.00 $\bar{x}$Sx = 73597.57

Sxy = 64297.00 $\frac{SxSy}{N}$ = 56818.74

Sy = 1061 $\bar{y}$ = 44.85 Sy^2 = 48865.00 $\bar{y}$Sy = 46819.75

Y = 85.30 - 0.1850 X

C (t) = 853.0 - 0.001850 K(t)

1946 - 47

Week ending on	Accumulated weekly catch - 5 boats - K (t)	Weekly total catch - 5 boats -	No. days fished	No. fine fishing days	Weekly catch on fine days - 5 boats -	Catch per boat per fine day C (t)
Oct. 5	0	4716	14	14	4704	336.4
12	4716	10446	25	24	10363	432.6
19	15162	3794	10	10	3749	374.9
26	18956	11788	24	24	11788	491.2
Nov. 2	30744	1324	3	3	1324	441.3
9	32068	3361	10	9	3223	358.1
16	35429	4780	14	10	4577	457.7
23	40209	1701	9	4	798	199.5
30	41910	1524	6	3	1032	344.0
Dec. 7	43434	3298	14	4	1494	373.5
14	46732	1354	7	3	948	316.0
21	48086	2177	6	4	1969	492.3
28	–	–	–	–	–	–
Jan. 4	50263	420	2	1	236	236.0
11	50683	470	2	–	–	–
18	51153	3244	8	8	3244	405.5
25	54397	914	5	2	598	299.0
Feb. 1	55311	2407	11	6	1766	294.3
8	57718	73	1	–	–	–
15	57791	1051	3	3	1051	350.3
22	58842	174	1	1	174	174.0
Mar. 1	59016	3004	12	8	2422	347.8
8	62020	1570	7	6	1476	246.0
15	63590	3156	9	8	3020	377.5
22	66746	2113	12	6	1523	304.6
29	68859	3716	13	5	2232	446.4
Apr. 5	72575	1113	7	3	821	273.7
12	73688	618	4	2	435	217.5
19	74306	2569	18	7	1643	234.7
26	76875	1402	9	3	636	219.3
30	78277	398	5	–	–	–
	78675					

N = 27

$\Sigma x = 1308$ $\bar{x} = 48.44$ $\Sigma x^2 = 75054.00$ $\bar{x}\Sigma x = 63359.88$

$\Sigma xy = 41506.00$ $\frac{\Sigma x \Sigma y}{N} = 43743.83$

$\Sigma y = 903$ $\bar{y} = 33.44$ $\Sigma y^2 = 32297.00$ $\bar{y}\Sigma y = 30196.33$

$Y = 45.56 - 0.2066\,X$ $C(t) = 455.5 - 0.002066\,K(t)$

1947 – 48

Week ending on		Accumulated weekly catch – 5 boats – X (t)	Weekly total catch – 5 boats –	No. days fished	No. fine fishing days	Weekly catch on fine days – 5 boats –	Catch per boat per fine day C (t)
Oct.	4	0	5024	12	8	3168	396.0
	11	5024	4385	15	10	3920	392.0
	18	9409	8738	23	23	8738	379.9
	25	18147	2740	14	–	–	–
Nov.	1	20887	3643	14	10	3326	332.6
	8	24530	5693	16	16	5693	355.8
	15	30223	765	3	–	–	–
	22	30988	1170	4	4	1170	292.5
	29	32158	4627	14	13	4512	347.1
Dec.	6	36785	1305	10	4	840	210.0
	13	38090	806	4	3	626	208.7
	20	38896	533	3	3	533	177.7
	27	39429	350	1	1	350	350.0
Jan.	3	–	–	–	–	–	–
	10	39779	1297	6	3	906	302.0
	17	41076	1890	12	4	1107	276.8
	24	–	–	–	–	–	–
	31	42966	195	2	–	–	–
Feb.	7	43161	415	3	1	280	280.0
	14	43576	416	2	2	416	208.0
	21	43992	194	2	–	–	–
	28	44186	471	4	–	–	–
Mar.	6	44657	2618	9	8	2474	309.3
	13	47275	972	9	4	724	181.0
	20	48247	1619	8	5	1115	223.0
	27	49866	2755	13	5	1491	298.2
Apr.	3	52621	1549	5	5	1549	309.8
	10	54170	2894	14	6	1876	312.7
	17	57064	3278	11	3	1037	345.7
	24	60342	3245	16	9	2347	270.8
	30	63587	1832	6	5	1699	339.8
		65419					

N = 24

Sx = 922 $\quad \bar{x}$ = 38.42 $\quad$ Sx^2 = 41786.00 $\quad$ $\bar{x}$Sx = 35423.24

Sxy = 24172.00 $\quad \frac{SxSy}{N}$ = 27314.25

Sy = 71.1 $\quad \bar{y}$ = 29.63 $\quad$ Sy^2 = 23057.00 $\quad \bar{y}$Sy = 21066.93

Y = 36.03 – 0.1795 X $\qquad$ C (t) = 360.3 – 0.001795

1948-49

Week ending on	Accumulated weekly catch – 5 boats – K (t)	Weekly total catch – 5 boats –	No. days fished	No. fine fishing days	Weekly catch on fine days – 5 boats –	Catch per boat per fine day C (t)
Oct. 2	0	1159	3	3	1159	386.3
9	1159	4687	15	11	4048	368.0
16	5846	3454	18	9	2634	292.7
23	9300	2163	9	8	2063	257.9
30	11463	1595	9	5	1523	304.6
Nov. 6	13058	3327	17	7	2474	353.4
13	16385	1773	8	5	1715	343.0
20	18158	1434	12	5	1036	207.2
27	19592	6781	20	20	6781	339.1
Dec. 4	26373	1533	7	5	1380	276.0
11	27906	884	10	-	-	-
18	28790	180	3	-	-	-
25		-	-	-	-	-
Jan. 1		-	-	-	-	-
8	28970	121	2	-	-	-
15	29091	2095	10	8	1885	235.6
22	31186	178	1	-	-	-
29	31364	276	2	1	176	176.0
Feb. 5	31640	279	3	-	-	-
12	31919	409	2	1	366	366.0
19	32328	147	1	-	-	-
26	32475	595	2	2	595	297.5
Mar. 5	33070	1055	4	3	974	324.7
12		-	-	-	-	-
19	34125	465	3	1	197	197.0
26	34590	2000	12	7	1729	247.0
Apr. 2	36590	1570	9	1	265	265.0
9	38160	4477	14	8	2434	304.6
16	42637	2262	8	5	1380	275.6
23	44899	1646	6	6	1646	274.3
30	46545	724	2	2	614	307.0
	47269					

$N = 22$

$Sx = 558$ $\bar{x} = 25.36$ $Sx^2 = 18368.00$ $\frac{(Sx)^2}{N} = 14150.88$

$Sxy = 15727.00$ $\frac{SxSy}{N} = 16359.55$

$Sy = 645$ $\bar{y} = 29.32$ $Sy^2 = 19577$ $\frac{(Sy)^2}{N} = 18911.40$

$Y = 33.12 - 0.1500\ X$ $C(t) = 331.2 - 0.001500\ K(t)$

1949-50

Week ending on		Accumulated weekly catch - 5 boats - K (t)	Weekly total catch - 5 boats -	No. days fished	No. fine fishing days	Weekly catch on fine days - 5 boats -	Catch per boat per fine day C (t)
Oct.	1						
	8	0	2808	15	7	2183	311.9
	15	2808	6015	19	11	4517	410.6
	22	6823	4226	12	7	3784	540.6
	29	13049	1623	9	9	1146	286.5
Nov.	5	14672	3100	10	5	2512	502.4
	12	17772	1821	5	-	-	-
	19	19593	4707	15	10	4269	426.9
	26		-	-	-	-	-
Dec.	3	24300	3698	17	12	3240	270.0
	10	27998	931	9	1	165	165.0
	17	28929	486	2	2	486	243.0
	24	29415	208	2	1	179	179.0
	31		-	-	-	-	-
Jan.	7	29723	3154	14	9	2616	290.7
	14	32877	914	4	4	914	228.5
	21	33791	-	-	-	-	-
	28		-	-	-	-	-
Feb.	4		-	-	-	-	-
	11	+ 4000	-	-	-	-	-
	18		-	-	-	-	-
	25		-	-	-	-	-
Mar.	4	37791	-	-	-	-	-
	11		35	1	-	-	-
	18	37826	2088	12	5	1277	255.4
	25	39914	2114	11	5	1037	207.4
Apr.	1	42028	1021	4	3	927	309.0
	8	43049	2396	8	3	1121	373.7
	15	45445	1843	10	3	1369	456.3
	22	47288	5660	13	12	5531	460.9
	29	52948	3718	10	10	3718	371.8
	30	56666	-	-	-	-	-

$N = 19$

$Sx = 542$ $\quad \bar{x} = 28.53$ $\quad Sx^2 = 19706.00$ $\quad \bar{x}Sx = 15463.26$

$Sxy = 17527.00$ $\quad \frac{SxSy}{N} = 17971.58$

$Sy = 630$ $\quad \bar{y} = 33.16$ $\quad Sy^2 = 23084.00$ $\quad \bar{y}Sy = 20890.80$

$Y = 36.15 - 0.1048\ X$ $\qquad C(t) = 261.5 - 0.001048\ K(t)$

1950-51

Week ending on	Accumulated weekly catch - 5 boats - K (t)	Weekly total catch - 5 boats -	No. days fished	No. fine fishing days	Weekly catch on fine days - 5 boats -	Catch per boat per fine day C (t)
Oct. 7	0	7177	21	16	6799	424.9
14	7177	3603	9	8	3282	410.3
21	10780	2612	15	11	2137	194.3
28	13392	3905	9	5	2520	504.0
Nov. 4	17297	4157	12	8	3780	472.5
11	21454	5835	15	13	5610	431.5
18	27289	2608	14	7	1498	214.0
25	29897	1117	4	3	976	325.3
Dec. 2	31014	146	3	-	-	-
9	31160	549	3	-	-	-
16	31709	2886	16	8	2380	297.5
23	34595	1690	10	5	1100	220.0
30	36285	176	2	-	-	-
Jan. 6	36461	602	5	1	153	153.0
13	37063	958	3	2	816	408.0
20	38021	2411	7	8	2411	301.5
27	40432	1348	7	-	-	-
Feb. 3		-	-	-	-	-
10	41780	928	5	3	668	222.7
17	42708	1796	9	5	1425	285.0
24	44504	810	5	-	-	-
Mar. 3	45314	822	3	3	822	274.0
10	46136	2996	11	10	2969	296.9
17	49132	3047	9	9	3047	380.8
24	52179	1943	9	8	1826	228.3
31	54122	3992	14	9	3372	374.7
Apr. 7	58114	2244	7	5	2116	423.2
14	60358	683	5	2	487	243.5
21	61041	881	7	4	992	248.0
28	61922	-	-	1	250	250.0
30		-	-	-	-	-

$N = 24$

$\Sigma x = 877$ $\quad \bar{x} = 36.54$ $\quad \Sigma x^2 = 39433.00$ $\quad \bar{x}\,\Sigma x = 32045.58$

$\Sigma xy = 36114.00$ $\quad \frac{\Sigma x \Sigma y}{N} = 27625.51$

$\Sigma y = 756$ $\quad \bar{y} = 31.50$ $\quad \Sigma y^2 = 26002.00$ $\quad \bar{y}\,\Sigma y = 23814.00$

$Y = 38.98 - 0.2046\ X$ $\qquad C(t) = 389.8 - .002046\ K(t)$

1951 - 52

Week ending on	Accumulated weekly catch – 5 boats – K (t)	Weekly total catch – 5 boats –	No. days fished	No. fine fishing days	Weekly catch on fine days – 5 boats –	Catch per boat per fine day C (t)
Oct. 6	0	5015	18	13	3849	296.1
13	5015	1704	6	4	1403	350.8
20	6719	4500	15	10	3467	346.7
27	11219	1511	15	8	1511	302.2
Nov. 3	12730	–	–	–	–	–
10	12730	2142	10	10	2142	214.2
17	14872	2182	11	7	1598	227.6
24	17054	922	4	4	922	230.5
Dec. 1	17956	951	4	4	951	237.8
8	18907	3471	18	9	2095	232.6
15	22378	517	6	–	–	–
22	22895	–	–	–	–	–
29		–	–	–	–	–
Jan. 5	22895	121	1	–	–	–
12	23016	201	1	1	2100	210.0
19		–	–	–	–	–
26	23217	373	4	–	–	–
Feb. 2	23590	956	8	3	533	177.7
9	24546	–	–	–	–	–
16		–	–	–	–	–
23		–	–	–	–	–
Mar. 1	24546	585	3	3	585	195.0
8		–	–	–	–	–
15	25151	1405	8	3	678	226.0
22	26536	1739	9	6	1480	246.7
29	28275	3948	18	12	2985	248.8
Apr. 5	32223	2797	21	12	2843	236.9
12	35020	1746	6	5	1476	295.2
19	37766	4999	25	11	3052	277.5
26	42765	1687	8	3	745	248.3
30	44452	56	1	–	–	–
	44508					

N = 19

$\Sigma x = 406$ $\bar{x} = 21.37$ $\Sigma x^2 = 11044$ $\bar{x}\Sigma y = 8676$

$\Sigma xy = 9980$ $\frac{\Sigma x \Sigma y}{N} = 10381$

$\Sigma y = 493$ $\bar{y} = 25.92$ $\Sigma y^2 = 12865$

$Y = 29.00 - 0.1440\, X$ $C(t) = 290.0 - 0.001440\, K(t)$

APPENDIX V B

Calculated average monthly catch per unit effort (sample fleet) – $C(t)$ – and accumulated catch of the whole fleet – $K_w(t)$ and regression lines for abundance estimates

$x = \frac{K_w(t)}{1000}$ $y = C(t)$ (data from Appendices I and III)

	1941-42		1942-43	
Month	$K_w(t)$	Av. $C(t)$	$K_w(t)$	Av. $C(t)$
Oct.	0	563.6	0	551.1
Nov.	150,090	563.4	125,200	552.2
Dec.	260,580	567.1	265,800	380.1
Jan.	341,080	403.8	278,600	447.2
Feb.	407,600	395.5	350,600	484.5
Mar.	465,680	426.0	392,500	401.8
Apr.	560,800	580.6	446,690	408.9
May	628,080		532,150	

1941-42

$N = 7$

$Sx = 2157$ $Sy = 3318$

$\bar{x} = 308.1$ $\bar{y} = 474.0$

$Sx^2 = 800577$ $Sy^2 = 1,625,418$

$\bar{x}Sx = 664572$ $Sxy = 937,636$

$\frac{SxSy}{N} = 1,024,418$

$Y = 603.5 - 0.4197X$

$C(t) = 603.5 - .0004197\ K_w(t)$

1942-43

$N = 7$

$Sx = 1818$ $Sy = 3262$

$\bar{x} = 259.7$ $\bar{y} = 466.0$

$Sx^2 = 623,848$ $Sy^2 = 1,547,468$

$\bar{x}Sy = 472136$ $Sxy = 810,194$

$\frac{SxSy}{N} = 847,188$

$Y = 529.3 - 0.2458X$

$C(t) = 529.3 - 0.0002458\ K_w(t)$

	1943-44		1944-45	
Month	$K_w(t)$	Av. $C(t)$	$K_w(t)$	Av. $C(t)$
Oct.	0	498.6	0	486.1
Nov.	72,150	407.6	125,500	489.9
Dec.	125,250	503.7	230,670	419.7
Jan.	210,050	466.9	275,120	510.5
Feb.	295,450	295.7	326,720	460.1
Mar.	324,660	342.1	369,540	465.7
Apr.	377,150	462.7	556,460	452.0
May	498,500		694,260	

1943-44

$N = 7$

$Sx = 1425$ $Sy = 2959$

$\bar{x} = 203.5$ $\bar{y} = 422.7$

$Sx^2 = 408,945$ $Sy^2 = 1,289,751$

$\bar{x}Sx = 289,296$ $Sxy = 574,450$

$\frac{SxSy}{N} = 601,529$

$Y = 468.7 - 0.2264X$

$C(t) = 468.7 - .0002264\ K_w(t)$

1944-45

$N = 7$

$Sx = 1882$ $Sy = 3614$

$\bar{x} = 268.9$ $\bar{y} = 516.3$

$Sx^2 = 690,664$ $Sy^2 = 1,902,794$

$\bar{x}Sy = 506,070$ $Sxy = 924,714$

$\frac{SxSy}{N} = 971,650$

$Y = 584.7 - 0.2545X$

$C(t) = 584.7 - 0.0002545\ K_w(t)$

Month	1945-46 $K_w(t)$	1945-46 Av. C(t)	1946-47 $K_w(t)$	1946-47 Av. C(t)
Oct.	0	544.8	0	426.0
Nov.	177,500	561.0	178,200	362.7
Dec.	340,700	371.2	270,600	401.0
Jan.	400,600	341.9	326,300	343.8
Feb.	464,350	375.7	375,900	320.6
Mar.	509,150	434.2	411,600	343.8
Apr.	729,750	393.2	497,900	237.1
May	842,250		535,100	

1945-46: $N = 7$

$Sx = 2623$ $Sy = 3022$

$\bar{x} = 374.7$ $\bar{y} = 431.7$

$Sx^2 = 1,316,043$ $Sy^2 = 1,350,532$

$\bar{x}Sx = 982,838$

$Sxy = 1,045,771$

$\frac{SxSy}{N} = 1,132,387$

$Y = 529.1 - 0.2600X$

$C(t) = 529.1 - .0002600\ K_w(t)$

1946-47: $N = 7$

$Sx = 2061$ $Sy = 2436$

$\bar{x} = 294.4$ $\bar{y} = 348.0$

$Sx^2 = 770,525$ $Sy^2 = 869,928$

$\bar{x}Sx = 606,758$

$Sxy = 665,879$

$\frac{SxSy}{N} = 717,228$

$Y = 439.8 - 0.3117X$

$C(t) = 439.8 - 0.0003117\ K_w(t)$

Month	1947-48 $K_w(t)$	1947-48 Av. C(t)	1948-49 $K_w(t)$	1948-49 Av. C(t)
Oct.	0	375.5	0	317.4
Nov.	172,500	344.7	77,500	324.5
Dec.	262,500	213.6	162,600	276.0
Jan.	299,500	287.6	187,100	229.0
Feb.	332,000	232.0	196,600	320.3
Mar.	341,800	272.3	199,600	263.8
Apr.	406,600	306.5	225,800	289.2
May	449,200		275,800	

1947-48: $N = 7$

$Sx = 1817$ $Sy = 2034$

$\bar{x} = 259.6$ $\bar{y} = 290.6$

$Sx^2 = 581,935$ $Sy^2 = 611,198$

$\bar{x}Sx = 471,693$

$Sxy = 497,364$

$\frac{SxSy}{N} = 527,968$

$Y = 362.7 - 0.2776X$

$C(t) = 362.7 - 0.0002776\ K_w(t)$

1948-49: $N = 7$

$Sx = 1051$ $Sy = 2020$

$\bar{x} = 150.1$ $\bar{y} = 288.6$

$Sx^2 = 197,507$ $Sy^2 = 590,348$

$\bar{x}Sx = 157,755$

$Sxy = 294,315$

$\frac{SxSy}{N} = 303,289$

$Y = 315.7 - 0.1804X$

$C(t) = 315.7 - 0.0001804\ K_w(t)$

	1949-50		1950-51	
Month	$K_w(t)$	Av. C(t)	$K_w(t)$	Av. C(t)
Oct.	0	401.0	0	368.5
Nov.	45,500	371.2	100,200	382.7
Dec.	72,100	208.5	182,600	267.7
Jan.	86,200	271.5	211,200	307.3
Feb.	100,500		232,200	265.0
Mar.	111,300	249.3	253,200	311.5
Apr.	132,700	419.3	306,700	320.4
May	179,400		333,200	

1949-50

N = 6

Sx = 448 Sy = 1921

$\bar{x}$ = 74.7 $\bar{y}$ = 320.2

Sx² = 44706 Sy² = 653,669

ΣSx = 33466

Sxy = 138,872

$\frac{SxSy}{N}$ = 143,435

Y = 350.5 − 0.4060X

C(t) = 350.5 − 0.0004060 $K_w(t)$

1950-51

N = 7

Sx = 1286 Sy = 2224

$\bar{x}$ = 183.7 $\bar{y}$ = 317.7

Sx² = 300,092 Sy² = 718,892

ΣSx = 236,238

Sxy = 390,777

$\frac{SxSy}{N}$ = 408,581

Y = 368.9 − 0.2788

C(t) = 368.9 − 0.0002788 $K_w(t)$

	1951-52	
Month	$K_w(t)$	Av. C(t)
Oct.	0	319.7
Nov.	41,900	224.3
Dec.	63,600	232.6
Jan.	78,000	185.8
Feb.	97,900	195.0
Mar.	102,900	244.9
Apr.	130,400	261.8
May	169,400	

N = 7

Sx = 514 Sy = 1665

$\bar{x}$ = 73.43 $\bar{y}$ = 237.86

Sx² = 48852 Sy² = 408,155

ΣSx = 37743

Sxy = 116,988

$\frac{SxSy}{N}$ = 122,259

Y = 272.7 − 0.4745X

C(t) = 272.7 − 0.0004745 $K_w(t)$

Appendix VI

Calculation of correction terms for estimating abundance from catch statistics.

Season	Total Landings: Sample Fleet	Total Landings: Unsampled Fleet	Correction of regression for total fleet $1 + \frac{k'e'}{k\,e} = 1 + \frac{\text{catch of unsampled fleet}}{\text{catch of sampled fleet}}$	k"e" = seasonal natural mortality	e z = no. boats x no. days: No. sample boats	No. days fished	product	Correction for natural mortality $= \frac{k''e''}{e}$
1941-42	134,842	547,208	5.0581	.0620	5	78.6	393	.0001578
42-43	114,023	438,127	4.8424	"	"	62.4	312	.0001987
43-44	100,436	393,064	4.9136	"	"	61.0	305	.0002033
44-45	130,477	563,783	5.3204	"	"	64.0	320	.0001938
45-46	111,353	730,897	7.5638	"	"	62.2	311	.0001994
46-47	79,675	455,425	6.7160	"	"	54.6	273	.0002271
47-48	65,419	383,781	6.8665	"	"	50.8	254	.0002441
48-49	47,269	228,531	5.8347	"	"	42.4	212	.0002925
49-50	56,666	121,234	3.1395	"	"	45.4	227	.0002731
50-51	61,922	271,278	5.3810	"	"	47.8	239	.0002594
51-52	44,508	124,892	3.8061	"	"	41.2	206	.0003010

APPENDIX VII

Calculations of Initial Abundance from Catch Statistics

Season	Observed Regression Coefficients k N	 $\hat{k}$	Correction for Unsampled Fleet $= 1 + \frac{k'e'}{ke}$	$k_f = \hat{k} \times \frac{1}{1+\frac{k'e'}{ke}}$	First Estimate of Abundance $\hat{N} = \frac{kN}{k_f}$ (lbs.)	Correction for natural mortality $= \frac{k''e''}{e}$	$k = \left(k_f - \frac{k''e''}{e}\right)\left(\frac{1}{1+\frac{k'e'}{ke}}\right)$	Abundance $N = \frac{kN}{k}$ (lbs.)
Method 1: C(t) on K(t) - i.e. Sample Fleet Statistics alone for regression line								
1941-42	622.8	.002072	5.0681	.0004096	1,520,500	.0001578	.0003784	1,646,000
42-43	541.7	.001596	4.8424	.0002863	1,879,000	.0001967	.0002472	2,190,000
43-44	492.5	.001519	4.9156	.0003091	1,593,300	.0002053	.0002678	1,833,000
44-45	669.6	.001522	5.3204	.0002530	2,241,900	.0001938	.0002265	2,603,000
45-46	553.0	.001860	7.5636	.0002446	2,260,800	.0001994	.0002185	2,533,000
46-47	435.5	.002066	6.7160	.0003106	1,402,100	.0002271	.0002768	1,573,000
47-48	365.3	.001795	6.8665	.0002614	1,397,500	.0002441	.0002259	1,617,000
48-49	331.2	.001510	5.6347	.0002571	1,288,200	.0002925	.0002069	1,601,000
49-50	361.5	.001046	3.1395	.0003338	1,083,000	.0002731	.0002469	1,464,000
50-51	389.8	.002064	5.3610	.0003837	1,015,900	.0002594	.0003169	1,230,000
51-52	290.0	.001440	3.6061	.0003783	766,600	.0005010	.0002993	969,000
Method 2: C(t) on K_w(t) - i.e. Sample and whole fleet statistics combined for regression line								
						$\frac{k''e''}{e} \times \frac{1}{1+\frac{k'e'}{ke}}$	$k = k_f - \left(\frac{k''e''}{e} \times \frac{1}{1+\frac{k'e'}{ke}}\right)$	
1941-42	603.3			.0004197	1,437,500	.00003120	.0003885	1,553,000
42-43	529.3			.0002438	2,171,000	.00004105	.0002028	2,610,000
43-44	468.7			.0002264	2,070,200	.00004158	.0001850	2,534,000
44-45	664.7		regression	.0002543	2,299,300	.00003645	.0002179	2,683,000
45-46	529.1	see k_f	is for	.0002500	2,035,000	.00002635	.0002537	2,264,000
46-47	439.6		whole fleet	.0003117	1,411,000	.00003561	.0002779	1,583,000
47-48	362.7			.0002775	1,306,600	.00003553	.0002420	1,499,000
48-49	315.7			.0001804	1,750,000	.00005613	.0001303	2,423,000
49-50	360.5			.0004050	883,500	.00000855	.0003174	1,104,000
50-51	368.9			.0002738	1,323,200	.00004821	.0002306	1,600,000
51-52	272.7			.0004748	574,700	.00007808	.0003654	690,000

Actual catch per tow and calculated catch per 5,400 sq. yd. tow, of marked and unmarked scallops during drag efficiency experiments on 40-minute ground, September 1950.

Tow Number	Total length of tow, yards	Total length of tow, minutes	% of tow on marked area	Length of tow on marked area (yards)	Marked Scallops actually recaptured	Marked Scallops per 5,400 yd.[2]	Unmarked Scallops captured	Unmarked Scallops per 5,400 yd.[2]
Sept. 5								
#1	900	17	82	738	28	34	396	396
2	900	19	100	900	28	28	371	371
3	900	19	100	900	46	46	382	382
Sept. 6								
#1	900	20	?	?	(5)	--	(488)	---
2	900	18	100	900	131	131	373	373
3	900	20	100	900	145	145	498	498
4	900	22	50	450	22	44	317	317
5	900	16	44	396	57	131	344	344
6	900	20	30	270	28	93	517	517
7	900	20	30	270	27	89	290	290
8	900	20	30	270	35	129	460	460
Sept. 8								
#1	450	10	100	450	103	205	209	418
2	900	25	100	900	113	113	320	320
3	900	25	100	900	120	120	513	513
4	900	24	100	900	50	50	475	475
5	800	25	100	800	29	33	399	448
6	900	18	100	900	134	134	392	392
7	675	15	50	338	31	83	295	391
8	900	18	100	900	22	22	308	308
9	900	17	100	900	100	100	318	318
10	600	16	100	600	61	95	359	542
11	600	15	50	300	29	87	198	289
Sept. 9								
#1	450	15	100	450	86	172	264	528
2	300	15	100	300	29	87	255	765
3	800	18	100	800	109	169	376	424
					1563	2339	8641	10,070

APPENDIX IX

Height of shells of Penobscot Bay 1951 and Digby 1950 collections of small scallops at time of formation of annuli and total shell height in September of year collected.

Penobscot Bay Sample			Digby Buoy Ground Sample											
Shell no.	Height at 1st annulus (March 1951)	Total Height (Sept. '51)	Shell no.	Height at 1st annulus (winter 49-50)	Total Height (Sept. '50)	Shell no.	Height at 1st annulus	Height at 2nd annulus	Total Height (Sept. '50)	Shell no.	Height at 1st annulus	Height at 2nd annulus	Total Height (Sept. '50)
1	3	11	1	2	8	25	2		12	53	4	20	27
2	2	8	2	2	8	26	2		13	54	8	20	30
3	2	12	3	1	8	27	2		13	55	6-7	22	29
4	2	7	4	2	10	28	3		13	56	5	17	29
5	2	10	5	2	10	29	2		15	58	3		15
6	2	11	6	2	10	30	2		15				
7	1	8	7	2	10	31	3		11				
8	2	11	8	2	10	32	2		14				
9	3	9	9	2	10	33	3		15				
10	2	10	10	3	10	34	3	10	14				
11	2	7	11	2	11	35	2	9 (?)	15				
12	2	9	12	2	12	36	2	12 (?)	16				
13	3	12	13	3	11	37	3		17				
14	2	8	14	2	12	38	4		18				
15	4	15	15	2	11	39	1	9	18				
16	2	9	16	2	11	40	2	8	18				
17	2	11	17	2	11	41	4		17				
18	2	9	18	2	10	42	3	15	19				
19	2	9	19	2	11	43	2	12	20				
20	2	9	20	2	12	44	4		21				
21	2	12	21	2	12	45	2		21				
22	2	10	22	1	12	46	2	15	23				
23	3	13	23	1	12	47	4	15	25				
24	3	12	24	2	12	48	2	14	23				

APPENDIX X

Average size of inshore, Digby Scallops of different year classes at time of formation of the annuli - 1950 shell collections.

Sample	year class	size at formation of annulus no: 1	2	3	4	5	6	7	8	9	10	11	12	No. in year class
Sample #1 Shelburne Cove, 2nd Ridge July 24/50	1947	8.0	19.0	40.0										4
	1946	6.5	14.5	24.4	69.7									13
	1945	8.3	17.4	30.1	54.4	82.4								9
	1944	6.8	15.2	28.6	55.6	76.6	94.2							5
	1943	7.0	15.0	28.5	61.8	81.3	94.3	105.0						4
	1942	7.2	14.7	25.9	54.9	78.8	93.7	104.1	111.3					31
	1941	7.1	14.7	25.4	53.8	78.9	93.9	103.5	109.9	113.7				37
	1940	6.8	14.3	25.1	50.0	74.6	90.8	101.7	108.1	112.5	115.1			9
	1938	6.7	15.0	24.3	53.3	78.0	92.0	102.0	109.7	116.3	122.0	123.0	125.0	3
	1937	6.0	13.0	21.5	53.0	78.0	92.5	107.0	114.5	122.0	128.0	131.5	133.5	2
	1936	6.0	11.0	17.0	47.0	75.0	89.0	101.0	110.0	117.0	124.0	128.0	132.0	1
Average		7.1	15.0	26.7	55.9	78.7	92.6	103.6	110.3	114.0	118.8	126.7	129.0	
Sample #2 Buoy Ground, Aug. 3/50	1946	5.2	11.8	21.3	36.5									22
	1945	6.4	14.6	25.6	46.5	68.1								10
	1944	6.9	14.3	24.9	40.5	62.7	85.5							20
	1942	5.0	10.5	18.5	31.0	60.5	82.0	98.5	108.5					2
	1941	5.5	10.9	17.6	31.0	56.5	84.3	100.8	110.9	118.0				13
	1940	5.4	11.3	18.3	30.1	54.7	81.4	100.1	110.6	117.6	121.8			18
	1939	5.3	10.3	18.2	29.3	54.2	79.2	96.0	106.7	114.7	119.8	124.3		6
	1937	5.5	10.5	19.3	32.8	60.3	86.0	102.5	113.5	120.0	126.3	131.3	135.0	4
	1935	5.3	11.0	19.2	33.6	58.2	82.6	99.4	111.0	118.6	125.4	131.2	134.4	5
	1934	5.1	11.0	17.1	28.3	52.0	77.0	95.7	107.3	115.1	122.6	127.2	131.3	14
Average		5.7	12.1	20.5	34.7	58.3	82.0	98.9	109.7	117.1	122.6	127.9	132.6	
Sample #3 Buoy Ground, Aug. [illegible]/50	1947	6.3	15.6	27.6										7
	1946	6.7	15.6	27.2	40.7									135
	1945	7.9	19.1	33.6	52.4	72.8								48
	1944	7.4	17.8	33.6	55.0	77.6	96.4							5
	1943	6.0	17.5	31.5	52.0	75.5	96.0	108.0						2
	1942	8.7	17.0	29.1	55.6	80.0	93.0	103.3	114.3					3
	1941	7.0	15.3	29.3	57.0	78.5	94.0	104.0	113.0	119.0				4
	1940	6.0	11.0	19.0	34.0	61.0	90.0	104.0	113.0	120.0	122.0			1
Average		7.0	16.5	28.9	44.5	73.8	94.6	104.6	113.5	119.2	122.0			
No. Measurements		437	437	437	426	256	189	159	153	117	63	35	29	2,738
Average		6.7	14.9	26.1	45.0	70.2	88.1	101.8	110.2	115.8	121.6	127.7	131.9	
Standard Deviation		1.0	2.7	5.8	11.6	10.0	5.8	3.2	2.4	2.6	3.4	3.2	3.3	

Water Temperatures for Prince Station 5 (90 meters)

Year	Water Temperature-P. Sta. 5, 90m. - °C.						3 month Averages				2 month Averages			
	July	Aug.	Sept.	Oct.	Nov.	Dec.	July-Sept.	Aug.-Oct.	Sept.-Nov.	Oct.-Dec.	July-Aug.	Aug.-Sept.	Sept.-Oct.	Oct.-Nov.
1924	5.54	7.83	9.06	9.91	8.61	7.02	7.48	8.93	9.19	8.51	6.69	8.45	9.49	9.26
25	6.76	7.14	9.24	7.61	7.21	5.82	7.71	8.00	8.02	6.88	6.95	8.19	8.43	7.41
26	5.90	7.43	8.78	9.68	7.97	5.82	7.37	8.63	8.81	7.82	6.66	8.11	9.23	8.83
27	6.39	7.85	7.96	9.53	8.81	8.07	7.40	8.45	8.77	8.80	7.12	7.91	8.75	9.17
28	7.05	8.85	9.72	10.06	9.79	6.91	8.54	9.54	9.86	8.92	7.95	9.29	9.89	9.93
29	6.48	6.87	8.68	8.81	6.64	(6.63)	7.34	8.12	8.04	(7.36)	6.68	7.78	8.75	7.73
1930	7.49	8.33	9.37	11.19	9.70	4.95	8.40	9.73	10.09	8.61	7.91	8.85	10.28	10.45
31	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32	7.18	7.40	10.18	10.08	9.20	6.80	8.25	9.22	9.82	8.69	7.29	8.79	10.13	9.14
33	7.34	8.56	8.96	9.21	8.57	6.55	8.29	8.91	8.91	8.11	7.95	8.76	9.09	8.89
34	6.63	7.89	8.56	10.08	9.01	6.93	7.69	8.84	9.22	8.67	7.26	8.23	9.32	9.55
35	6.46	8.11	8.72	9.29	(8.55)	5.79	7.76	8.71	(8.85)	(7.88)	7.29	8.42	9.01	(8.92)
36	7.36	8.42	9.42	10.19	8.65	6.63	8.40	9.34	9.42	8.49	7.89	8.92	9.80	9.42
37	7.91	8.71	9.65	9.77	9.63	8.22	8.76	9.38	9.68	9.21	8.31	9.18	9.71	9.70
38	6.81	8.19	9.34	10.01	9.80	7.62	8.11	9.18	9.72	9.14	7.50	8.77	9.68	9.91
39	6.03	7.60	10.10	(10.72)	9.03	6.22	7.91	(9.47)	(9.98)	(8.65)	6.82	8.85	(10.40)	(9.87)
1940	5.79	7.38	8.52	(9.03)	(8.35)	(6.51)	7.23	(8.31)	(8.63)	(7.79)	6.59	7.95	(8.78)	(8.69)
41	6.34	7.52	7.98	(8.46)	(7.82)	(6.10)	7.28	(7.99)	(8.09)	(7.46)	6.93	7.75	(8.22)	(8.14)
42		6.89	7.98	8.89	(7.82)	(6.10)	-	7.92	(8.23)	(7.60)	-	7.44	8.44	(8.36)
43	6.04	9.08	9.05	9.74	9.79	8.06	8.06	9.29	9.53	9.20	7.56	9.07	9.40	9.77
44	6.04	8.23	9.71	10.37	9.17	(7.42)	7.99	9.44	9.75	(8.99)	7.14	8.97	10.04	9.77
45	7.21	8.16	9.58	9.29	(9.39)	(7.32)	8.32	9.01	(9.42)	(8.67)	7.69	8.87	9.44	(9.34)
46	6.59	8.08	9.45	11.00	10.00	7.60	8.04	9.51	10.15	9.53	7.34	8.77	10.23	10.50
47	7.78	9.17	10.78	11.39	10.15	6.64	9.24	10.45	10.77	9.39	8.48	9.98	11.09	10.77
48	6.74	7.23	8.39	9.22	9.32	7.71	7.45	8.28	8.98	8.75	6.99	7.81	8.81	9.27
49	8.59	10.43	11.48	11.84	11.16	9.36	10.17	11.25	11.49	10.79	9.51	10.96	11.66	11.50
1950	7.04	8.13	11.15	10.20	9.75	8.55	8.77	9.83	10.33	9.50	7.59	9.64	10.68	9.98
51	8.59	9.39	10.68	10.88	10.60	8.39	9.55	10.32	10.72	9.96	8.99	10.04	10.78	10.74
52	8.23	9.11	9.18	10.52	8.45	7.30	8.84	9.60	9.38	8.76	8.67	9.15	9.85	9.49
Average	6.90	8.14	9.35	9.95	9.17	7.14								
#	27	28	28	25	23	22								

Brackets in first part of table indicate missing temperature observations. Values shown were calculated from the mean of all observations for that month times the ratio of the September observation in that year to the mean of all September observations.

Bracketed averages indicate that calculated values are included.

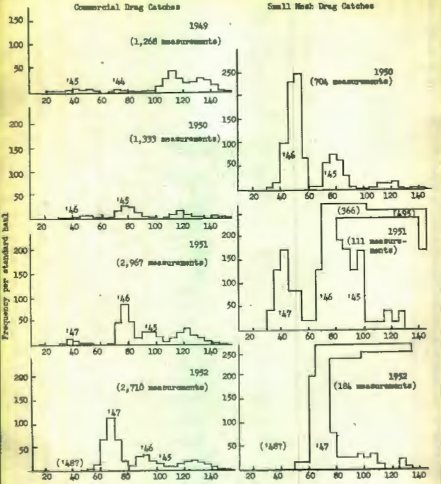

Fig. 21. Size frequency and year-class composition of Buoy Ground scallops.