Growth of five fishes in Texas bays in the 1960s

Gary C. Matlock
Texas Parks and Wildlife Department
4200 Smith School Road, Austin, Texas 78744

The estuarine sport and commercial fish fisheries in Texas have historically relied upon five species: black drum *Pogonias cromis*, red drum *Sciaenops ocellatus*, sheepshead *Archosargus probatocephalus*, southern flounder *Paralichthys lethostigma*, and spotted seatrout *Cynoscion nebulosus*. Regulation of these fisheries dramatically increased as human demand for fish generally increased through the 1980s. For example, the sale of red drum and spotted seatrout caught in Texas was prohibited in 1981, use of nets in coastal waters was prohibited in 1988, and size, bag, and possession limits were imposed for each species by 1988. Growth information was used in selecting appropriate regulations for optimizing yield and sustaining recruitment. However, comprehensive, coastwide growth rates were available only for red drum, black drum, and spotted seatrout caught in the late 1970s and 1980s when exploitation was extremely high (Doerzbacher et al. 1988, Green et al. 1990). Potential yields may be underestimated when based on growth rates obtained when fishing mortality is high. Tagging data from which growth parameters could be estimated for those species had been collected sporadically from the late 1950s through the early 1970s (Green 1986) when fishing effort was presumably lower than in the 1980s, but these data have not been examined. The objective of this study was to describe quantitatively the growth of black drum, red drum, sheepshead, southern flounder, and spotted seatrout tagged in the 1960s.

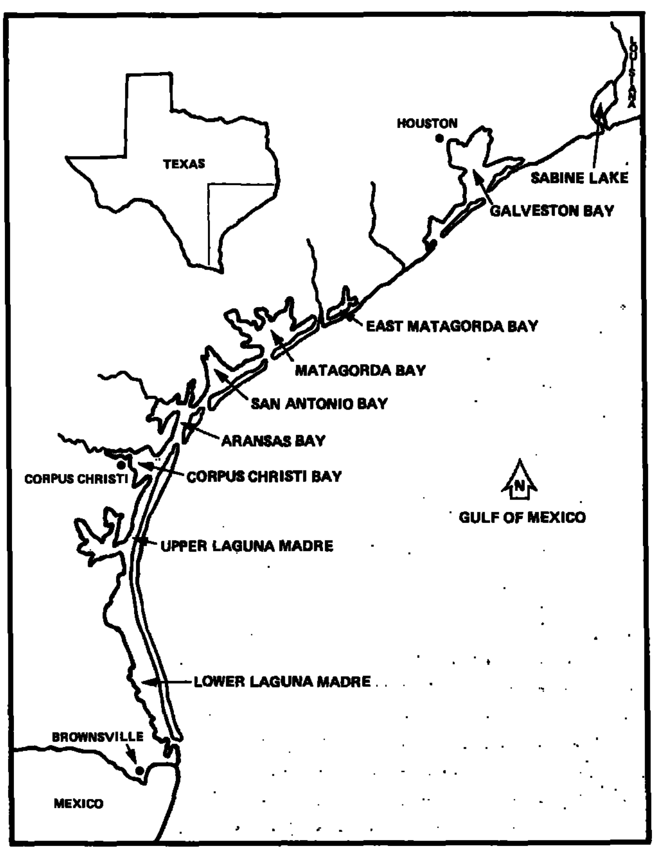

Figure 1
Location of Texas bay systems.

Methods

Data on total length (TL, mm) at tagging and recapture, and the number of days free until recapture for five fishes—black drum, red drum, sheepshead, southern flounder, and spotted seatrout—tagged by the Texas Parks and Wildlife Department (TPWD) in Texas bays (Fig. 1) and recaptured during the period 1950–75 were obtained from Green (1986). No length data were available for fish tagged in the Matagorda Bay system, however. Data resulted from a variety of projects designed to obtain life history information on fishes, mainly red drum and spotted seatrout. Fish for tagging were obtained using rod and reel, trotlines, and trammel and gill nets. Monel strap tags and internal abdominal tags were primarily used. The release of tagged fish and requests for information concerning recaptured fish were advertised through the news media and posters placed in areas frequented by fishermen. Non-monetary rewards of various types were usually offered for returned tags. Additional details are contained in Green (1986). The mean daily growth rate (G) was used to examine the suitability of the von Bertalanffy model for describing growth of each species. The growth rate was calculated as follows:

Manuscript accepted 9 March 1992.
Fishery Bulletin, U.S. 90:407–411 (1992).

$$G = (l_r - l_m)/d,$$

where l_r = TL at recapture,
l_m = TL at tagging, and
d = time in days between tagging and recapture.

A plot of mean daily growth rate versus TL at tagging for each species suggested asymptotic growth, since growth rate generally declined as size-at-tagging increased. Therefore, the von Bertalanffy growth model was chosen as an empirically-based description of growth (Moreau 1987) to which these tagging data were fit. Of the currently available estimating procedures for using tag data to describe growth following the von Bertalanffy growth equation, Fabens' (1965) method provides the most accurate estimates (Sundberg 1984). Data were analyzed using the Fishery Science Application System (Saila et al. 1988) and Fabens' (1965) iterated least-squares method for estimating K and L_∞ in the von Bertalanffy growth equation,

$$l_r = l_m + (L_\infty - l_m)[1 - \exp(-Kd)]$$

where l_r, l_m , and d are defined as above, and
L_∞ = the average TL in a population of fish allowed to grow indefinitely following the von Bertalanffy growth function, and
K = Brody's growth coefficient (per day).

Before analysis, data were screened following procedures of Doerzbacher et al. (1988) to eliminate outliers. Fish with growth rates >3 mm/day or <−3 mm/day were eliminated from the data set. The mean ±3 SD for the remaining data were then calculated, and fish with growth rates outside this range were also eliminated from the data set. Sufficient data were available to analyze tagged red drum separately by bay system (except for Sabine Lake and Matagorda Bay). Data for each of the other species were analyzed for all tagging locations combined.

The measure of effectiveness (P) used by Phares (1980) which is similar to the multiple correlation coefficient of linear regression (R^2) was used to determine how well the von Bertalanffy model fit the data:

$$P = (SSL - SSE)/SSL,$$

where SSL is the sum of squares of $(l_r - l_m)$, and SSE is the residual sum of squares of the model,

$$SSE = (l_r' - l_r)^2,$$

where l_r' is the model's predicted length-at-recapture, and n is the number of recaptured tagged fish (after data screening). The value of l_r' for each tagged fish was calculated following Parrack (1979):

$$l_r' = L_\infty - (L_\infty - l_m)\, e^{-K(d)}.$$

Standard errors of each estimated K and L_∞ were estimated using 10-fold cross-validation technique (a form of jackknife resampling) described by Verbyla and Litvaitis (1989). For each data set, the original data were randomly partitioned into ten subsamples, nine of which each contained 10% of the data, and one which contained the remainder. The first subsample was excluded from the data set, and K and L_∞ were reestimated. The first subsample was recombined with the data set, and the second subsample was excluded, and so on, until all 10 subsamples had been excluded. The standard error of each parameter of the original data set is approximated by the standard deviation of the mean of the 10 separate estimates made after removing each subsample.

Results and discussion

Most of the data reported for recaptured tagged fish during the 1960s were included in the analyzed data set (i.e., few outliers were found). Of 1630 recaptured fish, only 72 (4.4%) fish were excluded from the analyses (Table 1). Red drum from the lower Laguna Madre had the greatest proportion of outliers (13 of 69 fish). However, the size range at tagging of the remaining 56 fish was comparable to the range of red drum tagged in other bays. These results are similar to those of Doerzbacher et al. (1988) for red drum and black drum, and are supported by Ferguson et al. (1984) who demonstrated that red drum lengths reported by sportfishermen were accurate.

Mean daily growth rates of tagged fish during the time between release and recapture were about 0.2 mm/day for all species, except red drum which averaged about 0.4–0.7 mm/day (Table 1). These means mainly represent the growth of smaller fish within each range because the size data were skewed toward small fish. For example, of 254 recaptured black drum, over 250 were <300 mm TL at tagging and recapture. However, the estimates of daily growth for black drum, red drum, sheepshead, and spotted seatrout in this study were within the ranges of those reported by Colura et al. (1984), Cornelius (1984), Beckman et al. (1988, 1990, 1991), Doerzbacher et al. (1988), Murphy and Taylor (1989), Matlock (1990), and Green et al. (1990).

The estimated L_∞ for black drum, red drum, southern flounder, and spotted seatrout tagged in Texas

Table 1

Size, time free, and growth rate of five fishes tagged and released in Texas bays and recaptured by sport and commercial fishermen during the period 1950–75. Outliers were removed (screened) before anaylsis following the procedures described by Doerzbacher et al. (1988).

					TL (mm) at release		TL (mm) at recapture		Time free (days)		Growth rate (mm/day)	
Species	Bay system	No. tagged	No. in analysis	No. screened	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)
Black drum	All bays	28,423	254	6	160–750	317 (101)	175–965	373 (116)	4–4143	273 (467)	−1.167–1.438	0.187 (0.125)
Red drum	Galveston	1370	73	2	155–620	342 (104)	241–762	453 (123)	2–1079	204 (200)	−0.500–1.667	0.624 (0.395)
	San Antonio	1272	101	4	220–720	397 (96)	220–915	506 (120)	11–2432	204 (259)	−0.679–1.847	0.569 (0.343)
	Aransas	3061	435	7	175–615	360 (85)	230–838	473 (107)	2–784	206 (169)	−0.378–1.729	0.565 (0.365)
	Corpus Christi	835	58	4	185–520	322 (93)	280–762	462 (123)	3–692	199 (142)	0–1.686	0.733 (0.396)
	Upper Laguna Madre	2857	147	5	133–693	426 (121)	203–774	544 (110)	6–831	250 (177)	0.600–1.526	0.416 (0.316)
	Lower Laguna Madre	2202	56	13	151–685	326 (122)	171–1016	440 (146)	11–5078	412 (824)	−0.274–0.938	0.395 (0.267)
Sheepshead	All bays	6530	56	6	200–555	313 (74)	210–555	336 (75)	1–630	148 (119)	−0.085–0.779	0.167 (0.209)
Southern flounder	All bays	3176	21	0	255–505	337 (78)	250–560	394 (84)	1–546	197 (169)	0–0.647	0.223 (0.192)
Spotted seatrout	All bays	20,517	357	25	192–762	373 (90)	192–762	406 (98)	1–1315	173 (196)	−0.786–1.220	0.171 (0.276)

bays was about 840–950 mm TL, whereas the sheepshead estimate was about 470 mm (Table 2). Daily growth coefficients (K) were about 0.0005 (0.183 annualized) for black drum, southern flounder, and spotted seatrout, and about 0.001 (0.365 annualized) for red drum and sheepshead (Table 1). The 1960s estimates of L_∞ for black drum, red drum, sheepshead, and spotted seatrout in Texas were generally higher than comparable estimates made in the 1980s. Red drum L_∞ in the 1960s ranged from 879 mm in the upper Laguna Madre to 1177 mm in the Aransas Bay system; L_∞ was 918 mm in the 1980s (Doerzbacher et al. 1988). Values for black drum, sheepshead, and spotted seatrout were as follows (1960s vs. 1980s): 844 mm vs. 798 mm (Doerzbacher et al. 1988); fork length (FL) 478 mm vs. 419 mm (males) and 447 mm (females) (Beckman et al. 1991); and 836 mm vs. 691 mm (Green et al. 1990), respectively. No estimates were available for southern flounder in the 1980s.

Red drum growth varied among bays. Estimates of L_∞ for red drum in each bay system approximated 930 mm, except in Aransas Bay where L_∞ was 1177 mm, and K (annualized) varied between 0.3 and 0.5. Reasons for the interbay variation in L_∞ and K for red drum in the 1960s are unknown. However, factors affecting growth (e.g., fishing mortality, food supply, red drum density, and environmental conditions like salinity and temperature) varied among bays (Matlock 1984).

The estimated values of L_∞ for black drum and red drum from fish tagged in the 1960s and 1980s appear to be underestimates because the data include few adult fish which reside mostly in the Gulf of Mexico (Matlock 1987, 1991). The addition of older adults would probably increase L_∞ and reduce K for both species, but the change in parameter estimates would depend on the average maximum age and size actually reached relative to the largest fish included in the analysis. Parameter estimates (standard error) for the von Bertalanffy model for black drum (0–58 years old) growth in Florida were 1172 mm (±9 mm) and 0.124 mm (±0.0003 mm), respectively. When the von Bertalanffy growth equation was fit to length and age (from otoliths) data for adults off Louisiana, the estimate for L_∞ was 1000 mm FL (Beckman et al. 1991); recall, L_∞ for Texas black drum was 844 mm TL. However, Beckman et al. (1991) questioned the biological significance of their L_∞ estimates because an asymptotic

Table 2

Estimates of parameters (daily K and L_∞) in the von Bertalanffy growth equation for five fishes tagged in Texas bays during the period 1950–75 (N = number of fish used in analysis). Approximate standard errors (SE) were estimated using ten-fold validation (Verbyla and Litvaitis 1989). Annualized K and associated SE were estimated by multiplying daily K and daily SE by 365 days. Measure of effectiveness (P) reflects how well the von Bertalanffy model fit the data (Phares 1980).

Species	Bay system	N	K (±1 SE) Daily	K (±1 SE) Annual	L_∞ (mm) (±1 SE)	P (%)
Black drum	All bays	254	0.00048 (0.000039)	0.175 (0.014)	844 (40)	77.7
Red drum	Galveston	73	0.00116 (0.000118)	0.423 (0.043)	900 (61)	91.7
	San Antonio	101	0.00112 (0.000119)	0.409 (0.043)	978 (77)	88.3
	Aransas	435	0.00075 (0.000036)	0.274 (0.013)	1177 (33)	90.2
	Corpus Christi	58	0.00138 (0.000210)	0.504 (0.077)	940 (82)	90.0
	Upper Laguna Madre	147	0.00127 (0.000085)	0.464 (0.031)	879 (27)	90.0
	Lower Laguna Madre	56	0.00075 (0.000221)	0.274 (0.810)	957 (88)	87.0
Sheepshead	All bays	56	0.00098 (0.000289)	0.358 (0.105)	478 (36)	43.9
Southern flounder	All bays*	21	0.00063 (0.000066)	0.230 (0.024)	848 (32)	80.4
Spotted seatrout	All bays	357	0.00045 (0.000040)	0.164 (0.015)	836 (36)	63.0

* Convergence criteria (successive estimates differ by $<2\times10^{-6}$) was not met after 25 iterations.

size was not attained within the size range sampled and growth was practically linear beyond age 5. Further, neither the von Bertalanffy nor power model accurately described the growth of black drums younger than age 5. A similar result was found for red drum when the von Bertalanffy model was fit to data from fish from the Gulf of Mexico (Beckman et al. 1989). The estimates for L_∞ were 909 mm FL for males and 1013 mm FL for females, but estimates for K (0.137 for males and 0.088 for females) were smaller than published estimates based primarily on young fish (Beckman et al. 1989). They suggested that separate models may be necessary to describe growth of young red drum from estuarine areas or old fish from offshore.

The estimates for spotted seatrout growth are probably more accurate than those for the other four species. The sample size is large, and fish of all sizes are well represented in the data set, including adult spotted seatrout which generally reside in the bays (Perret et al. 1980). Estimates for L_∞ and K using published length-at-age data collected from spotted seatrout in the Gulf of Mexico sporadically during 1929–84 were 655 mm and 0.2 mm, respecitvely (Condrey et al. 1985).

The L_∞ estimate for southern flounder (848 mm TL) may be an overestimate, whereas L_∞ for sheepshead (478 mm TL) may be an underestimate. State records for southern flounder and sheepshead caught in Texas salt waters are 711 mm and 641 mm, respectively (Anonymous 1989). Reasons for the apparent bias are unknown but may be related to the few recaptures of tagged southern flounder (21 fish) and the few large sheepshead recaptured. Only one sheepshead was >500 mm TL.

Citations

Anonymous

1989 Texas state fish records. Tex. Parks Wildl. Dep. PWD-L-9000-5-3/89, Austin, 1 p.

Beckman, D.W., A.L. Stanley, J.H. Render, and C.A. Wilson

1990 Age and growth of black drum in Louisiana waters of the Gulf of Mexico. Trans. Am. Fish. Soc. 119:537–544.

1991 Age and growth-rate estimation of sheepshead *Archosargus probatocephalus* in Louisiana waters using otoliths. Fish. Bull., U.S. 89:1–8.

Beckman, D.W., G.R. Fitzhugh, and C.A. Wilson
1988 Growth rates and validation of age estimates of red drum, *Sciaenops ocellatus*, in a Louisiana salt marsh impoundment. Contrib. Mar. Sci. (Suppl.) 30:93–98.

Beckman, D.W., C.A. Wilson, and A.L. Stanley
1989 Age and growth of red drum, *Sciaenops ocellatus*, from offshore waters of the northern Gulf of Mexico. Fish. Bull., U.S. 87:17–28.

Colura, R.L., C.W. Porter, and A.F. Maciorowski
1984 Preliminary evaluation of the scale method for describing age and growth of spotted seatrout (*Cynoscion nebulosus*) in the Matagorda Bay system, Texas. Manage. Data Ser. 57, Tex. Parks Wildl. Dep., Coastal Fish. Br., Austin, 17 p.

Condrey, R.E., G. Adkins, and M.W. Wascom
1985 Yield-per-recruit of spotted seatrout. Gulf Res. Rep. 8(1):63–67.

Cornelius, S.E.
1984 Contribution to the life history of black drum and analysis of the commercial fishery of Baffin Bay, Vol. II. Tech. Rep. 6, Caesar Kleberg Wildl. Res. Inst., Kingsville, TX, 241 p.

Doerzbacher, J.F., A.W. Green, and G.C. Matlock
1988 A temperture compensated von Bertalanffy growth model for tagged red drum and black drum in Texas bays. Fish. Res. (Amst.) 6:135–152.

Fabens, A.J.
1965 Properties and fitting of the von Bertalanffy growth curve. Growth 25:265–289.

Ferguson, M.O., A.W. Green, and G.C. Matlock
1984 Evaluation of the accuracy and precision of volunteered size data from tagged red drum returns. N. Am. J. Fish. Manage. 4:181–185.

Green, A.W., L.W. McEachron, G.C. Matlock, and H.E. Hegen
1990 Use of abdominal streamer tags and maximum-likelihood techniques to estimate spotted seatrout survival and growth. Am. Fish. Soc. Symp. 7:286–292.

Green, L.
1986 Fish tagging on the Texas coast, 1950–1975. Manage. Data Ser. 99, Tex. Parks Wildl. Dep., Coastal Fish. Br., Austin, 206 p.

Matlock, G.C.
1984 A basis for the development of a management plan for red drum in Texas. Ph.D. diss., Texas A&M Univ., College Station, 287 p.
1987 Maximum total length and age of red drum off Texas. Northeast Gulf Sci. 9:49–52.
1990 The life history of red drum. *In* Chamberlain, G.W., R.J. Miget, and M.G. Haby (compilers), Red drum aquaculture, p. 1–22. TAMU-SG-90-603, Texas A&M Univ. Sea Grant Coll. Prog., College Station.
1991 Maximum total length and age of black drum off Texas. Northeast Gulf Sci. 11:171–174.

Moreau, J.
1987 Mathematical and biological expression of growth in fishes: Recent trends and further developments. *In* Summerfelt, R.C., and G.E. Hall (eds.), The age and growth of fish, p. 81–113. Iowa State Univ. Press, Ames.

Murphy, M.D., and R.G. Taylor
1989 Reporduction and growth of black drum, *Pogonias cromis*, in northeast Florida. Northeast Gulf Sci. 10:127–137.

Parrack, M.L.
1979 Aspects of brown shrimp, *Penaeus aztecus*, growth in the northern Gulf of Mexico. Fish. Bull., U.S. 76:827–836.

Perret, W.S., J.E. Weaver, R.O. Williams, P.L. Johansen, T.D. McIlwain, R.C. Raulerson, and W.M. Tatum
1980 Fishery profiles of red drum and spotted seatrout. Gulf States Mar. Fish. Comm. 6, Ocean Springs, MS, 60 p.

Phares, P.L.
1980 Temperature associated growth of white shrimp in Louisiana. NOAA Tech. Memo. NMFS-SEFC-56, Southeast Fish. Sci. Cent., Galveston, TX, 19 p.

Saila, S.B., C.W. Recksiek, and M.H. Prager
1988 Basic fishery science programs, a compendium of microcomputer programs and maual of operation. Dev. Aquacult. Fish. Sci. 18, Elsevier Sci. Publ. Co., NY, 178 p.

Sundberg, P.
1984 A Monte Carlo study of three methods for estimating the parameters in the von Bertalanffy growth equation. J. Cons. Cons. Int. Explor. Mer 41:248–258.

Verbyla, D.L. and J.A. Litvaitis
1989 Resampling methods for evaluating classfication accuracy of wildlife habitat models. Environ. Manage. 13:783–787.