PROCEEDINGS:

SEAMAP SHRIMP AND BOTTOMFISH SAMPLING GEAR WORKSHOP

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PROCEEDINGS OF THE SEAMAP SHRIMP AND BOTTOMFISH SAMPLING GEAR WORKSHOP

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PREFACE

A workshop on shrimp and bottomfish sampling gear was held on March 17, 1983 in conjunction with the 33rd Annual Spring Meeting of the Gulf States Marine Fisheries Commission in Austin, Texas. The workshop, chaired by John Watson of the National Marine Fisheries Service (NMFS)-Mississippi Laboratories, addressed such topics as trawling gear calibration and standardization, comparative catch rates and species composition, mesh size selectivity, gear efficiency, and present gear types in use by Gulf of Mexico fishery management agencies. Although the proceedings were recorded on tape, participants were requested to submit papers. Several of the papers have undergone minor statistical revisions for purposes of clarity and completeness; all authors' revisions are included in these proceedings.

Appreciation is gratefully extended to Perry Thompson (NMFS-Mississippi Laboratories, SEAMAP Coordinator from 1982-1984), Charles Lyles, Director of the Gulf States Marine Fisheries Commission from 1977-1983, Larry B. Simpson, present Director of the Commission, and Virginia K. Herring, Executive Assistant of the Commission, for their efforts in organizing and coordinating this first workshop of the SEAMAP Program. Appreciation is also extended to Geoffrey Matthews (NMFS-Galveston Laboratory) and Warren Stuntz (NMFS-Mississippi Laboratories) for their assistance to John Watson in reviewing manuscripts, to Andrew J. Kemmerer (NMFS-Mississippi Laboratories) for his assistance in developing the proceedings, and to the NMFS-Mississippi Laboratories for use of the diagram on otter trawl components. Finally, the patience of the SEAMAP Subcommittee during the preparation of these proceedings is most sincerely appreciated.

The Editors

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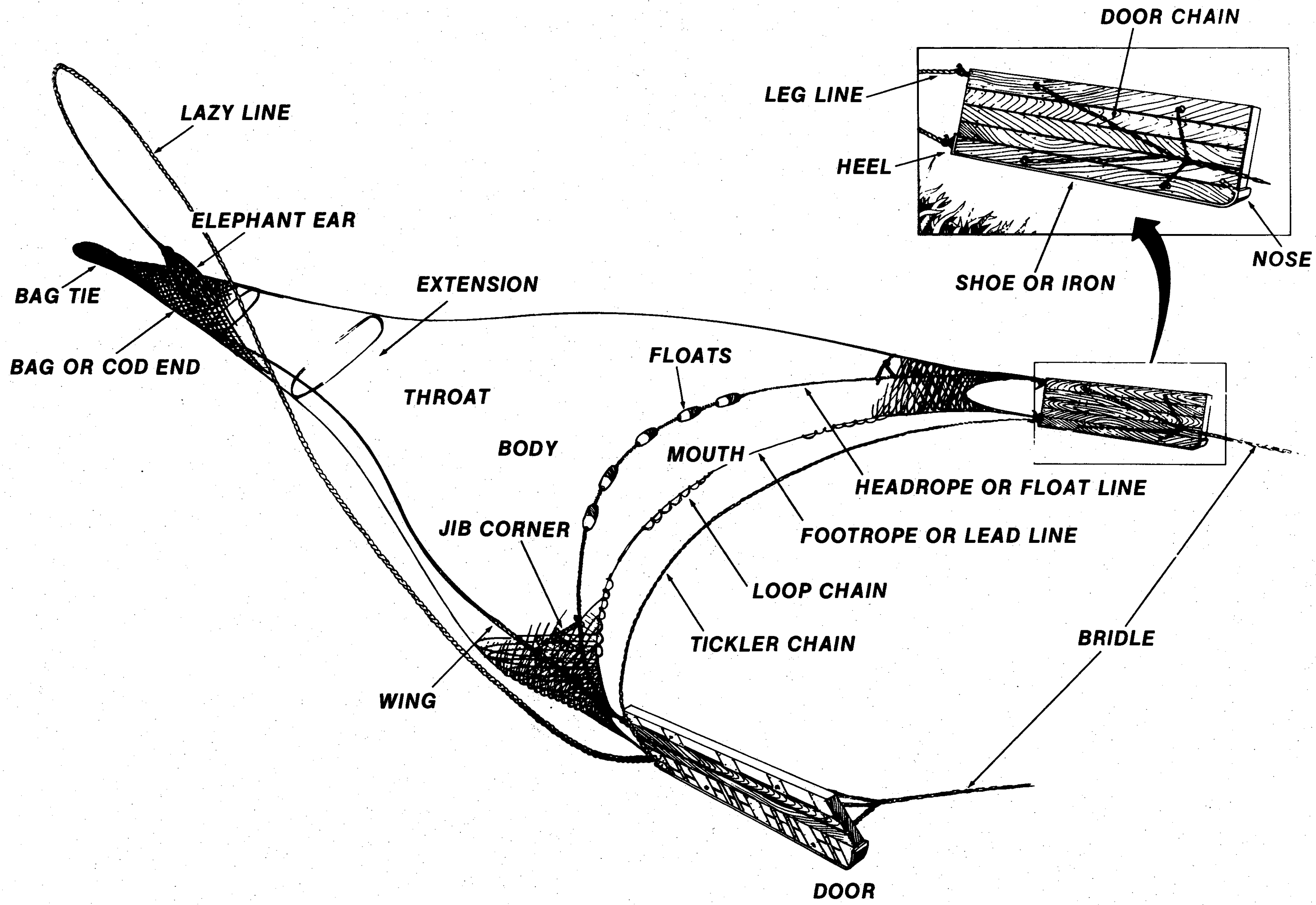
OTTER TRAWL COMPONENTS



INTRODUCTION

The Southeast Area Monitoring and Assessment Program (SEAMAP) is a state, Federal and university program for collection, management, and dissemination of fishery-independent data and information (collected without direct reliance on the statistics reported by commercial and recreational fishermen). Its purpose is to make such information available to management agencies, the commercial fishing industry, and researchers for the least possible cost. Administration and coordination of the Program is through the Gulf States Marine Fisheries Commission.

Fishery-independent information is essential to fishery management and development since statistics reported by fishermen (fishery-independent information) can be influenced significantly by economic conditions, vessel and gear designs, catch discard patterns, and other fishing practices. In 1981, SEAMAP was implemented under the auspices of the Commission's Technical Coordinating Committee to provide a cost-effective basis for obtaining fishery-independent information. The Program provides a forum for coordinating sampling platforms and procedures, and for regional planning of fishery survey activities. In addition to regular surveys of shrimp, groundfish, coastal herrings, plankton, and environmental conditions in the Gulf of Mexico, SEAMAP operates comprehensive systems for managing and distributing data on specimens collected during the surveys. All SEAMAP activities are designed to satisfy the Program's major goal, the coordination of fisheries assessment and monitoring programs to ensure compatible, cost-effective and useful data.

A critical problem was recognized at the onset of SEAMAP: many large and potentially useful data bases were not compatible because of the diversity in sampling gears, procedures, and data recording methods used throughout the region. This meant that existing data bases could not be combined for regional perspectives of particular fishery problems. It also meant that state and Federal investigators would be reluctant to change sampling methodology to some standardized approach as the resulting data would not be consistent or compatible with their unique data bases. Thus, one of the first cooperative efforts identified and conducted by SEAMAP was the hosting of a Shrimp and Bottomfish Sampling Gear Workshop at the 33rd Annual Spring Meeting of the Gulf States Marine Fisheries Commission, held in March 1983 in Austin, Texas. This workshop concentrated on bottom trawls, one of the most commonly used sampling tools in fisheries. The goal was to describe the various sampling methods, and from this description, develop a realistic protocol for intercalibrating bottom trawls and standardizing trawl data.

The proceedings of the workshop are based on seven papers and offer a remarkable contribution to the development of standardized gear and comparability studies. The authors, representing state, Federal, and university organizations, have incorporated current knowledge of trawling gear use in the papers, plus a considerable amount of practical experience. Participants at the workshop have already translated much of the information presented into improved sampling methods and gear calibration trials. It is the hope of workshop conveners and authors, and the editors of these proceedings, that the published record of the workshop will stimulate an increased emphasis on the development and calibration of standardized sampling methods.

The Editors

Proceedings of the SEAMAP Sampling Gear Workshop, 1983, 1—8

NEARSHORE SAMPLING DESIGN, GEAR, AND VESSELS USED BY STATE AGENCIES IN THE GULF OF MEXICO REGION

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ABSTRACT An overview is presented of the assessment and monitoring programs conducted by state fishery management agencies in the Gulf of Mexico region. Discussion includes gear, vessels, and sampling designs used by each organization, as well as target species, processing techniques, and hydrological parameters measured. Information is summarized in tabular form.

Biological assessment and monitoring are important to all state agencies charged with management of marine and estuarine resources in the Gulf of Mexico. Shrimp, groundfish, and crabs are of particular importance because of their value to the commercial and recreational fisheries. Data have been collected on the biology, distribution, movement, and relative abundance of these animals for many years. However, the exchange of data and information among states, and between the states and the National Marine Fisheries Service, has not kept pace with the accumulation of knowledge. In some cases, this is due to a lack of understanding about the various data available, but in other cases, the data are seemingly incompatible due to a lack of standardization of materials and methods.

The purposes of this paper are to present an overview of the various shrimp, groundfish, and crab assessment and monitoring programs conducted by the states of Florida, Alabama, Mississippi, Louisiana, and Texas, and describe the gear and vessels employed. It is hoped, with this overview, that studies will be performed to allow for comparable data in the Gulf region, thus increasing the overall state of knowledge.

TEXAS

The Texas Parks and Wildlife Department has an ongoing assessment and monitoring program aimed at juvenile and adult shrimp, groundfish, and blue crabs, but not at larvae and postlarvae. Sampling is conducted in nursery areas, major bay systems, and the territorial sea. The data are used to recommend management measures for the resources and provide information to the commercial and recreational fisheries.

Samples are taken along the shoreline during the day, with an 18.3-m (60-ft) bag seine having 19.1-mm (3/4-in) stretch mesh in the wings and 12.7-mm (1/2-in) stretch mesh in the 1.8-m (6-ft) bag. Ten shoreline samples are taken monthly (five per two-week period) in each bay system: Galveston Bay, West Bay, Matagorda Bay, San Antonio Bay, Copano Bay, Aransas Bay, Corpus Christi Bay, and the upper Laguna Madre system.

Major bay waters are sampled with a 6.1-m (20-ft) otter trawl with 38.1-mm (1 1/2-in) stretch mesh throughout and spread by 0.51 x 1.2-m (20 x 48-in) wooden otter boards. No tickler chain is used with this net. Twenty samples are taken each month (five in the upper portion and five in the lower portion every two weeks) in each of Galveston, Matagorda, San Antonio, Aransas, and Corpus Christi bay systems. In the upper and lower Laguna Madre, 10 samples are taken per month (five during each two-week period). Trawling occurs during daylight hours.

Eight samples are taken monthly (two each week) with the same 6.1-m (20-ft) trawl in each of five bay-to-Gulf passes. The passes sampled are Bolivar Roads (Galveston Bay), Pass Cavallo (Matagorda Bay), Lydia Ann Channel (Aransas Bay), Corpus Christi Ship Channel (Corpus Christi Bay), and Brazos Santiago (lower Laguna Madre).

A 12.2-m (40-ft) semiballoon otter trawl with 44.5-mm (1 3/4-in) stretch mesh throughout, spread by 0.91 x 2.13-m (3 x 7-ft) wooden doors, is used to collect samples in Texas' territorial sea (nine nautical miles). This net is equipped with a tickler chain. Twenty samples are taken each month in National Marine Fisheries Service statistical areas 19 and 20 (10 samples per area). One-half of these samples is taken during daylight hours and one-half at night. An additional 36 samples were taken during June-July 1982 in conjunction with the SEAMAP Program.

A minimum of 50 randomly chosen individuals of each shrimp species, if available, is sexed and measured. A minimum of 20 individuals of all other species collected is measured. Measurements of total length are recorded in 5-mm increments. The total number of individuals is recorded by species. Salinity, water temperature, and dissolved oxygen are recorded at each station.

Texas uses a variety of vessels to collect samples. The R/V WESTERN GULF, used for sampling in the territorial sea, is a 22.0-m (72-ft) steel hull, double-rigged trawler with a Caterpillar 343 TA (365-hp) engine. Bay trawl samples are collected with 9.14-m (30-ft) inboard vessels and 6.1-m (20-ft) outboards. Pickup trucks and 5.49-m (18-ft) outboard skiffs are used for seine samples.

LOUISIANA

The Louisiana Department of Wildlife and Fisheries conducts assessment and monitoring activities to collect data for managing marine and estuarine resources. Sampling is aimed primarily at penaeid shrimp, but data are retained on all species collected. Sampling is conducted in nursery areas, tidal passes, bays, and the territorial sea during daylight hours.

A 0.5-m (19.5-in) circular plankton net with 505-μm mesh, equipped with a flowmeter, is used to sample tidal passes for postlarval shrimp. The plankton samples are preserved and returned to the laboratory, where postlarval shrimp are identified to species and counted. During 1982, 21 tidal passes were sampled weekly from January 1 to September 30.

Trawl samples are collected in nursery areas weekly (March 1 to October 31) at 35 stations across Louisiana, using a 1.83-m (6-ft) otter trawl having 9.53-mm (3/8-in) bar mesh wings and 6.25-mm (1/4-in) bar mesh tail. Only shrimp are retained from these samples. Penaeid shrimp taken with this gear are identified to species and counted; the first 50 (selected at random) are measured (tip of rostrum to tip of telson) in 5-mm increments. Samples collected with 4.88-m (16-ft) trawls are treated in the same manner as 1.83-m (6-ft) trawl samples, except all species collected are processed.

In 1982, Louisiana used a 4.88-m (16-ft) otter trawl with 19.05-m (3/4-in) bar mesh wings and 6.25-mm (1/4-in) bar mesh tail to sample juvenile shrimp and fish in deeper lakes and bays, and in the territorial sea. A total of 33 inshore stations was sampled weekly from March 1 to October 31, then every two weeks from November 1 to February 28. Nineteen territorial sea samples were taken every two weeks from March 1 to October 31, and monthly from November 1 to February 28.

Conductivity, salinity, and water temperature readings are taken with each biological sample. Estimates are made of cloud cover, wind direction and speed, tidal stage, and sea state. Surface and bottom hydrology samples are taken at plankton stations. Surface hydrology samples are taken at 1.83-m (6-ft) trawl stations, with bottom hydrology sampled at 4.88-m (16-ft) trawl stations.

In addition to regular monitoring samples, a six-week period of intensive shrimp sampling is conducted yearly (April 1 to May 15) to provide the information necessary to set the brown shrimp season. During this period, 36 additional trawl samples are taken weekly.

In 1982, Louisiana participated in the SEAMAP Program and 4.88-m (16-ft) trawls were used weekly to sample at 1-fm intervals (1 to 5-fm) in Louisiana's territorial sea. These 10-minute tows were arranged by transects, one in each of the seven designated Coastal Study Areas. Sampling the Coastal Study Areas east of the Mississippi River was accomplished from June 1 to 11, and the five Coastal Study Areas west of the Mississippi River, from June 14 to July 16. All organisms taken in the trawl were identified to species and counted. The first 200 (selected at random) were measured in 1-mm increments (shrimp, tip of rostrum to tip of telson; other species, total length) and weighed to the nearest ounce. Additionally, the shrimp were sexed. Plankton samples were taken at the 1- and 5-fm stations using a 0.5-m circular plankton net. Louisiana's standard procedures were followed in taking and preserving these samples. Hydrological parameters (conductivity, salinity, water temperature, and dissolved oxygen) were measured one foot below the surface and one foot above the bottom at each station. In addition, physical parameter estimates (i.e., turbidity, percent cloud cover, wind speed and direction, and sea state) were recorded.

The Louisiana Department of Wildlife and Fisheries uses 3.96- to 5.18-m (13- to 17-ft) Boston Whalers with outboard motors to collect 1.83-m (6-ft) trawl samples. Boats 9.2 m (30 ft) long, of various designs are used for 4.88-m (16-ft) trawl samples. These boats may be diesel or gasoline, inboard or outboard.

MISSISSIPPI

The Gulf Coast Research Laboratory, located in Ocean Springs, Mississippi, has an ongoing program of assessment and monitoring aimed at shrimp, crabs, and groundfish. Samples of postlarvae, juveniles, and adult individuals are collected from nurseries, bays, and the territorial sea.

Collected data are reported to the Bureau of Marine Research, Department of Wildlife Conservation, where the data are considered in the process of managing the state's estuarine and marine resources. Data are also used, where possible, to inform user groups of stock abundance and condition from year to year.

Postlarval shrimp are sampled using a Renfro beam plankton trawl with a 1.88-m (6-ft) gape and 0.935-mm (.004-in) mesh aperture. The net is hand-towed at four stations twice each month and one station once monthly, along a path 50 m (164.04 ft) in radius.

Two stations are sampled once each month using a 15.2-m (50-ft) bag seine with 6.25-mm (1/4-in) bar mesh. The net is pulled varying distances from shore depending upon the bottom topography.

Samples are collected in open-water areas of bays and the Mississippi Sound using a 4.88-m (16-ft) otter trawl with 19.05-mm (1/4-in) bar mesh wings and 6.25-mm (1/4-in) bar mesh tail. Tows are taken twice each month along a transect from the Biloxi River to Horn Island. Additionally, a 9.14-m (36-ft) trawl is used for monthly sampling inside and outside Horn Island Pass, and three monthly samples in the vicinity of Cat Island from June through November. All tows are of 10 minutes duration and are taken during daylight hours. Hydrology samples are taken at each biological sampling station: surface and bottom salinities, temperatures, and dissolved oxygen.

Adult finfish are sampled monthly at six stations across Mississippi. Stations are located at inshore bays, Mississippi Sound near Round and Deer islands, and the north shore of the barrier islands adjacent to Dog Keys Pass. Sampling is effected with varied mesh gill nets. Each net is composed of four panels, each 45.7 m (149 ft) in length, with mesh sizes of 7.0 cm (2 3/4 in), 9.5 cm (3 3/4 in), 15.2 cm (6 in), and 20.3 cm (8 in).

Animals are sorted from beam plankton trawl, seine, and other trawl samples. For all crabs, carapace width (in 1-mm increments), weight, sex, maturity state, and growth stages are determined; ovarian stage is determined for mature females. Shrimp data includes length (tip of rostrum to tip of telson in 1-mm increments), weight, sex, and ecdysis stage. Female white shrimp with maturing ovaries are examined for exact gonadal condition. Fish are reported in standard lengths to the nearest millimeter and total body weight to the nearest 0.1 g, along with notes on gonadal development when appropriate. An aliquot up to 50 individuals of each species is taken, including minimum and maximum sizes. Total number and total biomass are also recorded for each species.

In June 1982, the Gulf Coast Research Laboratory participated in the SEAMAP survey. Sixteen samples were taken from Horn Island to the Chandeleur Islands extending to a depth of 15 fm. Comparison tows were conducted between the R/V TOMMY MUNRO and the R/V OREGON II.

The Laboratory uses a variety of vessels in its assessment and monitoring program. Beam plankton trawl and seine samples were collected using 4.74- to 6.4-m (15- to 21-ft) Boston Whalers with outboard motors 85 hp and up. Sixteen-foot (4.88-m) trawl samples were taken from several vessels: a 9.14-m (36-ft) fiberglass jet boat, a twin outboard motor boat, and a 10.97-m (36-ft) twin diesel inboard boat. The R/V TOMMY MUNRO, a 29.3-m (96-ft) steel hull trawler with 680-hp diesel engine, and the R/V HERMES, a 12.29-m (40-ft) steel hull diesel-powered vessel, were used to take the 10.97-m (36-ft) trawl samples.

The Mississippi Bureau of Marine Resources performs some additional sampling with a 9.11-m (32.5-ft) inboard boat during the period immediately prior to the opening of the brown shrimp season in Mississippi. A series of samples is collected during daylight hours with a 4.88-m (16-ft) otter trawl with 31.75-mm (1 1/4-in) stretch mesh throughout. Tows last 15 minutes at constant speed. Surface and bottom water temperatures, salinities, and dissolved oxygen samples are taken with each biological sample.

ALABAMA

The Marine Resources Division of the Alabama Department of Conservation and Natural Resources has a continuing assessment and monitoring program dealing with distribution and abundance of penaeid shrimp, groundfish, and blue crabs. Fifty-one samples are collected monthly from nurseries, major bays, and the territorial sea. Additional samples are taken as needed for specific management information (i.e., to determine opening day of the brown shrimp season). Data are used to make management decisions and to provide information on the abundance of stocks to commercial and recreational fishermen.

The Division collects 13 samples to assess and monitor postlarval shrimp, larval and juvenile fishes, blue crab megalopae, and first crab stages. A Renfro beam plankton trawl with a 1.8-m (6-ft) gape and 0.935-mm (.004-in) diameter mesh is used to take these samples. The net is towed approximately 130 m (426 ft) along the shore in nursery areas. Sampling frequency is increased two times each month from March through May.

A 15.2-m (50-ft) bag seine with 6.25-mm (1/4-in) bar mesh is towed, where water depth permits, approximately 8 m (26 ft) from shore; it is then pivoted 180 degrees and returned to shore for samples of juvenile shrimp, fishes and blue crab at 11 nursery stations.

Twenty-seven samples are collected during daylight hours with a 4.9-m (16-ft) two-seam balloon otter trawl with 38.1-mm (1 1/2-in) bar mesh in the body and 28.7-mm (1 1/8-in) bar mesh in the bag. The bag is equipped with a 6.25-mm (1/4-in) bar mesh liner. These samples are used to assess and monitor juvenile shrimp, fishes, and blue crab. Twenty-four of the samples are collected in major bays, and three in the territorial sea adjacent to Alabama's three bay-to-Gulf passes. Trawls are towed for 10 minutes at a constant speed. Bottom hydrological data collected at each biological station include water temperature, salinity, and dissolved oxygen.

Eight supplemental 4.88-m (16-ft) trawl samples are taken per week in Alabama's inside waters from April through June. These samples augment data used to set the opening of the brown shrimp season.

In the laboratory, all penaeid shrimp, finfish, and crabs of the genus *Callinectes* are separated to species. The total number of individuals is recorded for each species and total weight is determined for juveniles of each penaeid species. Up to 50 individuals of each species (except postlarval penaeids and *Callinectes* sp. megalopae) are measured to the nearest millimeter, fishes by standard length and penaeid shrimp from tip of rostrum to tip of telson. Crabs are sexed and up to 50 individuals of each sex are measured for carapace width.

Alabama's Marine Resources Division participated in the SEAMAP survey in June 1982. Samples were collected at pass stations in the territorial sea to coincide with sampling by the R/V OREGON II offshore Alabama. Additional bay samples were taken within the same week. Samples were collected using a 5.49-m (18-ft) outboard boat with a 115-hp engine, and a 7.01-m (23-ft) outboard boat with two 115-hp engines. Samples were taken and treated in the same manner as other assessment and monitoring samples.

FLORIDA

The Florida Department of Natural Resources has no ongoing assessment and monitoring work aimed at shrimp and groundfish. The agency, however, is involved with studies of oyster and clam resources for management purposes as part of the National Shellfish Sanitation Program, as are other states. The Department also conducts studies to provide life history and stock information on groupers, red drum, billfishes, snook, lobster, blue crabs, mackerel, and other species.

Florida has several projects aimed at collecting information on its blue crab resources. These are centered in Tampa Bay on the west coast and Indian River on the east coast. Population dynamics, including migrations, seasonal and areal distribution and abundance, and catch per unit effort, and such biological parameters as spawning, molting, disease and parasites, and habital requirements, are being studied in both regions. A tagging project has been started in Tampa Bay, to tag and release 10,000 blue crabs.

Additional studies are performed for special problems or areas of concern not directly connected with management activities (i.e., OCS activities and fish kills). Ecosystem and environmental studies are also conducted in bays, lagoons, and the territorial sea as specific projects or combined with other work, such as fishery habitat loss in estuaries.

Florida participated in the 1982 SEAMAP Program. Three 7-day cruises (May 14 to 20, June 8 to 14, and January 17 to 23) were conducted aboard the R/V HERNAN CORTEZ to collect ichthyoplankton samples at 53 stations on and off Florida's western shelf. Oblique bongo and neuston net tows were made at each station and environmental data designed by the SEAMAP Environmental Data Work Group were collected. Horizontal fluorometry measurements were collected between stations and approximately 180 chlorophyll samples were taken during the cruises. All ichthyoplankton samples were forwarded to the National Marine Fisheries Service in Miami for processing and transfer to the Polish Plankton Sorting Center, where they were sorted to the family level.

SUMMARY

Tables 1 through 4 summarize the gear, vessels, and sampling frequency of the state agencies in the Gulf region. It is evident that all Gulf coast states are routinely collecting data from their marine resources. If this data could ever be presented under one cover, it would certainly make an admirable companion to the information from SEAMAP samples. However, the variety of gear types, vessels, and sampling designs makes the comparability of available data difficult, and every effort should be made by each management agency to collect data in such a manner as to make ready comparison possible.

It is interesting to note that the fishery managers of each state are obtaining valid information about their resources and have been able to make sound management decisions based upon this information despite the disparity in techniques. In fact, much of the information collected by different states is compatible and has been used over the years to establish a "common" knowledge of the Gulf region.

It is certain, however, that more information could be obtained from the raw data available from the programs of the Gulf states if those data were known to be directly comparable. This will only be possible when standard methods and gear types are established, or a sufficient amount of information is available which will permit a reliable comparison of different gear types and sampling methods. Several papers dealing with gear comparison are being presented at this workshop and hopefully this workshop will spark enough interest in these problems to warrant further work.

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TABLE 1.

Summary of information on annual state larval and postlarval sampling in the U.S. Gulf of Mexico.

State	Gear	Number of samples	Frequency	Location	Animals sampled
Texas	N/A	0	N/A	N/A	N/A
Louisiana	1/2-m circular plankton net with 505- m mesh equipped with flowmeter	23	Weekly, January 1-September 30.	Tidal passes	Postlarval shrimp
Mississippi	Renfro beam plankton trawl	5	Twice each month, year round.	Nursery	Postlarval shrimp
Alabama	Renfro beam plankton trawl	13	Twice each month, March-May. Monthly, June-February.	Nursery	Postlarval, juvenile shrimp; larval, post-larval, juvenile fishes; megalopae, 1st stage, juvenile *Callinectes* sp. crabs
Florida	N/A	0	N/A	N/A	N/A

TABLE 2.

Summary of state seine sampling in the U.S. Gulf of Mexico.

State	Gear	Number of samples	Frequency	Location	Animals sampled
Texas	60-ft bag seine, 3/4-in stretch mesh wings, 1/2-in stretch mesh bag.	80	Monthly	Major bay systems	Shrimp, finfish
Louisiana	N/A	0	N/A	N/A	N/A
Mississippi	50-ft bag seine, 1/4-in bar mesh throughout	2	Monthly	Bays and Missisippi Sound	Shrimp, finfish, crabs
Alabama	50-ft bag seine with 1/4-in bar mesh throughout	11	Monthly	Bays, Mississippi Sound and territorial sea	Shrimp, finfish, crabs
Florida	N/A	0	N/A	N/A	N/A

TABLE 3.

Summary of state trawl samples taken in the U.S. Gulf of Mexico.

State	Gear	Vessel	Number of samples	Frequency	Location	Time	Length of tow	Animals sampled
Texas	20-ft 1 1/2-in stretch mesh throughout	30-ft inboard boats	110	Monthly	Major bays	Day	15 min	Shrimp, finfish
			40	Monthly	Passes	Day	15 min	Shrimp, finfish
	40-ft 1 3/4-in stretch mesh	R/V WESTERN GULF, 72-ft	20	Monthly	Territorial sea	Half-day	15 min	Shrimp, finfish
Louisiana	6-ft 3/8-in bar mesh wings, 1/4-in mesh tail	13 to 17-ft Boston Shalers	39	Weekly, (3/1-10/31)	Nurseries	Day	10 min	Shrimp
	16-ft 3/4-in bar mesh wings, 1/4-in bar mesh tail	30-ft boats	33	Weekly, (3/1-10/31) (11/1-2/28)	Inshore	Day	10 min	Shrimp, finfish
			19	(3/1/10/31) Monthly (11/1-2/28)	Territorial sea	Day	10 min	Shrimp, finfish
Mississippi	16-ft 3/4-in bar mesh wings, 1/4-in bar mesh tail	30-ft jet boat; a twin outboard; 36-ft twin inboard	8	Twice each month, year round	Bays and Mississippi Sound	Day	10 min	Shrimp, finfish, crabs
	36-ft 3/4-in bar mesh wings, 1/4-in bar mesh tail	R/V TOMMY MUNRO 96-ft steel hull trawler; R/V HERMES, 40-ft steel hull trawler	4	Monthly	Mississippi Sound and Territorial Sea	Day	30 min	Shrimp, finfish, crabs
Alabama	16-ft 1.5-in bar mesh wings, 1/4-in bar mesh tail	18-ft out-board; 23-ft outboard	24	Monthly	Bays and Mississippi Sound	Day	10 min	Shrimp, finfish, crabs
			3	Monthly	Territorial sea	Day	10 min	Shrimp, finfish, crabs
Florida	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A

TABLE 4.

Summary of SEAMAP survey participation by Gulf of Mexico state fishery management agencies.

State	Gear	Vessel	Number of samples	Time	Length of tow	Animals sampled
Texas	40-ft trawl 1-in mesh throughout	R/V WESTERN GULF, 72-ft steel hull trawler	(36) June-July	Night	1 fm in 30-min tows	All species identified to species, at least 20 of each species counted, measured; up to 50 shrimp sexed, measured from each trawl.
Louisiana	16-ft trawl 3/4-in bar mesh wings, 1/4-in bar mesh tail	30-ft boats of various designs	(35) June-July	Day	10 min at 1 fm intervals	All animals identified to species, counted and weighed.
Mississippi	40-ft trawl 1-in. mesh wing, 1 3/4-in tail	R/V TOMMY MUNRO, 96-ft steel hull trawler	(16) June	Night	1 fm in 30-min tows	Shrimp, crabs weighed, measured, sexual stage determined; finfish aliquot taken, measured, weighed.
Alabama	16-ft trawl 1 1/2-in bar mesh wings, 1/4-in bar mesh tail	18-ft outboard boat	(3) in territorial sea; (8) in Mississippi Sound; June	Day	10 min	All animals identified to species, measured and counted; total weight recorded for each species of shrimp.
Florida	Bongo and neuston nets	R/V HERNAN CORTEZ, 72-ft steel hull trawler	(53) May-June	Day	25-min deep tows; 20-min shallow tows	All ichthyoplankton forwarded to Miami for processing.

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COMPARISONS OF CATCH RATES AND SPECIES COMPOSITION BETWEEN A 16-FOOT AND A 50-FOOT TRAWL

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ABSTRACT Comparisons of catch rates and species composition were made for two sizes of nearshore sampling trawls (16-ft flat otter trawl and 50-ft balloon trawl) that were pulled in paired tows from the same vessel. Samples were taken monthly in 5 fm near Caminada Pass, Louisiana from September 1980 through February 1983. Species diversity and richness were significantly higher for the 50-ft trawl but evenness was the same for both gears. Regression analyses of the catches indicated that there were predictable relationships between trawls for total number, total weight and/or mean weight of individuals for several of the abundant species.

INTRODUCTION

Commercial harvest of penaeid shrimp and demersal fish in the nearshore waters of Louisiana has primarily been with otter trawls of various sizes. Small trawls, or try nets, are often used by the shrimpers to indicate the advisability of deploying their larger gear in a particular area. The Louisiana Department of Wildlife and Fisheries (LDWF) adopted the use of a 16-ft flat otter trawl, or try net, for inshore and nearshore investigations in 1968, in accordance with the recommendations of the Estuarine Technical Coordinating Committee of the Gulf States Marine Fisheries Commission (Perret et al. 1971). The Department began monitoring the Louisiana Offshore Oil Port (LOOP) in 1978, utilizing the 16-ft trawl. As LOOP operations would eventually extend to waters of approximately 20 fm, a 50-ft trawl was added to the monitoring program to insure that demersal nekton would be effectively sampled at these depths. At the intermediate depth of 5 fm, both trawls were used. This study design allowed LDWF to examine the suitability of each size trawl for the nearshore area, to determine if comparisons could be made between the historical 16-ft catch records and 50-ft catches, and to examine the use of a try net as an indicator of commercial harvest potential of an area.

MATERIALS AND METHODS

Demersal nekton was sampled monthly at a site 2½ miles offshore between Caminada Pass and Belle Pass in 5 fm (29°07'22" N. Lat., 90°05'00" W. Long.) from September 1980 through February 1983. Trawls of two sizes were pulled from the same vessel in a paired tow. A 10-min pull of a 16-ft flat otter trawl was made during the 15-min pull of a 50-ft balloon trawl. During the course of the study, vessel size changed, as the 56-ft shrimp vessel was replaced by an 82-ft shrimp vessel. Trawls were pulled in a straight line along the 5-fm contour during daylight hours.

Specimens collected in trawls were preserved on ice in the field. When samples were too large to preserve practically, a percentage was retained. The total weight and number of individuals of each species was recorded when less than fifty individuals of a species were caught. When more than fifty individuals of a species were caught, the weight of fifty individuals and the total weight of all individuals of that species were recorded and the total number of individuals was extrapolated from the weight relationship.

Robins et al. (1980) was used as the source for scientific names of fish, with identifications following Hoese and Moore (1977). Invertebrate nomenclature and identification were derived from Williams (1965), Gosner (1971), and Felder (1973).

Statistical analyses were done with the SAS software system. The Department of Experimental Statistics at Louisiana State University provided contractual statistical support. Effects of trawl size on selected diversity indices were examined with multivariate analyses of variance (using SAS GLM procedures) and analyses of variance using a randomized block design (blocking on the quarter of the year in which the sample was taken).

Regression analyses were used to examine the catch composition of both trawls for selected species (all species which constituted more than 3% of the total number of individuals in the 50-ft trawl, and the commercially important brown shrimp, Penaeus aztecus). The total number of individuals of the selected species and the total weight of the selected species were log transformed ([ln tot. num. +1] and [ln tot. wt. +1]) for regressing the catches of the 50-ft net on those of the 16-ft net.

The mean weight of individuals of the selected species in each size trawl was also analyzed by regression of the 50-ft catch on that of the 16-ft catch. When regression analyses showed significant relationships ($P \leq 0.05$) between the catches of the 50-ft and 16-ft trawls, a *t*-test was used

Specifications of the trawls and sampling are listed below:

	16-ft (4.9-in)	50-ft (15.4-m)
Style	flat otter	balloon
Duration of sample	10 min	15 min
Mesh	3/4-in (19-mm) bar wings 1/4-in (6-mm) bar codend	3/4-in (19-mm) bar wings and codend
Twine	#7	#18
Loop Chain	1/4 in (6 mm)	1/4 in (6 mm)
Tickler Chain	none	
Floats	5	5
Doors	16 in x 30 in (40 cm x 75 cm)	8 1/2 ft x 34 in (2.6 m x 0.9 m) on 56-ft (17.2-m) vessel 8 ft x 40 in (2.5 m x 1.0 m) on 82-ft (25.2-m) vessel

to determine if the catches were significantly different ($P \leq 0.05$).

RESULTS

Catch rates and species composition were determined for the 5-fm station (Table 1). The station was sampled 29 times between September 1980 and February 1983 with paired tows of the two trawl sizes. No samples were taken in June 1981. The 16-ft net caught a total of 52 species, while 69 species were represented in the 50-ft net's catch. A total of 73 species was caught at the 5-fm station, of which 48 were caught in both trawls. For purposes of comparison, unidentified species of Trachypenaeus shrimp are here treated as one species.

Hypoxic conditions (bottom dissolved oxygen concentrations ≤ 2.0 mg/l) occurred at the 5-fm station in July, August, and September 1981 and in May, June, and August 1982; dissolved oxygen content was 2.1 mg/l in July 1982. Trawl catches were small during hypoxic conditions. Nothing was caught in either trawl in July and September 1981, and in June through August 1982. One species occurred in the 16-ft net and two species in the 50-ft net in August 1981, while no species occurred in the 16-ft trawl and two occurred in the 50-ft trawl in May 1982.

Diversity Indices

The relationships of three diversity indices of the catch (Table 2) to gear size were analyzed jointly by MANOVA and were found to be significant. The relationship of each diversity index to gear size was then analyzed by ANOVA (randomized block design, blocked in quarters) (Table 3). The 50-ft trawl catch had significantly ($P \leq 0.05$) more diverse community structures (H') and significantly ($P \leq 0.05$) higher species richness components (D). The evenness of equitability indices (J') were not significantly different for the two different gear sizes.

Number of Individuals of Selected Species

Of the total catch from the 50-ft trawl, 11 species each constituted 3% or more of the total number of individuals, including Micropogonias undulatus (11%), Arius felis (9%), Trachypenaeus spp. (9%), Cynoscion arenarius (9%), Penaeus setiferus (8%), Stellifer lanceolatus (7%), Anchoa mitchilli (7%), Peprilus burti (6%), Leiostomus xanthurus (6%), Lolliguncula brevis (6%), and Trichiurus lepturus (4%). Of the total catch from the 16-ft trawl, only four species each constituted 3% or more of the total number of individuals: Anchoa mitchilli (59%), Lolliguncula brevis (10%), Micropogonias undulatus (6%), and Trachypenaeus spp. (6%).

Regression analyses of the total numbers of individuals (ln tot. num. +1) of the more abundant species and Penaeus aztecus in the 50-ft trawls versus those in the 16-ft trawls showed significant relationships ($P \leq 0.05$) for 10 of the 12 species analyzed (Penaeus setiferus, Anchoa mitchilli, Micropogonias undulatus, Leiostomus xanthurus, Arius felis, Lolliguncula brevis, Trichiurus lepturus, Stellifer lanceolatus,

TABLE 1.

Abundant nekton species by number and weight at 5-fm intervals for simultaneous trawls of 16 ft and 50 ft, September 1980 through February 1983 (all sampling dates combined).

	16-ft trawl				50-ft trawl			
Species	Number	% of total catch	Weight (g)	% of total wt.	Number	% of total catch	Weight (g)	% of total wt.
Micropogonias undulatus	340	5.97	5814	15.61	2016	10.75	126717	22.58
Arius felis	118	2.07	2061	5.53	1728	9.22	72050	12.84
Trachypenaeus spp.	331	5.82	468	1.26	1678	8.95	3878	0.69
Cynoscion arenarius	130	2.28	1746	4.69	1671	8.91	39662	7.07
Penaeus setiferus	64	1.13	1176	3.16	1514	8.07	26674	4.75
Stellifer lanceolatus	105	1.84	983	2.64	1396	7.44	15612	2.78
Anchoa mitchilli	3368	59.19	5453	14.64	1241	6.62	4391	0.78
Peprilus burti	121	2.13	746	2.00	1184	6.31	51157	9.12
Leiostomus xanthurus	41	0.72	1506	4.04	1149	6.13	69812	12.44
Lolliguncula brevis	555	9.75	2589	6.95	1113	5.94	16681	2.97
Trichiurus lepturus	22	0.39	263	0.71	819	4.37	18619	3.32
Larimus fasciatus	137	2.41	873	2.34	449	2.39	3197	0.57
Chloroscombrus chrysurus	28	0.49	220	0.59	442	2.36	13903	2.48
Penaeus aztecus	25	0.44	239	0.64	326	1.74	3079	0.55
Brevoortia patronus	0	0.00	0	0.00	230	1.23	7872	1.40
Callinectes similis	18	0.32	28	0.07	208	1.11	666	0.12
Etropus crossotus	15	0.26	162	0.43	177	0.94	1751	0.31
Menticirrus americanus	16	0.28	1228	3.30	165	0.88	19125	3.41
Anchoa hepsetus	82	1.44	981	2.63	154	0.82	2475	0.44
Bairdiella chrysoura	26	0.46	803	2.16	145	0.77	8648	1.54
Sphoeroides parvus	46	0.81	236	0.63	139	0.74	1023	0.18
Squilla empusa	10	0.18	55	0.15	118	0.63	880	0.16
Bagre marinus	3	0.05	180	0.48	54	0.29	4491	0.80
Archosargus probatocephalus	2	0.03	2570	6.90	25	0.13	23432	4.18
Sciaenops ocellata	0	0.00	0	0.00	2	0.01	5386	0.96
Pogonias cromis	1	0.02	5900	15.84	1	0.00	3830	0.68

TABLE 2.

Diversity indices used for analysis of nekton assemblages.

Shannon - Weaver:[a]	$H' = -\sum_{i=1}^{S} P_i \ln P_i$
Margalef index:[b]	$D = \frac{S-1}{\ln N}$
Evenness index:[a]	$J' = \frac{H'}{\ln S}$

P_i = Proportion of the ith species
S = Number of species
N = Number of specimens
H' = Community structure diversity
D = Species richness
J' = Equitability

[a]Pielou 1975

[b]Margalef 1968

Trachypenaeus spp. and Peprilus burti [Table 4]). The total number (ln tot. num. +1) in the 50-ft trawl for five of the species with significant relationships between trawls was not significantly ($P \leq 0.05$) different than the total number for those species in the 16-ft trawls (Anchoa mitchilli, Arius felis, Trichiurus lepturus, Trachypenaeus spp. and Peprilus burti).

Total Weights of Selected Species

Each of nine species constituted 3% or more of the total weight of the 50-ft net's catch. These species were Micropogonias undulatus (23%), Arius felis (13%), Leiostomus xanthurus (12%), Peprilus burti (9%), Cynoscion arenarius (7%), Penaeus setiferus (5%), Archosargus probatocephalus (4%), Menticirrhus americanus (3%), and Trichiurus lepturus (3%). Each of 10 species constituted 3% or more of the total weight of the 16-ft net's catch: Pogonias cromis (16%), Micropogonias undulatus (16%), Anchoa mitchilli (15%), Lolliguncula brevis (7%), Archosargus probatocephalus (7%), Arius felis (6%), Cynoscion arenarius (5%), Leiostomus xanthurus (4%), Menticirrhus americanus (3%), and Penaeus setiferus (3%).

Regression analyses of the total weights (ln total wt. + 1) of abundant species and Penaeus aztecus in the 50-ft trawls versus those in 16-ft trawls showed significant relationships ($P \leq 0.05$) between the catches for 11 of the 12 species analyzed: (Penaeus aztecus, Penaeus setiferus, Anchoa mitchilli, Micropogonias undulatus, Leiostomus xanthurus, Cynoscion arenarius, Arius felis, Trichiurus lepturus, Stellifer lanceolatus, Trachypenaeus spp. and Peprilus burti) (Table 5). The total weights of these species with significant relationships between trawls were not found to be significantly different (Table 5).

Mean Weight of Individuals of Selected Species

Regression analyses showed significant relationships ($P \leq 0.05$) between the mean weight of individuals from the different size trawls for 5 of the 12 species analyzed (Penaeus aztecus, Penaeus setiferus, Micropogonias undulatus, Arius felis, Lolliguncula brevis) (Table 6). When significant relationships were analyzed further, the 50-ft trawl mean weights of individuals of three species (Penaeus setiferus, Micropogonias undulatus and Arius felis) were not significantly different ($P \leq 0.05$) than the mean weights of individuals of those species from the 16-ft trawl.

DISCUSSION

Analyses of catch composition of the 16-ft and 50-ft trawls showed certain significant relationships between the catches of the two gears. The R^2's of the significant regression relationships of total weight, number and mean individual weight indicated that generally, between 30% and 60% of the variation in the 50-ft trawls was accounted for in the catch of the 16-ft trawls. In view of the large amount of variation inherent in trawl data due to the clumped distribution of the organisms, these R^2's would appear to be reasonable expectations for these types of models.

TABLE 3.

Analyses of variance of diversity indices between the 50-ft and 16-ft trawl catches.

H'

	df	SS	P>F
Quarter	3	0.517	0.7153
Trawl size	1	2.491	0.0142
Error	40	15.161	
Total (corrected)	44		

D

	df	SS	P>F
Quarter	3	6.479	0.0804
Trawl size	1	9.322	0.0025
Error	40	35.727	
Total (corrected)	44		

J'

	df	SS	P>F
Quarter	3	0.111	0.3579
Trawl size	1	0.052	0.2205
Error	40	1.343	
Total (corrected)	44		

H = community structure diversity
D = species richness
J' = evenness

TABLE 4.

Regression analyses of total numbers (natural log transformed data) of individuals of abundant species in the 50-ft trawls on those in 16-ft trawls.

Species	df total	R^2	intercept	slope	SE/slope	$P \leq [t_{Hoi}\, b_i=0]$	$P \leq [t_{Hoi}\, b_i=1]$
Penaeus aztecus	14	0.08	3.93	0.30	0.27		
Penaeus setiferus	20	0.46	5.56	0.40	0.10	**	**
Anchoa mitchilli	19	0.70	-1.29	1.01	0.15	**	
Micropogonias undulatus	16	0.46	4.56	0.62	0.17	**	*
Leiostomus xanthurus	15	0.25	6.41	0.42	0.19	*	*
Cynoscion arenarius	19	0.14	5.91	0.30	0.17		
Arius felis	15	0.31	5.21	0.54	0.21	*	
Lolliguncula brevis	21	0.25	4.48	0.39	0.15	*	**
Trichiurus lepturus	18	0.26	4.62	0.60	0.24	*	
Stellifer lanceolatus	16	0.25	4.36	0.50	0.22	*	*
Trachypenaeus spp.	14	0.77	2.15	0.90	0.13	**	
Peprilus burti	15	0.27	3.70	0.70	0.30	*	

* $P \leq 0.05$

** $P \leq 0.01$

TABLE 5.

Regression analyses of total weights (natural log transformed data) of abundant species in the 50-ft trawls on those in 16-ft trawls.

Species	df total	R^2	intercept	slope	SE/slope	$P \leq [{}^{t}Hoi\,{}^{b}i=0]$	$P \leq [{}^{t}Hoi\,{}^{b}i=1]$
Penaeus aztecus	14	0.31	1.91	0.88	0.36	**	
Penaeus setiferus	20	0.53	2.61	1.05	0.22	**	
Anchoa mitchilli	19	0.58	-0.64	0.77	0.15	**	
Micropogonias undulatus	16	0.49	1.86	0.81	0.21	**	
Leiostomus xanthurus	15	0.36	2.60	1.09	0.38	*	
Cynoscion arenarius	19	0.56	2.21	0.89	0.18	**	
Arius felis	15	0.36	2.46	0.82	0.29	*	
Lolliguncula brevis	21	0.14	2.48	0.36	0.20		
Trichiurus lepturus	18	0.20	2.20	0.96	0.45	*	
Stellifer lanceolatus	16	0.49	2.16	1.06	0.26	**	
Trachypenaeus spp.	14	0.80	1.73	0.86	0.11	**	
Peprilus burti	15	0.26	1.55	0.71	0.31	*	

* $P \leq 0.05$
** $P \leq 0.01$

TABLE 6.

Regression analyses of mean weight, individuals of abundant species in the 50-ft trawls on those in 16-ft trawls.

Species	df total	R^2	intercept	slope	SE/slope	$P \leq [t_{Hoi} b_i = 0]$	$P \leq [t_{Hoi} b_i = 1]$
Penaeus aztecus	4	0.94	4.09	0.48	0.06	**	**
Penaeus setiferus	11	0.88	2.37	0.86	0.09	**	
Anchoa mitchilli	13	0.13	2.35	0.43	0.32		
Micropogonias undulatus	11	0.39	15.83	1.09	0.42	*	
Leiostomus xanthurus	4	0.03	48.11	0.16	0.50		
Cynoscion arenarius	15	0.09	28.85	0.38	0.32		
Arius felis	9	0.62	23.61	1.01	0.27	**	
Lolliguncula brevis	19	0.49	11.49	0.51	0.12	**	**
Trichiurus lepturus	7	0.02	21.12	0.18	0.49		
Stellifer lanceolatus	9	0.23	8.14	0.42	0.27		
Trachypenaeus spp.	10	0.00	2.51	-0.01	0.30		
Peprilus burti	10	0.01	27.71	0.34	0.82		

* $P \leq 0.05$
** $P \leq 0.01$

Variations in diversity indices and catch composition were related not only to length of horizontal opening of the trawls but also to other experimental differences. The higher vertical opening and tickler chain of the 50-ft trawl increased the chance of catching pelagic and benthic organisms, respectively. The towing time of the 50-ft trawl was 50% longer than that of the 16-ft trawl, which increased the chance that rarer species would be caught.

Both sizes of trawls appeared to be suitable for use in the nearshore area. Each trawl had some advantages over the other. The 50-ft trawl showed a more diverse community structure but the 16-ft trawl could be used to predict much of the 50-ft catch, which could result in cost savings. The most predictable (highest R^2) relationships were between the mean individual weights of shrimp (Penaeus aztecus and P. setiferus) caught by each trawl. The 16-ft trawl sampled the same Penaeus shrimp populations as the 50-ft trawl and provided an excellent indicator of the size of shrimp available to the trawls.

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COMPARISON OF THE CATCH RATES OF THREE TRAWLS IN OFFSHORE TEXAS WATERS

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ABSTRACT Analyses suggest that a 4.3-m (14-ft) trawl can be as good an indicator of the relative abundance and size of shrimp in offshore waters as a 12.2-m (40-ft) or 13.7-m (45-ft) trawl. Forty-five paired trawl comparisons were made between July 1981 and February 1982. At each station a 4.3-m trawl was towed simultaneously with either a 12.2-m or a 13.7-m trawl. Linear regressions were fitted to both catch/tow and mean length of shrimp from the paired trawls. Correlation coefficients for the three sets of data for catch/tow ranged from 0.817 to 0.886. The regression coefficients were 5.225 and 5.172 for Penaeus aztecus from the night-time trawls and 2.516 for P. setiferus from the daytime tows.

Correlation coefficients for the three regression lines for mean length ranged from 0.934 to 0.978. Regression coefficients ranged from 0.952 to 1.234 Analysis of covariance showed no significant difference between the three regression equations, so the data sets were combined into one equation. The resulting 95% confidence interval around the regression coefficient was 1.012-1.163. Since the 95% confidence interval of the intercept encompassed zero, the trawls were apparently catching similar sized shrimp.

INTRODUCTION

Penaeid shrimp surveys in the Gulf of Mexico have predominately used trawls to collect specimens for study. Many different types and sizes of trawls have been used by researchers to gather data on this valuable resource, but very little information is available on the comparison of catch rates of different sized trawls pulled simultaneously. Most of the previous work has compared either catch rates in small trawls pulled in close proximity (Kjelson and Johnson 1978) or in large, similar-sized trawls pulled at the same time (Matthews 1982).

If reliable and comparable catch and trend information can be collected using smaller, less expensive trawls, sampling programs can be conducted more economically. The subsequent time and labor saved in taking and processing samples could allow for an increase in the number of samples taken and possibly lower sample variance. An additional benefit would be the option to use smaller, faster, less-expensive boats to conduct surveys in the Gulf.

During 1981 and 1982, the Texas Parks and Wildlife Department (TPWD) investigated the feasibility of using small trawls to collect data on penaeid shrimp in the Gulf of Mexico. The initial stages of the project compared three sizes of trawls that were used in TPWD's Gulf Research Program. If the catches of penaeid shrimp in the various trawls are proportional, and reliable calibration formulas are developed, then data collected with smaller trawls may be compared to historical TPWD data and data from surveys based on collections made with larger trawls, such as those of the SEAMAP Program.

The specific objectives of this paper are (1) to compare the number of penaeid shrimp caught in the 4.3-m (14-ft) trawl with the number caught in the 12.2-m (40-ft) and 13.7-m (45-ft) trawls; and (2) to compare the mean size of penaeid shrimp collected in the 4.3-m (14-ft) trawl with the mean size collected by the 12.2-m (40-ft) and 13.7-m (45-ft) trawls.

MATERIALS AND METHODS

The study area was the Texas offshore waters between Port Aransas (28°N) and the Port Mansfield Channel (26°30'N). The depth range was 7 m (23 ft) to 79 m (261 ft) with 89% of the stations between 7 m (23 ft) and 42 m (139 ft). All trawls were towed from TPWD's R/V WESTERN GULF, a double-rigged, 21.9-m (72-ft) steel-hull shrimp trawler.

At each station a 4.3-m (14-ft) trawl and either a 12.2-m (40-ft) or 13.7-m (45-ft) trawl were towed simultaneously. The 4.3-m (14-ft) trawl had 5.1-cm (2-in) stretched mesh in the body and 4.4-cm (1.8-in) mesh in the bag. It was equipped with a tickler chain and was spread by wooden doors 0.4-m (1.3-ft) high and 0.8-m (2.6-ft) long (Appendix A). Both large nets had 5.1-cm (2-in) stretched mesh webbing in the body and 4.4-cm (1.8-in) mesh in the bag. Each was equipped with a tickler chain, and was spread by wooden doors 0.9-m (2.9-ft) high and 2.1-m (6.8-ft) long.

Three separate sets of trawl comparisons were made between July 1981 and February 1982. The first two sets dealt with numbers and measurements of Penaeus aztecus, while the third set dealt with numbers and measurements of P. setiferus. The first set of comparative tows was taken at night from July to September 1981. During this period 20 stations were sampled. At each station a 30-min tow was made with the 4.3-m (14-ft) and 13.7-m (45-ft) trawls. The second set of tows was made between October 1981 and February 1982 with the 4.3-m (14-ft) trawl and the 12.2-m (40-ft) semiballoon trawl. Both trawls were pulled for 30 min at each of 12 stations. The third set of samples was collected between November 1981 and February 1982 using the 4.3-m (14-ft) and 12.2-m (40-ft) trawls; 10-min tows were made during the daytime at 13 stations.

Samples were processed on the afterdeck of the R/V WESTERN GULF by culling all penaeid shrimp from the catch and sorting the shrimp by species. For each species, all shrimp were weighed en masse. If $\leq$50 shrimp were caught, all were individually measured. All shrimp measurements were for total length from tip of rostrum to tip of telson. If $\geq$50 shrimp were caught, a subsample of at least 50 shrimp was randomly selected from the catch, weighed en masse, and the individuals measured. The remainder of that species was weighed and the total number was estimated by multiplying the number of shrimp per pound (from the subsample) by the total weight of that species.

Linear regressions were calculated for catch/tow and for mean lengths of shrimp from the paired trawls of individual data sets (Sokal and Rohlf 1981). The precision of the mean lengths used in the regressions was made approximately equal by deleting mean lengths calculated with less than six shrimp (Snedecor and Cochran 1980).

A suspected outlier was also removed from the 13.7-m (45-ft) data set. No female shrimp were recorded from the smaller net in this paired tow, which created an unusually small mean length. Since this was the only sample (out of 17) that did not contain large female brown shrimp it is probable that they were inadvertently overlooked.

RESULTS

Abundance

The number of shrimp caught in the smaller trawl correlated well with the number caught in the larger trawl for each of the three sets of paired data (Figures 1-3). Correlation coefficients for these three data sets were 0.882, 0.817 and 0.886, respectively. The regression coefficients for the first two sets of data (nighttime - P. aztecus) were 5.225 and 5.172, respectively. The paired tows for the third set of data (daytime - P. setiferus) had a regression coefficient of 2.516, only half as large as in the other sets. The catch/tow data were not subjected to an analysis of covariance because of widely disparate ranges in the original data.

Size

Regression analyses showed that the 4.3-m (14-ft) trawl captured the same size shrimp as the larger trawls. The range and mean length of shrimp in each trawl are presented in Tables 1-3. The mean sizes usually differed $\leq$5-mm between paired trawls. Correlation coefficients for the regression lines for mean lengths from the three data sets were 0.934, 0.963, and 0.978, while the regression coefficients were 1.234, 0.952, and 1.083, respectively. The analysis of covariance indicated there was no significant difference between the regression coefficients, the intercepts, or the residual variances, so the data sets were combined to give one regression equation (Figure 4). For the combined regression line the 95% confidence interval around the regression coefficient was 1.012-1.163.

DISCUSSION

Small trynets have been used by commercial shrimp fishermen for years as indicators of shrimp abundance. These analyses provide some data on the catch/tow relationship between small trawls and large trawls pulled simultaneously. The 67-78% portion of the catch/tow relationship (i.e., the range of r^2's) explained by the three regression lines may be low for use as standardization formulas for specific quantitative comparisons, but are probably adequate for the trend analyses on which most resource agencies base their management recommendations.

The correlation between trawls in the three data sets remained high while the regression coefficients for P. aztecus and P. setiferus were quite different. The two data sets for P. aztecus were based on 30-min tows at night while the P. setiferus data were based on 10-min tows during the day. The relative efficiency of the trawls under different light conditions, tow durations or overall numbers of shrimp, may be a factor in the differences we found. The small number of comparisons in each data set may have also contributed to the disparity.

Many researchers have pointed out that trawl efficiency depends on such factors as gear design, trawling technique, bottom type, water temperature, time of day, turbidity of the water, etc. (Taylor 1953; Roessler 1965; Gulland 1966; Loesch et al. 1976; Chittenden 1978). Size and behavior of the organisms, even within the same species, affect the gear efficiency. Loesch et al. (1976) found that the efficiency for small trawls on Barataria Bay was about 33-50% for brown shrimp, while Seidel (1972) estimated commercial shrimp trawlers using large nets captured 25-50% of the penaeid shrimp in the area trawled. These two efficiency estimates appear similar.

Recent studies have been made to determine the catch efficiency of individual trawls and to develop techniques and equipment necessary to measure their performance (Watson 1976; Loesch et al. 1976; Wathne 1977; Kjelson and Johnson 1978).

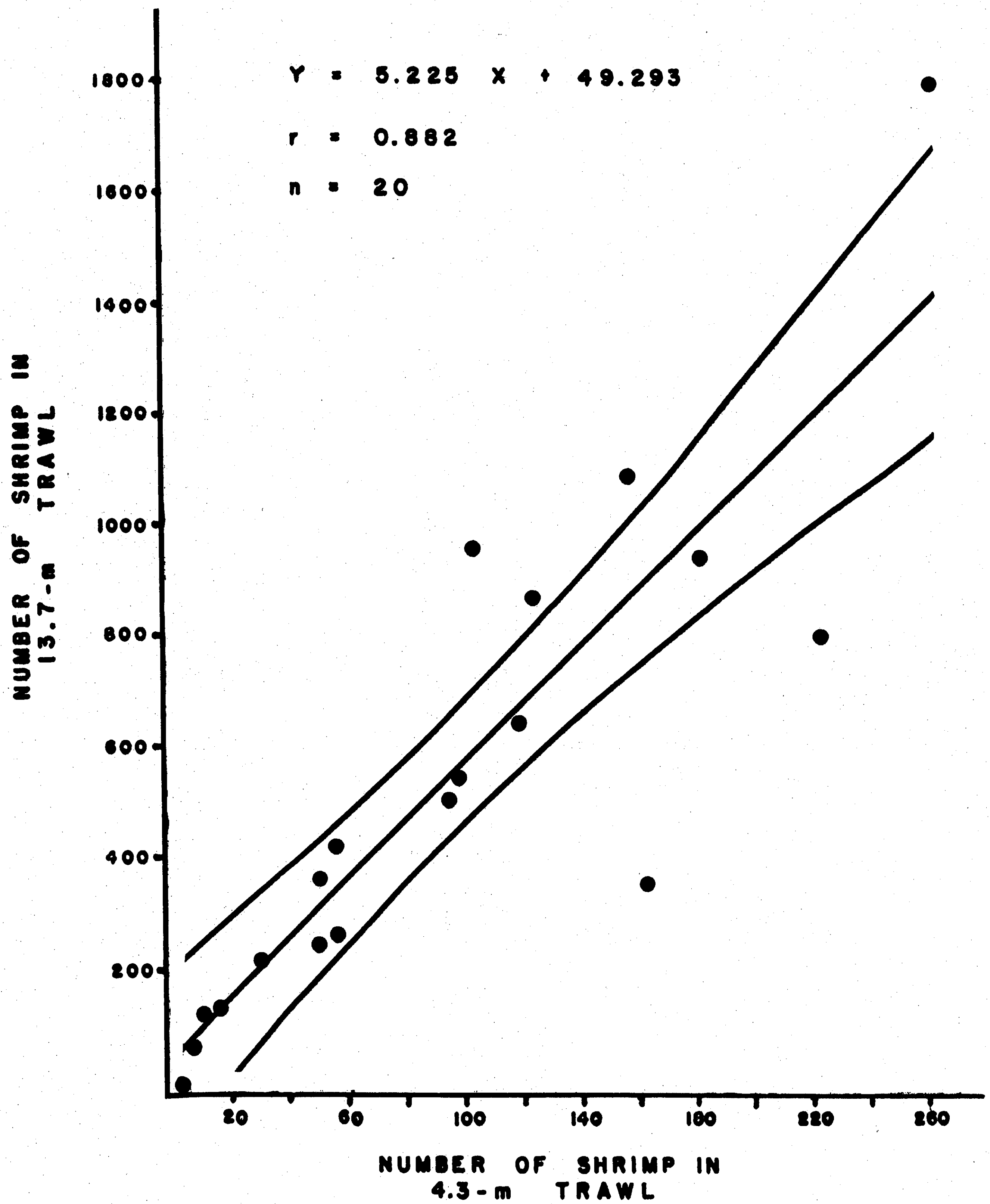

Figure 1. Actual paired data and the calculated regression line with 95% confidence limits for the catch/tow relationship of Penaeus aztecus caught in 30-minutes trawls during July-September 1981.

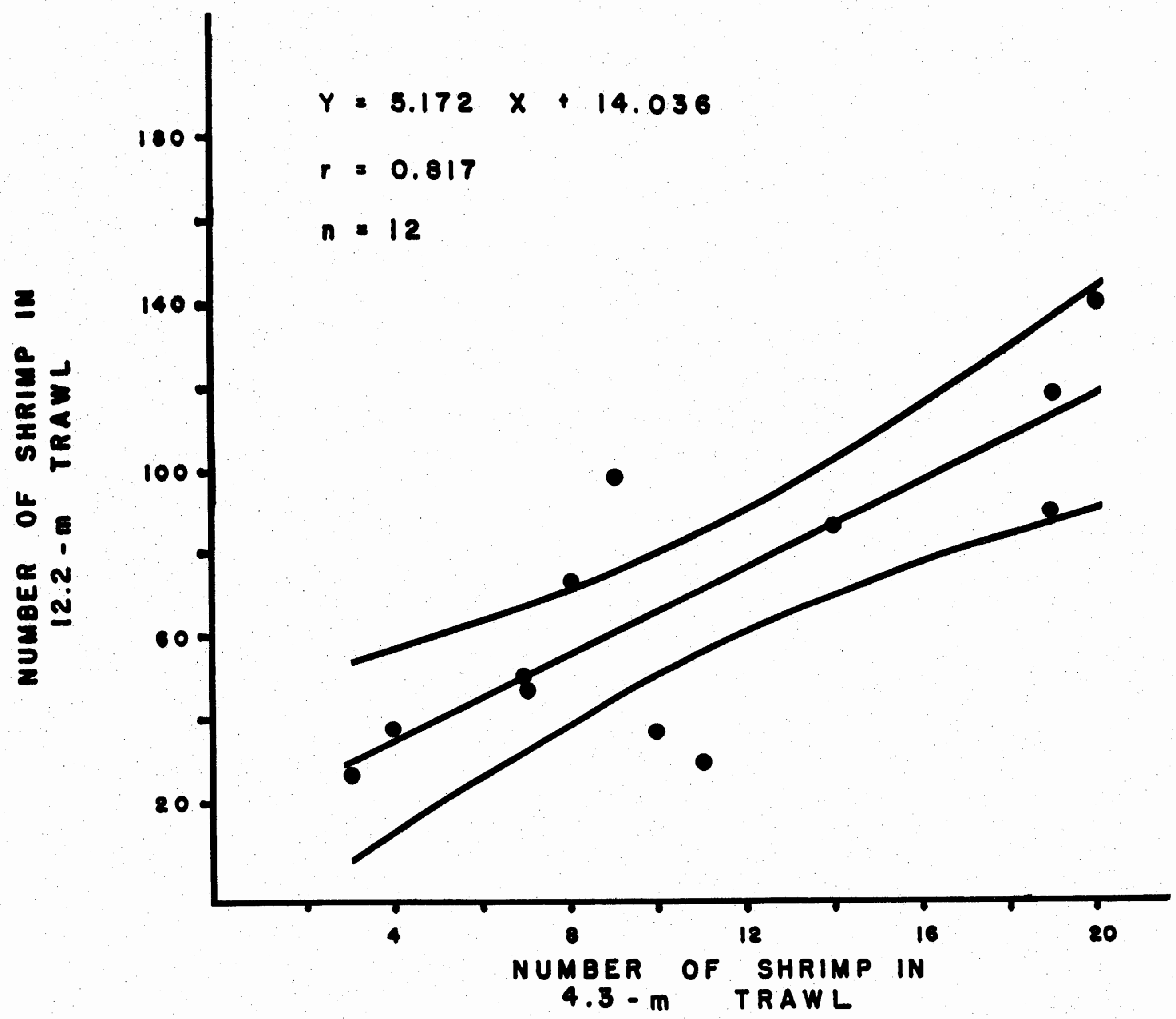

Figure 2. Actual paired data and the calculated regression line with 95% confidence limits for the catch/tow relationship of Penaeus aztecus caught in 30-minutes trawls during October 1981-February 1982.

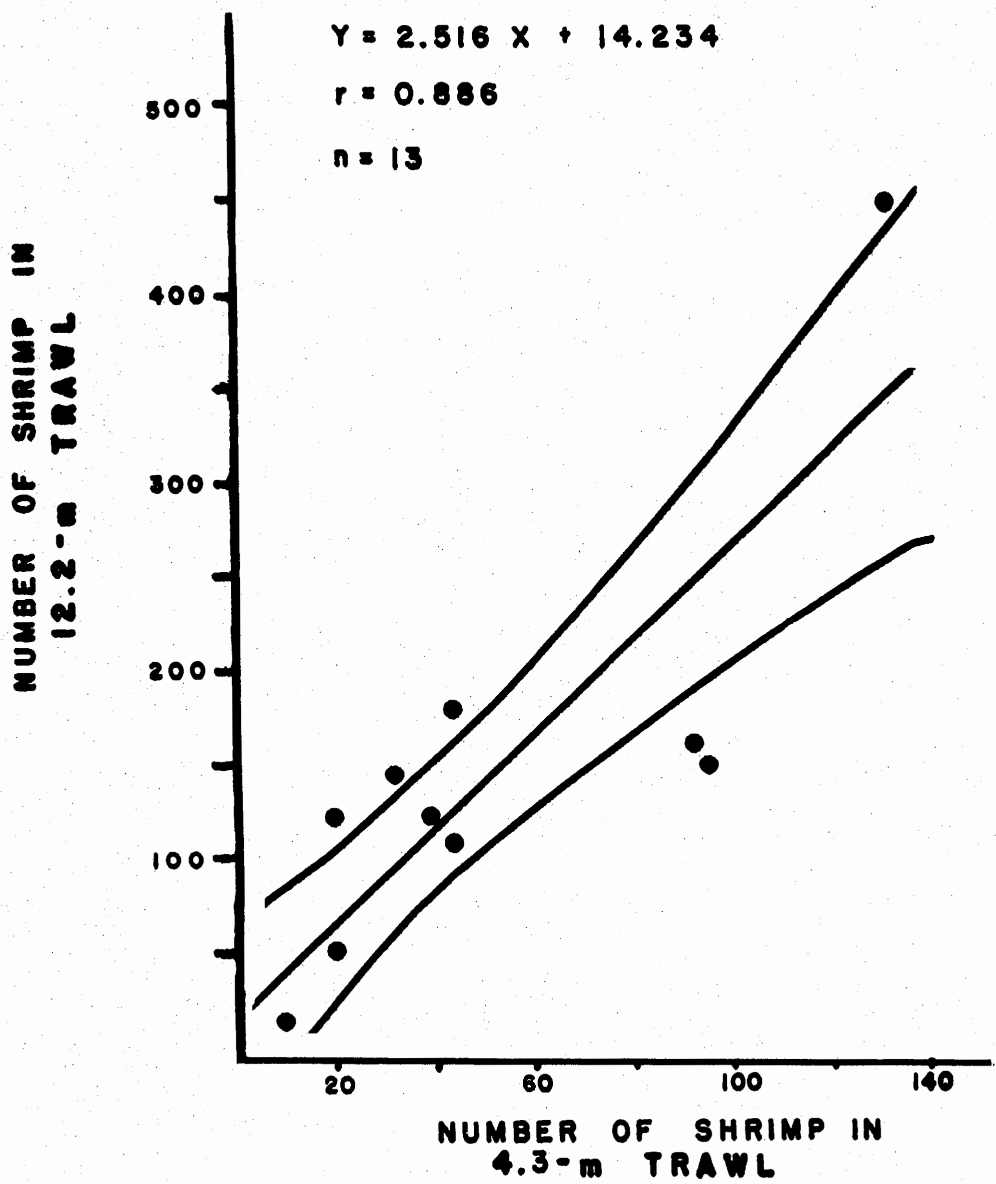

Figure 3. Actual paired data and the calculated regression line with 95% confidence limits for the catch/tow relationship of Penaeus setiferus caught in 10-minute trawls during November 1981-February 1982.

TABLE 1.

Data summary of Penaeus aztecus caught in 30-min paired tows at night using 4.3-m (14-ft) and 13.7-m (45-ft) trawls. Shrimp measurements in millimeters.

Tow no.	Date	Depth (m)	Net size (m)	No. shrimp caught	No. shrimp measured	Minimum length	Maximum length	Mean length
1	7/23/81	15	4.3	2	2	95	113	104
			13.7	0				
2	7/23/81	24	4.3	260	49	90	141	108
			13.7	1796	50	90	132	107
3	7/24/81	33	4.3	181	47	90	156	116
			13.7	945	50	93	181	121
4	7/24/81	42	4.3	162	50	85	176	115
			13.7	352	50	85	170	121
5	7/24/81	51	4.3	103	50	93	160	119
			13.7	958	50	88	177	117
6	7/29/81	42	4.3	98	50	79	153	115
			13.7	545	50	94	166	119
7	7/29/81	33	4.3	94	50	97	168	129
			13.7	501	51	96	172	128
8	7/30/81	24	4.3	118	50	94	165	124
			13.7	641	50	94	164	125
9	7/30/81	15	4.3	156	50	84	178	122
			13.7	1090	50	67	157	114
10	8/05/81	40	4.3	222	49	93	152	112
			13.7	801	50	92	167	119
11	8/05/81	31	4.3	123	50	83	162	122
			13.7	870	50	97	185	121
12	8/06/81	22	4.3	56	56	72	154	121
			13.7	422	50	84	155	117
13	8/06/81	13	4.3	30	30	64	172	97
			13.7	218	50	67	168	87
14	8/26/81	40	4.3	56	56	93	167	121
			13.7	269	50	92	167	124
15	8/26/81	31	4.3	50	50	94	172	128
			13.7	244	50	108	172	138
16	8/26/81	22	4.3	50	50	87	164	121
			13.7	360	50	82	163	124
17	8/27/81	13	4.3	0				
			13.7	20	20	73	146	105
18	9/21/81	40	4.3	10	10	121	163	146
			13.7	124	50	107	179	151
19	9/21/81	31	4.3	16	16	102	163	134
			13.7	133	50	108	176	144
20	9/21/81	22	4.3	6	6	103	122	112
			13.7	66	66	103	178	132

TABLE 2.

Data summary of *Penaeus aztecus* caught in 30-min paired tows at night using 4.3-m (14-ft) and 12.2-m (40-ft) trawls. Shrimp measurements in millimeters.

Tow no.	Date	Depth (m)	Net size (m)	No. shrimp caught	No. shrimp measured	Minimum length	Maximum length	Mean length
1	10/20/81	42	4.3	8	8	142	170	156
			12.2	74	50	123	182	160
2	10/20/81	33	4.3	7	7	126	172	147
			12.2	48	48	118	180	150
3	10/20/81	24	4.3	19	19	88	166	124
			12.2	119	52	87	166	128
4	11/04/81	42	4.3	9	9	98	177	148
			12.2	99	50	121	178	153
5	11/04/81	33	4.3	19	19	123	181	143
			12.2	91	48	121	173	142
6	11/04/81	24	4.3	14	14	98	158	125
			12.2	87	50	93	170	128
7	11/23/81	42	4.3	4	4	153	180	166
			12.2	38	38	129	179	147
8	11/23/81	33	4.3	7	7	129	156	139
			12.2	50	50	131	181	148
9	2/16/82	79	4.3	11	11	140	184	155
			12.2	35	35	137	190	158
10	2/16/82	69	4.3	20	20	138	192	154
			12.2	141	50	138	192	153
11	2/16/82	60	4.3	3	3	142	175	154
			12.2	27	27	136	189	154
12	2/16/82	51	4.3	10	10	120	168	146
			12.2	37	37	137	178	153

TABLE 3.

Data summary of *Penaeus setiferus* caught in 10-min paired tows during the day using 4.3-m (14-ft) and 12.2-m (40-ft) trawls. Shrimp measurements in millimeters.

Tow no.	Date	Depth (m)	Net size (m)	No. shrimp caught	No. shrimp measured	Minimum length	Maximum length	Mean length
1	11/24/81	7	4.3	0				
			12.2	1	1			92
2	11/24/81	11	4.3	19	19	93	122	117
			12.2	121	50	97	182	123
3	11/24/81	11	4.3	0				
			12.2	2	2	121	123	122
4	11/24/81	7	4.3	0				
			12.2	2	2	105	133	119
5	12/30/81	7	4.3	94	50	81	116	98
			12.2	150	50	58	109	98
6	1/06/82	7	4.3	20	20	76	108	92
			12.2	49	49	74	121	95
7	1/06/82	11	4.3	43	43	82	122	101
			12.2	180	50	82	144	102
8	1/27/82	7	4.3	136	50	75	107	94
			12.2	450	50	73	112	91
9	1/27/82	11	4.3	31	31	88	138	116
			12.2	146	50	97	137	115
10	1/27/82	11	4.3	9	9	96	137	117
			12.2	14	1[a]			118
11	1/27/82	7	4.3	92	50	88	129	102
			12.2	160	50	78	122	102
12	2/11/82	11	4.3	38	38	78	121	96
			12.2	122	50	74	117	93
13	2/11/82	7	4.3	43	43	71	119	88
			12.2	109	50	72	112	89

[a]One shrimp was found and measured; total number estimated by subsampling 1/14 of 870-kg total catch.

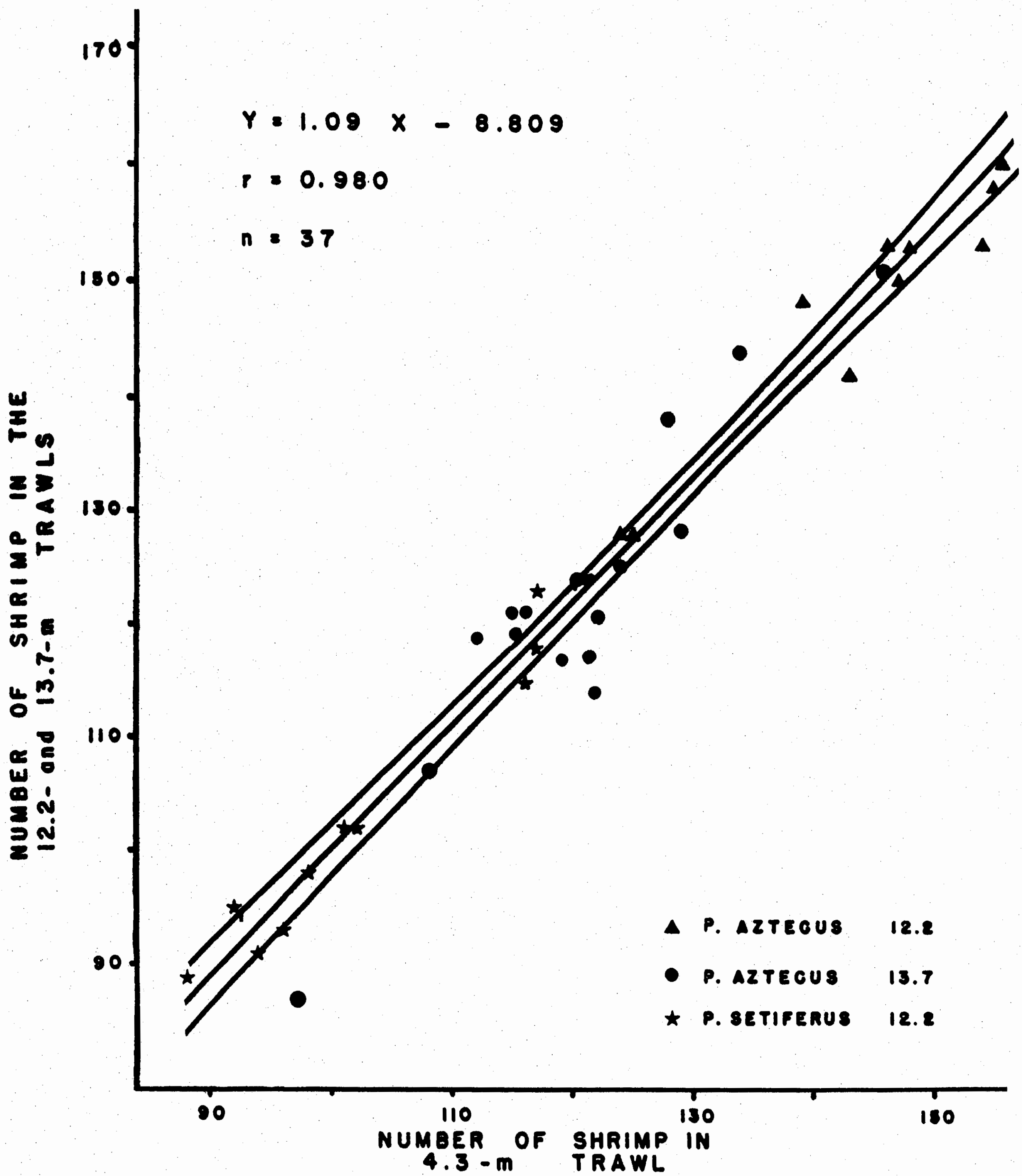

Figure 4. Actual paired data and the calculated regression line with 95% confidence limits for the mean total length relationship of penaeid shrimp caught in trawls during July 1981-February 1982.

If these techniques can be refined to the point where individual trawls can be "calibrated", then comparison of biological data will be simplified.

Until this is possible, researchers should make every effort to reduce the variance in their sampling programs. Gulland (1966) states that this can best be done by stratification into nearly uniform units and taking as many samples as possible--even at the cost of reducing the size of the sample if necessary. Taylor (1953) supports this viewpoint and feels the variance may be reduced, and the amount of information increased, by decreasing the size of the observed mean. He suggests accomplishing this by reducing the length of the tow and the size of the trawl.

These analyses show that a small trawl can be a reliable indicator of the size of shrimp in offshore waters. They also indicate that catch/tow relationships can be determined for both smaller trawls and the larger, historical trawl sizes that would allow researchers to develop more efficient sampling programs using smaller trawls, and benefit from valuable trend information that has been gathered over the years.

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APPENDIX A.

SPECIFICATIONS FOR SHRIMP TRAWLS USED IN TEXAS PARKS AND WILDLIFE DEPARTMENT GULF RESEARCH PROGRAM

General Description and Specifications

45-ft Texas jib trawl (TPWD)

°Net is 13.7 m (45 ft) wide along headrope
°Body is 51-mm (2-in) stretched measure #18 nylon mesh (470 meshes)
°Jib corners are 51-mm (2-in) knotless webbing (47 meshes)
°Headrope and footrope are 12.7-mm (1/2-in) trawl cable with 0.91-m (3-ft) leads
°120 x 120 mesh bag of 44-mm (1 3/4-in) stretched measure #36 nylon mesh with straps for lazy line
°2.13-m (7-ft) chafing gear; 50 x 40 meshes of #72 knotless webbing (90 mm - 3 1/2 in)
°Entire trawl treated with green net guard
°Footrope weighted with lead net weights
°Tickler chain used; 6.4 mm (1/4 in links)
°Spread by wooden trawl doors with steel runners; 0.91 m (3 ft) high by 2.13 m (7 ft) long
°Standard Gulf trawl used prior to September 1981; purchased from City Net Shop in Aransas Pass, Texas for $600.00 in July 1980

40-ft semiballoon shrimp trawl (NMFS)

°Net is 12.2 m (40 ft) wide along headrope; 14.4 m (47 ft, 3 in) along footrope
°Body is 51-mm (2-in) stretched measured #18 nylon mesh
°Headrope and footrope of 11.1-mm (7/16-in) trawl cable
°Bag of 44-mm (1 3/4-in) stretched measure #36 nylon mesh
°Chafing gear not used
°Entire trawl treated with green net guard
°Headrope with 5 sponge floats (85 mm dia. by 75 mm long)
°Footrope with 15 mud rollers (threaded on); 125 mm dia. by 215 mm long
°Footrope weighted Texas-loop style with 4.8-mm (3/16-in) galvanized chain (hung 16 links per foot)
°Tickler chain used; 6.4 mm (1/4 in links)
°Spread by wooden trawl doors with steel runners; 0.91-m (3-ft) high by 2.13-m (7-ft) long
°Standard 40-ft net used by NMFS in SEAMAP/Shrimp/Groundfish Surveys; built at McNair Net & Supply, Inc., Galveston, Texas and Pascagoula, Mississippi.

15-ft Gulf trynet (TPWD)

°Net is 4.3 m (14 ft) along headrope; 4.7 m (15 ft, 4 in) along footrope (hanging to hanging)
°Body is 51-mm (2-in) stretched measure #12 nylon mesh
°Headrope and footrope of 11.1-mm (7/16-in) polypropylene rope
°Bag is 44-mm (1.75-in) stretched measure #24 nylon mesh
°Chafing gear not used
°Entire trawl treated with black net guard
°Headrope with 1 sponge float (85 mm dia. by 75 mm long)
°Mud rollers not used
°Footrope weighted with lead trawl weights
°Tickler chain used; 4.8-mm (3/16-in) links
°Spread by wooden Gulf trynet doors with steel runners; 0.44 m (17 in) high by 0.83 m (33 in) long
°This is the standard 15' trynet (#7222) used in the Rockport/Aransas Pass area; sold by Gulf King Marine and Industrial Supply, Aransas Pass, Texas for $68.38 in July 1981.

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MESH SIZE SELECTIVITY STUDY OF PENAEID SHRIMP TRAWLED FROM GALVESTON BAY, TEXAS, MAY 1981

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ABSTRACT The number and size of penaeid shrimp retained in trawls were found to be dependent upon the mesh size and twine size of the trawl. During the study, brown shrimp, Penaeus aztecus, were smaller ($\bar{x}$ = 81.0 to 85.5 mm) than white shrimp, P. setiferus, ($\bar{x}$ = 118.8 to 128.5 mm). There were no significant differences in the total number of white shrimp caught by the different trawl mesh sizes. The larger mesh sizes resulted in significantly larger white shrimp being caught. Trawls with larger mesh sizes caught significantly fewer brown shrimp than did trawls with smaller mesh sizes; however, there was no significant difference among the mean size of shrimp caught. This suggested that when there was a wide range in the size of shrimp available, the larger mesh trawl caught larger shrimp without a decrease in the total number of white shrimp caught. When the shrimp were fairly uniform in size, trawls with larger meshes resulted in smaller total catches with no difference among the mean sizes of brown shrimp caught. Larger twines may change the effective mesh size; for example, a trawl made with number 12 twine having a stretched mesh of 47.6 mm may catch the same number and size of shrimp as a trawl made with number 9 twine having a stretched mesh of 44.5 mm. Towing trawls for relatively short periods showed a linear relationship between the catch (number) and tow time (a 45-min tow resulted in three times the number of shrimp caught as a 15-min tow). These tow times were not found to affect the size of the shrimp caught.

INTRODUCTION

The shrimp fishery of Texas is the most valuable commercial fishery in the state. Total landings for brown shrimp (Penaeus aztecus), white shrimp (P. setiferus) and pink shrimp (P. duorarum) were 24.0 million kg in 1978 and were valued at $141.1 million (U.S. Department of Commerce 1980). Another segment of this fishery is the bait shrimp fishery. During 1978, 1.06 million kg of bait shrimp were landed in Texas and were valued at $6.8 million (Center for Wetland Resources 1978). The estimated 1980 harvest was 1.4 million kg (Jim Morgan, NMFS, personal communication). Present shrimping regulations permit bay shrimping with a minimum stretched mesh size of 33.0 mm (1 1/3 in) during a spring bay shrimping season and a minimum stretched mesh size of 44.5 mm (1 3/4 in) during a fall bay shrimping season.

While it is generally accepted that the mesh size of a trawl is effective in limiting the size and number of shrimp caught, the relationship has not been well defined. A study of Regan et al. (1956) attempted to measure capture efficiency with mesh sizes ranging from 44.5 to 63.5 mm (1 3/4 to 2 1/2 in) stretched mesh for different size shrimp but their study included neither nets of the mesh sizes used by the Texas bay fishery nor shrimp of the sizes associated with it. Another study by Berry and Hervey (1964) also attempted to relate mesh selectivity to mesh size and time of tow. Their study showed linear relationships between size of shrimp caught and mesh size of the trawl, and size of shrimp caught and duration of tow. However, very few details were provided regarding the experimental design (sample sizes, species and number of shrimp caught, etc.) or the reliability of the results.

The objective of this study is to describe the relationships between the mesh size of an otter trawl, the lapsed time of the tow and the number and size of white and brown shrimp retained. This information will be used to enhance management of the Texas shrimp fishery.

MATERIALS AND METHODS

This study was conducted in Clear Lake, an estuary of about 518 ha in the Galveston Bay system. It is 4.0 km (2.6 mi) long and less than 1.6 km (1 mi) wide (Diener 1975). The estuary averages 1.2 m (3.9 ft) in depth (maximum depth: 4.3 m [14.1 ft] in channel areas). The waters are typically low in salinity. Pullen (1969) reported a salinity range of 0.1 to 17.1°/oo. In 1979, the 66th Texas Legislature designated Clear Lake as a shrimp nursery area.

Three 6.1-m (20-ft) flat otter trawls having stretched mesh sizes of 38.1, 44.5 and 47.6 mm

(1 1/2, 1 3/4 and 1 9/10 in) were constructed for use in this study. The 38.1-mm (1 1/2-in) and 44.5-mm (1 3/4-in) mesh trawls were constructed of 9-thread nylon twine. The trawls were attached to 50.8 x 121.9-cm (20 1/2 x 48 3/4-in) otter doors having iron bottom runners measuring 6.4 x 38.1 x 1372.0 mm (1/4 x 1 1/2 x 54 3/4-in). The headrope and footrope were secured 25.4-cm (10 1/6-in) from the back of the trawl doors. The towing lines were 13.8-mm (1/2-in) in diameter and 31.8-m (104.3-ft) in length.

Thirty-six trawls were taken from 7 May to 12 May 1981 in five different areas in Clear Lake. The five sampled areas (Figure 1) were established based on the ability to delineate one area from another by visible landmarks and on the fact that there was sufficient area in which to make a 45-min tow. Data from a recent Texas Parks and Wildlife Department (TPWD) study (Benefield and Baker 1980) indicated that both white and brown shrimp having various lengths could be expected to be present in Clear Lake during the time of this study. Six samples were collected with each of the three mesh sizes and with two tow times (18 to 15 min and 18 to 45 min). A sampling schedule was arranged such that every area was represented in each cell of a two-way analysis of variance. The occurrence of an area more than once in a cell was random.

Between five and six samples were collected each day. The first sample of the day was selected at random; subsequent samples were taken sequentially. This design was used because of the limited time in which the sampling had to be accomplished, and to help minimize the effect different shrimp densities in different areas might have on the analysis (a Latin Square design was approximated). A 7.9-m (25.9-ft) inboard boat was used to tow the trawl at ~ 1000 rpm (3 mph) in a serpentine manner to avoid the trawl passing over bay bottom that had been disturbed by the propeller wash. Trawling was accomplished so that an area of bay bottom was never trawled twice during any one sample.

Shrimp from each sample were sorted according to species and counted and weighed en masse. At least 60 shrimp of each species were randomly selected from each sample and measured from tip of rostrum to end of telson. Mean length and variance were calculated for each sample. Other species in each sample were ignored.

Differences in mean lengths and mean catches between mesh sizes and different trawl times were determined using a two-way analysis of variance (Sokal and Rohlf 1969). Linearity in the catch rate function was tested with a t-test, assuming that a 45-min tow should result in three times the catch (in numbers) of a 15-min tow. The number of shrimp caught per sample was converted to log (number +1) to achieve equal variances.

RESULTS

The 36 trawl samples collected in Clear Lake contained 3360 penaeid shrimp (2015 brown shrimp and 1325 white shrimp). Catches according to

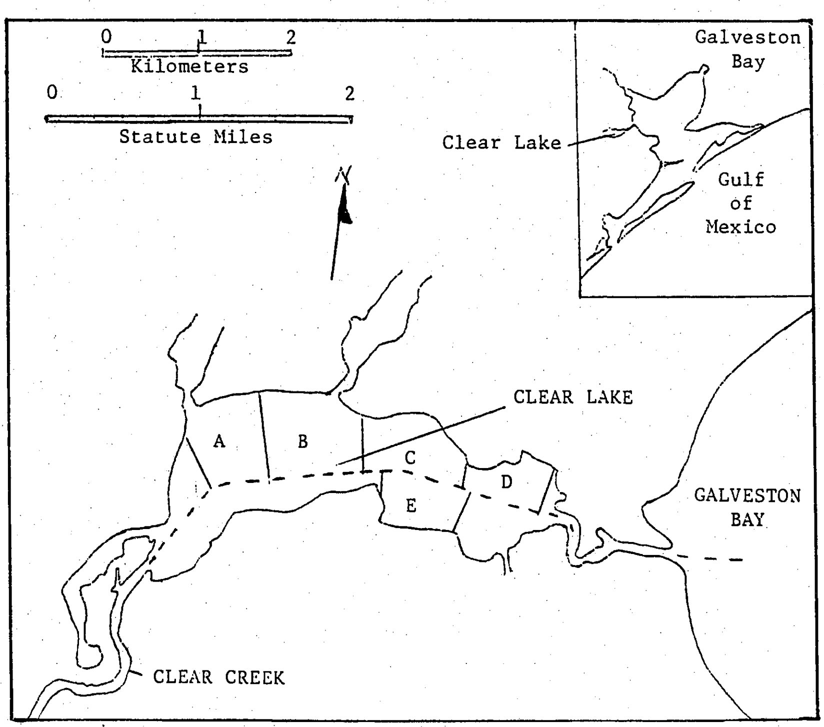

Figure 1. Clear Lake showing mesh selectivity sample stations.

trawl mesh size were: 38.1-mm (1 1/2-in) net - 1469 brown shrimp, 480 white shrimp; 44.5-mm (1 3/4-in) net - 320 brown shrimp, 463 white shrimp; 47.6-mm (1 9/10-in) net - 227 brown shrimp, 402 white shrimp. The number of shrimp contained in each sample varied from 7 to 966. A mistake in scheduling or execution of the design resulted in one area being missed in three of the six cells for the analysis of variance (Table 1).

No significant differences were found in the mean length of brown shrimp either caught by different mesh sizes (F_s = 0.862, df = 2,29) or resulting from different tow times (F_s - 1.498, df = 1,29). The mean length of brown shrimp had a narrow range (81.0 ± 5.4 mm for 15-min tows using 44.5-mm (1 3/4-in) stretched mesh to 85.5 ± 1.5 mm for 45-min tows using 38.1-mm (1 1/2-in) mesh (Table 2).

The 38.1-mm (1 1/2-in) mesh trawl caught smaller white shrimp than did the 44.5-mm (1 3/4-in) mesh trawl or the 47.6-mm (1 9/10-in) trawl (F_s = 7.712, df = 2,30). The differences found for the white shrimp mean lengths were most likely due to the small mean lengths obtained for the 38.1-mm (1 1/2-in) mesh trawl (118.8 ± 0.8 mm) because the mean lengths for the other two mesh sizes were much larger and numerically closer together (44.5-mm, or 1 3/4-in, trawl - 128.5 ± 1.5 mm; 47.6-mm, or 1 9/10-in, trawl - 121 ± 2.9 and 125.0 ± 0.7 mm). The mean length of white shrimp did not vary with the time of the tow (F_s = 0.92, df = 1,30).

The mean catch of brown shrimp in each trawl (Table 3) was found to vary with the size of the mesh (F_s = 12.070, df = 2,300) and the duration of the tow (F_s = 27.212, df = 1,30). Both the 44.5-mm (1 3/4-in) and 47.6-mm (1 9/10-in) mesh trawls caught fewer brown shrimp than did the 38.1-mm (1 1/2-in) mesh trawl pulled the same length of time. The 47.6-mm (1 9/10-in) mesh trawl caught 82% fewer shrimp than the 38.1-mm (1 1/2-in) trawl while the 44.5-mm (1 3/4-in) mesh trawl caught 80% fewer shrimp than the 38.1-mm (1 1/2-in) trawl. The total number of brown shrimp caught in the 45-min tows was 3.8 to 9.0 times greater than the number caught in the 15-min tows. The mean multiplier (5.8 ± 1.6) was not significantly different from 3.0, indicating that the catch in a 45-min tow was a simple multiple of the catch in a 15-min tow. The difference in the mean catch of brown shrimp caught per sample was apparently due to the large catches in the 38.1-mm (1 1/2-in) trawl. There were no differences in the mean catches between the 44.5-mm (1 3/4-in) trawl and the 47.6-mm (1 9/10-in) trawl.

The mean catch of white shrimp varied with the length of the tow (F_s = 51.202, df = 1,30) but not with the mesh size of the trawl (F_s = 0.729, df = 2,30). Although the interaction term in the analysis of variance was not significant, the mean catch in the 15-min tows for the 44.5-mm (1 3/4-in) and 47.6-mm (1 9/10-in) trawls was less than the mean catch in the 38.1-mm (1 1/2-in trawl, 15.3 ± 2.1 and 13.7 ± 6.7 shrimp respectively. Larger sample sizes might show these to be different from the mean catch of 22.7 ± 5.1 shrimp obtained from the 38.1-mm (1 1/2-in) mesh trawl. The 45-min tows did not show a similar pattern (the largest mean catch obtained was from the 44.5-mm (1 3/4-in) trawl). The mean difference between the number of shrimp caught in a 15-min tow and a 45-min tow was 3.4 ± 0.5. Again, this difference was not significantly different from 3.0 and the catch in a 45-min tow was considered to be a simple multiple of the catch in a 15-min tow.

DISCUSSION

The data in this study indicated that the regulation of mesh sizes used in trawls can be very effective in controlling the number and size of shrimp retained. Berry and Hervey (1964) reported a linear relationship between the length of shrimp retained in a trawl and the mesh size of the trawl. The present study failed to show this relationship for the brown shrimp (mean lengths were the same for all mesh sizes). White shrimp retained in the 38.1-mm (1 1/2-in) trawl were smaller than the shrimp retained in the 44.5-mm (1 3/4-in) and 47.6-mm (1 9/10-in) trawls but there was no difference in the lengths of shrimp retained by the 44.5-mm (1 3/4-in) and 47.6-mm (1 9/10-in) trawls. The reason brown shrimp mean lengths were the same for all three mesh sizes was that all brown shrimp were approximately the same size during the sampling period. The reasons mean lengths of white shrimp were the same for the 44.5-mm (1 3/4-in) and 47.6-mm (1 9/10-in) trawls were most likely that the larger twine size in the 47.6-mm (1 9/10-in) trawl decreased the size of the holes in the nets as well, and the difference between the 38.1-mm (1 1/2-in) stretched mesh and the 44.5-mm (1 3/4-in) stretched mesh was greater than the difference between the 44.5-mm (1 3/4-in) mesh and the 47.6-mm (1 9/10-in) mesh.

Regan et al. (1956) reported increased rates of escapement of pink shrimp as the mesh size was increased from 44.5 to 63.5 mm (1 3/4 to 2 1/2 in). This study also found higher rates of escapement (lower mean catch rates) for small brown shrimp in the 44.5-m (1 3/4-in) and 47.6-mm (1 9/10-in) mesh trawls than for the 38.1-mm (1 1/2-in) mesh trawl. Again, the failure to detect different catch rates for the 44.5-mm (1 3/4-in) and 47.6-mm (1 9/10-in) mesh trawls was due to both the 47.6-mm (1 9/10-in) trawl being made of number 12 twine and the smaller difference between the two mesh sizes. The clogging of a trawl (the process of the catch progressively filling the holes of the trawl) theoretically could cause the trawl to become more efficient the longer it is towed. If this were true, catches in trawls towed for 45 min should be more than three times the catches of trawls towed for 15 min. Although the catches in the 45 min tows of this study averaged 3.4 (white shrimp) to 5.9 (brown shrimp) times greater than catches of trawls towed for 15 min, these means were not significantly greater than 3.0, and it was assumed that the relationship between the catch and the time towed was a simple linear function for time periods and trawls involved. The failure to detect a difference in this study may also be due to the small sample size. The relatively large standard errors indicated that the differences would have to be two to three times greater than occurred to indicate a difference in the sample sizes.

TABLE 1.

Number and mean size (mm) of shrimp caught in each sample by mesh size, tow time and species.

Mesh size (mm)	Tow time (min)	Area sampled	Date sampled	Time sampled	White shrimp Number caught	White shrimp Mean length	Brown shrimp Number caught	Brown shrimp Mean length
38.1	15	A	7	0852	44	115.6	71	87.9
(1 1/2 in)		B	12	1058	27	119.2	38	83.6
		C	8	0937	10	116.3	46	87.3
		D	13	1117	26	126.5	13	81.6
		D	14	0850	14	123.8	40	84.9
		E	11	1000	15	117.0	40	82.4
	45	A	8	1128	25	118.4	13	86.8
		A	13	0908	75	120.2	64	80.1
		B	15	1029	30	121.1	103	86.6
		C	14	1003	37	122.8	146	87.5
		D	7	1047	123	118.5	843	89.0
		D	12	0850	54	122.1	52	82.1
44.5	15	B	12	0958	17	130.3	3	73.0
(1 3/4 in)		C	8	0840	23	128.0	2	72.0
		C	15	1123	13	135.3	4	96.3
		D	14	1055	16	129.4	0	-
		E	7	1154	16	124.7	17	73.0
		E	11	0940	16	128.0	6	92.0
	45	A	11	1025	73	121.1	26	80.5
		A	14	0847	63	125.2	15	83.0
		B	7	0915	93	123.4	122	85.5
		C	12	1120	54	124.4	14	83.2
		D	8	0958	60	124.2	77	88.2
		E	15	0910	19	131.7	34	88.0
47.6	15	A	15	1006	6	122.2	1	83.0
(1 9/10 in)		B	11	1118	20	129.2	8	84.3
		B	14	0921	15	128.4	2	83.0
		C	7	1026	5	110.0	29	84.6
		E	8	1101	20	116.6	4	79.3
		E	13	0844	16	124.2	1	73.0
	45	A	12	1005	59	122.7	35	84.6
		B	8	0842	71	123.7	52	83.5
		C	13	1020	43	125.4	20	84.3
		D	11	0903	68	123.8	40	85.5
		D	12	1222	51	126.1	18	82.4
		E	14	1117	28	128.2	16	77.3

TABLE 2.

Mean length (mm) and standard error for brown shrimp (*Penaeus aztecus*) and white shrimp (*P. setiferus*) by trawl mesh size and tow time.

		Brown shrimp		White shrimp	
Tow time	Trawl mesh size (mm)	Mean length	Standard error	Mean length	Standard error
15 min	38.1 (1 1/2 in)	84.5	± 1.0	118.8	± 2.2
	44.5 (1 3/4 in)	81.0	± 5.4	128.5	± 1.5
	47.6 (1 9/10 in)	81.2	± 1.8	121.7	± 2.9
45 min	38.1 (1 1/2 in)	85.5	± 1.5	120.5	- 0.8
	44.5 (1 3/4 in)	85.2	± 1.3	124.8	± 1.5
	47.6 (1 9/10 in)	83.0	± 1.3	125.0	± 0.7

TABLE 3.

Mean catch (number) and standard error for brown shrimp (*Penaeus aztecus*) and white shrimp (*P. setiferus*) per tow by mesh size and tow time.

		Brown shrimp		White shrimp	
Tow time	Trawl mesh size (mm)	Mean length	Standard error	Mean length	Standard error
15 min	38.1 (1 1/2 in)	41.3	± 7.6	22.7	± 5.1
	44.5 (1 3/4 in)	5.3	± 2.5	15.3	± 2.1
	47.6 (1 9/10 in)	7.8	± 4.5	13.7	± 2.1
45 min	38.1 (1 1/2 in)	186.8	± 131.8	57.4	± 15.1
	44.5 (1 3/4 in)	48.0	± 17.6	60.2	± 9.5
	47.6 (1 9/10 in)	30.0	± 5.8	53.3	± 6.6

Most of the problems associated with the study of mesh selectivity in trawls can be attributed to insufficient knowledge of sizes of organisms available in areas being trawled, the density of organisms in the area, and the many different combinations of ways in which a trawl can be utilized. This study attempted to reduce as many of these variables as possible. An area was selected that historically had two species of shrimp varying greatly in size and having fairly high numbers. Interference in the analysis of comparing mean sizes and mean catches was reduced by designing the sampling schedule so that local differences in shrimp densities and changes in shrimp densities over time were removed or reduced. The conclusions resulting from this study were based on the assumption that if significant differences in shrimp densities or sizes occurred among the five sampling areas, then the approximated Latin Square design (all areas were not equally represented in each cell) removed the effects of these differences from the analyses. The standardized trawling procedure used with this study and the relatively short time period required to complete the study contributed to the reliability of the results. In short, the comparisons involved the variables mesh size, twine size and tow time, not different shrimp densities and sizes among areas or dates.

Similar studies in the future would be enhanced if at least three widely different tow times and three equally spaced but widely different mesh sizes were used. If twine size is to be a variable, each size should be represented in each of the mesh sizes and trawl times. The continued use of a Latin Square design and a short sampling season are desirable.

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EFFICIENCY EVALUATION OF FOUR SHRIMP TRAWLS IN TERMS OF CATCH RATE AND SPECIES COMPOSITION

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ABSTRACT The efficiency for four shrimp trawl sizes using different fishing configurations was evaluated for total catch, total finfish and crustaceans, and Atlantic croaker weight and number. Paired and unpaired trawls were analyzed by multivariate analysis for paired data and unbalanced four-way analysis of variance for unpaired data. A modified Friedman's test was used to rank species composition by weight for randomized block design. No statistically significant differences were found among catch rates for unpaired data in terms of vessel speed, towing duration, day/night, or length of leglines. Significant differences in catch rates for paired data were found when analyzed by net size, door size, and length of towing warp. No significant differences were noted when analyzing ranked species composition, and all gear configurations appeared to fish similarly.

INTRODUCTION

When studying biological and population aspects of a given stock, fishery biologists must be concerned not only with the total catch but also with its component parts. The catch must be analyzed in terms of its significance to the total population being sampled, and fishing gear, in terms of species selectivity. Fishing gear selectivity is revealed by changes in the species and size composition of catches. It is therefore essential to define trawl characteristics and fishing gear requirements which best satisfy research objectives and reflect true stock size and composition.

Prior to initiating groundfish assessment activities in the north central Gulf of Mexico, it was necessary to define a standard sampling trawl. In addition to trawl specifications, indices of catch variability for population components, through comparative fishing, were required. Comparative fishing for the present study was defined as either simultaneously towed trawls or single trawls towed within a small unit area. Variation in captured organisms' weight and number between similar and dissimilar trawl types is important in computing confidence intervals on estimates of actual stock size. Comparative fishing experiments provide measurements between gear types, fishing times, catch composition, and inter- and intra-net variation. Interpretation of this information provides knowledge for the selection of a standard sampling trawl and survey design, and must include both biological characteristics of the species which comprise the exploited population, and the technical properties of the trawling gear.

This paper presents data obtained on four resource survey cruises in 1972 (NMFS-SEFC Cruises 36, 40, and 42) and 1975 (Cruise 57) of the NOAA Ship OREGON II; to define and refine standard sampling gear and survey design. Findings from data obtained on cruises 36, 40, and 42 were presented at the 1983 SEAMAP Trawling Gear Calibration Workshop; results of subsequent analysis of cruise 57 data have been added to provide further insight.

MATERIALS AND METHODS

Data from the four cruises conducted by the Mississippi Laboratories' Pascagoula Facility, were grouped into two categories according to differences in sampling technique. Data from cruises 36, 40, and 42 were combined because sampling included only paired tows, whereas cruise 57 data were analyzed separately because all tows were unpaired.

Although different net and door size combinations were used (Tables 1 and 2), there were similarities in gear construction. Doors were of wood, in two sizes, 8 ft x 40 in (2.5 x 1.0 m) and 10 ft x 4 1/3 in (3.1 x 1.1 m), with chain bridles; the 8-ft x 40-in (2.5 x 1.0-m) doors were heavier than those used in the commercial shrimp and bottomfish fisheries because of the high number of tows to which they would be subjected and the towing vessel's weight and power. Nets (40 ft, or 12.3 m; 55 ft, or 16.9 m; 70 ft, or 21.5 m; and 82 ft, or 25.2 m) semiballoon shrimp trawls were equipped with a tickler chain, mud rollers on the footrope and three sponge floats on the headrope. Doors and nets were built by one

TABLE 1.

Trawl combinations used during NOAA Ship OREGON II cruises 36, 40 and 42. Tow duration: 10-20 min. Differences in catch rates were based on trawl A minus trawl B.

	A		B			
Trawl combination	Trawl net (semi-balloon)	Door size	Trawl net (semi-balloon)	Door size	Replications	Warp length
1	40 ft	8' x 40"	40 ft	8' x 40"	31	Equal
2	40 ft	8' x 40"	40 ft	8' x 40"	24	Unequal
3	40 ft	10' x 40"	40 ft	8' x 40"	63	Equal
4	55 ft	8' x 40"	40 ft	8' x 40"	18	Equal
5	55 ft	8' x 40"	40 ft	8' x 40"	10	Unequal
6	55 ft	10' x 44"	40 ft	8' x 40"	86	Equal
7	40 ft	8' x 40"	70 ft	10' x 40"	10	Unequal
8	55 ft	8' x 40"	55 ft	8' x 40"	27	Unequal
9	55 ft	8' x 40"	70 ft	10' x 44"	10	Unequal
10	70 ft	10' x 44"	70 ft	10' x 44"	10	Unequal

40 ft = 12.3 m
55 ft = 16.9 m
70 ft = 21.5 m

manufacturer to reduce construction variations, and were made with similar twine (#18 in the body, #42 in the bag) and mesh sizes (stretch mesh of 1 1/4 in [31 mm] in the body, 1 in [25 mm] in the bag). Trawls were towed with a 40-fm (74-m) towing bridle attached to the main towing warp.

Catch processing was also similar for all cruises. Catches weighing less than 22.7 kg (50 lb) were processed in their entirety, while larger catches were subsampled at approximately 10% of the total catch weight, except for exceptionally large catches where time constraints required taking proportionally smaller samples. Samples were sorted by species and counted, weighed and recorded on data forms. Additional recorded data included position, depth, gear size, minutes fished, time of day, towing speed and duration, and total catch weight. Total catch weights were calculated on the ratio of total catch weight to sample weight.

Although cruise objectives for the four cruises were similar, there were differences in sampling design and methods. Ten unique gear combinations were used during cruises 36, 40, and 42 (Table 1), occupying a total of 289 stations. Cruise 36 was designed to evaluate the performance of three net and two door sizes, as well as a proposed sampling scheme for a resource assessment program. Trawling occurred during 10 days in April 1972 within a 10-square-mile area south of Pascagoula, Mississippi, at depths of 18-20 fm (33-37 m) on grounds exploited by the industrial bottomfish fleet. Sampling was conducted continually throughout the cruise. The study area was subdivided into 26 randomly-selected two-square-mile sample plots. A minimum of five double-rigged replications were attempted for each gear combination. All tows were made along depth contours in a westerly direction, to insure that only one depth per tow was sampled. Initial tows were 30 min, but large catches necessitated reducing towing time to 20 min to facilitate catch processing. Warp length was either 80 or 90 fm (148 or 166 m) to reduce entanglement between the inboard doors.

Cruises 40 and 42 were conducted in September and November 1972, respectively. Tows were paired during both cruises as time permitted, to further evaluate the designated sampling trawl. Sampling occurred between 88° and 92° W. Long., at depths of 9-90 m (5-50 fm) and all tows were 10 min.

During cruise 57 (April 1975), 16 gear combinations were tested and 293 stations occupied (Table 2). The study area consisted of six adjacent 25-square-mile blocks south of Pascagoula, at depths of 16-20 fm (30-37 m). The three smaller nets were towed at 2.0, 2.5 and 3.0 kn respec-

TABLE 2.

Trawl combinations used during NOAA Ship OREGON II cruise 57.
All tows 10-min duration.

Gear code	Trawl net (semiballoon)	Door size	Towing speed (kn)	Legline length (ft)	Replications
1	40 ft	8' x 40"	2.0	-	20
2	40 ft	8' x 40"	2.5	-	20
3	40 ft	8' x 40"	3.0	-	20
4	55 ft	10' x 44"	2.0	-	20
5	55 ft	10' x 44"	2.5	-	20
6	55 ft	10' x 44"	3.0	-	20
7	70 ft	10' x 44"	2.0	-	20
8	70 ft	10' x 44"	2.5	-	20
9	70 ft	10' x 44"	3.0	-	20
10	82 ft	10' x 44"	2.0	30	10
11	82 ft	10' x 44"	2.5	30	15
12	82 ft	10' x 44"	3.0	30	15
13	82 ft	10' x 44"	3.5	30	15
14	82 ft	10' x 44"	2.5	12	26
15	82 ft	10' x 44"	3.0	12	17
16	82 ft	10' x 44"	3.5	12	15

40 ft = 12.3 m
55 ft = 16.9 m
70 ft = 21.5 m
82 ft = 25.2 m

tively, and the 82-ft (25.2-in) net at 3.5 kn, for evaluation of gear performance relative to towing speed. The 82-ft (25.2-m) net was also fished with 12- and 30-ft (3.7- and 9.2-m) leglines to determine their effect on gear performance.

Catches were standardized in kg/hr per foot of headrope length through multiplying the catch (in kg) by sixty, divided by minutes fished; the product of this sum was then divided by headrope length. Multivariate and univariate paired $\underline{t}$ tests, and corresponding adjusted $\underline{F}$ tests, were performed on data from cruises 36, 40, and 42; an unbalanced four-way analysis of variance (using an underlying model with and without all possible interaction effects of the four main factors) was performed on data from cruise 57.

The multivariate paired $\underline{t}$ tests were performed to compare the mean vectors (with 11 considered variables) for trawl sets A and B (Table 1) after the null hypothesis:

$$\mu\begin{bmatrix} \underline{A} & & \underline{B} \\ tc & - & tc \\ tf & - & tf \\ tcr & - & tcr \\ acn & - & acn \\ acw & - & acw \\ sn & - & sn \\ sw & - & sw \\ ssn & - & ssn \\ ssw & - & ssw \\ lpn & - & lpn \\ lpw & - & lpw \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

where

μ = population mean
tc = total catch
tf = total finfish
tcr = total crustaceans
acn = number of Atlantic croaker
awn = weight of Atlantic croaker
sn = number of spot
sw = weight of spot
ssn = number of silver seatrout
ssw = weight of silver seatrout
lpn = number of longspine porgy
lpw = weight of longspine porgy.

For each gear code with a sufficiently large sample size (n = 11), the resulting multivariate $\underline{F}$ statistic and corresponding $\underline{P}$ value were computed. Nonrejection of the above hypothesis provided lack of evidence to conclude any differences among the means of the 11 considered variables of trawls A and B. Rejection of the hypothesis implied the existence of some mean difference, therefore each variable was analyzed separately for significant differences. At this stage, two different techniques were used to analyze each of the variables: (1) the univariate paired $\underline{t}$ test, which is somewhat liberal in guarding the level of significance (Morrison 1976); and (2) adjusted $\underline{F}$ tests, somewhat conservative in guarding the level of significance (Morrison 1976).

The unbalanced four-way analysis of variance for cruise 57 data was performed to analyze the impact of various levels of main factors (net size, speed, day versus night, and legline length) on the response variables (total catch, total finfish, total crustaceans, total other organisms, and Atlantic croaker weight and number). The analysis was performed with the Statistical Analysis System (SAS) package. The underlying model without interaction effects is

$$Y_{ijklm} = \mu + \alpha_i + \beta_j + \gamma_k + \delta_l + \epsilon_{ijklm}$$

where: Y_{ijklm} = m^{th} response on the considered variable under the i^{th} level of net size, j^{th} level of speed, k^{th} level of day or night, and the l^{th} level of legline length

α_i = i^{th} level of net size, i = 1, 2, 3, 4 (40, 55, 70, 82)

β_j = j^{th} level of speed, j = 1, 2, 3, 4 (2.0, 2.5, 3.0, 3.5)

γ_k = k^{th} level of day or night, k = 0, 1 (day, night)

δ_l = l^{th} level of legline length, l = 1, 2, 3 (0, 12, 30)

ϵ_{ijklm} = random error associated with the m^{th} response under the (i, j, k, l)th combination of the main factors

m = 1, 2, . . ., n_{ijkl}, where

n_{ijkl} = number of measurements taken under (i, j, k, l)th combination.

Analysis was also performed with a more complicated model which included all possible interaction effects of the four main factors. Theoretical aspects of these analyses used linear models (Graybill 1976, Searle 1971).

Friedman's test was utilized for significant differences in the distribution of rank for the seven major species caught by the various gear combinations or codes tested (Tables 1 and 2). Species composition data from cruise 57 were ranked by magnitude of catches under each gear code. These data were then ranked within species and the totals of each gear code computed and tested for significant differences. Friedman's test is a nonparametric test dealing with rank, hence is less powerful than the corresponding parametric test, and could overlook some significant categories (Conover 1980).

RESULTS

Trawl data are inherently highly variable and show considerable variation among catch rates, ranging from numerous low to a few high catches. Data evaluation for NOAA Ship OREGON II cruises 36, 40, and 42 will be discussed separately from those of cruise 57 because of the different analytical techniques used.

Results of paired trawl data (cruises 36, 40, 42) using multivariate analysis for the 10 trawl combinations are listed on Table 3. If multivariate analysis indicated statistically significant differences, two different methods were then used to test each variable separately for significant difference.

No consistent pattern was evident in the paired data. Catch rates between similar 40-ft (12.3-m), 55-ft (16.9-m), and 70-ft (21.5-m) trawls towed simultaneously showed no difference between nets. On 6 of the 10 trawl combination sets, one trawl was towed with a warp 10 fm (18.5 m) longer than the other trawl. In all instances, the trawl with the longer warp had the largest catch, although this increased catch rate was not always statistically significant. When considering net size as a single effect, some significant differences between trawls were observed (Figure 1). Catch rates of both the 40-ft (12.3-m) and 70-ft (21.5-m) trawls with 10-ft x 44-in (3.1 x 1.1-m) doors were statistically different from other trawl combinations. The 40-ft (12.3-m) trawl had a lower catch rate because the oversized doors caused the net to overspread and tend bottom lightly. Conversely, the 70-ft (21.5-m) trawl had the highest catch rate, also significantly different from other trawls tested. Larger trawls open higher vertically and tend to catch greater amounts of "off-bottom" species, accounting in part for the higher mean catch rate. The 70-ft (21.5-m) trawl data also showed fewer small catches (25%) than the other trawl combinations (50%), which increased its overall mean catch rate.

Analysis of paired trawl data from cruises 36, 40, and 42 showed significant differences among most gear combinations in terms of total catch and total finfish. However, fewer significant differences were noted between species numbers and weight among the various gear combinations tested (Table 3). In two instances (gear codes 3 and 5 on Table 3), the differences resulted from the 40-ft (12.3-m) trawl with 8-ft x 40-in (2.5 x 1.0-m) doors outfishing its paired trawl. Larger trawls outfished smaller trawls in four instances (gear codes 4, 6, 7 and 9 on Table 3); interactions between warp length must be considered in several of these cases, as warp length affects catch rates.

A total of 154 units on gear combinations and variables tested, including tests within categories, showed only 35 (23%) with significant differences. Warp length differences were associated with 21 (60%) of the total significant differences observed. One trawl combination consisted of a 40-ft (12.3-m) trawl with oversized, 10-ft x 44-in (3.1 x 1.1-m) doors towed against a standard trawl, with 8-ft x 40-in (2.5 x 1.0-m) doors; this paired combination had seven significantly different catch rates. When the effects of warp length and oversized doors were combined, 28 significant differences were noted, accounting for 80% of the 35 significant differences. Small sample sizes undoubtedly account for some nonsignificant differences observed in the paired trawl data. Eleven of the significant differences noted were attributed to the standard 40-ft (12.3-m) trawl with 8-ft x 40-in (2.5 x 1.0-m) doors outfishing its paired trawl.

Analysis of data collected during cruise 57 was performed on six variables, including total catch, total finfish, total crustaceans, total other organisms, and weight and number of Atlantic croaker. Computed ANOVA results are listed on Tables 4-7, except for total catch and total other organisms, which are not listed because total catch and total finfish are mirror images of one another, and total other organisms showed no significant differences between any of the variables tested. This absence of significant differences is attributed to the large number of "zero" responses (i.e., few organisms listed in the "other" category were caught).

In testing the impact of the main factors on response variables, a highly significant difference was found between net size and towing speed. There were no significant differences between length of leglines for any tested response variable and none for day versus night trawling, except in the total crustaceans category (Tables 4-7). A major portion of the crustaceans caught consisted of brown shrimp, which burrow during daylight hours and emerge at night; the high level of significance between day and night total crustacean catches is thus not surprising.

Catch rates by net size for total finfish and total catch showed similar patterns with respect to mean catch rates and their associated 95% confidence intervals. The pattern of total finfish catch between trawl sizes is shown on Figure 2, and reflects the heavy contribution of finfish to the total catch (Table 8). It can be readily seen that the 40-ft (12.3-m), 55-ft (16.9-m) and 82-ft (25.2-m) trawls were practically indistinguishable in terms of total finfish, and the 70-ft (21.5-m) trawl had a sigificantly lower catch rate (Figure 2).

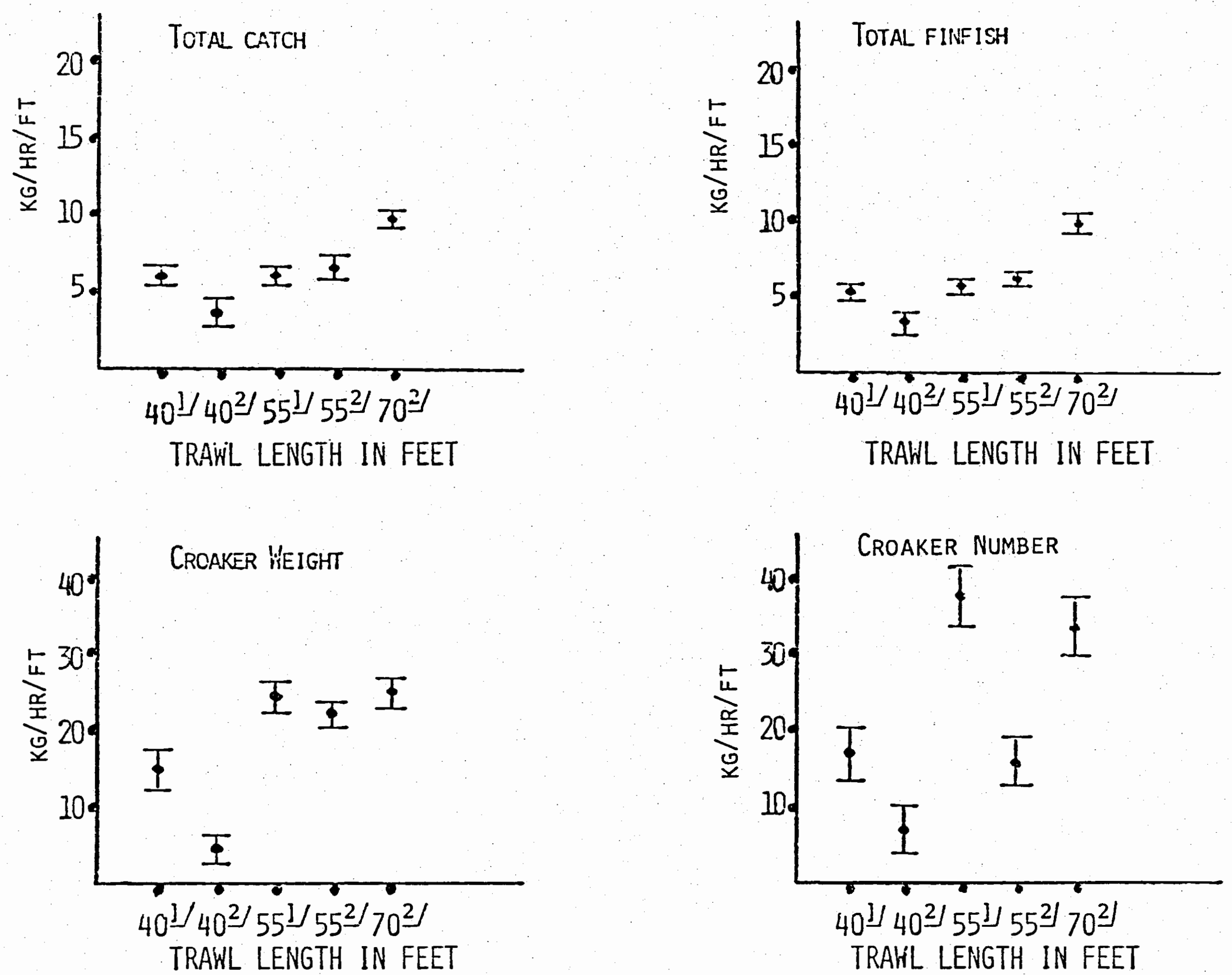
Results of analyzing trawling speed for total finfish, crustaceans, and number of Atlantic croaker are shown in Figures 3-5. Weight of Atlantic croaker was not analyzed as this species accounted for about 78% of the total finfish weight (Table 8), and it showed patterns similar to those seen for finfish and croaker numbers (Figures 3 and 5). Significant differences were noted only at a speed of 3.0 kn, in conjunction with the 70-ft (21.5-m) trawl. These differences were apparently associated with trawl size rather than speed; when speed was analyzed against all tested variables, catch rates were no longer significant. In addition to differences observed at 3.0 kn, the 82-ft (25.2-m) and 70-ft (21.5-m) trawls were significantly different for total finfish and croaker number at 2.5 kn. At 2.0 kn, the only significant difference between trawls was for catch rates of crustaceans, where the 40-ft (12.3-m) trawl and heavy doors appeared to fish the bottom very hard and resulted in an increased catch of crustaceans. Day/night results are shown in Figure 6, although no significant differences were noted among the trawls. The 70-ft (21.5-m) trawl displayed the greatest divergence in catch rates and showed significant differences within daytime trawls.

TABLE 3.

Summary of results (obtained by multivariate techniques) on the 11 considered variables and various trawl combinations fished during NOAA Ship OREGON II cruises 36, 40 and 42.

Trawl combinations	Statistical test		Total catch (weight)	Total finfish (weight)	Total crustaceans (weight)	Atlantic croaker (number)	Atlantic croaker (weight)	Spot (number)	Spot (weight)	Silver seatrout (number)	Silver seatrout (weight)	Longspine porgy (number)	Longspine porgy (weight)
			Variables tested for significant differences										
1	MT		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
2	MT	F	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS
		UT_2	*	*	*	*	*	*	*	*	*	NS	NS
3	MT	F	*	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
		UT_2	*	*	*	NS	NS	NS	NS	NS	NS	*	*
4	MT	F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
		UT_2	*	*	*	NS	NS	NS	NS	NS	NS	NS	NS
5	UT_1		*	*	NS	*	*	NS	NS	NS	NS	NS	NS
6	MT	F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
		UT_2	*	*	NS	*	*	NS	NS	NS	NS	NS	NS
7	UT_1		*	*	NS	NS	NS	NS	NS	*	*	NS	NS
8	MT		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
9	UT_1		*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS
10	UT_1		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

MT = Multivariate paired *t*-test.
F = Adjusted *F*-test to determine level of significance when multivariate test indicated significant difference.
UT 1 or 2 = Univariate paired *t*-test when sample size was 10 or less (T_1); or to determine level of significance when multivariate test indicated significant difference (T_2).
NS = No significant difference (at 0.05 level) between the variable means for trawls A and B.
* = Significant difference.



1/ Door size = 8-ft x 40-in wooden doors
2/ Door size = 10-ft x 44-in wooden doors

Figure 1. Mean values and associated confidence intervals (95%) for total catch, total finfish, croaker weight, and croaker number in kg/hr/ft of headrope or number/hr/ft of headrope for data obtained during NOAA Ship OREGON II cruises 36, 40, and 42.

TABLE 4.

Results of four-way ANOVA for unbalanced data for total finfish, NOAA Ship OREGON II, Cruise 57.

Source of variation	df	Sum of squares	Mean square	F	P
Main factor					
Net size	2	1548.004	-	15.48	0.0001
Speed	3	647.227	-	4.31	0.0056
Day/night	1	61.370	-	1.23	0.2689
Legline length	1	3.813	-	0.08	0.7826
Explained error	8	2844.738	355.592	7.11	0.0001
Residual error	284	14200.715	50.002		
Total	292	17045.453	-		

TABLE 5.

Results of four-way ANOVA for unbalanced data for total crustaceans, NOAA Ship OREGON II, Cruise 57.

Source of variation	df	Sum of squares	Mean square	F	P
Main factor					
Net size	2	0.211	-	21.88	0.0001
Speed	3	0.038	-	2.65	0.0482
Day/night	1	0.106	-	22.05	0.0001
Legline length	1	0.000	-	0.00	0.9584
Explained error	8	0.477	0.060	12.36	0.0001
Residual error	284	1.369	0.005		
Total	292	1.846			

TABLE 6.

Results of four-way ANOVA for unbalanced data for total weight of Atlantic croaker, NOAA Ship OREGON II, Cruise 57.

Source of variation	df	Sum of squares	Mean square	F	P
Main factor					
Net size	2	1101.062	-	12.71	0.0001
Speed	3	981.026	-	7.55	0.0001
Day/night	1	95.682	-	2.21	0.1383
Legline length	1	9.554	-	0.22	0.6390
Explained error	8	2949.907	368.738	8.51	0.0001
Residual error	284	12302.015	43.317		
Total	292	15251.922	-		

TABLE 7.

Results of four-way ANOVA for unbalanced data for number of Atlantic croaker, NOAA Ship OREGON II, Cruise 57.

Source of variation	df	Sum of squares	Mean square	F	P
Main factor					
Net size	2	138916.460	-	11.65	0.0001
Speed	3	111970.954	-	6.26	0.0005
Day/night	1	14467.243	-	2.43	0.1204
Legline length	1	2665.128	-	0.45	0.5043
Explained error	8	359916.577	44989.572	7.55	0.0001
Residual error	284	1693313.715	5962.37		
Total	292	2053230.292	-		

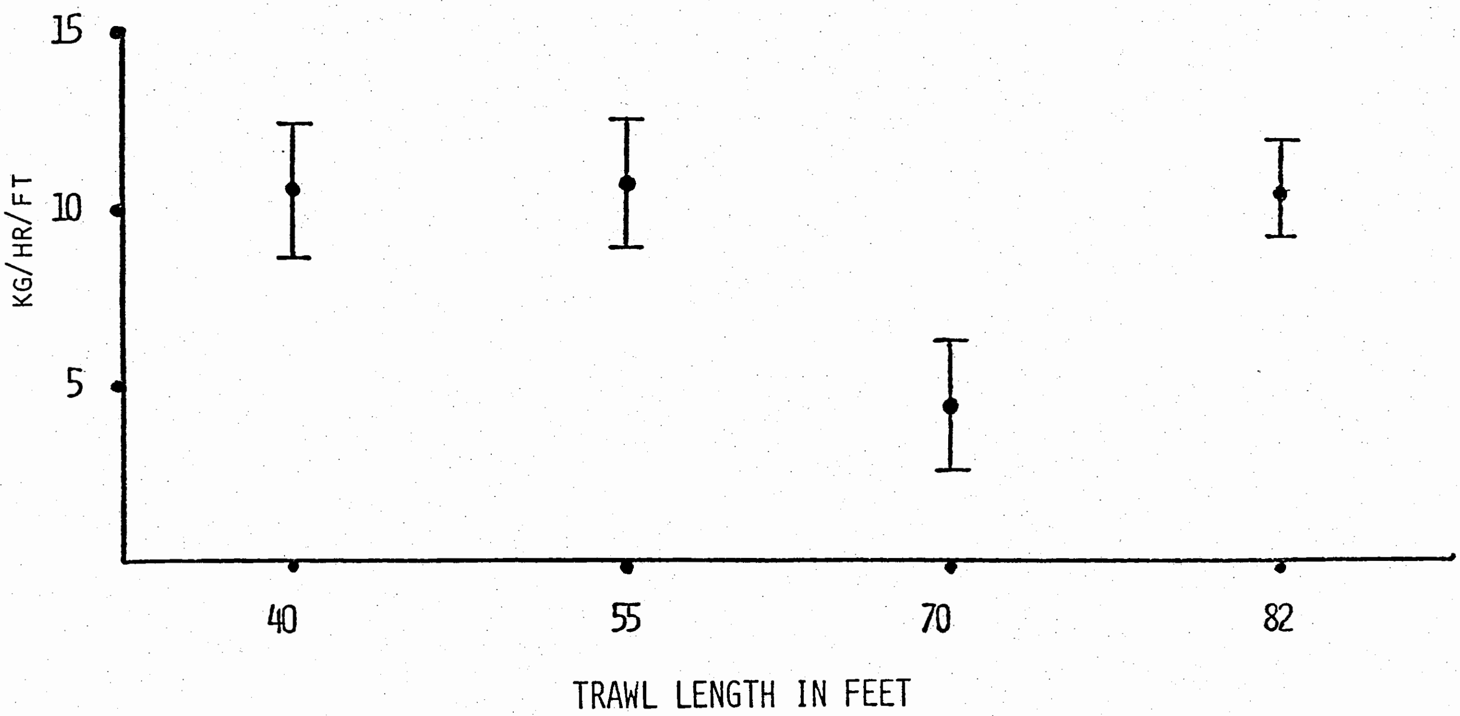


Figure 2. Mean value and associated confidence interval (95%) for total finfish in kg/hr/ft of headrope for NOAA Ship OREGON II Cruise 57.

TABLE 8.

Percent composition of major faunal components for all data combined, NOAA Ship OREGON II, cruises 36, 40, 42, and 57.

	Percent of total catch	
	Cruises 36, 40 and 42	Cruise 57
Total finfish	93.3	99.8
Total crustaceans	3.2	0.2
Other invertebrates	3.5	0.0
	100.0	100.0
Species Composition:		
Atlantic croaker	29.1	77.8
Spot	10.4	2.8
Longspine porgy	9.3	0.7
Silver seatrout	8.3	0.9
Gulf butterfish	4.9	3.6
Hardhead catfish	3.0	0.1
Atlantic cutlassfish	1.9	4.3
Sand seatrout	1.7	4.4
	68.6	94.6
Northern brown shrimp	1.0	0.0
Northern white shrimp	.1	0.0
	1.1	0.0
Combined other organisms	30.8	5.4

Species composition was analyzed to evaluate fishing characteristics and species availability. Species were ranked by weight for dominance in the catch and Friedman's rank test was performed on the various combinations of net size, vessel speed, and length of leglines.

Finfish represented between 93.3% (cruises 36, 40 and 42) and 98.8% (cruise 57) of the total catch, of which eight species accounted for 68.6 (cruises 36, 40, 42) and 94.6% (cruise 57). Shrimp accounted for 1.1% of the total catch (cruises 36, 40, and 42) (Table 8). Species composition, expressed as percent of total catch on cruise 36 (Figures 7-14) remained reasonably similar except for the 40-ft (12.3-m) versus the 70-ft (21.5-m) trawl (Figure 9) and the 55-ft (16.9-m) versus the 70-ft (21.5-m) trawl (Figure 11). Friedman's test was performed on species composition for the respective paired trawl combinations (cruises 36, 40, and 42) and on the unpaired trawl data (cruise 57). No significant differences were found between any tested rankings. Minor positional differences were noted for some species but none were of a magnitude determined statistically significant. Although the two data sets sampled different populations of groundfish with species ranking quite differently, no significant differences were found among gear configurations tested within each data set.

No significant differences were detected among any of the 10 gear combinations evaluated for cruises 36, 40, and 42 or any of the 16 combinations evaluated for cruise 57. Statistically, each net fished the population proportionately, with each net exhibiting similar fishing characteristics. No further discussion will be presented concerning the effects of day versus night or length of leglines on catches, as these factors showed no significant differences within any of the variables tested.

DISCUSSION

A fundamental problem associated with the determination of differences in mean catch rates of different trawls is an inadequate understanding of (a) the distributional patterns of species sampled, and (b) sampling variation. In this study, finfish and crustaceans were distributed in a patchy rather than random distribution through-

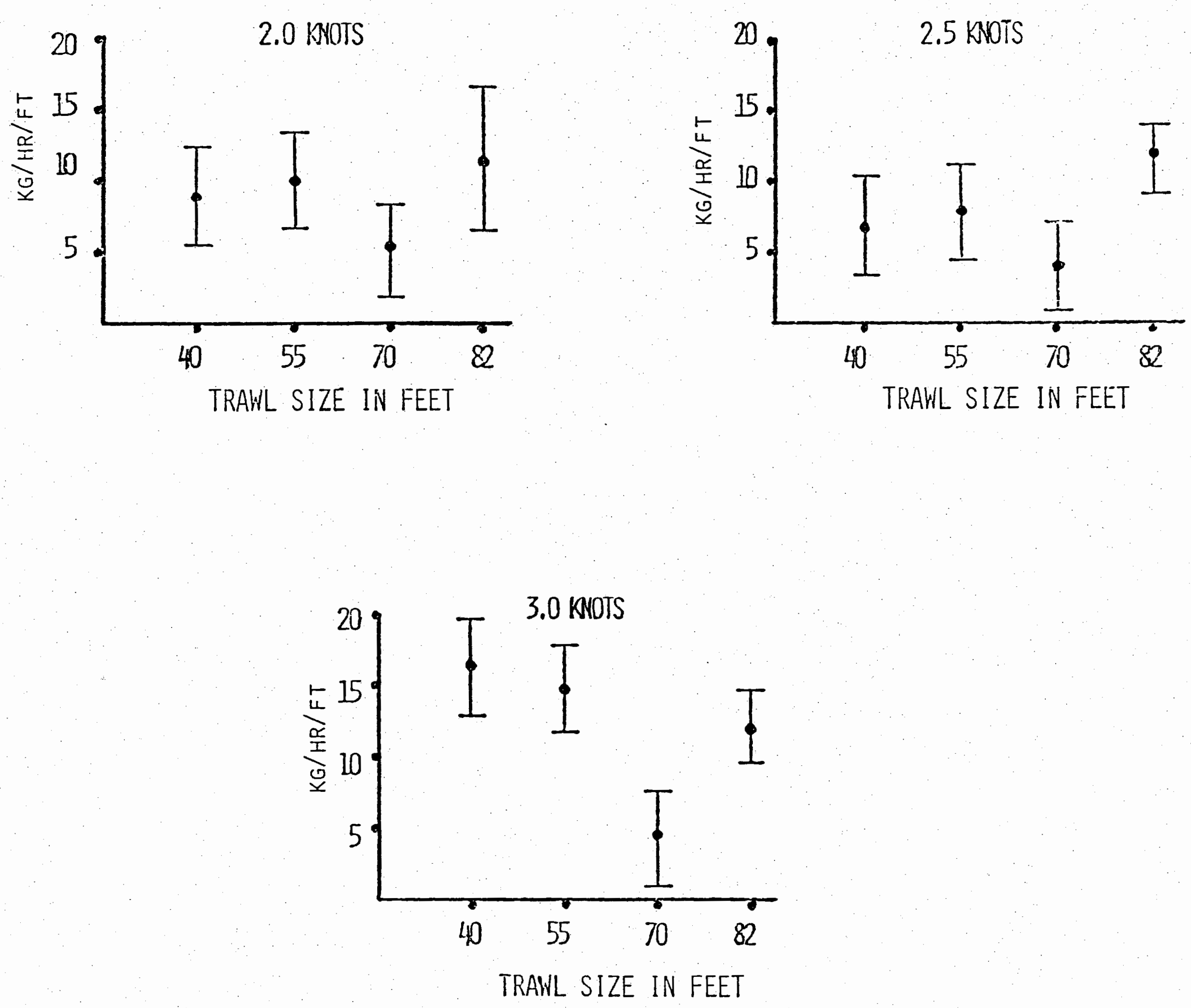


Figure 3. Mean values and associated confidence interval (95%) for total finfish at 2, 2.5, and 3 knots from NOAA Ship OREGON II Cruise 57. Values are expressed as kg/hr/ft of headrope length.

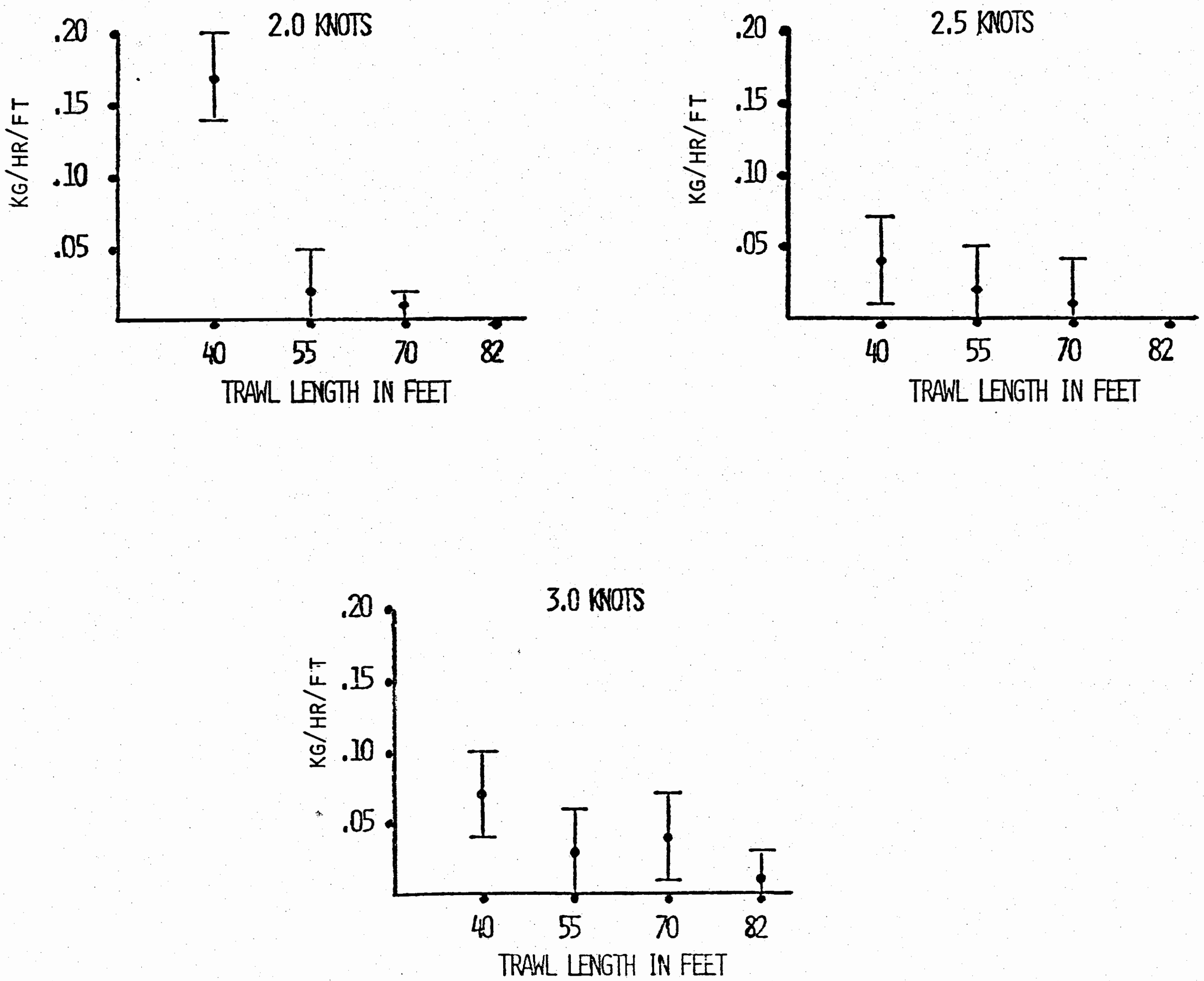


Figure 4. Mean values and associated confidence interval (95%) for total finfish at 2, 2.5, and 3 knots from NOAA Ship OREGON II Cruise 57. Values are expressed as kg/hr/ft of headrope and length.

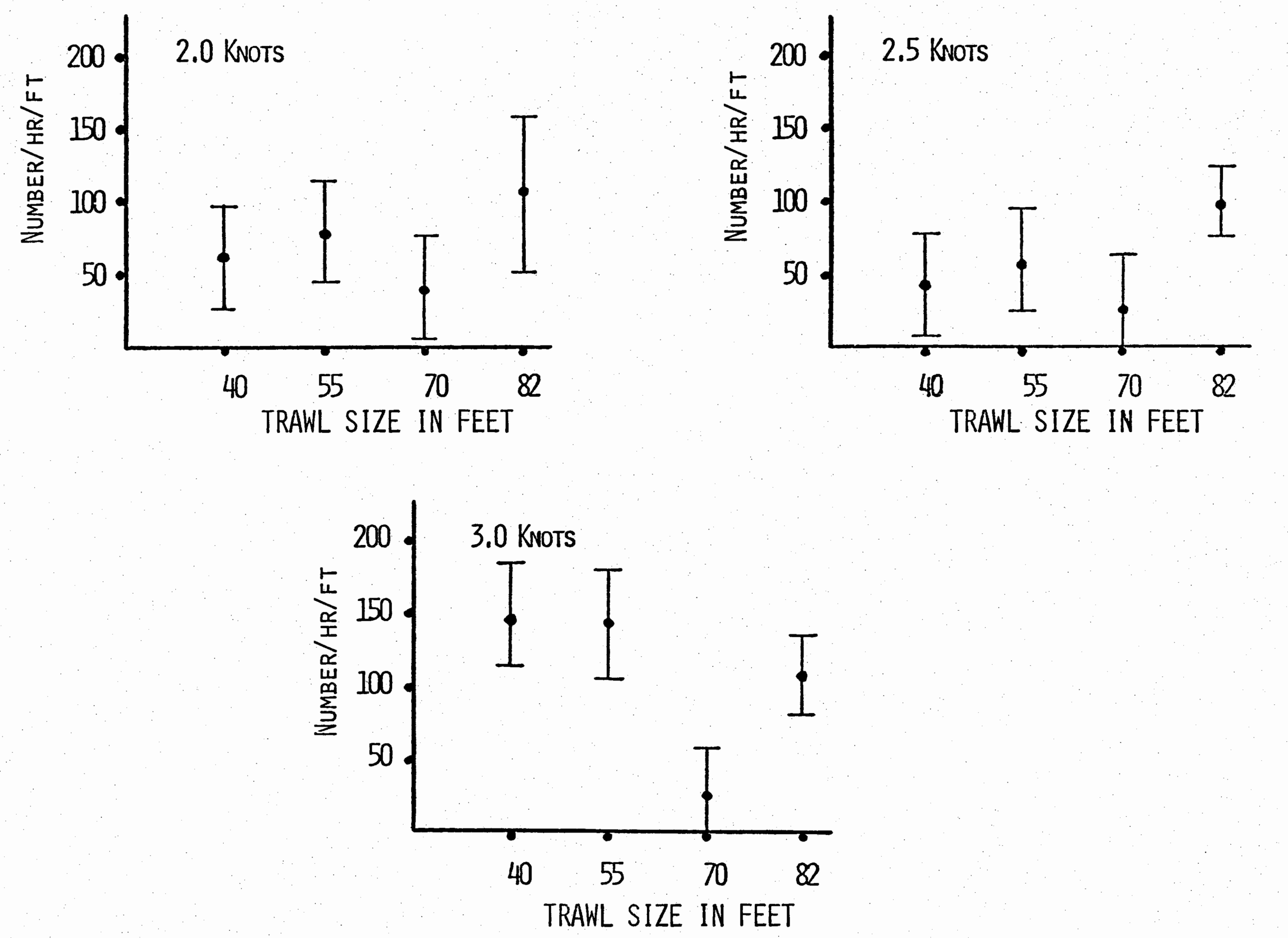


Figure 5. Mean values and associated confidence intervals (95%) for number of Atlantic croaker at 2, 2.5, 3.0 knots from NOAA Ship OREGON II Cruise 57. Values are expressed as number/hr/ft of headrope length.

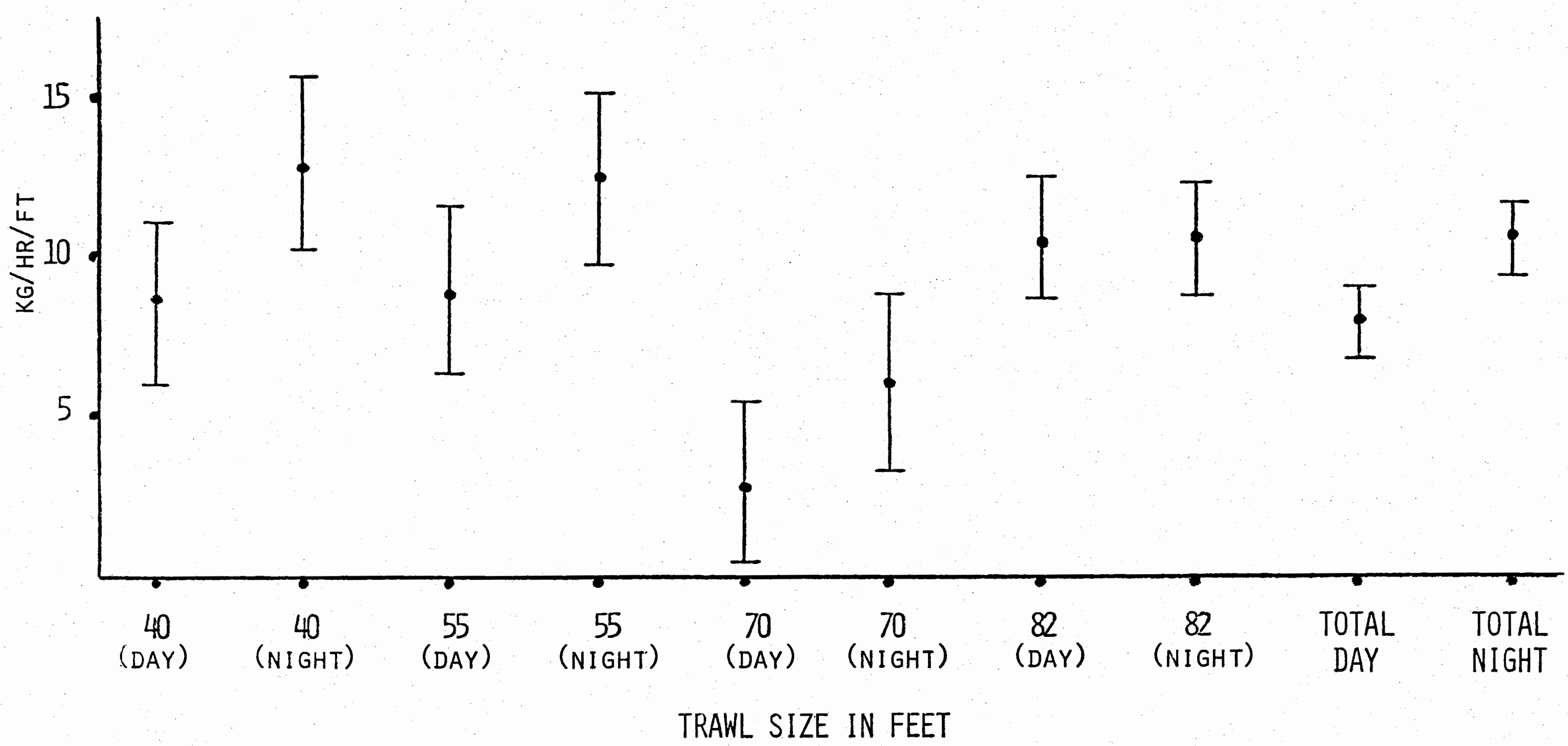


Figure 6. Mean values and associated confidence intervals (95%) for day-night differences between the four trawl sizes and all data combined from NOAA Ship OREGON II Cruise 57. Values are expressed as kg/hr/ft of headrope length.

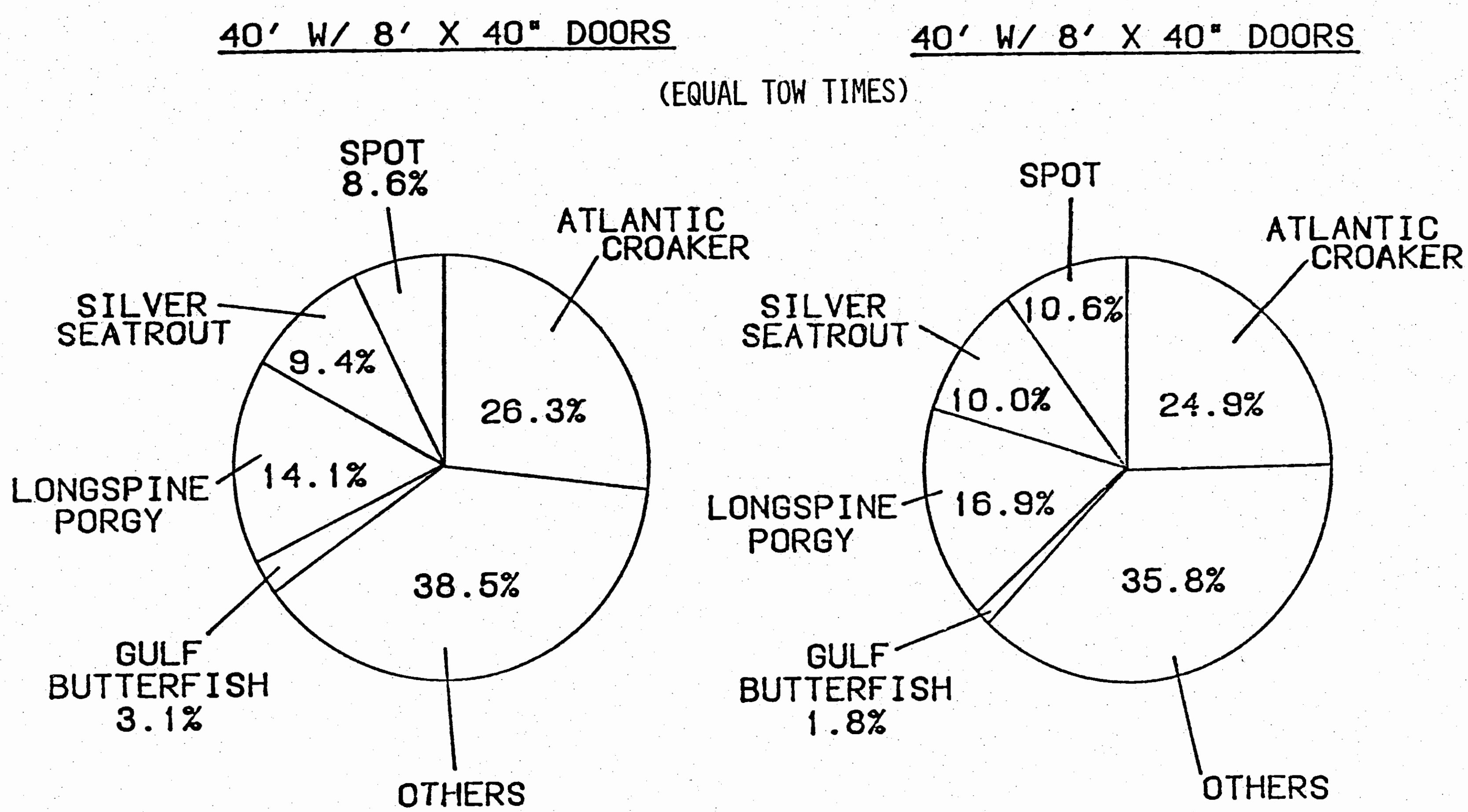


Figure 7. Catch composition of five major fish species expressed as percent (weights) of the total catch for paired comparisons between two 40'-trawls with 8' x 40" doors.

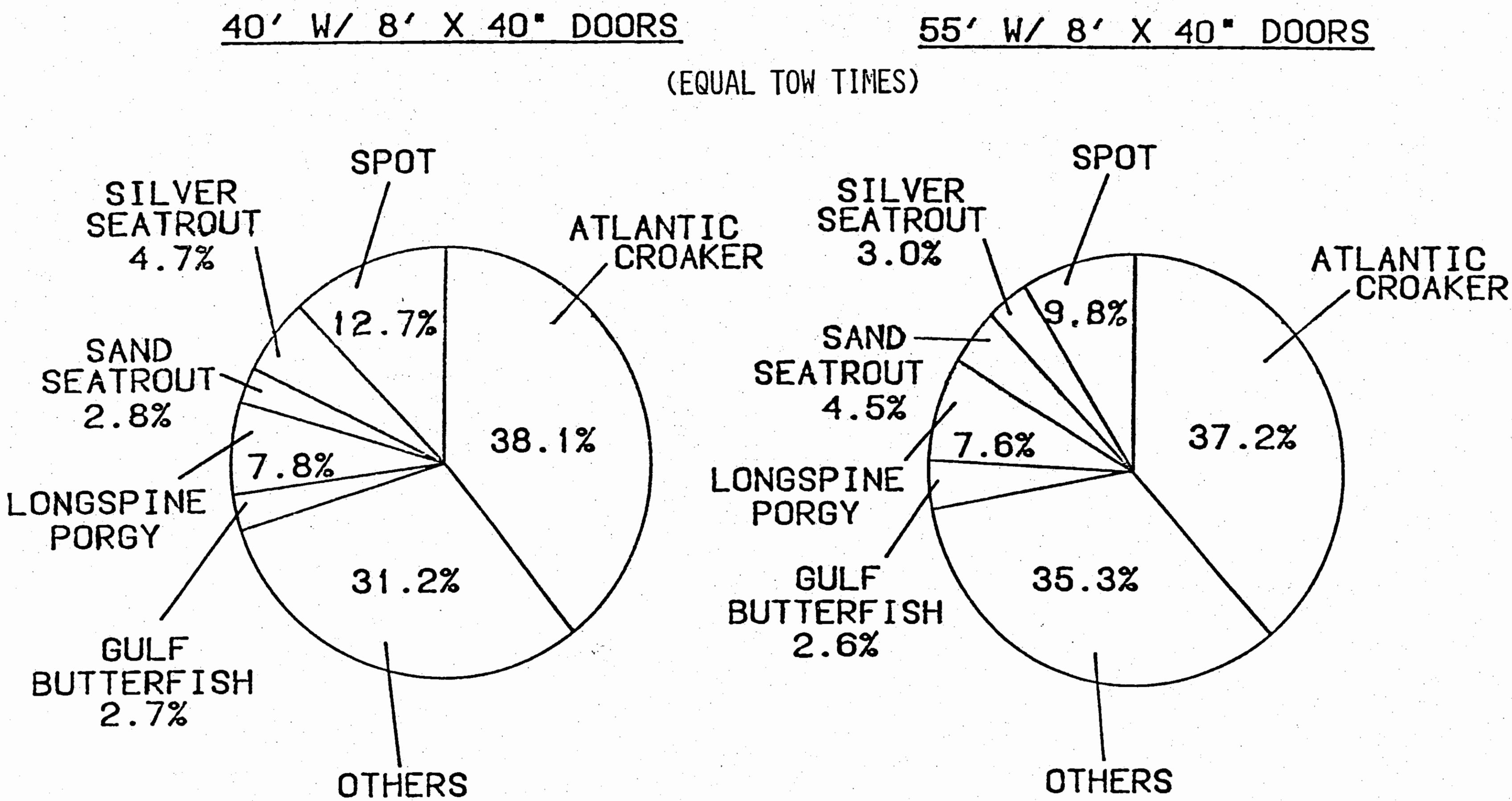


Figure 8. Catch composition of six major fish species expressed as percent (weight) of the total catch for paired comparisons between a 40'-trawl with 8' x 40" doors and a 55'-trawl with 8' x 40" doors.

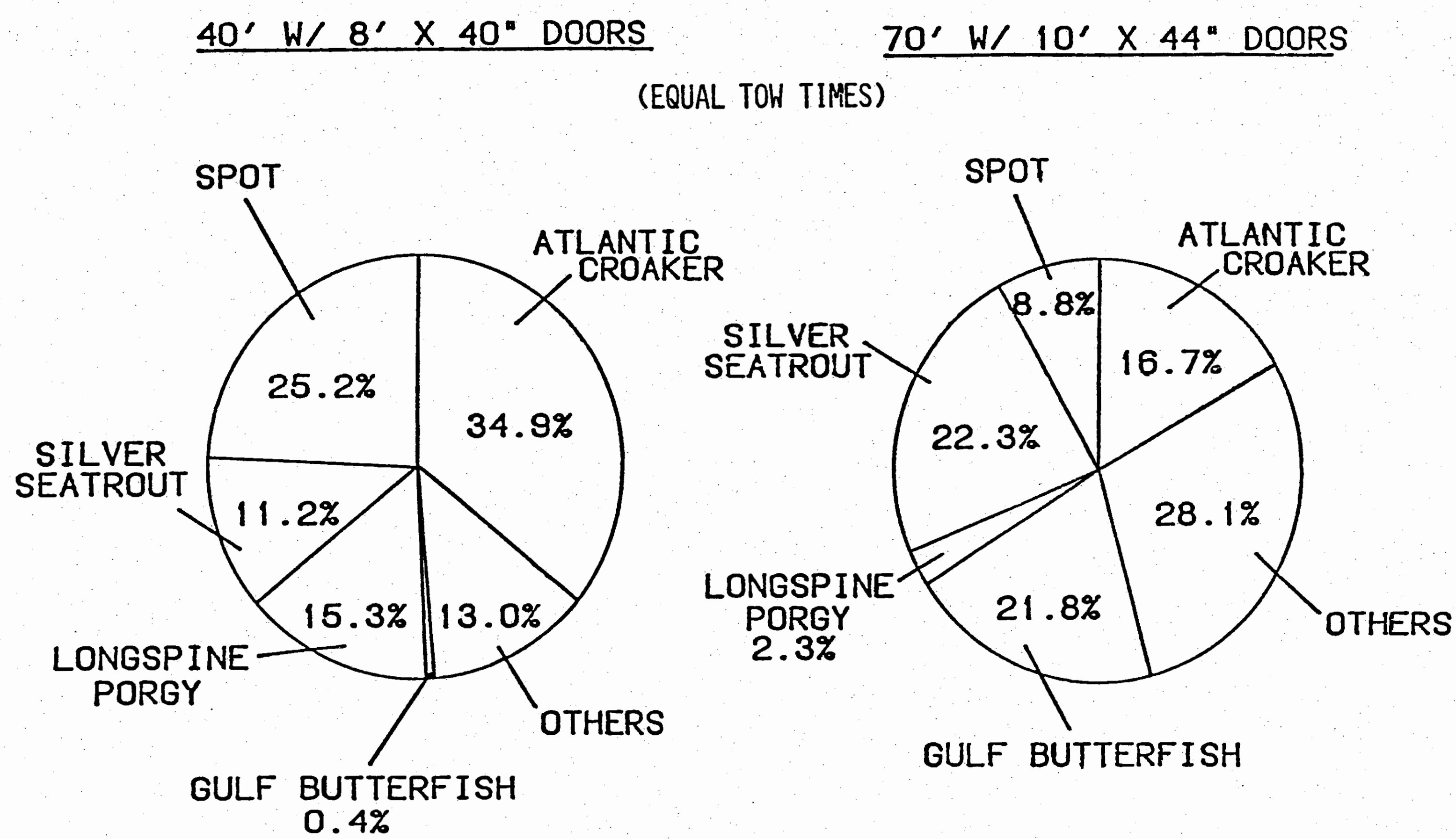


Figure 9. Catch composition of five major fish species expressed as percent (weight) of the total catch for paired comparisons between a 40'-trawl with 8' x 40" doors and a 70'-trawl with 10' x 44" doors.

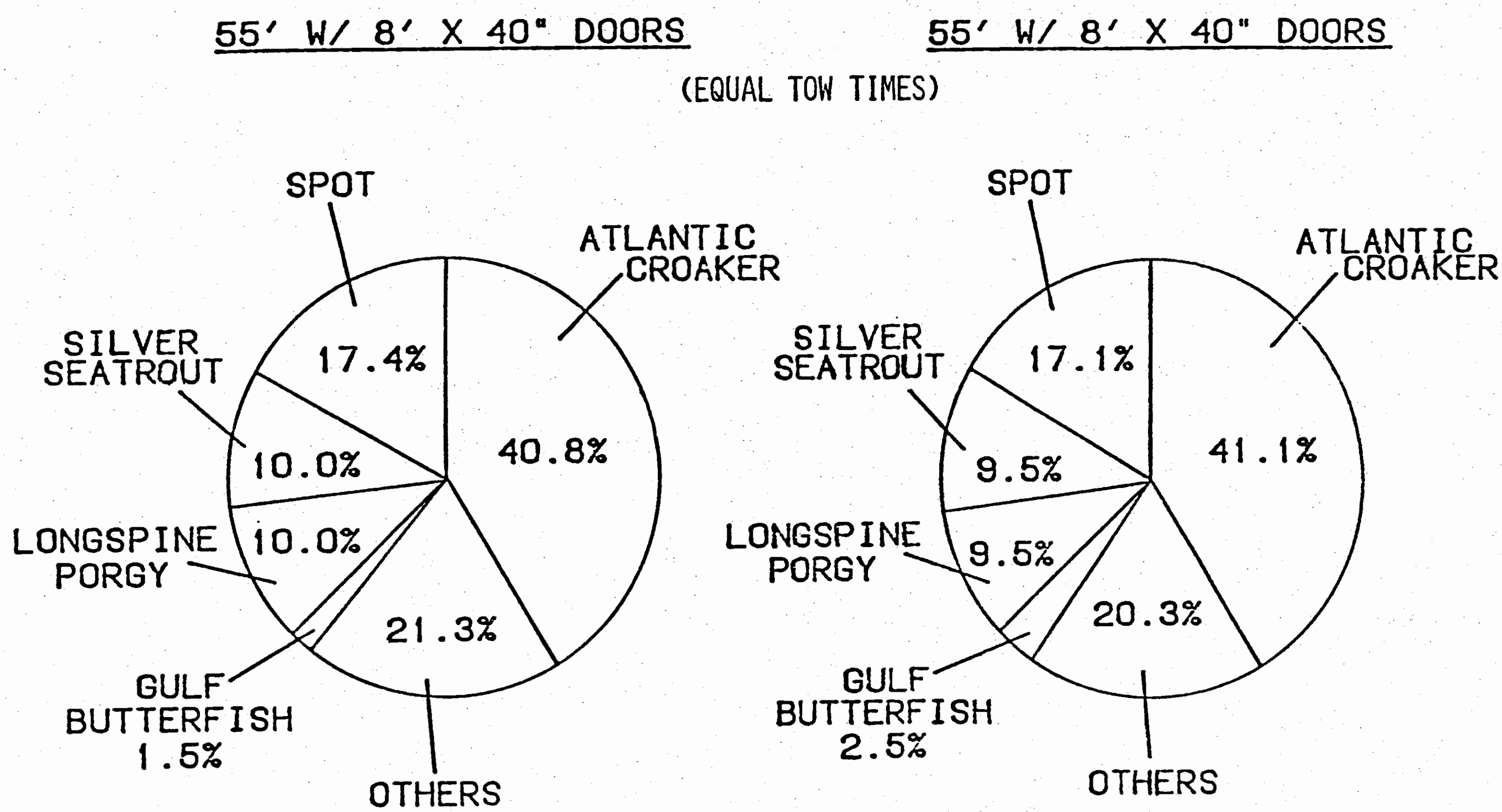


Figure 10. **Catch composition of five major fish species expressed as percent (weight) of the total catch for paired comparisons between two 55'-trawls with 8' x 40" doors.**

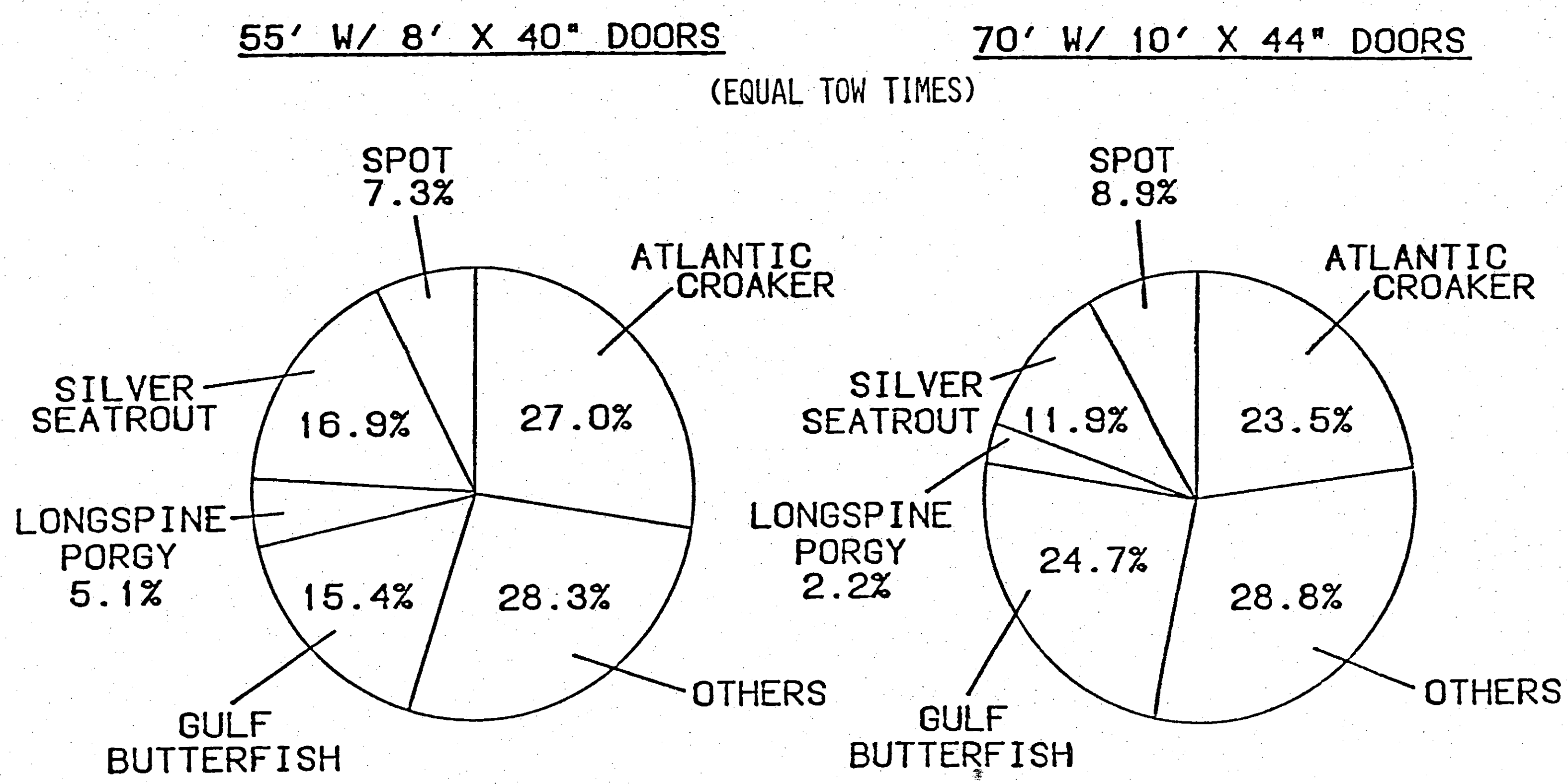


Figure 11. Catch composition of five major fish species expressed as percent (weight) of the total catch for paired comparisons between a 55'-trawl with 8' x 40" doors and a 70'-trawl with 10' x 44" doors.

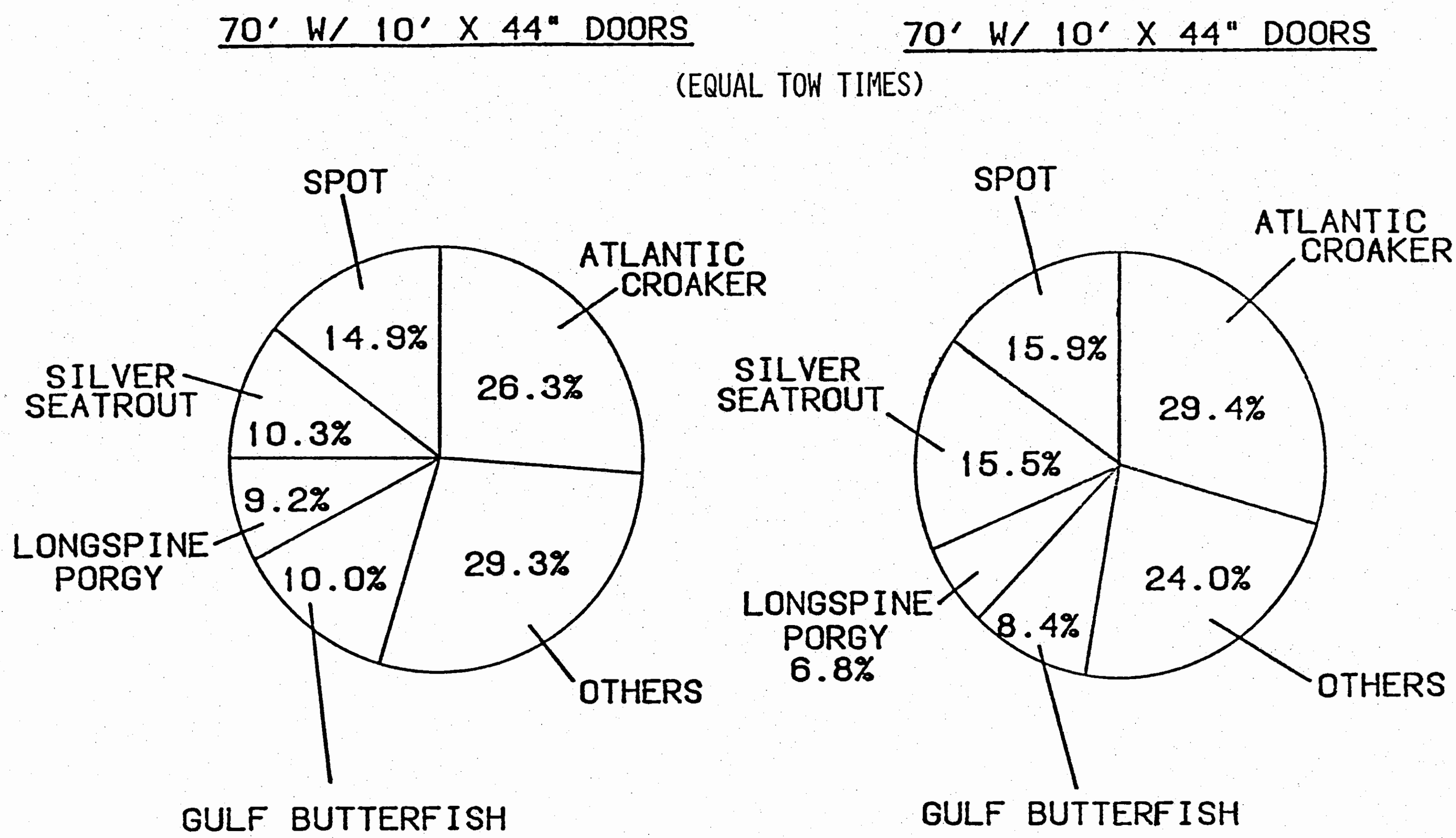


Figure 12. Catch composition of five major fish species expressed as percent (weight) of the total catch for paired comparisons between two 70'-trawls with 10' x 44" doors.

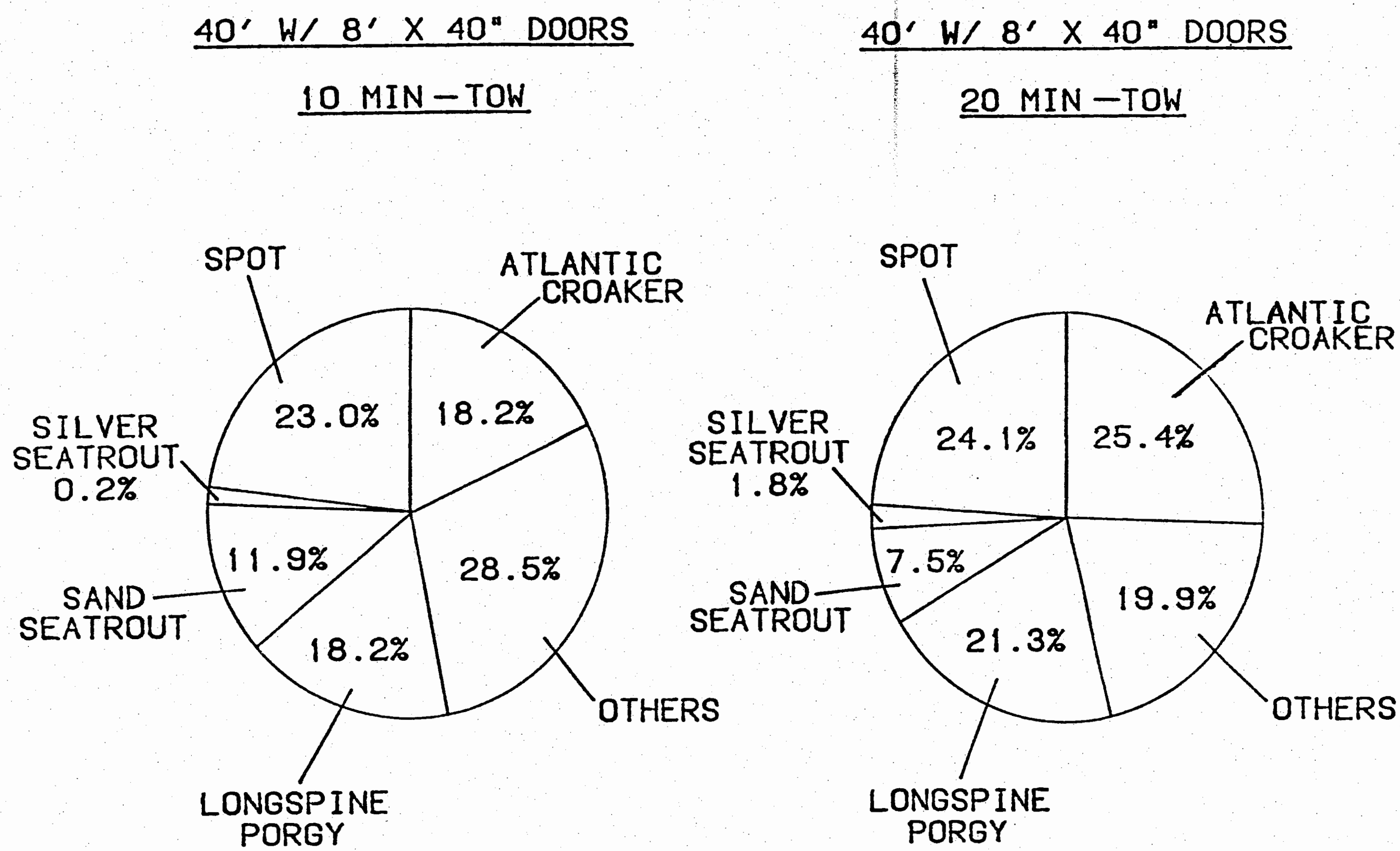


Figure 13. Catch composition of five major fish species expressed as percent (weight) of the total catch for paired comparisons between two 40'-trawls with 8' x 40" doors, one fished for 10 minutes and the other for 20 minutes.

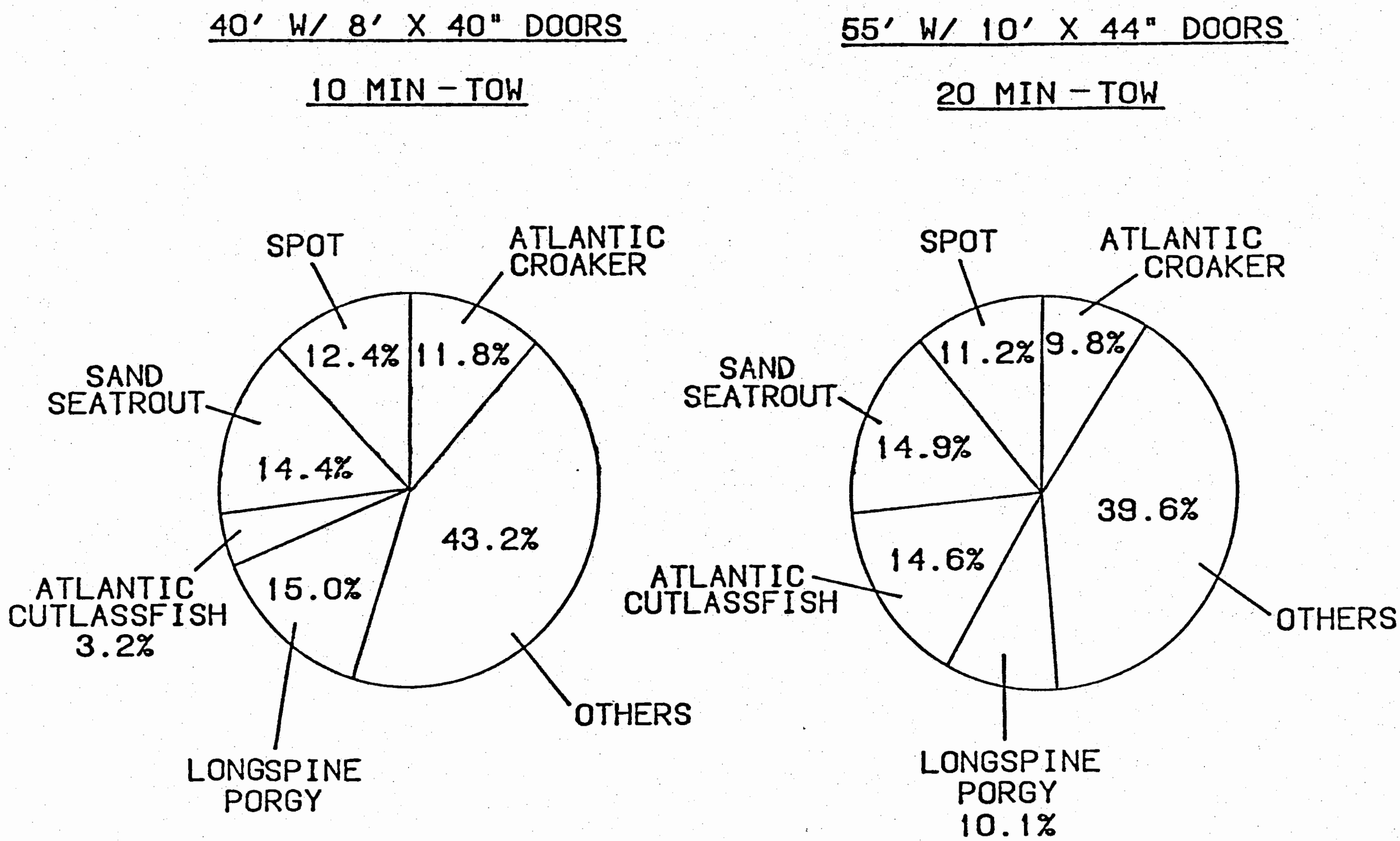


Figure 14. Catch composition of five major fish species expressed as percent (weight) of the total catch for paired comparisons between a 40'-trawl with 8' x 40" doors fished for 10 minutes and a 55'-trawl with 10' x 44" doors fished for 20 minutes.

out the sampling area, observable in the schooling behavior of fishes, fathometer traces, and the catches themselves. The magnitude of variation seen in trawl catches, for any of the sampling configurations, could not be explained if the distribution of organisms were random. Mean catch rates ranged broadly by number and weight for both total catch and species composition, with heterogeneity evident in the component species. Although Atlantic croaker was often the dominant species, other species were frequently caught. Variation and patchiness in the distribution of animals can be demonstrated by observing the catch rates of two simultaneously towed trawls. Variances, which were generally quite large throughout the data set, were a function of great differences in the catches and small sample size.

Simultaneously-towed trawls displayed two important characteristics: (1) few significant differences were noted between trawls when comparing normalized catch rates, and (2) there was a general similarity in the species caught and the proportional composition of the dominant species. The divergent catch rates of the 70-ft (21.5-m) trawl between paired and unpaired data (Figures 1 and 2) cannot be explained. The high mean values seen during cruises 36, 40, and 42 were in part a function of the longer warp length and fewer low catch rates. The general absence of significant differences between normalized catch rates of the 40-ft (12.3-m), 55-ft (16.9-m), 70-ft (21.5-m), and 82-ft (25.2-m) trawls suggests that any of these trawl configurations could be used to sample the population in a statistically similar manner.

Approximately 200 species of finfish are found on the northern Gulf of Mexico commercial fishing grounds, but only 10 to 20 species comprise a major portion of this fauna (Roithmayr 1965; Gutherz et al. 1975; Kemmerer et al. 1982). Dominant species in this study were among the top 20 species reported in the literature and are listed in Table 8.

The low incidence of positional differences and similarity of species composition suggest a general similarity of trawl efficiency in sampling the inshore northern Gulf resources. This similarity is substantiated by the lack of significant differences in Friedman's test.

Evaluation of several trawl combinations, considering different warp length, tow speed, and tow duration, indicated that in general, the 40-ft (12.3-m) trawl was not statistically different from any other trawl configuration in its ability to sample a population. Catch rates were affected by warp length, as in all cases the longer warp length was associated with a higher catch rate. Tow speed and net size were shown to be highly significant during cruise 57; these differences were associated with the decreased catch of the 70-ft (21.5-m) trawl at 3.0 kn. When differences in catch rates and species rank were noted, they were generally observed in those species caught less frequently. In such species, small changes in abundance can display significant shifts in statistical values.

Selection of a standard sampling trawl involves the assurance that the selected trawl adequately samples the population, and its catch truly reflects the major components of the stock. Although the 40-ft (12.3-m) trawl generally had a lower overall catch rate, differences in the species rank and catch rates were generally statistically insignificant.

In addition to sampling gear features, consideration must also be given to gear costs, ease of handling, and time required to process catches. Smaller trawls and doors are approximately 40% less costly to purchase and easier to repair. They provide smaller catches, and frequently, more information since the entire catch may be processed rather than subsampled. Smaller catches could also increase the number of replications, thereby reducing variability and increasing precision of the estimates.

RECOMMENDATIONS

Considering the amount of variation and the small sample sizes for some factors in this study, we recommend a statistically designed trawl experiment to further evaluate trawl performance between different trawl sizes. Trawl sizes should include those addressed in this paper, with additional evaluations of smaller and larger trawls. Catch rates, along with variations in species composition and catchability, should be analyzed. A survey design with sufficient replications and a balanced number of samples per sample unit must be selected and rigidly followed. Consideration should be given to evaluating 20-ft (6.2-m), 30-ft (9.2-m), 40-ft (12.3-m), 55-ft (16.9-m), 70-ft (21.5-m), 90-ft (27.7-m), and 120-ft (36.9-m) trawls of similar design, appropriate door size, and varying tow duration.

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THREE PAIRED-TOW STUDIES TESTING FOR EQUIVALENCE IN SHRIMP SAMPLING

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ABSTRACT Three sets of shrimp catch data from paired tows between the FRS OREGON II and other research vessels were analyzed. Two-way analysis of variance and Wilcoxon's signed-ranks tests were used. Recommendations for minimizing effort and maximizing information gain are given.

INTRODUCTION

Sampling a large population such as that of brown shrimp along the Texas Gulf coast requires an extensive effort. Estimation of the standing stock of this brown shrimp population would entail a large sampling effort--too large for a single vessel to accomplish in the short time period available. Thus the need arises to use two or more vessels and standardize their catch rates.

The National Marine Fisheries Service (NMFS) studied the shrimp stock in the northwest Gulf of Mexico during the 1981 and 1982 Texas Closures (May to July), using several vessels. During the 1981 study, the FRS OREGON II of NMFS was assisted in its sampling program by the RV WESTERN GULF of the Texas Parks and Wildlife Department (TPWD). In 1982, a similar study was incorporated into the SEAMAP program and the FRS OREGON II was assisted in its sampling of a much wider area by three vessels: the RV TOMMY MUNRO of the Gulf Coast Research Laboratory (Mississippi); the RV JEFF & TINA, contracted by NMFS to collect off Louisiana; and the RV FLORA MAE, contracted by TPWD to collect off Texas. Paired tows were made between the FRS OREGON II and the other vessels, except the RV FLORA MAE, to test for sampling equivalence.

This report reviews the three paired-tow studies involving the FRS OREGON II. It also offers recommendations on methodology for paired-tow operations in general.

THEORY

Paired Tows

Under ideal conditions, several paired tows are made between vessels at the start of a sampling program. The data obtained are analyzed on the spot to identify differences in catch rates and to make necessary changes in a vessel's rigging or techniques. If changes are required, additional paired tows are made to again test for equivalence in sampling. The essential features of such a paired-tow test are worth briefly defining: 1) Usually there are only two vessels involved. 2) Standard sampling gear and rigging are used, the same as will be used during the remainder of the sampling program. 3) Both vessels tow at their normal trawling speeds; it is preferable that these speeds be identical, but not essential, as the most important point is that each vessel should use its normal trawling speed (i.e., the trawling speed to be used during the remainder of the sampling program). 4) The towing time during a paired tow should be the same as for standard sampling. 5) Vessels should be as close together as feasible during each paired tow, as it is essential that both vessels sample the same population density.

Statistics

Analysis of catch rates from paired tows can be accomplished with either parametric or non-parametric statistical tests. Each method has its limitations and requirements. The appropriate parametric test is the two-way analysis of variance (ANOVA). It requires that sampling be random, that the error components of each measurement be independent and normally distributed, and that the variances be equal. Replicate measurements are needed from each vessel to test the data for these requirements. The Wilcoxon's signed-ranks test is the appropriate non-parametric test for paired tows. Its limitation is that it requires a minimum of six paired tows to detect a significant difference between vessels' catch rates at the 95% probability level. If a significant difference is detected, adjustments are made to the gear, rigging, and techniques used. If differences still exist after retesting with more paired tows, correlation and regression analyses are used to establish a standardization equation equilibrating catch rates between the two vessels.

CASE STUDIES

FRS OREGON II and the RV WESTERN GULF

During the 1981 Texas Closure, nine paired tows were made by the FRS OREGON II and the RV WESTERN GULF. Port and starboard nets were towed from each vessel during each of the paired tows, and each tow lasted 30 minutes. Catch rates ranged from 0.1 to 79.1 lb of shrimp per 30 min drag with a 42-ft semiballoon shrimp trawl (Table 1).

TABLE 1.

Shrimp catch rates and their means and variances for paired tows between the FRS OREGON II and the RV WESTERN GULF during the 1981 Texas Closure. Catch rates are in pounds of shrimp per 30-min drag with a 42-ft (12.2-m) semiballoon shrimp trawl.

OREGON II

Port	Starboard	Mean	Variance
8.9	6.0	7.45	4.205
4.7	4.0	4.35	0.245
75.1	40.1	57.60	612.500
41.5	33.4	37.45	32.805
79.1	30.2	54.65	1195.600
35.6	24.4	30.00	62.720
9.5	5.0	7.25	10.125
10.9	8.1	9.50	3.920
8.6	4.9	6.75	6.845

WESTERN GULF

Port	Starboard	Mean	Variance
7.9	6.5	7.20	0.980
6.6	5.4	6.00	0.720
60.5	62.5	61.50	2.000
36.5	35.0	35.75	1.125
57.0	55.5	56.25	1.125
5.3	5.0	5.15	0.045
9.7	11.4	10.55	1.445
7.8	6.3	7.05	1.125
1.1	1.8	1.45	0.245

Within-vessel means and variances of catch rates for each of the paired tows were calculated and used to test the requirements for analysis of variance. Bartlett's test for homogeneity of variances (Sokal and Rohlf 1969) and Taylor's method for assessing the relationship between the variances and the means (Taylor 1961) showed the original catch rates should be transformed before applying an ANOVA.

Taylor's method states: LOGvariance = A + B (LOGmean), with the suggestion that:

if B =	transform the original data to their:
1	square roots
2	logarithms
3 or more	negative fractional exponent (=Z) $Z = 1 - B/2$

For the FRS OREGON II and RV WESTERN GULF paired tows, $\overline{B} = 1.498$, and I chose to transform the data to their natural logarithms.

The 2-way ANOVA showed significant differences in mean catch rates between vessels and among paired tow locations (Table 2). The interaction term was also significant, indicating that the differences between vessels were dependent upon location. Observing the catch rates and plotting the two-tracks of the vessels for each paired tow (Figure 1), it became evident that during the sixth and ninth paired tows, the FRS OREGON II probably sampled areas with greater shrimp concentrations than did the RV WESTERN GULF. After inspecting the other catch data (= finfish plus miscellaneous) for all paired tows, it became apparent that shrimp patchiness was the problem. When data from the sixth and ninth tows were

TABLE 2.

Comparison of two two-way ANOVA tests for shrimp catch rates of paired tows by the FRS OREGON II and the RV WESTERN GULF during the 1981 Texas Closure. Catch rates are in pounds of shrimp per 30-min drag with a 42-ft (12.2-m) semiballoon shrimp trawl; data were transformed to their natural logarithms.

A. NINE PAIRED TOWS (=LOCATIONS)

Source of Variation	DF	SS	MS	F
Locations	8	6.7947	0.8493	55.7613***
Vessels	1	0.1451	0.1451	9.5256**
Interaction	8	0.9462	0.1183	7.7648***
Error	18	0.2742	0.0152	
Total	35	8.1602		

B. SEVEN PAIRED TOWS (=LOCATIONS)

Source of Variation	DF	SS	MS	F
Locations	6	4.9427	0.8238	55.5095***
Vessels	1	0.0112	0.0112	0.7512 ns
Interaction	6	0.0646	0.0108	0.7250 ns
Error	14	0.2078	0.0148	
Total	27	5.2261		

*** = significant at the 99.9% level.
** = significant at the 99.0% level.
ns = not significant at the 95% level.

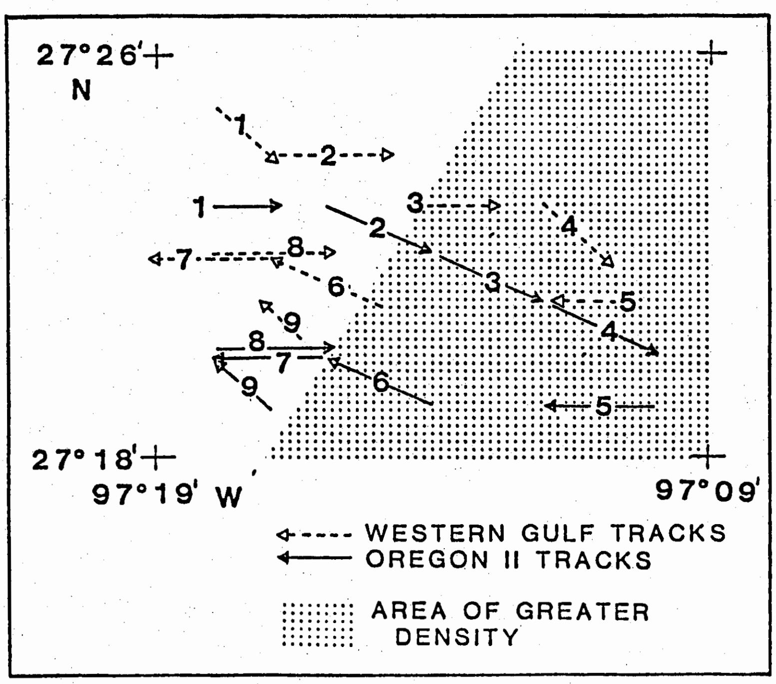

Figure 1. Tow tracks for the paired tows made by the FRS OREGON II and the RV WESTERN GULF during the 1981 Texas Closure survey.

discarded and the ANOVA performed on the remaining seven, only the differences among the mean catch rates for the paired tows (= locations) remained significant. The differences between vessels, and the interaction term were no longer significant, suggesting the two vessels were sampling equivalently and a standardization factor need not be calculated.

FRS OREGON II and the RV TOMMY MUNRO

During the 1982 SEAMAP study, seven paired tows were made between these two vessels. Only one net was towed by each vessel during each paired tow. Trawling times varied under 30 minutes. All catch rates were standardized to the equivalents of 30-min tows to make them comparable. The 30-min shrimp catch rates ranged from 0.55 to 8.86 lb (Table 3). Because there were no replicates but there were more than six tows, a Wilcoxon's signed-ranks test was used to test for differences between the vessels' catch rates.

A significant difference between vessels was detected (Table 3). Inspection of the data revealed large differences between vessels and those differences did not correlate (r = 0.07 n.s.). It appears there was a problem in gear, rigging, technique or a combination of these aboard the RV TOMMY MUNRO which prevented it from catching shrimp consistently in proportion to the catches made by the FRS OREGON II. An adjustment in gear, rigging, and technique, followed by additional paired tows and subsequent analysis, would have been proper in this case. As it stands, the data from the RV TOMMY MUNRO cannot be standardized with those of the FRS OREGON II. We should note two things about the catch rates of the RV TOMMY MUNRO: first, they are probable underestimates of shrimp abundance; and second, the differences between the vessels' catch rates were declining steadily, which suggests that improvements in gear adjustments and sampling technique were being made aboard the RV TOMMY MUNRO to obtain more accurate samples.

TABLE 3.

Shrimp catches, catch rates, differences, and signed ranks for paired tows by the FRS OREGON II and the RV TOMMY MUNRO during the 1982 SEAMAP study. Catch rates are in pounds of shrimp per 30-min drag with a 42-ft (12.2-m) semiballoon shrimp trawl (= CPUE).

Tow No.	Vessel	Minutes towed	Catch	CPUE	Differences in CPUE	Signed rank
1	OREGON II	22	6.5	8.9		
	TOMMY MUNRO	22	0.4	0.6	8.3	+6
2	OREGON II	30	8.4	8.4		
	TOMMY MUNRO	30	0.7	0.7	7.4	+5
3	OREGON II	10	2.6	7.8		
	TOMMY MUNRO	9	0.9	3.0	4.8	+4
4	OREGON II	30	5.1	5.1		
	TOMMY MUNRO	28	1.8	1.9	3.2	+3
5	OREGON II	17	2.4	4.2		
	TOMMY MUNRO	15	0.6	1.2	3.0	+2
6	OREGON II	11	0.5	1.4		
	TOMMY MUNRO	10	0.3	0.9	0.5	+1
7	OREGON II	12	0.5	1.2		
	TOMMY MUNRO	12	0.5	1.2	0.0	none

Results of a Wilcoxon's signed ranks test:
Sum of the "+" = 21
Sum of the "-" = 0
T = 0*

* = significant at the 95.0% level

FRS OREGON II and the RV JEFF & TINA

Only four paired tows were made by the FRS OREGON II and the RV JEFF & TINA during the 1982 SEAMAP closure study. Again, only one net was towed by each vessel during each paired tow, and trawling times were usually less than 15 minutes. Catch rates were standardized to the equivalents of 30-min tows, and as such, ranged from 0.0 to 9.9 lb (Table 4). A paired comparison test could be used to test for differences between vessels' catch rates, but inspection of the catch rates revealed a substantial interaction component which would make the F-test in the ANOVA inefficient and misleading. This would typically end the analysis with insufficient statistical support for concluding whether the vessels were equivalent samplers.

A meaningful way to continue the analysis of these data is to obtain a substitute measure of the expected within-vessel error, using it to test for interaction and for differences in catch rates between vessels and among tows (= locations). Such an error term was obtained from five paired tows made by the FRS OREGON II and the RV WESTERN GULF in 1981, where the catch rates were in the range of catch rates for this case (see Table 1). Admittedly, this is making the assumption that the within-vessel error for the FRS OREGON II has not changed, and that the within-vessel error of the RV JEFF & TINA was of a similar magnitude.

The two-way ANOVA on LOG_e (catch rate +1)-transformed data showed significant differences among paired tows (= locations) and between vessels (Table 5). The interaction term was not significant at the 95% level, but was at the 98% level. A plot of the tow-tracks showed the possibility that the FRS OREGON II sampled in a dense patch of shrimp during the third paired tow while the RV JEFF & TINA did not (Figure 2). When the third paired tow was discarded, only the differences among the three remaining paired tows were significant. With substantial reservations, it appears these two vessels were equivalent samplers and that no standardization was required.

RECOMMENDATIONS

1) Paired-tow tests should be made at the start of a sampling program, and the data analyzed on the spot in case changes and retesting are required.

2) Vessels should be as close together as feasible when making paired tows. If they are not sampling the same density of shrimp, data from the paired tow might be discarded, resulting in a waste of time and effort. The likelihood of sampling different densities increases with distance between vessels.

3) Towing duration should be the same as for standard sampling operations.

4) A minimum of six paired tows should be required, permitting application of either a parametric test (two-way ANOVA or a paired comparisons test) or a non-parametric test (Wilcoxon's signed-ranks test).

5) Port and starboard nets should be used by each vessel for each tow.

6) Accurate and precise recordings of starting and stopping positions and times should accompany each tow in case tow-tracks and density plots are needed to clarify differences or to justify discarding certain deviant tows.

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TABLE 4.

Shrimp catches and catch rates for paired tows by the FRS OREGON II and the RV JEFF & TINA made during the 1982 SEAMAP survey. Catch rates are in pounds of shrimp per 30-min drag with a 42-ft (12.2-m) semiballoon shrimp trawl (= CPUE).

Tow No.	Vessel	Minutes towed	Catch	CPUE
1	OREGON II	12	0.3	0.8
	JEFF & TINA	12	0.0	0.0
2	OREGON II	14	3.9	8.4
	JEFF & TINA	13	4.3	9.9
3	OREGON II	17	3.4	6.0
	JEFF & TINA	15	0.5	1.0
4	OREGON II	10	0.5	1.5
	JEFF & TINA	11	0.4	1.1

TABLE 5.

Comparison of two two-way ANOVA tests for shrimp catch rates of paired tows by the FRS OREGON II and the RV JEFF & TINA during the 1982 SEAMAP study. Catch rates (+1) were transformed to their natural logarithms. The error term was computed from 1981 data using paired tows between the FRS OREGON II and the RV WESTERN GULF.

A. FOUR PAIRED TOWS

Source of variation	DF	SS	MS	F
Locations	3	4.4808	1.4936	28.075**
Vessels	1	0.4226	0.4226	7.944*
Interaction	3	0.5448	0.1816	3.414 ns
Error	9	0.4788	0.0532	

B. THREE PAIRED TOWS

Source of Variation	DF	SS	MS	F
Locations	2	4.4332	2.2166	41.665**
Vessels	1	0.0572	0.0572	1.075 ns
Interaction	2	0.1255	0.0628	1.180 ns
Error	9	0.4788	0.0532	

** = significant at the 99.0% level.
* = significant at the 95.0% level.
ns = not significant at the 95.0% level.

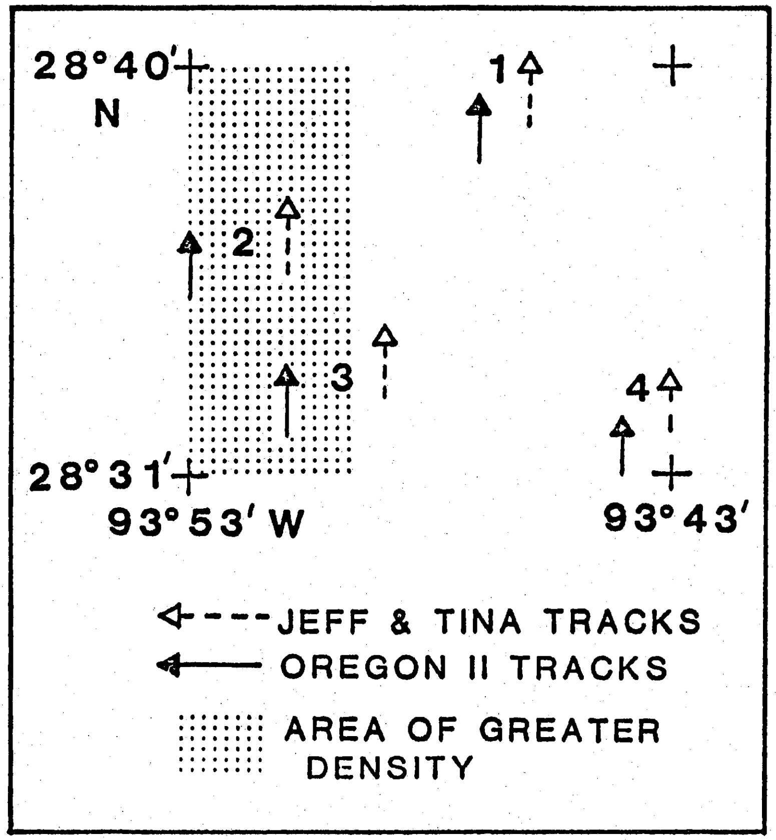

Figure 2. Tow tracks for the paired tows made by the FRS OREGON II and the RV JEFF & TINA during the 1982 SEAMAP survey.

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TECHNIQUES AND METHODOLOGY FOR "CALIBRATING" SHRIMP AND BOTTOMFISH SAMPLING GEAR

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ABSTRACT Coordinated SEAMAP sampling presents an opportunity to sample all life stages of important species, and entire stocks throughout their range, for a comprehensive description of the resource. The cooperative pooling of data from the different agencies requires calibration of the gear used by each agency in order to calculate conversion factors for combined analysis of data collected with different gears. The first step in calibrating trawling gear is to standardize sampling gear components, construction, rigging, and operation, thereby reducing catch variability. Comparative tows are then made between different gears, and correction factors calculated using regression statistics. Trawl performance is measured by scuba techniques and electronic mensuration gear to determine the catch per unit area needed to compare gear performance and determine accurate correction factors. This knowledge can then provide the information necessary to calculate catchability coefficients for the different species and provide the reliable estimates of stock abundance and status necessary for sound management.

INTRODUCTION

The advent of the cooperative SEAMAP effort provides, for the first time, an opportunity to conduct broad, systematic surveys over all Gulf of Mexico waters of state and national interest. Pooling state and National Marine Fisheries Service (NMFS) survey capabilities provides an opportunity to sample all life stages of important species and entire stocks throughout their range, and, as well, a comprehensive description of the resource habitat. The cooperative pooling of effort, however, presents a problem since gear types and methodologies used by the various participants are not the same.

A major source of SEAMAP data is benthic trawling, an area in which there is divergence in gear and methodology. All states and NMFS have conducted trawl surveys on a more or less continuous basis for a number of years. Generally, 16- to 20-ft (4.9- to 6.1-m) trawls have been used as standards for inshore sampling, and 40- to 50-ft (12.2- to 15.2-m) trawls have been used offshore. Towing time, mesh size, trawl configuration, method of rigging, vessel size, towing speed, and treatment of the data vary by organization. A change in present sampling gear or techniques would, in some cases, jeopardize long-term data bases. Where such a situation exists, conversion factors must be developed to insure comparability for catch rates and species composition among samples taken by different gears and methodologies.

Conversion factors can go far toward consolidating previously collected data so that past trends and relative abundance can be assessed. Information is needed now and in the future, however, on the absolute abundance and status of Gulf resources. Both of these objectives can only be derived accurately and precisely if trawl variables are measured by common units to which calibration measurements are made.

Before discussing methods for calibrating shrimp and bottomfish sampling gear, we must define the term "calibration" as it applies to trawling gear. Calibration is defined as the measurement of trawling gear performance in order to calculate conversion factors which allow combined analysis of data collected with different gears. Calibration involves determining catch rates for different gears for each species of interest, and comparing the catch rates by statistical analysis. Regression analysis is used to determine predictable relationships between the catches. Regression coefficients can be calculated for different gear and used as conversion factors which allow combined analysis. The correlation efficiency among data from different gear can be significantly improved by minimizing the variability in both catch data and accuracy of measurements. Catch variability, in turn, can be reduced by standardizing gear and sampling procedures and accuracy improved by determining precise units of measurement.

STANDARDIZATION OF SAMPLING GEAR

Shrimp and bottomfish sampling gear generally consists of various sizes and types of otter trawls. The type, size, and horsepower of the sampling vessel, and the preference of the research agency, dictate which type of trawl is used. This sampling gear consists of many components, each of which affects the performance of the gear. In order to effectively calibrate sampling gear, the variability in gear performance must be reduced as much as possible by standardizing the various components. Otter trawl components which should be standardized are presented in Table 1.

Standardization of each organization's particular gear is mandatory to effective calibration. Examples of performance difference between gear types and rigging configurations are presented in Tables 2-4. Data on trawl gape dimensions for five identically rigged trawl types indicate horizontal spread differences ranging from 67% to 73% of the trawl headrope lengths and vertical openings from 3.5 to 4.0 ft (1 to 1.2 m) (Table 2). The horizontal spread of a 60-ft (18.3-m) super X-3 trawl varied from 62% when spread with 7-ft x 3-ft (2.13-m x 0.9-m) doors to 77% with 10-ft x 40-in (3.1-m x 1.0-m) doors and the vertical opening decreased from 4.0-ft to 3.0-ft (1.2 to 0.9-m) (Table 3).

The effect of varying amounts of flotation on trawl gape, with resulting variability in the vertical and horizontal openings of trawls is shown in Table 4. These examples indicate the need to standardize gear components and rigging for consistent performance. When purchasing or constructing sampling gear, attention to details of material specifications and construction techniques will insure such standardization. Many commercially manufactured fishing gears do not meet the quality control standards needed for scientific sampling gear. We have received netting in which the mesh size varied more than 1/2 in (18 mm) for 2-in. (50-mm) webbing. Hanging ratios and overall size of trawls may vary considerably between trawls assembled from the same net pattern. Detailed specifications and acceptable tolerances should be given and quality control demanded for sampling gear. Our experience in analysis of data from paired tows indicates that a significant amount of variability in trawling gear performance can be reduced by attention to detail in construction, rigging, proper "tuning" and operation of the gear.

The development of harvesting and sampling gear requires direct comparison of gear performance between standard rigged trawls and modified experimental trawls. This experience has resulted in techniques and procedures which reduce the error associated with variation in the operation of trawling gear (Watson et al. 1984). Variability in catch rates between trawl tows can be great, requiring large sample sizes to obtain reliable results. With proper construction, rigging, "tuning," and operation of trawls, this variability can be reduced, increasing the reliability and confidence of the data.

TABLE 1.

Components of a benthic otter trawl system.

Component	Specifications required for standardization
Main towing cable	Wire type and diameter, scope ratios
Bridle	Wire type and diameter, length.
Doors	Type and size, material specifications including: iron size and width; chain type, size, and setting; timber size and type; and construction details.
Trawl net	Type, mesh sizes, twine type and diameter, mesh count, hanging ratio, hanging rope (type and size), headrope length, footrope length, legline length, net treatment, and special rigging.
Floats	Type, size and placement.
Weights	Type, size and placement.
Tickler chain	Type, size and setting (length).

TABLE 2.

Comparison of gape dimensions for five 60-ft (18.7-m) trawls on 9-ft x 40-in (2.8-m x 1-m) doors.

Trawl type	Spread	Vertical opening	Spread ratio
(1) Flat	40 ft (12.2 m)	4.0 ft (1.2 m)	67%
(2) Semiballoon	40 ft (12.2 m)	4.0 ft (1.2 m)	67%
(3) Western Jib Trawl	41 ft (12.8 m)	3.5 ft (1.1 m)	68%
(4) Balloon	42 ft (13.1 m)	3.5 ft (1.1 m)	70%
(5) Super X-3	44 ft (13.8 m)	3.5 ft (1.1 m)	73%

TABLE 3.

Relative gape dimensions for 60-ft (18.7-m) super X-3 trawl with increasing door size.

Door size	Vertical opening	Horizontal spread	Spread ratio
7 ft x 36 in (2.2 x 0.9 m)	4.0 ft (1.2 m)	37 ft (11.5 m)	62%
8 ft x 40 in (2.5 x 1.0 m)	3.5 ft (1 m)	43 ft (13.4 m)	72%
10 ft x 40 in (3.1 x 1.0 m)	3.0 ft (0.9 m)	46 ft (14.4 m)	77%

TABLE 4.

Relative gape dimensions of flat and semiballoon trawls with and without floats.

Trawl type	Headrope length	Door size	No. of 6"x8" spongex floats	Vertical opening	Horizontal spread	Spread ratio
Flat	60 ft (18.7 m)	8 ft x 40 in (2.5 x 1.3 m)	0	4.0 ft (1.2 m)	40 ft (12.2 m)	67%
Flat	60 ft (18.7 m)	8 ft x 40 in (2.5 x 1.3 m)	10	11.5 ft (3.6 m)	33 ft (10.3 m)	55%
Flat	70 ft (21.8 m)	9 ft x 40 in (2.8 x 1.3 m)	0	4.0 ft (1.2 m)	44 ft (13.8 m)	63%
Flat	70 ft (21.8 m)	9 ft x 40 in (2.8 x 1.3 m)	20	11.0 ft (3.4 m)	37 ft (11.4 m)	53%
Semiballoon	50 ft (15.6 m)	7 ft x 36 in (2.2 x 1.1 m)	0	3.0 ft (0.9 m)	31 ft (10.9 m)	70%
Semiballoon	50 ft (15.6 m)	7 ft x 36 in (2.2 x 1.1 m)	14	8.0 ft (2.5 m)	31 ft (9.7 m)	62%
Semiballoon	68 ft (21.2 m)	9 ft x 40 in (2.8 x 1.3 m)	0	4.0 ft (1.2 m)	46 ft (14.2 m)	68%
Semiballoon	68 ft (21.2 m)	9 ft x 40 in (2.8 x 1.3 m)	20	7.0 ft (2.2 m)	43 ft (13.2 m)	63%

Following standardization of trawling gear, construction, rigging, "tuning", and operation of a trawl should be addressed. The only way consistency of operation can be assured is frequent monitoring and accurate recording of the trawl's operational characteristics. The most frequent causes of gear-induced variation in catch rates are improper rigging and "tuning" of the trawling gear, and failure to monitor the operational condition of the trawl. Improper rigging can result in two identically constructed trawls having grossly different catch results. Examples of rigging differences which we have found to cause significant differences in catch rates include: length and size of tickler chains, footrope weight and/or headrope flotation and placement, length of leglines, door chain settings and adjustments, rigging of door lines and lazy lines, bridle length and size, and main cable size and scope ratio. An example of catch variability due to differences in trawl rigging is presented in Table 5.

Shrimp catch data from paired tows (identical nets on each side of the vessel) show the variability associated with differences in the tickler chain rigging. Ten paired tows with identically rigged trawls, one with the tickler set 36 in (0.9 m) shorter than the footrope and one with the tickler even with the footrope, yielded mean shrimp catch rates of 28.6 lb/hr and 12.4 lb/hr respectively. When the ticklers were rigged 48 in (1.2 m) shorter than the footrope on both trawls, the ten paired tows yielded mean shrimp catch rates of 51.1 lb/hr and 54.1 lb/hr respectively.

Assuming the trawls are constructed to standard specifications and identically rigged, some "tuning" is necessary to ensure consistent operation. Tuning of trawling gear consists of checking indicators of trawl performance and making necessary rigging adjustments to ensure continued proper operation. A properly operated bethic otter trawl should: (1) maintain close contact with the bottom, (2) provide horizontal spread between 60 and 80% of its headrope length, (3) operate with its tickler chain ahead of the footrope but behind the headrope, and (4) have a door angle of attack of approximately 36° with a slight outward vertical tilt.

A correctly rigged trawl will exhibit two indicators of the trawl's operational performance: (1) "shine" on the door shoe and footrope loop chain, and (2) catch composition and consistency. "Shine" is the lustre on the metal of the door shoe and loop chain caused by abrasion on the substrate. A trawl fishing correctly will exhibit shine on the bottom 6 to 8 links of each loop of chain around the entire length of the footrope, indicating that the footrope is fishing within 4 to 6 in (10 to 15 cm) of the bottom. An initial inspection of the loop chain after several tows will indicate whether the trawl is fishing on the bottom and the approximate distance of the footrope from the bottom. Shine on the trawl door's shoes can indicate the correct door angle of attack, door tilt, scope ratio, and trawling speed. If the trawl is operating correctly, the shoes will shine across their entire leading edge and taper to a point on the back or trawling edge. Shine only on the back or heel of the shoe indicates an improper tow cable scope ratio or door chain setting. If the shine is uniform across the entire shoe, the scope ratio may be incorrect or the tilt angle of the door inadequate. The angle of the shine on the shoe can be measured to indicate the door angle of attack. An improper angle of attack will also be shown by hard footrope-bottom contact if the trawl is underspread, and no footrope-bottom contact if the trawl is overspread. Shine only on the front portion, or nose, of the door indicates either improper door chaining, inadequate setback in the trawl footrope, or inadequate weight on the footrope.

TABLE 5.

Effect of tickler chain setting on trawl performance. Results of paired tows with identically rigged 65-ft (20-m) Mongoose trawls on 9-ft x 40-in doors.

Trawl	Tickler chain setting	No. of tows	Shrimp catch (lb/hr)
A	36 in (0.9 m) shorter than footrope	10	28.6
B	even with footrope	10	12.4
A	48 in (1.5 m) shorter than footrope	10	51.1
B	48 in (1.5 m) shorter than footrope	10	54.1

Catch composition and consistency should also be used to evaluate operation of the trawl. The amount of benthic invertebrate fauna and debris in the catch indicates the degree of the trawl's bottom contact and the efficiency of the tickler chain. Changes in catch consistency can indicate operational problems. The most common problems causing significant variation in catch rates and composition are tangling of the tickler chain or other trawl components, damage to the trawl, hanging or bogging the trawl, and stretching of the tickler chain. Most operational problems are immediately recognizable, but some are subtle and may go unnoticed without careful and regular inspection of the gear. The most common gear-related sources of significant catch variability which may go unnoticed are tickler chain tangling or maladjustment due to stretching, and holes or tears in the net; the net should be inspected and the tickler chain setting checked daily. Thus, with standardized construction, rigging, tuning, and operation of sampling gear, it is possible to calibrate individual gear types and sizes, and reliably compare results.

CALIBRATION OF SAMPLING GEAR

Calibration of sampling gear is best accomplished by conducting either paired sampling between the different gears to be calibrated, or to a "standard" gear which has been calibrated previously. Calibration should preferably be conducted using the vessels which will be used in the sampling problems. Paired tows are made between the different gears and vessels and the catch rates calculated for each gear. The data are then analyzed by linear regression to determine the predictability between the catches. If the predictability is good (high correlation coefficients), regression coefficients can then be used as conversion factors, allowing combined analysis of data sets collected with different gears.

The correlation between catch rates for different gears can be improved by increasing the accuracy of the data. This can be accomplished by increasing the precision of measurement units used to describe the catch data. Most trawl data are collected as catch per tow or catch per unit time; these are the simplest to collect and adequate for most sampling programs. However, catch per area swept, or volume filtered, more precisely describe gear performance and are thus more useful in estimating population levels.

Direct measurement of trawl performance is necessary to obtain these units of measurement, which include trawl horizontal spread, headrope vertical height, footrope height above bottom, distance covered over bottom (ground speed), and water speed.

There are basically two methods for collecting the trawl performance data necessary to determine these units: (1) scuba diving, and (2) electronic mensuration. Both methods have their advantages and limitations, and basic measurements required to determine trawl performance (horizontal spread, vertical opening, and height above bottom) can be derived from both. Measurements of trawls under operational conditions by scuba diving techniques (Wickham and Watson 1976) is overall the more effective method, as divers can observe the entire trawl in operation, direct adjustments, and take any measurements necessary to compare trawls. Electronic mensuration with acoustic equipment is limited in the quantity and quality of selected measurements, but has two advantages over diver measurements: (1) electronic equipment can monitor a trawl's performance in deep or turbid water, beyond safe diver capabilities; and (2) it can be used to continuously monitor trawl performance and changes throughout long tows. Other information which is necessary to determine trawl performance and can be measured electron- ically includes bottom time, ground covered (ground speed), and water speed of different trawls for varying water depths, tow duration, and vessels.

A combination of diver evaluation and electronic monitoring will ultimately produce the most reliable and accurate data. Trawl performance varies with rigging changes among vessels and under varying fishing conditions. Repeatable data are essential, and where direct comparison between vessels, water depths, bottom and sea conditions, etc. is required, the best approach is to first use divers to initially assess, adjust, and establish each trawl's performance characteristics. Trawl performance can then be electronically monitored during actual sampling operations to determine variation in trawl performance, and catch data from comparative trawling tests used to determine accurate correction factors which will allow comparison of different sampling efforts.

The final step is to establish a catchability coefficient for the standard sampling trawl. The difficulty in establishing such a coefficient for each fish species will probably preclude any meaningful evaluation in the near future. Several researchers have attempted to determine catchability coefficients for fishes, but with generally limited success (Loech et al. 1976, Kjelson and Johnson 1978). Numerous approaches to the problem are possible, but generally, results have had considerable variation. A slightly better situation exists for shrimp: through the use of an electric shrimp trawl, an accurate catchability coefficient can be determined for brown and pink shrimp, the two major Gulf of Mexico shrimp species (Seidel 1972, Watson 1976).

SUMMARY

The broad-based sampling of shrimp and bottomfish stocks through cooperative surveys by state and Federal agencies (SEAMAP) requires "calibration" of various sampling gears in order to produce comparative comprehensive data on stock status throughout the species' range. Prerequisite to calibration of sampling gear is standardization of trawl components, construction, rigging, tuning and operation. Effective calibration is extremely difficult without significantly reducing performance variability through the standardization of gear and techniques. As-

suming standardization of gear and techniques by each agency, the next step is to measure the performance of sampling gear, employing scuba diving techniques and electronic mensuration for each agency's research vessel and sampling techniques. Data collected should include: trawl horizontal spread, vertical opening, height above bottom, bottom time, ground and water speed, and general trawl configuration. These data can be used to calculate precise units of measurement (i.e., area swept and/or volume filtered per unit of time), and these units used to directly compare performance of different sampling gears on the same or different vessels. With adequate performance information between different gears and/or vessels, catch results can be analyzed and correction factors determined to provide comparative data. Ideally, comparative tows should be made between vessels and gears to provide the correction factors with catchability coefficients determined or estimated for each sampling gear. Accurate gear performance data are mandatory to reliably estimate catchability values. An accurate determination of catchability is possible for trawls sampling pink and brown shrimp through the use of electric shrimp trawl technology. Catchability values for other shrimp and bottomfish species are presently difficult to derive, but estimates of ranges should be calculated to the best of our ability in order to provide the reliable estimates of stock abundance and status necessary for sound management.

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WORKSHOP DISCUSSION

Moderator's Comments: To begin the discussion, I would like to briefly summarize the information presented by the authors and their conclusions and recommendations. An overview of the assessment and monitoring programs conducted by the participating states in the Gulf of Mexico SEAMAP Program was presented by Steve Heath of the Alabama Department of Conservation and Natural Resources. The states appear to use a diversity of gear types and sizes, and sampling designs, which makes the comparison of data difficult. Valuable information could be obtained from data presently available through state programs if those data were directly comparable. A need exists either to standardize methods and gear, or to collect information which will allow a reliable comparison of different gear types and sampling methods.

Karen Foote of the Louisiana Department of Wildlife and Fisheries, presented information from catch comparison studies between 16- and 50-ft trawls. The results indicate that predictable relationships exist between the trawls for total number, total weight, and mean individual weight of several of the abundant species sampled, but species diversity and richness were significantly greater for the 50-ft trawl. For commercial shrimp species, there was a predictable relationship between the catch rates of the 16- and 50-ft trawls.

A similar study by Terry Cody and Billy Fuls of the Texas Parks and Wildlife Department, and presented by Terry Cody, indicated the presence of a predictable relationship for relative abundance and size of shrimp between 15-ft, (4.6-m), 40-ft (12.3-m), and 45-ft (13.8-m) trawls used in this study. Their analyses suggest that (1) a small trawl can be a reliable indicator of shrimp size in offshore waters, and (2) catch/tow relationships can be determined for different trawl sizes, allowing comparison of different data bases.

Richard Benefield presented information on the selectivity of mesh sizes on penaeid shrimp from a study by Albert Green and himself, both of the Texas Parks and Wildlife Department. They found that both the number and size of penaeid shrimp retained in trawls are consequences of the mesh size and twine size of the trawl.

Butch Pellegrin presented results of a study by Elmer J. Gutherz and himself, of the National Marine Fisheries Service in Pascagoula, Mississippi, and Arvind K. Shah, of the University of South Alabama, evaluating the efficiency of four different sized trawls. Catch rates of 40-ft (12.3-m), 55-ft (16.9-m), 70-ft (21.5-m), and 82-ft (25.2-m) trawls were analyzed for total catch, total finfish, total crustaceans, and Atlantic croaker weight and numbers. No statistically significant differences were found among normalized catch rates (catch per foot of headrope) in terms of vessel speed, towing duration, or day-versus-night sampling. Significant differences in catch rates were found, however, when the data were analyzed by net size, door size, and length of towing warp. No significant differences were found in species composition. The authors concluded that the different trawl sizes sample the populations studied in a similar manner, and recommended a statistically designed trawl experiment to further evaluate trawl performance between different trawl sizes. Such a test should include trawl sizes from 20-120 ft (6.2-36.9 m), of similar design, appropriate door size and equal tow duration. They further recommmended that (1) the sampling design contain adequate replication, and (2) a balanced, selected number of samples per sample unit be followed precisely. Analysis of the data should also include catch rates, variations in species components, and catchability.

Jeff Matthews, of the National Marine Fisheries Service in Galveston, Texas, presented findings of research conducted in 1981-1982 on paired tows between the NOAA Ship OREGON II and state research vessels. The results showed significant differences both among paired tows and between vessels. The author defined several problems associated with the sampling design and made recommendations for future tests:

1) Paired tows should be made at the start of a sampling program, and the data analyzed immediately to accommodate needed changes and retesting.

2) Vessels should trawl as close together as is feasible when making paired tows.

3) Towing duration should be the same as for standard sampling operations.

4) A minimum of six paired tows should be made.

5) Port and starboard nets should be used by each vessel during every tow.

6) Accurate recording of starting and ending positions and times should accompany data from each tow, in case tow-tracks and density plots are needed either to clarify differences or justify discarding deviant tow data.

The final paper, outlining techniques for calibrating shrimp and bottomfish gear, by John W. Watson and Wilber R. Seidel of the National Marine Fisheries Service in Pascagoula, Mississippi, was presented by Wil Seidel. Trawling gear calibration was defined as measuring trawling gear performance in order to calculate conversion factors that allow combined analysis of data collected with different gears. The authors suggested that the fist step in calibrating trawling gear is to standardize sampling gear components, construction, rigging, and operation, thus reducing catch variability. Comparative tows can then be made between different gears and correction factors calculated with regression statistics. They further suggested that the accuracy of the correction factors can be improved by using more precise units of measurement to evaluate gear performance. Scuba diving techniques and electronic mensuration gear can be used to measure trawl performance and determine catch per unit area, which can in turn be used to more precisely compare gear performance and determine accurate correction factors.

In summary, I think the presentations today have offered a great deal of information which can be used to plan better calibration studies. Such research should focus on developing accurate correction factors between gears, thus allowing combined analysis of data from different agencies and, subsequently, the reliable estimates of stock abundance and status necessary for sound management. With these remarks, I would like to open up the floor for questions and panel discussion.

Question - Alan Huff (FL)

I would like to poll the panel to ask if they feel comfortable with the information gained in these studies in using data from different groups and how they feel the data can be used.

Answer - Jeff Matthews (NMFS)

Having worked with the National Marine Fisheries Service historical data set and also with the Texas Parks and Wildlife inshore data set, I would feel confident in using the data for trend information but not for predicting exact numbers. I think with more analysis of gear performance we can approach actually predicting quantities or numbers of shrimp, rather than trends.

Comment - Steve Heath (AL)

For several years I have compared the Alabama data with J.Y. Christmas and other biologists in Mississippi with their data to coordinate the opening of the brown shrimp season across the two states. The comparison of trends between the two states has been very good in terms of relative abundance and growth rates.

Question - John Watson (NMFS)

One of the questions we should address is exactly what type of information the SEAMAP organization is seeking. Are we looking at relative indexes or trends, or is SEAMAP sampling designed to provide standing stock estimates or total abundance?

Answer - Walter Tatum (AL)

I think we are primarily looking at relative abundance and species composition and size classes of the catches.

Comment - C.E. Bryan (TX)

I think it is a practical matter that we will be looking at relative abundance for a long time with the long-term goal being to estimate catchability coefficients.

Comment - Alan Huff (FL)

I think our short-term goal should be to incorporate the calibration methodology presented in the paper by John Watson and Wilber Seidel and provide some funding so that the states can assess their gear and make sure it's tuned correctly. I have done a lot of trawl sampling where I go to the net house, grab a net, put it on the boat and throw it over the side and now all of a sudden I am not feeling too comfortable with that. I would like to see a document (set of procedures) produced that would standardize our operating procedures so that our biologists can be consistent with their sampling.

Comment - Lynn Benefield (TX)

We have a similar problem and I certainly agree with Alan that we need to standardize our gear and techniques. I was very interested in the paper on procedures for standardizing sampling gear. I think this should be the first step in our program to standardize our gear and sampling procedures.

Comment - Walter Nelson (NMFS)

I think the conclusion we have reached is that at this point we are talking about trend information, and even for trend information the data have got to be comparable between times and between areas. There seem to be two ways to do this: (1) have everybody standardize and use the same gear and the same methodology, or (2) draw comparability information between trawl types or trawl sizes between groups. The question is that simple at this point. How much standardization can we do and how much calibration are we going to have to do?

Comment - John Watson (NMFS)

I agree and I think we can propose some recommendations to achieve these goals. One recommendation would be to draft a standard sampling manual so that each state could standardize its gear and procedures and document the type gear and rigging used. Another recommendation would be to standardize the rigging and operating procedures used in the joint SEAMAP sampling cruises and make some measurements on the gear to derive common units of measurement between the vessels in order to derive conversion factors.

Comment - J.Y. Christmas (GCRL)

I think you have summarized what can be done very well. I have always thought that it is especially important that biologists become fishermen and understand the gear and pay attention to it. Most of the people that conduct sampling are not fishermen and really don't understand that the trawl has to be tuned. I would like to see training in this area as part of the marine advisory service. I think that it is very important that the sampling be consistent. It seems to me that this has been a productive effort and there is good potential for continuing and expanding the direction and effort that we have initiated with the long-term goal of establishing catchability coefficients.