# PENAEID SHRIMP ABUNDANCE AND RIVERINE FLOW IN SAN ANTONIO BAY, TEXAS

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*Abstract*: The relationships of abundance of brown shrimp (*Penaeus aztecus* Ives) and white shrimp (*P. setiferus* L.) to spring and fall river flow into San Antonio Bay, Texas were studied. Standing crop indices determined from trawl sampling and bay commercial landings were poorly correlated; only those indices obtained from trawl samples were deemed valid. Brown shrimp abundance showed no detectable relationship to changes in freshwater inflow; white shrimp abundance, however, showed a significant positive correlation with May-June inflow and with the previous year's September-October inflow.

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Species which are highly unstable in population size from year to year have only a small proportion of their variability in numbers accounted for by density-dependent mechanisms while most of the variance can be attributed to extrinsic factors (Watt 1968). Abundances of brown shrimp and white shrimp in Texas bays are highly variable. Extrinsic factors are probably responsible for most of the variability in annual abundance of shrimp in Texas bays.

Chin (1960) suggested that heavy fishing activity might have caused the major decline in white shrimp catch in the 1940's and 1950's. Gunter and Hildebrand (1954), Viosca (1958), and Barrett and Gillespie (1975), however, attributed fluctuations in white shrimp annual catch to variations in rainfall.

Gunter and Edwards (1969) noted a difference between Louisiana and Texas in the effects of freshwater inflow on white shrimp catch. The white shrimp harvest in Texas for 1973 (a high rainfall year in both states) was the highest for the period 1958 to 1973, while Louisiana experienced a large reduction; Barrett and Gillespie (1975) found this to substantiate the positive correlation in Texas and the negative correlation in Louisiana between freshwater introduction and white shrimp catch.

For brown shrimp, Gunter and Edwards (1969) found no relation between commercial catch and freshwater influx in either Texas or Louisiana. However, Barret and Gillespie (1973) found in Louisiana that above average spring and summer river discharges and rainfall substantially reduced the amount of optimum nursery areas and thus reduced the brown shrimp standing crop.

Williams (1969), Ford and St. Amant (1971) and Gaidry and White (1973) found that numbers of postlarvae entering the bays bore no relationship to commercial shrimp landings for that year. Apparently, conditions in the bay—not recruitment—determine shrimp standing crop (White 1975). One of the most important factors controlling conditions in the bays and estuaries is river inflow. The object of this study is to relate spring abundance of brown shrimp and fall abundance of white shrimp to spring and fall riverine flow in San Antonio Bay, Texas.

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## STUDY AREA

The San Antonio Bay system is located on the mid-Texas coast at latitude 28° 20' N, longitude 96° 40' W and includes Guadalupe, Hynes, San Antonio, Shoalwater, Espiritu Santo, Barroom and Ayers Bays. Total surface water area is 460 km$^2$. Average depth of the unmodified estuary is approximately 1.2 m; maximum natural depth is 2 m (Childress et al. 1975).

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Physical and chemical characteristics which control the ecological structure of this area are dependent upon the combined flows of the San Antonio and Guadalupe Rivers whose confluence is 18 km above the head of the bay. Drainage area of the San Antonio River is 10,830 $km^2$; the average annual rainfall in the river basin is 79 cm. The Guadalupe River contributes the major portion of fresh water to the estuary as it drains 15,720 $km^2$; average annual rainfall is 81 cm. Average annual flow of the Guadalupe River at Victoria (U.S. Geological Survey gauging station; drainage area: 13,463 $km^2$) is 1,530 x $10^6 m^3$. Average discharge of the San Antonio River at Goliad (drainage area: 10,155 $km^2$) is 552 x $10^6 m^3$/yr (U.S.G.S. 1976). Fresh water enters Guadalupe Bay in the northern part of the system and salt water enters from Pass Cavallo to the southeast and from Cedar Bayou to the southwest. Total exchange time of this system, based on bay volume of 774 x $10^6 m^3$, has been estimated to be 1.3 months during high river flow periods and 5.9 months during average flow periods (Steed 1971).

Victoria weather station records (1951-1970) show maximum rainfall occurred in May, June, September and October and minimum rainfall occurred from November through April. Fourteen years (1960-1973) of monthly flow data from the watershed indicate maximum flows occurred in months with maximum rainfall while minimum flows occurred in July and August (Fig. 1).

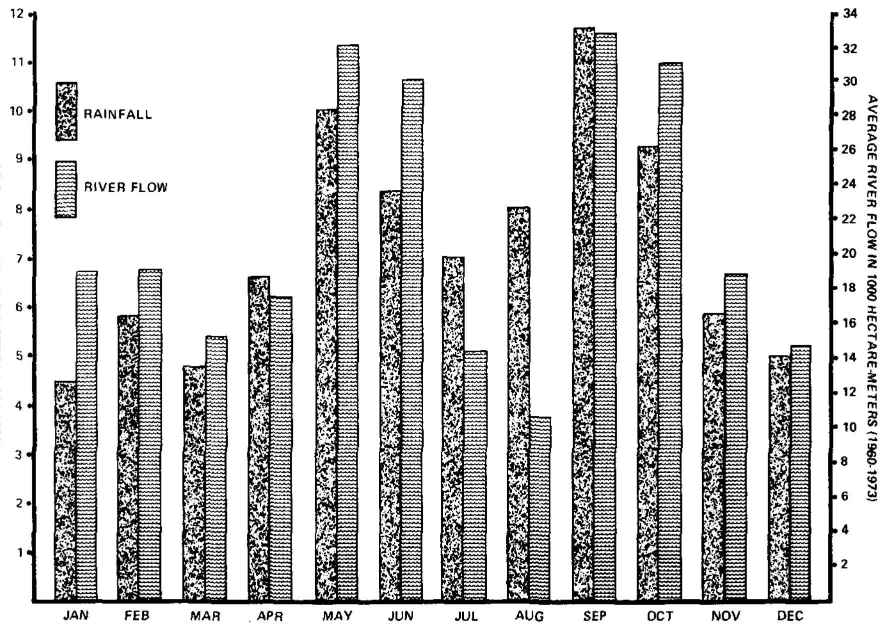


Fig. 1. Comparison of monthly average rainfall and river flow into San Antonio Bay.

## METHODS

San Antonio Bay commercial shrimp landings data were taken from National Marine Fisheries Service monthly *Shrimp Landings* from 1959 to 1975. Information extracted included pounds (heads-off) of each species of shrimp landed and the number of fishing trips made each month. Data on monthly river inflow to San Antonio Bay for the period 1960 to 1975 were provided by Texas Water Development Board.

Trawl sample data for San Antonio Bay were collected from 1961 to 1968 and from 1970 to 1974 by Texas Parks and Wildlife Department's coastal fisheries biologists. Six sampling stations were chosen as representative of San Antonio Bay's shrimp grounds and were used throughout the study (except that 2 sites were not sampled in 1962 and 1963); sampling in 1961 was so sporadic as to be judged unusable. Trawls at each station were usually made bimonthly. Sampling was standardized by trawling 15 min/station at 3 knots in a circular pattern using a 3 m otter trawl of 32 mm mesh with a 17 mm mesh cod end. Number and size of shrimp of each species caught per trawl were recorded.

Brown shrimp are important to Texas bay fisheries from May through July and white shrimp from August through November (Chin 1960). Only those periods were considered in the attempt to relate shrimp populations to inflow, as suggested by Williams (1969). An annual trawl sample index for each species was obtained by averaging shrimp counts from all stations for the period May through July for brown shrimp and August through November for white shrimp. An annual commercial landings index was obtained by summing the bay landings from May through July for brown shrimp and from August through November for white shrimp. An annual commercial landings per unit effort index for each species was obtained by dividing the annual commercial landings index by the number of trips made.

The effects of cumulative inflow (Gunter and Edwards 1969, Childress et al. 1975) were not examined because of the difficulties with auto-correlation in the flow data and in deciding what time period (i.e., 3 mo, 1 yr, 2 yr) would be meaningful; the spring and fall pulses in rainfall and inflow were chosen instead.

May plus June and September plus October inflows were chosen as representative of the spring and fall pulses of rainfall and inflow. Collier and Hedgpeth (1950) noted a double peak curve in the monthly distribution of rainfall in the San Antonio-Guadalupe River drainage. This same double peak curve was noted in the period 1951 to 1970 (Fig 1).

## RESULTS

### *Commercial Landing and Biological Sampling Data*

For both brown and white shrimp, correlations between biological sampling data and commercial landings data from San Antonio Bay showed that population size indices determined from trawl samples are not significantly ($P > 0.05$) correlated to those from commercial landings. A comparison of brown shrimp commercial landings in pounds for May through July and average number of brown shrimp caught per trawl from May through July for the years 1962-1968 and 1970-1973 gave a correlation coefficient of 0.22 (9 d.f.). A comparison of white shrimp landings for August through November and average catch per trawl of white shrimp in the same period for the years 1962-1968 and 1971-1973 gave a correlation of 0.21 (8 d.f.).

Correlations between biological sampling catch per trawl and commercial catch per trip were also examined. Average annual brown shrimp commercial landings per trip for the months May-July were not significantly correlated ($r = 0.44$, $P > 0.05$) with biological sample catch per trawl. No meaningful relationship was found between white shrimp average commercial landings per trip and number of shrimp caught per trawl sample ($r = 0.08$, $P > 0.05$). Trawl samples were used to indicate population trends throughout the remainder of the analysis.

### *Brown Shrimp Abundance and Freshwater Inflow*

Correlation of the average number of brown shrimp in trawl samples with spring freshwater inflow produced no significant relationship ($r = 0.00$, $P > 0.05$). No significant correlation was found between one year's fall inflow and the following year's abundance of brown shrimp ($r = -.18$, $P > 0.05$). An examination of plots of brown shrimp numbers versus May-June inflow (Fig. 2) and versus September-October inflow (Fig. 3) also produced no discernible pattern.

Annual abundance of brown shrimp was not affected significantly by spring or fall inflow to San Antonio Bay within the range of inflow observed. High inflows due to Hurricane Beulah in the fall of 1967 were followed by a negligible increase in brown shrimp abundance in 1968.

### *White Shrimp Abundance and Freshwater Inflow*

Variations of the average number of white shrimp in trawl samples from San Antonio Bay with freshwater inflow showed a predictive relationship (Fig. 4). Correlation of May-June inflow with white shrimp numbers was highly significant ($r = 0.85$, $P < 0.01$). The 3 highest white shrimp abundance figures correspond with May-June inflows in excess of $1{,}250 \times 10^6 m^3$.

No significant relationship was noted between white shrimp numbers and September-October inflow from the same calendar year ($r = 0.06$, $P > 0.05$). However, white shrimp abundance varied significantly with inflow from the previous fall ($r = 0.74$, $P < 0.05$).

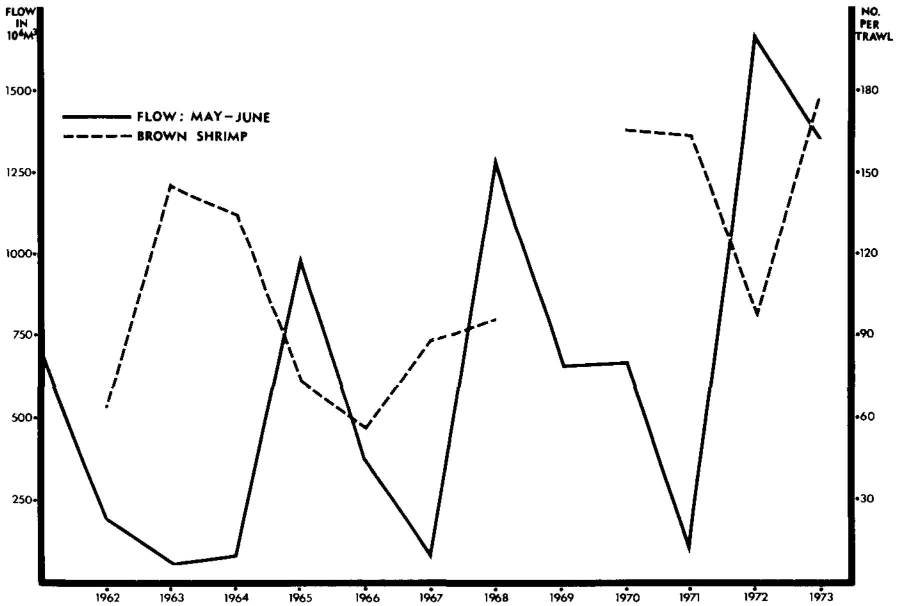


Fig. 2. Brown shrimp abundance compared with May-June inflow to San Antonio Bay.

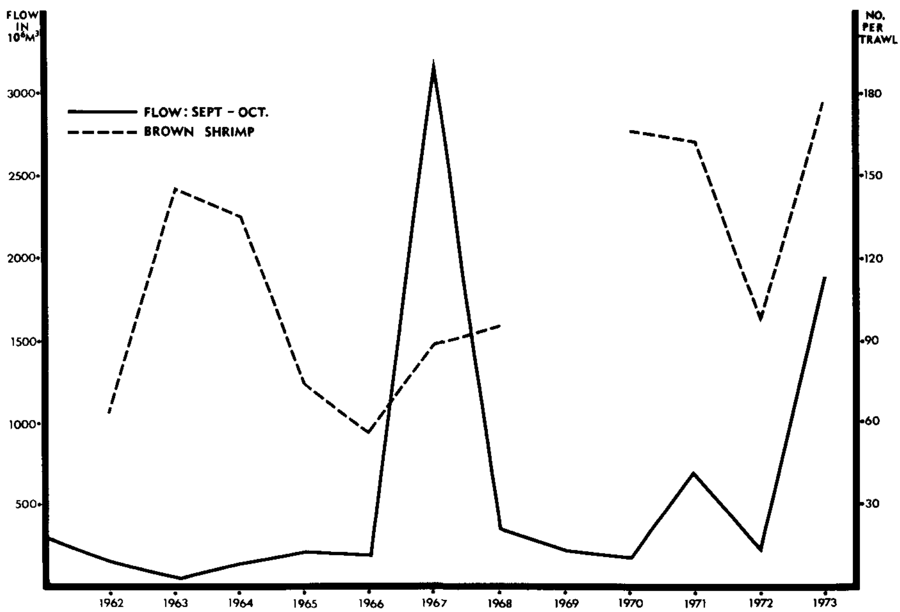


Fig. 3. Brown shrimp abundance compared with September-October inflow to San Antonio Bay.

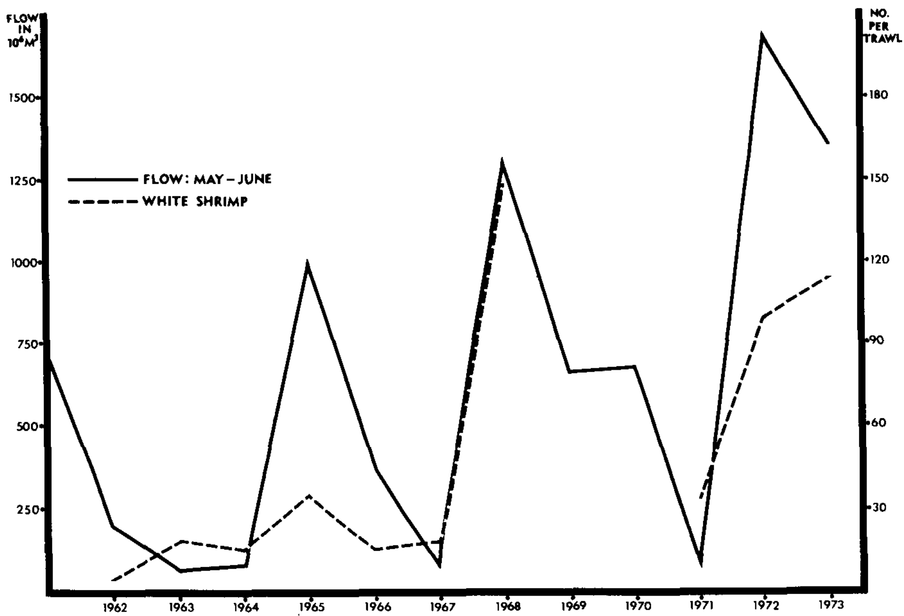


Fig. 4. White shrimp abundance compared with May-June inflow to San Antonio Bay.

White shrimp numbers increased 8-fold the year following high inflows due to Hurricane Beulah in September and October of 1967. (Fig. 5).

## DISCUSSION

Trawl data from a theoretically sound sampling program are probably better indicators of shrimp abundance than commercial landings data. Kutkuhn (1962) says that catch per trawl with a standardized trawling schedule should be a better indicator of shrimp abundance than commercial catch because of less error and bias due to number and duration of trawls, size and efficiency of gear, and bay trawl area chosen. In San Antonio Bay, a poor relationship between trawl sample catch and commercial landings and also between trawl sample catch and commercial landings per trip was found.

In San Antonio Bay, brown shrimp abundance in May through July was not affected positively or negatively by increases or decreases in May-June inflow or the previous September-October inflow. White shrimp numbers in August through November varied positively with increases in spring inflow although they were unaffected by fall inflow (from same calendar year). White shrimp numbers varied with inflow during the previous fall although not as closely as with May-June inflow. In 1968 after high fall inflow due to Hurricane Beulah in 1967, white shrimp abundance rose sharply, similar to the stimulating effect of hurricanes on white shrimp production noted by Gunter and Hildebrand (1954) and Viosca (1958). Relatively dry Hurricane Celia in 1970 did not elicit such a response, however. Apparently white shrimp (found predominantly in low salinity nursery areas) reacted positively to increases in freshwater inflow whether from spring rains or the previous fall's storms while brown shrimp (normally found in higher salinity nursery areas) showed no detectable reaction.

Barrett and Gillespie (1973) and Venkataramiah et al. (1974) suggested the possibility of increasing production of shrimp by controlling river discharge. However, Hedgpeth (1966) recommended that projects altering the flux of an estuarine system be approached with particular caution.

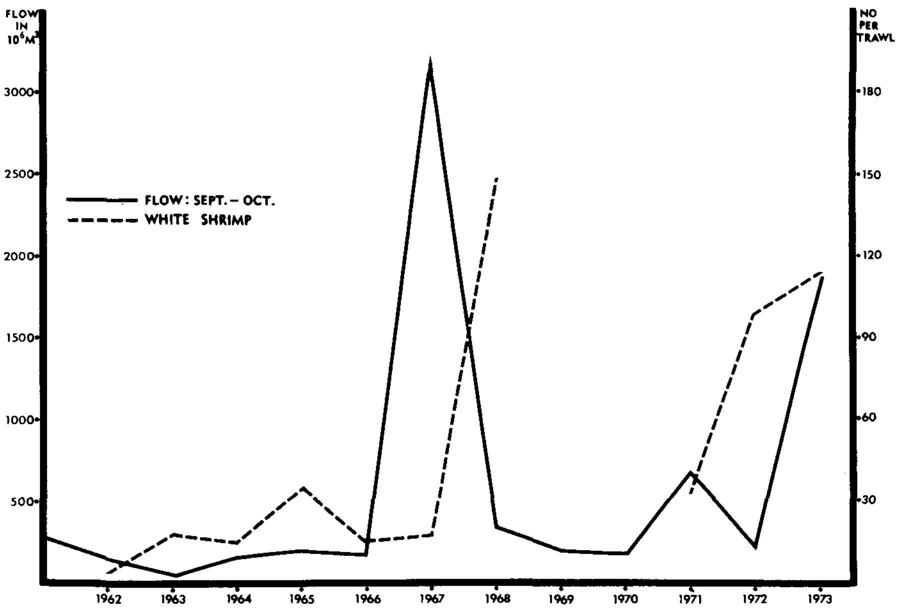


Fig. 5. White shrimp abundance compared with September-October inflow to San Antonio Bay.

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