ESTUARINE FISHERY DYNAMICS AND FRESHWATER INFLOW FLUCTUATIONS IN THE SAN ANTONIO BAY SYSTEMS, TEXAS

GARY L. POWELL, Environmental Division, Texas Department of Water Resources, Austin, TX 78711

Abstract: The quantity, quality, and timing of freshwater inflows to the San Antonio bay system are recognized as major factors in fishery production. A methodology has been developed using commercial fishery statistics and gaged inflow records to analyze the fishery dynamics and its relation to freshwater inflows from the contributing river basins. Statistical correlation analysis and assessment of "best" versus "worst" years of production were employed to evaluate the effects of year to year fluctuations in freshwater inflows. Although somewhat rudimentary, the results of the analyses are clear enough to be of practical value for future water resources planning and management. an inflow regime, with a monthly distribution of 1.48 x 10^6 total annual ha-m of freshwater, is presented that could meet the minimum sustaining requirements of the estuary's fisheries.

Proc. Annual Conf. S.E. Assoc. Fish & Wildlife Agencies 31:498-504

Texas has the distinction of possessing one of the most fertile and diverse estuarine regions in the world. The Texas coast contains 7 major estuarine systems and several smaller ones spread along approximately 644 linear km of Gulf coastline (Fig. 1). The importance of freshwater inflows to Texas coastal fishery production was first established by Hildebrand and Gunter (1953) and is underscored by the fact that Texas river basins contribute only about 4.4 percent of the total freshwaters entering the northern Gulf of Mexico. This low percentage contribution reflects the relative scarcity of freshwaters available to Texas estuaries and the crucial significance of those freshwaters which are or should be available for beneficial functions like fishery production, salinity control, nutrient biogeochemical cycling, and waste assimilation/flushing (Armstrong and Brown 1976, Copeland 1966, Dawson and Armstrong 1975, Gunter 1961, and Parker 1955).

Under legislative mandate of the 64th Texas Legislature (1975), the Texas Water Development Board (now a part of the Department of Water Resources) was directed "to investigate the effects of freshwater inflows upon bays and estuaries of Texas and to complete comprehensive studies regarding the development of methods of providing and maintaining the ecological environment thereof." This study is a part of the Board's comprehensive Bays and Estuaries Program.

MATERIALS AND METHODS

The Guadalupe estuary, herein referred to as the San Antonio bay system, contains approximately 57,870 surface ha, includes the San Antonio, Espiritu Santo, and Mesquite bays, and is the third largest estuary on the Texas coast (Fig. 2). Gaged freshwater inflows contributed to the bay system from the combined flows of the Guadalupe and San Antonio rivers account for about 81 percent of the total freshwater inflows and have averaged 2.129 x 10^6 ha-m during the 1941-1974 period of record. The remaining 19 percent of the freshwater inflows are contributed from contiguous ungaged drainage areas.

The effect of freshwater inflows on the estuarine fisheries was investigated using historical gaged inflow data from the U.S. Geological Survey Water-Data Reports (1959-1976) and commercial harvest data from the U.S. Department of Commerce Fisheries Statistics (1962-1976). Since these government data are reported and published in non-metric units, analyses and results are reported likewise. Statistical correlation analysis was employed to assess the strength of the fishery dependence on inflows of nutrient-laden freshwaters. In addition, tabular analysis of the freshwater inflow distribution occurring during the "best" versus "worst" years of fishery production was performed to assess the effects of divergent inflow regimes.

The commercial "finfish" harvest, as used in this study, refers to harvest of the following teleosts: croaker (*Micropogon undulatus*), black drum (*Pogonias cromis*), red drum (*Sciaenops ocellata*), flounders (*Paralichthys* spp.; mostly *P. lethostigma*), *sea catfish* (*Arius felis*), spotted seatrout (*Cynoscion nebulosus*), and sheepshead (*Archosargus probatocephalus*). Similarly, the commercial "shellfish" harvest refers to harvest of blue crab (*Callinectes sapidus*), oyster meats (*Crassostrea virginica*), heads-on brown shrimp (*Penaeus aztectus*), and heads-on white shrimp (*Penaeus setiferus*).

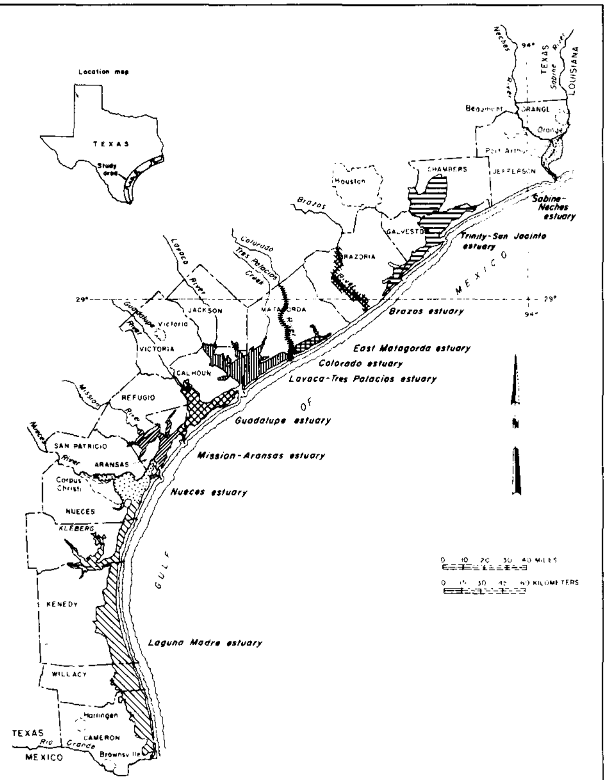

Figure 1
Locations of the Estuaries

Base from Official State Highway Map of Texas, 1971

Fig. 1. The Texas coastal zone, showing locations of the estuaries.

RESULTS AND DISCUSSION

Total commercial "finfish" and "shellfish" harvests taken within the San Antonio bay system have averaged 2.618 x 10^6 lb annually over the last decade of record (1967-1976), with the "shellfish" category accounting for 88.7 percent of the total. In this regard, *it should be noted that the majority of the fishery production from the estuary is not* caught within the system, but rather is harvested on the fishing grounds of the open Gulf of Mexico in association with production from other regional estuaries (Copeland et al. 1974). However, of 8 identifiable fishery production areas on the Texas coast, the San Antonio bay system ranks third in commercial "shellfish" harvest and sixth in commercial "finfish" harvest overall since 1962, based on the within-system harvest.

Results of correlation analysis performed on antecedent freshwater inflows versus the 1962-1976 "finfish" harvest data are graphically displayed in Fig. 3. The correlation coefficient (r) was computed at 0.801 ($P < 0.001$), which suggests that about 64.2 percent of the year to year variations in "finfish" harvest may be associated with fluctuations in the 3 yr average antecedent freshwater inflows occurring in March through June. This is a critical seasonal period in the Texas estuarine nursery habitats for growth and survival of the postlarvae and juveniles of many fish species (Gunter 1957, King 1971). Based on the analysis of the 15 yr period of record, springtime inflows of less than 741,667 acre-feet are generally characterized by "finfish" harvests below the 237,260 lb average.

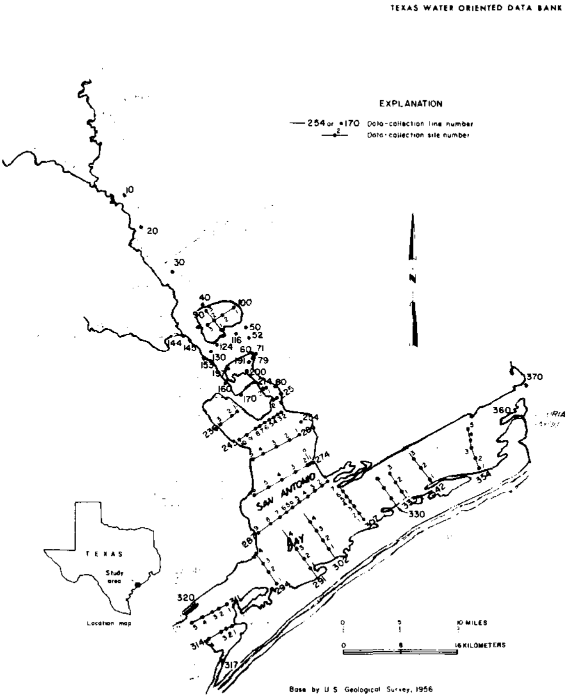

Figure 2
Data-collection sites in the Guadalupe estuary
U.S. Geological Survey

Fig. 2. The Guadalupe estuary study area.

In the preceding analysis, average antecedent springtime inflows from the 3 previous years before harvest are utilized because poor water years can affect the young, however, the overall effect may not appear until members of the affected year-class have grown large enough to enter the adult population and be represented in the commercial harvests. Similar analysis was performed on the 1962-1976 red drum catch component of the "finfish" category and results are shown in Fig. 4. The correlation coefficient (r) was computed at 0.850 ($P < 0.001$), implying that about 72.7 percent of the year to year variations in red drum catch may be associated with fluctuations in antecedent springtime inflows. Based on the analysis, springtime inflows of less than 741,667 acre-feet are generally characterized by red drum catches below the 81,073 lb average.

Commercial "shellfish" harvests during the 1962-1976 period of record were also analyzed with respect to springtime inflows, but without averaging antecedent inflows or lagging the harvests since the predominant species exhibit almost complete annual turnover in their life-cycles (Lindner and Cook 1970, Cook and Lindner 1970). Results of the analysis are shown in Fig. 5. The correlation coefficient (r) was computed at 0.658 ($P < 0.01$), suggesting that about 43.3 percent of the year to year variations in "shellfish" harvest may be associated with fluctuations in the springtime inflows. Although not as strong as the previous analyses, the "shellfish" correlation is still surprisingly strong considering the life history differences between species that are lumped together in this category (Cook and Lindner 1970, Lindner and Cook 1970, Copeland and Hoese 1966,

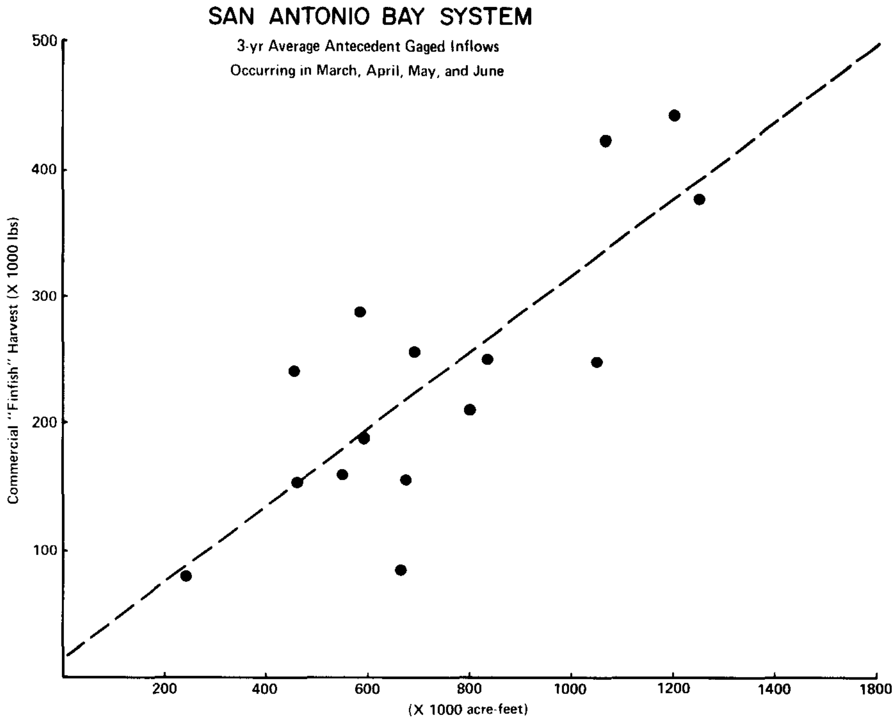

Fig. 3. Correlation of 3 yr average antecedent inflows occurring in March-June (X 1,000 acre-feet) versus 1962-1976 commercial "finfish" harvests (X 1,000 lbs). r = 0.801.

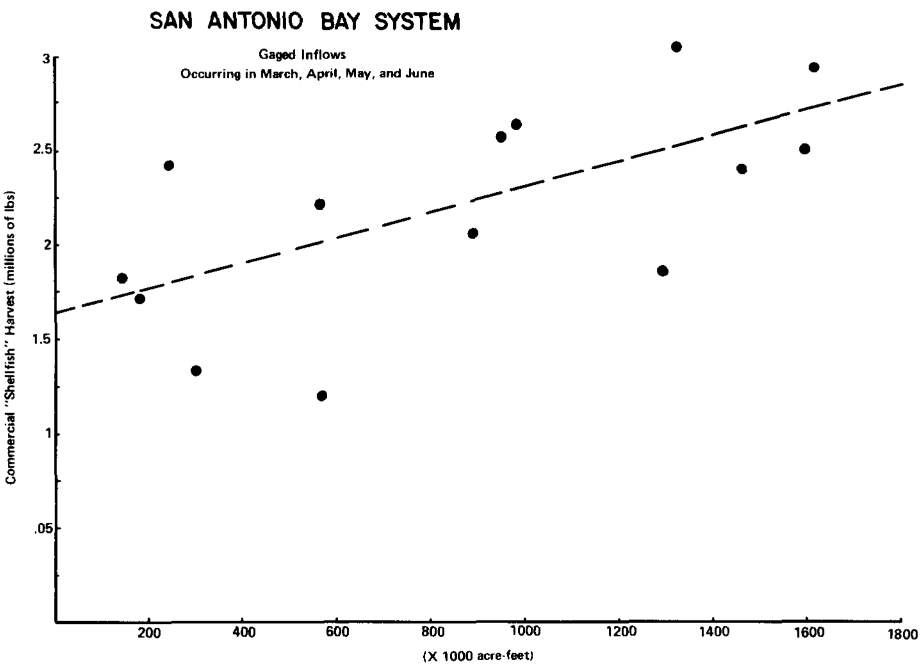

Fig. 4. Correlation of 3 yr average antecedent inflows occurring in March-June (X 1,000 acre-feet) versus 1962-1976 commercial red drum harvests (X 1,000 lbs). r = 0.850.

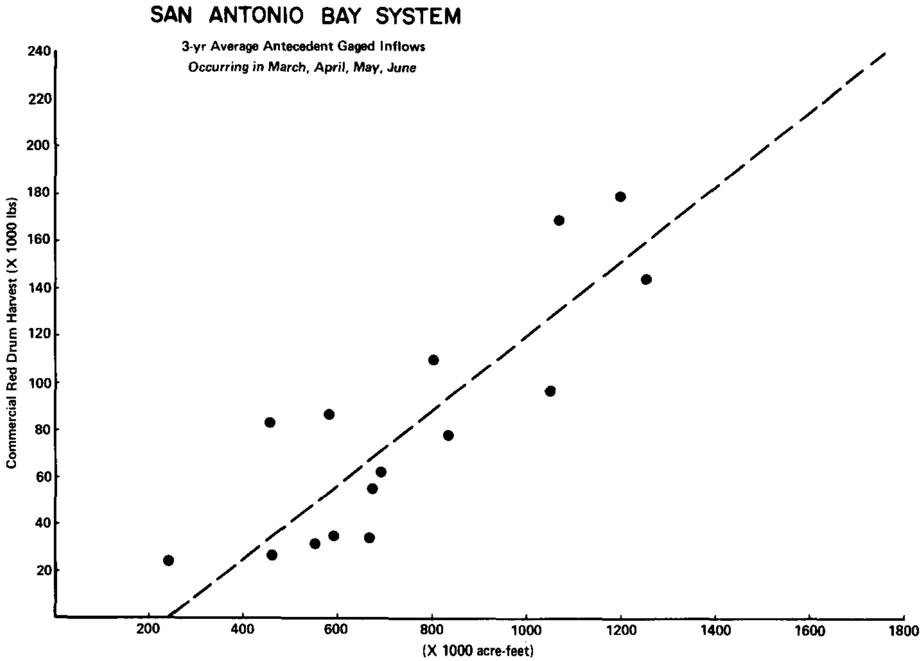

Fig. 5. Correlation of March-June inflows (X 1,000 acre-feet) versus 1962-1976 commercial "shellfish" harvests (millions of lbs). r = 0.658.

and More 1969). Based on the analysis, springtime inflows of less than 814,000 acre-feet are generally characterized by "shellfish" harvests below the 2.162 x 10^6 lb average.

Since Childress et al. (1975), have specifically noted the abundant production of white shrimp in the San Antonio bay system, a tabular analysis of the freshwater inflow distributions occurring during the "best" versus "worst" years of commercial white shrimp harvest (1962-1976) was performed and results are given in Table 1. In general, it can be observed that the "best" years are characterized by greater than normal freshwater inflows with an average of 39.2 percent arriving in the May-June interval. On the other hand, the "worst" years are characterized by less than normal freshwater inflows with an average of only 16.5 percent arriving in the May-June interval. Thus, both the quantity and distribution of freshwater inflows appear to be important factors in the production of white shrimp. The May-June interval may be especially crucial because it coincides with the beginning of postlarval immigration into the estuarine nursery habitats and enhances their subsequent growth and survival (King 1971, Lindner and Cook 1970). The anomalous behavior of the 1964 and 1976 data resulted in their omission from the analysis as noted. Although no satisfactory explanation is available for the 1964 data, low within-bay harvest in 1976 may be because of very high freshwater inflows late in the growing season that might hasten the emmigration of bay stocks to the Gulf waters. This explanation is especially attractive since the 1976 shrimp season produced near-record harvests off the Texas Gulf coast. The 1962-1976 commercial white shrimp harvests averaged 840,400 lb, while the May-June freshwater inflows averaged 534,000 acre-feet over the same period of record.

Although the preceding analyses are somewhat rudimentary, results are clear enough to be of practical value for freshwater and fishery resources planning and management. As municipal, industrial, agricultural, and other freshwater user demands increase within the contributing river basins, the potential exists for substantial future alteration of the estuary's freshwater inflow regime through impoundment and diversion activities (Copeland 1974). Based on the results of these analyses and the historical data of harvest and hydrology, an approximate freshwater inflow regime is exhibited in Table 2 that could be anticipated to meet the minimum freshwater inflow requirements for sustaining the estuary's fishery production. The approximate regime has a total of 1.2 x 10^6 acre-feet

Table 1. Distribution of gaged freshwater inflows (10^3 acre-feet) occurring in the "best" versus "worst" years of white shrimp *(Penaeus setiferus* Linnaeus) commercial harvest (10^3) lbs).

White Shrimp Years	*Total Gaged Freshwater Inflows*	*Jan.-April Inflows (%)*	*May-June Inflows (%)*	*July-Dec. Inflows (%)*	*Commercial Harvest*
"Best"					
1965	2,113	720 (34.1)	746 (35.3)	647 (30.6)	1,415.0
1964*	706	277 (39.2)	87 (12.3)	342 (48.4)	1,379.7
1968	2,896	1,279 (44.2)	920 (31.8)	697 (24.1)	1,203.2
1970	1,574	630 (40.0)	532 (33.8)	412 (26.2)	1,121.6
1972	2,298	418 (18.2)	1,286 (56.0)	594 (25.8)	959.1
Mean Ave.	2,220	762 (34.3)	871 (39.2)	588 (26.5)	1,174.7
"Worst"					
1963	521	246 (47.2)	70 (13.4)	205 (39.3)	359.1
1976*	3,752	661 (17.6)	809 (21.6)	2,282 (60.8)	412.1
1966	1,141	481 (42.2)	294 (25.8)	366 (32.1)	485.5
1971	1,238	186 (15.0)	73 (5.9)	979 (79.1)	493.9
1962	765	287 (37.5)	161 (21.0)	317 (41.4)	602.3
Mean Ave.	916	300 (32.7)	150 (16.3)	467 (50.9)	485.2

*Omitted from calculation of mean averages.

Table 2. Approximate gaged freshwater inflow regime (monthly percent distribution with total acre-feet) to meet minimum sustaining fishery requirements of the San Antonio bay system.

Month	*Sustaining Inflow Regime (%)*	*Historical Inflow Regime (%)*
January	3.1	7.0
February	3.1	7.9
March	9.4	6.8
April	9.4	8.8
May	20.3	14.0
June	20.3	10.5
July	4.7	6.3
August	4.7	4.0
September	12.5	11.6
October	6.3	11.2
November	3.1	6.7
December	3.1	5.4
Total Gaged Inflow	1,200,000	1,726,000

of gaged freshwater inflows with 59.4 percent (712,800 acre-feet) scheduled for the March-June spring season and 40.6 percent (487,200 acre-feet) scheduled for the May-June interval. This compares favorably with the suggestion of Childress et al. (1975), that a minimum inflow of 1.3 x 10^6 acre-feet per year could possibly maintain commercial shellfish production above 1.5 x 10^6 lb annually. The average long-term (1941-1974) historical gaged inflow and its monthly percent distribution are also given in Table 2 for comparison.

Certainly, the timing and magnitude of the approximate inflow regime can only provide the opportunity for the estuary to be viable and productive. There are, of course, no guarantees of fishery production based on freshwater inflows alone because of the many environmental factors like temperature, tides, nutrients, and human disruptive activities that are capable of mediating this production (Kutkuhn 1966).

LITERATURE CITED

Armstrong, N. E., and B. A. Brown. 1976. Exchange of carbon, nitrogen, and phosphorus in Lavaca bay, Texas marshes, Vol. I: The role of sediments in nutrient exchange in the Lavaca bay brackish march system. Center for Research in Water Resources, Univ. Tex., Tech. Report No. 147. 83 pp.

Childress, R. E., Bradley, E. Hagen, and S. Williamson. 1975. The effects of freshwater inflows on hydrological and biological parameters in the San Antonio bay system, Texas. Texas Parks and Wildlife Dept. Rep. 190 pp.

Cook, H. L., and M. J. Lindner. 1970. Synopsis of biological data on the brown shrimp *Penaeus aztecus aztecus* Ives, 1891. FAO Fish. Rep. 57(4):1471-1497.

Copeland, B. J. 1966. Effects of decreased river flow on estuarine ecology. J. Wat. Poll. Cont. Fed. 38:1831-1839.

_______________. 1974. Impoundment systems. Pages 168-179 *in* Coastal ecosystems of the United States, Vol. III, The Conservation Foundation.

_______________, and H. D. Hoese. 1966. Growth and mortality of the American oyster, *Crassostrea virginica,* in high salinity shallow bays in central Texas. Publ. Inst. Mar. Sci. Univ. Texas. 11:149-158.

_______________, H. T. Odum, and F. N. Moseley. 1974. Migrating subsystems. Pages 422-453 *in* Coastal Ecosystems of the United States, Vol. II, The Conservation Foundation.

Dawson, A. J., and N. E. Armstrong. 1975. Exchange of carbon, nitrogen, and phosphorus in Lavaca bay, Texas marshes, Vol. II: The role of plants in nutrient exchange in Lavaca bay brackish marshes. Center for Research in Water Resources, Univ. Texas, Tech. Rep. No. 129. 115 pp.

Gunter, G. 1957. Predominance of the young among marine fishes found in freshwater. Copeia 1:13-16.

___________. 1961. Some relations of estuarine organisms to salinity. Limnol. Oceanogr. 6(2):182-190.

Hildebrand, H. H., and G. Gunter. 1953. Correlation of rainfall with Texas catch of white shrimp, *Penaeus setiferus* (Linnaeus). Trans. Amer. Fish. Soc. 82:(151-155.

King, B. D. 1971. Study of migratory patterns of fish and shelfish through a natural pass. Texas Parks and Wildlife Dept., Tech. Series No. 9, 54 pp.

Kutkuhn, J. H. 1966. The role of estuaries in the development and perpetuation of commercial shrimp resources. Pages 16-36 *in* Spec. Publ. No. 3, Amer. Fish. Soc., Washington, D.C.

Lindner, M. J., and H. L. Cook. 1970. Synopsis of biological data on the white shrimp *Penaeus setiferus* Linnaeus, 1767. FAO Fish. Rep. 57(4):1439-1469.

More, W. R. 1969. A contribution to the biology of the blue crab (*Callinectes sapidus* Rathbun) in Texas, with a description of the fishery. Texas Parks and Wildlife Dept., Tech. Series No. 1. 31 pp.

Parker, R. H. 1955. Changes in the invertebrate fauna, apparently attributable to salinity changes, in the bays of central Texas. J. Paleont. 29:193-211.