June 14, 1994

PRELIMINARY CRUISE RESULTS
NOAA SHIP MILLER FREEMAN
CRUISE NO. 94-03

COMBINED ECHO-INTEGRATION TRAWL SURVEY
AND FOCI RESEARCH EFFORT OF WALLEYE POLLOCK IN SHELIKOF STRAIT

CRUISE PERIOD, AREA, AND SCHEDULE

Scientists from two groups within the Alaska Fisheries Science Center (AFSC) conducted an echo-integration trawl (EIT) survey (Acoustics Group) and recruitment study [Fisheries-Oceanography Coordinated Investigations (FOCI) Group] directed at walleye pollock (Theragra chalcogramma) in the Gulf of Alaska (GOA). The research was conducted aboard the NOAA ship Miller Freeman from March 11 to April 9, 1994, for a total of 30 sea days. The cruise began in Dutch Harbor immediately following the EIT survey work in the Bering Sea (MF94-02). Changes in the scientific party were made in Kodiak and Larsen Bay. Areas of operation included the Shumagin Islands and Shelikof Strait areas.

The itinerary for the Miller Freeman was as follows:

March 10	Embark scientists in Dutch Harbor
March 11-12	Transit to Shumagin Islands area; en route conduct EIT survey along shelf break
March 12-14	Conduct EIT survey of Shumagin Islands area
March 15-23	Pass 1 EIT survey of Shelikof Strait area
March 23-24	Deploy FOCI moorings (M4, M3) and occupy Line 8 stations
March 24-26	Pass 2 EIT survey of Shelikof Strait; Kuliak Bay sphere calibration
March 26-27	Deploy FOCI mooring (M2); transit to Kodiak to exchange portion of scientific party

March 28-April 1	Deploy FOCI mooring (M1); conduct FOCI operations within Shelikof Strait
April 1	Larsen Bay touch and go to disembark portion of scientific party; sphere calibration
April 2-8	Pass 3 EIT survey of Shelikof Strait area
April 8-9	Conduct FOCI operations within Shelikof Strait; transit to Kodiak; disembark scientists

OBJECTIVES

The primary objectives of the cruise are divided into those of the Acoustics Group and those of the FOCI Group.

The objectives of the Acoustics Group were to:

1. collect echo-integrator data and midwater and bottom trawl data necessary to determine the distribution, biomass, and biological composition of walleye pollock in the areas of operations; and

2. calibrate the scientific acoustic system using standard sphere techniques.

The objectives of the FOCI Group were to:

1. continue acquisition of long-term biological and physical time series;

2. conduct an ichthyoplankton survey in Shelikof Strait to determine the horizontal patterns of distribution and abundance of walleye pollock eggs in relation to spawning adults;

3. spawn mature pollock and rear the eggs for larval studies in Seattle, Washington, and Newport, Oregon;

4. investigate vertebrate and invertebrate predation on pollock eggs;

5. deploy surface moorings containing physical and biological sensors at four locations in the study area;

6. calibrate chlorophyll absorbance meters on the four surface moorings and a single subsurface mooring;

7. obtain female copepod/egg ratio samples in parallel with walleye pollock egg samples to examine match/mismatch of food production with first feeding larvae;

8. obtain discrete sea surface chlorophyll samples in the Shelikof Strait area for mapping spatial patterns; and

9. conduct vertical casts with a video camera/light system to observe small-scale distribution patterns of walleye pollock.

Secondary objectives of the cruise, submitted by other researchers on a not-to-interfere basis, were to:

1. collect ovary tissue samples for genetic stock structure studies,

2. collect bile samples from pollock in several GOA areas for comparison with those from Prince William Sound (PWS) (PWS samples not collected during MF94-03) to determine fish exposure levels to petroleum,

3. collect various fishes and invertebrate specimens for use in teaching collections and marine mammal diet studies,

4. collect stomach samples from several fish species which are considered potential predators of pollock,

5. collect tissue samples from potential marine mammal prey species for use in a stable isotope study to determine important prey of several marine mammal taxa, and

6. photograph pollock gonads to document developmental stages.

The Acoustic Group's EIT survey operations and preliminary results are described below and followed by those for the FOCI group.

VESSEL, ACOUSTIC EQUIPMENT, AND TRAWL GEAR

The survey was conducted on board the NOAA ship Miller Freeman, a 66-m (216-ft) stern trawler equipped for fisheries and oceanographic research. Acoustic data were collected with a quantitative echo-sounding system (Simrad EK500[1]). A Simrad 38 kHz split-beam transducer was mounted on the bottom of the vessel's centerboard. With the centerboard fully extended, the transducer was 9 m below the water surface. System electronics were housed in a portable laboratory mounted on the vessel's weather deck. Data from the Simrad EK500 echo sounder/receiver

[1]Reference to trade names or commercial firms does not constitute U.S. Government endorsement.

were stored and processed using the Simrad BI500 echo-integration and target-strength data collection and analysis software on a SUN workstation.

Midwater echosign was sampled using a modified Northern Gold 864 midwater rope trawl (NET Systems, Inc., Bainbridge Island, Washington). The trawl was constructed with ropes in the forward section and stretch mesh sizes ranging from 163 cm (64 in) immediately behind the rope section to 8.9 cm (3.5 in) in the codend. It was fished in a bridleless configuration and was fitted with a 3.2-cm (1.25-in) mesh codend liner. Length of the headrope was 94.5 m (310 ft) when measured between the attachment points at the breastline. Length of the footrope was 50 m (164 ft) when measured between the tom weight attachment points. The breastlines measured 79.4 m (260.5 ft). The net was fished with 1.8-m X 2.7-m (6-ft X 9-ft) steel V-doors [1,000 kg (2,200 lb)] and 227-kg (500-lb) tom weights on each side. Vertical net opening, depth, and temperature at depth were monitored with a Furuno wireless net sounder system attached to the headrope of the trawl.

Fish on and near bottom were sampled with a polyethylene Nor'eastern high-opening bottom trawl equipped with roller gear. The trawl was constructed with stretch mesh sizes that ranged from 13 cm (5 in) in the forward portion of the net to 8.9 cm (3.5 in) in the codend. It was fitted with a nylon codend liner with a mesh size of 3.2 cm (1.25 in). The 27.2-m (89.1-ft) headrope held 21 floats [30 cm (12 in) diameter]. A 24.7-m (81-ft) chain fishing line was attached to the 24.9-m (81.6-ft) footrope which was constructed of 1-cm (0.4-in) 6 x 19 wire rope wrapped with polypropylene rope. The 24.2-m (79.5-ft) roller gear was constructed with 36-cm (14-in) rubber bobbins spaced 1.5-2.1 m (5-7 ft) apart. A solid string of 10-cm (4-in) rubber disks separated some of the bobbins in the center section of the roller gear. Two 5.9-m (19.5-ft) wire rope extensions with 10-cm (4-in) and 20-cm (8-in) rubber disks were used to span the two lower flying wing sections and were attached to the roller gear. The roller gear was attached to the fishing line using chain toggles [2.9 kg (6.5 lb) each] which were comprised of five links and one ring. The trawl was rigged with triple 54.9-m (180-ft) galvanized wire rope dandylines. The net was fished with 1.8-m X 2.7-m (6-ft X 9-ft) steel V-doors [1,000 kg (2,200 lb)]. Vertical net opening, depth, and temperature at depth were monitored with a Furuno wireless net sounder system attached to the headrope of the trawl.

Vertical profile measurements of water temperature and salinity were collected at most trawl stations and the calibration sites using a Seabird CTD (conductivity/temperature/depth) system. Temperature profile data were collected at two sites using expendable bathythermographs (XBT). The acoustic Doppler current profiler was slaved to the EK500 and operated continuously

throughout the cruise in the water profiling mode because attempts to detect the bottom when in the bottom tracking mode were unsuccessful.

SURVEY METHODS

Echo-integration trawl surveys were conducted in two areas within the GOA. An exploratory survey was conducted in the Shumagin Islands area to determine whether significant spawning aggregations of pollock were present. The survey was primarily composed of zig-zag transects over water depths that generally ranged between 50-250 m (Fig. 1). In the Shelikof Strait area, three survey passes were conducted to assess the distribution, abundance, and biological characteristics of pollock. (The "Shelikof Strait area" refers to Shelikof Strait and the area surveyed between Middle Cape and Chirikof Island.) The survey transects were oriented parallel to one another on all passes. During the first survey pass, transects were spaced about 14 km (7.5 nmi) apart except in the area along the western side of the Strait where 7 km (3.7 nmi) spacing was used (Fig. 2). Greater sampling effort was allocated to the western side of the Strait since it has historically contained most of the pollock spawning biomass. The second survey pass covered only the western side of the Strait and was composed of transects spaced 7 km (3.7 nmi) apart (Fig. 3). The third survey pass trackline was identical to that for pass 1 (Fig. 4). Transects generally did not extend into waters less than about 75 m in depth. All passes began in the southern Strait area.

Survey operations were conducted 24 hours a day. Vessel speed averaged about 11 knots during transecting, although it varied between 5 and 13 knots depending upon weather conditions. Severe weather during the first Shelikof Strait survey pass required skipping several of the transect lines near Sitkinak Strait and then completing them near the end of the pass.

The acoustic system was used to collect echo-integration and in situ target-strength data during survey operations. Estimates of absolute pollock abundance will be derived from the former data after they are appropriately scaled.

Midwater and bottom trawl hauls were made at selected locations to identify echosign and provide biological samples during all survey passes. Additional biological samples were collected from midwater trawl hauls made during FOCI operations between survey passes 2 and 3. The average trawling speed was about 3 knots. The vertical net opening for the midwater rope trawl averaged about 21 m (range 19-24 m). The Poly Nor'eastern trawl vertical mouth opening was about 6 m (range 5-8 m). When the Nor'eastern bottom trawl was fished in midwater, vertical net opening averaged 7 m (range 7-8 m).

Standard catch sorting and biological sampling procedures were used to provide weight and number by species for each haul. Pollock were further sampled to determine sex, fork length (FL), age, maturity, and body and ovary weights. An electronic platform scale was used to determine all weights taken from individual pollock specimens. Fish lengths were usually taken with a Polycorder measuring device. Ovary tissue samples for stock structure (genetic) studies and cephalopod and fishes for marine mammal studies were frozen. Fecundity samples were placed in Gilson's solution.

Standard sphere calibrations were conducted in Kuliak Bay on March 26 and Larsen Bay on April 1. A partial calibration was conducted in Missak Bay on March 31 to determine if a drop in transmit power had occurred during the previous night. On all calibrations, measurements were made on the acoustic properties of a copper sphere suspended below the transducer. The standard sphere (60.0 mm diameter) has a known target strength of -33.6 dB. Split-beam target-strength and echo-integration data were collected with the Simrad EK500 system to describe transducer beam pattern characteristics and system gain parameters. In Missak Bay, however, only on-axis target strength measurements of the sphere were made.

PRELIMINARY RESULTS

Biological, Physical Data, and Acoustic System Calibration

Biological data were collected at 58 trawl locations in the Shumagin Islands and Shelikof Strait areas (Figs. 1-5). Trawl station and catch data are summarized for all hauls in Table 1. Biological data collected for pollock are tallied in Table 2. A total of 2 successful XBT and 41 CTD casts were made at all but the first trawl location during the Acoustics Group's operations (Tables 3, 4). Additional CTD casts were made by the FOCI Group at the FOCI trawl locations, as well as at other locations within Shelikof Strait (see FOCI Results Section).

Results of the standard sphere calibration work indicated that the acoustic system parameters were similar to those estimated during earlier cruises. The partial calibration at Missak Bay also produced normal results.

Shumagin Islands Area

About 740 km (400 nmi) of survey trackline were completed in the Shumagin Islands area between March 12-14 (Fig. 1). Dense pollock echosign was patchily distributed throughout the survey area (Fig. 6). The aggregations were often in midwater and often over relatively shallow water depths (i.e., less than about 200 m). A total of four midwater trawl hauls sampled regions

where the most dense aggregations were found; immediately south of the Shumagin Islands, between Unga and Nagai Islands in West Nagai Strait, immediately west of Cape Kupreanof in Stepovak Bay, and in the Shumagin Gully (Figs. 1, 6). Pollock was the dominant fish species captured; all other species composed less than one percent of the catch (Table 5). The pollock captured in the first three hauls were characterized by unimodal size distributions with modal lengths centered around 45 cm (Fig. 7). In contrast, fish taken over deeper water in the Shumagin Gully produced a bimodal size distribution with modal lengths centered around 45 and 33 cm. Unweighted, random samples of female and male pollock greater than 40 cm FL indicated that most were in a post-spawning ("spent") stage of maturity development (Fig. 8). The sex ratio was not markedly different from 0.5 for any haul (range 0.4-0.6). The gonado-somatic index (GSI; gonad weight/total body weight) for mature, prespawning females did not exhibit a positive association with length (Spearman $r = -0.003$, $P > 0.05$, Fig. 9).

A CalVET net and bongo net tow were conducted slightly to the west of Cape Kupreanof (see FOCI section) prior to detecting pollock echosign in this region. These tows were made to provide indirect evidence on whether significant pollock spawning had occurred earlier in the area (i.e., presence/absence of eggs in water column). Support for spawning pollock was observed on February 18, 1994, when the Miller Freeman transited across extremely dense and spatially-extensive echosign in this area while en route from Seattle to Dutch Harbor (Dan Twohig, pers. comm.). Unfortunately, no tows were made on the echosign at that time. Pollock eggs were caught in both the CalVET and bongo net tows during MF94-03, however. These results, as well as the occurrence of post-spawning pollock in the area, indicate the presence of potentially-important spawning aggregations in the Shumagin Islands area.

Shelikof Strait Area

Biological data were collected at 44 midwater (41 rope and 3 bottom trawls fished in midwater) and 9 bottom trawl locations in the Shelikof Strait area during the three survey passes and the FOCI operations between survey passes 2 and 3 (Table 1). Pollock was the dominant fish species captured in midwater trawl hauls, although substantial numbers of eulachon (Thaleichthys pacificus) were also caught south of Uyak Bay (Tables 1, 6). Pollock ranked first in numbers and weight among fishes captured in the bottom trawl hauls (Table 7). Arrowtooth flounder (Atheresthes stomias) and eulachon were the next most common species in these hauls.

The first survey of Shelikof Strait took place between March 15-23 and comprised about 1,575 km (850 nmi) of acoustic transects and 17 trawl hauls (Fig. 2). A distributional plot of the acoustic backscattering attributed primarily to pollock for

this survey pass is presented in Fig. 10. Moderate pollock echosign was observed in the southernmost region of the Strait area along several transects between Chirikof Island and Sitkinak Strait (Figs. 2, 10). Most of this echosign was observed within about 50-100 m of the bottom. Midwater trawl hauls in this region of the Strait area caught pollock between 9-65 cm FL with modal lengths around 12, 23, 33, and 47 cm (Fig. 11). The smaller modal lengths were largely absent in the more northerly regions of the Strait, as described below.

The densest pollock aggregations during pass 1 were broadly distributed near Capes Kekurnoi and Kuliak along the west side of the Strait (Figs. 2, 10). This area has historically contained the greatest densities of pollock during surveys conducted in March. Again, most fish were detected within 50-100 m of the bottom. Midwater tows within this area produced fish that ranged in size from 9-65 cm with modal lengths often 46 cm or more (Fig. 11). Pollock size distributions based on the bottom trawl hauls exhibited similar patterns to those from midwater catches (Fig. 12).

The second survey pass through Shelikof Strait took place between March 24-26 and comprised about 370 km (200 nmi) of acoustic transects and 4 trawl hauls (Fig. 3). This pass was designed to better describe the spatio-temporal distributional patterns for pollock within the area of the Strait where the largest densities of spawners were detected during the first pass. A distributional plot of the acoustic backscattering attributed primarily to pollock for this survey pass is presented in Fig. 13. Most pollock echosign was detected within 50-100 m of the bottom and broadly distributed around Cape Kekurnoi and particularly Cape Kuliak. The size distribution plots of pollock from this pass were generally similar to those produced from trawl catches in this area during other times of the survey (Fig. 11).

The third survey pass through the Shelikof Strait area was conducted between April 2-8 and included 22 successful trawl hauls (Fig. 4). The trackline pattern was similar to that completed during pass 1. However, preliminary acoustic results for this last survey pass are not yet available. Pollock size compositions showed similar patterns to those observed on earlier passes (Fig. 11). Thus, younger, smaller-size classes of pollock were relatively common south of about Middle Cape but declined in abundance to the north along the west side of the Strait. Midwater tows within this area of relatively high spawner densities along the west side of the Strait caught fish that ranged in size from 9-66 cm with modal lengths of 46 cm or more (Fig. 11). Pollock size compositions based on the bottom trawl hauls generally exhibited similar patterns to those from the midwater catches (Fig. 12).

A total of 6,061 pollock were sampled for maturity from the demersal and midwater catches during the survey. No females less than 30 cm FL, or males less than 28 cm FL, were mature (Figs. 14-15). Gonado-somatic indices exhibited a slight positive correlation with length for mature, prespawning females (Spearman $r = 0.130$, $P < 0.05$; Fig. 16). The unweighted maturity compositions of randomly-sampled female pollock greater than 35 cm FL differed over the survey period. Most fish were in a mature stage of development during passes 1-2 (March 15-26), were spawning during the FOCI effort (March 29-31), and were spent by pass 3 (April 2-8, Fig. 17). Maturity data from pollock taken in midwater trawls have not been compared with those from bottom trawls at this time.

FOCI Operations/Results

Most FOCI operations were conducted within the Shelikof Strait area. Four CalVET net tows and one bongo net tow were conducted in the Shumagin Islands area and one mooring was deployed near Gore Point (see below). After each midwater and bottom trawl haul, a CalVET net was attached to the wire above the CTD rosette to collect walleye pollock eggs (0.500 mm mesh) and copepod nauplii (0.053 mm mesh). A CTD cast was done at mooring site 94-43 to calibrate the mooring CTD probes. Moorings M2 through M4 were deployed during Passes 1-2. Triplicate CalVET tows and bongo tows were made in the general area of Moorings M3 and M4 and followed with a CTD cast which also collected chlorophyll samples. Line 8 time series stations (FOX 56-61) were occupied on March 23-24. At each station CTDs, chlorophylls, micro-zooplankton, nutrients, and 20- and 60-cm bongos equipped with 0.153 and 0.333 mm mesh, respectively, were collected. A Seacat CTD was incorporated into the bongo array to provide physical data during the tow.

Following the inport in Kodiak to exchange scientists, the M1 mooring was deployed off Gore Point. A CalVET/CTD cast was conducted to calibrate the M1 sensors. Seven acoustic transects were then run in the northern part of Shelikof Strait off Cape Kuliak to confirm that the dense pollock spawning aggregations detected during survey pass 1 were still at this location. Once confirmed, a site-intensive study was conducted in the area over the next 72 h to examine diel predation on walleye pollock eggs. Collections were made of zooplankton predators on pollock eggs using a 1 m^2 Tucker trawl in areas of high egg abundance. Samples were taken from between depths of 0-150 m and 150-250 m during both daylight and nighttime hours from March 29-31. A small plankton net (Clarke-Bumpus) was suspended within the Tucker trawl to verify the presence and estimate the abundance of eggs. The midwater rope trawl was used to collect adult pollock for examination of egg cannibalism. Adult pollock were successfully spawned, and the fertilized eggs were transported

to Seattle and Newport. A CalVET/CTD cast was also made within each diel period to collect information on egg density and water column structure.

During the third survey pass through the Strait, additional CalVET samples were collected at each trawl station, as well as stomachs of adult pollock for predation studies. Time was also allotted on the last day to complete a series of gear comparisons and to collect more invertebrate predators and live samples for shipboard experiments. A tally of the operations completed during the survey is presented in Table 8, and a summary of operations for each station is presented in Table 9. Locations of midwater trawls are presented in Fig. 5 and for other FOCI sampling operations in Figs. 18-22.

In cooperation with the Acoustics Group scientists, in situ orientation and behavior of spawning adult pollock were examined by deploying a low-light level video camera in spawning aggregations during the diel study and at other times during the cruise. Using the camera in a real-time mode did not provide clear pictures due to scattering by particulate matter in the water column. Using the camera in a playback mode on the CTD rosette provided a better picture of fish images.

FOCI Summary

Spawning aggregations of adult pollock were found in the deep trough along the Alaska Peninsula side of Shelikof Strait off Cape Kuliak and Cape Kekurnoi. Initial examination of the egg distribution data suggests that spawning was confined mainly to the western side of Shelikof Strait but some eggs were present on the Kodiak side. Analysis of the CalVET samples will be necessary before further interpretation of the results are possible. Spawning of adult pollock was still in progress at the end of the cruise but appeared to peak during late March and early April. The various studies utilizing pollock eggs which were initiated on board the ship are currently in progress in Seattle.

SCIENTIFIC PERSONNEL

Name	Sex/ Nationality	Position	Organization	Embark/ Disembark
Chris Wilson	M/USA	Chief Scientist	AFSC	Mar 10/Apr 9
Terry Tinker	M/USA	Electronics Tech.	AFSC	Mar 10/Apr 9
Dan Twohig	M/USA	Electronics Tech.	AFSC	Mar 10/Apr 9
Steve de Blois	M/USA	Fish. Biologist	AFSC	Mar 10/Apr 9
Lynn Faughnan	F/USA	Fish. Biologist	AFSC	Mar 10/Apr 9
Taina Honkalehto	F/USA	Fish. Biologist	AFSC	Mar 10/Apr 9
Scott McEntire	M/USA	Fish. Biologist	AFSC	Mar 27/Apr 1
Jimmie Traynor	M/USA	Fish. Biologist	AFSC	Mar 10/Mar 27
Ric Brodeur	M/USA	Fish. Biologist	AFSC/FOCI	Mar 27/Apr 9
Jay Clark	M/USA	Fish. Biologist	AFSC/FOCI	Mar 10/Mar 27
Nazila Merati	F/USA	Fish. Biologist	AFSC/FOCI	Mar 27/Apr 9
Kevin Kinsey	M/USA	Field Oper. Spec.	PMEL/FOCI	Mar 10/Mar 27
Doug Schleiger	M/USA	Field Oper. Spec.	PMEL/FOCI	Mar 10/Mar 27
Amy Hirons	F/USA	Graduate Student	UAF	Mar 10/Mar 27

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FOCI - Fisheries-Oceanography Coordinated Investigations, Seattle, Washington
PMEL - Pacific Marine Environmental Laboratory, Seattle, Washington
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