Form 2-102 (Rev. July 1963)

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES

Revision #1

OPERATING PROGRAM

Field Station or Office of Origin	Region or Area	
Woods Hole, Massachusetts	Region 3, Gloucester, Massachusetts	
Subactivity (Symbol and Title)	**Program Title:**	**Program No.**
131 Coastal and Offshore Research	Haddock	131.3

PROGRAM COMPONENTS OF COST	Previous Program	This Action	Current Program
10. Personal Services (Detail on reverse side)	22,929		22,929
21. Travel and Transportation of Persons	300		300
22. Transportation of Things			
23. Rent, Communications & Utility Services			
24. Printing and Reproduction			
25. Other Services			
26. Supplies and Materials	1,000		1,000
31. Equipment	700		700
Other			
Sub Total Program Direct Cost	24,929		24,929
Program Indirect Cost - T/A	8,000		8,000
TOTAL OPERATING PROGRAM Alb IV	~~27,500~~ 60,429	+3,300	~~30,800~~ 63,729

BREAKDOWN BY PROGRAM FEATURE

NUMBER	PROJECT	Previous Program	This Action	Current Program
A	Biology of Haddock	24,929		24,929
	Sub Total Program Direct Cost	24,929		24,929
	Program Indirect Cost - T/A	8,000		8,000
	TOTAL OPERATING PROGRAM Alb IV	~~27,500~~ 60,429	+3,300	~~30,800~~ 63,729

ESTIMATE OF EXPENDITURES BY QUARTERS - F.Y. 19

Object Class	First	Second	Third	Fourth
Personal Services				
All Other Expenditures				
otal Operating Program				

Prepared By: Howard W. Graham — Laboratory Director — 10/28/~~63~~

Approved By: _____

Name — Title — Date

30579

Personnel (name)	Grade	Cost
Grosslein	GS11	9,402
McDermott	9	7,665
Hersey	5	5,862
Total personal services		22,929

Region #3

Briefing Statement
(In thousands of dollars)

Program with Increase

Coastal and Offshore Research
(Subactivity)

No.	Title		1965	Increase	1964	1963	1962
		$	65.0	3.0	62.0	61.0	60.6
131	Haddock	PP	3	0	3	3	3

Increase:

Need: Nominal increase will be used to apply against salary increases and increased cost of supplies.

Additional positions: None.

Program:

Objective: To study the biology of the Northwest Atlantic haddock which is one of the important species now managed under international mesh regulation. The biological studies are necessary to evaluate the effect of regulations.

Accomplishments FY 1963: A special study of the effects of errors in reading scales and otoliths was completed. A Canadian - United States study of the population structure of the Browns Bank haddock was completed.

Base of Operations: Woods Hole, Massachusetts

REVIEW OF LITERATURE ON HADDOCK IN THE NORTHWEST ATLANTIC

I. Distribution of the species

On the basis of differences in age and length compositions of landings, growth rates, seasonal variations in fisheries and tagging studies, Needler (1930a) concluded there were three major population groups of haddock in the Northwest Atlantic--New England, Nova Scotian, and Newfoundland. The distribution of returns from haddock tagged off the coast of Maine, Schroeder (1942), and differences in growth rate between Georges and Browns Bank, Schuck and Arnold (1951), Wise (1957), add confirmation to this division. In a preliminary study Vladykov (1935) reported differences in average vertebral numbers among haddock from the three regions. In a more intensive study Clark and Vladykov (1960) confirmed the differences in vertebral numbers for the three regions and also concluded that the Nova Scotian population could be further subdivided into three subpopulations (western, central, and eastern). Grosslein (1962) reported on a summary by various ICNAF investigators of current knowledge of haddock stocks in the convention area. It was concluded that there are at least three stocks in Newfoundland waters (western Newfoundland, St. Pierre Bank, Grand Bank), two distinct stocks in Nova Scotian waters (eastern and western Nova Scotia separated by the Scotian Gulf), and tentatively three more or less separate adult groups in New England waters (Bay of Fundy and northern Gulf of Maine, inshore waters near Cape Cod, and offshore waters on Georges Bank).

II. History of the U. S. haddock fishery

From 1880 to the early 1900's U. S. haddock landings were fairly stable with average annual landings at about 54 million pounds (Needler, 1930b; Herrington, 1941; unpub. ms.; Power, 1958). In this period haddock were caught chiefly by hand line and later by line trawls, particularly on western parts of Georges Bank (Rich, 1930).

Steam trawlers appeared in the early 1900's and offshore fishing effort increased (Alexander, Moore, and Kendall, 1915; Rich, 1930). The catch rose steadily with increase in the number of trawlers, and U. S. fishermen landed an average of 77 million pounds from 1904-1918 (Power, 1958). Prior to 1921 most haddock were marketed fresh, but thereafter the industry began filleting and packaging haddock for sale throughout all New England; and in 1926 quick freezing appeared and haddock sales became nationwide. U. S. landings rapidly increased from approximately 90 million pounds in 1921 to a peak of 294 million in 1929, the bulk of this harvest coming from Georges Bank. From 1929 to 1934, haddock abundance and fishing effort both declined substantially resulting in a drastic decline in U. S. landings (Schuck, 1951; Graham, 1952; Taylor, 1958). From 1934-1941 there was an upward trend in both landings and abundance on Georges Bank, and during the 1940's average annual haddock landings from Georges Bank have been about 100 million pounds (Graham, 1952). Since 1950 Georges Bank landings have averaged about 83 million pounds a year and abundance has been at a level somewhat below that of the 1940's (unpublished data, U. S. Fish and Wildlife Service).

The precipitous decline of landings and abundance on Georges immediately following the peak in 1929 aroused concern in the industry for conservation of the stock, and led to the establishment of a haddock investigation by the U. S. Bureau of Fisheries. Systematic collection of detailed landings statistics and age and length samples have been obtained since 1931. The development of statistical procedures for recording catch and effort, and sampling landings, were described by Rounsefell (1948 and 1957). Schuck (1951) gave a detailed description of haddock landings by season and subdivision for Georges Bank during the period 1931-48, including estimated numbers and pounds of haddock at each size landed in each market category. Length frequency and scale samples collected from Georges Bank and Gulf of Maine haddock landings since 1931 were published by McCann and Dreger (1963) and the age-length composition of the 1956 U. S. haddock landings from New England have been described (Clark and Dreyer, 1961).

The seasonal and geographic distribution of fishing effort for haddock by the U. S. otter-trawl fleet was described (Schuck, 1952).

At the beginning of the U. S. haddock investigation attention was focused on the extent of destruction of young haddock (too small for market) by the otter trawlers, and means of preventing this destruction (Herrington, 1933, 1935, 1936, 1941, and 1944; Schuck, 1947; Royce and Schuck, 1950; Premetz, 1953, and 1954). Clark (1952) reported on mesh selection experiments by the Woods Hole laboratory and subsequently a minimum mesh size of 4 1/2 inches was recommended for otter trawlers fishing haddock stocks in ICNAF subarea 5 (Graham, 1952). The recommendation was adopted in 1953 and the apparent effects of the first year of mesh regulation was described (Graham and Premetz, 1955). A more recent evaluation of the mesh regulation was reported by an ICNAF working group on fishery assessment (Anon., 1962), based on more recent information on mesh selection (Clark, McCracken, and Templeman, 1958). At the present time it appears that further increase in mesh size would result in slight if any gain in yield per recruit from subarea 5 haddock stocks.

III. General life history

Fecundity

Earll (1880) examined ovaries from a small sample of haddock taken off the coast of Massachusetts. The haddock were from 48 to 71 cm. long and the egg counts ranged from 169,000 to 1,840,000.

Maturation

From observations on Georges Bank haddock taken in the spring, Clark (1959) reported that nearly half of 2-year-old males were mature, and all males were mature at age 3. About 80 percent of 3-year-old females were mature, but only the larger fish of this age group ($\geq$ 37 cm.). All males and females age 4 and older were mature.

Haddock on Browns Bank and adjacent inshore waters mature about one year older than on Georges Bank (Clark, 1959; Kahler, 1960).

Spawning

From knowledge of the location of concentrations of spawning fish obtained from commercial fishermen, and from knowledge of regions where newly spawned gadoid eggs were abundant, it has long been known that haddock spawn at various places along the coastal belt from Cape Cod to the entrance of the Bay of Fundy, but chiefly on Georges and Browns Banks (Bigelow and Welsh, 1925; Bigelow and Schroeder, 1953). Walford (1938) conducted extensive egg surveys in 1931 and 1932 on Georges Bank, and found that peak spawning occurred in February and March, and that the largest spawning concentrations were located on eastern parts of the bank. More recent egg and larval surveys in New England waters have confirmed that eastern Georges Bank and Browns Bank are the major haddock spawning centers, and that peak spawning occurs in February-March on Georges, and in April on Browns (Marak and Colton, 1961; Marak, Colton, and Foster, 1962; and Marak, et al., 1962). In these more recent surveys the Hardy continuous plankton recorder was used in order to obtain synoptic coverage of the entire Gulf of Maine, in an attempt to follow egg and larval drift as well as delineate spawning centers. The efficiency of the recorder as a survey instrument was evaluated by Colton and Marak (1962).

Information on development of eggs and larvae of haddock was reported by Walford (1938), Bigelow and Schroeder (1953), and Marak and Colton (1961).

Food habits

Analysis of haddock stomach contents in New England waters has revealed in every case that rather small, sedentary invertebrates form the major portion of the diet (Clapp, 1912; Homans and Needler, 1944; Bigelow and Schroeder, 1953; Wigley, 1956). In Wigley's study the percentage volume of each major food group was as follows:

Group	% Volume
Crustacea	33
Mollusca	18
Echinodermata	15
Annelida	10
Pisces	2

Examination of stomachs from larval haddock taken in spring surveys in four different years in the Gulf of Maine revealed that adults and juveniles of four species of copepods, and larval copepods represented the major portion of the diet (Marak, 1960).

Behavior

Seasonal movements of haddock on Georges Bank have been inferred from the regular seasonal fluctuations in abundance on certain parts of the Bank (Schuck, 1951). The most notable example is the concentration of spawners on the northeastern parts of Georges Bank and to a lesser extent in the south channel during winter and early spring. Also Colton (1955) found differences between the spring and summer distribution of haddock on Georges according to age and depth. The older haddock tend to move into deeper water with vernal warming.

The tendency for haddock to aggregate in schools was clearly demonstrated by analysis of the frequency distributions of otter-trawl catches of haddock (Taylor, 1953).

Clark (1958a) observed behavior of haddock inside an otter trawl by means of underwater television gear, and concluded that chafing gear did not inhibit escapement of fish from the cod end. Livingstone (1962) also observed haddock in the cod end of a trawl and from their behavior suggested that fish attempted to keep pace with the trawl (a visual response) and appeared not to make any active attempt to escape.

The vertical distribution of haddock larvae on Georges Bank was investigated with high speed multi-depth samplers, and it was found that larvae tend to be concentrated in the upper 20-30 meters (Miller, Colton, and Marak, 1963). Furthermore periodic fluctuations in larval depth distribution were correlated with vertical changes in the thermocline; about 80 percent of the larvae captured were taken within confines of the thermocline.

Growth

Several studies have been conducted to determine the validity of age readings obtained from haddock scales and otoliths. The consistency of scale reading for Georges Bank haddock was reviewed by Clark (1958b) and the time of formation of annuli on haddock scales determined (Jensen and Clark, 1958). Comparisons of age readings from scales and otoliths were reported by Kohler and Clark, 1958. Finally evidence for validity of age readings from scales of Georges Bank haddock was put forward by Jensen and Wise, 1962. Graham (1952) summarized information on growth rate of Georges Bank haddock and noted that it was greater than for haddock in any other waters.

Comparisons of length at age for haddock on Georges and Browns Banks indicated that the haddock of the latter area had significantly slower growth (Schuck and Arnold, 1951). Back-calculated body lengths based on a body-scale relation for Browns Bank fish, also showed slower growth than that reported for Georges Bank (Wise, 1957).

Clark and Dietsch, 1959, summarized length-weight data for haddock in the northwest Atlantic.

Taylor, Jensen, and Stoddard (1959) examined variations in growth rate of Georges Bank haddock during the period 1953-1958, and concluded that these variations were too small to account for observed increases in average weight of landed fish.

Mortality

Schuck (1949) reported a significant correlation between estimated decreases in stock and removals in the Georges Bank haddock fishery for the period 1931-47, which indicated that natural mortality probably was low. Taylor (1958) attempted to estimate natural mortality rate from a regression of fishing intensity on abundance at age; data based on ages 4-5, and 5-6 provided two estimates of natural mortality near zero which tended to confirm Schuck's conclusion.

Annual total mortality for Georges Bank haddock, 1931-48, was estimated to be 45 percent (Graham, 1952).

IV. Environmental factors affecting haddock populations

Recruitment

From egg and larval surveys with the Hardy plankton recorder, and from analysis of drift bottle returns and the drift of surface buoys, Colton and Temple (1961) concluded that surface drift on Georges Bank was predominantly offshore during the haddock spawning season (February-April), and that under average conditions eggs and larvae would be carried away from Georges Bank.

Chase (1955) obtained a significant negative correlation between haddock brood strength and an index of offshore wind on Georges Bank during the spawning season for the period 1928-1951.

Adult population

The decline of the haddock fishery on Nantucket Shoals in the 1920's and concurrent changes in other fisheries has been related to the general climatic warming in this region (Taylor, Bigelow and Graham, 1957; Royce, Buller, and Premetz, 1959).

Herrington (1948) reported that during the period 1912-30 minimum recruitment of young haddock to the fishery occurred at the lowest and highest levels of adult stock suggesting a density-dependent relation between spawning stock and recruitment. At high levels of adult stock Herrington suggested that competition for food between yearling and adult haddock was the cause for lower recruitment. When moderate stock levels in the 1940's failed to produce the expected increases in recruitment Herrington suggested that overall food supply may have declined.

V. Miscellaneous

Rounsefell (1942) conducted field experiments with three tag types (Petersen disc, opercle; bachelor button, opercle; internal anchor) and obtained returns of 13-21 percent, with the Petersen disc yielding the highest return. Jensen (1958) demonstrated the superior corrosion resistance of stainless steel to nickel pins on tagged haddock held in aquaria. Also Jensen recorded the nature of damage to the fish caused by tags.

Royce and Schuck (1954) developed a multiple linear regression formula based on catch of major age groups and on past and predicted fishing effort, which permitted forecasts of haddock landings from Georges Bank one year in advance.

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