SOME PRELIMINARY STUDIES OF THE EFFECTS OF A STATIC MAGNETIC FIELD ON THE LIFE CYCLE OF THE *LEBISTES RETICULATUS* (GUPPY)

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ABSTRACT *Lebistes reticulatus* (guppy) was subjected to a continuous treatment of a 500-G homogeneous magnetic field within a specially designed horseshoe magnet encompassing a small aquarium. The experiment was carried through several generations with the following results: in the first generation, the brood size was normal but the gestation period was reduced by 30%; the second generation had an average reduction of spawn rate of 50% and a reduction of the gestation period of 30%; and in the third generation, reproduction was completely inhibited as long as the fish remained within the magnetic field.

Since the turn of the century, the influence of static magnetic fields on biological subjects has been under investigation with ever increasing interest. However, experimental verification of positive effects of any given field strength on a given biophysical or biochemical reaction, on a specific cellular process, or on the total development of a given organism, has not been reported. The most recent biophysical literature continues to support contradictory views concerning the biological effects of static magnetic fields.

This investigation, which is similar to the study of Dunlop and Schmidt (1969), reports on the sensitivity of a living organism, the guppy (*Lebistes reticulatus*), to a magnetic field of medium strength over a period of several generations. The author has devised a critical experiment to test the hypothesis that a permanent static magnetic field of ~ 500 G may produce changes in the life cycle and growth patterns of living organisms. This hypothesis is supported by the findings of Valentinuzzi (1962), Mulay and Mulay (1961), Barnothy and Barnothy (1964), and D'Souza et al. (1969). With this previous work in mind, the following experiments were performed over a period of four years.

EXPERIMENTAL PROCEDURE

The experiment was designed to allow for the development of the total life cycle of the guppy from fertilization through gestation, spawning, and maturity to refertilization, all proceeding within a permanent homogeneous magnetic field of 500 G.

Specially designed aquaria 8 cm wide by 30.5 cm long by 25.5 cm high were constructed with 3.5-mm thick commercial window plastic sheets, brand name "Plastolite." Each experimental aquarium was placed within the ends of a modified horseshoe magnet (Fig. 1). The magnetic field was measured and mapped weekly with a Cenco direct-reading Hall-effect gauss meter (Cenco Instruments Corp., Brooklyn, N.Y.). Fig. 2 is a map of the magnetic field in which the guppies used in this experiment were sustained for at least 180 and up the 360 d. The uniformity of the field is due to the large pole pieces that completely covered the long sides of the aquaria. As the field was checked weekly with the gauss meter, small magnets were added as needed to keep the field constant in time. Each experimental aquarium had a matched control with a nonfunctional horseshoe-magnet arrangement.

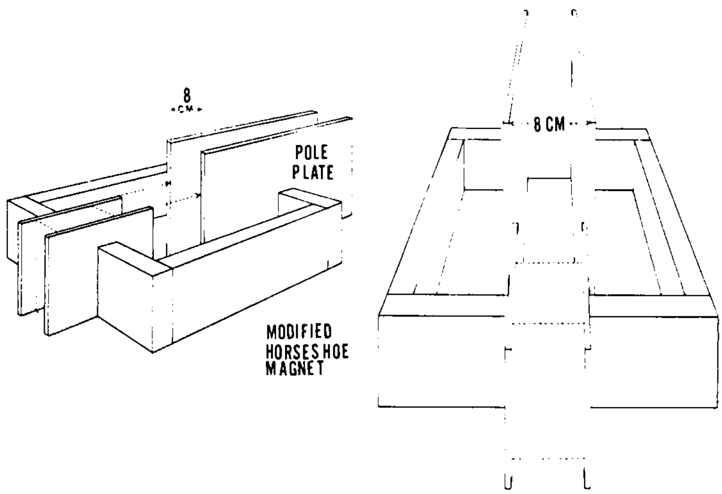


FIGURE 1 Modified plastic aquarium built to fit between the pole pieces of a modified horseshoe magnet.

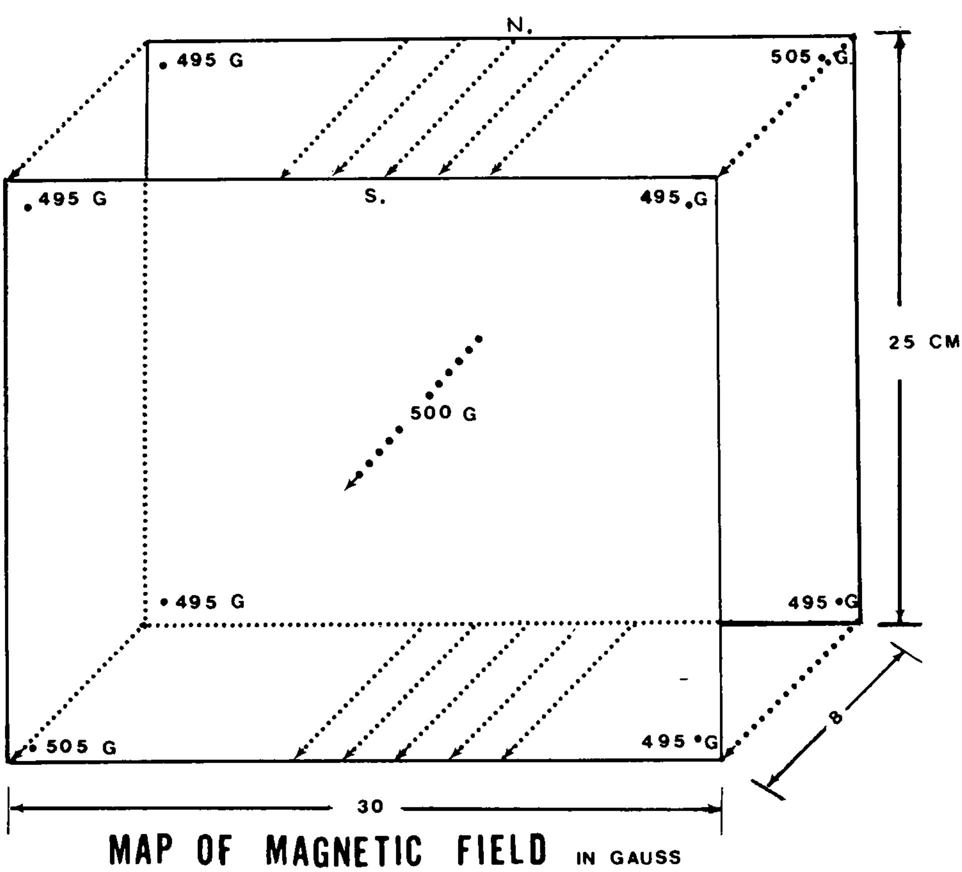


FIGURE 2 Map of magnetic field between pole pieces.

Each aquarium was prepared with equal amounts of tap water that had been aged for at least 3 d. Glass plate covers were kept on each aquarium to reduce evaporation. Standard commercially washed gravel and identical filter and aeration equipment were supplied to each aquarium. The permanent magnets used in the experiments were obtained from General Magnetic Corporation (Alma, Mich.). Six pairs of mature stock guppies were obtained from three different sources and kept in a large general holding tank. The first generation of guppies from this parent stock were used to begin the experiment.

Treatment

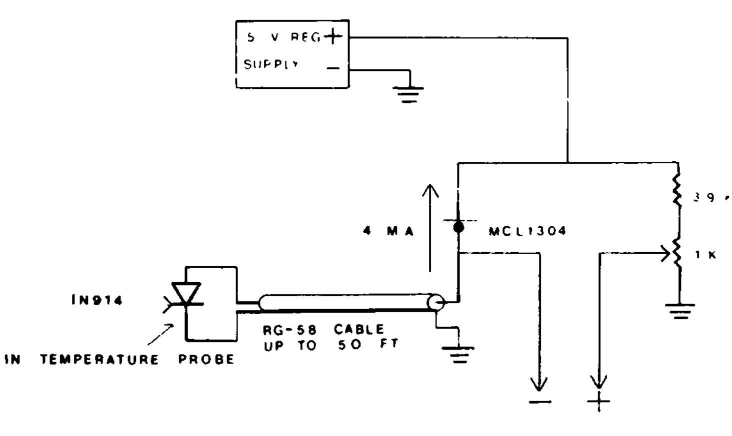
The offspring from the parent stock were separated by sex, and the males and females were placed in separate holding tanks for a period of sixty-two d to eliminate the possibility of fertilization and to insure adequate growth and development.

At the end of the holding period, mating pairs were randomly selected, paired, and placed in each of six aquaria. Three aquaria, used as controls, were shielded from the experimental aquaria by distances of 244 to 304 cm. At these distances no magnetic fields other than the earth's magnetic field could be measured. In line with the control tanks, the three experimental aquaria were placed within the ends of the modified horseshoe magnets and subjected to a 500-G homogeneous magnetic field throughout the experiment.

Each pair of control and experimental aquaria were considered as one run. Each aquarium was supplied daily with 0.05 gm of commercial grade tropical fish food. Each aquarium was monitored for temperature, with a voltage analog (a diagram has been included of the wiring of the analog as Fig. 3); light exposure, six times daily, with a Weston sight meter (Weston Instruments Inc., Newark, N.J.); and filtration rate, with the standard La Motte adjustable airflow meter (La Motte Chemical Products Co., Chestertown, Md.).

DATA FROM THE EXPERIMENTAL GROUP

The guppies mating in the magnetic field spawned within 19 d with an average brood of 19 offspring. When sex could be determined (about 7–12 d after birth) the male offspring were separated from the female offspring and each group placed in a separate holding tank in which the exposure to the constant 500-G magnetic field and all other conditions remained



VOLTAGE ANALOG OF TEMPERATURE

FIGURE 3 Voltage analog of temperature recording design.

TABLE I

CONTROL AND STATIC MAGNETIC-FIELD-TREATED GUPPIES

Run	1st Generation							2nd Generation							3rd Generation						
	A	B		C		D		A	B		C		D		A	B		C		D	
	d	*n*		*mm*		*mg*		*d*	*n*		*mm*		*mg*		*d*	*n*		*mm*		*mg*	
Static magnetic-field-treated guppies																					
1	19	9(M)	10(F)	44(M)	52(F)	0.18(M)	1.52(F)	20	3(M)	6(F)	44(M)	55(F)	0.20(M)	0.62(F)	160	0(M)	0(F)	43(M)	61(F)	0.67(M)	0.76(F)
2	18	7	12	44	54	0.23	0.69	20	4	7	43	53	0.32	0.71	160	0	0	43	60	0.67	0.76
3	20	8	12	43	54	0.19	0.71	17	2	7	44	54	0.34	0.72	200	0	0	44	62	0.60	0.87
4	17	7	10	43	49	0.16	0.71	18	3	6	46	57	0.37	0.72	200	0	0	44	63	0.68	0.87
5	19	6	12	46	54	0.19	1.63	17	3	6	44	56	0.36	0.73	300	0	0	43	60	0.71	0.89
6	20	9	10	45	56	0.21	0.62	19	3	7	44	53	0.24	0.69	360	0	0	43	64	0.71	0.89
7	19	7	11	48	59	0.22	0.62	20	2	6	43	54	0.24	0.56	160	0	0	42	63	0.71	0.92
8	18	8	13	42	57	0.23	0.60	19	3	6	43	53	0.27	0.61	160	0	0	44	61	0.70	0.93
9	20	9	10	44	56	0.24	0.64	20	3	6	44	66	0.20	0.68	200	0	0	44	61	0.70	0.83
Ave:	18.8	8	11	44	54	0.21	0.63	13	3	6	44	56	0.28	0.67		0	0	43	62	0.69	0.86
Control: nontreated guppies																					
1	27	9(M)	12(F)	26(M)	39(F)	0.12(M)	0.21(F)	27	9(M)	12(F)	25(M)	40(F)	0.23(M)	0.42(F)	28	9(M)	14(F)	27(M)	39(F)	0.22(M)	0.40(F)
2	28	8	14	27	40	0.14	0.25	26	7	16	26	39	0.24	0.41	27	8	20	26	40	0.23	0.41
3	27	7	12	27	38	0.21	0.38	29	8	11	27	40	0.21	0.43	26	7	15	27	40	0.14	0.39
4	29	5	16	26	39	0.18	0.26	29	6	13	26	40	0.22	0.39	27	8	17	28	21	0.15	0.38
5	27	7	14	27	39	0.20	0.27	30	7	12	25	38	0.24	0.31	28	7	14	26	37	0.12	0.37
6	28	9	13	26	40	0.21	0.31	27	8	16	25	40	0.23	0.35	27	6	13	27	43	0.14	0.40
7	28	7	11	27	40	0.12	0.28	26	7	15	26	39	0.22	0.30	27	6	13	28	40	0.15	0.40
8	27	6	12	27	39	0.19	0.29	28	6	14	26	39	0.24	0.39	28	7	·14	29	39	0.15	0.41
9	27	7	13	27	38	0.19	0.29	27	9	13	27	40	0.23	0.29	26	9	16	26	29	0.14	0.39
Ave:	27.5	7	13	27	39	0.17	0.28	27.6	7	15	29	39	0.24	0.37	27	7	15	27	39	0.18	0.39

A, gestation time; B, brood size; C, length 70 days after spawning; D, wet-weight 70 days after spawning; M, males; F, females; Ave, average.

constant. The guppies used for the experimental group remained in the magnetic field for their lifetimes. The guppies not selected for mating in the experimental tanks were returned to the general holding tank.

After 62 d of separation to allow for maturity and growth and to prevent possible fertilization, three pairs from the brood of second generation fish were mated and each pair placed in an experimental aquarium. Again, after 19 d, offspring were spawned from this mating. The broods so spawned averaged nine fish, always with fewer males than females. See Table I.

The above procedure was repeated. In this third generation there was no reproduction as long as the fish were held within the magnetic field. The experimental conditions were continued for an additional 180 d. No fertilization or spawning was manifested by the third generation pairs during this time.

Half of the third generation experimental group was then removed from the magnetic field and placed in nonmagnetized tanks. By the end of 180 d these fish had produced a fourth generation brood small (3–4 males and 6–7 females), compared to the normal brood of nontreated fish, at the end of 180 d. Data from these experiments is presented in Table I and on the generation flow chart, Fig. 4. The complete experimental procedure took about 1½ yr. However, the author was able to conduct the experimental procedure nine times in a time span of 4 yr by using multiple tanks and tank dividers.

Experimental and control members of the fourth generation of mating were separated by

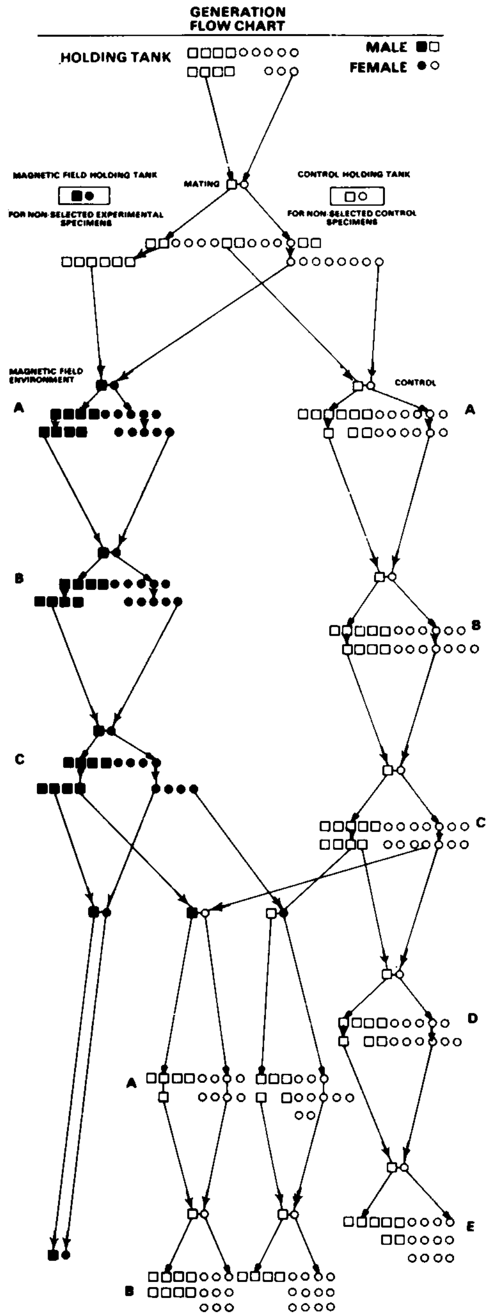


FIGURE 4 Generation flow chart of life cycle of the *Lebistes reticulatus*.

sex for 62 d followed by random pair selection and mating. These mixed pairs produced in normal gestation time of 27.5 d, comparable to the control groups of the experiment.

It was noted that while within the magnetic field each generation appeared to develop larger adult guppies, with the female becoming much larger than the males (Figs. 5 and 6). Those guppies that remained in the magnetic field continued to be sterile. One pair existed without mortality for 728 d in a 500-G field. Normal laboratory lifespan is 652 d.

DATA FROM CONTROL GROUP

Male and female offspring of the parent stock were taken from the holding tank, separated according to sex, and placed in separated tanks for 62 d. This procedure allowed for maturation, growth, and prevention of fertilization. At the end of the 62 d three pairs were randomly selected, mated, and placed in three aquaria. The control aquaria were identical to the experimental aquaria, except for the absence of the magnetic field.

After 27.5 d, each pair of guppies in the control group spawned an average of 17 to 19 offspring. The routine procedure, sex separation and random mating, was followed through successive generations and yielded brood sizes that varied by 1% (Fig. 5). By using multiple tanks and different parent fish, the complete experimental procedure was repeated nine times.

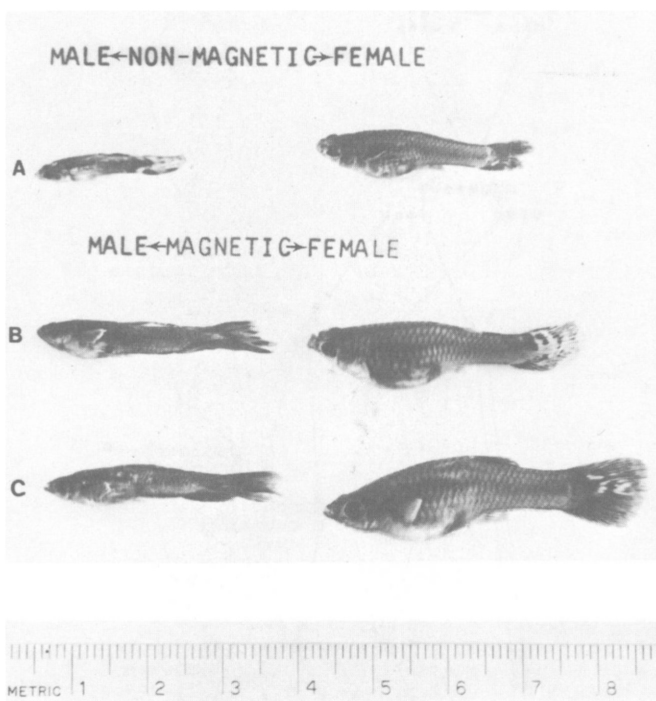


FIGURE 5 Lateral view of the *Lebistes reticulatus* after 180 d. (*A*) Male and femald nonmagnetic environment control group. *A*, *B*, and *C* denote generations. (*B*) Male and female first generation magnetic field environmentally treated offspring. (*C*) Male and female second generation magnetic field environmentally treated offspring.

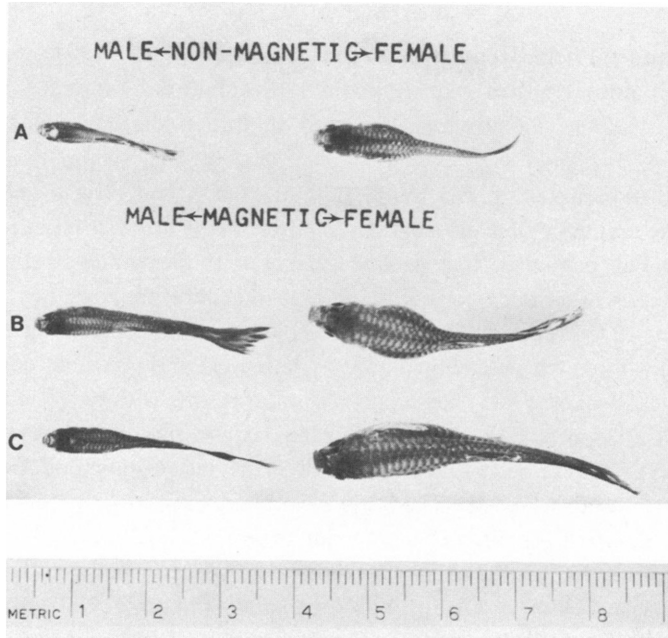


FIGURE 6 Dorsal view of the *Lebistes reticulatus* after 180 d. (*A*) Male and female nonmagnetic environment control group. (*B*) Male and female first generation magnetic field environmentally treated offspring. (*C*) Male and female second generation magnetic field environmentally treated offspring.

OTHER EXPERIMENTATION

In an effort to determine if the magnetic field sterilization process was sex selective, one control female was mated with a third generation magnetic-field-treated male. Similarly, one control male was mated with a third generation magnetic-field-treated female. Without the benefit of a magnetic field other than the geomagnetic field, these mated pairs spawned a brood of seven offspring within 19–20 d after fertilization. The procedure of sex separation for 62 d followed by random mating was carried out with these offspring. The gestation period of 27.5 d was completed and two from each set of three pairs spawned a brood of average size. Alternate mating of the offspring from these broods appeared to produce normal offspring in the average gestation period based upon our current laboratory control standards. Thereafter they continued to reproduce as normal guppies (Fig. 5, the control group). The above procedure was repeated with random selection of specimens from various generations with consistent results. Additional research is underway in our laboratory to rule out the question of whether or not the cause is magnetically or electrically induced. This data will be reported at a later date.

RELATED RESEARCH

A perusal of the literature does not reveal a reported experiment that has covered the entire life cycle through several generations of a subject. Neurath (1969) reported what he considered to be clear-cut evidence of the existence of inhibiting effects produced by a high-strength magnetic field. Reports by Barnothy and Barnothy (1964) based on numerous experiments with mice confirm that reproductive inhibition is induced by high-strength magnetic fields. Halpern (1966) also observed inhibition of algae placed in very high magnetic fields.

In the present experiment it was found that magnetic-field effects are not permanent. Removal from the magnetic field environment of some of the brood from different generations resulted in these fish beginning to reproduce at about the laboratory normal rate in 90 d. Brood size was nearly laboratory normal in the second generation.

Blatt and Kuo (1976) reported the absence of biomagnetic effects in nitella. Halpern and van Dyke (1966) worked with algae in a low magnetic field and reported reduction in size and number of colonies. Becker (1963) has reported similar results with bacteria in a low magnetic field. Brown (1962) reported the responses of planaria and protozoa to very weak horizontal magnetic fields. Brown et al. (1960, 1964) describe weak magnetic field effects using mollusks. El'Darov and Kholodav (1964) were able to report size reduction along with reproduction acceleration for birds in a constant magnetic field. Green and Halpern (1966) report growth stimulation in chickens. Veneziano (1965) performed collaborating work with chicken tissue in vitro. Observations by Van Dyke and Halpern (1965) of the effects on the whole organism of a mouse placed in a low magnetic field for 1 yr showed a shortened life span, diffuse tissue hyperplasia, infertility, cannibalism, and supine positioning.

One can also find reported attempts to correlate illness, deaths, etc., with geomagnetic disturbances or fluctuations (Düll and Düll, 1935 and Alvares, 1935). Further work by Becker et al. (1961) has been reported to be inconclusive.

Exposure times in a magnetic field reported in the literature vary from a few seconds to more than five years. However, it appears that no one has considered the effects of a static magnetic field on successive generations of an organism. The intensities of the applied magnetic fields in the studies reviewed vary from very low fields comparable to the geomagnetic field (a few hundred milligauss) up to fields of several hundred.

THEORETICAL COMMENTS

The primary purpose of this study was to determine experimentally if a constant 500-G magnetic field environment would have an effect on the life cycle of the *Lebistes reticulatus*. The research showed that such an environment does indeed affect both reproduction and growth. It is beyond the scope of this work to attempt to link these changes to specific chemical or cellular processes. One suggestion might be intracellular communication by diffusion at sensitive levels that respond to very small concentration shifts in order to be affected by the electric or magnetic fields applied. Now it would appear to be the mechanism that governs cell population growth.

The author is presently engaged in research that may determine whether the cause of the observed changes are due to the magnetic field alone, to the induced electric fields in the guppies, or to some other mechanism. To those readers who would like an excellent overview of the work done in biomagnetic research and the techniques for the measurements of susceptibility, the writings of L. N. Mulay (1961–1964) are suggested.

SUMMARY AND CONCLUSIONS

This study demonstrates that prolonged (lifetime) exposure to a homogeneous magnetic field of 500 G produces the following responses in the *Lebistes reticulatus:* (*a*) The first generation exhibits a gestation period shortened by 30%, but there is a normal number of offspring in the brood. (*b*) The second generation also exhibits a 30% shortening of the average gestation period from the control normal, but with an average reduction of the spawning rate by 50%. (*c*) The third generation appears to have complete inhibition of the reproductive process as long as the subjects remain in the magnetic field.

The author concludes that a static magnetic field of 500 G, which is of a strength well in excess of the geomagnetic field (~1 G) but not as large as fields used by some workers, will generate an environment at first favorable to growth and accelerated development in the fish. On the other hand, prolonged exposure over the life cycle of the subject generates an environment that inhibits reproduction.

It has also been demonstrated that the effects of the magnetic field are not permanent. The removal from the magnetic-field environment of some of the brood from different generations resulted in these fish beginning to reproduce at about the normal rate after a dormant period of 90 d. The sizes of the broods approach normal in the second generation and the growth patterns of the offspring regress to normal in successive generations.

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