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GULF OF MEXICO COMMERCIAL SHRIMP POPULATIONS—TRENDS AND CHARACTERISTICS, 1956–59

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ABSTRACT

Those phases of Gulf of Mexico fisheries concerned with the catching, landing, and initial processing of commercial shrimps are briefly described. Knowledge of each species' distribution and habits, manner of capture, handling, etc., is reviewed in an attempt to ensure proper interpretation of production statistics which are employed to draw inferences about commercial brown, pink, and white shrimp populations. Methods of collecting, projecting, and compiling fishery statistics are critically examined to ascertain the relative accuracy and hence the usefulness of the statistics themselves. Real or potential biases acknowledged, available statistics for each species are used (1) to derive population density indices and (2) to delineate and trace population spawning classes. Short- and long-term trends in population strength are examined in light of trends in corresponding yield. Untoward fluctuations in yield are explained, where possible, in terms of observed population characteristics and their apparent relation to changes in environment and intensity of exploitation.

Although annual shrimp yields on a Gulfwide basis varied mildly, those of some species and in certain areas often fluctuated sharply, with fishing success in 1957 having been particularly poor. On the average, the brown shrimp proved to be the most important species, contributing roughly 56 percent by weight to total annual landings. Pink and white shrimp followed in that order, making up 22 and 20 percent, respectively.

Centers of density in Gulf of Mexico brown, pink, and white shrimp stocks occurred, respectively, off the coasts of Texas, southwest Florida and Yucatan, and Louisiana. Corresponding 4-year population trends were up moderately for the brown shrimp but down perceptibly for both the pink and white shrimp. Too intense harvesting of small shrimp immediately after recruitment is postulated as the cause of attrition in the Sanibel-Tortugas (southwest Florida) pink shrimp fishery. The sharp 1957 decline in the Louisiana white shrimp fishery is largely attributed to factors associated with intense storm systems which are believed to have compounded expected natural mortality during inshore phases of that year's early-season spawning class. Too heavy fishing on the dominant early-season spawning class generated the following year postponed initiation of a recovery trend.

Considerable evidence supports the hypothesis that two periods of heightened activity characterize annual spawning patterns in shrimp stocks lying off the northern and eastern Gulf coast.

GULF OF MEXICO COMMERCIAL SHRIMP POPULATIONS—TRENDS AND CHARACTERISTICS, 1956–59

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Shrimp populations inhabiting shallow coastal waters of the Gulf of Mexico support intensive and valuable fisheries. Fluctuating about a level of 200 million pounds and trending very slightly upward, annual yields over the past decade (1950–59) have risen steadily in value and generally resulted in increased gross receipts for Gulf fishermen and processors. If ex-vessel sales of landings indicate the relative worth of fish or shellfish supplies, then Gulf of Mexico shrimp stocks now rank, collectively, as the most valuable of North American commercial fishery resources.

The close of the decade saw, however, an adverse departure from the value trend established during the preceding 9 years. In 1959, a 22-percent drop in value despite a moderate increase in yield created economic stress throughout much of the industry. Sharply rising imports are generally credited with having fostered this plight. The situation brightened somewhat in 1960 when the yield rose still higher and its value jumped 15 percent.

Notwithstanding the effects of expanding imports on the utilization of domestic supplies, development of management programs for shrimp stocks in United States coastal waters persists as a major objective. Such programs would so regulate fishing that maximum yields consistent with population stability are realized on a continuing basis.[1] Preliminary studies which establish how populations react to varying degrees of exploitation and, at the same time, to a variable environment, necessarily constitute the framework supporting any management program. These studies and, subsequently, the methods used to prescribe optimum fishing rates and predict yields, require detailed statistics of past and current fishing operations.

Acknowledging this need, the Bureau of Commercial Fisheries initiated in 1956 a continuing survey of commercial shrimping activities in the Gulf of Mexico. On the one hand, this survey provides the fishing industry with up-to-the-minute information on trends in shrimp production and marketing of shrimp products; on the other hand, it furnishes data needed to assess the shrimp resource itself and, ultimately, to formulate a resource management program. The following report describes the present survey, reviews trends in annual shrimp yields, attempts an appraisal of commercial shrimp populations employing commercial statistics, and suggests where improvements would enhance the survey's usefulness.

THE GULF OF MEXICO SHRIMP FISHERY

SPECIES EXPLOITED

A half dozen or so members of the family Penaeidae (Crustacea: Decapoda) support the extensive Gulf of Mexico shrimp fishery. Only three, however, contribute significantly to the overall yield. The top-ranked species include the brown shrimp, *Penaeus aztecus* Ives; pink shrimp, *P. duorarum* Burkenroad; and white shrimp, *P. setiferus* (Linnaeus). Lesser forms in descending order of importance are the seabob, *Xiphopeneus krøyeri* (Heller); *P. brasiliensis* Latreille; *P. schmitti* Burkenroad; and *Trachypeneus* spp. Of these less important shrimps, only the seabob enjoys specific commercial status although it has never contributed more than two percent to the total shrimp production in any one year. The remaining species are frequently taken in small

[1] Changing economy and consumer habits represent important but uncontrollable variables which may preclude attainment of "maximum sustained yields."

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amounts together with brown, pink, or white shrimp, but due to difficulty in distinguishing them from the latter species, are never differentiated by the fishing industry.

Species having potential commercial value include the royal red shrimp, *Hymenopenaeus robustus* Smith, a deep-water species, and the rock shrimps, genus *Sicyonia*, particularly *S. brevirostris* Stimpson, which frequently attains high densities in many areas.

This report treats exclusively the larger, more abundant varieties, namely, the brown, pink, and white shrimp. These are sought on the continental shelf and in contiguous inshore waters from the Florida Keys counterclockwise around the Gulf to the Yucatan Peninsula. Coastal, bathymetric, and seasonal distribution depends upon the species and, to some extent, the general locale. Although all three species occur throughout the Gulf, brown and white shrimp are most abundant along the northern and western coasts, whereas pink shrimp tend to concentrate to the south and east. A major task now confronting biologists is determining whether primary shrimp stocks are homogeneous over their ranges, or whether they comprise discrete subpopulations overlapping in space, time, or both.

The question of population definition is prompted in part by the unique life history of common penaeid shrimps. In general, eggs are fertilized and spawned in the oceanic habitat of the parent shrimp. After a very short incubation period, a small larva or nauplius emerges. Rapid growth accompanied by gross morphological changes ensues, the larva, now a component of the zooplankton, being quickly carried shoreward into broad and shallow estuaries. Transformation to adult likeness and habits occurs somewhat before or as the larva enters inshore waters. Here the shrimp, now a postlarva or juvenile, maintains rapid growth for the next 2 or 3 months. As maturation approaches, it departs from the "nursery" grounds, returning to the parental offshore habitat where its life cycle is completed. The average life span of the more important penaeids is thought to approximate 18 months although there are indications that many female shrimp continue to breed to a more advanced age, tending to make this estimate somewhat low. Pink shrimp captured as large and mature adults have been maintained in aquaria at the Bureau of Commercial Fisheries Biological Laboratory, Galveston, Tex., for periods exceeding 1 year.

In reconsidering the problem of stock homogeneity, questions arise concerning the relationship between offshore aggregations and the utilization of inshore waters by their progeny. Are there discrete offshore populations that can be consistently defined in terms of specific inshore waters which nurture their offspring? That is, do individual shrimp, after their sojourn in specific inshore waters, return to reproduce in their natal offshore areas; or do most juveniles migrate coastally to other suitable offshore habitat, their progeny, in turn, being nurtured in inshore waters adjacent thereto? Or is there a more or less random interplay between subgroups making up a given stock and the inshore areas their developing progeny occupy, such relationship being tempered to a large degree by varying oceanographic conditions? The fact that mortality in inshore waters is being increasingly compounded by artificial factors, especially by intensified harvest of subadult shrimp, dictates the need for a better understanding of each stock's spatial relationships.

TYPES OF FISHERIES

Each of the common Gulf shrimps is subject to utilization over a broad spectrum of life history stages. Large and small shrimp are utilized for food while the small ones are also important as sport fishing bait. In practically all inshore and offshore waters, commercial and noncommercial fisheries heavily exploit shrimp ranging from small juveniles to the largest adults. The degree to which activities of either interest prevail in a particular area depends largely upon local statutes.

Some States, for example, permit extensive commercial and noncommercial harvesting of small shrimp for human consumption, whereas others stringently enforce closed-season and minimum-size laws. Development of markets made possible by machinery that permits economical processing of small-size ("cocktail") shrimp has stimulated demands for this product. In inshore waters where size laws restrict commercial harvest of immature shrimp for table use, bait shrimp fisheries are now firmly established. These have exhibited such phenomenal growth in recent years that in some areas their collective income frequently exceeds that of the adjacent offshore fishery.

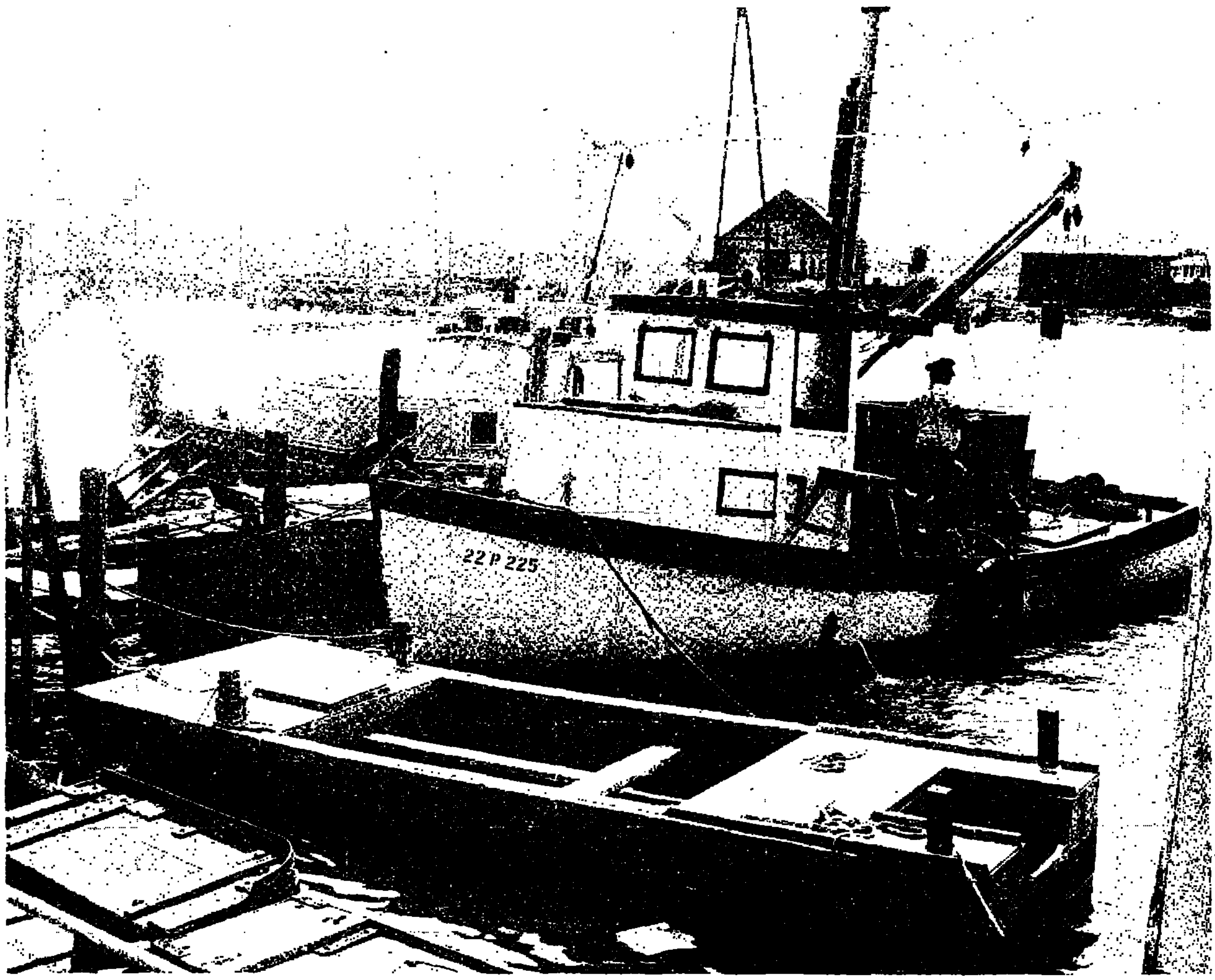

FIGURE 1.—Typical Gulf coast "inshore" shrimp trawler. (Such vessels are in the 30-ft. class, are single-rigged, and have a very shallow draft. This particular vessel has been adapted to a commercial bait-shrimp fishing operation.)

Distinct subunits of the Gulf of Mexico shrimp fishery may thus be defined as follows:

(1) Noncommercial fishery—composed of an untold number of sport fishermen taking mostly immature shrimp for personal use from shallow coastal waters. Fishing gear consists mainly of small otter trawls pulled with outboard-powered craft.

(2) Commercial bait fishery—comprising a fairly large number of professional fishermen taking immature shrimp, almost exclusively in inshore waters, solely for the purpose of supplying bait (live and dead) to a growing population of anglers. Except for the craft, which are inboard-powered and slightly larger, the gear is similar to that described for the noncommercial fishery (Inglis and Chin, 1959).

(3) Commercial fishery—representing the core of the Gulf shrimp industry and composed of a large number of professional fishermen who traditionally seek (1) the larger, mature shrimp inhabiting all coastal offshore waters and (2) small, immature shrimp in certain inshore waters. Except for a very small amount of processing waste which is ground into meal, all of this fishery's harvest is destined for human consumption, the larger shrimp being processed for sale in a fresh or frozen condition, the smaller shrimp being dried or canned.

CHARACTERISTICS OF COMMERCIAL SHRIMP FLEET

Trawlers (fig. 1) of very distinctive design and similar construction comprise a large and highly mobile shrimp fleet. Practically all units par-

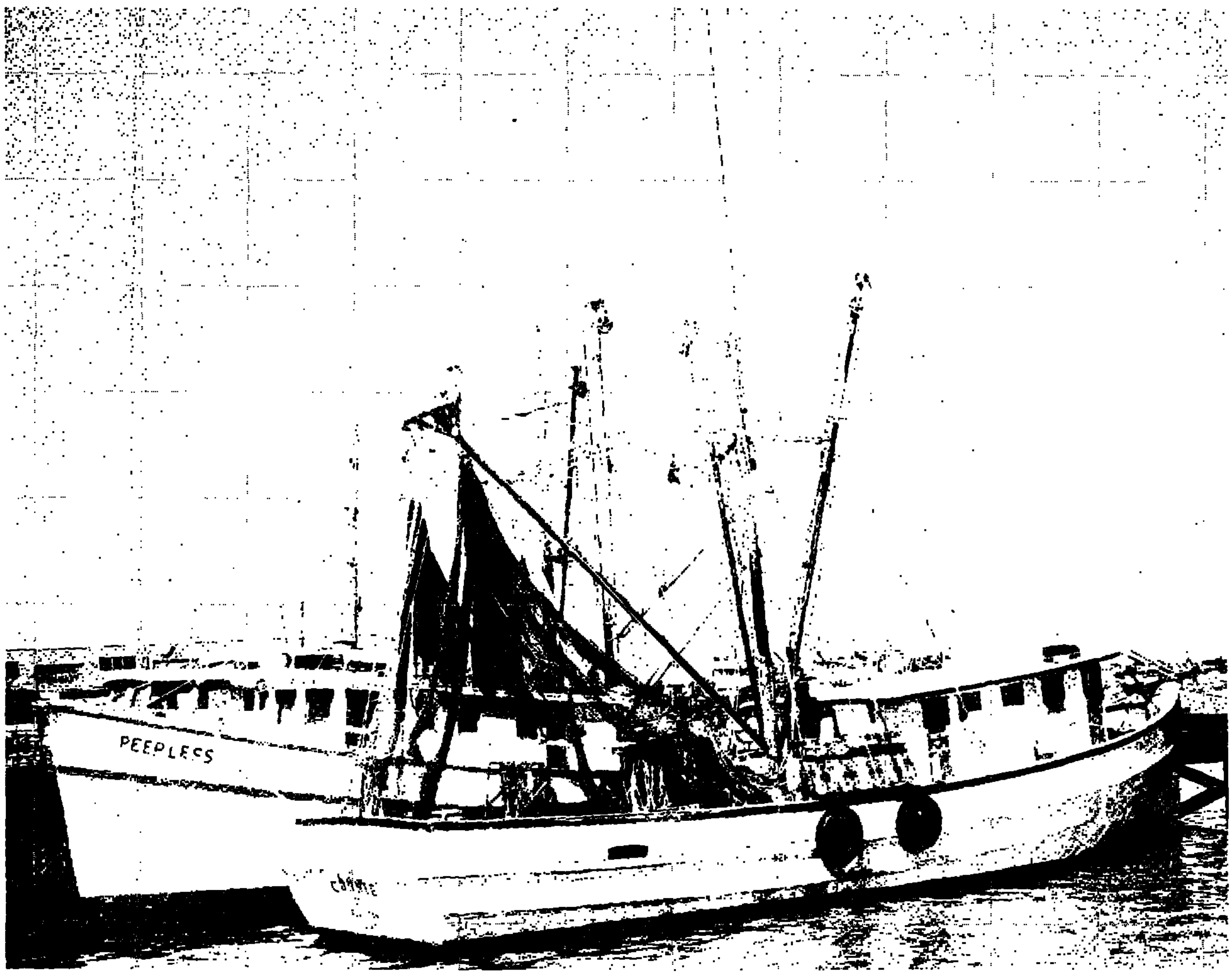

FIGURE 2.—Modern Gulf of Mexico "offshore" shrimp trawler. (This vessel was built in 1958, is 57 ft. long, has a capacity of 55 gross tons, a 150-horsepower engine, and is double-rigged.)

ticipating in inshore commercial fisheries are small, shallow-draft, low-powered boats of less than 5 tons net capacity. Most recent estimates place their number between three and four thousand.

Although shallow-draft like their inshore counterparts, shrimp trawlers (fig. 2) plying offshore waters are more sturdily constructed, have greater internal capacity, and are fitted with correspondingly larger power plants. The average sea-going trawler, qualified by an indication of slight increase in size during the period 1956–59, has a register length of about 57 feet, an internal capacity of 50 gross tons, and a power plant rated at 160 horsepower. Significantly, such specifications vary within rather narrow limits for a high proportion of the United States offshore fleet, whose size is estimated at between four and five thousand vessels.

Gulf shrimp trawlers (figs. 2, 3, 4) may be equipped with only the most essential and simplest of navigational devices. Smaller vessels (shorter than 45 feet) ordinarily possess no electronic aids, but many larger craft are fitted with radiotelephones, fathometers, automatic pilots, and radio navigation equipment. Radar, loran, and fish-finding devices will be found only on the largest trawlers.

Following a period of transition (1955–57), trawler rigging throughout the offshore fleet is now quite uniform. Whereas every vessel prior to 1956 was rigged to pull a single large trawl from a boom located amidship and projecting aft, most offshore trawlers are currently equipped to tow two smaller trawls from booms projecting laterally. Today, the greatest number of single-rigged vessels will be found in the inshore fleet; the capacity to pull two trawls being more or less restricted to larger vessels. Practically all sea-going trawlers constructed since 1958 are double rigged.

Among offshore fishermen there is unanimity of opinion that two sets of small gear are generally easier to handle than a single large gear. Although reducing vessel maneuverability to some extent, they increase speed and range of fishing operations, and lend stability to the vessel when trawling. Some disagreement prevails, however, as to the relative catching ability of two small trawls contrasted to that of one large trawl. It would appear that in some circumstances, disadvantages inherent in one arrangement might offset advantages in the other, resulting in a comparable efficiency from a production standpoint. Knake, Murdock, and Cating (1958) give a comprehensive review of double-rig design and operation.

For the most part, Gulf of Mexico shrimp trawls are quite uniform in shape and dimension. Single- and double-rig trawls are usually "flat" in design, "balloon" types being in the minority. In offshore trawling gear, cod-end mesh dimensions are more or less fixed at 2 or 2¼ inches stretch measure although shrinkage may reduce the average mesh size of individual nets to as

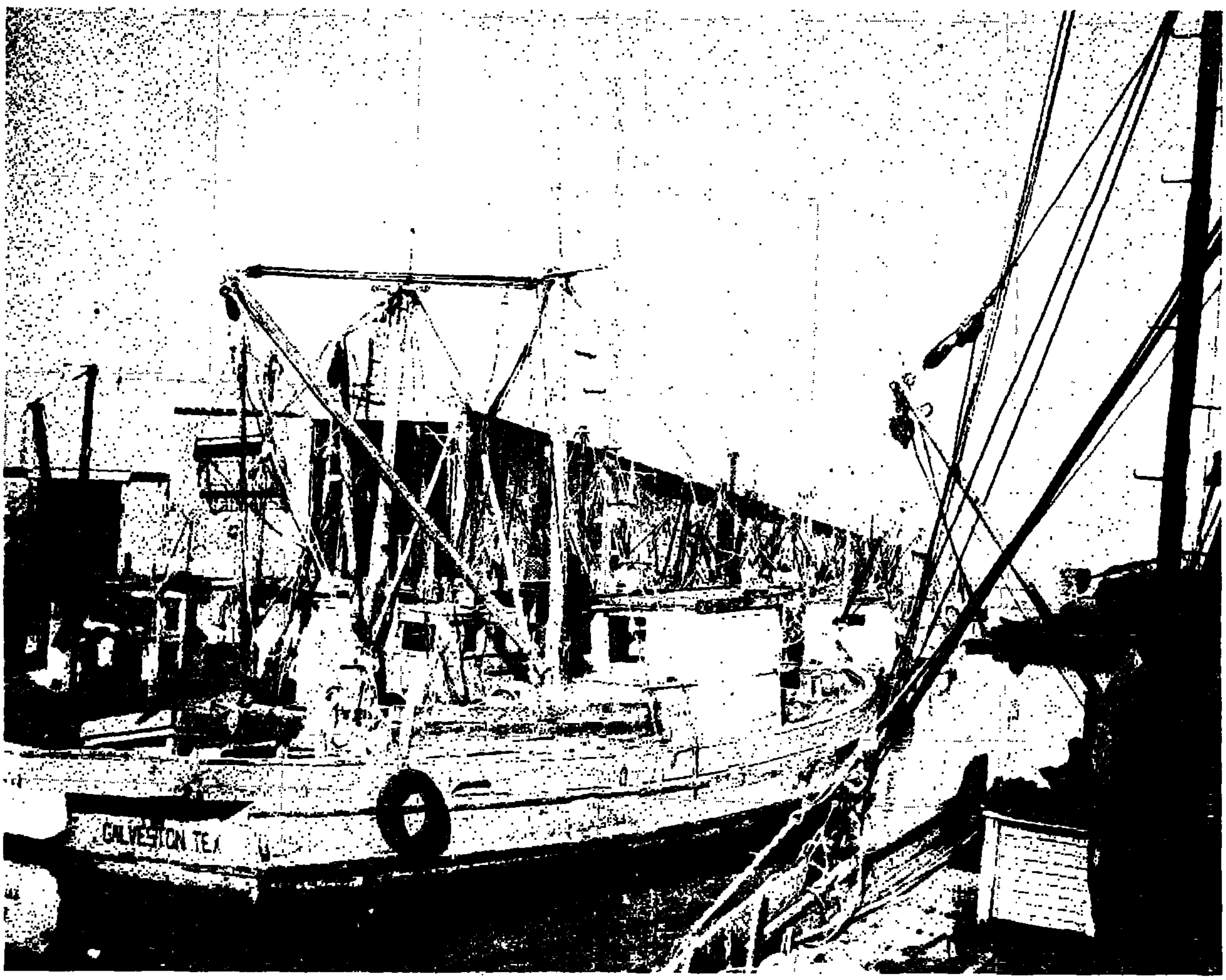

FIGURE 3.—Gulf shrimp trawler of earlier design used in nearshore and inshore fishing operations. (This vessel was constructed in 1943, is in the 40-ft. class, and is single-rigged.)

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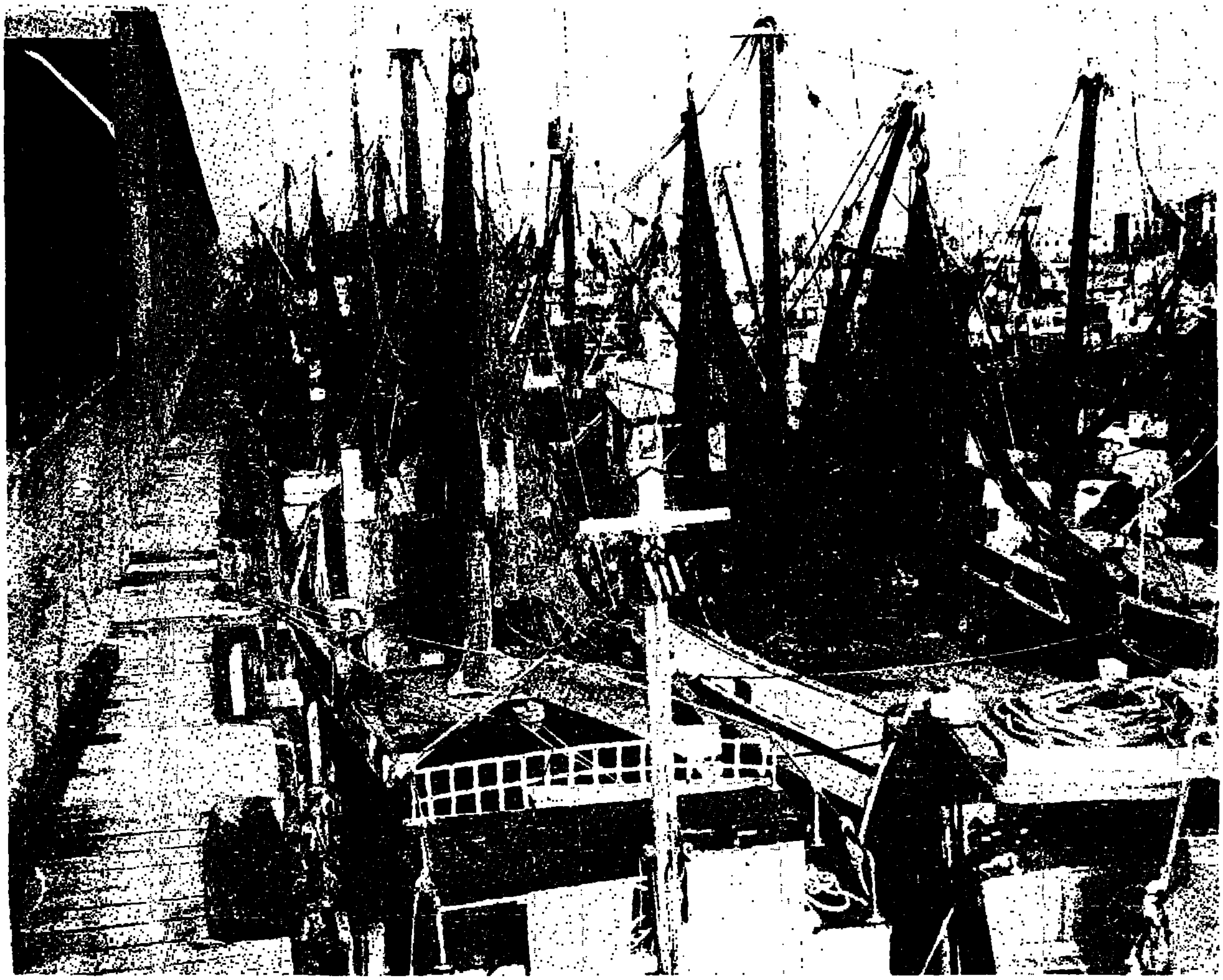

FIGURE 4.—Portion of shrimp fleet operating out of Galveston, Texas. (Both inshore and offshore, single-rig and double-rig trawlers are pictured.)

little as 1½ inches. Mesh size in inshore trawls varies little from 1½ to 1⅝ inches. Thread sizes range from 48 to 36 or less in the cod end and from 18 to 12 in the body and wings. Widths of nets along the lead line vary as the size of the vessel but most single-rig vessels fish 90- to 110-foot "flat" or 60- to 90-foot "balloon" nets, and most double-rig vessels fish 40- to 45-foot "flat" nets. In addition, almost every shrimp trawler is fitted with a small (10-foot) searching or "try" net that is towed from a stern davit. At least one innovation at the lead line, the so-called "tickler" chain, has become a standard net accessory. A new one, consisting of wooden discs loosely strung along the lead line, is said to increase net efficiency and greatly reduce gear losses on bad bottom. All nets are fished by means of two otter doors, to each of which a net wing is attached directly. The doors, in turn, are hung on a bridle which joins a single towing warp just forward of the net. A few fishermen are presently experimenting in offshore waters with modified beam trawls, several designs of which have met with success in the inshore bait shrimp fishery.

FISHING OPERATIONS

Length of fishing trip from departure to first landing ranges, in accordance with distance to the shrimping grounds, from 1 to more than 50 days. Whereas most trips along the upper Gulf coast are ordinarily of 1 to 5 days' duration, trips from United States ports to the distant Campeche grounds occasionally cover a 7-week period. In the latter situation, vessels may transship their catches on others periodically departing for home port and then continue to fish until they, too, leave the fishing grounds at the end of the period indicated. Depending on the species sought, only a relatively small proportion of the time away from port may be spent in actual fishing.

Routine operating procedure is to fish the main net or nets for 1½- to 5-hour periods depending on the density of shrimp. When shrimp exhibit patchy distribution and are scarce, the "try" net is fished continuously for 20- or 30-minute periods until its catch indicates that profitable quantities are available. Searching may frequently extend over as much as 5 days before the main nets are lowered into paying concentrations of market-size shrimp.

Most offshore fishing is at night, reflecting nocturnal activity of brown and pink shrimp which greatly increases their availability. An average night's fishing for these species covers about 10 hours during which time the nets are hauled two to five times, the mean being about three. White shrimp are generally fished during daylight hours, though in certain seasons they may be taken at night along with brown shrimp.

Catches are sorted and iced immediately or soon after removal from the net. If individual shrimp are large and not too numerous, they are beheaded prior to icing. In all other instances, heads remain intact until final processing ashore (fig. 5). Discards of undersized shrimp may be substantial at certain seasons, but accurate measures of their magnitude for any season or area have never been obtained.

More specific details of shrimp fishing and processing operations may be found in U.S. Fish and Wildlife Service (1958).

COMMERCIAL FISHERY STATISTICS

Accurate statistics of trawling operations and shrimp production in the Gulf of Mexico were not maintained prior to 1956. In that year a Gulf-wide statistical survey was inaugurated to provide a continuous flow of data that would facilitate studies of fishery economy and biology. It has since functioned with no major changes.

From the outset, however, survey resources permitted full statistical coverage only of that fishery centering on the commercial utilization of shrimp for human consumption. Operations and production in noncommercial and commercial bait fisheries have gone largely unrecorded. As a consequence, available statistics give an incomplete picture of total shrimp harvest in the Gulf coast area, and allow appraisal of only those portions of populations supporting what was defined earlier as the "commercial" fishery.

In studies using data obtained from sources such as the present survey, a review of survey design and techniques helps to place in proper perspective interpretations of analyses to which resulting data may be subjected.

DISTRIBUTION OF SURVEY PERSONNEL

Sixteen "statistical" or "port" agents record the day-to-day operations and production of the United States commercial shrimp fleet. Strategically located at landing ports around the Gulf—four in Florida, one each in Alabama and Mississippi, and five each in Louisiana and Texas—they canvass fishermen and processors for detailed information on location and amount of fishing, volume and composition of shrimp landings, and current marketing conditions, relaying it after necessary adjustment to Washington, D.C., for final processing. This consists of assembling the data on a monthly basis and publishing them in tables entitled "Gulf Coast Shrimp Catch by Area, Depth, Variety, and Size."

IDENTIFICATION OF FISHING GROUNDS

To facilitate geographical assignment of commercial trawling effort and hence classification of shrimp landings as to origin, the continental shelf of the Gulf of Mexico has been subdivided coastwise into 40 statistical subareas (fig. 6). Numbered counterclockwise beginning off the Florida Keys, these have been further subdivided from the shoreline to 45 fathoms into three depth zones, and grouped into eight coastal areas. Bottom areas for each statistical unit are given in table 1.

DISTRIBUTION AND AMOUNT OF FISHING EFFORT

One of two important variables involved in measuring demersal populations is the time spent trawling, referred to herein as fishing effort. It was and continues to be estimated by means of equivocal sampling and projection techniques. A system of interviewing trawler captains provides the basis for acquiring this and other information.

The number of trawler captains each port agent is able to interview, per week, may vary from none to 25 or more depending on his other duties, the likelihood of contacting captains during the hours he can set aside for this purpose, and the cooperation of the captains themselves. As time and circumstances permit, landing sites are visited and information concerning operations of their trawlers is solicited from those captains who are on hand. Data on areas and depths fished as well as time spent trawling at each fishing position are entered on a "Report of Interview." Also sought are the captain's observations of the number of other craft that operated in the vicinity of his trawler during its most recent trip.

It is then assumed: (1) that all trawlers landing at a given port operated in the same general area(s) and at the same depths as those for which data were secured by interview, and (2) that for all craft, a simple linear relationship obtains between amount of trawling time and size of corresponding

FIGURE 5.—Unloading catch of whole shrimp at a modern Gulf coast processing plant. Hopper (at far end of conveyor) is lowered into vessel's hold and facilitates unloading. (Ice is removed by means of bath situated midway along the conveyor which carries the shrimp to the processing facility.)

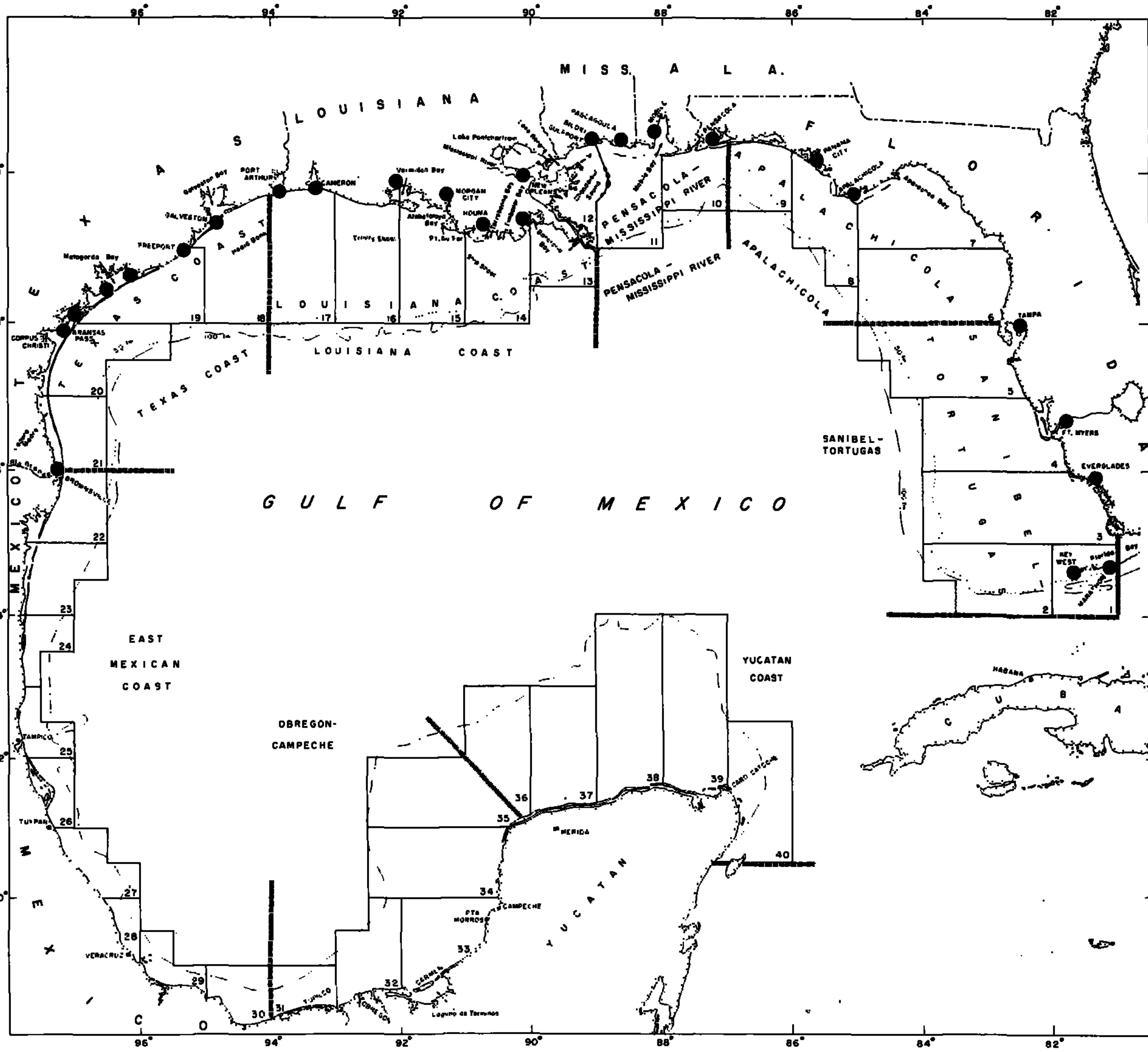

FIGURE 6.—System for coding origin of shrimp landings and position of commercial shrimping operations in the Gulf of Mexico. Shaded circles indicate principal landing ports.

catch. Fishing positions during concurrent trips of trawlers whose captains are not interviewed are projected and coded accordingly. The quantity of effort expended is calculated by merely dividing their known catches by a projection factor derived from catch-effort ratios of the vessels actually sampled for operating data. Effort is recorded to the nearest tenth in terms of days' trawling time or, more precisely, the total number of hours trawled divided by 24. "Day" then does not refer to a calendar day but merely represents a coding device.

Biases affecting the usefulness of effort data secured by this technique will be discussed in a later section, but two shortcomings should be pointed out here. The first concerns estimating nonproductive fishing effort. During certain seasons considerable amounts of searching ("try-netting") and fishing time are expended with negligible results. Under the present system, such activity goes unaccounted for since effort is estimated for and assigned only to vessel-trips for which a shrimp sale is recorded. Exclusion of this nonrewarded effort obviously leads to under-

TABLE 1.—*Projected bottom area off the Gulf of Mexico coast from Marathon, Florida, to Cabo Catoche, Yucatan* [1]

[Square nautical miles]

Coastal area and subarea [2]	Depth (fm.)			
	0–10	10–20	20–45	Total
Sanibel–Tortugas:				
1	1,410	45	60	1,515
2	650	1,045	1,355	3,050
3	2,400	2,080	3,120	7,600
4	1,230	1,665	2,575	5,470
5	950	1,420	2,755	5,125
Subtotal	6,640	6,255	9,865	22,760
Apalachicola:				
6	1,750	2,825	2,050	6,625
7	2,860	1,915	80	4,855
8	430	1,485	840	2,755
9	60	765	790	1,615
Subtotal	5,100	6,990	3,760	15,850
Pensacola–Mississippi River:				
10	330	1,315	805	2,450
11	895	950	1,030	2,875
12	185	----------	----------	185
Subtotal	1,410	2,265	1,835	5,510
Louisiana Coast:				
13	420	220	475	1,115
14	990	680	970	2,640
15	1,810	760	1,225	3,795
16	1,580	1,590	1,610	4,780
17	1,950	1,800	1,660	5,410
Subtotal	6,750	5,050	5,940	17,740
Texas Coast:				
18	1,770	1,370	1,660	4,800
19	885	1,815	825	3,525
20	360	965	1,710	3,035
21	285	610	1,350	2,245
Subtotal	3,300	4,760	5,545	13,605
East Mexican Coast:				
22	395	660	1,245	2,300
23	280	440	1,055	1,775
24	320	225	615	1,160
25	270	400	805	1,475
26	270	330	525	1,125
27	160	230	480	870
28	145	160	350	655
29	125	170	390	685
30	110	230	540	880
Subtotal	2,075	2,845	6,005	10,925
Obregon–Campeche:				
31	130	605	385	1,120
32	565	935	655	2,155
33	2,485	1,375	835	4,695
34	1,935	1,810	2,230	5,975
35	450	1,710	5,560	7,720
Subtotal	5,565	6,435	9,665	21,665
Yucatan Coast:				
36	235	530	2,055	2,820
37	835	1,460	2,765	5,060
38	920	1,260	4,625	6,805
39	965	1,140	3,775	5,880
40	320	585	875	1,780
Subtotal	3,275	4,975	14,095	22,345
Gulf of Mexico	34,115	39,575	56,710	130,400

[1] Source: Charts issued by U.S. Coast and Geodetic Survey and U.S. Navy Hydrographic Office. Untrawlable bottom not delineated.
[2] Refer to figure 1.

estimates of individual vessel and fleet trawling time. Secondly, the assumption that all vessels operating out of or landing at a particular port fish in close proximity may not always be valid. It is acknowledged, however, that portions of the fleet fishing a specific locale usually tend to aggregate on shrimp concentrations occurring there. The question of how fishing positions and effort are assigned to vessels operating in periods during which interview data cannot be obtained remains unreconciled.

LANDINGS

Equivalent in importance to the variable, "effort," is the corresponding variable, "catch." The present statistical survey attempts to account for all commercial shrimp landings through a daily or weekly canvass of processing plants. From dealers' receipts, port agents transcribe the details of landings for each vessel-trip on a "Shrimp Schedule" form. An estimated 97–100 percent of all Gulf shrimp landings are so reported each year. Contrasted to other types gathered by the survey, data of commercial landings may be considered complete and, in addition, quite precise, since they are factors in business transactions. Unfortunately, recorded landings may not always represent the amount of shrimp actually caught. This is usually attributable to the periodically widespread practice of discarding at sea small or otherwise undesirable shrimp.

Origin

Each landing is coded according to its known or "estimated" origin in the same manner as that described earlier for coding a vessel's fishing position.

Prorating landings by depth of capture is one procedure here that could lead to misrepresentation of tabulated data. If a captain states that he trawled in several depth zones but cannot specify how his trawling time and catches were apportioned among them, his total effort and corresponding catch will be coded, respectively, as having been expended in and taken from the zone of greatest depth fished. Accumulations of catch-by-depth data obtained by interview for a very small proportion of the commercial shrimp fleet, and by projection therefrom for the greater part of the fleet, have limited usefulness in depth distribution studies of commercial species. Some will be falsely described as having been available in larger quantities over a greater depth range than they actually were.

Species Composition

Along much of the Gulf coast, processors distinguish between commercial varieties commonly occurring together by assigning slightly different ex-vessel prices to each. A breakdown by species for each landing is thus obtained automatically when transcribing landing data from dealers' records.

In some areas, however, closely related species are not differentiated by price. Here mixed landings of two species may be described as entirely composed of one or the other, resulting in distorted catch figures for both. Examples of areas in which this situation periodically exists are southwest Florida and Texas. In the former area, *Trachypeneus* spp., which have little commercial value because of their small size, frequently enter pink shrimp landings in small amounts. In contrast, pink shrimp often dominate spring landings at Freeport, Aransas Pass, and perhaps other Texas ports, being purchased and entering dealers' records as brown shrimp. The degree to which past landing data from these and other areas are so biased has not been determined. An attempt is being made to rectify this problem by establishing a Gulf-wide catch-sampling program.

No evidence of preference on the part of the commercial fleet for a particular species (in situations where more than one were equally available) was detected in the present study.

Size Composition

Ex-vessel sales are prorated on the basis of each landing's size composition as well as its species composition, with larger shrimp bringing higher prices. Landings are thus recorded according to the sizes purchased from the fisherman, the breakdown being carried through to final tabulation.

Although such a practice might appear to obviate the need for sampling shrimp landings to secure a picture of population size or age structure, closer scrutiny raises some doubt as to the commercial data's usefulness for this purpose. Comparability of size composition data from different Gulf areas may be suspect due to the following biases of unknown degree: (1) varying minimum-size laws; (2) differential dealer and gear selectivity; (3) changing prices; and (4) different grading methods. Further discussion of these factors will be deferred to a later section.

CONVERSION FACTORS

As a convenience to commercial interests, shrimp landing statistics are compiled in terms of "tail" or headless weight. In keeping with the ecological convention of maintaining unit correspondence between yield and biomass, all landings reported herein have been converted to whole or "heads-on" weight. This was accomplished by applying the factor 1.68 to catch data published for each common species.

Unfortunately, the statistical reliability of this factor has not been established. Moreover, current studies indicate that among commercial Penaeidae, the factors relating headless to whole weight vary widely between species and to a lesser extent between sexes and from season to season within species, and are measurably less than formerly believed. Ratios between total and tail weight for the brown, pink, and white shrimp and seabob (sexes combined over all seasons) have been found to deviate only slightly (coeficients of variation are 3 percent or less) from 1.61, 1.60, 1.54, and 1.53, respectively. These represent significant departures from the traditional 1.68.

Conversion from headless to whole weight would not constitute a problem if all shrimp were landed and weighed heads-on. Published data could be restored to their original and desired state by simply applying the reciprocal of whatever factor was used to convert them to heads-off units. But commercial shrimp are not handled in uniform fashion around the Gulf. Many are landed heads-on, many heads-off, the former being converted to heads-off units immediately upon being landed. The degree to which either practice is followed in each area is unknown and, consequently, so is the relative accuracy of adjusted landings data. If landings heads-on predominate, the inaccuracy of data converted using a generalized factor will be minimal. But if heads-off landings are the rule, data converted using the same factor (1.68) will not reflect true catch (heads-on) weights for all species. In either case, landing data will not be comparable from area to area and, in some instances, from port to port within an area.

Further complications arise if conversion of catch-by-size data is desired. All such data are recorded in terms of number of headless shrimp per pound, with eight or nine "size-count" categories in common use along the Gulf coast. Notwithstanding the possible influence of biases noted in the foregoing section, any conversion of landings within size-count categories would necessitate a corresponding change in the size-count scale. Size-count notation for headless and corresponding whole shrimp is given in table 2.

TABLE 2.—*Numbers per pound of headless and corresponding whole shrimp. A constant ratio of 1.68 between total and "tail" weight is assumed*

Number of headless shrimp per pound	Weight per "tail" (oz.)	Weight per whole shrimp (oz.)	Approximate number of whole shrimp per pound
10	1.60	2.69	6
12	1.33	2.23	7
15	1.07	1.80	9
18	.89	1.50	11
20	.80	1.34	12
25	.64	1.08	15
30	.53	.89	18
35	.46	.77	21
40	.40	.67	24
50	.32	.54	30
60	.27	.45	35
68	.24	.40	40
75	.21	.35	45

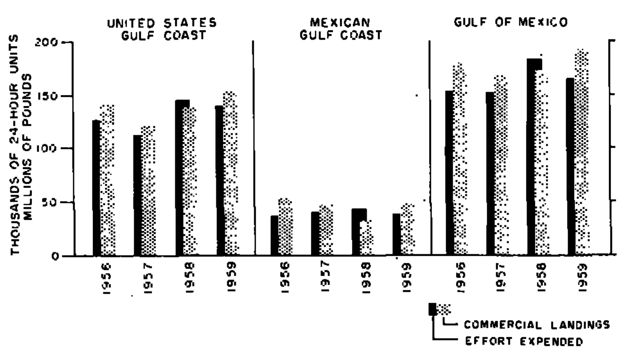

FIGURE 7.—Effort expenditure and total commercial landings by the United States shrimp fleet, Gulf of Mexico, 1956–59.

FISHING EFFORT AND TOTAL SHRIMP YIELD, 1956–59

For the years 1956–59, annual fishing effort on Gulf of Mexico shrimp grounds deviated only slightly from an average of 169 thousand days (fig. 7, table 3). Corresponding shrimp harvests exhibited no startling trend, fluctuating between 167 and 193 million pounds with a maximum deviation from the 4-year mean of only 8 percent. Effort expended in and catches from foreign Gulf waters averaged 23 and 22 percent, respectively, of overall Gulf of Mexico totals (tables 3 and 4).

Another look at overall effort and catch data after they are separated into their spatial and

TABLE 3.—*Fishing effort expended by United States commercial shrimp trawlers in the Gulf of Mexico, 1956–59* [1]

[24-hour units]

Coastal area	Year			
	1956	1957	1958	1959
Sanibel-Tortugas:				
Inshore	0	0	0	0
Offshore	17,519.0	17,335.9	20,689.9	17,097.9
Total	17,519.0	17,335.9	20,689.9	17,097.9
Apalachicola:				
Inshore	1,692.6	2,601.4	2,564.3	1,799.6
Offshore	2,262.5	1,739.3	1,686.5	1,382.0
Total	3,955.1	4,340.7	4,250.8	3,181.6
Pensacola-Mississippi River:				
Inshore	12,780.8	12,669.8	12,530.3	15,547.2
Offshore	12,871.6	10,260.6	6,941.3	9,654.8
Total	25,652.4	22,930.4	19,471.6	25,202.0
Louisiana Coast				
Inshore	15,700.6	13,112.4	20,209.4	21,405.8
Offshore	30,225.4	18,103.0	32,554.3	32,368.9
Total	45,926.0	31,215.4	52,763.7	53,774.7
Texas Coast:				
Inshore	2,267.7	3,927.0	4,726.7	4,157.7
Offshore	31,801.7	33,699.3	41,859.1	35,057.7
Total	34,069.4	37,626.3	46,585.8	39,215.4
United States Gulf Coast:				
Inshore	32,441.7	32,310.6	40,030.7	42,910.3
Offshore	94,680.2	81,138.1	103,731.1	95,561.3
Total	127,121.9	113,448.7	143,761.8	138,471.6
East Mexican Coast:				
Inshore	0	0	0	0
Offshore	14,375.4	17,267.0	24,191.6	17,611.3
Total	14,375.4	17,267.0	24,191.6	17,611.3
Obregon-Campeche:				
Inshore	0	0	0	0
Offshore	22,235.8	21,490.7	16,899.2	19,709.1
Total	22,235.8	21,490.7	16,899.2	19,709.1
Mexican Gulf Coast:				
Inshore	0	0	0	0
Offshore	36,611.2	38,757.7	41,090.8	37,320.4
Total	36,611.2	38,757.7	41,090.8	37,320.4
Total Gulf of Mexico:				
Inshore	32,441.7	32,310.6	40,030.7	42,910.3
Offshore	131,291.4	119,895.8	144,821.9	132,881.7
Total	163,733.1	152,206.4	184,852.6	175,792.0

[1] Breakdown of fishing effort according to amounts expended seasonally in inshore and offshore waters is made in appendix table 1.

TABLE 4.—*Commercial shrimp landings by United States trawlers, Gulf of Mexico, 1956–59* [1]

[Thousands of pounds]

Coastal area and species	Year			
	1956	1957	1958	1959
Sanibel-Tortugas:				
Brown	0	0	1.3	0.7
Pink	21,392.6	16,688.8	24,698.8	13,914.7
White	0	0	0	2.0
Seabobs	0	0	0	0
Total	21,392.6	16,688.8	24,700.1	13,917.4
Apalachicola:				
Brown	285.0	560.3	992.2	1,240.5
Pink	1,337.7	898.0	2,500.8	11.1
White	852.3	1,281.6	1,358.0	582.9
Seabobs	79.7	348.9	16.7	229.8
Total	2,554.7	3,088.8	4,867.7	2,064.3
Pensacola-Mississippi River:				
Brown	16,395.5	15,284.7	8,793.4	19,103.8
Pink	799.9	881.9	194.4	281.1
White	6,984.5	3,181.9	4,967.9	7,513.4
Seabobs	4.7	0	0.8	16.3
Total	24,184.6	19,348.5	13,956.5	26,914.6
Louisiana Coast:				
Brown	21,245.4	18,572.8	16,424.9	27,260.5
Pink	2.6	0	18.9	10.2
White	28,741.7	10,526.4	23,971.4	24,066.4
Seabobs	1,521.3	742.7	1,826.3	3,708.1
Total	51,511.0	29,842.3	42,241.5	55,045.2
Texas Coast:				
Brown	37,318.9	49,008.0	40,477.0	49,564.5
Pink	62.4	7.0	126.3	15.9
White	4,410.4	3,568.9	11,475.0	8,259.1
Seabobs	0	0.2	2.2	0
Total	41,791.7	52,584.1	52,080.5	57,839.5
United States Gulf Coast:				
Brown	75,244.8	83,425.8	66,688.8	97,170.0
Pink	23,595.2	18,475.7	27,539.2	14,233.0
White	40,988.9	18,558.8	41,772.3	40,423.8
Seabobs	1,605.7	1,091.8	1,846.0	3,954.2
Total	141,434.6	121,552.1	137,846.3	155,781.0
East Mexican Coast:				
Brown	16,374.0	23,760.2	18,423.0	18,511.0
Pink	4.7	0	10.1	16.0
White	48.3	2.5	259.7	241.6
Seabobs	0	0	0	0
Total	16,427.0	23,762.7	18,692.8	18,768.6
Obregon-Campeche:				
Brown	751.1	398.2	815.5	1,560.6
Pink	24,541.1	21,281.0	13,430.3	16,402.6
White	19.6	86.4	358.6	202.3
Seabobs	0	0	0	0
Total	25,311.8	21,765.6	14,604.4	18,165.5
Mexican Gulf Coast:				
Brown	17,125.1	24,158.4	19,238.5	20,071.6
Pink	24,545.8	21,281.0	13,440.4	16,418.6
White	67.9	88.9	618.3	443.9
Seabobs	0	0	0	0
Total	41,738.8	45,528.3	33,297.2	36,934.1
Total Gulf of Mexico:				
Brown	92,369.9	107,584.2	85,927.3	117,241.6
Pink	48,141.0	39,756.7	40,979.6	30,651.6
White	41,056.8	18,647.7	42,390.6	40,867.7
Seabobs	1,605.7	1,091.8	1,846.0	3,954.2
Total	183,173.4	167,080.4	171,143.5	192,715.1

[1] Breakdown of landings according to amounts taken seasonally from inshore and offshore waters is made in appendix tables 2-4.

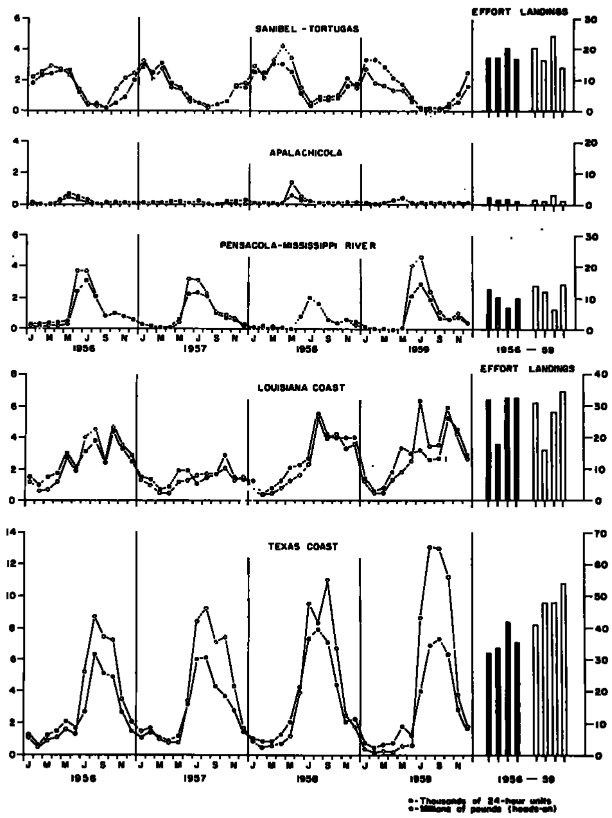

FIGURE 8.—Effort expenditure and commercial shrimp landings by United States trawlers operating off the United States Gulf coast, 1956–59.

temporal components reveals, however, significant fluctuations and trends within coastal units. For instance, effort and total yield exhibited distinct seasonal patterns in the Sanibel-Tortugas, Pensacola-Mississippi River, Louisiana Coast, and Texas Coast offshore areas. Total landings periodically dropped to unfavorable lows in the Sanibel-Tortugas (1957, 1959), Pensacola-Mississippi River (1958), and Louisiana Coast (1957) areas (fig. 8); established a significant upward trend in the Texas Coast area; and declined appreciably over the 4-year period in the Obregon-Campeche area. Annual effort expenditure and yield were comparatively stable in the Apalachicola area (figs. 8 and 9). Waters off the Texas and Louisiana coasts ranked, in that order, as top shrimp producers.

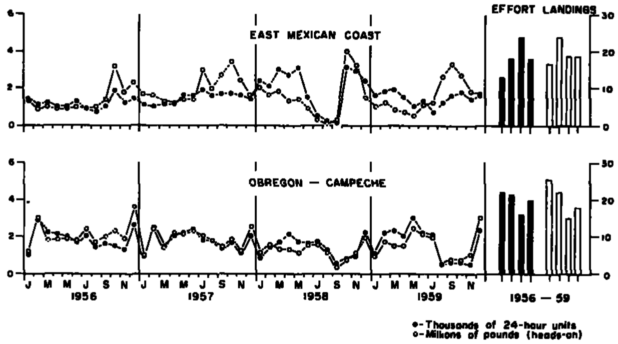

FIGURE 9.—Effort expenditure and commercial shrimp landings by United States trawlers operating off the Mexican Gulf coast, 1956–59.

The sinuous nature of monthly yield curves indicates to some extent the seasonal reproductive patterns typical of the short-lived penaeid shrimps. High correspondence between curves of effort and yield generally reflects the techniques used to estimate the former from the latter.

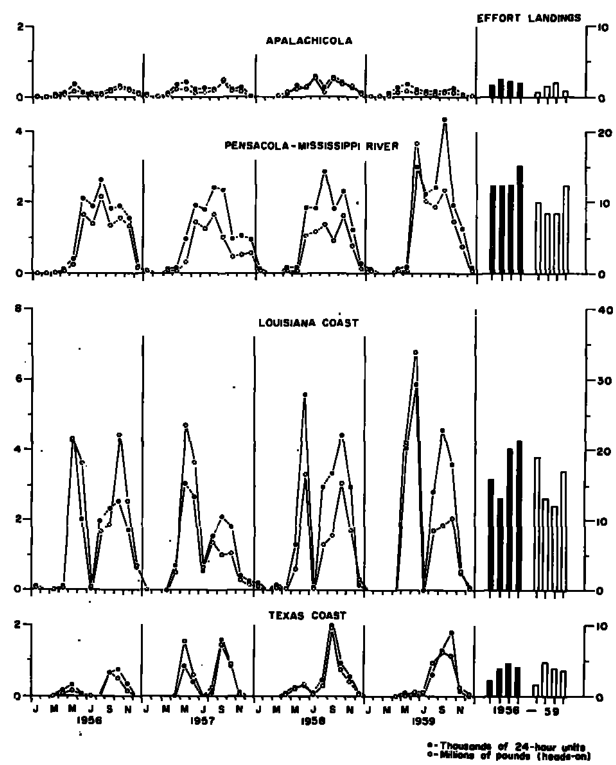

FIGURE 10.—Effort expended in and commercial shrimp landings from inshore waters along the United States Gulf coast, 1956–59.

Exploitation of "table" shrimp by the United States fleet in inshore (estuarine) waters bordering the Gulf of Mexico is restricted to northern coastal areas (table 3). Practically all landings from such waters consist of small shrimp, some of which are dried, but most of which are now economically machine-processed for canning.

Of the four northern Gulf coast areas designated in this report, the Louisiana Coast area claims the greatest acreage of inshore waters. This is reflected in its inshore shrimp production which, during 1956–59, annually exceeded that of any other area (fig. 10). Note, however, that while inshore landings from adjacent areas exhibited little tendency toward marked fluctuation, those from the Louisiana marshes did, with adverse lows occurring in 1957 and 1958.

A breakdown of landings by years, coastal area (offshore and inshore waters combined), and species reveals major differences in amounts of the various shrimps taken commercially from each area (table 4). Relative to those of other species belonging to the same taxon and occupying the same range, fluctuations in a particular species population as evidenced by its yield may be masked when dealing with data of composite landings. Obviously, the degree to which fluctuations in each population comprising a multispecies fishery govern overall yield patterns depends largely upon how much the species overlap in occurrence. Attempts to reconcile unusual drops in total yield must therefore take into account variations in the catches of each species contributing to it. Moreover, they must rely on available commercial statistics to depict accurately in space and time, the population size and structure.

METHODS OF POPULATION APPRAISAL

Before attempting to determine how commercial fish and shellfish populations react to exploitation and a varying environment, suitable indicators of population size and composition must be obtained. The capacity of commercial statistics to provide these is wholly contingent upon the nature of the species involved and the mechanics underlying its exploitation.

FISHABLE BIOMASS INDEX

Definition and Theory

Shrimp, being demersal organisms capable of instantaneous but limited vertical and lateral movement, are highly susceptible to capture by bottom trawls of all types. The average minimum size of shrimp retained by "standard-mesh"[2] trawls sets the lower limit of what is referred to herein as the fishable population. Hence the *fishable biomass* is that fraction (in terms of weight) of a commercial population, which comprises those individuals vulnerable to capture with the gear commonly used by the fishery. Whether or not landing data include everything caught by the gear employed is a matter of vital concern. It is recognized that even though standard-mesh trawls may be used at all times, the minimum size of shrimp *selected* from their catches, not the minimum size *actually caught*, sets the lower limit of that part of the overall population about which corresponding commercial statistics can give any information. The extent to which selection practices prevail varies in unpredictable fashion from area to area and season to season. Departures from the definition of fishable biomass given above can also be attributed to fishing practices wherein standard-mesh gear is employed, but aggregations of shrimp of a specified minimum size are first sought out by trial fishing. Although this circumvents sorting catches predominated by small shrimp, and thereby mitigates the discard problem, the resulting statistics are quite restrictive as to the information they give about the whole population.

Assume now that the geographic range of a given shrimp population is approximately known. If the manner in which commercial trawls are deployed over it during equivalent time increments is also known, an index to the true probability with which a standard unit of the fishable biomass will have been removed can be derived for each increment. A factor proportional to the *average* harvestable biomass is thus obtained when the corresponding (total) commercial catch is divided by this "probability-of-capture" index. The latter has been termed the "effective overall fishing intensity" ($\tilde{f}$) by Beverton and Holt (1957) who discuss its theoretical aspects and derivation. For any time interval and population, it is the weighted average of all fishing intensities calculated for each trawling subarea included in the population's range. The fishing intensity in any subarea is simply the ratio between the amount of effort expended therein and the subarea's size. Weighting factors are the subareas' corresponding biomass indices. Since the ratio between catch (in weight) and effective overall fishing intensity is proportional to the fishable biomass, it follows that the fishing intensity is also proportional to the fishing mortality parameter, an important consideration in attempts to evaluate the latter.

To obtain biomass indices directly, Gulland (1955) uses a method almost identical mathematically to that introduced by Beverton and Hold (1957). For a short interval of time, say a month, catch (in weight)-effort ratios are calculated for each subarea within a species range. A weighted average catch-effort ratio is then determined, the sizes of each subarea consitituting the weighting factors. This ratio, the same as that derived above, is theoretically proportional to the size of the population's exploitable fraction, and hence is termed a fishable biomass index. In effect, it is a density estimator in which the effects of uneven distribution of fishing effort are eliminated by a process analogous to stratified sampling.

Error and Bias

Many factors, however, operate to alter the theoretical utility of this index. Some of these, namely error and bias associated with compiling landing and effort data, have already been discussed. Controlling their influence entails refinement of sample projection and data collection techniques. Superimposed on compilation defects, however, are still others which, because of their inconstancy, are very difficult to cope with. Two classes may be readily distinguished.

The first affects the comparability of effort statistics and stems from differences in trawler fleet composition along with nonuniformity of operating conditions. All trawlers are not equally powerful, are not manned by equally efficient crews, and do not operate under identical climatological and sea conditions. For instance, since gear efficiency is directly related to ground speed (up to some optimum point), under conditions of uniform shrimp density, identically powered and rigged vessels operating against the current would normally be expected to make smaller catches per unit time than those operating with it. The writer has observed a low resultant ground speed

[2] The term "standard-mesh" is defined as that size mesh most commonly used in a particular fishery, be it inshore or offshore. Both fisheries are treated separately throughout this report with 1⅝-inch mesh being considered the standard inshore, 2¼-inch mesh the standard offshore. A major requirement is that this average mesh size remain constant.

(water speed minus velocity of opposing surface current) to render forward progress of trawling gear almost negligible. Under the same conditions but traveling in the opposite direction, indications were that too high a resultant ground speed kept the gear off the bottom a high proportion of the time, even at reduced power settings. This was an extreme situation involving operations in deep water (150 fm.) and a very confused sea, but it does serve to illustrate that there is always a "best" combination of factors that results in maximum efficiency for any piece of gear. It would seem quite unlikely that this combination is attained in every fishing operation (see also Dickson, 1961). Also, all other factors being equal, larger trawlers with greater horsepower ratings tend to outfish their lesser counterparts (U.S. Fish and Wildlife Service, 1959). Such factors interacting to varying degree and generating operational biases of unknown magnitude, conceivably play a major role in governing the accuracy of the fishable biomass index.

At least one form of operational bias, that due to differential power of trawlers, has been the subject of detailed study. Gulland (1956) provides a method for its elimination if accurate effort and catch data can be obtained for individual vessels on a per unit space and time basis. As already noted, however, effort statistics used in the present study were projected from sample interview data on the premise that all trawlers are equally efficient. Such treatment automatically nullifies "standardization" of available effort data.

The second class of defects includes miscellaneous error or bias arising from natural factors. For example, patchy distribution of shrimp could result in highly variable catches by individual vessels despite uniform effort, the magnitude of corresponding "sampling error" being such that index precision is greatly diminished. Also, "saturation" of trawls by the species sought as well as by associated fauna, e.g., other invertebrates and fishes, reduces gear efficiency and thereby compounds the inaccuracy of the population density index. Finally, all of a population's fishable biomass may not be available because rough bottom and sundry impediments preclude trawling over portions of its geographic range.

Assumptions

Once the purposes of a statistical survey are clearly defined, an objective should be to minimize the combined effects of sampling error and bias on the estimates being sought. This implies that, in situations such as described here, detailed information on: weather and sea conditions; trawling course with respect to wind and current; water speed; vessel size, horsepower, gear reduction ratio, and screw specifications; fishing gear specifications; incidence of miscellaneous fauna in the catch; etc. should accompany basic effort and catch data, all recorded on a per vessel-trip, per unit space and time basis. Appropriate adjustments would eliminate unwanted effort bias to a substantial degree. Refined catch-effort data would permit a more sophisticated statistical treatment and hence a minimizing of sampling error. Higher quality biomass indices would result.

The condition of available effort data plus the lack of information that would allow adjustment for bias and reduction of error, thwarted attempts to rectify defects in the data used to construct biomass indices. As a consequence, some assumptions regarding the magnitude and effect of error and bias associated with operational and natural factors had to be made. Thus, acknowledged uniformity in size composition of major portions of both inshore and offshore trawler fleets led to the conclusion that bias due to differential efficiency of operating unit was probably not too great. Effects of varying crew ability, climatological and sea conditions, and contagious distribution of shrimp were, within each of the smallest time increments employed, assumed random with zero expectation. And, any shrimp otherwise vulnerable but unavailable because of untrawlable bottom presumably comprised a constant fraction of the total shrimp biomass. Since most interest attached to population trends generated over a 4-year period, an overriding assumption was that the direction and magnitude of all error or bias remained constant for each time interval within that period.

Computation

Calculation of monthly indices for those portions of a population's fishable biomass that occupied offshore areas proceeded according to Gulland's (1956) technique. The seaward limit of each species "commercial" range was arbitrarily set at the 45-fathom contour, this decision was based upon catch statistics (appendix), depth distribution studies (e.g., Burkenroad, 1939), and miscellaneous observations (e.g., Springer and Bullis, 1956). To simplify calculations, three subsubareas or depth zones were designated for each coastal subarea, viz., 0–10, 11–20, and 21–45 fathoms. Catch and effort totals for each were obtained by combining data from included 5-fathom depth zones. In a few instances where no effort was expended in a particular depth zone, information derived by consolidating data from adjacent zones was assumed indicative of population status in that zone.

To illustrate the mechanics of index computation, let us select for treatment some statistics typical of the Gulf coast shrimp fishery. Table 5 gives published commercial effort and brown shrimp catch figures (June 1958) for each of 12 unequal subsubareas comprising the Texas Coast offshore trawling grounds. If it is assumed that these statistics are reasonably accurate and that the biomass as manifested by the ratio of catch to effort (d_i) was constant within each of the i subsubareas throughout the period indicated, then, from the theory outlined above, the best index of *overall* population biomass is the weighted mean catch-effort ratio for each subsubarea. Hence

$$\sum_i w_i d_i = 0.68 = \text{Fishable Biomass Index}$$

where w_i, the areal weighting factor, is the proportion of the total occupied area represented by the i^{th} subsubarea. The following identity relates, in terms of their notation, the corresponding concepts of Gulland (1955, 1956) and Beverton and Holt (1957):

$$\frac{\sum_i Y_i}{\bar{f}} = \frac{\sum_i Y_i}{\dfrac{\sum_i f_i\left(\dfrac{Y_i}{f_i}\right)}{\sum_i \dfrac{Y_i}{f_i}}} = \frac{\sum_i Y_i}{\dfrac{\sum_i Y_i}{\sum_i \dfrac{Y_i}{f_i}}} = \sum_i \frac{Y_i}{f_i}$$

$$= \frac{\sum_i a_i \dfrac{Y_i}{g_i}}{\sum_i a_i} = \frac{\sum_i a_i d_i}{\sum_i a_i} = \sum_i w_i d_i$$

where $f_i = g_i / a_i$ is the fishing intensity in the i^{th} subsubarea; Y_i/f_i is the index of fishable biomass in the i^{th} subsubarea; and the remaining notation is as given in the heading of table 5.

TABLE 5.—*Commercial statistics from the offshore (brown) shrimp fishery in the Texas Coast area, June 1958*

Statistical subarea	Depth subsubarea (fm.) i	Area (sq. naut. miles) a_i	Areal weighting factor w_i	Total effort (24-hr. units) g_i	Total catch (1,000's of lb.) Y_i	Total catch / Total effort d_i
18	0–10	1,770	0.13	246.5	64.6	0.26
	11–20	1,370	.10	731.6	822.8	1.13
	21–45	1,660	.12	6.1	6.2	1.02
19	0–10	885	.06	149.8	38.0	.25
	11–20	1,815	.13	685.5	500.1	.73
	21–45	825	.06	3.6	1.7	.47
20	0–10	360	.03	148.1	140.1	.95
	11–20	965	.07	1,694.5	1,652.1	.98
	21–45	1,710	.13	18.0	10.6	.60
21	0–10	285	.02	6.8	1.2	.18
	11–20	610	.05	284.0	200.9	.71
	21–45	1,350	.10	396.5	236.2	.60
Area totals		13,605	1.00	4,371.0	3,674.5	.84

The value obtained, 0.68, may also be referred to as the "catch per unit effective fishing intensity" to distinguish it from the "simple catch per unit fishing effort", 0.84, the value obtained and employed as a population index if, as would have been necessary had effort and catch statistics not been available on a subsubarea basis, the biomass were assumed uniformly distributed throughout the coastal area being studied. Had the latter situation prevailed, an overall population level too high by about 24 percent would have been indicated.

Since commercial fishing effort tends to concentrate in areas of greatest density, the simple catch-effort ratio usually "overestimates" overall population density. Actually, this ratio would constitute as good an index of population size as that between catch and intensity if the effort distribution bias remained constant. This not being the rule, the catch-intensity ratio thereby establishes itself as the more efficient and consistent of the two possible estimators. In cases where there is no alternative but to use the simple catch-effort ratio as a biomass index, a high proportion of its differential between successive time intervals could just as easily be attributed to changes in effort distribution as to real changes in population biomass.

Crude monthly indices of biomass during those stages of population development occurring in inshore waters were secured by calculating the ratio between total commercial catch and total unweighted effort as recorded for such waters. These totals were obtained for each coastal area by summing monthly catch and effort data over specific inshore waters included therein. Such indices are termed "yields per day's trawling" to distinguish them from their offshore counterparts, "fishable biomass indices."

SIZE-AGE STRUCTURE: FISHABLE BIOMASS

Commercial landings classified according to the sizes of shrimp comprising them afford some insight into fishable biomass age structure only if the landings represent the defined biomass with reasonable accuracy. Any effects of differential bias due to (1) fisherman or gear selectivity; (2) nonuniform distribution of shrimping effort with respect to stratification by age within the fished population; (3) minimum-size restrictions; and (4) varying grading practices must be assumed negligible, or at least constant in time.

Totals for the seven or eight size categories into which commercial shrimp landings are separated give weight frequencies whose modes, it is believed, crudely delineate the age classes, or "*broods*", making up the exploited biomass. The term "brood" is used to define groups of shrimp, each member of which is produced (i.e., spawned and hatched) within a designated interval of time. These intervals are specified as covering periods of heightened spawning activity and extend roughly 1 month on either side of points in time at which modal spawning occurs. Note that modal spawning does not necessarily recur at precisely the same point in successive (corresponding) seasons.

Monthly weight frequency distributions for each coastal area were obtained by summing, within each size category, the landings from each subarea and depth zone. Plotted serially and fitted with smooth curves, the size-distribution modes traced each brood from its recruitment to its disappearance from the fishery (fig. 11). The curve for each brood is the typical sigmoid curve describing population growth in weight. Its disposition with respect to the ordinate is irrelevant, the midpoints of each size class being arranged arbitrarily theron. In the present report, the procedure of plotting size-distribution modes is carried out only for those population segments occupying offshore areas, portions found on inshore grounds being almost always composed of a single, newly produced brood.

Of the biases associated with the commercial catch-by-size data used herein, that due to different grading practices is potentially the most serious. Two such methods are commonly em-

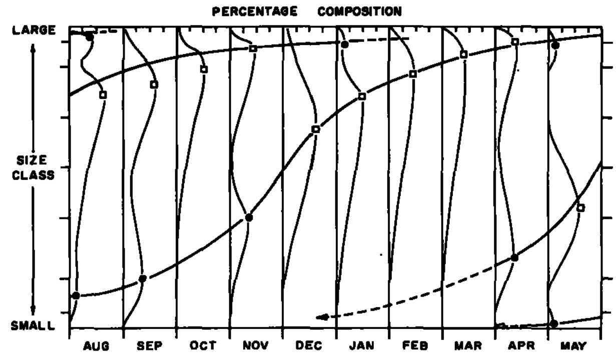

FIGURE 11.—Hypothetical example showing method of delineating shrimp "broods" from weight composition of monthly commercial catches. (Light lines displaced vertically are monthly weight-frequency curves. Squares denote dominant weight-frequency modes. Shaded circles indicate lesser modes. Dark lines displaced horizontally trace progress of individual broods in fishery.)

ployed around the Gulf, viz., "box-grading" and "machine-grading." The former entails taking a representative 5-pound sample of the landing, separating its contents into standard size categories, calculating the proportion in each category, and prorating the landing accordingly. In the latter method, the entire landing is run through a mechanical sorting device.

Grading machines are found at relatively few Gulf ports. But even if available, they may not be used, each fisherman reserving the option of selling his catch on a box-grade basis if he so desires. The problem here is that data of box-graded and machine-graded landings are not comparable for areas in which both methods are used. From the standpoint of getting a true picture of catch size composition, machine-grading is obviously far superior to box-grading. Where machine-graded landings would be expected to yield monthly weight frequency curves truly representative of those of the fishable biomass, or at least of the landings themselves, weight frequencies based on box-graded landings would not, the probability of their exhibiting all modes being quite low. Consolidating the two types of data confounds the net bias and necessitates interpreting weight frequency curves resulting therefrom with some reservation.

INTEGRATION OF DATA

Classical approaches to predicting the yields of, and assessing the effects of artificial and environmental factors on, exploited fish and shellfish stocks incorporate devices known as mathematical population models. In recent years there has developed a specialized branch of fishery biology devoted solely to the measurement of their parameters. These include, in the deterministic sense, the basic constants of fecundity or recruitment, growth, and mortality. Their estimation presents no simple task, and it is significant to note that valid measures of each are contingent upon how well population age structure can be delineated (Watt, 1959, p. 391).

Means for separating commercial shrimp landings into component age classes to secure a picture of population age structure have not yet been devised. Shrimp population research along classical lines is consequently precluded. Differential effects of fishing on shrimp broods at successive ages, relationships between population size and fishing intensity, parent-progeny relationships, and estimation of natural mortality, for example, remain undocumented in statistical terms.

To extract the maximum amount of information on shrimp population status from the kind of data available, the alternative method of generalizing on inferences drawn from graphic integration and interpretation of yield, biomass, and modal-weight curves is employed. Thus comparative trends in yield and biomass should establish, relatively speaking, whether specified stocks adequately maintained themselves during the period over which statistics were collected. Simultaneous data on biomass (age) composition and relative brood strengths aid in reconciling significant deviations in stock mass and, with constant fishing intensity, corresponding fluctuations in yield. The latter information also provides a broader basis for speculating as to how differential fishing on broods making up a given biomass affects their collective potential from the standpoints of yield and reproductive capacity.

POPULATION TRENDS AND CHARACTERISTICS

BROWN SHRIMP

General Occurrence and Features

The brown shrimp is sought in offshore and adjoining inshore waters of the Gulf of Mexico from northwest Florida westward to Mexico. Its commercial range covers approximately 66,000 square (nautical) miles of the Gulf's continental shelf.

Intensive exploitation of the brown shrimp did not begin until the close of World War II. Declining abundance of the industry's mainstay, the white shrimp, prompted a campaign to develop markets for the ever-present brown shrimp, which heretofore had never enjoyed comparable market status. The first catches of any commercial consequence were reportedly made off Texas in about 1947, off Mississippi and Alabama in 1950, and in the Gulf of Campeche in 1951 (U.S. Fish and Wildlife Service, 1958).

During the period 1956–59 this species ranked number one, annually averaging 56 percent (by weight) of shrimp landed at Gulf ports by United States commercial fishermen. In contrast the second- and third-rank species, pink and white shrimp respectively, contributed only 22 and 20 percent. Understandably, the brown shrimp currently attracts most of the attention being given conservation of the Gulf of Mexico's collective shrimp resources.

Over its range of exploitation, the brown shrimp exhibits a pronounced gradient of abundance. Indices similarly derived for all species and areas, and averaged over all months for the years 1956 through 1959, revealed a steady increase from east to west in the mean harvestable biomass of this species (table 6). Maximum stock density now occurs off Texas and eastern Mexico, this being approached in terms of relative density only by pink shrimp fished off southwest Florida and in the Gulf of Campeche. Peak production from its waters marks the Texas coast as the brown shrimp's focal habitat and, coincidentally, the center of the Gulf's extensive shrimp industry.

TABLE 6.—*Mean annual index of fishable biomass—commercial shrimp populations in offshore Gulf of Mexico waters, 1956–59*

Area	Species		
	Brown	Pink	White
Sanibel–Tortugas	----------	0.97	----------
Apalachicola	0.15	.29	0.24
Pensacola–Mississippi River	.64	.04	.22
Louisana Coast	.52	----------	.45
Texas Coast	.88	----------	.15
East Mexican Coast	1.11	----------	----------
Obregon–Campeche	----------	.81	----------
Yucatan Coast [1]	----------	----------	----------

[1] Not available.

Biologically speaking, the brown shrimp seems to differ little from other commercial species. Taxonomic differences, for example, are quite subtle; and except for minor differences in chronology, events in its morphological development parallel those characterizing life histories of other shallow-water Penaeidae. Ecological factors would therefore be expected to play the dominant if not the more apparent role in separating this species from its relatives. For instance, although the greater proportion of each commercial variety's developing young may temporarily utilize (at different times) the same estuarine habitat, the parents show marked differences in their bathymetric distribution. Thus brown shrimp adults commonly are found on the outer reaches of the continental shelf, suggesting a greater transport distance for newly hatched larvae, and indicating a correspondingly longer migration for juveniles from estuary to offshore spawning ground. In addition, cursory observations tend to support the consensus that a substrate appreciably softer than those ordinarily occupied by its commercial relatives typifies the brown shrimp's habitat (Hildebrand, 1955; Williams, 1958). If the substrate is a major limiting factor, such a requirement may well explain the dominance of this species on the continental shelf from Mississippi Sound westward.

In examining the recent status of the brown shrimp in Gulf of Mexico waters, I view its biomass as a continuous "stock" or population over the range of primary exploitation. However, the possibility of this stock being composed of units or subpopulations enjoying varying degrees of "discreteness" should not be discounted. Though our knowledge in this area is nil, the likelihood of any unit being isolated physically or genetically would seem quite remote. Recent mark-recapture studies in Texas and Louisiana waters indicated, for example, an east to west movement of at least portions of successive generations, each member of which can trace its lineage to a spawning aggregation maintained to the east, presumably in the western part of the Delta area (U.S. Fish and Wildlife Service, 1960; Louisiana Wild Life and Fisheries Commission, 1960).

For convenience in presenting and interpreting data, the brown shrimp stock is divided into two units between which interchange is believed minimized by a natural barrier, namely, the Mississippi River Delta and impinging edge of the continental shelf. Subdivision of the areas lying east and west of the Delta is strictly arbitrary. And although the term "populations" is used freely to identify biomass units within these coastal areas (and subareas), it is used in an artificial sense and in no way implies that actual subpopulations (or "races"), if these exist, have been defined.

Eastern Gulf Populations

Data of fishing effort and yield as related to commercial utilization of brown shrimp populations along the northeastern Gulf coast are given, respectively, in appendix tables 1 and 2. These have been condensed because of space considerations from more extensive tables giving catch-by-depth data on a subarea basis, the subareas involved here being those numbered from 8 through 12 (fig. 1). The two general areas upon which consolidation was based are identified as the Apalachicola and Pensacola-Mississippi River areas. Note that indices used to assess populations or portions of a stock occupying any coastal area were computed from uncondensed data, i.e., data tabulated on a statistical subarea-depth zone basis. Inshore catches are given by specific water body in appendix table 5.

Commercial yield.—During the period 1956–59, brown shrimp production off northwestern Florida (Apalachicola area) was greatly overshadowed by that off Alabama, Mississippi, and eastern Louisiana combined (Pensacola to Mississippi River area) (fig. 12A). Population yields as reflected by commercial landings showed a steady increase from 0.1 to 0.7 million pounds annually in the Apalachicola area, and marked fluctuation between 5.3 and 12.6 million pounds annually in the Pensacola-Mississippi River area. Production in both areas experienced typical midwinter lows and midsummer highs. Although of a much lower order of magnitude, production peaks in the former area occurred slightly in advance of those in the latter.

Fishable biomass.—Comparison of biomass indices revealed upward trends in annual overall brown shrimp abundance from the Mississippi River eastward (fig. 12B). Marked deviations from what might be considered normal fluctuations in seasonal abundance were not apparent. As suggested by the corresponding yield data, a greater biomass, on the average, occupied the more westerly portion of the northeastern Gulf

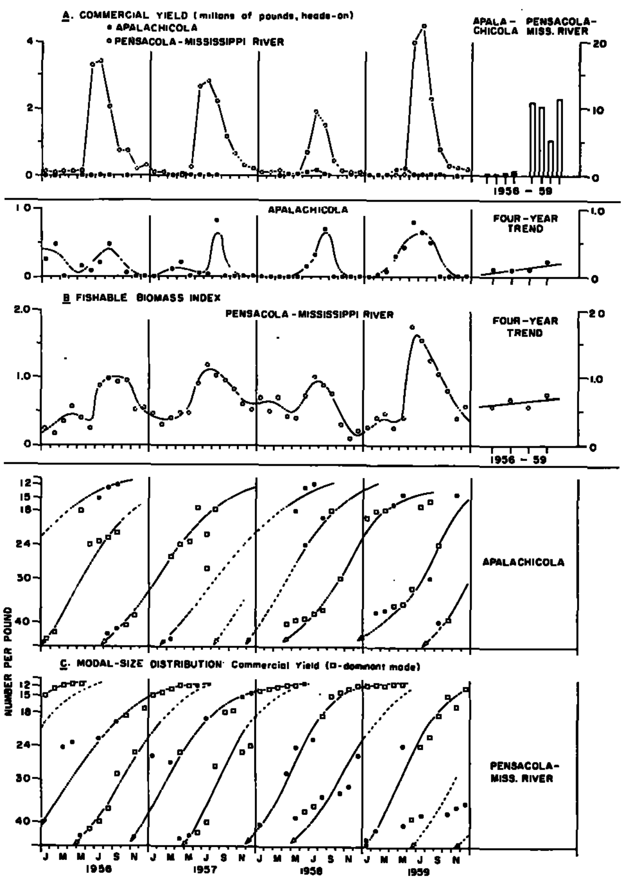

FIGURE 12.—Yield and structure of brown shrimp populations off the northeastern Gulf coast, 1956–59.

coast area. Population cycles as exhibited by biomass curves derived for the Apalachicola and Pensacola-Mississippi River areas showed appreciable similarity except that brown shrimp abundance dropped to a much lower level during the winter months off Apalachicola. This was likely due to the fact that specimens maturing and remaining in this area had already passed out of the range of fishing operations at winter's onset. Whereas the range of year-round exploitation may extend to 45 fathoms in the Pensacola-Mississippi area, it rarely goes beyond 20 fathoms in the Apalachicola area.

Population characteristics.—The brown shrimp population inhabiting eastern Gulf waters evidently produces two broods per year (fig. 12C). Roughly describing population age structure, distribution of modal-sizes comprising monthly yields suggested alternate roles for alternate broods—one "reproductive", one "commercial."

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Those broods forthcoming in late summer and fall (indicated by shaded arrows) are usually of comparatively small size due, perhaps, to reduced survival, increase in weight slowly, and apparently contribute little to the annual yield (cf. figs. 12A, 12B, and 12C). Their residuals, however, seemingly constitute the greater proportion of spawning populations which produce the "commercial" broods in succeeding years. These broods, in contrast, are generated in late winter and early spring (indicated by light arrows), are larger due to better survival during larval and postlarval stages, increase in weight more quickly, contribute disproportionately more to the annual yield (cf. figs. 12A, 12B, and 12C), and, accordingly, make up a smaller proportion of the spawning population. Significantly, late winter-spring broods are harvested at an early age (fig. 12C) with few individuals surviving to maturity. Those that do mature supplement, by virtue of what might be termed "compensatory" growth, the spawning population represented primarily by members of the preceding or fall-winter brood. This relationship is shown in figure 12C where coalescence of members of adjacent pairs of life history curves is vaguely suggested. For the most part, fall-winter broods impart little evidence of existence or strength on the biomass curves until the following fall and winter when their mature elements contribute to small catches. (Note slight modes on curves in fig. 12B during early 1956, 1958, and 1959 in the Pensacola-Mississippi River area.)

Comparative interpretation of figure 12C is rendered somewhat difficult by the paucity of data for the Apalachicola area. Despite this shortcoming, the interrelationships of successive broods still seem sufficiently clear. Causes of variation about the fitted lines do pose a question, however. Part of this variation could be attributed to differential fishing with respect to biomass distribution ("sampling error") and, perhaps, to disproportionate vulnerability or availability of sexes, but most is probably due to the fact that spawning continues in varying degree throughout the year.[3] Even though two peaks of spawning may nearly always be defined, this definition is

[3] One year's (1961) biological sampling on the continental shelf by personnel at the Bureau of Commercial Fisheries Biological Laboratory, Galveston, Texas, has revealed the presence in every month of the year of brown shrimp ready to spawn.

often weak due to the magnitude and success of interim spawning being sustained at comparatively high levels. The exact position of one peak relative to the other is therefore difficult to resolve.

The evidence for two broods per year substantiates earlier opinion as to the seasonal reproductive activity in brown shrimp off the upper Gulf coast (Gunter, 1950). Additional evidence in a later section will permit further discussion of this feature of brown shrimp life history.

Inshore population phases.—Up to this point discussion has been limited to the dynamics of offshore phases in the eastern Gulf's brown shrimp population. If attention is turned to inshore phases, parallels to events in offshore population phases may be readily noted.

In both the Apalachicola and Pensacola-Mississippi River areas (but more noticeably in the latter), distributions of monthly commercial yields from offshore and inshore waters correspond very precisely during the period 1956–59 (cf. figs. 12A and 13A). Annual yields fluctuated in like manner although the offshore catches were about twice those of inshore catches.

Closer comparison of curves describing seasonal patterns for offshore and inshore yields from the Pensacola-Mississippi River area reveals that, on the average, peaks in offshore yields lagged slightly behind those in inshore yields (figs. 12A and 13A). This lag reflects the expected pattern for juveniles (spring brood) migrating from inshore "nursery grounds" to parental habitat offshore, pointing up the relationship between inshore and adjacent offshore fisheries and stimulating speculation as to the effect harvesting a brood's prerecruits (in terms of the offshore fishery) could have on attaining the maximum yield from that brood.

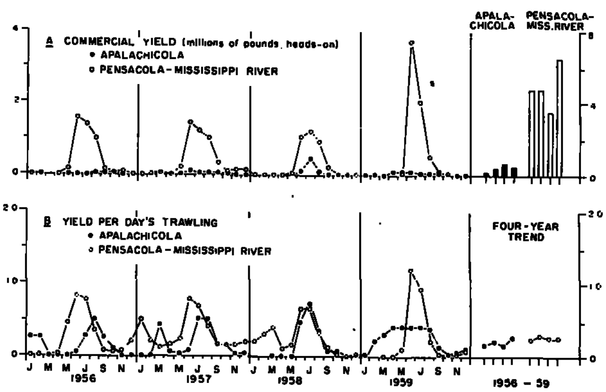

FIGURE 13.—Total and average yield of brown shrimp populations in inshore waters along the northeastern Gulf coast, 1956–59.

Taking into account the species concurrent migratory and growth patterns, it is presumed that such attainment would be realized shortly following egress from inshore waters, or at a point in space and time where shrimp size is equivalent to that at which individuals average about 30 (heads-on) to the pound. The reasoning here derives from an examination of curves in sections B and C of figure 12. Those for the Pensacola-Mississippi River area provide the best points of departure. In 1956 and 1957, maximum population biomass, mainly due to the contributions of late winter-spring broods (light arrows, fig. 12C), was attained during August–September (fig. 12B). Observe now that the brood curves, reflecting average growth of shrimp comprising each brood, exhibit inflections which occurred during the same period. Thus, with growth rates having reached a maximum and the broods themselves attaining maximum weight, biomass from this point on was largely governed by mortality factors. The average size of shrimp at the time of greatest brood mass is shown to have been, as stated above, roughly that at which 30 whole (50 headless) uniform-size individuals weigh 1 pound. In the present example, the greater proportion of shrimp taken by the offshore fleet was, on the average, composed of individuals not much larger than those taken by the inshore fleet.

Corroborating the case for two population broods annually, curves fitted to average monthly yields from inshore waters likewise indicated the occurrence of two broods, one in late summer or fall, the other in late winter or early spring, respectively, the "reproductive" and "commercial" broods referred to earlier (fig. 13B). Moreover, sustained trawling provided crude year-round indices of brown shrimp abundance in the eastern Gulf's inshore waters. These indices suggested, despite lessened reliability of midwinter values, a continuous influx of larvae and tended to confirm the hypothesis of protracted spawning activity. Four-year trends in average commercial yields from inshore population phases closely approximated those derived for offshore phases.

Summary of 4-year status.—During 1956–59, eastern segments of the northern Gulf of Mexico's

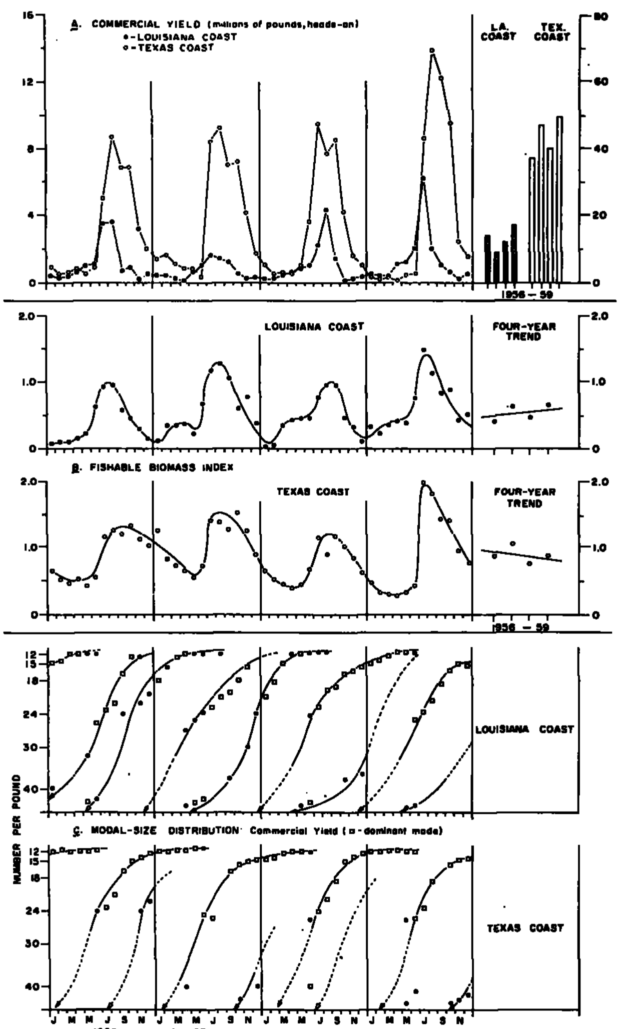

FIGURE 14.—Yield and structure of brown shrimp populations off the northwestern Gulf coast, 1956–59.

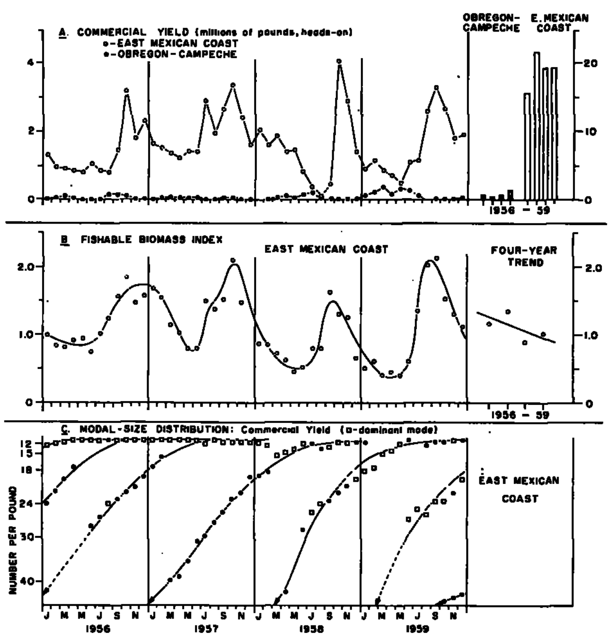

FIGURE 15.—Yield (to United States fishermen only) and structure of brown shrimp populations off the Mexican Gulf coast, 1956–59.

brown shrimp stock exhibited no marked departure from the norm obtained for that period. Although commercial offshore and inshore yields diminished significantly in 1958, the corresponding fishable biomass remained at approximately the same level as that attained the 2 previous years. Slightly upward population trends were noted for the 4-year period. Yield composition displayed the same year-to-year pattern. Heavy midyear catches were comprised predominantly of small shrimp, and light late- and early-year catches of comparatively larger shrimp. Assuming intensity of fishing remains more or less constant, i.e., fall-winter broods are not exploited more heavily than past observations indicate, midyear yields of small to medium-size shrimp should stabilize at the 1956–59 level.

Western Gulf Populations

Analysis of western segments of the northern Gulf coast's brown shrimp stock proceeded on a coastal-area basis as before. Commercial effort and catch data for the Louisiana Coast (statistical subareas 13 to 17), Texas Coast (subareas 18 to 21), and East Mexican Coast (subareas 22 to 30) areas are given in condensed form in appendix tables 1 and 2. The latter table also includes small quantities of brown shrimp taken in the Obregon-Campeche area (subareas 31 to 34). Annual landings from specified inshore waters will be found in appendix table 5.

Commercial yield.—Brown shrimp production off the northwestern Gulf coast during the years 1956–59 fluctuated about annual averages of 12.4, 43.3, and 19.3 million pounds, respectively, in the Louisiana, Texas, and east Mexican coastal areas. Landings by the United States fleet ranged from a low of 8.2 million pounds taken off Louisiana in 1957, to a high of 49.4 million pounds harvested off Texas in 1959. Yield trends were up in all areas with Texas exhibiting the steepest climb.

Yield curves again displayed the typical midyear highs and winter lows (figs. 14A and 15A). Comparison of curves also revealed the same westward lag in maximum seasonal production noted earlier in the eastern Gulf. Peaks usually occurred during July–August off Louisiana, August–October off Texas, and September–November off eastern Mexico.

Fishable biomass.—Biomass curves derived for western portions of the northern Gulf's brown shrimp stock paralleled those describing eastern portions. Dominant modes of the curve determined from data of commercial operations off Louisiana occurred slightly ahead of or at the same time as those of the Texas curve (fig. 14A). Modes of the curve for eastern Mexico were generally displaced still later (fig. 15A). As also indicated by corresponding yield curves, this suggests a pattern of gross westerly drift for major portions of vernal broods, probably associated with their seaward migration from upper Gulf nursery grounds.

A gradual westward increase in brown shrimp abundance is demonstrated by biomass curves for successive coastal areas being displaced on their ordinates at increasingly higher levels. Four-year abundance trends, on the other hand, exhibited a decline from east to west. Louisiana's available biomass was slightly upward, that off Texas experienced a mild decline, while that off eastern Mexico fell off moderately (cf. figs. 14B and 15B). A pattern thus emerged for the northern Gulf's brown shrimp stock—an upward 4-year trend for eastern segments, a nearly static situation for those centrally located, and a perceptibly downward trend for westernmost segments.

Whether this pattern developed purely by chance or resulted from factors operating differentially yet systematically on adjacent biomass units is problematical. The cumulative effect of a compounded fishing mortality associated with the seasonal westward movement of newly recruited broods is a distinct possibility. Of significance here is the fact that suitable inshore nursery grounds diminish rapidly in extent as one proceeds westward from the Delta. Heavy fishing on broods produced to the east coupled with light recruitment from areas to the west could conceivably result in a systematic population decline from east to west.

It should be noted that biomass curves depicting western portions of the brown shrimp stock may not always be comparable to those describing eastern portions. Commercial fishing off Texas and Mexico, for example, is typically more selective than that off the remaining upper coast. Texas markets are such that small shrimp are ordinarily unacceptable and fishermen consequently avoid landing them, often through discarding, but usually by seeking out aggregations of larger specimens. Moreover, legislation enacted in 1959 encourages fishermen in the Texas Coast area to defer from trawling on predominantly small brown shrimp during June and July by closing coastal waters up to a distance of 10 miles offshore.

Obviously, these factors act to minimize the amount of information yielded by biomass indices computed from commercial statistics. Furthermore, attempts to explain differences in interarea population trends are defeated if fishing practices in adjacent areas are such that resulting statistics lead to incomparable fishable biomass indices. It is quite apparent (fig. 14C) that the definition of fishable biomass as given earlier in terms of "standard" Gulf trawling gear does not hold for all areas.

Population characteristics.—Despite the commercial fishery's tendency toward increased selectivity of larger shrimp on the Gulf's western grounds, catches during 1956–59 periodically consisted of brown shrimp covering a size range sufficient to describe (although somewhat sketchily) the structure of the biomass whose components would ordinarily be vulnerable to the gear employed under conditions of nonselective fishing (figs. 14C and 15C). More specifically, catch composition data included in statistics of fishing activities off Louisiana appeared relatively free of the selectivity bias, whereas those included in statistics of operations off Texas and Mexico did not. The effects of "biased sampling" frequently complicated the picture of population size structure in the latter areas.

Distribution of modes of weight-frequency curves derived for monthly landings taken off Louisiana and Texas provided additional evidence for semiannual brown shrimp broods in upper Gulf waters (fig. 14C). In the western Gulf, however, the timing of each brood's appearance seemed advanced somewhat beyond that of its counterpart in the eastern Gulf, indicating correspondingly later spawning peaks in western areas. This was especially apparent in Texas waters where broods corresponding to those forthcoming in late summer and fall in eastern waters are generated slightly later, usually during fall and winter.

The coalescence of fall and spring broods described for eastern portions of the upper Gulf's brown shrimp stock was simulated in stock segments lying off Louisiana. However, the relative importance of each brood to the offshore fishery displayed a reversal. Whereas spring broods (light arrows) sustained the commercial fishery to the east, fall or winter broods (shaded arrows) sustained it in the western Gulf, the Louisiana coastal area seemingly being the transition point.

Spring broods in Louisiana waters usually did not contribute measurably to the offshore fishable biomass until late the same year or early the year following. Offshore yields at such times were small but, on the average, composed of mature individuals surviving from the previous spring. Their presence was reflected on the biomass curve by minor, early-year modes (cf. figs. 14A, 14B, and 14C). Dominant modes, on the other hand, invariably indicated the presence, during midsummer, of the stronger fall or winter broods. These contributed the greater portions of annual yields though mean shrimp size during peak harvest (July–August) was somewhat less than that characteristic of spring broods fished during the winter months immediately following their appearance.

Late fall or winter broods also dominated the year-round fishery off Texas and eastern Mexico. Not as well defined in offshore waters as their winter counterparts, spring broods in this area played obscure roles. Their contributions to the offshore fishery were negligible during brood years but probably significant in succeeding years (figs. 14C and 15C). The extent to which spring broods supplement each year's spawning populations remains problematical but there is no question that they sustain important inshore bait fisheries. Lack of appropriate data precludes further discussion.

Factors operating to produce two "generations" of brown shrimp annually are as intangible as their mechanics are complex. But worthy of consideration as an indicator of what underlies this phenomenon is an easily measured environmental parameter, namely, temperature. If the species spawns within an optimum temperature range lying somewhere between annual minimum and maximum temperatures on the floor of the continental shelf, two spawnings per year would be expected; one at some point on the ascending limb of the annual temperature curve, the other at a corresponding point on the descending limb. Taking into account the species capacity for rapid growth, it is reasonable to conjecture further that at least portions of a brood forthcoming at one intercept of the spawning isotherm and seasonal temperature curve would complement the spawning population giving rise to the brood appearing at the subsequent intercept. Until a brood becomes extinct, its residuals would be expected to attain maturity and breed at successive intercepts.

Alignment of periods of maximum spawning intensity with annual sea temperature curves suggests, however, that spawning is associated with seasonal temperature reversals rather than with some optimum temperature. Periods of peak spawning were determined: (1) by extrapolation from brood curves projected backward in time, inferring some knowledge of early growth in penaeid populations (Hudinaga, 1942; Pearson, 1939); and (2) through cursory but systematic observations of ovarian development in spawning populations off the upper Texas coast, such observations being made in the course of research conducted by the Bureau of Commercial Fisheries Biological Laboratory, Galveston Tex. Roughly speaking, heightened spawning activity in the northwestern Gulf's brown shrimp stock seems to occur, on the average, during the period March–April, and again during the period September–October.

Continuous sea temperature data for the northern Gulf shelf are scanty with most of those available representing surface measurements taken at selected shore stations. Lindner and Anderson (1956, p. 621) present comparative bottom temperature curves (inshore; offshore at 3 fm.; and offshore at 10 fm.) constructed from measurements taken during 1931–34 in the Barataria Bay, Louisiana, area. Annual sea temperature curves derived from measurements obtained over extended periods at various other locations are given in figure 16. The more extensive of these, however, reflect conditions in areas some distance removed from what are believed to be principal brown shrimp spawning areas. How well they match seasonal temperature patterns at, say,

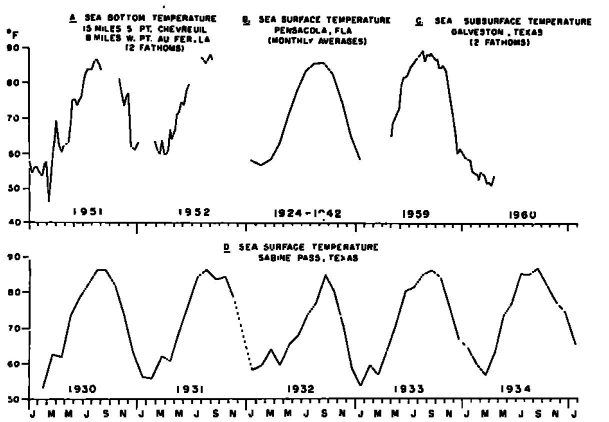

FIGURE 16.—Sea temperatures at selected locations along the northern Gulf of Mexico coast.

Sources: A. and M. College of Texas (1952); A. and M. College of Texas (1955), data collected by U.S. Coast and Geodetic Survey; U.S. Fish and Wildlife Service (Unpublished data); A. and M. College of Texas (1955), data collected by U.S. Fish and Wildlife Service.

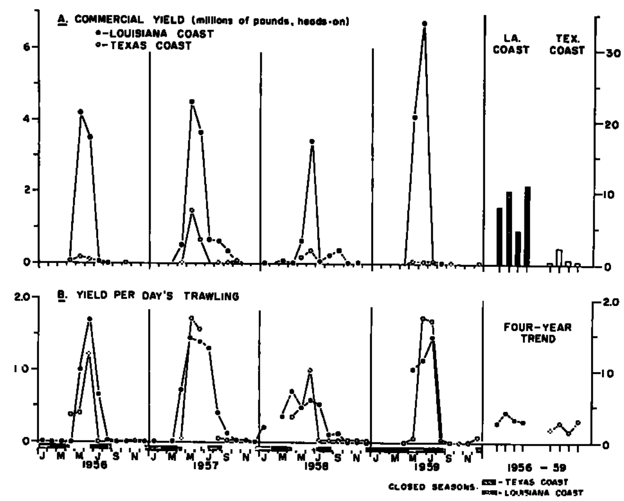

FIGURE 17.—Total and average yield of brown shrimp populations in inshore waters along the northwestern Gulf coast, 1956–59.

20–40 fathoms, is therefore a matter for conjecture.

Assuming reasonable correspondence in the shape and displacement of annual shore-surface and offshore-bottom temperature curves, it may be concluded with the aid of figure 16 that peak spawning activity in the upper Gulf's brown shrimp stock is associated with initiation of: (1) a rapidly increasing rate of temperature change in the spring, and (2) a rapidly decreasing rate of change in the fall.

A knowledge of underlying mechanisms notwithstanding, the fact that semiannual broods sustain the upper Gulf's commercial fishery further complicates brown shrimp population studies. Since successive broods are not subjected to the same environmental stresses, parameters of reproductivity, growth, and mortality may be expected to vary widely from brood to brood and from area to area. This would offer potential difficulty in attempts to project yields on a calendar year basis.

Inshore population phases.—Closed seasons and minimum size limits restrict the annual harvest of brown shrimp from inshore waters of the northwestern Gulf. Most stringently regulated are Texas estuaries from which only negligible amounts (commercial: human consumption) were taken during the 4-year period under study (fig. 17A). Louisiana's inshore catches, on the other hand, were considerably greater but also fluctuated markedly. Actually, average annual brown shrimp production from Louisiana bays approached that of the adjacent offshore fishery and exceeded that of all other inshore waters on the upper Gulf coast. As also noted in the eastern Gulf, annual production maxima for the western Gulf's inshore waters usually occurred slightly before those for offshore waters (cf. figs. 13A and 17A). Comparison of inshore average yield and offshore biomass curves revealed a similar correspondence.

The dynamics of population phases supporting inshore commercial fisheries provoke some interesting speculation about the western Gulf of Mexico brown shrimp stock as a whole. There is no debating the fact that spring broods, first appearing en masse as 3- to 4-week-old larvae at the entrances to inshore waters during late March to mid-April, sustain inshore fisheries for the ensuing 2 or 3 months. Juvenile brown shrimp, for instance, comprised 87 to 99 percent, respectively, of commercial bait shrimp landings from Galveston Bay in June and July, 1960.[4] These shrimp grow rapidly during the inshore phase and, by the time they begin migrating to offshore waters, usually in June and July, they may attain a size equivalent to that at which 42 specimens

[4] Galveston Bay bait shrimp landings for June and July, 1960, totaled 0.20 and 0.15 million pounds, respectively.

(heads on) weigh 1 pound. Their fate after leaving the bays has already been discussed.

But what of the fall broods? Except for representation by small numbers of postlarvae and subsequently an occasional juvenile, they do not appear at entrances to or in inshore waters at the times they might be expected. Commercial trawling, even though greatly reduced at this time, is still sufficient to confirm their presence or absence in inshore waters during late fall and winter months. Where, then, do members of fall or early winter broods pass their prerecruitment phase? The answer, logically, must be: in offshore areas where spawning takes place and mass shoreward transport of eggs and larvae is held to a minimum, or in nearshore areas when unsuitable conditions preclude further movement of developing postlarvae into bays. From the standpoints of brown shrimp population dynamics and management, implications of this apparent phenomenon warrant further attention.

Summary of 4-year status.—For the most part, western portions of the northern Gulf of Mexico brown shrimp stock showed no significant change and all now appear to be in good condition. Over the period 1956–59, the trend in annual commercial biomass was slightly upward in Louisiana waters, absent or only slightly downward in Texas waters, and perceptibly downward in east Mexican waters.

Though typically fluctuating, brown shrimp yields from all waters, except Texas inshore waters tended to rise during the period of study. Notable departures from what might be considered normal fluctuations were the relatively sharp declines in annual yields from Louisiana's offshore waters in 1957 and its inshore waters in 1958. The former can be partly explained by the occurrence and aftereffects of a damaging hurricane which impeded fishing operations during June and July. The latter was due to the relatively poor success of the spring brood of 1958. This, in turn, could also be attributed to hurricane damage in the form of reduced spawning potential and nursery ground capacity.

The downward 4-year trend in fishable brown shrimp biomass off eastern Mexico seemed to be largely due to a low population level in 1958. Figure 15C reveals that large individuals, members of the 2 previous years' fall-winter broods, normally dominated annual yields. Exploitation of broods produced in 1956 and 1957 was restricted to their medium-size and larger components, except in 1957 when shrimp of rather small size helped to make that year's catch the largest of the 4-year period. Assuming constant natural mortality for all fall-winter broods, this had the effect of preventing the 1956–57 winter brood from attaining its potential maximum, thereby resulting in a diminished available biomass during mid-1958.

POPULATION TRENDS AND CHARACTERISTICS

PINK SHRIMP

General Occurrence and Features

During the period 1956 through 1959, catches of pink shrimp averaged 22 percent of all shrimp taken annually from the Gulf of Mexico by United States fishermen. Commercial landings ranged from a high of 48.0 million pounds in 1956 to a low of 30.6 million pounds in 1959 (table 4). Yielding only about one-fifth of the Gulf's overall shrimp harvest, stocks of this species nevertheless constitute the sole support of important fisheries in certain Gulf coast areas.

Although pink shrimp are sought over approximately 56,000 square (nautical) miles of the continental shelf, only one-fourth of this area contributes the preponderance of annual catches. Harvestable concentrations are occasionally found in the northern Gulf, but primary stocks tend to be restricted to its southeasterly perimeter. Specifically, the latter occur off southwest Florida (Sanibel-Tortugas) and northwest Yucatan (Obregon-Campeche), their average densities comparing favorably with or exceeding those calculated for stocks of related species exploited elsewhere in the Gulf (table 6).

Biologically, the pink shrimp differs little from other commercial Penaeidae. Anatomical features are very similar to those of brown and white shrimp. Its life history, except for possible differences in reproductive potential and in timing of events, is also practically identical to theirs, with population development involving an oceanic egg and larval phase, an estuarine postlarval and juvenile phase, and an oceanic adult (progenitor) phase. Growth is also comparable where the pink shrimp occurs with either or both the brown and white species. And, as will be shown in a later section, its population structure is similar.

Ecological features distinguishing the pink shrimp from its close relatives are not well defined.

Cursory observations suggest, however, that whereas adult population segments distribute themselves over the same depth range as that occupied by brown shrimp, maximum density occurs at a somewhat lesser depth. This is particularly apparent in instances where both species inhabit the same general area. But, as speculated upon earlier when discussing the distribution of brown shrimp, the underlying factor may be substrate composition. On the basis of extensive field observations, Hildebrand (1955) concluded that over the same bathymetric range, brown shrimp prefer a very soft mud substrate and pink shrimp a somewhat harder and coarser bottom. A similar conclusion was reached by Williams (1958), who conducted substrate selectivity experiments under laboratory conditions with juveniles of both species. As additional factors controlling the distribution of littoral Penaeidae, food preferences or habits as they relate to substrate type should not be discounted.

Pink shrimp, like brown and white shrimp, also display a marked tendency to move to deeper water with advancing age (Iversen, Jones, and Idyll, 1960). This movement presumably occurs, for the most part, over substrate characterizing the species habitat.

The Sanibel-Tortugas Population

Undergoing intensive exploitation for the first time about 1950, the pink shrimp population occurring off southwest Florida has since supported a valuable commercial fishery. Arbitrarily delimited, its habitat extends coastwise from the vicinity of Tarpon Springs on the north to just beyond the Keys on the south (fig. 6). The seaward limit at all points has been set at the 45-fathom contour although population fragments may be found in deeper water. Within these boundaries the population disperses itself over a projected bottom area of some 23,000 square nautical miles with Florida Bay and adjacent estuaries serving as "nursery" grounds for its immature phases. Studies are currently being undertaken to determine whether the population is actually continuous as presumed, or whether it is separated into two discrete units at about the 26th parallel.

Commercial fishing on the Sanibel-Tortugas grounds now continues with varying intensity the year round (fig. 18). Spatial distribution of

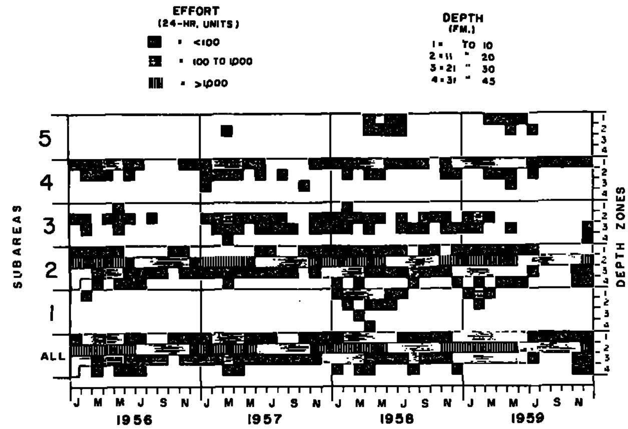

FIGURE 18.—Distribution (schematic) of fishing effort in the Sanibel–Tortugas area, 1956–59.

trawling effort follows a somewhat regular pattern. Greatest concentrations occur between 5 and 25 fathoms just north of the Dry Tortugas (statistical subarea 2) and in 5–15 fathoms off Sanibel Island (subarea 4). Operations are gradually extending to intermediate and outlying areas though untrawlable bottom precludes intensive fishing in many of these.

Condensed data of commercial effort and landings for the Sanibel-Tortugas area are given in appendix tables 1 and 3, respectively.

Commercial yield.—Over the period 1956–59, annual pink shrimp production in the Sanibel-Tortugas area fluctuated about an average of 19.2 million pounds, this representing about 11 percent of the total Gulf production of all species. Landings ranged from a high of 24.7 million pounds in 1958 to a low of 13.9 million pounds in 1959. Despite a practically constant expenditure of effort, the 4-year production trend was down appreciably, its slope reflecting an average decline of about 1.5 million pounds per year. Particularly interesting is the fact that the catch of 1958 was the largest ever recorded for the so-called Tortugas fishery, and that of 1959 the second lowest (cf. Idyll, 1957, table 4). This dramatic drop together with a long-term waning trend in production have stimulated concern for the fishery's future welfare.

The yield curve derived from monthly landings reveals that peak production in the Sanibel-Tortugas fishery is attained during winter and early spring (November–May), 80–85 percent of each calendar year's catch being made in that period

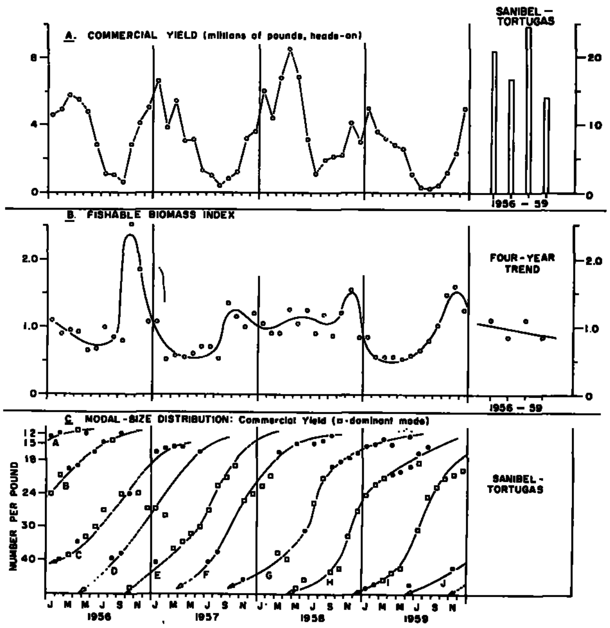

FIGURE 19.—Yield and structure of the pink shrimp population off the southwest Florida coast (Sanibel–Tortugas area), 1956–59.

(fig. 19 A). This seasonal pattern contrasts with those of upper Gulf coast fisheries wherein production normally reaches a maximum during late summer and fall months.

Fishable biomass.—A plot of monthly catch-per-unit-intensity values suggests that the Tortugas population's fishable biomass maintained itself within fairly narrow limits during the better part of the 4-year study period (fig. 19B). As would have been expected, seasonal deviations did occur, their analysis providing, perhaps, the principal clues in defining causes for the fishery's attrition. Meriting special attention are the reduced population levels sustained through the early months of 1957 and 1959, together with a perceptibly downward population trend during the 4-year period.

A comparison of figures 19A and 19B indicates little correspondence between yield and fishable biomass other than a suggestion that low annual yields seemed to occur in years when the population maintained itself at minimum levels. Yields considerably lower than average paralleled low biomass levels during the early portions of 1957 and 1959, the relationship in the latter year constituting the most noteworthy example. Although the population during 1956 and 1958 remained at levels appreciably higher than those in 1957 and 1959, it is not unreasonable to conjecture that excessive fishing in each preceding year could have contributed to the low population levels and hence yields in the years respectively succeeding them.

Population characteristics.—Semiannual periods of peak spawning activity, already indicated for stocks of other Gulf species, seem to be typical of Sanibel-Tortugas pink shrimp as well. These are revealed by serial plots of (catch) size composition data which are believed reasonably descriptive of the population's actual size or age structure (fig. 19C). Production of broods indicative of peak spawning activity corresponded rather well with that noted for brown shrimp off the northeastern Gulf coast, spawning evidently taking place in late winter or early spring (light arrows) and in late summer or early fall (shaded arrows).

On the other hand, intrayear variation in relative brood strengths appeared negligible, contrasting sharply with the great seasonal variation typical of brown shrimp broods produced along much of the upper Gulf coast. The degree of exposure to exploitation at different stages of brood development did vary seasonally, however. This is indicated in figure 20 where crude estimates of the absolute contributions of each brood at successive developmental stages are graphically shown. These estimates were obtained by merely subdi-

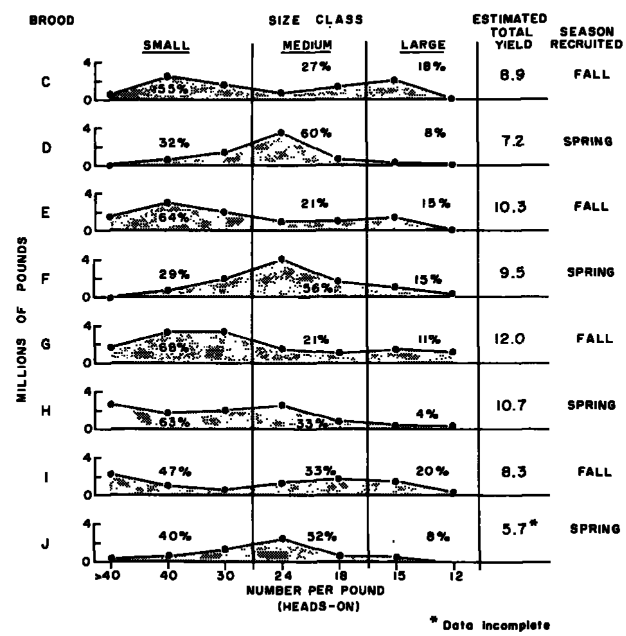

FIGURE 20.—Relative yields per brood by size class—Sanibel–Tortugas pink shrimp population, 1956–59.

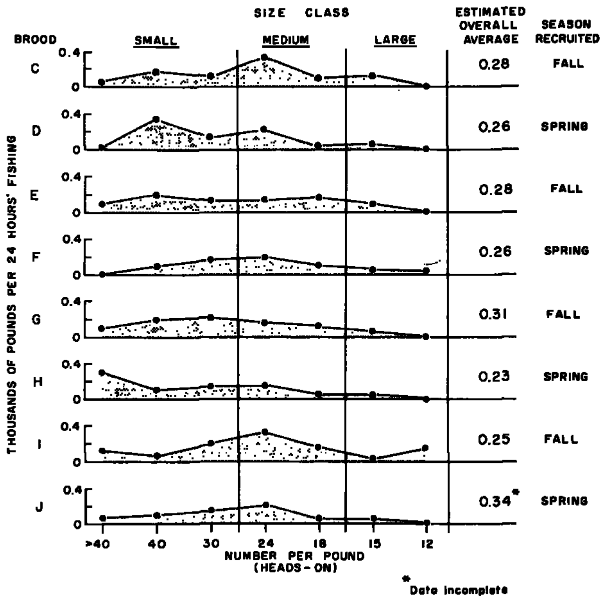

FIGURE 21.—Yield per 24 hours' fishing by brood and size class—Sanibel–Tortugas pink shrimp population, 1956–59.

viding monthly landings at the low, intermodal points on corresponding weight frequency curves. Note that those broods recruited in the fall ordinarily yielded the greater portion of their virtual biomass at juvenile (small) stages, whereas those recruited in the spring yielded most heavily at more advanced stages. A similar but not as pronounced pattern is reflected in figure 21 which depicts the average weight by size class contributed by each brood at successive life history stages. The relative uniformity of average "small-shrimp" catches yielded by broods considered in this study suggests a correlation between availability of newly recruited broods (small shrimp) and the amount of effort expended in their capture. Since peak fishing traditionally occurs shortly after its appearance, the fall brood is subjected to comparatively disproportionate exposure at such times. Evidence suggests that the degree of exploitation suffered by broods at and for a short period following recruitment not only governs the magnitude of fluctuation in annual yields but controls their composition as well.

Growth in fished (or recruited) portions of the Sanibel-Tortugas population was fairly uniform during the 4-year study period. Assuming delineation of successive generations in figure 19C is reasonable, members of broods recruited in the spring, on the average, grew slightly faster and attained maturity earlier than members of broods recruited in the fall. The former required an average of 13 months contrasted to the latter's 15 months to grow from a size equivalent to 31–40, to 9–12 shrimp to the pound. A growth differential between sexes is recognized for commercial Penaeidae (e.g., Lindner and Anderson, 1956), but its manifestations in the present analysis are obscured. Sex composition data would have permitted an evaluation of the effects of a variable sex ratio on growth patterns in the total population.

Summary of 4-year status.—The Sanibel-Tortugas pink shrimp stock evidenced more sensitivity to the mechanics of exploitation than any stock thus far examined. Causes of widely fluctuating and declining annual yields despite a relatively static effort expenditure can be traced to differential fishing on broods immediately following their recruitment. This is reflected in what appears to have been a progressively greater demand for and utilization of small shrimp during the 4-year study period (fig. 22). The net result has been a corresponding downward trend in stock biomass (fig. 18B), the dependent fishery at the same time being subject to varying availability and inconsistent quality in terms of size of shrimp harvested. In striving to obtain higher and higher production, operations and general economy have had to depend more and more on harvests of small, non-premium shrimp. Unfortunately, information on the value of landings taken annually from the Sanibel-Tortugas stock is not available for trend study. But Idyll (1957) stated that the fishery's annual net profits reportedly showed a gradual decline for the years 1953 through 1956, even though production in the latter year represented an alltime high. Indications are that the trend has not changed.

Examples of how recent patterns of exploitation have contributed to the present status of the Sanibel-Tortugas fishery may be readily provided. As previously stated, relatively heavy fishing on small post recruits visibly curtailed the expected potential of certain broods. For instance, note in figure 19C that brood "H" was fished comparatively hard immediately following recruitment (cf. fig. 19A), and at a period when the total pink shrimp biomass was at a reduced level (fig. 19B). To reiterate, peak biomass ordinarily occurs during early and midwinter (fig. 19B) with the major portion of each calendar year's catch being made during and for a short time following this period (fig. 19A). But although brood "H" sustained early 1959 production, it did so at an appreciably reduced level, the consequence being that the catch in 1959 was the lowest in recent years. Moreover, its quality was lessened because the fishery had to rely upon very small shrimp belonging to the subsequent brood, "I".

This gross analysis is clarified somewhat in figures 20 and 21, which roughly delineate absolute and average yields by size classes for successive broods. In both figures, the serial relationships inferred above are reasonably clear. Harvest of small shrimp [35 count (whole) and smaller] in excess of that amount presumably compensating for natural mortality markedly reduces the expected yield of premium shrimp. Unfortunately, measurement of each brood's biomass at recruitment was impossible, thereby precluding provision of a basis for comparing broods and for studying the effects that varying fishing intensities at different developmental stages had on total brood yields. With controlled fishing, however, a yield curve such as described by brood "F" (figs. 20 and 21) would appear to approach that which is most desirable from the standpoint of achieving maximum utilization of the resource. Note that its mode occurs at the 25–30 (41–50 heads-off) count-size range, the point on the population growth curve where the rate seemingly reaches a maximum.

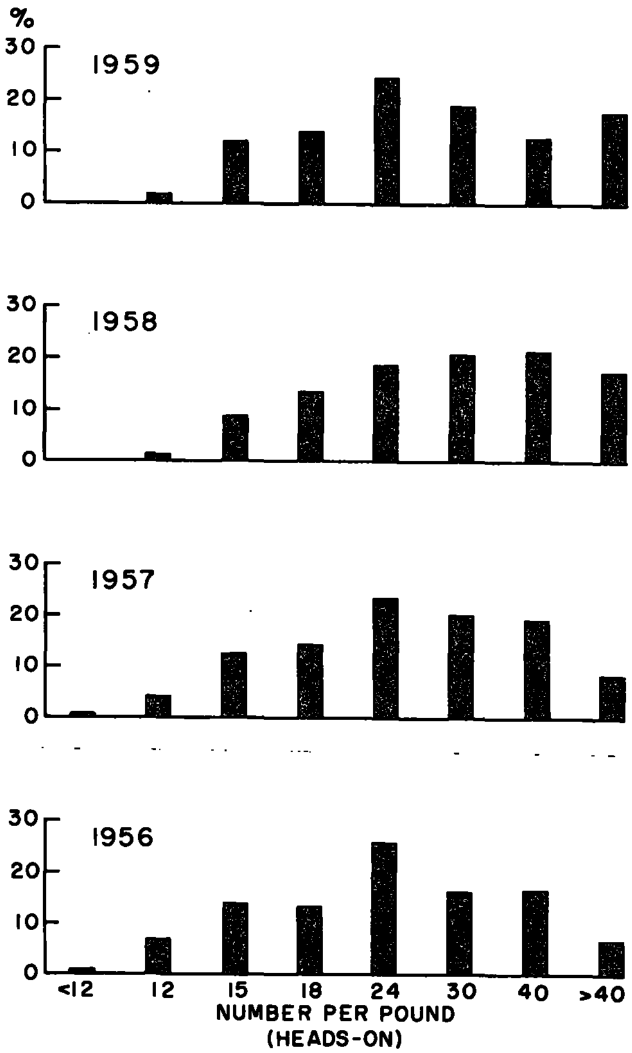

FIGURE 22.—Relative size composition of commercial pink shrimp landings from the Sanibel-Tortugas area, 1956–59.

The foregoing explanation of the Tortugas fishery's 4-year decline was founded on the premise that within- and between-year recruitment remained fairly constant. This assumption is not refuted upon gross examination of available data. The problem then was one of deciding at what stage of population growth the resource should be cropped so as to obtain the maximum virtual yield. No mention was made of the possibility that the Tortugas stock on the whole was being overfished although a continuation of present trends might justify its speculation. Up to the present stage of development in the Tortugas fishery, the pink shrimp population supporting it has displayed great resiliency in overcoming any adversities that might have been associated with exploitation. Presumably, the species high reproductive potential and the relatively undisturbed state of its inshore nursery grounds have thus far offset any incursions due to fishing on the mature stock. On the one hand, this suggests the likelihood that environment control could enhance the carrying capacity of estuarine waters in which immature shrimp undergo early development, with annual recruitment and yields being supplemented accordingly. On the other, it stresses the importance of protecting existing nursery areas from ill-advised modifications, and carefully regulating the take of juvenile shrimp there. However, the possibility of excessive fishing on the mature stock resulting in levels of reproduction below those approaching nursery ground capacity should not be discounted.

Upper Gulf Populations

Pink shrimp play a comparatively minor role in the penaeid species complex characteristic of the northern Gulf coast. Only along the more easterly reaches do they enter commercial catches in any quantity, and then with very irregular frequency. In some areas, especially in Texas, pink shrimp are bought and sold as brown shrimp. Such a practice masks the actual contribution of this species to local fisheries, and at certain seasons may seriously bias data of brown shrimp landings as well.

Condensed statistics of trawling effort and pink shrimp landings in the Apalachicola and Pensacola-Mississippi River areas are given in appendix tables 1, 3, and 5. Trace amounts of pink shrimp taken in areas west of the Mississippi River are also recorded in table 4.

Commercial yield.—Yields of pink shrimp from offshore waters in the Apalachicola and Pensacola-Mississippi River areas averaged about 7 percent of all shrimp taken annually in these areas during the period 1956–59. Production in the Apalachicola area fluctuated widely between a maximum of 2.1 million pounds in 1958 and a minimum the following year of only 11,000 pounds (fig. 23). Landings originating in waters off Alabama, Mississippi, and eastern Louisiana collectively showed a steady decline from a 1956 high of about 0.8 million pounds. Production in

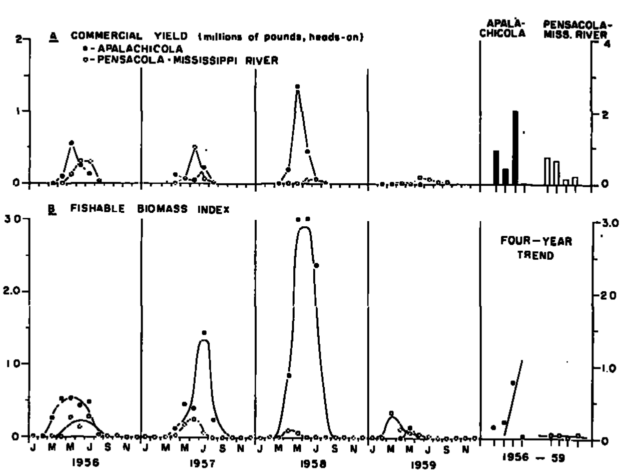

FIGURE 23.—Yield and biomass of pink shrimp populations off the northeastern Gulf coast, 1956–59.

both areas closely followed the seasonal patterns typical of related species, reaching a maximum during the spring or early summer. The largest quantity of pink shrimp taken elsewhere off the upper Gulf coast was 0.1 million pounds caught off Texas in 1958. As noted earlier, this figure (as well as landings of the same species in other years) is too low due to misclassification of the pink shrimp in the Texas coast area.

Fishable biomass.—Limited data provide a sketchy picture of offshore populations during the 4-year study period. For the pink shrimp population off Apalachicola, they indicate a significant buildup in strength during 1956–58, followed by a dramatic and inexplicable decline in 1959 (fig. 23B). Peak abundance of small to medium shrimp occurred annually during May–July with especially large quantities available in 1957 and 1958. There is general similarity in pink shrimp yield and population patterns between the Sanibel-Tortugas and Apalachicola areas (cf. figs. 19 and 23), stimulating conjecture as to population continuity in the eastern Gulf.

As expected on the basis of low yield, biomass indices reflected a correspondingly low level of abundance for pink shrimp occupying the waters between Pensacola and the mouth of the Mississippi River (fig. 23B). Seasonal modes occurred either slightly in advance of, or at about the same time as those observed for the Apalachicola area. Year-to-year variation in their magnitude was insignificant, there being no evidence of a population trend during the 4 years of study.

Inshore population phases.—Even less noteworthy than its offshore status was the pink shrimp's status in adjacent inshore waters. Bays and estuaries in the Apalachicola area yielded a maximum of only 416,000 pounds in 1957, and those in the Pensacola-Mississippi River area a maximum of 196,000 pounds in the same year (fig. 24A). Annual landings held fairly steady in both areas with the exception of a sharp 1959 dropoff in the Apalachicola area. Pink shrimp in catches from inshore waters were outweighed by brown and white shrimp in almost every instance. Inshore waters contributing to the northern Gulf's commercial shrimp fisheries are shown in appendix table 5.

The seasonal occurrence and relative density of pink shrimp in inshore waters of the Apalachicola and Pensacola-Mississippi River areas may

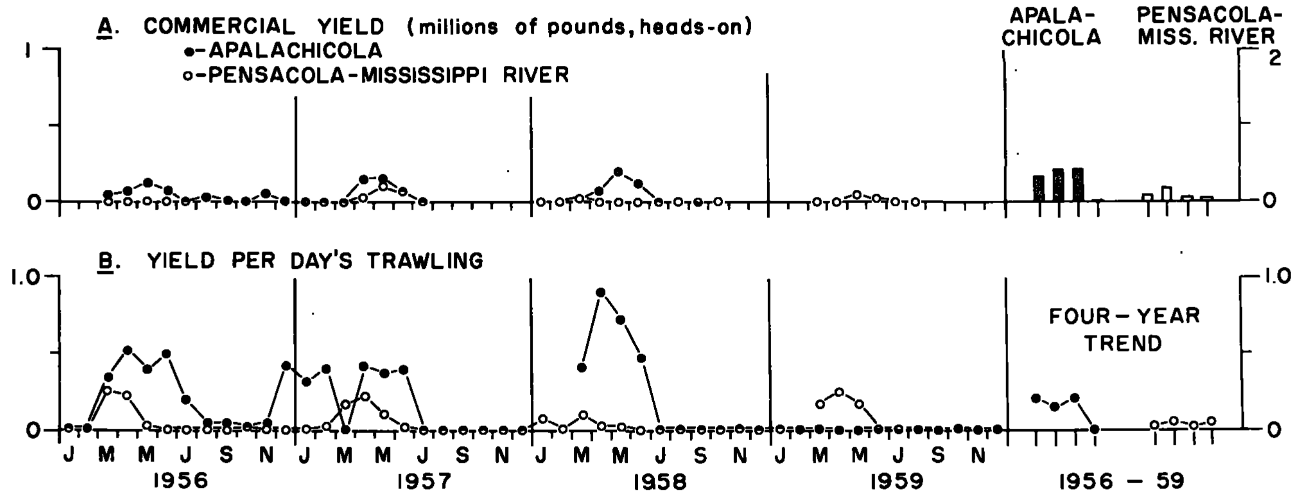

FIGURE 24.—Total and average yield of pink shrimp populations in inshore waters along the northeastern Gulf coast, 1956–59.

be inferred from serial plots of average catches (fig. 24B). Larvae evidently begin appearing on the inshore nursery grounds toward the end of the calendar year. Growth to a fishable size is attained late the same winter and early the following spring. That migration from inshore waters is well underway by May is corroborated by concurrent increases in offshore catches. By the end of August pink shrimp have practically disappeared from inshore waters. Data on size composition of catches made in adjacent offshore waters are inadequate to prove whether or not more than one period of peak spawning activity occurred each year, but they suggest a single peak extending over a period of 1 or 2 months.

Summary of 4-year status.—Except for 1958, pink shrimp contributed little to upper Gulf coast fisheries. Four-year population trends were either very pronounced and meaningless due to widely fluctuating population levels (Apalachicola), or nonexistent with populations holding steady at very low levels (Pensacola-Mississippi River). All data point to the fact that the pink shrimp's commercial range extends no farther westward than the Apalachicola area.

The Gulf of Campeche Population

Shrimp stocks lying off the northern coast of Yucatan, although reconnoitered by the Japanese as early as 1936, were not fished significantly until the close of World War II. Operations on the so-called Obregon-Campeche grounds by United States vessels began about 1950 and have steadily expanded ever since.

Three species of Penaeidae support the Gulf of Campeche fishery. Brown and white shrimp are found in commercial quantities off Tupilco and Obregon (statistical subareas 31 and 32), while pink shrimp predominate north of Carmen and west of Campeche (statistical subareas 33–35). No United States fleet activity in the Yucatan Coast area (statistical subareas 36–40) has been reported in recent years.

On the basis of comparisons with data supplied by the Mexican Bureau of Fisheries and Allied Industries for the years 1956 and 1957, the Mexican fleet accounts for about 56 percent of all shrimp harvested annually in the Campeche area (appendix table 6). Reflecting to some extent a respect for Mexico's claim to a 9-mile territorial limit, the United States fleet takes only about 6 percent and 1 percent, respectively, of the total brown and white shrimp harvest, but almost 65 percent of the total pink shrimp catch. United States vessels concentrate their activities on the extensive flats within a radius of 15 to 80 miles west of Morros Point.

Statistical coverage of the fleet fishing the Obregon-Campeche grounds is complicated somewhat by the fact that trawlers completing a trip may land portions of catches of as many as a half dozen other trawlers still on the fishing grounds, and only a fraction of what they themselves caught while away from port. This very efficient system of "freighting" (or transshipping), wherein vessels stagger their departures to and from the distant Campeche grounds, greatly enhances the quality of shrimp arriving at United States ports, but renders difficult the problem of assigning effort and catches to individual trawlers. Fortunately, most of the Campeche fleet operates out of a few Florida and Texas ports where statistical agents, with the full cooperation of the fishing industry, have devised effort and catch accounting methods so effective that statistics of United States fleet operations in the Gulf of Campeche may be included among the most accurate of all statistics describing the Gulf shrimp fishery. Such statistics, condensed from more extensive tables, are given in appendix tables 1 and 3.

Commercial yield.—After reaching a high of about 33 million pounds in 1953, annual landings of Campeche pink shrimp by United States fishermen stabilized at 24–25 million pounds over the period 1954–56 (Idyll, 1957, table 4). Thereafter (1957–59), they steadily declined to a low of 13.4 million pounds in 1958 but then began to climb again, reaching 16.4 million pounds in 1959 and about 18 million pounds in 1960. The lowest annual take recorded prior to 1958 was 8–9 million pounds in 1951, early in the fishery's development.

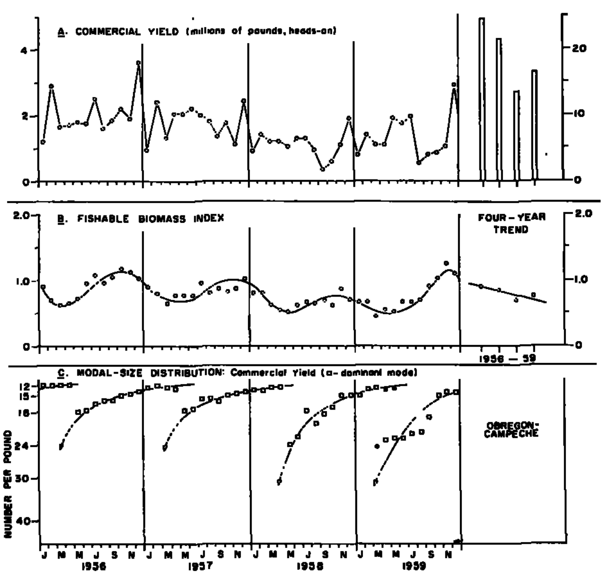

FIGURE 25.—Yield (to United States fishermen only) and structure of the pink shrimp population off the Mexican Gulf coast, Obregon-Campeche area, 1956–59.

In contrast to seasonal catch patterns in most shrimp producing areas, the 1956–59 pattern for pink shrimp on the Campeche flats showed relatively steady year-round production (fig. 25A). Greatest month-to-month variation occurred during midwinter with the highest monthly production in December and (until fall catches dropped below "normal" in 1958 and 1959) the lowest in January. This sharp drop is believed to reflect intensification of adverse fishing conditions rather than marked seasonal changes in shrimp abundance.

Fishable biomass.—Here, as in the case of the Texas brown shrimp fishery, the definition given "fishable biomass" does not hold. This is due to the rather rigid restrictions concerning the sizes of shrimp landed that the fishery imposes upon itself. The United States fleet fishing the Campeche pink shrimp population is, perhaps, the most selective of any comparable unit operating in Gulf waters. Rarely are Campeche landings composed of a predominance of shrimp smaller than 19–24 heads-on count size. And only in recent years has the average size landed fallen below 16–18 whole shrimp to the pound. The task of maintaining quality control, i.e., sorting the decreasing numbers of large shrimp from increasing catches of small shrimp, is reportedly becoming more and more difficult. The consequence of such practices is that landings are not representative of that portion of the population ordinarily vulnerable to the gear employed, and interpretations given analyses of associated statistics apply only to members occupying the upper size or age strata.

Involving only the population phases comprising shrimp equivalent to 19–24 count size (heads-on) and larger, a plot of monthly biomass indices for the period 1956–59 yields the seasonal abundance curve typical of Gulf shrimp populations (fig. 25B). Its amplitude of relatively low order can be attributed to the fact that landing statistics pertained solely to older population segments, the curve itself in no way reflecting actual status of the greater part of pink shrimp aggregations occupying the grounds. Thus the most useful conclusions that can be drawn from figure 25B are that available quantities of premium pink shrimp on the Campeche flats reach a seasonal peak during the fall, and, during the 4-year study period, experienced a significant decline.

Population characteristics.—Little information on population age structure could be obtained by plotting weight composition modes of monthly Campeche landings. As intimated above, weight composition curves were almost exclusively unimodal with large shrimp predominating at all times (fig. 25C). Conclusive evidence of more than one period of heightened spawning per year is lacking, but bimodal weight-frequency curves for spring landings in 1959 suggest that two peaks in annual spawning activity may also be characteristic of the Campeche pink shrimp population.

Summary of 4-year status.—Accurate but restrictive statistics gave only a vague picture of conditions in the Campeche pink shrimp population. Composed primarily of large-size shrimp, yields to United States fishermen declined sharply over the period 1956–58, but increased measurably during the next 2 years. Of significance was the drop in apparent abundance of large shrimp commencing in 1958 and sustained through 1959. Whether this was caused by excessive fishing alone, or by a combination of fishing and adverse environmental conditions, will always remain problematical. The Campeche fishery serves as a good example of one in which a lack of all-inclusive yield data (i.e., landings plus discards) inhibits proper population analysis. If landing statistics truly represented what was actually caught, further investigation of the Campeche population's dynamics would be justified.

POPULATION TRENDS AND CHARACTERISTICS

WHITE SHRIMP

General Occurrence and Features

Once the primary objective of commercial shrimping interests, the white shrimp now occupies a relatively minor position in the Gulf of Mexico's overall shrimp picture. For many years it constituted the sole support of a thriving fishery in bays and bayous along the Louisiana-Texas coast. There was no need to venture into the open Gulf until about the mid-1930's when prospects of an expanding market prompted the fishery's extension. The offshore fishery then developed rapidly, reaching its zenith in the mid-1940's. Gradually, however, and for reasons not yet clear, domestic white shrimp supplies diminished to the point where related species began to attain competitive status. Accelerating production of brown and pink shrimp from newly discovered domestic and foreign grounds finally overtook that of white shrimp in the mid-1950's. The former two species have since maintained a superior position.

During the period 1956–59, white shrimp ranked third behind brown and pink shrimp, annually averaging but 20 percent of all shrimp taken from Gulf waters by United States fishermen. Although subordinate on a Gulfwide basis, this species, like the pink shrimp, still sustains local fisheries in certain coastal areas.

Because of its longer history as a commercial species, the white shrimp has been studied more extensively than all other species combined. Nevertheless, there is still much to be learned about its life history and habits. Taxonomically, the white shrimp is very similar to the brown and pink shrimp although distinction between it and either of the latter two species is more clear-cut than that between the brown and pink shrimp themselves. Aside from their timing, events in the white shrimp's life history follow the same sequence and otherwise simulate those characteristic of littoral penaeids. Growth appears comparable to that of closely related varieties where they and the white shrimp are subject to similar ecological stresses. Reproductive potential is also believed to be approximately equivalent though much uncertainty prevails concerning shrimp fecundity. Actual egg counts have never been made for any species, but ova production in the white shrimp has been estimated without any indication of statistical reliability. King (1948) mentions "* * * the half million or so eggs which the average female will produce * * *"; Anderson, King, and Lindner (1949) state that "A count made by the authors on the ripe ovaries of a female, 172 mm. total length with spermatophore attached, revealed a total of approximately 860,000 eggs"; Lindner and Anderson (1954) specify that "A female will lay about 500,000 eggs at each spawning. * * *"

As already noted, when two or more species occur in the same general area, littoral Penaeidae may also be discriminated on the basis of apparent ecological requirements. Substrate quality has been cited as a major factor in brown and pink shrimp distribution; white shrimp likewise are thought to distribute themselves accordingly (Hildebrand, 1954; Williams, 1958). Notwithstanding the fact that generations produced by each species may undergo early development on the same inshore nursery grounds, the displacement of adult population segments in offshore waters is reasonably discrete. Whereas pink shrimp adults tend to occupy sand-shell bottoms of firm consistency, brown and white shrimp are most often found on much softer bottoms, typically soft clay, mud, or terrigenous silt. Substrates inhabited by the latter two species are difficult to differentiate but a second factor, bathymetry, helps to resolve the problem. Contrasted to their deep-water counterparts, mature white shrimp are ordinarily found only in the nearshore shallows (0–15 fm.), sometimes even in those portions of inshore waters nearest the sea. Whether or not substrate and bathymetry are the major factors governing distribution of littoral Penaeidae on the continental shelf remains problematical.

White shrimp occur in widely varying quantity at nearly every point on the Gulf's continental shelf. A notable exception is that portion of the shelf lying off southwest Florida (statistical subareas 1–4). Commercial concentrations are well defined in humid or semi-humid areas bordered by extensive estuarine complexes. One such area is that lying between Tupilco and Carmen on the east Mexican coast. Here a fairly dense population of white shrimp, fished in Gulf of Campeche waters by the Mexican fleet, seems to be associated with numerous coastal lagoons, especially the Laguna de Terminos. The most important commercial concentrations, however, occur in and off the northern Gulf coast marshes between Apalachicola and central Texas, with peak population strength being attained in and adjacent to Louisiana's vast estuarine complex (table 6).

Although most white shrimp are taken from 20 fathoms or less, the species may occasionally be found at depths up to 45 fathoms (Springer and Bullis, 1952). The 45-fathom contour is therefore taken as the approximate seaward limit of the species range. In addition, the northern Gulf of Mexico stock is arbitrarily subdivided into those units lying east and west of the Mississippi River Delta. Commercial statistics of effort and production (1956–59) are given in condensed form by months and depths for all coastal areas in appendix tables 1 and 4. Inshore production by specific water body is summarized for the same period in appendix table 5.

Eastern Gulf Populations

Commercial yield.—Over the period 1956–59, white shrimp annually averaged 13 percent by weight of all shrimp taken commercially from offshore waters in the Apalachicola and Pensacola-Mississippi River areas. Landings ranged from a low of 1.2 million pounds in 1957 to a high of 2.0 million pounds in 1959.

Production in the Apalachicola area was relatively stable, mildly fluctuating between 0.3 and 0.5 million pounds annually. Landings from the Pensacola-Mississippi River area were more erratic, dropping from 1.7 million pounds in 1956 to 0.7 million pounds in 1957, and then climbing again to 1.7 million pounds in 1959 (fig. 26A). Seasonal landing patterns for both areas show that each year's white shrimp production peaked approxi-

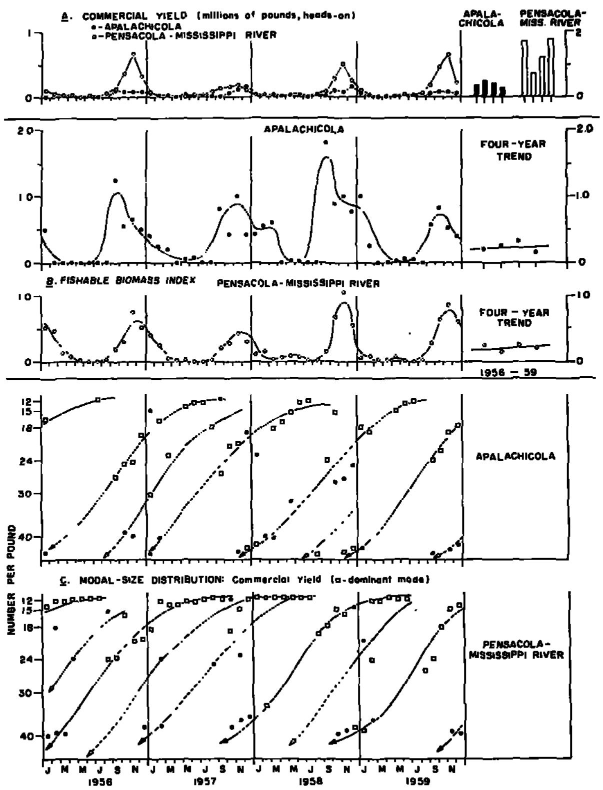

FIGURE 26.—Yield and structure of white shrimp populations off the northeastern Gulf coast, 1956–59.

mately 5 months after brown shrimp production reached its highest level (cf. figs. 12A and 26A). Larger sizes of shrimp (40 or less whole shrimp to the pound) nearly always predominated during periods of maximum offshore production (October–December).

Fishable biomass.—Population density curves exhibited the same pattern of seasonal fluctuation already described for other exploited shrimps (fig. 26B). Greatest white shrimp biomass, with which peak commercial production coincided, occurred in both areas toward the end of each calendar year. Although white shrimp biomass in the Apalachicola area usually exceeded that in the Pensacola-Mississippi River area during corresponding periods of maximum density, greater expenditures of effort for larger and more available shrimp resulted in greater yields from the latter area. Annual levels of fishable biomass were comparable for both areas, as were the 4-year trends which indicated a slight overall population rise.

Population characteristics.—Despite rather sketchy data, semiannual spawning in the northeastern Gulf's white shrimp stock was suggested by modal-size distributions derived from monthly landings (fig. 26C). Spawning is evidently protracted throughout much of the year but, using time of recruitment as a point of reference, heightened activity appears to take place during late spring and early summer (shaded arrows), and again in late fall and early winter (light arrows). This contrasts with a similar phenomenon noted for the coexistent brown shrimp stock in which corresponding periods of peak spawning occur somewhat later, respectively, in late summer and late winter.

Relative strengths of age classes generated through intensified spawning at the beginning and close of the annual reproductive season (late spring-early winter) varied considerably. Broods forthcoming at the season's beginning (shaded arrows) were consistently larger and obviously played the dominant role in sustaining the stock and thus the fisheries dependent upon it. Remnants of broods produced during later stages of the annual spawning season, while apparently contributing little to either offshore or inshore fisheries, probably aided in population maintenance by complementing spawning populations. The comparatively greater strength of early-season broods is emphasized on the corresponding 4-year biomass curves (cf. figs. 26B and 26C). Seasonal modes reflected the occurrence of these broods in the form of (1) recruits-of-the-year and (2) 1-year-old adults, the proportion of each group varying from year to year. Modes largely representing late-season broods are barely noticeable.

Early-season reproductive classes themselves experienced appreciable year-to-year variation both as to time of recruitment and size at recruitment. The former is attributable only to varying environmental conditions, whereas the latter could be due to the cumulative effects of fishing and undue environmental changes. Any deleterious effects of fishing, if operative, were so vague as to be undetectable. But the possible effects of large-scale environmental changes warrant some comment.

The question arises, for example, as to whether the intense storm systems which lashed the Gulf coast west of the Delta in June and August, 1957, could have caused substantial environmental changes in areas as far east as the Pensacola-Mississippi River area. Landings of white shrimp from offshore and inshore waters, as well as the species' overall population level, were down markedly in this area during the last half of that year (figs. 26–27, A and B). The decline becomes more dramatic when it is noted that effort expended in offshore and inshore waters during the period July–December was down only 17 and 5 percent, respectively, from that expended during the same period in 1956, while corresponding white shrimp

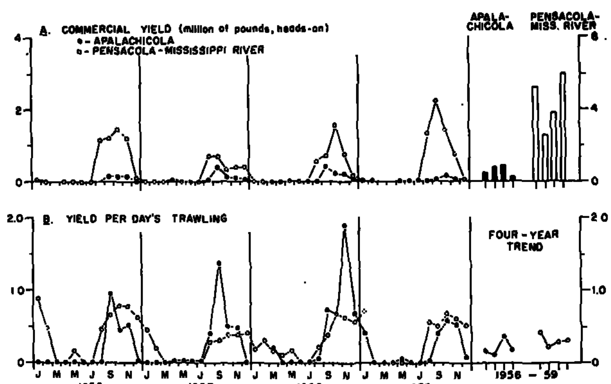

FIGURE 27.—Total and average yield of white shrimp populations in inshore waters along the northeastern Gulf coast, 1956–59.

landings were down 61 and 53 percent. The low 1957 yield must therefore be attributed more to a reduction in population size and availability than to poor fishing conditions and hence widespread reduction of fishing operations during the season of peak white shrimp density. Population reduction, in turn, may well have been attributable to poor survival in the early-season spawning class of 1957, excessive mortality having occurred during larval and inshore phases when adverse environmental conditions (high tides and extensive flooding, excessive turbulence, etc.) due to severe storms could be expected to exact the greatest toll.

On the average, growth rates in white shrimp populations fished off the northeastern Gulf coast were lower than those in populations off the northwestern Gulf coast. A more comprehensive discussion of growth in upper Gulf white shrimp stocks is deferred to a later section.

Inshore population phases.—During the period 1956–59, conditions in the northeastern Gulf's inshore fisheries for white shrimp very nearly paralleled those in adjacent offshore fisheries. Differing chiefly in amplitude, seasonal and annual yields in the Apalachicola and Pensacola-Mississippi River areas experienced the same order of fluctuation (figs. 26A and 27A). Seasonally, peak production of small shrimp in inshore waters occurred 1 to 2 months earlier than that of somewhat larger shrimp in offshore waters.

White shrimp comprised, on the average, about 45 percent by weight of all shrimp taken from inshore waters in both areas. Annual inshore landings in the Apalachicola area averaged 1.5 times corresponding offshore landings, and ranged from a high of 0.9 million pounds in 1958 to a low of 0.3 million pounds the following year. In the Pensacola-Mississippi River area the differential between inshore and offshore landings increased to a factor of 3.2, with inshore landings ranging from a high of 5.8 million pounds in 1959 to a low of 2.5 million pounds in 1957.

Crude indices of seasonal white shrimp density on inshore grounds reemphasize the dominant role played by early-season spawning classes (fig. 27B). Peak biomass is attained during the period September-November and occurs slightly in advance of maximum seasonal biomass in contiguous offshore waters (cf. fig. 26B). This reflects continuous migration of juveniles from inshore to offshore waters during that period. Late-season spawning classes are barely evident in figure 27B as very small modes recurring annually during April-May in both areas and in most years.

Summary of 4-year status.—White shrimp production exhibited similar patterns in offshore and inshore fisheries during the period 1956–59. No 4-year trend was evident in the Apalachicola area, but a very steep upward trend following substantial declines in 1957 was noted for fisheries in the Pensacola-Mississippi River area. Inshore production of small shrimp consistently exceeded offshore production of larger shrimp in both areas.

Four-year trends in overall relative density were comparable for offshore and inshore population phases, being slightly up in both areas. No relationship between intensity of fishing on either inshore or offshore population phases and total yields in the same and subsequent years was apparent. The greatly reduced catch of white shrimp from the Pensacola-Mississippi River area in 1957 is at least partly attributed to the side effects of intense storm systems which hit the coast just west of the Mississippi River Delta in June and August of that year. Extensive flooding due to abnormally high tides and excessive runoff is hypothesized as having caused higher-than-normal inshore mortality in 1957's early-season spawning class.

Fluctuations in white shrimp population strength and yield appeared to be largely governed by environmental factors. Provided these do not attain extreme proportions, and effort remains constant or does not greatly exceed recent expenditures, white shrimp landings in the Apalachicola and Pensacola-Mississippi River areas should stabilize at the same or just below levels recorded for the period 1956–59. There is some indication that white shrimp in the Apalachicola area could, on the average, withstand slightly heavier exploitation.

Northwestern Gulf Populations

Commercial yield.—The northwestern Gulf of Mexico annually surpasses all other areas in the production of white shrimp. Highest yields have been consistently obtained from that portion of the coastal stock inhabiting Louisiana's offshore and inshore waters.

In each of the years 1956 through 1959, the Louisiana Coast area contributed, on the average,

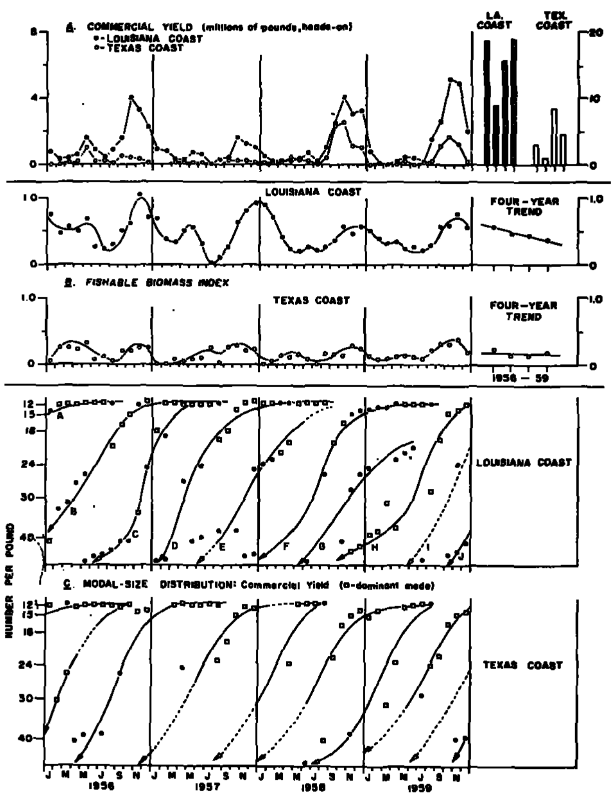

FIGURE 28.—Yield and structure of white shrimp populations off the northwestern Gulf coast, 1956–59.

72 percent of all white shrimp taken off the United States Gulf coast. Of all species harvested offshore within the area itself, white shrimp averaged 51 percent. Landings ranged from a low of 7.7 million pounds in 1957 to a high 17.9 million pounds in 1959 (fig. 28A). The 1957 catch represented a 55-percent drop from the level of the previous year and restimulated widespread concern for the white shrimp's future welfare (Viosca, 1958). Annual landings have since recovered, however, and in 1959 exceeded those of 1956. But, present status of the white shrimp notwithstanding, the question: "What caused the long-term decline from a 1945 production peak of well over 110 million pounds?"[5] remains unanswered.

Ranking second in offshore production, the Texas Coast area contributed 20 percent of the white shrimp taken commercially each year off the United States Gulf coast. This constituted but 9 percent of the weight of all species harvested annually from offshore waters within the area itself. Landings ranged from 1.0 million pounds in 1957 to 7.8 million pounds in 1958 (fig. 28A).

Seasonal distribution of white shrimp landings in the Louisiana and Texas Coast areas differed slightly from that noted in areas east of the Delta. Peak offshore harvest took place annually about a month earlier (in October as contrasted to November), and at the same time as or immediately following peak brown shrimp production. In addition, a secondary production mode usually occurred in May.

Fishable biomass.—Because size selectivity biases appeared minimal and all vulnerable sizes therefore reasonably well represented, biomass indices derived from offshore fishery statistics are believed to give a reliable picture of white shrimp population strength in the Louisiana Coast area. This was not the case in the Texas Coast area where purposive fishing for only the larger shrimp sizes was again evident. Seasonal distributions of biomass indices for both areas compared as to position of modes on the time axes but differed as to amplitude and relative displacement on the quantity axes (fig. 28B). The fishable stock off Louisiana maintained a higher average level over the 4-year period, 1956–59, but fluctuated more widely within and between seasons than did that off Texas. Despite increasing yields, the former apparently suffered a comparatively severe setback in 1957 from which it has not yet recovered. The Texas stock, on the other hand, has remained nearly stable, its fluctuating yields being largely attributable to vicissitudes of the industry, abundance of other varieties, etc. Midyear modes which were barely evident on biomass curves derived for the Apalachicola and Pensacola-Mississippi River areas show quite prominently on the Louisiana and Texas curves.

Since seasonal modes on biomass curves for adjacent statistical areas were usually positioned at corresponding points in time, coastwise drift of white shrimp juveniles migrating seaward is considered to have been negligible.

Population characteristics.—Evidence for two annual periods of increased spawning activity in upper Gulf coast white shrimp stocks is amplified in figure 28C. Good representation of vulnerable

[5] Data taken from "Fishery Statistics of the United States—1956", Statistical Digest No. 43, U.S. Fish and Wildlife Service, 1958. Since large-scale exploitation of the brown shrimp was not yet underway, practically all of this production is assumed to have consisted of white shrimp.

sizes in Louisiana landings provides a synoptic picture of population size structure in what is considered the nucleus of these stocks. Heightened spawning in November–December and in June–July may be inferred, respectively, from offshore recruitment surges in May–June (light arrows) and again in November–December (dark arrows). This pattern is quite similar to that described for populations in the northeastern Gulf. Year-to-year variation in extent of maximum spawning activity and timing of recruitment is again obvious; but a major distinction when comparing reproductive patterns for stocks in both areas is the enhanced significance of late-season broods (light arrows) to offshore and inshore fisheries in the northwestern Gulf areas. Secondary yield and biomass modes occurring in May or June (figs. 28A and 28B) are attributed in large part to late-season broods supplementing remnants of the prior year's early-season brood (fig. 28C). Populations giving rise to early- and late-season broods are believed to be predominated by survivors of the previous year's corresponding broods. The degree of predominance appears to vary widely, however, being largely dependent upon the relative initial strength and subsequent survival of each brood comprising a spawning population.

The foregoing description of the white shrimp's seasonal reproductive pattern agrees to some extent with that already given by Lindner and Anderson (1956). Also in general accord with the findings of these authors are gross conclusions that may be drawn from figure 28C regarding growth in recruited (offshore) population phases. If this figure gives a reasonably faithful picture of spawning class progress, note on curves tracing broods in populations fished off Louisiana that growth in weight is, on the average, comparatively slow during the period November–April. This agrees with statements made by Lindner and Anderson (1956) who used increase in body length rather than increase in weight as the growth criterion. By means of tagging experiments they showed that white shrimp of most sizes (105–175 mm. total length) ordinarily fished by the offshore fleet experienced reduced growth during winter months, and that growth during this season was approximately constant regardless of size. Over the remainder of the year, growth rates, as would be expected, were much greater in the smaller sizes (105–125 mm. total length at release) than in the larger sizes (155–175 mm. total length at release).

Compared to rate of growth measured in terms of length, rate of growth in weight is fairly low in the small sizes, increases to a maximum somewhere in the middle of the shrimp's overall size range, and then tapers off as the maximum attainable size is approached. Using increase in weight as the growth criterion and maintaining correspondence with Lindner and Anderson's results based on length increments, note in figure 28C that seasonal growth varied from year to year. Thus the late-season spawning class of 1955 (Louisiana Coast, brood B) apparently grew more rapidly the following November–April (1956–57) than did those of 1956 and 1957 (broods E and G) during the winters of 1957–58 and 1958–59, respectively. Average size in the 1956 class, for example, only increased from that equivalent to 24, to not quite 16 whole shrimp to the pound over the period December–April, about a 30 percent weight increase. This is contrasted to a 150 percent increase in average weight for the 1955 class during the corresponding season a year earlier.

The principal lesson derived here is that population growth in white shrimp (and very likely other species as well) is dynamic and therefore difficult to predict. Mark-recapture studies can only contribute growth estimates derived over short periods of time from a limited number of individual animals. Such estimates may be questionable not only from the standpoint of overall representativeness, but also from the standpoint of expected consistency in space and time. Before resource productivity can be projected, average growth in populations treated as units and broken down insofar as possible according to their component age classes, is the factor demanding measurement. This is best achieved in the case of exploited populations through analyses of appropriate commercial statistics. Current statistics, unfortunately, provide only a crude or "qualitative" picture of population growth. Progressive elimination of data biases should provide increasingly accurate growth parameter estimates together with some indication of their expected variability. For the present, however, eye estimates of optimum growth from serial alignment of what are considered representative weight-frequency distributions must suffice.

Figure 28C suggests that maximum rate of growth in the northwestern Gulf of Mexico white shrimp stock, although varying in magnitude from generation to generation, occurs, on the average, somewhere within that size range having limits equivalent to the weights at which 25 to 30 individual whole shrimp weigh 1 pound (41–50 count, heads off). This compares with evidence as to size at which growth in weight reaches a maximum in the northeastern stock, as well as in the Gulf's major stocks of brown and pink shrimp. But because information concerning natural mortality rates is lacking, answers to the question: "Where on the population growth curve do weight losses due to natural mortality begin to offset weight gains due to growth?" cannot be given. If natural mortality from the juvenile stage upward proves negligible, harvesting should be restricted to shrimp whose growth rate is approaching or has reached a maximum. Should natural mortality prove appreciable, utilization at a smaller average size may be indicated.

As in the case of northern Gulf of Mexico brown shrimp populations, semiannual periods of intensified spawning activity in coexisting white shrimp populations defy explanation. The mechanics of physiological adaptation to a highly variable environment are not understood, but temperature is believed to be a major if not the primary factor governing spawning activity in littoral Penaeidae. This relationship has already been considered in discussing the reproductive cycle of the brown shrimp. It was concluded that heightened spawning in brown shrimp populations off the northern Gulf coast was related to seasonal temperature reversals and not to some fixed "optimum" temperature.

A similar conclusion may apparently be drawn for the white shrimp except that increased spawning activity seems more closely related to reduction in rate of temperature change as seasonal minimum and maximum temperatures are approached. This can be construed to be in agreement with Lindner and Anderson (1956), who make the very general statement: "Spawning in Louisiana appears to be more closely associated with rising and falling temperatures than with absolute temperature."

Inshore population phases.—Over the period 1956–59, white shrimp comprised about 45 percent of all shrimp taken annually from inshore waters in the Louisiana and Texas Coast areas. Inshore catches usually accounted for about one-half of all white shrimp taken in the former area, and two-thirds of that harvested each year from the latter area. Yearly white shrimp landings from Louisiana's inshore waters fluctuated between a high of 11.4 million pounds in 1956 and a low of 2.8 million pounds the following year. Inshore landings from the Texas Coast area ranged from a low of 1.3 million pounds in 1956 to highs of about 3.6 million pounds in 1958 and 1959 (fig. 29A). Prospects for the Texas inshore fishery are encouraging. On the basis of incomplete data for 1960, the upward production trend established during 1956–59 is being maintained.

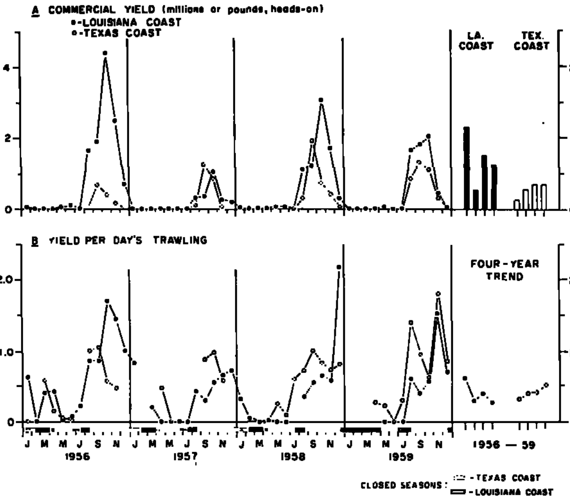

FIGURE 29.—Total and average yield of white shrimp populations in inshore waters along the northwestern Gulf coast, 1956–59.

A negative production trend signified by the decrease in Louisiana's 1957 inshore landings was countered with legislative action in the form of closed seasons more stringently enforced than those previously in effect. Accordingly, laws closing inshore waters of the State to all shrimping from the beginning of July to mid-August [6] and again from mid-December to the end of the following April, went into effect in 1958. Production in the offshore white shrimp fishery has since recuperated nicely, but the trend in the inshore fishery is still far from that desired.

[6] The "spring" season was extended to mid-July in 1960.

Enactment of such laws obviously implies that excessive fishing on certain population segments was or could have been primarily responsible for the fishery's downfall. Indeed, Viosca (1959), without any supporting evidence or explanation of probable mechanics, blames overfishing along with the 1952–57 drought. Aided by fairly complete and up-to-date statistics, one can now better speculate as to what did cause the demise of the Louisiana white shrimp fishery in 1957, and whether or not the aforementioned laws have been or will be effective in bringing about its recovery.

Closed seasons during the 4-year study period precluded complete pictures of white shrimp density patterns on inshore trawling grounds in the Louisiana and Texas Coast areas. As already mentioned, Louisiana exercised spring and winter closures beginning in 1958. From 1956 through 1958, Texas restricted large-scale commercial operations on its inshore waters to the periods March–mid-July and September–mid-December. In 1959 it eliminated the "spring" season and restricted commercial bay operations to the period mid-August–mid-December.

Despite resulting discontinuity, abundance curves derived for inshore population phases in both areas nevertheless suggest the occurrence of two annual modes (fig. 29B). A continuous curve for the Louisiana Coast area in 1956 and a practically complete curve for the Texas Coast area in 1958 verify a spring surge in abundance (April–May), and a dominant fall wave with peak varying annually between the months September to December. Close correspondence between catch and abundance patterns for inshore and adjacent offshore fisheries emphasizes, as Lindner and Anderson (1956) also point out, the proximity of inshore and offshore environments constituting white shrimp habitat. In contrast, the time lapse in migration from inshore to offshore grounds is considerably greater for brown shrimp due to the greater distances involved. Seasonal density and yield for the latter species, as shown earlier, reach a maximum in offshore waters a month or more following peak abundance and catch in contiguous inshore waters.

Annual and 4-year trends in white shrimp abundance on the northwestern Gulf's inshore grounds generally corresponded to those describing population phases on offshore grounds (cf. figs. 28–29 A and B). The significant feature in every case but one was the sharp drop in overall population levels in 1957, inshore phases in the Texas Coast area apparently escaping the effects of whatever caused the widespread decline. These effects manifested themselves through markedly reduced white shrimp production in inshore and offshore fisheries as far east as the Pensacola-Mississippi River area.

Failure of the 1957 fisheries in the Pensacola-Mississippi River area has been partially attributed to the poor success of that year's early season spawning class. Side effects of intense storms striking the coast west of the Delta were, in turn, conjectured as having been the cause. Since these storms centered in the Louisiana Coast area, it is hypothesized further that they contributed in even greater degree to population damage and production decline there. Thought to have wrought the most damage was hurricane "Audrey" which hit the coast just east of the Louisiana–Texas border on June 27. Storm surges brought tides of almost 14 feet above mean sea level (m.s.l.) in the Cameron, La., area; 4 feet above m.s.l. in Garden Island Bay, La., 250 miles to the east; and 3 feet above m.s.l. at Port Aransas, Tex., 220 miles to the west. Low-lying areas in Louisiana were inundated up to 25 miles inland (Moore and staff, 1957). Tropical storm "Bertha", not quite attaining hurricane intensity, shortly followed "Audrey", striking the coast in the same general area on August 9. The highest accompanying tide, 4.7 feet above m.s.l., was recorded in Vermilion Bay, La.

The occurrence of these storms coincided with periods of peak inshore and nearshore concentrations of (1) migrating juveniles representing the 1956 late-season brood, and (2) late postlarvae and juveniles representing the 1957 early-season brood. Although the mechanics involved are obscure, it is conceivable that factors such as: extended periods of high salinity, destruction of cover and food supplies, and excessive turbulence, all induced by extraordinarily high tides, acted corporately to disperse and otherwise exert greater-than-normal mortality in white shrimp populations during vulnerable inshore phases.

Excessive fishing on spawning populations giving rise to late-season and early-season broods in 1956 and 1957, respectively, is discounted as a contributing factor. Comparatively speaking, indices of mean biomass for offshore and inshore population phases suggested that white shrimp spawning potential in 1956 and early 1957 was more than adequate.

Although effort expenditure fell off during the latter half of 1957, the decline was not sufficient to account for the disproportionate drop in landings. Effort expended on inshore and offshore grounds in the Louisiana Coast area during July–December, 1957, was 72 and 51 percent, respectively, of that expended during the same period in 1956. Corresponding landings, on the other hand, were only 25 and 36 percent of those recorded in 1956. About the same amount of effort expended in Texas offshore waters during the latter half of 1956 was recorded for 1957, but the corresponding white shrimp catch declined 43 percent. In contrast, the Texas inshore fishery doubled its production of white shrimp during the same period with only a 55-percent increase in effort expenditure. Most of this, however, came from bays along the southern half of the Texas coast, outside the main area of storm damage.

Significantly, brown shrimp landings from Louisiana's offshore waters were off 43 percent in the last half of 1957 despite expectations of as successful a spring brood for that year as was produced the previous year. Note however, that this drop was not out of line with the 49-percent drop in corresponding effort expenditure. Recall also that overall mean population biomass during 1957 was up in all northwestern Gulf areas. In fact, brown shrimp landings from offshore waters in the Texas Coast area increased 15 percent over those for 1956. All evidence thus suggests that coexistent brown shrimp populations did not suffer the effects of those factors to which the demise of the white shrimp population was attributed. Reduction of brown shrimp catches off Louisiana (July–December, 1957) must therefore be considered a result of a proportionate decrease in shrimping effort brought about by extended periods of unfavorable operating conditions.

A similar conclusion cannot be drawn for the western Gulf of Mexico white shrimp stock and the fishery it sustains. Record low landings from Louisiana waters in 1957 must be ascribed more to a real decline in population strength than to relaxed exploitation during a period when the white shrimp normally attains peak density and availability. The import of factors contributing to this decline is also manifested in the magnitude of the following year's landings. Thus, notwithstanding an immediate return of effort expenditure to its 1956 level (figs. 8 and 10), restoration of landings to their former level has lagged for 2 years.

The effectiveness of newly enacted closed-season laws (inshore waters: Louisiana, 1958) in bringing about this recovery appears questionable. Most noteworthy, perhaps, is the fact that these closures generally coincide with or occur shortly after seasonal ebbs in the white shrimp's nursery ground phases. Records show that in years prior to enactment of the latest and most effective closed-season law (1956–58), white shrimp landings (inshore) over the period January–April, and December, averaged but 6 percent of each year's total. The closed season, mid-December through April, in effect, protects (1) residuals of early-season spawning classes, most of whose representatives will have already passed to offshore waters by the time the fishing season closes, and (2) late-season broods, the postlarvae of which begin to move into inshore areas at about the same time. Most members of the less important late-season classes will have attained commercial size when the fishing season reopens in May. Though now protected on inshore areas, these classes have never contributed significantly to inshore or offshore fisheries.

On the other hand, early-season broods which are fished heavily in inshore waters during late August through November are the same broods dominating the offshore fishery which reaches peak production almost simultaneously. They support the white shrimp fishery but are not now afforded anywhere near the extensive protection given late-season broods.[7] Nor is additional protection called for *unless* a significant relationship between fishing rate and brood size (or recruitment) manifests itself.

Available statistics do not permit establishing whether or not such a relationship prevailed. But, despite improved yields, the white shrimp stock in the northwestern Gulf has shown little sign of recuperating from the 1957 ebb. This

[7] The closed season mid-July to mid-August offers early-season white shrimp broods protection from excessive fishing on precommercial sizes. Inshore production of brown shrimp has not been affected by either closure.

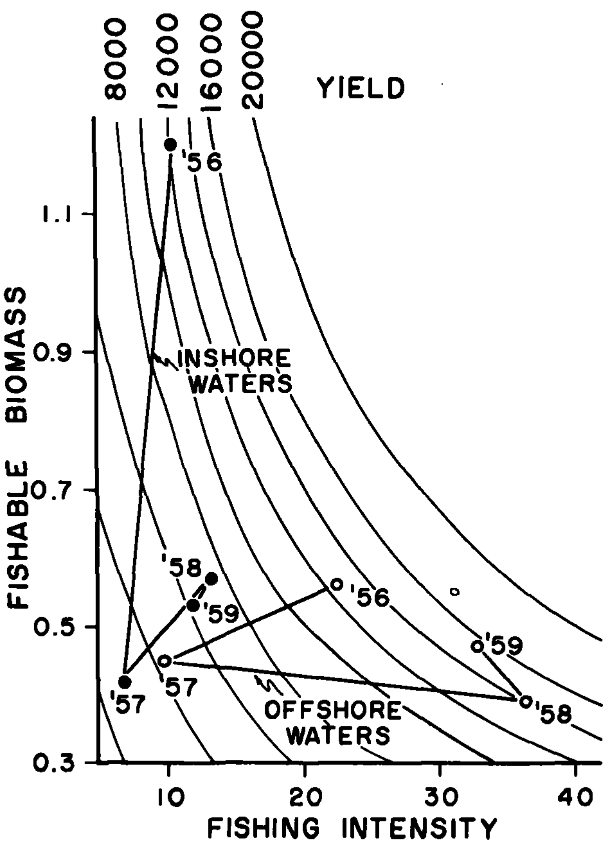

Figure 30.—Relationship between fishable white shrimp biomass and fishing intensity in successive early-season spawning classes, Louisiana Coast, 1956–59. [Yield is in thousand-pound units.]

could be due to too heavy fishing pressure having been exerted too soon after extreme population setbacks. If each year's dominant early-season spawning classes are roughly separated by analyzing only those statistics for the months July–December, plots of mean annual biomass against corresponding fishing intensity mildly suggest such a possibility (fig. 30). In Louisiana's offshore waters, quadrupled fishing intensity in 1958 had the apparent effect of delaying initiation of a recovery trend until the following year. Unfortunately for the white shrimp, 1958 was a year in which record high shrimp prices induced extra-heavy fishing to recover losses suffered the preceding year. Most of this was directed at brown shrimp with the low-level white shrimp population suffering coincidentally. Effects of exploitation inshore are also well illustrated and, in fact, may well have been the controlling factors. A doubling of the fishing intensity in 1958 seemingly contributed to the decline in the offshore population phase the same year, and in itself may have stifled an earlier upsurge in the overall population. Relaxation of fishing pressure on the inshore phase in 1959 resulted in concomitant recovery in offshore (spawning) population phases.

In summary, the question is not so much one of whether, following periods of high natural mortality, fishing intensity should be regulated at all, but one of deciding at what season such regulation would be most effective. Little benefit can be expected from suspending fishing in inshore waters when population phases there are at minimal density. On the other hand, closed seasons in offshore waters supporting multispecies fisheries are out of the question altogether.

Summary of 4-year status.—White shrimp production in the Louisiana and Texas Coast areas experienced a sharp drop in 1957. Since then, trends in the more important offshore and inshore fisheries have been up, but return to 1956 production levels has been slow. Incomplete data for 1960 indicate that former high levels will be attained or surpassed this year.

Analysis of effort and catch statistics revealed that the low production in 1957 reflected a severe population decline. This in turn was attributed to the dire effects of intense storm systems which are believed to have compounded expected natural mortality during inshore phases in that year's early-season spawning class. Further analysis eliminated, insofar as available data permitted, the possibility that excessive fishing on spawning stocks or proportionately reduced fishing intensity, rather than poor survival alone, had resulted in the diminished landings.

Trends in overall stock strength were up in the Texas Coast area but gave little hint, despite improved yields, of population recovery in the Louisiana Coast area. Too heavy fishing on dominant early-season spawning classes in 1958 caused postponement of a recovery trend. Relaxed pressure initiated one in 1959. A direct "within-season" relationship between (1) fishing intensity on inshore phases and (2) strength of offshore phases was suggested. Closed inshore seasons first enforced in 1958 were largely ineffectual in bringing about a recovery in that portion of the coastal stock supporting Louisiana's white shrimp fishery.

Other Gulf Populations

Production of white shrimp in Gulf areas other than those already mentioned was negligible during the 4-year study period. A trace was recorded from the Sanibel-Tortugas area (statistical subarea 5) in 1959, and United States fleet landings from the combined East Mexican Coast and Obregon-Campeche areas ranged from less than 0.1 million pounds in 1956 to 0.6 million pounds in 1958 (table 4). As noted earlier, white shrimp taken by United States fishermen comprised only an estimated 1 percent of the total poundage of this species harvested in Mexican waters. Data are too sketchy to permit analyses of white shrimp populations in these areas.

SUMMARY

Those phases of Gulf of Mexico fisheries concerned with the catching, landing, and initial processing of commercial shrimps are briefly described. Knowledge of each species distribution and habits, manner of capture, handling, etc., is reviewed in an attempt to ensure proper interpretation of production statistics as employed to draw inferences about commercial shrimp populations.

The Bureau of Commercial Fisheries continuous survey of Gulf shrimp fisheries is examined critically as to kind and quality of statistics collected. Sources of inaccuracy in effort and landing statistics are pointed out. Effort data, for example, are incomplete due to an inability to determine the extent of "searching" and nonproductive operations, and biased to varying degree in direction and magnitude because of suspect sample projection techniques. Data of overall commercial landings are quite complete, but those for certain species may be biased since distinction between species is not always uniform around the Gulf. Landings, moreover, do not always represent actual catches, or reflect the composition of available populations. More often than not they result from (1) culling catches dominated by small, nonpremium shrimp, or (2) extensive searching for concentrations of premium-size shrimp. Commercial size-classification statistics thereby suffer because their capacity to depict actual size or age structure of exploited populations is lessened.

With real or potential biases being acknowledged, available statistics for each species are used (1) to derive population density indices and (2) to delineate and trace population spawning classes (broods). Short- and long-term trends in population strength are examined in light of trends in corresponding yield. Untoward fluctuations in yield are explained, where possible, in terms of observed population characteristics and their apparent relation to changes in environment and intensity of exploitation.

Commercial statistics reveal that over the period 1956–59, the Gulf of Mexico annually yielded between 167 and 193 million pounds of shrimp to United States fishermen. This represented an average yearly expenditure of 169,000 days' trawling time. About three-fourths of both total effort and yield, respectively, was expended in and taken from waters along the United States coast. Inshore landings and corresponding effort averaged about 21 and 28 percent, respectively, of United States totals. Although overall landings varied mildly during the 4-year study period, those for certain species and in certain areas fluctuated sharply, with fishing success in 1957 having been generally poor.

Of the three major commercial species supporting Gulf of Mexico shrimp fisheries, brown shrimp were the most important, contributing, on the average, 56 percent of annual harvests. Greatest production consistently came from offshore and inshore waters along the northwestern Gulf coast, with Texas waters recognized as this species center of abundance. Over the period 1956–59, brown shrimp population levels rose in the Apalachicola, Pensacola-Mississippi River, and Louisiana Coast areas, remained steady or fell only slightly in the Texas Coast area, and fell perceptibly in the East Mexican Coast area. Corresponding yield trends either remained steady or rose in all areas. Immediate consequences of increasing fishing intensity on declining populations in the Texas and East Mexican Coast areas are problematical.

Serial alignment of monthly weight-frequency curves derived from catch-by-size statistics gave a crude picture of age structure in Gulf of Mexico brown shrimp stocks. Progression of modes inferred two periods of heightened spawning activity each year—one in late winter or early spring, the other in late summer or early fall. Relative strengths of these spawning classes (or broods) obviously varied between as well as within years, but, on the average, early-season classes appeared to be the dominant ones. Superposition of

seasonal spawning and temperature patterns suggested that increased spawning activity was more closely related to temperature reversals than to some fixed or optimum spawning temperature.

Contributing an average of but 22 percent yearly to Gulf of Mexico shrimp landings, pink shrimp ranked second to brown shrimp. Although of relatively minor status on a Gulfwide basis, the species does contribute significantly to the local economy in certain areas. Indeed, since it is the only species of commercial importance occurring off south Florida, the pink shrimp constitutes the sole support of the valuable Sanibel-Tortugas fishery. Practically all Gulf of Mexico pink shrimp production originates in the Sanibel-Tortugas and Gulf of Campeche areas.

Semiannual periods of increased spawning activity also characterize the Sanibel-Tortugas pink shrimp stock. During the period covered by available statistics, relative strengths of early-season and late-season broods appeared roughly equivalent.

From 1956 through 1959, commercial yields of pink shrimp from the Sanibel-Tortugas area suffered a gradual decline. This reflected a downward trend in stock biomass which developed despite a nearly constant (annual) fishing intensity. Whether the effects of too high a sustained, overall fishing intensity were just beginning to manifest themselves during the study period could not be verified due to the lack of prior effort data. The likelihood of excessive fishing being the primary causative factor is considered remote, however, and diminishing population levels are thought to be more a result of greater utilization of small shrimp. Increasingly heavy exploitation of new recruits as they enter the fishery and before their average growth rate reaches a maximum appears to have systematically reduced annual available biomass.

Annual pink shrimp landings from the Gulf of Campeche also experienced a significant downward trend over the period 1956–59. But due to the Campeche fishery's highly selective nature and, consequently, the limited utility of resulting statistics, detailed appraisal of the underlying population was not attempted.

Closely approaching pink shrimp from a production standpoint, white shrimp ranked third in importance to the Gulf of Mexico shrimp industry, comprising about 20 percent of annual shrimp landings. Practically all of this species came from northern Gulf waters with the Louisiana Coast area each year contributing roughly 72 percent of United States Gulf coast totals.

Analyses of monthly size composition data indicated protracted spawning in white shrimp stocks with heightened activity occurring at the beginning and close of each spawning season, April–December. Relative strengths of corresponding spawning classes differed from year to year while early-season classes appeared consistently superior to late-season classes. Average growth compared with that of brown and pink shrimp but varied between early- and late-season classes, and among corresponding classes in different years. Attainment of commercial size is prolonged in late-season classes due to slowed growth during winter months.

Over the period 1956–59, annual white shrimp yields remained relatively stable in the Apalachicola area and rose in the Texas Coast area. Population trends were slightly up in both areas. In contrast, white shrimp fisheries in the Pensacola-Mississippi River and Louisiana Coast areas experienced a severe setback in 1957. Recovery has been fairly rapid in both areas with 1959 landings approaching 1956 levels. But, while white shrimp biomass displayed an upward trend during 1958–59 in the Pensacola-Mississippi River area, population recovery in the Louisiana Coast area lagged perceptibly.

The sharp decline of important white shrimp fisheries in 1957 is largely attributed to factors associated with intense storm systems which are believed to have compounded expected natural mortality during inshore phases of that year's early-season spawning class. Too heavy fishing on the dominant early-season spawning class in 1958 is postulated as having postponed a population recovery trend in the Louisiana Coast area. Relaxed pressure seemingly initiated one in 1959. Closed inshore seasons first enforced in 1958 cannot be credited with having expedited recovery since they mainly include periods during which fishable white shrimp normally exhibit minimal density. White shrimp population strength appears primarily governed by the environment, but excessive fishing intensity too soon after a catastrophic ebb may stifle quick recovery.

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APPENDIX

TABLE A1.—*Effort expended by the United States commercial shrimp fleet in the Gulf of Mexico, 1956–59*

[24-hour units' trawling]

Area and depth (fm.)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
SANIBEL-TORTUGAS													
1956													
Inshore	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
0–10	2.5	110.9	235.6	229.6	230.1	17.6	6.1	--------	--------	1.2	5.0	11.2	849.8
11–20	1,485.4	1,931.0	2,210.5	2,177.9	2,234.2	1,134.2	380.3	442.9	191.6	495.9	921.8	1,834.4	15,440.1
21–45	318.2	262.6	79.0	254.5	204.3	23.3	3.6	5.8	2.5	--------	3.8	71.5	1,229.1
Offshore	1,806.1	2,304.5	2,525.1	2,662.0	2,668.6	1,175.1	390.0	448.7	194.1	497.1	930.6	1,917.1	17,519.0
1957													
Inshore	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
0–10	69.5	126.5	148.4	153.3	97.1	29.9	1.6	--------	--------	.4	21.1	2.5	650.3
11–20	2,816.4	2,400.7	2,755.4	1,608.7	1,447.1	740.7	415.7	252.7	306.7	495.6	1,373.8	1,405.2	16,018.7
21–45	61.0	68.8	154.9	81.8	28.9	35.1	11.7	20.2	6.0	12.3	67.6	118.6	666.9
Offshore	2,946.9	2,596.0	3,058.7	1,843.8	1,573.1	805.7	429.0	272.9	312.7	508.3	1,462.5	1,526.3	17,335.9
1958													
Inshore	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
0–10	16.5	278.0	499.4	794.3	467.5	174.4	50.2	1.7	3.0	.1	73.2	130.1	2,488.4
11–20	2,272.3	1,972.1	2,341.1	2,211.7	2,000.7	877.6	320.9	508.8	639.5	764.6	1,523.4	1,355.0	16,787.7
21–45	176.1	257.9	241.6	88.6	97.6	3.0	4.6	189.8	45.8	3.7	72.4	232.7	1,413.8
Offshore	2,464.9	2,508.0	3,082.1	3,094.6	2,565.8	1,055.0	375.7	700.3	688.3	768.4	1,669.0	1,717.8	20,689.9
1959													
Inshore	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
0–10	223.3	324.9	398.2	509.5	321.9	160.8	39.8	21.0	15.2	12.0	60.3	53.9	2,140.8
11–20	2,363.6	1,963.9	2,136.6	1,341.5	1,288.7	671.9	190.9	136.3	149.4	330.6	535.6	1,481.2	12,590.2
21–45	523.1	891.4	322.5	307.0	115.5	140.7	12.6	--------	--------	--------	4.8	44.3	2,366.9
Offshore	3,110.0	3,180.2	2,857.3	2,158.0	1,726.1	973.4	243.3	157.3	164.6	342.6	600.7	1,584.4	17,097.9
APALACHICOLA													
1956													
Inshore	12.5	1.5	85.2	123.0	328.7	123.6	60.2	119.6	175.9	306.9	296.7	58.8	1,692.6
0–10	23.3	3.5	3.8	183.7	566.2	213.7	204.9	4.0	.4	148.0	125.9	176.3	1,653.7
11–20	8.0	.5	--------	--------	225.4	237.9	38.9	15.0	83.1	--------	--------	--------	608.8
21–45	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Offshore	31.3	4.0	3.8	183.7	791.6	451.6	243.8	19.0	83.5	148.0	125.9	176.3	2,262.5
1957													
Inshore	40.6	26.5	112.2	352.5	420.9	185.8	248.5	172.5	480.0	250.4	257.5	54.0	2,601.4
0–10	107.8	93.6	117.1	79.3	207.3	44.0	42.0	11.0	17.3	87.0	122.8	248.9	1,178.1
11–20	--------	--------	--------	200.5	28.3	120.7	114.0	7.5	1.0	59.0	27.7	2.5	561.2
21–45	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Offshore	107.8	93.6	117.1	279.8	235.6	164.7	156.0	18.5	18.3	146.0	150.5	251.4	1,739.3
1958													
Inshore	--------	--------	13.0	82.9	286.9	241.8	607.0	276.7	543.1	315.9	104.8	92.2	2,564.3
0–10	62.8	8.0	36.3	124.2	510.7	281.9	146.1	67.2	8.9	99.3	57.5	155.4	1,558.3
11–20	--------	--------	--------	.4	46.8	17.7	19.0	8.5	--------	1.0	20.5	14.3	128.2
21–45	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Offshore	62.8	8.0	36.3	124.6	557.5	299.6	165.1	75.7	8.9	100.3	78.0	169.7	1,686.5
1959													
Inshore	2.5	17.4	94.4	254.8	348.9	231.0	167.8	130.0	170.1	255.5	103.2	24.0	1,799.6
0–10	81.9	16.9	12.9	262.2	385.7	105.3	50.9	14.5	53.6	75.4	131.5	113.8	1,304.6
11–20	1.0	--------	--------	--------	6.9	46.5	17.5	5.5	--------	--------	--------	--------	77.4
21–45	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Offshore	82.9	16.9	12.9	262.2	392.6	151.8	68.4	20.0	53.6	75.4	131.5	113.8	1,382.0

TABLE A1.—*Effort expended by the United States commercial shrimp fleet in the Gulf of Mexico, 1956–59*—Continued

[24-hour units' trawling]

Area and depth (fm.)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
PENSACOLA-MISSISSIPPI RIVER													
1956													
Inshore	27.5	2.7	10.8	66.2	432.7	2,110.1	1,917.5	2,682.0	1,878.6	1,905.9	1,547.7	199.1	12,780.8
0–10	17.3	9.0	.5	4.0	48.3	1,455.4	1,643.0	907.3	170.4	393.0	538.1	152.1	5,338.4
11–20	43.5	27.0	--------	39.8	194.2	886.1	1,363.0	688.9	369.6	287.8	216.7	204.3	4,320.9
21–45	334.8	325.0	405.0	351.6	323.1	112.6	15.0	438.5	252.6	300.4	82.9	270.8	3,212.3
Offshore	395.6	361.0	405.5	395.4	565.6	2,454.1	3,021.0	2,034.7	792.6	981.2	837.7	627.2	12,871.6
1957													
Inshore	23.8	12.2	58.3	157.3	930.6	1,881.1	1,796.3	2,429.2	2,365.2	982.4	1,077.3	956.1	12,669.8
0–10	23.5	4.5	1.0	1.7	176.3	1,587.4	1,452.5	555.9	65.0	63.3	64.3	20.8	4,016.2
11–20	92.4	14.3	8.3	--------	181.1	640.7	826.7	1,014.5	365.7	283.3	245.9	225.3	3,898.2
21–45	124.1	153.6	48.3	34.7	236.7	25.5	--------	574.4	602.8	284.8	140.9	120.4	2,346.2
Offshore	240.0	172.4	57.6	36.4	594.1	2,253.6	2,279.2	2,144.8	1,033.5	631.4	451.1	366.5	10,260.6
1958													
Inshore	49.6	10.0	18.0	168.6	153.0	1,866.3	1,791.4	2,867.7	1,810.9	2,313.0	1,195.5	286.3	12,530.3
0–10	2.0	2.5	2.0	8.2	10.4	571.2	1,024.6	518.5	62.8	131.2	220.0	97.2	2,650.6
11–20	26.6	72.9	12.1	8.4	14.4	152.6	886.7	845.9	306.0	165.3	143.9	230.7	2,865.5
21–45	142.5	122.2	196.3	116.7	11.3	54.1	13.2	195.2	192.3	101.8	144.7	134.9	1,425.2
Offshore	171.1	197.6	210.4	133.3	36.1	777.9	1,924.5	1,559.6	561.1	398.3	508.6	462.8	6,941.3
1959													
Inshore	23.3	--------	1.6	42.3	174.9	2,997.8	2,234.4	2,425.5	4,344.7	1,940.5	1,249.7	112.5	15,547.2
0–10	26.0	20.3	1.0	2.1	24.7	1,279.4	740.2	605.4	175.9	301.1	301.5	94.4	3,572.0
11–20	83.5	15.3	5.5	4.2	81.0	827.9	1,766.6	1,047.2	484.2	135.6	283.3	182.0	4,916.3
21–45	91.3	16.0	13.5	6.9	11.4	--------	343.0	212.4	143.4	119.4	133.6	75.6	1,166.5
Offshore	200.8	51.6	20.0	13.2	117.1	2,107.3	2,849.8	1,865.0	803.5	556.1	718.4	352.0	9,654.8
LOUISIANA COAST													
1956													
Inshore	107.3	6.0	6.0	21.5	4,234.2	1,999.7	86.8	1,942.3	2,344.5	2,567.3	1,709.5	675.5	15,700.6
0–10	829.2	500.1	481.6	438.3	1,813.7	1,222.5	586.7	892.2	1,664.7	3,213.5	2,590.3	1,880.3	16,113.1
11–20	76.3	130.1	312.1	350.1	284.7	836.0	2,257.0	2,839.6	533.7	921.7	658.8	456.6	9,656.7
21–45	621.2	392.3	732.3	976.8	879.2	35.2	258.9	15.7	60.5	282.3	68.1	133.1	4,455.6
Offshore	1,526.7	1,022.5	1,526.0	1,765.2	2,977.6	2,093.7	3,102.6	3,747.5	2,258.9	4,417.5	3,317.2	2,470.0	30,225.4
1957													
Inshore	6.0	--------	1.5	667.2	3,079.4	2,599.3	512.0	1,621.4	2,136.0	1,807.2	420.9	261.5	13,112.4
0–10	861.0	747.1	446.6	587.4	1,287.6	1,330.1	114.0	699.0	1,255.8	2,672.1	1,398.8	833.4	12,232.9
11–20	451.3	346.7	127.3	196.0	516.7	475.5	952.4	698.0	428.7	161.0	54.4	231.4	4,639.4
21–45	142.3	258.4	185.2	180.5	87.1	.7	4.5	141.5	7.0	37.7	37.7	148.1	1,230.7
Offshore	1,454.6	1,352.2	759.1	963.9	1,891.4	1,806.3	1,070.9	1,538.5	1,691.5	2,870.8	1,490.9	1,212.9	18,103.
1958													
Inshore	182.1	--------	178.7	9.0	1,340.0	5,552.2	38.0	2,984.1	2,382.5	4,413.6	2,990.4	138.8	20,209.4
0–10	306.8	179.6	257.8	603.4	1,174.9	1,895.9	349.0	2,129.1	3,038.9	3,539.3	3,715.7	3,425.6	20,616.0
11–20	189.4	276.4	198.2	112.0	402.5	306.4	1,538.5	2,656.1	854.7	48.9	58.7	189.9	6,831.7
21–45	517.2	107.4	373.0	643.9	555.8	127.6	794.0	701.4	334.6	412.0	213.6	326.1	5,106.6
Offshore	1,013.4	563.4	829.0	1,359.3	2,133.2	2,329.9	2,681.5	5,486.6	4,228.2	4,000.2	3,988.0	3,941.6	32,554.3
1959													
Inshore	--------	--------	--------	--------	4,036.0	5,814.0	1.0	2,831.4	4,591.5	3,585.0	467.3	79.6	21,405.8
0–10	391.8	46.8	84.9	478.2	1,613.9	1,755.2	192.8	1,315.4	1,736.4	4,748.0	4,284.6	1,938.6	18,586.6
11–20	399.7	173.1	211.2	288.7	887.7	1,118.9	2,854.8	1,141.8	889.7	303.8	222.2	521.8	9,013.4
21–45	600.6	562.7	555.6	1,056.1	790.1	123.4	146.3	166.2	109.8	175.1	78.5	404.5	4,768.9
Offshore	1,392.1	782.6	851.7	1,823.0	3,291.7	2,997.5	3,193.9	2,623.4	2,735.9	5,226.9	4,585.3	2,864.9	32,368.9

TABLE A1.—*Effort expended by the United States commercial shrimp fleet in the Gulf of Mexico, 1956–59*—Continued

[24-hour units' trawling]

Area and depth (fm.)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
TEXAS COAST													
1956													
Inshore	.5	--------	5.4	153.7	320.2	75.7	2.0	--------	652.8	725.5	331.9	--------	2,267.7
0–10	.4	8.1	114.5	111.8	965.7	354.3	247.1	57.7	468.2	478.6	290.9	59.8	3,157.1
11–20	161.4	63.2	39.2	624.5	844.2	950.0	3,235.3	5,801.9	3,576.4	3,627.2	1,497.3	732.9	21,153.5
21–45	893.6	593.0	834.6	494.4	255.4	388.5	185.5	431.7	1,125.3	710.3	822.8	756.0	7,491.1
Offshore	1,055.4	664.3	988.3	1,230.7	2,065.3	1,692.8	3,667.9	6,291.3	5,169.9	4,816.1	2,611.0	1,548.7	31,801.7
1957													
Inshore	--------	--------	--------	22.0	858.3	401.0	--------	104.5	1,597.6	884.9	58.7	--------	3,927.0
0–10	1.6	1.8	10.1	35.9	55.1	60.9	80.9	208.8	190.8	185.4	203.4	51.4	1,086.1
11–20	154.4	41.6	210.5	221.0	590.7	3,002.4	5,916.0	5,602.0	3,785.3	3,280.6	1,791.2	465.8	25,061.5
21–45	929.3	1,386.4	922.6	667.1	580.3	264.8	19.3	281.2	370.6	290.8	809.2	1,030.1	7,551.7
Offshore	1,085.3	1,429.8	1,143.2	924.0	1,226.1	3,328.1	6,016.2	6,092.0	4,346.7	3,756.8	2,803.8	1,547.3	33,699.3
1958													
Inshore	--------	--------	--------	52.0	284.9	343.8	70.4	466.9	1,951.5	932.7	546.2	78.3	4,726.7
0–10	.5	--------	57.2	441.5	311.9	552.6	559.3	570.0	1,179.5	1,377.8	765.9	1,111.4	6,927.6
11–20	309.3	42.5	26.6	354.0	1,568.8	3,395.6	6,525.8	7,285.3	5,854.7	2,787.3	978.0	854.1	29,982.0
21–45	835.1	763.3	802.4	552.2	266.0	424.2	206.5	8.9	90.2	244.6	383.2	372.9	4,949.5
Offshore	1,144.9	805.8	886.2	1,347.7	2,146.7	4,372.4	7,291.6	7,864.2	7,124.4	4,409.7	2,127.1	2,338.4	41,859.1
1959													
Inshore	--------	--------	--------	14.2	95.7	33.1	66.5	643.6	1,287.7	1,831.3	157.3	28.3	4,157.7
0–10	139.9	11.3	34.4	200.9	432.8	33.2	111.8	254.3	668.4	962.3	775.9	127.9	3,753.1
11–20	245.6	140.1	172.2	211.3	1,136.8	1,087.0	3,506.7	5,638.7	5,940.0	4,550.3	1,577.0	1,050.2	25,255.9
21–45	422.1	374.4	582.7	329.9	236.4	83.8	458.7	995.7	736.6	757.4	500.8	570.2	6,048.7
Offshore	807.6	525.8	789.3	742.1	1,806.0	1,204.0	4,077.2	6,888.7	7,345.0	6,270.0	2,853.7	1,748.3	35,057.7
EAST MEXICAN COAST													
1956													
Inshore	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
0–10	--------	--------	--------	2.7	2.7	--------	2.7	6.0	--------	--------	--------	--------	14.1
11–20	27.8	167.2	32.7	128.3	156.4	149.7	144.1	128.1	240.2	259.8	354.0	151.4	1,939.7
21–45	1,397.2	945.2	1,157.7	881.1	843.2	1,149.7	744.5	570.5	740.8	1,639.3	1,005.3	1,347.1	12,421.6
Offshore	1,425.0	1,112.4	1,190.4	1,012.1	1,002.3	1,299.4	891.3	704.6	981.0	1,899.1	1,359.3	1,498.5	14,375.4
1957													
Inshore	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
0–10	1.7	1.9	5.7	4.7	7.6	8.5	5.9	1.6	.2	--------	--------	--------	37.8
11–20	74.0	39.3	121.7	111.0	138.1	193.1	843.5	769.8	542.5	279.7	478.6	472.4	4,003.7
21–45	1,017.0	974.9	1,041.2	925.6	1,593.1	1,463.8	1,053.6	672.7	1,194.8	1,426.9	1,162.2	999.7	13,525.5
Offshore	1,092.7	1,016.1	1,168.6	1,041.3	1,738.8	1,665.4	1,903.0	1,441.1	1,737.5	1,706.6	1,640.8	1,472.1	17,627.0
1958													
Inshore	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
0–10	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	83.6	185.7	269.3
11–20	263.1	117.5	97.7	119.5	129.7	238.5	151.0	7.1	68.4	634.9	463.8	552.1	2,843.3
21–45	2,163.0	1,995.1	2,868.3	2,554.1	2,965.9	1,313.2	275.0	111.1	214.7	2,475.5	2,344.3	1,798.8	21,079.0
Offshore	2,426.1	2,112.6	2,966.0	2,673.6	3,095.6	1,551.7	426.0	118.2	283.1	3,110.4	2,891.7	2,536.6	24,191.6
1959													
Inshore	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
0–10	39.3	16.3	11.7	40.1	107.7	54.3	.4	--------	--------	--------	--------	--------	269.8
11–20	170.6	106.7	393.2	193.5	191.7	408.5	294.4	407.4	287.4	418.8	191.4	305.8	3,369.4
21–45	1,425.1	1,679.9	1,505.4	1,306.7	727.3	747.2	356.9	853.8	1,299.5	1,443.4	1,195.0	1,431.9	13,972.1
Offshore	1,635.0	1,802.9	1,910.3	1,540.3	1,026.7	1,210.0	651.7	1,261.2	1,586.9	1,862.2	1,386.4	1,737.7	17,613.3

TABLE A1.—*Effort expended by the United States commercial shrimp fleet in the Gulf of Mexico, 1956–1959*—Continued

[24-hour units' trawling]

Area and depth (fm.)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
OBREGON-CAMPECHE													
1956													
Inshore													
0–10	176.0	203.0	313.0	153.5	201.5	153.4	58.3	21.3	7.1	19.9	5.5	182.3	1,494.8
11–20	714.7	1,924.5	1,302.3	1,661.9	1,521.1	1,422.0	1,909.3	1,291.7	1,583.8	1,172.3	860.9	2,022.6	17,387.1
21–45	143.8	737.4	590.5	319.3	202.9	81.4	38.7	75.0	36.1	310.7	413.4	404.7	3,353.9
Offshore	1,034.5	2,864.9	2,205.8	2,134.7	1,925.5	1,656.8	2,006.3	1,388.0	1,627.0	1,502.9	1,279.8	2,609.6	22,235.8
1957													
Inshore													
0–10	209.1	570.2	410.0	300.0	157.0	158.5	116.2	103.9	58.8	125.1	25.5	145.1	2,379.4
11–20	447.2	1,655.9	951.5	1,699.0	1,958.6	2,084.6	1,606.9	1,501.4	1,242.2	1,243.4	717.6	1,555.1	16,663.4
21–45	178.0	249.3	176.2	166.1	102.2	183.4	123.9	62.5	112.6	380.7	307.1	405.9	2,447.9
Offshore	834.3	2,475.4	1,537.7	2,165.1	2,217.8	2,426.5	1,847.0	1,667.8	1,413.6	1,749.2	1,050.2	2,106.1	21,490.7
1958													
Inshore													
0–10	104.4	335.9	362.4	338.7	315.0	132.6	95.7	43.3	47.8	49.0	39.1	157.7	2,021.6
11–20	549.8	864.7	1,029.4	1,365.1	1,340.3	1,449.6	1,522.2	967.9	394.6	667.3	434.9	980.6	11,566.4
21–45	187.5	360.1	306.6	432.7	109.2	100.2	155.6	72.1	2.3	97.7	430.2	1,057.0	3,311.2
Offshore	841.7	1,560.7	1,698.4	2,136.5	1,764.5	1,682.4	1,773.5	1,083.3	444.7	814.0	904.2	2,195.3	16,899.2
1959													
Inshore													
0–10	212.0	431.0	561.5	334.6	723.1	251.8	23.5	28.3	31.7	73.8	15.2	388.8	3,075.3
11–20	522.1	1,269.0	1,197.4	1,319.4	1,796.2	1,807.0	2,044.8	518.1	586.9	577.5	411.9	1,576.2	13,626.5
21–45	259.3	509.0	621.9	397.2	380.6	90.8	76.4	8.1	4.4	58.0	214.0	387.6	3,007.3
Offshore	993.4	2,209.0	2,380.8	2,051.2	2,899.9	2,149.6	2,144.7	554.5	623.0	709.3	641.1	2,352.6	19,709.1

TABLE A2.—*Brown shrimp landings by the United States commercial fleet, Gulf of Mexico, 1956–59*

[Thousands of pounds, heads on]

Area and depth (fm.)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
APALACHICOLA													
1956													
Inshore	3.5	0.4			4.0	6.2	16.5	59.9	46.4	50.4	0.8		188.1
0–10	1.6	.8			7.2		5.8	2.0		20.6			38.0
11–20		.3			15.8	24.9	10.4	7.5					58.9
21–45													
Offshore	1.6	1.1			23.0	24.9	16.2	9.5		20.6			96.9
1957													
Inshore			48.4	11.1	5.2	13.8	125.0	88.5	63.5	43.5	12.1	21.1	432.2
0–10			30.6	43.5	2.0		3.4	9.6					89.1
11–20				29.7		2.6	.3	6.2					38.8
21–45													
Offshore			30.6	73.2	2.0	2.6	3.7	15.8					127.9
1958													
Inshore						115.2	442.3	102.0	39.5	22.5	2.0		723.5
0–10				.3	9.9	88.6	125.2	32.4	.2		1.5		258.1
11–20						1.8	1.5	7.1				.2	10.6
21–45													
Offshore				.3	9.9	90.4	126.7	39.5	.2		1.5	.2	268.7
1959													
Inshore	.1	4.5	29.2	103.2	144.5	100.1	70.6	50.3	24.5	9.6	5.7	2.9	545.1
0–10	.1	.8	3.9	250.3	284.9	52.1	29.2	6.2	6.2		.3		634.0
11–20					2.0	44.2	12.1	3.1					61.4
21–45													
Offshore	.1	.8	3.9	250.3	286.9	96.3	41.3	9.3	6.2		.3		695.4

TABLE A2.—*Brown shrimp landings by the United States commercial fleet, Gulf of Mexico, 1956–59*

[Thousands of pounds, heads on]

Area and depth (fm.)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
PENSACOLA-MISSISSIPPI RIVER													
1956													
Inshore	.3	--------	--------	2.0	196.6	1,621.9	1,375.6	990.2	163.8	76.4	107.4	39.8	4,574.0
0–10	2.0	.3	--------	3.4	31.8	2,121.7	2,059.3	971.7	62.2	11.8	49.4	6.2	5,319.8
11–20	4.0	3.5	--------	18.0	34.6	979.1	1,324.5	667.3	415.3	358.5	106.7	126.2	4,037.7
21–45	179.3	119.3	185.0	175.2	148.7	245.8	6.4	411.4	292.3	389.5	76.6	234.5	2,464.0
Offshore	185.3	123.1	185.0	196.6	215.1	3,346.6	3,390.2	2,050.4	769.8	759.8	232.7	366.9	11,821.5
1957													
Inshore	11.8	2.2	5.9	25.5	215.4	1,468.7	1,219.7	991.9	345.1	132.7	153.2	175.1	4,747.2
0–10	1.3	--------	.5	.3	83.5	2,180.3	1,807.0	518.6	24.5	10.9	11.4	7.7	4,646.0
11–20	50.4	2.5	2.0	--------	61.0	467.2	988.8	1,118.4	406.7	295.3	171.5	113.6	3,677.4
21–45	95.4	109.4	27.4	19.8	127.3	18.1	--------	580.4	715.7	316.3	120.1	84.2	2,214.1
Offshore	147.1	111.9	29.9	20.1	271.8	2,665.6	2,795.8	2,217.4	1,146.9	622.5	303.0	205.5	10,537.5
1958													
Inshore	10.4	2.8	7.4	18.3	23.0	1,059.4	1,177.5	894.6	233.2	45.7	9.4	4.4	3,486.1
0–10	1.7	.8	1.3	1.0	.8	597.6	1,072.5	459.8	33.6	9.6	1.5	2.9	2,183.1
11–20	15.1	30.2	7.9	3.7	7.6	103.8	825.7	836.5	270.6	73.1	25.7	13.4	2,213.3
21–45	109.2	93.1	152.0	79.8	6.0	30.4	13.8	146.5	146.5	36.5	17.0	80.1	910.9
Offshore	126.0	124.1	161.2	84.5	14.4	731.8	1,912.0	1,442.8	450.7	119.2	44.2	96.4	5,307.3
1959													
Inshore	1.0	--------	--------	--------	21.0	3,668.4	2,080.8	536.8	120.8	43.5	16.8	8.9	6,498.0
0–10	6.6	--------	--------	.2	3.7	2,634.6	1,073.7	677.2	50.4	43.3	36.0	13.8	4,539.5
11–20	8.4	5.0	4.9	1.1	33.9	1,388.9	2,912.3	1,439.9	607.3	98.8	110.4	150.7	6,761.6
21–45	37.0	11.8	4.5	2.4	6.2	--------	519.1	262.2	197.4	128.4	91.1	44.6	1,304.7
Offshore	52.0	16.8	9.4	3.7	43.8	4,023.5	4,505.1	2,379.3	855.1	270.5	237.5	209.1	12,605.8
LOUISIANA COAST													
1956													
Inshore	--------	--------	--------	--------	4,243.2	3,493.1	55.9	5.9	--------	--------	--------	--------	7,798.1
0–10	8.4	9.4	5.2	6.2	640.2	288.3	212.9	137.9	65.2	30.2	22.5	42.5	1,468.9
11–20	9.2	3.2	14.3	91.6	82.2	740.2	3,032.6	3,452.7	527.7	522.0	153.7	400.2	9,029.6
21–45	461.5	250.5	409.6	510.9	356.0	18.5	303.2	13.4	62.7	387.9	70.1	104.5	2,948.8
Offshore	479.1	263.1	429.1	608.7	1,078.4	1,047.0	3,548.7	3,604.0	655.6	940.1	246.3	547.2	13,447.3
1957													
Inshore	--------	--------	--------	513.1	4,532.1	3,672.3	666.6	656.0	316.8	--------	--------	--------	10,356.9
0–10	20.8	11.8	5.2	66.7	318.2	457.3	134.6	298.2	593.0	168.0	55.1	19.8	2,148.7
11–20	307.6	246.8	48.4	21.7	254.5	547.2	1,478.2	996.9	656.5	295.3	115.9	163.6	5,132.6
21–45	112.2	160.4	92.2	61.0	49.4	1.2	11.8	254.9	10.6	43.7	41.3	95.8	934.5
Offshore	440.6	419.0	145.8	149.4	622.1	1,005.7	1,624.6	1,550.0	1,260.1	507.0	212.3	279.2	8,215.8
1958													
Inshore	36.6	--------	64.3	6.5	612.9	3,365.4	20.8	241.4	340.4	1.0	3.7	--------	4,693.0
0–10	15.8	2.1	.5	2.0	152.2	518.3	24.4	253.2	38.5	6.0	43.2	55.8	1,112.0
11–20	21.2	147.0	138.6	74.7	242.3	284.6	1,557.7	4,060.1	1,265.2	31.1	31.2	191.0	8,044.7
21–45	158.1	78.5	235.2	496.1	427.1	95.3	523.0	19.8	101.0	126.5	161.4	153.2	2,575.2
Offshore	195.1	227.6	374.3	572.8	821.6	898.2	2,105.1	4,333.1	1,404.7	163.6	235.8	400.0	11,731.9
1959													
Inshore	--------	--------	--------	--------	4,134.6	6,794.9	1.5	9.2	--------	--------	--------	--------	10,940.2
0–10	5.4	4.9	.8	--------	427.7	597.3	138.8	37.8	16.5	34.8	24.9	12.2	1,301.1
11–20	290.3	128.9	191.4	258.2	326.1	1,401.8	5,884.7	1,770.4	868.7	400.5	185.8	476.7	12,183.5
21–45	215.0	283.4	276.7	716.0	439.0	45.4	196.4	188.7	128.4	177.9	54.8	114.0	2,835.7
Offshore	510.7	417.2	468.9	974.2	1,192.8	2,044.5	6,219.9	1,996.9	1,013.6	613.2	265.5	602.9	16,320.3
TEXAS COAST													
1956													
Inshore	--------	--------	--------	57.0	122.6	96.9	4.9	--------	--------	49.2	--------	--------	330.6
0–10	--------	--------	5.7	3.2	9.9	102.3	152.9	36.0	23.0	6.0	5.5	4.2	348.7
11–20	99.6	37.3	14.1	360.7	306.8	610.5	4,765.3	8,097.8	5,170.9	5,677.2	2,043.9	1,011.7	28,195.8
21–45	808.7	438.3	586.8	372.8	166.5	250.2	205.6	611.4	1,735.9	1,128.3	1,135.8	1,003.5	8,443.8
Offshore	908.3	475.6	606.6	736.7	483.2	963.0	5,123.8	8,745.2	6,929.8	6,811.5	3,185.2	2,019.4	36,988.3
1957													
Inshore	--------	--------	--------	1.3	1,547.6	630.0	--------	3.4	1.3	34.8	--------	--------	2,218.4
0–10	1.0	1.8	3.9	.7	2.4	9.4	69.0	215.5	33.9	13.4	18.0	.3	369.3
11–20	204.1	97.6	185.5	186.0	406.6	3,251.3	8,335.2	8,600.3	6,368.2	6,771.1	2,973.1	491.7	37,870.7
21–45	1,227.2	1,536.4	857.0	612.9	401.5	175.9	27.6	398.8	533.4	473.9	1,099.9	1,205.1	8,549.6
Offshore	1,432.3	1,635.8	1,046.4	799.6	810.5	3,436.6	8,431.8	9,214.6	6,935.5	7,258.4	4,091.0	1,697.1	46,789.6

TABLE A2.—*Brown shrimp landings by the United States commercial fleet, Gulf of Mexico, 1956-59*—Continued

[Thousands of pounds, heads on]

Area and depth (fm.)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
TEXAS COAST—continued													
1958													
Inshore	-	-	-	18.6	128.7	366.1	.8	-	.7	-	.7	.5	516.1
0-10	.2	-	.2	29.2	71.7	243.9	809.3	325.9	95.6	27.4	7.9	9.7	1,621.0
11-20	274.0	29.2	13.3	174.6	861.7	3,176.2	8,520.3	7,346.3	8,348.8	3,809.7	1,204.7	619.0	34,377.8
21-45	767.1	533.9	547.5	301.9	132.0	254.9	158.3	7.4	149.7	374.5	446.4	288.5	3,962.1
Offshore	1,041.3	563.1	561.0	505.7	1,065.4	3,675.0	9,487.9	7,679.6	8,594.1	4,211.6	1,659.0	917.2	39,960.9
1959													
Inshore	-	-	-	-	6.6	57.5	114.1	24.0	6.7	-	-	3.0	211.9
0-10	.5	0.3	.5	2.7	7.7	2.9	131.9	253.8	83.2	75.4	25.2	6.5	590.6
11-20	110.7	52.8	50.9	56.3	362.4	531.0	7,502.0	10,723.4	10,654.1	8,088.9	1,854.9	922.8	40,910.2
21-45	245.1	147.0	273.0	118.3	106.2	38.1	944.7	1,945.3	1,313.8	1,420.9	660.1	639.3	7,851.8
Offshore	356.3	200.1	324.4	177.3	476.3	572.0	8,578.6	12,922.5	12,051.1	9,585.2	2,540.2	1,568.6	49,352.6
EAST MEXICAN COAST													
1956													
Inshore	-	-	-	-	-	-	-	-	-	-	-	-	-
0-10	-	-	-	2.7	-	-	1.7	8.4	-	-	-	-	12.8
11-20	32.9	129.0	27.9	104.1	109.8	113.6	134.1	156.9	369.3	460.7	357.5	228.2	2,224.0
21-45	1,310.5	826.9	963.6	759.9	674.6	915.2	706.9	642.4	1,117.5	2,668.2	1,438.6	2,112.9	14,137.2
Offshore	1,343.4	955.9	991.5	866.7	784.4	1,028.8	842.7	807.7	1,486.8	3,128.9	1,796.1	2,341.1	16,374.0
1957													
Inshore	-	-	-	-	-	-	-	-	-	-	-	-	-
0-10	1.3	1.5	3.4	2.3	3.0	6.9	7.6	1.8	.2	-	-	-	28.0
11-20	114.9	59.9	127.1	112.6	103.0	185.8	1,325.1	1,018.8	776.3	479.1	723.4	512.4	5,538.4
21-45	1,626.7	1,557.4	1,222.0	1,128.8	1,290.9	1,224.4	1,579.3	953.2	1,874.3	2,925.2	1,706.4	1,105.2	18,193.8
Offshore	1,742.9	1,618.8	1,352.5	1,243.7	1,396.9	1,417.1	2,912.0	1,973.8	2,650.8	3,404.3	2,429.8	1,617.6	23,760.2
1958													
Inshore	-	-	-	-	-	-	-	-	-	-	-	-	-
0-10	-	-	-	-	-	-	-	-	-	-	4.2	1.8	6.0
11-20	232.2	122.8	68.9	67.4	44.2	150.9	146.6	7.7	111.5	775.1	363.9	306.2	2,397.4
21-45	1,815.6	1,498.2	1,787.4	1,304.0	1,341.4	706.3	214.6	86.9	364.2	3,295.2	2,516.8	1,089.0	16,019.6
Offshore	2,047.8	1,621.0	1,856.3	1,371.4	1,385.6	857.2	361.2	94.6	475.7	4,070.3	2,884.9	1,397.0	18,423.0
1959													
Inshore	-	-	-	-	-	-	-	-	-	-	-	-	-
0-10	-	4.3	-	.2	4.2	-	.5	-	-	-	-	-	9.2
11-20	75.8	49.7	164.6	73.9	75.5	617.9	612.7	808.6	594.2	542.4	184.6	218.3	4,018.2
21-45	814.0	1,106.5	691.0	621.2	345.4	494.6	550.5	1,787.2	2,734.2	2,141.1	1,590.9	1,607.0	14,483.6
Offshore	889.8	1,160.5	855.6	695.3	425.1	1,112.5	1,163.7	2,595.8	3,328.4	2,683.5	1,775.5	1,825.3	18,511.0
OBREGON-CAMPECHE													
1956													
Inshore	-	-	-	-	-	-	-	-	-	-	-	-	-
0-10	-	-	-	-	-	-	-	-	-	-	-	-	-
11-20	-	4.5	13.9	36.6	4.2	2.7	19.5	26.8	70.1	13.9	15.5	6.2	213.9
21-45	37.8	82.6	112.7	21.5	-	21.8	12.7	94.5	40.4	84.7	2.5	26.0	537.2
Offshore	37.8	87.1	126.6	58.1	4.2	24.5	32.2	121.3	110.5	98.6	18.0	32.2	751.1
1957													
Inshore	-	-	-	-	-	-	-	-	-	-	-	-	-
0-10	-	-	-	-	-	-	-	-	-	-	-	-	-
11-20	5.2	30.6	8.1	11.4	15.8	14.6	.5	1.7	25.5	6.2	11.6	1.8	133.0
21-45	3.9	18.0	35.4	40.8	22.2	29.1	5.7	2.0	31.8	69.2	7.1	-	265.2
Offshore	9.1	48.6	43.5	52.2	38.0	43.7	6.2	3.7	57.3	75.4	18.7	1.8	398.2
1958													
Inshore	-	-	-	-	-	-	-	-	-	-	-	-	-
0-10	-	-	-	-	-	1.0	1.3	-	-	-	-	-	2.3
11-20	-	3.2	12.8	26.7	59.1	99.9	125.0	11.1	10.8	2.9	1.5	39.5	392.5
21-45	-	38.0	61.2	80.1	22.8	57.1	91.1	37.2	-	21.0	2.5	9.7	420.7
Offshore	-	41.2	74.0	106.8	81.9	158.0	217.4	48.3	10.8	23.9	4.0	49.2	815.5
1959													
Inshore	-	-	-	-	-	-	-	-	-	-	-	-	-
0-10	2.5	1.2	2.4	.2	.5	34.9	-	-	-	-	-	.2	41.9
11-20	31.1	99.0	131.4	98.0	225.1	217.6	84.7	-	-	-	37.8	62.6	987.3
21-45	61.3	104.8	209.3	59.4	54.5	8.4	9.9	-	9.2	13.6	1.0	-	531.4
Offshore	94.9	205.0	343.1	157.6	280.1	260.9	94.6	-	9.2	13.6	38.8	62.8	1,560.6

TABLE A3.—*Pink shrimp landings* [1] *by the United States commercial fleet, Gulf of Mexico, 1956–59*

[Thousands of pounds, heads on]

Area and depth (fm.)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
SANIBEL-TORTUGAS													
1956													
Inshore	---	---	---	---	---	---	---	---	---	---	---	---	---
0–10	1.3	98.9	239.1	169.5	159.0	7.6	3.7	---	---	13.3	5.7	8.9	707.0
11–20	1,834.4	2,124.2	2,634.1	2,390.7	2,088.4	1,381.7	441.5	393.3	244.6	1,550.1	2,008.1	2,396.2	19,487.3
21–45	450.2	224.8	63.3	213.2	134.9	15.9	4.2	2.3	.8	---	7.6	81.1	1,198.3
Offshore	2,285.9	2,447.9	2,936.5	2,773.4	2,382.3	1,405.2	449.4	395.6	245.4	1,563.4	2,021.4	2,486.2	21,392.6
1957													
Inshore	---	---	---	---	---	---	---	---	---	---	---	---	---
0–10	49.4	71.9	91.1	94.1	52.6	21.1	.8	---	---	.5	21.5	3.3	406.3
11–20	3,210.3	1,815.4	2,502.6	1,349.4	1,461.6	622.5	473.7	181.4	371.3	573.6	1,507.1	1,691.7	15,760.6
21–45	55.6	37.4	98.8	39.1	18.0	15.5	7.6	11.8	6.9	13.3	80.8	137.1	521.9
Offshore	3,315.3	1,924.7	2,692.5	1,482.6	1,532.2	659.1	482.1	193.2	378.2	578.4	1,609.4	1,832.1	16,688.8
1958													
Inshore	---	---	---	---	---	---	---	---	---	---	---	---	---
0–10	22.0	329.3	842.2	1,106.8	858.1	185.8	63.8	2.0	3.0	---	86.3	103.0	3,602.3
11–20	2,771.2	1,635.3	2,397.9	3,024.5	2,478.0	1,278.2	380.5	714.0	990.2	1,071.0	1,906.6	1,191.1	19,838.5
21–45	185.1	197.4	145.4	78.4	67.1	1.2	6.5	237.7	36.8	3.7	91.4	207.3	1,258.0
Offshore	2,978.3	2,162.0	3,385.5	4,209.7	3,403.2	1,465.2	450.8	953.7	1,030.0	1,074.7	2,084.3	1,501.4	24,698.8
1959													
Inshore	---	---	---	---	---	---	---	---	---	---	---	---	---
0–10	163.6	235.8	202.4	273.5	161.9	86.2	32.8	23.2	12.3	12.8	85.0	46.4	1,335.9
11–20	1,914.7	1,096.6	1,273.4	926.1	1,130.5	432.6	138.4	88.4	167.8	551.9	1,045.0	2,406.1	11,171.5
21–45	402.3	477.5	154.5	178.1	52.0	60.7	5.9	---	---	---	6.9	69.4	1,407.3
Offshore	2,480.6	1,809.9	1,630.3	1,377.7	1,344.4	579.5	177.1	111.6	180.1	564.7	1,136.9	2,521.9	13,914.7
APALACHICOLA													
1956													
Inshore	---	---	31.1	66.5	128.2	61.8	12.9	5.0	6.9	3.0	33.8	25.4	374.6
0–10	---	---	1.0	100.0	349.2	263.9	118.3	---	---	---	---	---	832.4
11–20	---	---	---	---	113.4	---	17.3	---	---	---	---	---	130.7
21–45	---	---	---	---	---	---	---	---	---	---	---	---	---
Offshore	---	---	1.0	100.0	462.6	263.9	135.6	---	---	---	---	---	963.1
1957													
Inshore	13.6	11.1	---	156.6	159.9	73.9	.5	---	---	---	---	---	415.6
0–10	---	---	---	10.1	58.8	24.5	66.8	.3	---	---	---	---	160.5
11–20	---	---	---	107.0	14.9	39.8	157.7	2.5	---	---	---	---	321.9
21–45	---	---	---	---	---	---	---	---	---	---	---	---	---
Offshore	---	---	---	117.1	73.7	64.3	224.5	2.8	---	---	---	---	482.4
1958													
Inshore	---	---	5.4	74.8	209.3	116.8	2.0	---	---	2.9	---	---	411.2
0–10	---	---	.7	203.1	1,173.0	371.3	34.1	3.9	---	---	---	---	1,786.1
11–20	---	---	---	.2	169.3	69.5	64.5	---	---	---	---	---	303.5
21–45	---	---	---	---	---	---	---	---	---	---	---	---	---
Offshore	---	---	.7	203.3	1,342.3	440.8	98.6	3.9	---	---	---	---	2,089.6
1959													
Inshore	---	---	---	---	---	---	---	---	---	---	---	---	---
0–10	---	.1	---	3.2	5.4	.8	---	---	---	---	---	---	9.5
11–20	---	---	---	---	1.6	---	---	---	---	---	---	---	1.6
21–45	---	---	---	---	---	---	---	---	---	---	---	---	---
Offshore	---	.1	---	3.2	7.0	.8	---	---	---	---	---	---	11.1

See footnote at end of table.

TABLE A3.—*Pink shrimp landings*[1] *by the United States commercial fleet, Gulf of Mexico, 1956–59*—Continued

[Thousands of pounds, heads on]

Area and depth (fm.)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
PENSACOLA—MISSISSIPPI RIVER													
1956													
Inshore	--------	--------	2.7	15.6	12.3	8.4	.8	--------	--------	--------	--------	--------	39.8
0–10	--------	--------	--------	--------	5.5	42.2	11.3	--------	--------	--------	--------	--------	59.0
11–20	--------	--------	--------	--------	112.4	271.2	294.7	2.4	--------	--------	--------	--------	680.7
21–45	--------	--------	--------	--------	2.2	2.0	9.1	7.1	--------	--------	--------	--------	20.4
Offshore	--------	--------	--------	--------	120.1	315.4	315.1	9.5	--------	--------	--------	--------	760.1
1957													
Inshore	--------	.5	10.7	35.3	83.5	65.2	.5	--------	--------	--------	--------	--------	195.7
0–10	--------	--------	--------	.2	51.2	212.5	5.4	.2	--------	--------	--------	--------	269.5
11–20	--------	--------	--------	--------	49.2	281.7	81.5	.8	--------	--------	--------	--------	413.2
21–45	--------	--------	--------	--------	.3	3.2	--------	--------	--------	--------	--------	--------	3.5
Offshore	--------	--------	--------	.2	100.7	497.4	86.9	1.0	--------	--------	--------	--------	686.2
1958													
Inshore	4.4	--------	1.8	6.6	3.5	7.1	1.3	.3	--------	13.6	--------	--------	38.6
0–10	--------	--------	--------	3.7	2.0	26.9	20.3	.5	--------	--------	--------	--------	53.4
11–20	--------	--------	--------	--------	.5	24.5	73.9	2.7	--------	--------	--------	--------	101.6
21–45	--------	--------	--------	--------	--------	.5	.3	--------	--------	--------	--------	--------	.8
Offshore	--------	--------	--------	3.7	2.5	51.9	94.5	3.2	--------	--------	--------	--------	155.8
1959													
Inshore	--------	--------	.3	10.4	30.2	9.7	3.9	.2	--------	--------	--------	--------	54.7
0–10	--------	--------	1.2	.5	3.0	67.2	1.8	1.7	--------	--------	--------	--------	75.4
11–20	--------	--------	.3	.3	10.6	30.9	71.4	24.5	--------	--------	--------	--------	138.0
21–45	--------	--------	--------	.8	.3	--------	10.4	1.5	--------	--------	--------	--------	13.0
Offshore	--------	--------	1.5	1.6	13.9	98.1	83.6	27.7	--------	--------	--------	--------	226.4
OBREGON—CAMPECHE													
1956													
Inshore	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
0–10	212.9	205.6	261.1	136.1	171.8	164.0	80.6	32.6	9.4	31.3	7.4	242.1	1,554.9
11–20	854.7	2,034.5	1,032.0	1,321.5	1,470.3	1,538.4	2,283.2	1,561.6	1,808.0	1,709.5	1,206.7	2,774.6	19,595.0
21–45	127.2	658.3	368.5	239.6	191.4	66.1	28.1	6.4	14.0	457.4	674.6	559.6	3,391.2
Offshore	1,194.8	2,898.4	1,661.6	1,697.2	1,833.5	1,768.5	2,391.9	1,600.6	1,831.4	2,198.2	1,888.7	3,576.3	24,541.1
1957													
Inshore	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
0–10	238.9	561.5	356.6	295.5	169.9	164.1	126.6	129.4	60.4	134.5	24.5	166.3	2,428.2
11–20	505.5	1,557.0	802.2	1,623.0	1,801.7	1,950.0	1,745.1	1,583.6	1,214.2	1,222.6	758.4	1,735.0	16,498.3
21–45	217.0	247.5	114.8	122.1	83.3	138.9	121.4	66.4	75.4	371.7	329.1	466.9	2,354.5
Offshore	961.4	2,366.0	1,273.6	2,040.6	2,054.9	2,253.0	1,993.1	1,779.4	1,350.0	1,728.8	1,112.0	2,368.2	21,281.0
1958													
Inshore	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
0–10	108.9	347.6	280.7	210.4	204.1	119.2	91.4	42.3	45.5	41.7	32.2	129.9	1,653.9
11–20	594.0	733.8	729.9	787.9	804.9	1,178.6	1,177.6	910.1	350.4	545.7	477.3	786.4	9,076.6
21–45	187.9	319.9	191.7	208.1	49.2	35.3	40.3	29.7	2.5	59.5	590.8	984.9	2,699.8
Offshore	890.8	1,401.3	1,202.3	1,206.4	1,058.2	1,133.1	1,309.3	982.1	398.4	646.9	1,100.3	1,901.2	13,430.3
1959													
Inshore	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
0–10	200.8	325.1	361.9	268.6	616.9	228.5	23.4	36.6	36.6	88.5	18.1	471.9	2,676.9
11–20	399.8	797.2	588.0	798.3	1,101.9	1,497.6	1,815.9	513.7	754.8	699.2	639.9	1,941.4	11,547.7
21–45	180.6	298.4	174.0	206.0	180.3	56.6	62.5	8.6	--------	64.2	397.8	549.0	2,178.0
Offshore	781.2	1,420.7	1,123.9	1,272.9	1,899.1	1,782.7	1,901.8	558.9	791.4	851.9	1,055.8	2,962.3	16,402.6

[1] See table 4 (text) for summary of landings from other areas.

TABLE A4.—*White shrimp landings* [1] *by the United States commercial fleet, Gulf of Mexico, 1956–59*

[Thousands of pounds, heads on]

Area and depth (fm.)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
APALACHICOLA													
1956													
Inshore	0.2								168.5	143.5	156.1	2.7	471.0
0–10	9.8						7.6		.5	81.5	83.2	88.0	270.6
11–20	4.4								106.3				110.7
21–45													
Offshore	14.2						7.6		106.8	81.5	83.2	88.0	381.3
1957													
Inshore				17.0	12.9	1.5	4.2	71.6	430.8	128.0	128.0	.5	794.5
0–10	45.0	24.5	25.5	.3	43.0	5.4	1.5	.1	14.3	40.5	89.3	130.3	419.7
11–20					.1	8.6	.5		.8	23.7	32.7	1.0	67.4
21–45													
Offshore	45.0	24.5	25.5	.3	43.1	14.0	2.0	.1	15.1	64.2	122.0	131.3	487.1
1958													
Inshore			2.7	1.2	7.1	.3	.7	13.3	400.0	220.2	199.8	62.3	907.6
0–10	25.8	4.3	22.2	1.5	16.2	33.3	3.5	2.9	16.3	102.3	60.9	125.5	414.7
11–20					1.0					.8	22.8	11.1	35.7
21–45													
Offshore	25.8	4.3	22.2	1.5	17.2	33.3	3.5	2.9	16.3	103.1	83.7	136.6	450.4
1959													
Inshore	1.0	2.0			4.7	.5	.3	4.4	67.4	149.2	54.9	2.2	286.6
0–10	49.7	4.5	.5	<.1	21.9	5.9	2.5		30.6	63.3	69.9	46.2	295.0
11–20	1.3												1.3
21–45													
Offshore	51.0	4.5	.5	<.1	21.9	5.9	2.5		30.6	63.3	69.9	46.2	296.3
PENSACOLA-MISSISSIPPI RIVER													
1956													
Inshore	22.8	1.3		5.0	33.3	25.7	7.6	1,166.9	1,194.1	1,487.5	1,217.8	123.5	5,285.5
0–10	11.3	4.5	.2		3.7	10.4	4.2	47.9	88.5	281.1	425.0	128.5	1,005.3
11–20	32.1	7.7		6.4	4.9	9.1	2.0	11.1	12.8	75.3	194.7	112.1	468.2
21–45	56.8	22.2	13.6	12.8	2.5	1.5			2.5	3.4	44.2	66.0	225.5
Offshore	100.2	34.4	13.8	19.2	11.1	21.0	6.2	59.0	103.8	359.8	663.9	306.6	1,699.0
1957													
Inshore	11.1	2.7	1.3	3.2	7.2	7.1	21.8	680.9	663.3	333.1	373.9	371.6	2,477.2
0–10	14.3	1.7			7.2	8.7	5.0	27.6	31.2	38.6	42.5	6.7	183.5
11–20	42.7	5.7	1.0		6.2	4.5	1.2	24.4	42.3	59.8	95.6	67.2	350.6
21–45	22.7	1.8	.1	.2	9.7			25.7	31.7	25.5	34.6	18.6	170.6
Offshore	79.7	9.2	1.1	.2	23.1	13.2	6.2	77.7	105.2	123.9	172.7	92.5	704.7
1958													
Inshore	8.7	2.9	2.7	15.4	11.1	15.5	1.7	544.7	695.9	1,548.3	745.1	162.5	3,754.5
0–10		.5		.3	1.2	10.1	.3	8.2	20.3	110.5	172.2	57.1	380.7
11–20	5.0	17.5	.5	.5	1.0	8.4	3.2	11.4	31.2	105.0	164.6	157.8	506.1
21–45	11.9	.5	1.5		.3	6.9		5.0	22.8	64.5	164.8	48.4	326.6
Offshore	16.9	18.5	2.0	.8	2.5	25.4	3.5	24.6	74.3	280.0	501.6	263.3	1,213.4
1959													
Inshore	16.5				1.0	3.9		1,323.2	2,214.4	1,394.2	766.8	55.8	5,775.8
0–10	30.6	.7		.1	5.7	9.9	.2	28.4	159.4	324.6	299.4	81.2	940.2
11–20	75.4	1.3			.7	16.0	5.0	29.1	19.0	80.6	274.0	99.2	600.3
21–45	25.0	1.8	.8	.5	.2		2.5	.1	7.7	42.2	82.2	34.1	197.1
Offshore	131.0	3.8	.8	.6	6.6	25.9	7.7	57.6	186.1	447.4	655.6	214.5	1,737.6

See footnote at end of table.

TABLE A4.—*White shrimp landings* [1] *by the United States commercial fleet, Gulf of Mexico, 1956–59*—Continued

Area and depth (fm.)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
LOUISIANA COAST													
1956													
Inshore	67.2		2.5	9.4	66.4	146.3	19.0	1,651.8	1,893.9	4,390.7	2,492.8	699.7	11,439.7
0–10	643.3	231.5	267.0	264.3	1,023.0	672.7	277.0	577.4	1,473.7	3,378.8	2,819.7	2,142.5	13,770.9
11–20	68.7	85.2	151.5	133.2	161.1	212.2	95.4	286.0	124.3	529.9	490.6	212.2	2,550.3
21–45	93.9	36.1	54.8	259.2	446.5	8.7	36.0	1.5	4.0	2.9	6.0	31.2	980.8
Offshore	805.9	352.8	473.3	656.7	1,630.6	893.6	408.4	864.9	1,602.0	3,911.6	3,316.3	2,385.9	17,302.0
1957													
Inshore	5.0		.3	10.8	4.5	5.4		696.2	651.7	1,010.0	274.7	190.3	2,848.9
0–10	685.4	451.1	304.4	270.8	358.8	371.8	.2	160.4	440.3	1,676.1	1,146.9	869.4	6,735.6
11–20	177.7	129.2	33.8	102.0	217.4	44.7	2.0	11.1	15.1	14.1	3.9	87.4	838.4
21–45	18.8	28.4	13.9	6.9	4.9			4.4		1.0	2.9	22.3	103.5
Offshore	881.9	608.7	352.1	379.7	581.1	416.5	2.2	175.9	455.4	1,691.2	1,153.7	979.1	7,677.5
1958													
Inshore	61.7		8.6		28.2	4.7		1,075.7	1,223.5	3,059.1	1,713.9	302.4	7,477.8
0–10	229.0	103.1	160.1	226.8	402.4	696.2	195.2	962.5	2,549.7	3,829.7	3,007.0	3,050.4	15,412.1
11–20	137.4	56.6	43.7	13.1	41.0	45.9	25.9	11.3	8.9	14.4	29.9	54.1	482.2
21–45	132.0	3.9	17.3	10.2	7.4	1.3	2.3	.5	2.7	237.6	65.0	119.1	599.3
Offshore	498.4	163.6	221.1	250.1	450.8	743.4	223.4	974.3	2,561.3	4,081.7	3,101.9	3,223.6	16,493.6
1959													
Inshore					20.8	16.6		1,661.4	1,831.9	2,055.6	484.5	56.4	6,127.2
0–10	423.7	50.1	59.6	266.6	507.0	386.1	113.4	1,398.4	2,182.2	5,076.3	3,761.9	1,524.9	15,750.2
11–20	132.7	18.3	1.7	23.9	137.8	111.4	21.5	57.8	347.6	139.6	134.9	203.8	1,331.0
21–45	281.7	34.1	10.4	14.1	19.0	2.0	.5	22.2	26.5	87.2	42.2	318.1	858.0
Offshore	838.1	102.5	71.7	304.6	663.8	499.5	135.4	1,478.4	2,556.3	5,303.1	3,939.0	2,046.8	17,939.2
TEXAS COAST													
1956													
Inshore			3.2	24.2	22.2	.7	5.4		686.8	420.8	155.9		1,319.2
0–10	.2	6.7	79.8	81.3	793.3	103.5	98.8	4.0	509.0	448.7	294.7	70.4	2,490.4
11–20	1.7	3.5	8.7	99.5	298.4	45.5	49.7	15.6	3.9	9.2	3.2	1.5	540.4
21–45	4.9		10.6	13.8	27.6	2.7		.8					60.4
Offshore	6.8	10.2	99.1	194.6	1,119.3	151.7	148.5	20.4	512.9	457.9	297.9	71.9	3,091.2
1957													
Inshore				10.8	9.7			209.8	1,474.4	872.8	33.6		2,611.1
0–10			2.4	10.2	36.6	30.9	2.7		256.9	243.6	269.3	54.3	906.9
11–20			1.8		2.5	5.9	1.0	.8	3.9	15.8	2.0	16.0	49.7
21–45												1.2	1.2
Offshore			4.2	10.2	39.1	36.8	3.7	.8	260.8	259.4	271.3	71.5	957.8
1958													
Inshore				2.2	75.4	37.8	43.5	335.7	1,946.4	773.1	389.6	62.8	3,666.5
0–10			34.3	240.6	109.4	164.3	15.6	460.3	1,872.0	2,506.1	894.8	810.9	7,108.3
11–20	2.0	.7	.2	5.7	45.2	27.6	.5	17.6	482.0	53.4	35.1	26.7	696.7
21–45	.5		.5	.3		.3				.2		1.7	3.5
Offshore	2.5	.7	35.0	246.6	154.6	192.2	16.1	477.9	2,354.0	2,559.7	929.9	839.3	7,808.5
1959													
Inshore				4.0	21.7		20.2	902.5	1,228.2	1,103.4	283.9	24.2	3,588.1
0–10	62.7	3.7	16.0	74.3	157.6	14.8	36.3	159.3	933.6	1,558.2	1,110.0	108.0	4,234.5
11–20	4.9		.5	3.7	74.4	11.3	20.0	47.4	55.8	80.1	60.8	74.4	433.3
21–45					1.2					0.5	.7	.8	3.2
Offshore	67.6	3.7	16.5	78.0	233.2	26.1	56.3	206.7	989.4	1,638.8	1,171.5	183.2	4,671.0

[1] See table 4 (text) for summary of landings from other areas.

TABLE A5.—*Commercial shrimp landings [1] from inshore waters along the United States Gulf coast, 1956–59*

[Thousands of pounds, heads on]

Area	1956					1957					1958					1959				
	Total	Percent species comp.				Total	Percent species comp.				Total	Percent species comp.				Total	Percent species comp.			
		B	P	W	S		B	P	W	S		B	P	W	S		B	P	W	S
Florida:																				
Charlotte Harbor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tampa Bay	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apalachicola Bay [2]	579.8	12	10	77	1	973.2	11	12	74	3	1,236.0	25	12	63	T	297.7	16	-	84	-
St. George Sound [2]																91.9	96	-	4	-
St. Andrew Bay	76.1	18	64	18	-	94.4	51	44	5	T	61.2	6	11	83	-	44.2	82	-	18	-
St. Joseph Bay	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26.5	93	-	7	-
Choctawhatchee Bay	59.5	34	61	5	-	49.7	35	65	-	-	69.7	60	40	T	-	20.2	93	-	7	-
Pensacola Bay	326.6	25	71	4	-	555.4	48	40	13	-	674.2	55	33	12	-	351.3	94	-	6	T
Alabama:																				
Mobile Bay	1,796.8	61	T	39	-	1,708.4	81	3	16	-	1,811.0	69	T	31	-	1,728.8	75	-	25	-
Perdido Bay	34.4	-	100	-	-	-	-	-	-	-	5.4	100	-	-	-	-	-	-	-	-
Mississippi:																				
Mississippi Sound	2,990.6	53	T	47	T	3,194.2	74	4	22	-	2,504.4	58	1	41	-	5,166.0	78	1	21	-
Louisiana:																				
Lake Borgne	14.3	100	-	-	-	340.9	30	-	70	-	1,404.0	17	-	83	-	478.3	40	-	60	-
Lake Pontchartrain	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	221.8	-	-	100	-
Breton Sound [2]	5,068.9	37	-	63	T	2,176.3	42	T	58	-	1,555.0	35	T	65	-	3,566.0	26	-	74	T
Chandeleur Sound [2]																1,168.6	23	T	77	-
Garden Island Bay [2]	-	-	-	-	-						131.5	77	-	23	T	10.2	-	-	100	-
East Bay [2]	-	-	-	-	-	-	-	-	-	-						60.6	100	-	T	-
Bay Adam	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22.7	100	-	-	-
Timbalier Bay	4,790.9	46	-	54	T	3,815.8	77	-	23	-	2,375.7	39	-	59	2	4,127.4	82	-	18	-
Barataria and Caminada Bays	8,337.2	43	-	57	T	4,090.3	86	-	14	-	4,298.6	46	T	53	1	6,140.6	75	-	25	T
Lake Salvador	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	132.9	100	-	-	-
Little Lake	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	63.0	-	-	100	-
Terrebonne Bay	1,902.1	40	-	59	1	2,562.3	84	-	15	1	276.7	23	-	77	-	907.9	72	-	28	-
Caillou Bay	3,950.4	33	-	67	T	2,887.2	61	-	32	7	161.8	70	-	30	-	764.9	36	-	64	-
Lake Barre [2]	-										1,428.5	T	-	99	1	1,221.0	58	-	42	-
Lake Felicity [2]	-	-	-	-	-	-	-	-	-	-						435.0	100	-	-	-
Lake Pelto	-	-	-	-	-	-	-	-	-	-	2,088.2	32	-	66	2	2,291.7	46	-	54	-
Lake de Cade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.9	100	-	-	-
Lake Mechant	-	-	-	-	-	-	-	-	-	-	10.8	-	-	100	-	42.8	100	-	-	-
Lost Lake	-	-	-	-	-	-	-	-	-	-	1.8	100	-	-	-	2.9	-	-	100	-
Fourleague Bay	-	-	-	-	-	-	-	-	-	-	1,436.6	53	-	43	4	169.3	68	-	32	-
Vermilion and Cote Blanche Bays	279.9	-	-	96	4	7.7	-	-	33	67	74.9	43	-	57	-	578.1	-	-	98	2
Calcasieu Lake	40.3	-	-	100	-	86.5	-	-	96	4	105.0	-	-	100	-	138.3	-	-	100	-
Sabine Lake	15.0	-	-	100	-	1.0	-	-	100	-	-	-	-	-	-	-	-	-	-	-
Texas:																				
East Bay	-	-	-	-	-	T	-	-	100	-	.7	-	-	100	-					
West Bay	-	-	-	-	-	-	-	-	-	-	3.2	-	-	100	-	13.1	-	-	100	-
Galveston Bay	180.9	4	-	96	-	623.4	T	-	100	-	770.6	-	-	100	-	1,082.4	2	-	98	-
Trinity Bay	-	-	-	-	-	120.5	-	-	100	-	7.7	-	-	100	-	-	-	-	-	-
East Matagorda Bay [2]																-	-	-	-	-
Matagorda Bay [2]	609.3	-	-	100	-	1,492.3	14	-	86	-	1,670.3	12	-	88	-	1,457.4	6	-	94	-
Lavaca Bay [2]																23.5	-	-	100	-
San Antonio Bay [2]																339.0	22	-	78	-
Espiritu Santo Bay [2]	285.8	2	-	98	-	335.0	47	-	53	-	333.1	-	-	100	-	-	-	-	-	-
Mesquite Bay [2]																-	-	-	-	-
Aransas Bay [2]	304.4	41	-	59	-	1,296.3	82	-	18	-	789.3	7	T	93	-	573.2	1	-	99	-
Copano Bay [2]																0.7	-	-	100	-
Corpus Christi Bay [2]																294.8	1	-	99	-
Upper Laguna Madre [2]																6.7	100	-	-	-
Lower Laguna Madre [2]	264.1	74	-	26	-	273.2	40	-	60	-	668.0	40	9	51	T	-	-	-	-	-
Nueces Bay [2]																3.4	-	-	100	-
Baffin Bay [2]																6.6	-	-	100	-

[1] Includes only shrimp taken commercially for human consumption.
[2] Data prior to 1959 are combined catches from these waters.

B—brown shrimp; P—pink shrimp; W—white shrimp; S—seabobs; T—trace, less than 1 percent.

TABLE A6.—*Comparative shrimp landings from waters off the Mexican coast of the Gulf of Mexico, 1956–57*

[Thousands of pounds, heads on]

Coastal area and subareas	Species	United States fleet		Mexican [1] fleet		Total	
		1956	1957	1956	1957	1956	1957
East Mexican Coast:							
22–30	Brown	16,374.0	23,760.2	1,503.0	1,655.2	17,877.0	25,415.4
	Pink	4.7	0	0	0	4.7	0
	White	48.3	2.5	501.1	551.5	549.4	554.0
	Total	16,427.0	23,762.7	2,004.1	2,206.7	18,431.1	25,969.4
Obregon-Campeche:							
31–35	Brown	751.1	398.2	8,617.6	8,963.5	9,368.7	9,361.7
	Pink	24,541.1	21,281.0	11,686.5	13,216.1	36,227.6	34,497.1
	White	19.6	86.4	8,779.0	9,187.2	8,798.6	9,273.6
	Total	25,311.8	21,765.6	29,083.1	31,366.8	54,394.9	53,132.4
Mexican Gulf Coast:							
22–35	Brown	17,125.1	24,158.4	10,120.6	10,618.7	27,245.7	34,777.1
	Pink	24,545.8	21,281.0	11,686.5	13,216.1	36,232.3	34,497.1
	White	67.9	88.9	9,280.1	9,738.7	9,348.0	9,827.6
	Total	41,738.8	45,528.3	31,087.2	33,573.5	72,826.0	79,101.8

[1] Data supplied by Mexican Bureau of Fisheries and Allied Industries; species composition of Mexican production based upon crude estimates.