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VARIABILITY OF GROWTH, MEAT COUNT AND REPRODUCTIVE CAPACITY IN *PLACOPECTEN MAGELLANICUS*: ARE CURRENT MANAGEMENT POLICIES SUFFICIENTLY FLEXIBLE?

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ABSTRACT

It is now accepted that depth is a major factor affecting the biology of the scallop, *Placopecten magellanicus* throughout its range. Recent studies have demonstrated variations in a number of allometric relationships, growth rate and reproductive capacity between populations from various depths. Growth rate in deep waters is consistently slower than in animals from more shallow areas. The adductor muscle weight, the basis for many aspects of management policy, can vary by as much as 200% for scallops of the same shell height taken from different areas. More recently, it has been shown that scallops from deep water populations exhibit diminished or non-existent reproductive capacities.

Current management policies are reviewed with reference to variation in parameters such as growth rate, meat counts and reproductive capacity. It is suggested that considerable flexibility may be required in management so as to account for peculiarities of individual populations.

The giant scallop, _Placopecten magellanicus_ Gmelin, supports an intensive fishery throughout its range from the Strait of Belle Isle, Newfoundland to Cape Hatteras, North Carolina, USA (See Fig. 1). The State of Maine alone issued 700 scallop boat and hand licenses for calendar year 1986. The adductor muscle (meat) is the only portion commonly marketed in the United States. The allometric relationship of this muscle to shell height is the link to the age structure of the population. Since the adductor muscle is the basis for many aspects of management such as production and yield per recruit, and with the recent controversy over count per pound, special emphasis has been placed on the relationship between meat weight and shell height. This relationship has been studied in various scallop populations in the Gulf of Maine-Bay of Fundy-Georges Bank region over a number of years and has been shown to differ between areas, (Chaisson, 1951; Dickie & Medcof, 1956; Bourne, 1964; Haynes, 1966; Caddy _et al._, 1970; Naidu, 1975; U.S. FMP-Appendix 1, 1978; Jamieson, 1979; Jamieson _et al._, 1981a; Jamieson _et al._, 1981b; Serchuk _et al._, 1982; Serchuk and Rak, 1983; Worms and Choinard, 1984; Worms _et al._, 1986; Schick _et al._, 1987) and over time in the same area (Haynes, 1966; Karlsson, 1969; Naidu, 1969); Jamieson, 1979; Jamieson, _et al._ 1981d; Robinson _et al._, 1981; Serchuk 1983; Worms and Davidson, 1986; Schick _et al._, 1987). Changes in the relationship between years have been found by Poirier (1973), Jamieson (1979) Serchuk and Rak (1983) , Robert _et al._ (1985) and Schick _et al._ (1987)(Table). Other researchers have listed the meat weight to shell height relationship for specific areas (Medcof, 1949; Chaisson, 1950; Hidu, 1977; Jamieson and Lundy, 1979; Jamieson _et al._ 1980; D'Amours and Pilote, 1982; Mohn _et al._, 1984; Naidu and Cahill, 1984; Sinclair, 1985). Hidu et al., (1977) has shown a wide variability in calculated meat volume for scallops from the same shell height from one area near Stonington, Maine.

A decrease in meat weight with increasing water depth has been shown by Hart (1967) and Caddy and Chandler (1969). Naidu (1984) has examined the seasonal changes in the relationship between the quick muscle and the whole muscle of sea scallops from St. Pierre Bank off Newfoundland. This data is all summarized in Tables 1-3 and Figure 2. The differences in adductor muscle weight for scallops with the same shell height is quite clear and can vary for a 100 mm scallop from 8.9 to 19.9g depending on the area of collection.

To further complicate the picture, the size of the adductor muscle varies with season (Serchuk, 1983; Robinson et al., 1981; Jamieson, 1979; Jamieson et al., 1981c; Gould, 1983; Serchuk, 1983; Robert et al., 1982; Schick et al., 1987) (See Table 4).

A reasonable description of growth is necessary for an understanding of the population dynamics of any resource and for the formulation of management policies. This data, like the adductor muscle/shell height relationships, is used for stock assesssment and management purposes. Like the relationship between adductor muscle and shell height, growth rates also vary considerably between areas with the shell height of a 4 year old scallop ranging from approximately 75 to 120 mm (Figure 3; Table 5). Growth rates of P. magellanicus have been shown to vary with increasing age, between years at one location, between locations and with changing environmental conditions associated with either depth or temperature (Chaisson, 1952; Robert et al., 1985; Posgay and Merrill, 1979; MacDonald and Thompson, 1985; Naidu, 1975; Serchuk et al., 1982; Jamieson, 1979; Choinard, 1984).

Finally, it has been demonstrated that with increasing depth of occurrence, scallops exhibit a reduced reproductive output (estimated gamete production) (MacDonald and Thompson, 1985b, 1986; Barber et al., 1987) and a reduced reproductive effort (proportion of non-respired, assimilated energy allocated to reproduction)(MacDonald et al., 1987; Barber et al., 1987; Robert and Lundy, 1985) (Fig. 4). Further, it was suggested by Barber et al. (1987) that the reduction in fecundity of scallops from deep water populations renders them reproductively nonviable. The unimodal size frequency distribution of this and other deep-water populations (Serchuk and Rak, 1983; Schick et al., 1987) indicates rather that recruitment (from other areas) occurs sporadically. The existence of non-reproductive populations or non-self-sustaining populations then poses the question: do these specific populations need to be managed at all?

Sea scallop management has historically been a local issue. In both Canada and the USA, historical regulations have dealt with local scallop fishery problems caused either by overfishing or by conflicts with other fisheries. Scallop management efforts started in the USA when the state of Maine imposed a summer closure sometime between 1901 and 1917. In Canada, management started in 1920 with a summer closure in territorial waters near Digby, Nova Scotia. Today, many local management regulations are still in effect and many more have been implemented to conserve the stocks and control gear conflicts. Also today, there are large questions raised as to the proper methods to use for the conservation of the offshore scallop stocks found on Georges Bank, in the Gulf of Maine and in the Mid-Atlantic Bight.

In the USA, no regulation of the offshore fishery existed prior to 1983 other than what the industry imposed upon itself. In inshore waters, however, scallop management has existed for a long time. Maine has had long-standing regulations for the conservation of the scallop stocks within its three-mile territorial limits. New Hampshire has had conservation regulations of a 3-1/4 minimum shell height and an April 15 through October 31 closed season since 1977. Massachusetts, with the largest offshore scallop fishery out of New Bedford, has had no regulations due to the lack of need with no large inshore beds of sea scallops. Recently, each state has modified their regulations to at least comply with the USA federal regulations for the Fisheries Conservation Zone (FCZ), but Maine's regulations remain even more restrictive. Historically, Maine has had a 3 inch minimum shell size since 1956 and a closed season from April 16 to October 31. Maine's closed season has varied slightly over the years from its initiation between 1901 and 1917, but has consistently limited the season to a winter fishery. Other historical regulations have dealt with specific areas for either conservation or gear conflict purposes. Maine has imposed limits on season, drag size and gear type by area for selected problem areas.

Current scallop fishery regulations in Maine comply with the Fisheries Management Plan and include further restrictions. Specific area restrictions on season, gear type and gear size have been increased primarily to reduce gear conflict between the draggers and fixed gear fisheries. General restrictions include a ban on nighttime fishing for scallops, a drag size limit of 5'6" from November 1 to November 30, a drag size limit of 10'6" from December 1 to April 15, a limit of 2 bushel of shellstock, or 4 quarts shucked meat taken by means other than conventional drag from November 1 to December 31, and the requirement for a hand-fishing license for divers and a boat license for draggers. Current fishery regulations in New Hampshire close the fishery from April 15 through October 31, comply with the FCZ-FMP and remove the 10% tolerance on minimum size for scallops taken by divers.

In Canada, the fishery for scallops in the Bay of Fundy has been regulated since 1920 when overfishing of the stocks prompted a closed season in territorial waters from June 1 through October 15 and a minimum shell size of 4 inches. In 1931 an additional extra-territorial waters closure was imposed from August 16 through October 15. Also in 1931, a 4 inch minimum mesh regulation, a prohibition of dumping viscera on the scallop beds, and a prohibition of soaking the meats in freshwater were imposed on the fishery. Local closures of May 1 through October 31 for Lunenberg County and February 1 through November 30 for Digby Basin were also imposed in 1931 to limit overfishing of inshore beds. In April, 1936 the closed season was reduced to June 1 through September 30 and in April 1938 it was increased to May 1 through September 30. During the 1930's the fishermen gradually changed from a 4 inch mesh to a 2-5/8 inch mesh. In 1938 a maximum drag width of 5.5 meters (18 feet) was imposed. The Bay of Fundy regulations did not change again until 1950 when a closure line was established 7 miles offshore with a May 1 through August 31 closure inside the line and no closure outside the line. This was abolished in 1966 and reestablished in 1973 after a temporary closure in 1971. Also in 1973 the fleet size was frozen at 54 boats by limited entry. Even so, the fleet size grew to almost 100 boats by 1984 and remains at that level today. Current regulations call for logbooks to be kept by all boats licensed with a Bay of Fundy license with the exception of "3 mile" permits which allow inshore fishing only.

The Georges Bank scallop fishery was unregulated by either Canada or the USA until the late 1960's, when Canada initiated required logbook submission. In 1973, Canada instituted limited entry into the Georges Bank fishery and imposed a limit of 60 meats per pound. In May, 1974 this limit was increased to 50 meats per pound and in June, 1975 to 45 meats per pound and again in May, 1976 to 40 meats per pound. Further regulations in March 1977 limited each trip to 12 days dock to dock, and 30,000 pounds maximum catch per trip. Also in 1977 a maximum landed weight per boat per 4 month period of 180,000 pounds of meat was imposed. In 1981, the 40 meats per pound limit was relaxed in Canada due to industry pressure and lack of a meat count limit in the USA fishery. In 1983, the meat count limit was increased to 39 meats per 500 grams weight (ca. 35 meats/pound) and in 1986 the limit was increased to 33 meats per 500 grams (ca. 30 meats/pound). Also in a 1986 a TAC (Total Allowable Catch) of 4,100 tons with no more than 9% taken in the first quarter was imposed.

Historically, the only regulations in the USA offshore scallop fishery, which includes Georges Bank, the Gulf of Maine and the Mid-Atlantic Bight as far south as Cape Hatteras, have been imposed by industry in the form of specified crew size, maximum allowable time at sea per trip, minimum time at the dock between trips and a maximum of two tows dumped on deck at one time prior to shucking. With the advent of the 200 mile Fisheries Conservation Zone, the New England and Mid-Atlantic Fisheries Management Councils developed and implemented the

Sea Scallop Fisheries Management Plan to regulate the fishery. The basis for managing the Georges Bank, Gulf of Maine and Mid-Atlantic scallop fisheries under the FMP has been to increase yield per recruit by controlling age/size of recruitment by imposing a maximum average meat count. The FMP was implemented in May, 1983 and imposed a 30 meat count maximum with an equivalent shell height of 3-1/2 inches. The Regional Director of NMFS immediately increased the count to 35 with a shell height minimum of 3-3/8 inches due to the unwillingness of Canada to go along with a 30 count maximum. This temporary change in the limits was to be in effect until January, 1984 when the limits would go to 30 meats per pound and 3-1/2 inches shell height. The 30 count regulation was delayed until January, 1986 due to industry and political pressures and the 35 meat count was retained. Under this scheme of an average meat count, small scallop meats may be mixed with large meats as long as the average meets the maximum count requirement.

In 1984 a large set of scallops in the Great South Channel of Georges Bank promised to sustain the scallop fishery for some time. However, most of this set was harvested at a small size and the meats were mixed with larger meats to achieve the 35 count maximum. Almost the entire set was harvested at way below its potential yield per recruit and before it was able to significantly contribute to reproduction. To prevent this from happening again, the Councils proposed Amendment 1 to the FMP that would institute a 40 count minimum meat size, which would create an average meat count of around 30, but would prohibit the mixing of scallops much smaller than the minimum size. This effort has brought much criticism from the industry.

Amendment 1 to the FMP went into effect January 1, 1986, but was delayed by the Regional Director of NMFS and was recinded May 28, 1986. Scallop management then returned to the FMP and the 30 count average with a 10% tolerance (effectively a 33 count average) and 3-1/2 inch shell height was imposed. The shell height of 3-1/2 inches is based on an average shell height to meat weight regression showing the shell height for a 30 count scallop meat. Industry criticism has been levied against the 3-1/2 inch shell size as well. The industry arguments center on the fact that the shell height to meat weight relationship is highly variable from location to location and from season to season. With scallop sets occurring at different locations in different years, or even in the same year, having one shell height to meat weight regression represent the whole fishery they claim is unreasonable. Currently, shellstockers can harvest scallops in the Mid-Atlantic Bight at 3-1/2 inch shell height that have meats too small for the at-sea shuckers to harvest even at 33 count. With the large recruitment of recent year classes producing at present a bonanza for the shellstockers and little for the at-sea shuckers, there is much asperity in the industry with cries of unfair management practices.

In response to industry criticism, the Councils have put forth Amendment 2 to the FMP, which contains several options for management of the scallop resource. During several hearings on these options, industry spokesmen have made it clear that most options presented are untenable, or at least unpalatable to them. The one option worth considering to them is the so-called Option A where a 3-1/2 inch shell height minimum would go into effect. This would be enforced by having each boat bring 3 bushels of scallops, in the shell, into port, shuck them out after the shells are measured to insure compliance with the 3-1/2 inch limit and have the meat count per pound determined. The sample meat count must be equal to or greater than the meat count of the catch to have the trip be legal. While this option would involve more busy work for both industry and enforcement, it would treat shellstockers and at-sea shuckers equally. Other options presented to industry combine the concepts of closed areas on a rotating basis, reductions in days at sea per year, total closures, and maintaining the 30 meat count average with adjustable average count per pound based on seasonal differences and with an adjustable minimum shell height of 3-1/2 inches to 4 inches (Table 6). Each option would include further restrictions on maximum dredge width and other gear restrictions, daylight-only unloading, a mandatory hail and/or effort restrictions. Various factions in the industry strongly support either Option A or a combination of gear and effort restrictions with no middle ground visible between them at present.

We are not the first to discuss the problems of management associated with the variability of growth, meat count and/or reproductive capacity in P. magellanicus. Serchuk (1983) and Serchuk and Rak (1983) have both argued the pros and cons of a standard meat size/count. Most recently, Worms and Davidson (1986) presented a summary of scallop meat weight/shell height relationships and their implications for resource management in the Gulf fo St. Lawrence.

We have presented a summary of the data extant on variations in growth, allometric relationship of the shell height and adductor muscle and reproductive capacity of various populations of the giant scallop, P. magellanicus. Inasmuch as the goals of management are to optimize yield while at the same time stabilizing the catches, it seems reasonable that considerable attention should be paid to the high level of variability that can occur in meat weight within a given fishing area. Since a single meat count is obviously not going to be valid 'across the board', different meat count and/or shell height regulations are needed for separate areas/fishing zones. It is further suggested that, since seasonal and yearly variation in meat weights have been demonstrated, meat count regulations should be based on yearly sampling and set on a seasonal and area-specific basis. While a constantly changing count/size limit will undoubtedly cause problems with regard to compliance and enforcement, it will strip away inequities between harvesting techniques and increase yield to the fishermen by effectively increasing Y/R and allowing management closer to the limits of the resource.

At a time when the scallop fishery is increasing, and for a species which experiences such drastic fluctuations (Fig. 1), management can't be too careful in the regulations it imposes.

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Table 1

Sea scallop adductor weight to shell height regressions from fisheries sources. Data fitted to equation $Y = ax^b$, where Y = adductor muscle weight, x = shell height, a is a constant and b is the slope.

	$a \times 10^{-5}$	b	r^2	n	Source
MAINE DMR					
Inshore Gulf of Maine					
Inshore Maine 1977–83	4.876	2.76	0.92	715	Maine DMR data from Boothbay Harbor region
Shallow Water Gulf of Maine 84–85	3.772	2.86	0.96	535	Schick et al. (1987)
Offshore Gulf of Maine					
Jeffreys Basin and Fippennies Ledge 1980	0.132	3.48	0.93	1726	NMFS, Maine and Mass. commercial samples (8)
Machias 1981	1.077	3.00	0.83	1141	Maine DMR commercial samples from 5, 7 and 8 miles S. of Libby Island, Machias Bay
Deep Water Gulf of Maine 1984–85	1.756	2.91	0.82	457	Schick et al. (1987)
U.S. NATIONAL MARINE FISHERIES SERVICE					
Inshore Gulf of Maine					
Penobscot Bay 1960-62	0.059	3.66	-	1107	Haynes (1966)
Offshore Gulf of Maine					
Jonesport 1982	1.906	2.87	0.96	1248	Serchuk (1983)
Other Gulf of Maine 1982	0.449	3.25	0.99	513	Serchuk (1983)
Georges Bank 1978-1982	0.777	3.17	0.98	5863	Serchuk and Wigley (1984)
CANADA - BAY OF FUNDY					
Inshore					
Passamaquoddy Bay 1960-62	0.483	3.24	-	3600	Jamieson & Lundy (1979)
Digby Inshore	0.426	3.24	-	-	Jamieson, Witherspoon and Chandler (1981)
Offshore					
Digby Offshore	1.239	2.93	-	-	Jamieson, Witherspoon and Chandler (1981)

Table 2

Calculated adductor muscle weight (g) at shell height (mm) for sea scallops from inshore and offshore sites in the Gulf of Maine

	CALCULATED ADDUCTOR WEIGHT (g)											
	GULF OF MAINE INSHORE					GULF OF MAINE OFFSHORE				CANADA INSHORE		CANADA OFFSHORE
Shell Hgt.(mm)	Boothbay Region	shallow water GOM	Penobscot Bay	Jeffries Basin Fippen. Ledge	Machias	deep water GOM	Jonesport	other GOM	Georges Bank	Passama-quoddy Bay	Inshore Digby	Offshore Digby
40	1.29	1.45	0.43	0.50	0.69	0.80	0.76	0.72	0.93	0.74	0.66	0.61
50	2.39	2.75	0.97	1.08	1.34	1.53	1.43	1.48	1.89	1.53	1.36	1.17
60	3.96	4.63	1.90	2.03	2.31	2.60	2.42	2.69	3.36	2.76	2.46	2.00
70	6.60	7.19	3.33	3.47	3.68	4.07	3.76	4.43	5.48	4.55	4.06	3.13
80	8.76	10.54	5.44	5.53	5.49	6.00	5.52	6.84	8.37	7.01	6.25	4.64
90	12.13	14.76	8.37	8.33	7.81	8.45	7.74	10.03	12.16	10.27	9.16	6.55
100	16.22	19.95	12.30	12.02	10.72	11.48	10.47	14.13	16.98	14.45	12.88	8.91
120	26.83	33.60	23.98	22.68	18.52	19.52	17.67	25.55	30.27	26.09	23.26	15.21
130	33.46	42.25	32.14	29.96	23.54	24.64	22.23	33.14	39.01	33.82	30.14	19.22
140	41.05	52.23	42.15	38.77	29.40	30.57	27.50	42.16	49.34	43.00	38.32	23.89
150	49.66	63.62	54.26	49.29	36.16	37.36	33.53	52.76	61.41	53.77	47.92	29.24
160	59.34	76.52	68.72	61.71	43.89	45.08	40.35	65.07	75.35	66.27	59.07	35.32

Calculated from the meat weight/shell height equation from:

[1]Maine DMR research collections in Boothbay and the Sheepscot and Damariscotta rivers, 1977-1983.
$\log_{10}$ meat weight (g) = 4.31 + 2.76 $\log_{10}$ shell height

[2]Maine DMR quarterly research samples from the Damariscotta River, Feb. 1984-May 1985.
$\log_{10}$ meat weight (g) = -4.42 + 2.86 $\log_{10}$ shell height

[3]NMFS commercial samples in Penobscot Bay, Maine 1960-1962 (Haynes 1966).
$\log_{10}$ meat weight (g) = -6.23 + 3.66 $\log_{10}$ shell height

[4]NMFS, Maine and Massachusetts commercial samples from Jeffreys Basin and Fippennies Ledge, 1980 (Serchuk and Rak, 1983).
$\log_{10}$ meat weight (g) = -5.88 + 3.48 $\log_{10}$ shell height

[5]Maine DMR commercial samples from 5, 7.5, and 8 miles S. of Libby Island, Machias Bay, 1981.
$\log_{10}$ meat weight (g) = -4.97 + 3.00 $\log_{10}$ shell height

[6]Maine DMR quarterly research samples from 20 miles S. Boothbay Harbor, Maine, Feb. 1984-May 1985.
$\log_{10}$ meat weight (g) = -4.76 + 2.91 Log_{10} shell height

[7]NMFS 1982 Jonesport research vessel survey (Serchuk and Rak, 1983).
$\log_{10}$ meat weight (g) = -4.72 + 2.87 $\log_{10}$ shell height

[8]NMFS 1982 research vessel survey (Serchuk and Rak, 1983)
$\log_{10}$ meat weight (g) = -5.35 + 3.25 $\log_{10}$ shell height

[9]NMFS 1978-1982 research vessel surveys (Serchuk and Wigley, 1984)
$\log_{10}$ meat weight (g) = -5.11 + 3.17 $\log_{10}$ shell height

[10]Canadian research samples from Passamaquoddy Bay, New Brunswick 1960-1962 (Jamieson and Lundy, 1979).
$\log_{10}$ meat weight (g) = -5.32 + 3.24 $\log_{10}$ shell height

[11]Canadian research samples from <9.7km off Digby, Nova Scotia, 1977-1979 (Jamieson, et al. 1981).
$\log_{10}$ meat weight (g) = -5.37 + 3.24 $\log_{10}$ shell height

[12]Canadian research samples from >9.7km off Digby, Nova Scotia 1977-1979 (Jamieson, et al. 1981).
$\log_{10}$ meat weight (g) = -4.91 + 2.93 $\log_{10}$ shell height

Table 3

Calculated adductor muscle weight (g) at shell height (mm) for sea scallops from inshore and offshore sites in the Gulf of Maine

CALCULATED ADDUCTOR WEIGHT (g)

	GULF OF MAINE INSHORE			GULF OF MAINE OFFSHORE						CANADA INSHORE		CANADA OFFSHORE
Shell Hgt.(mm)	Boothbay Region	shallow water GOM	Penobscot Bay	Jeffries Basin Fippen. Ledge	Machias	deep water GOM	Jonesport	other GOM	Georges Bank	Passama-quoddy Bay	Inshore Digby	Offshore Digby
40	1.29	1.45	0.43	0.50	0.69	0.80	0.76	0.72	0.93	0.74	0.66	0.61
50	2.39	2.75	0.97	1.08	1.34	1.53	1.43	1.48	1.89	1.53	1.36	1.17
60	3.96	4.63	1.90	2.03	2.31	2.60	2.42	2.69	3.36	2.76	2.46	2.00
70	6.60	7.19	3.33	3.47	3.68	4.07	3.76	4.43	5.48	4.55	4.06	3.13
80	8.76	10.54	5.44	5.53	5.49	6.00	5.52	6.84	8.37	7.01	6.25	4.64
90	12.13	14.76	8.37	8.33	7.81	8.45	7.74	10.03	12.16	10.27	9.16	6.55
100	16.22	19.95	12.30	12.02	10.72	11.48	10.47	14.13	16.98	14.45	12.88	8.91
120	26.83	33.60	23.98	22.68	18.52	19.52	17.67	25.55	30.27	26.09	23.26	15.21
130	33.46	42.25	32.14	29.96	23.54	24.64	22.23	33.14	39.01	33.82	30.14	19.22
140	41.05	52.23	42.15	38.77	29.40	30.57	27.50	42.16	49.34	43.00	38.32	23.89
150	49.66	63.62	54.26	49.29	36.16	37.36	33.53	52.76	61.41	53.77	47.92	29.24
160	59.34	76.52	68.72	61.71	43.89	45.08	40.35	65.07	75.35	66.27	59.07	35.32

Calculated from the meat weight/shell height equation from:

[1] Maine DMR research collections in Boothbay and the Sheepscot and Damariscotta rivers, 1977-1983.
$\log_{10}$ meat weight (g) = 4.31 + 2.76 $\log_{10}$ shell height

[2] Maine DMR quarterly research samples from the Damariscotta River, Feb. 1984-May 1985.
$\log_{10}$ meat weight (g) = -4.42 + 2.86 $\log_{10}$ shell height

[3] NMFS commercial samples in Penobscot Bay, Maine 1960-1962 (Haynes 1966).
$\log_{10}$ meat weight (g) = -6.23 + 3.66 $\log_{10}$ shell height

[4] NMFS, Maine and Massachusetts commercial samples from Jeffreys Basin and Fippennies Ledge, 1980 (Serchuk and Rak, 1983).
$\log_{10}$ meat weight (g) = -5.88 + 3.48 $\log_{10}$ shell height

[5] Maine DMR commercial samples from 5, 7.5, and 8 miles S. of Libby Island, Machias Bay, 1981.
$\log_{10}$ meat weight (g) = -4.97 + 3.00 $\log_{10}$ shell height

[6] Maine DMR quarterly research samples from 20 miles S. Boothbay Harbor, Maine, Feb. 1984-May 1985.
$\log_{10}$ meat weight (g) = -4.76 + 2.91 Log_{10} shell height

[7] NMFS 1982 Jonesport research vessel survey (Serchuk and Rak, 1983).
$\log_{10}$ meat weight (g) = -4.72 + 2.87 $\log_{10}$ shell height

[8] NMFS 1982 research vessel survey (Serchuk and Rak, 1983)
$\log_{10}$ meat weight (g) = -5.35 + 3.25 $\log_{10}$ shell height

[9] NMFS 1978-1982 research vessel surveys (Serchuk and Wigley, 1984)
$\log_{10}$ meat weight (g) = -5.11 + 3.17 $\log_{10}$ shell height

[10] Canadian research samples from Passamaquoddy Bay, New Brunswick 1960-1962 (Jamieson and Lundy, 1979).
$\log_{10}$ meat weight (g) = -5.32 + 3.24 $\log_{10}$ shell height

[11] Canadian research samples from <9.7km off Digby, Nova Scotia, 1977-1979 (Jamieson, et al. 1981).
$\log_{10}$ meat weight (g) = -5.37 + 3.24 $\log_{10}$ shell height

[12] Canadian research samples from >9.7km off Digby, Nova Scotia 1977-1979 (Jamieson, et al. 1981).
$\log_{10}$ meat weight (g) = -4.91 + 2.93 $\log_{10}$ shell height

Table 4

Calculated mean of adductor muscle weights for a standard scallop (120mm shell height) by gametogenic season.

LOCATION	Year	SEASONAL ADDUCTOR WEIGHT (g) Mature Oct-Mar	Ripening Apr-July	Spawning Aug-Sept	SOURCE
Shallow GOM Quarterly	1984	33.9	34.5	31.4	Schick et al. (1987)
	1985	35.0	37.9		Schick et al. (1987)
Shallow GOM Monthly	1984	32.0	33.3	30.2	Schick et al. (1987)
	1985	35.9	36.6	29.2	Schick et al. (1987)
	1986	28.1	33.6	27.8	Schick et al. (1987)
	1987	31.3			Schick et al. (1987)
Deep GOM Quarterly	1984	17.7		19.5	Schick et al. (1987)
	1985	18.5	23.9		Schick et al. (1987)
Deep GOM Monthly	1984	14.7	20.3	17.5	Schick et al. (1987)
	1985	17.6	19.0	16.6	Schick et al. (1987)
	1986	19.4	18.5	16.6	Schick et al. (1987)
	1987	20.9			Schick et al. (1987)
Georges Bank	1958-1962	25.6	28.4	21.8	Serchuk (1983) Weights calculated from Haynes (1966) regressions.
Narragansett Bay	1968-1969	26.3	22.6	18.8	Serchuk (1983) Weights calculated from Karlsson (1970) regressions.
Damariscotta River	1979	21.7	28.9	26.6	Estimated adductor weights from Robinson, et al. (1981) quick adductor dry weights and catch weight to quick weight ratios and regression of adductor wet weight to adductor dry weight from shallow Gulf of Maine scallops from this paper.
	1980	26.9	32.8		Estimated adductor weights from Robinson, et al. (1981) quick adductor dry weights and catch weight to quick weight ratios and regression of adductor wet weight to adductor dry weight from shallow Gulf of Maine scallops from this paper.

Table 5

Parameters of the Von Bertalanffy growth equation ($H_t = H\infty (1 - e^{-k(t-t_o)})$ for the sea scallop, Placopecten magellanicus

Von Bertalanffy Parameters H∞	k	t_o	r^2	Location	Source
				Newfoundland, Canada	
				Port-au-Port Bay	Naidu, 1975
152	0.21	-0.48		Boswarlos	
161	0.19	-0.88		West Bay	
140	0.27	0.11		Fox Is. River	
				Sunnyside	MacDonald and Thompson, 1985
176.5	0.19	0.55	0.97	10 m	
165.5	0.20	0.63	0.97	20 m	
158.4	0.16	0.10	0.97	31 m	
				Dildo	MacDonald and Thompson, 1985
174.5	0.19	0.66	0.97	10 m	
168.2	0.19	0.37	0.96	20 m	
147.8	0.22	0.74	0.97	31 m	
				Terre Nova N.P.	MacDonald and Thompson, 1985
163.1	0.24	1.26	0.90	10 m	
151.1	0.22	0.37	0.94	20 m	
146.0	0.17	-0.88	0.92	31 m	
				Colinet	MacDonald and Thompson, 1985
158.6	0.18	0.54	0.96	6 m	
160.1	0.19	0.72	0.96	16 m	
				Northumberland St., P.E.I., Canada	
				Tormantine Bed	Choinard, 1984
103.76	0.37	0.67		July	
108.83	0.33.	0.46		November	
114.8	0.28	-0.28		Central Strait	Jamieson, 1979
				Bay of Fundy, N.B., Canada	
				St. Andrews	MacDonald and Thompson, 1985
166.9	0.21	0.51	0.96	10 m	
166.0	0.21	0.53	0.98	31 m	
170.2	0.19	0.20	0.97	76 m	
174.3	0.22	-1.24		Gulf of Maine, USA	Serchuk et al., 1982
				Georges Bank, USA	
148.9	0.26	1.00		Georges Bank	Posgay, 1962
145.5	0.38	1.50		Georges Bank	Brown et al., 1972
146.4	0.35	1.40		Georges Bank	Posgay, 1976
143.6	0.37	1.00		Georges Bank	Posgay, 1979
152.5	0.34	-1.45		Georges Bank	Serchuk et al., 1982
161.38	0.18	1.20		Georges Bank	Roddick and Mohn, 1985
146.5	0.30	1.32		Northeast Peak	Posgay, 1959
141.8	0.28	1.00		Northern Edge	Posgay, 1959
151.8	0.30	-1.13		Mid-Atlantic Bight, USA	Serchuk et al., 1982
				Northumberland Strait	
128.0	0.19	-1.10		Eastern Region	Jamieson 1979
114.8	0.28	-0.20		Central Region	Jamieson 1979
127.8	0.22	-0.50		Western Region	Jamieson 1979
126.2	0.21	-0.40		All Regions	Jamieson 1979
131.0	0.21	0.77		Bathurst	Worms et al. 1986
114.0	0.25	0.73		Cape Tormentine	Worms et al. 1986
106.9	0.30	0.77		Pictom	Worms et al. 1986

Table 5 (cont.)

Parameters of the Von Bertalanffy growth equation ($H_t = H_\infty (1 - e^{-k(t-t_o)})$ for the sea scallop, *Placopecten magellanicus*

Von Bertalanffy Parameters H_∞	k	t_o	r^2	Location	Source
				Scotian Shelf	
108.8	0.36	1.60		Browns Bank	Jamieson et al. 1981
113.5	0.27	1.31		Browns Bank	Robert et al. 1985
113.1	0.27	1.37		Browns Bank	Robert et al. 1986
124.6	0.28	1.60		German Bank	Jamieson et al. 1981
130.6	0.23	1.39		German Bank	Robert et al. 1985
130.9	0.23	1.39		German Bank	Robert et al. 1986
160.3	0.18	1.28		Middle Ground	Robert et al. 1985
161.5	0.18	1.34		Middle Ground	Robert et al. 1986
156.0	0.20	1.35		Sable, Western Bank	Robert et al. 1985
139.1	0.21	1.38		Sable, Western Bank	Robert et al. 1986
156.0	0.18	1.28		Furcher Shoals	Robert et al. 1985
155.8	0.18	1.22		Furcher Shoals	Robert et al. 1986
				Gulf of St. Lawrence	
149.7	0.14	0.71		Basse-Côte Nord	D'Amours and Pilote 1982
147.2	0.25	0.44		Iles de la Madeleine	D'Amours and Pilote 1982
				Gulf of Maine	
174.3	0.22	-1.24		Gulf of Maine	Serchuk et al. 1982
207.0	0.14	-0.23		Damariscotta River	Langton et al. 1986
218.0	0.13	0.17		Jericho Bay	Schick et al. 1987
148.0	0.27	0.10		Ringtown Island	Schick et al. 1987
116.0	0.28	-0.01		20 mi. S. of BBH	Schick et al. 1987
223.0	0.09	-0.37		W. Jeffreys Ledge	Schick et al. 1987
				Bay of Fundy	
151.0	0.36	0.68		Grand Manan 1932	Naidu 1975
145.5	0.24	0.80		Grand Manan	Dadswell et al. 1983
145.5	0.24	0.80		< 110m off Digby	Jamieson and Fundy 1979
145.4	0.22	0.53		Inside closure off Digby	Jamieson et al. 1981
134.9	0.23	0.56		Outside closure off Digby	Jamieson et al. 1981
153.7	0.21	1.39		< 85 m 1982	Robert et al. 84
153.7	0.20	1.35		< 85 m 1983	Robert et al. 84
151.0	0.21	1.44		> 85 m 1982	Robert et al. 84
144.5	0.22	1.45		> 85 m 1983	Robert et al. 84
149.0	0.28	0.45		Digby 1932	Naidu 1975
146.9	0.22	0.35		St. Pierre Bank	Naidu and Cahill 1984
152.5	0.34	0.88		Georges Bank	NEFMC-Appl. 1978
141.0	0.34	0.56		Georges Bank (1966)	Naidu 75
161.4	0.18	1.20		Georges Bank all rings	Roddick and Mohn 1985
131.6	0.30	1.65		Georges Bank final ring	Roddick and Mohn 1985
139.3	0.25	1.27		Georges Bank final & second ring	Roddick and Mohn 1985
158.8	0.23	0.43		Mid-Atlantic, Narragansett Bay	Karlsson 1969

Table 6

Sea Scallop Fisheries Management Plan: Options Available Under Amendment 2

Option	Method of Management
A	Shell height minimum of 3-1/2 inches. Each vessel brings in a three-bushel sample of live scallops in the shell. The crew shucks the sample and NMFS agents determine the meat count average of the sample and then checks the rest of the trip. The trip count must be equal to, or smaller than, the three-bushel sample.
B	The fishing grounds would be split into four areas and the grounds would have staggered closures. The vessels would reduce their number of days at sea by 24%.
C	The fishery would be completely shut down during January or February combined with an additional 36% reduction in days at sea, or totally shut down during the month of June combined with an additional 30% reduction in days at sea.
D	Keep the current 30 meat count average with a system for adjusting the count based on seasonal meat differences and establish an adjustable minimum shell height of 3-1/2 inches to 4 inches.
Other	All four options would entail additional restrictions such as maximum dredged width and other gear restrictions, day-light-only unloading, a mandatory hail and/or effort restrictions.

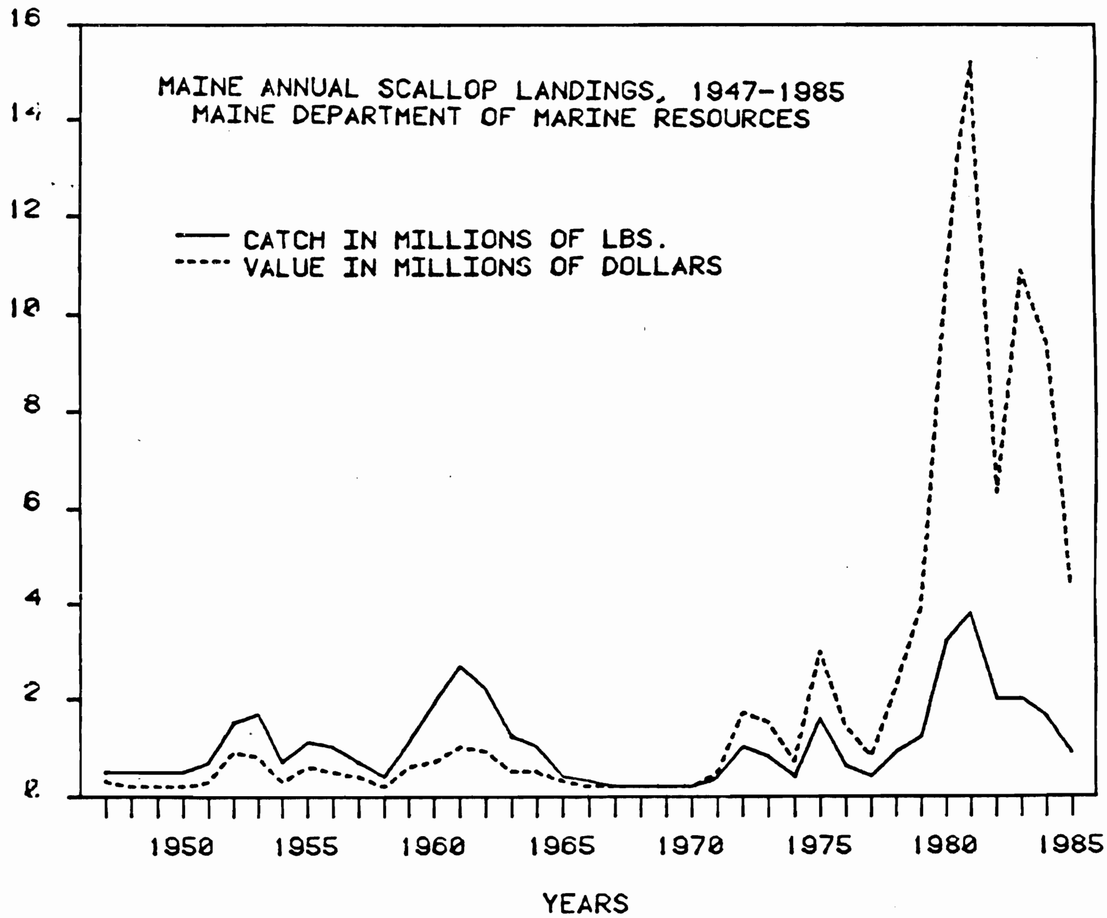

Figure 1. Annual scallop (*Placopecten magellanicus*) landings for the state of Maine (USA) 1947-1985. Note fluctuations over the entire period and the major increase in landings in the mid 1970's.

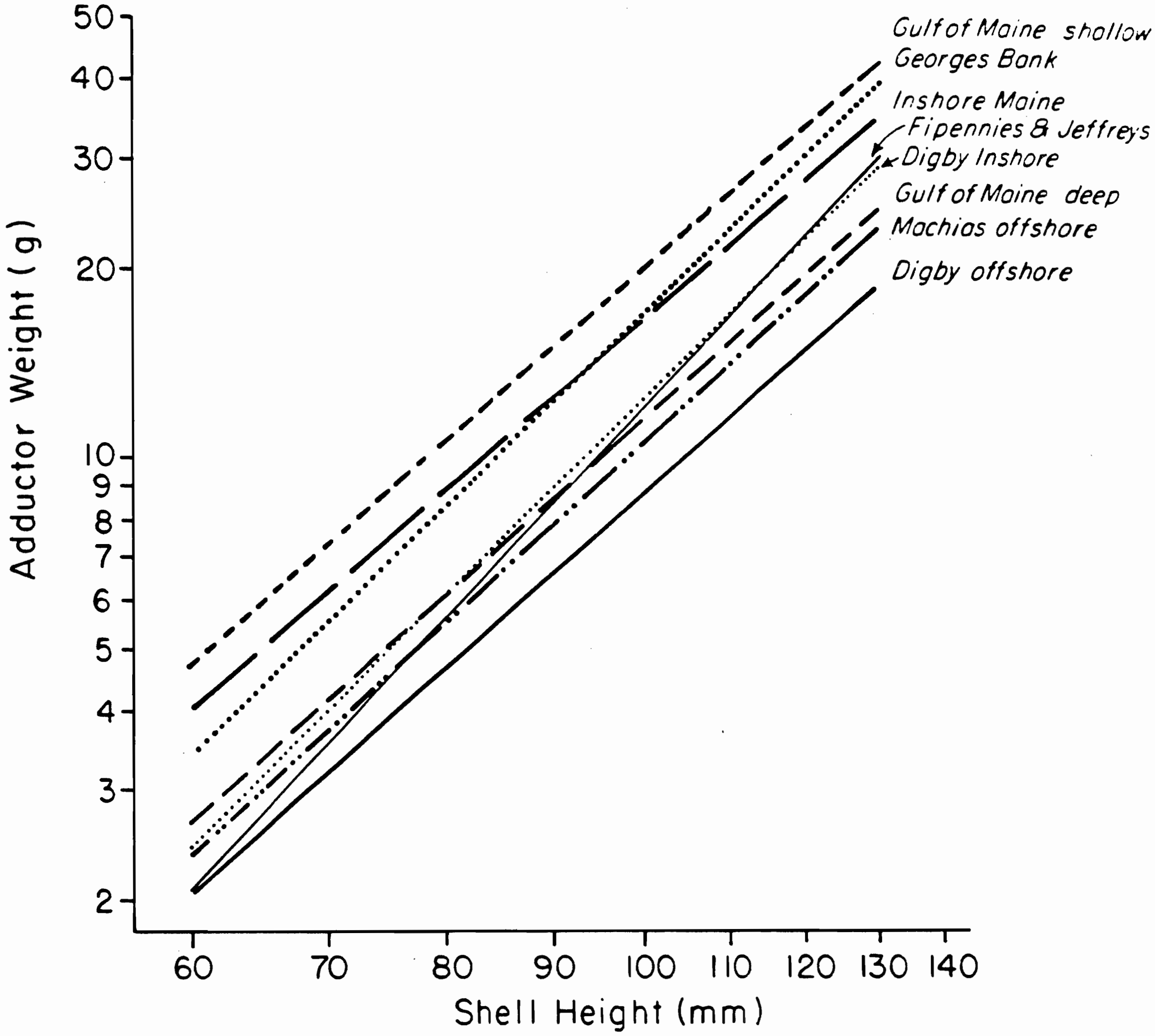

Figure 2. Regression analyses for adductor weight vs. shell height for *P. magellanicus* from various geographic locations. Sources: Schick et al., (1987); Serchuk and Wigley (1984); Schick (unpublished); Serchuk (1983); Jamieson et al. (1981).

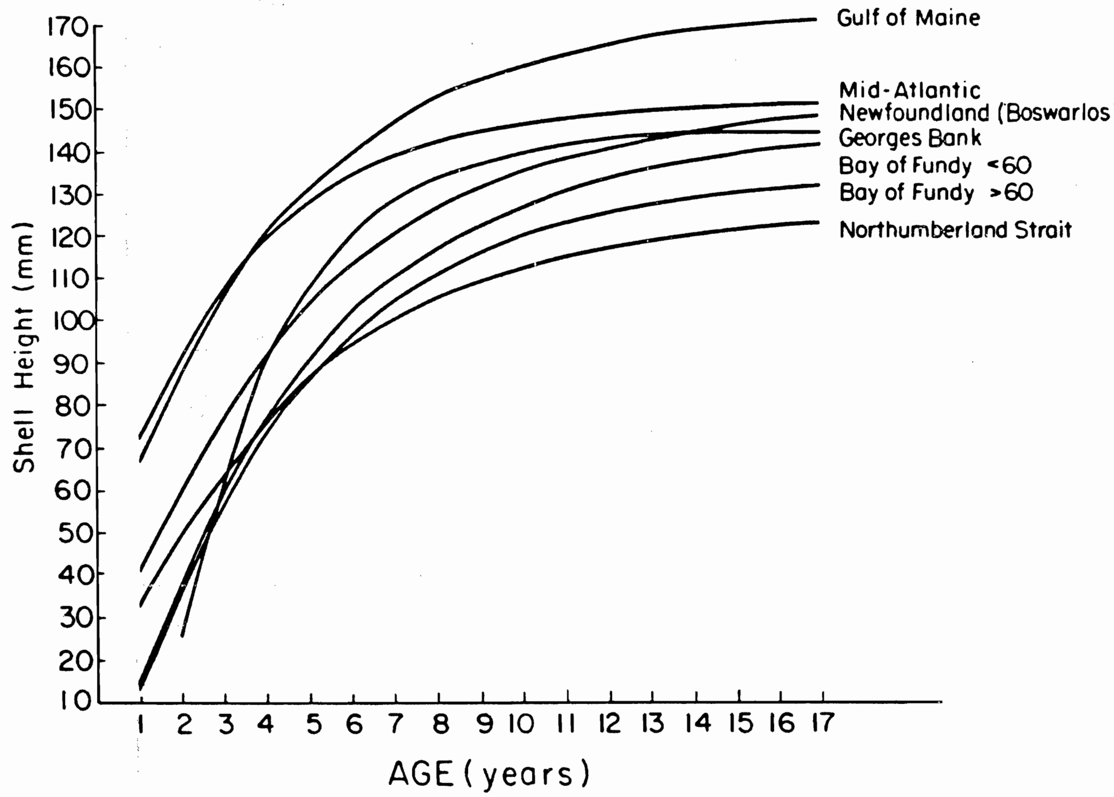

Figure 3. vonBertalanffy growth curves for *Placopecten magellanicus* throughout its range.

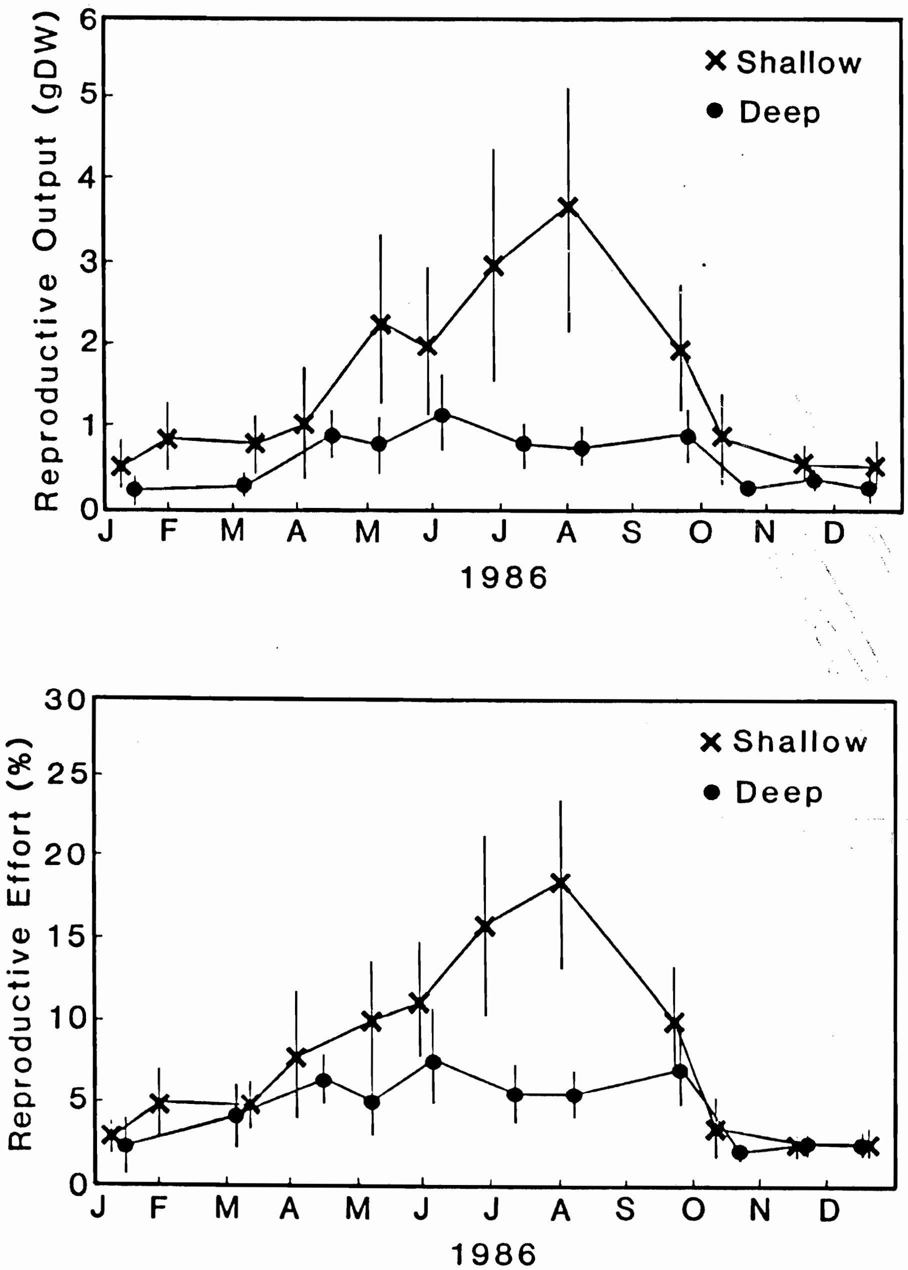

Figure 4. Reproductive output and reproductive effort for *Placopecten magellanicus* from shallow water and deep water sites in the Gulf of Maine. From Barber et al. (1987).