Contract No:

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy.

Disclaimer:

Striped Bass Spawning in Non-estuarine Portions of the Savannah River

F. Douglas Martin and Michael H. Paller
Environmental Sciences and Biotechnology Department
Savannah River National Laboratory
Aiken, South Carolina 29808

Abstract:

Historically, the estuarine portions of the Savannah River have been considered to be the only portion of the river in which significant amounts of striped bass (*Morone saxatilis*) spawning normally occur. A reexamination of data from 1983 through 1985 shows a region between River Kilometers 144 and 253 where significant numbers of striped bass eggs and larvae occur with estimated total egg production near that currently produced in the estuarine reaches. It appears possible that there are two separate spawning populations of striped bass in the Savannah River.

Introduction:

Historically striped bass (*Morone saxatilis*) spawning occurred as far up the Savannah River as the Fall Line (also known as the Augusta Shoals) at about river kilometer (RK) 326; however, currently striped bass have difficulty migrating in any numbers past the New Savannah Bluff Lock and Dam (RK 302) (Meyer et al. 2003). This exclusion was thought in the past to be unimportant because the estuarine portion of the Savannah River near Savannah, especially the Back River channel, has long been believed to be the most important spawning area for Savannah River striped bass (Gilbert et al. 1985). Dudley et al. (1977) stated that one of the reasons for believing that the Back River is the main spawning area for Savannah River striped bass is because of the regularity with which the Richmond Hill Hatchery personnel caught ripe brood fish there. Another reason for believing the estuarine spawning area is or was the primary spawning area relates to the observation that, immediately after tide gates became operational and changed the salinity regime of the Back River, Savannah River striped bass declined by about 95% (Van Den Avyle and Maynard 1994; Van Den Avyle et al. 1995; Reinert et al. 2005). Van Den Avyle and Maynard (1994), however, noted that eggs were routinely captured at RK50 indicating that there must be some spawning occurring in the Savannah River above the estuary. Other than this aside, very little has been published about striped bass spawning in the upriver portions of the Savannah River; this report is based on a reworking of the data from the single ichthyoplankton study reported for the upriver area (Paller et al. 1986).

Study Site:

The Savannah River is formed by the confluence of the Tugaloo and Seneca Rivers in northeast Georgia and flows southeast through the Piedmont and

Coastal Plain physiographic regions to the Atlantic Ocean. Water flow in the Savannah River is controlled by a system of reservoirs located upstream of the study area, which extended from just below the New Savannah Bluff Lock and Dam at River Kilometer (RK) 301 about 253 km downstream to RK47.6. This portion of the river is broad and free-flowing with substrates of silt, sand, gravel, and clay. The study area was mostly upstream of the estuarine portion of the river, which reaches upstream to approximately RK 50.

There were 27 river stations between RK47.6 and RK 301 during both 1983 and 1984. The two most downriver stations were tidally influenced but the lowest one was more than 24 km above the salt wedge. For 1985 the five most downriver stations were dropped and one station at RK234 was added so that there were 23 stations between RK 144 and RK 301.

Methods:

We used paired 0.5 m plankton nets with 505 µm mesh to collect ichthyoplankton. The current speed was sufficient for the nets to be deployed for stationary sampling. Deployment time was adjusted, based on measured current velocity, to filter approximately 50 m^3 of water. Calibrated flow meters were mounted in the mouths of each net to calculate actual volume filtered. Ichthyoplankters were preserved in 10% formalin and transported to the laboratory where they were sorted and identified.

Sampling stations were transects and each had a minimum of three subsurface tows (0.5 m below surface); these were near the South Carolina shore, near the Georgia shore, and mid-channel. The station was also sampled at approximately 0.5 m above bottom where the depth was greater than two meters. Samples were taken weekly, February through July for 1983 through 1985.

Densities of fish eggs and larvae were calculated as number of organisms/1000 m^3. Mean densities for each sampling station each week were calculated by averaging samples for both nets and from all subsamples taken at the sampling station that week. We computed the number of striped bass eggs and larvae transported past each sampling station from estimates of station mean ichthyoplankton densities and mean station discharge rates (m^3/s, USGS, http://waterdata.usgs.gov/ga/nwis/current?type=flow). The number of striped bass ichthyoplankters transported over time at each sampling station was calculated by averaging ichthyoplankton transport between each pair of consecutive sample dates, multiplying this mean by the elapsed time between sample dates, and summing the intervals.

Estimates of egg transport distance were made using means of current speed for the month of May when almost all spawning occurred and an estimated temperature dependent minimum hatching time. Station specific monthly mean temperatures for the stations having the highest densities of eggs and larvae for each year were used to estimate the minimum hatching time. Information for the hatching time was taken from Hardy (1978). The minimum hatching time was estimated at 33 hours for 1983, 38 hours for 1984, and 36 hours for 1985.

Results

The total numbers of striped bass eggs and larvae collected from the study area were 940 in 1983, 1381 in 1984, and 1226 in 1985. In 1983 striped bass eggs and larvae were found at almost all sampling sites with the exception of a few sites in the upper portion of the study area (Figure 1). Striped bass egg and larvae distribution was quite different in 1984 with the stations at RK268 and RK283 lacking eggs and larvae and no stations from RK129 down river having eggs or larvae. All stations sampled in 1985 had striped bass eggs and larvae, but we cannot say whether eggs or larvae were present at the lower stations that did not have them in 1984 because we did not sample those stations.

Relatively high densities of striped bass ichthyoplankton occurred between RKs 144 and 253 during all years. This pattern was especially conspicuous in 1984, when eggs and larvae were largely confined to this portion of the river. If peak larval densities can be taken to indicate preferred spawning reaches, it appears that the portion of the river between RKs144 and 253 was highly utilized. This area is well above the river estuary (Figure 1).

Calculations of the numbers of eggs transported past a sample station can provide an indication of the eggs produced at and upstream of the sample station. By dividing this number by the typical fecundity of Savannah River striped bass (approximately 500,000 eggs per female per year, Will et al. 2002, Figure 2), it is possible to obtain a rough estimate of the number of females that produced the eggs. The number of eggs transported past the sample stations in the region of peak spawning activity (RKs 144 - 253) over the entire February – July sample period averaged about 16 million in 1983 (95% CI = 5-27), 24 million in 1984 (95% CI = 16-33), and 10 million in 1985 (95% CI = 4-17), with maxima of 82 million, 83 million, and 51 million, respectively (Table 1). It is likely that the maxima provide a better basis for estimating the number of spawning females than the averages because the latter include sample stations at which the number of eggs was low because of egg mortality and/or because they were upstream of some or most spawning females. Based on the maxima, the estimated numbers of spawning females in the reach between RK144 and RK 253 was 164 in 1983, 166 in 1984, and 102 in 1985.

Discussion

The assumption that the majority of striped bass spawning has historically been in the estuary is supported by movements of electronically tagged adults. Dudley et al. (1977) showed that the Little Back River and its tributaries were the most heavily used spawning reaches visited by tagged fish. They also noted that

some tagged fish moved as much as 240 km up river after completion of spawning near Savannah, and at least one striped bass captured near Augusta and marked with an external anchor tag was captured on the Savannah estuarine spawning grounds. On the other hand, our data clearly show that substantial spawning occurs upstream of the estuary, with an apparent aggregation of spawning fish each year between RKs 144 and 253.

Our estimates of the number of eggs produced and the number of spawning females in the upriver area are similar to estimates for the Savannah River estuary. We estimated the annual number of eggs produced in the upriver area to range from 51 to 83 million during 1983-1985 (Table 2). These numbers are within the egg production range estimated for the lower river, 37 million to 142 million (Will et al 2001). Similarly, our estimates of the number of spawning females in the upriver area (102 to 166) are within the range estimated for the lower river (<40 to 925, Table 2).

Bulak et al. (2004) estimated that the number of spawning fish over 30 cm was around 400 in the nearby Combahee River, a number comparable to estimates for the Savannah River. However, there may be less striped bass spawning in the Savannah River than in the Congaree/Wateree River, also located in South Carolina, where egg production estimates were two orders of magnitude greater than in the Savannah River (Table 3). A number of other more northerly Atlantic coast rivers were also characterized by egg production estimates about two orders of magnitude greater than for the Savannah River. It is unknown whether these differences still persist or whether striped bass egg production in the Savannah River is comparable to that in Florida Atlantic and Gulf Coast rivers where data are unavailable for comparison.

Bulak et al. (2004) found that there is very little inter-river movement of striped bass among the seven coastal rivers of South Carolina, and the stocks are basically isolated and independent. This is a different situation from the more

northerly populations such as those in the Chesapeake Bay drainages (Chapman 1990). Limited mobility may contribute to the likelihood of a single river containing more than one distinct population, which remains a possibility for the Savannah River. In the Hudson River Raney and de Sylva (1953) and Raney et al. (1954) reported, based on morphometrics, that there was a sedentary subpopulation that lives upriver from the migratory population. Waldman et al. (1996) found no genetic support for this sedentary subpopulation but could also not disprove its existence. On the other hand, Secor and Piccoli (1996) identified groups of individual striped bass within the Hudson River that appeared to be permanent residents of the river, seldom or never leaving the oligohaline-mesohaline portions of the river.

Peak densities of striped bass eggs and larvae occurred in May at temperatures from 16.1 to 21.0 C in all three years. By May river discharge and consequently current speed was relatively similar among years. Using the temperature specific minimum hatching time, the distance between the probable location of spawning and the point in the river where the eggs hatched was about 111 km in 1983, 119 km in 1984, and 92 km in 1985. Based on growth rates and transport rates in all three years, the larvae from upriver spawning (above RK225) should move to inshore backwater nursery areas some place between Ebenezer Creek (RK72) and Big Collis Creek (RK48) so that the nursery grounds for the upriver stock would be within 30 km of the nursery area for the estuarine stock. If spawning occurs as far down river as RK200, and it appears to, there may be commingling of populations on the nursery grounds. However, commingling of juveniles on nursery grounds does not rule out separate populations. Morris et al. (2003) report for the Stewacke River of Nova Scotia that otolith chemistry indicates the sea-going and resident striped bass populations share the same nursery areas; they also reported that the three major genotypes of striped bass from the Roanoke River also share nursery areas. Secor and Piccoli (1996) identified groups of individual striped bass within the Hudson River that appeared to be permanent residents of the river, seldom or never leaving the oligohaline-

mesohaline portions of the river but there was no supporting evidence for separate spawning areas for the two populations.

Whether there is one or more population of striped bass in the Savannah River hinges on spawning site fidelity of adult striped bass, whether these adults fixate on their natal spawning site or simply return to the place they spawned at first, and how much wandering occurs between populations. Young and Isely (2002) have shown that striped bass in J. Strom Thurmond Reservoir (Clarks Hill Lake) do demonstrate spawning site fidelity. What we do not know is whether this fidelity is based on natal spawning area preference and how much wandering there is between the estuarine and upriver spawning areas.

Acknowledgements:

References:

Bulak, J.S., N.M. Hurley, Jr., and J.S. Crane. 1993. Production, mortality, and transport of striped bass eggs in Congaree and Wataree Rivers, South Carolina. Pages 29-37 *in* L.A. Fuiman, editor. Water quality and the early life stages of fishes. American Fisheries Society, Symposium 14, Bethesda, Maryland.

Bulak, J.S., C.S. Thomason, K. Han, and B. Ely. 2004. Genetic variation and management of striped bass populations in the coastal rivers of South Carolina. North American Journal of Fisheries Management 24:1322-1329.

Chapman, R.W. 1990. Mitochondrial DNA analysis of striped bass population in Chesapeake Bay. Copeia 1990:355-366.

Dudley, R.G., A.W. Mullis, and J.W. Terrell. 1977. Movements of striped bass (*Morone saxatilis*) in the Savannah River, Georgia. Transactions of the American Fisheries Society 106:314-322.

Gilbert, R.J., S. Larson, and A. Wentworth. 1985. The relative importance of the lower Savannah River as a striped bass spawning area. University of Georgia, School of Forest Resources, Dingell-Johnson Project F-39, Georgia, Final Report, Athens, Georgia.

Hardy, J. D., Jr. 1978. Development of fishes of the Mid Atlantic Bight. An atlas of egg larval and juvenile stages. Vol. III. Aphredoderidae through Rachycentridae. USFWS, Biological Services Program, FWS/OBS-78/12. Washington, D.C.

McGovern, J.C. and J.E. Olney. 1996. Factors affecting survival of early life stages and subsequent recruitment of striped bass on the Pamunkey River, Virginia. Canadian Journal of Fisheries and Aquatic Sciences 53:1713-1726.

Meyer, J, and 11 others. 2003. Summary report supporting the development of ecosystem flow recommendations for the Savannah River below Thurmond Dam. University of Georgia. available http://ga.water.usgs.gov/news/drought99/droughtrefs.html

Morris, J.A., Jr., R.A. Rulifson, and L.H. Toburen. 2003. Life history strategies of striped bass, *Morone saxatilis*, populations inferred from otolith microchemistry. Fisheries Research 62:53-63.

Olney, J.E., J.D. Field, and J.C. McGovern. 1991. Striped bass egg mortality, production, and female biomass in Virginia rivers, 1980—1989. Transactions of the American Fisheries Society 120:354-367.

Paller M.H., B.M. Saul, and D.V. Osteen. 1986. Distribution and abundance of ichthyoplankton in the mid-reaches of the Savannah River and selected tributaries. Environmental and Chemical Sciences, Inc, (ECS-SR-27) report to E.I. du Pont de Nemours and Company, Savannah River Plant, Aiken, South Carolina

Raney, E.C. and D.P. de Sylva. 1953. Racial investigations of the striped bass, *Roccus saxatilis* (Walbaum). Journal of Wildlife Management 17:495-509.

Raney, E.C., W.S. Woolcott, and A.G. Mehring. 1954. Migratory pattern and racial structure of Atlantic coast striped bass. Transactions of the North American Wildlife and Natural Resources Conference 19:376-396.

Reinert, T.R., C.A. Jennings, T.A. Will and J.E. Wallin. 2005. Decline and potential recovery of striped bass in a Southeastern U.S. estuary. Fisheries 30(3):18-25.

Rulifson, R.A. and C.S. Manooch III. 1990. Recruitment of juvenile striped bass in the Roanoke River, North Carolina, as related to reservoir discharge. North American Journal of Fisheries Management 10:397-407.

Rutherford, E.S., E.D. Houde, and R.M. Nyman. 1997. Relationship of larval-stage growth and mortality to recruitment of striped bass, *Morone saxatilis*, in Chesapeake Bay. Estuaries 20:174-198.

Secor, D.H. and E.D. Houde. 1995. Temperature effects on the timing of striped bass egg production, larval viability, and recruitment potential in the Patuxent River (Chesapeake Bay). Estuaries 18:527-544.

Secor, D.H. and P.M. Piccoli. 1996. Age- and sex-dependent migrations of striped bass in the Hudson River as determined by chemical microanalysis of otoliths. Estuaries 19:778-793.

Van Den Avyle, M.J. and M.A. Maynard. 1994. Effects of saltwater intrusion and flow diversion on reproductive success of striped bass in the Savannah River estuary. Transactions of the American Fisheries Society 123:886-903.

Van Den Ayvle, M.J., J. Wallin, and C. Hall. 1995. Restoration of the Savannah River striped bass population. American Fisheries Society Symposium 15:572.

Waldman, J.R., K. Nolan, J. Hart, and I.I. Wirgin. 1996. Genetic differentiation of three key anadromous fish populations of the Hudson River. Estuaries 19:759-768.

Will, T.A., T.R. Reinert, and C.A. Jennings. 2001. Assessment of spawning sites and reproductive status of striped bass, *Morone saxatilis*, in the Savannah River Estuary. University of Georgia, Warnell School of Forest Resources, Report to the Georgia Ports Authority. Available: http://sav-harbor.com/Study%20Reports/SBS%20report/Final_Report.PDF

Will, T.A., T.R. Reinert, and C.A. Jennings. 2002. Maturation and fecundity of a stock-enhanced population of striped bass in the Savannah River estuary, U.S.A. Journal of Fish Biology 60:532-544.

Young, S.P. and J.J. Isely. 2002. Striped bass annual site fidelity and habitat utilization in J. Strom Thurmond Reservoir, South Carolina-Georgia. Transactions of the American Fisheries Society 131:828-837.

Tables:

Table 1. Estimated number (millions) of striped bass eggs and larvae transported past sample stations (indicated by river km) in the Savannah River

River km	1983	1984	1985
47.7	21.4	0.0	not sampled
64.4	11.1	0.0	not sampled
80.8	4.0	0.0	not sampled
96.6	40.4	0.0	not sampled
112.6	4.0	0.0	not sampled
128.7	6.3	0.0	not sampled
143.8	18.2	4.7	7.1
157.0	8.0	4.9	4.0
177.1	9.5	11.2	5.0
193.2	82.4	28.6	4.4
207.6	5.1	25.8	17.7
207.9	29.9	21.6	21.1
221.7	0.7	37.1	1.3
227.9	0.0	19.7	0.3
228.2	0.0	82.8	1.6
234.6	0.0	0.0	1.9
242.2	7.7	38.8	7.7
242.8	0.6	30.1	1.0
244.8	14.2	12.2	11.8
245.1	60.5	16.2	10.5
249.9	30.3	35.3	51.1

250.1	0.0	9.3	8.0
250.2	35.0	35.3	43.4
252.8	0.0	23.2	1.6
253.0	0.6	8.1	0.3
253.3	0.0	18.5	6.7
268.3	37.4	0.0	34.2
283.4	0.6	0.0	0.3
301.3	0.0	0.6	0.3

Table 2. Estimated numbers of spawning female striped bass in the estuarine and upriver reaches of the Savannah River. Egg population estimates for 1999 and 2000 in the estuary are from Will et al. (2001). Number of eggs captured for 1984 in the estuary is from Gilbert et al. (1985).

Location	Year	No. eggs collected	Egg population estimate	Estimated No. Spawning Females
Estuary	2000		142,000,000	< 150
Estuary	1999		37,000,000	< 40
Estuary	1984	2775		925
Upriver	1983	940	82,000,000	164
Upriver	1984	1381	83,000,000	166
Upriver	1985	1226	51,000	102

Table 3. Estimated striped bass egg production in several Atlantic coast rivers.

Study	Drainage & State	Min. Egg Production	Max. Egg Production	Max Annual Mean Discharge (CFS)
Bulak et al. 1993	Congaree / Wateree, SC	10.99×10^9	22.93×10^9	15,130
Rutherford et al. 1997	Upper Bay, MD	1.8×10^9	14.6×10^9	66,560
Rutherford et al. 1997	Potomac, MD-VA	1.34×10^9	11.3×10^9	24,370
Rulifson & Manooch 1990	Roanoke, NC	3.44×10^8	4.93×10^9	15,330
McGovern & Olney 1996	Pamunkey, VA	2.3×10^9	2.7×10^9	1,859
Olney et al. 1991	Pamunkey, VA	0.32×10^9	2.69×10^9	1,859
Olney et al. 1991	James, VA	0.79×10^9	1.25×10^9	12,150
Olney et al. 1991	Rappahannock, VA	0.96×10^9	1.01×10^9	1,198
Olney et al. 1991	Mattaponi, VA	0.28×10^9		1,210
Secor & Houde 1995	Patuxent, MD	6.64×10^8		595.3
Will et al. 2001	Savannah (Estuary), SC-GA	3.7×10^7	14.2×10^7	20,900
This study	Savannah, SC-GA	5.1×10^7	8.3×10^7	20,900

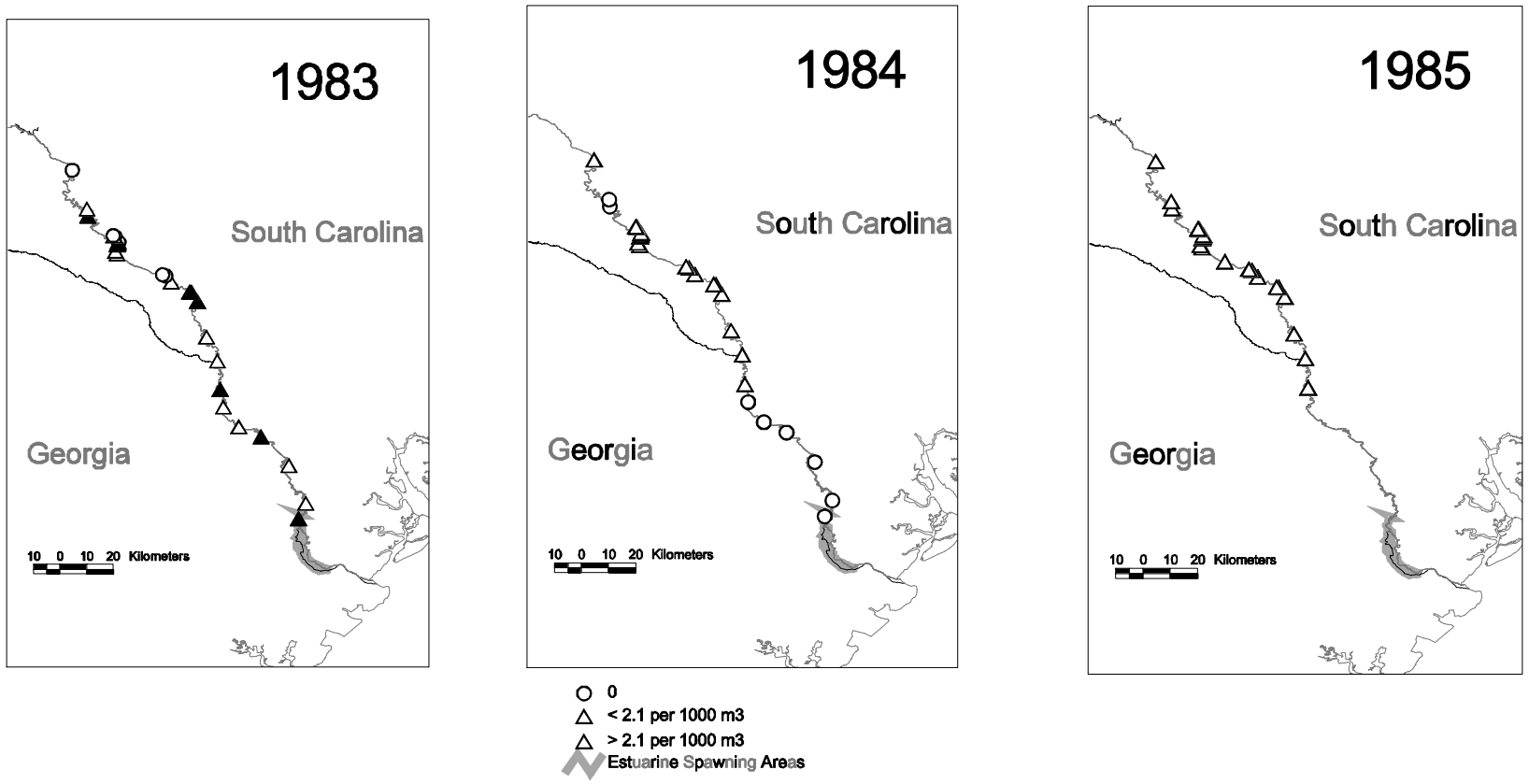
Figure Captions:

Figure 1. Striped bass egg and larval density at non-estuarine sampling stations.

Figure 2. Weight-fecundity relationships for Savannah River striped bass. Data from Will et al. (2002).

Figures:

Figure 1



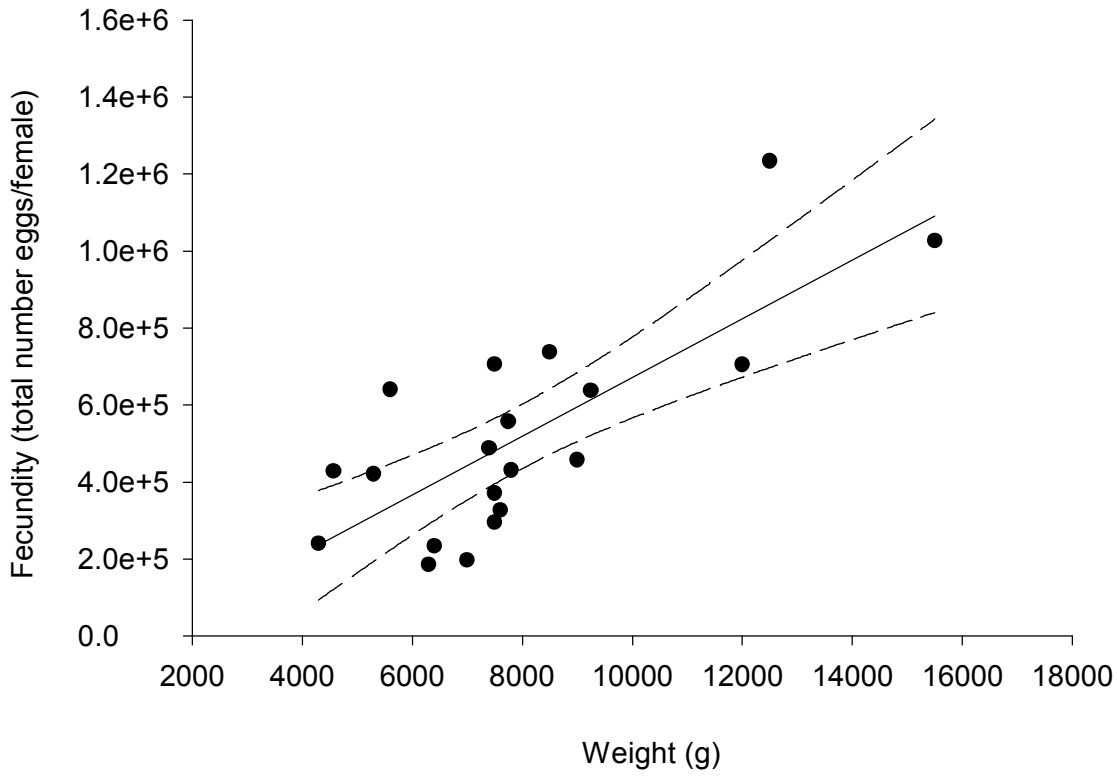

Fecundity (total number eggs/female)
1.6e+6
1.4e+6
1.2e+6
1.0e+6
8.0e+5
6.0e+5
4.0e+5
2.0e+5
0.0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Weight (g)

Figure 2