FOLIA MALACOLOGICA
Vol. 19(1): 41–49
ISSN 1506-7629
The Association of Polish Malacologists
& Faculty of Biology, Adam Mickiewicz University
Poznań 2011
doi:10.2478/v10125-011-0002-y

# THE EFFECT OF MAGNETIC FIELD ON FARMED POPULATIONS OF *HELIX ASPERSA* O. F. MÜLLER, 1774

MACIEJ LIGASZEWSKI[1], ANDRZEJ ŁYSAK[2], PIOTR JANAS[3], ZOFIA MACH-PALUSZKIEWICZ[1]

[1]Institute of Animal Husbandry, State Research Institute in Kraków, Sarego 2, 31-047 Kraków, Poland
[2]Andrzej Frycz Modrzewski Kraków University, Kanonicza 9, 31-002 Kraków, Poland
[3]Agricultural University of Cracow, Mickiewicza 24/28, 30–059 Kraków, Poland
(e-mail: mligasze@izoo.krakow.pl)

ABSTRACT: In order to assess the effect of alternating electromagnetic and direct magnetic field on adult *Helix aspersa* O. F. Müller and their eggs, adults and eggs of *H. aspersa maxima* Taylor and *H. aspersa aspersa* O. F. Müller were exposed to such fields with different parameters, and the following life cycle traits were observed: condition of hibernating adults, their survival rate during hibernation and reproduction, egg mass, hatching success, growth rate of hatchlings and body mass of next generation adults. Adults were exposed to sinusoidal, alternating electromagnetic fields of 50 Hz, 100 Hz and 200 µT, and magnetic induction of 50 Hz, as well as a field of 175 µT and 10–1000 Hz (repetition period 80 minutes). Egg batches were exposed to direct magnetic fields of magnetic induction 5 µT and 10 µT and alternating electromagnetic fields of analogous induction and frequency of 50 Hz. The effects varied depending on the parameters of the fields, subspecies and life cycle stage. Adult *H. aspersa maxima* was more sensitive to the changes in characteristics of electromagnetic field than *H. aspersa aspersa*, but the two subspecies showed a similar reaction to exposing their eggs to direct or alternating magnetic field. Probably direct field had a greater selection effect compared to alternating field, removing weaker genotypes at embryonic stage; this resulted in a greater mean body mass of the next generation adults. The results are preliminary; further studies, with further modifications of parameters of the fields applied are necessary.

KEY WORDS: *Helix aspersa aspersa*, *Helix aspersa maxima*, magnetic field, electromagnetic field, life cycle, snail farming

## INTRODUCTION

Recent studies dealing with the effect of magnetic and electromagnetic fields on various development stages of animals, and conducted in Poland, were concerned mainly with technologies of breeding and farming of numerous fish species of economic importance (FORMICKI & WINNICKI 1996, PERKOWSKI & FORMICKI 1997, FORMICKI & PERKOWSKI 1998, WINNICKI et al. 2004, FORMICKI et al. 2004a). The terrestrial edible snail *Helix aspersa* O. F. Müller, 1774 has recently gained importance in Poland, being a farmed species. Technologies of its keeping and breeding in the country require further studies extended to include new aspects of its farming environment (ŁYSAK et al. 2008). Compared to many other terrestrial snails, *H. aspersa* takes relatively short time (4–6 months) to reach maturity. This character, unusual in members of the genus *Helix*, makes it useful for laboratory studies on the life cycle. Our experiments were aimed at ascertaining the effect of alternating electromagnetic field and direct magnetic field of experimentally adjusted physical parameters on different stages of the life cycle of the species.

## MATERIAL AND METHODS

The material included snails of two subspecies of *H. aspersa*: *H. aspersa aspersa* O. F. Müller, 1774 and *H. aspersa maxima* Taylor, 1883. They came from populations kept since 1996 as stocking material for the experimental snail farm in Balice near Kraków, Institute of Animal Husbandry, State Research Institute in Kraków. The Institute keeps four such populations of *H. aspersa*: "Balice" and "French" populations of *H. aspersa aspersa* and "Balice" and "Albino" populations of *H. aspersa maxima*. Snails from the "Balice" populations of each subspecies were selected for the experiment. The experiment was to ascertain the effect of magnetic and electromagnetic fields on the life cycle of snails in farm conditions, from winter torpor of adults, through their reproduction to the next generation. The following life cycle parameters were recorded: physical condition of adults during winter torpor, their survival rate during winter torpor and reproduction, egg mass and hatching success; body mass increment and body mass in adults of the next generation. Details of methods are shown in Tables 1–2 and Figs 1–7. The two experiments differed in the intensity of the magnetic field.

### Experiment I

The experiment was to ascertain the effect of magnetic field on the condition of adult *H. aspersa* and their later reproduction. The fields used were: sinusoidally alternating electromagnetic field of 50 Hz frequency and magnetic induction with the amplitude of 50, 100 and 200 μT, and alternating field with induction amplitude of 175 μT, frequency from 10 to 1000 Hz, and repetition period of 80 minutes. Magnetic fields of high homogeneity were generated by specially constructed, two-section coils of 60 cm diameter, connected in the Helmholtz system. The experiments were conducted in the hibernation chamber of the experimental farm of the Institute, with constant air temperature of 6°C and relative humidity ranging from 70% to 80%. Linen bags contained samples of adult *H. aspersa* in winter torpor, destined to reproduce in the spring. Each sample included 30 individuals. The snails were kept in such conditions from October 2006 till March 2007. The control included snails not subject to the effect of magnetic field. From March to May 2007 the experimental snails reproduced in a specially adapted farm enclosure. Each experimental group was placed in a farming tray with soil-filled breeding containers. The offspring was raised till the age of six weeks in special trays.

### Experiment II

The experiment was aimed at ascertaining the effect of direct magnetic field and alternating electromagnetic field on the development of eggs and results of their incubation; the development of hatchlings till maturity (lip completion) was observed after switching off the magnetic fields. Two kinds of direct field of 5 and 10 μT were used, the values being by three orders of magnitude higher than in experiment I. The two kinds of alternating field had the same intensity and frequency of 50 Hz. Control eggs were not subject to magnetic fields. The hatchlings were then kept in experimental trays and observed during six weeks; after that period their shells were marked with nitro enamel, with a different colour for each experimental group. The juveniles were released in an enclosure in a glasshouse, with soil sown with mustard seed and oil rapeseed. Feed mixture for snails was provided on wooden palettes, and the vegetation was sprinkled with water once a day. Body mass of the resulting adults was determined in the autumn.

## RESULTS

### Experiment I

Adult snails of all groups subject to magnetic fields during winter torpor showed a considerable increase in body mass after reproduction next year, compared to the end period of hibernation (Fig. 1). This pertained also to control snails. The mean body mass increment in experimental groups of *H. aspersa maxima* ranged from 32.0 % to 75.9%, and in those of *H. aspersa aspersa* from 32.6 to 49.0% (Fig. 2). Compared to the control group and the group subject to electromagnetic field of 175 μT and 10–1000 Hz, the mean body mass of *H. aspersa maxima* following reproduction was the greatest in the experimental groups earlier exposed to fields of 100–200 μT and 50 Hz. The body mass of the snails of this subspecies increased with increase in the amplitude of magnetic induction from 50 μT to 200 μT. The increase in body mass in that period was a compensation for the body mass decrease during the winter torpor (Fig. 2). However, in the case of the experimental groups of *H. aspersa aspersa* in which the mean relative decrease in body mass during the winter torpor was greater than in the respective groups of *H. aspersa maxima*, the compensation was incomplete.

During winter torpor the survival rate among *H. aspersa maxima* from experimental groups exposed to all the experimental magnetic fields was smaller, and in the case of *H. aspersa aspersa* greater than in control groups (Fig. 3). The natural survival rate during

Table 1. Mean mass of egg from egg batches of mature *Helix aspersa* subject to alternating electromagnetic field

| Kind of field | Number of egg batches | Egg mass [mg] | | | | |
|---|---|---|---|---|---|---|
| | | Mean | SD | SE | Range | V (%) |
| | | *Helix aspersa maxima* | | | | |
| Control | 17 | 41.2[a. A] | 8.8 | 2.1 | 17–53 | 21.4 |
| field 50 µT, 50 Hz | 8 | 42.8[a. A] | 4.2 | 1.5 | 35–49 | 9.9 |
| field 100 µT, 50 Hz | 9 | 43.8[a] | 2.9 | 1.0 | 41–48 | 6.5 |
| field 200 µT, 50 Hz | 8 | 52.6[b. B] | 6.3 | 2.2 | 42–62 | 11.9 |
| field 175 µT, 10–100 Hz | 5 | 48.8[b] | 8.2 | 3.7 | 41–61 | 16.8 |
| | | *Helix aspersa aspersa* | | | | |
| Control | 15 | 30.3 | 4.1 | 1.1 | 24–38 | 13.6 |
| field 50 µT, 50 Hz | 15 | 28.8[a. A] | 4.3 | 1.1 | 22–39 | 14.8 |
| field 100 µT, 50 Hz | 7 | 34.3[b. B] | 6.4 | 2.4 | 22–41 | 18.6 |
| field 200 µT, 50 Hz | 12 | 29.3[a] | 3.0 | 0.9 | 24–34 | 10.1 |
| field 175 µT, 10–100 Hz | 12 | 28.8[a] | 5.2 | 1.5 | 22–41 | 18.0 |

a, b – statistically significant differences (P<0.05);
A, B – highly statistically significant differences (P<0.01)

Table 2. Percent of hatching from egg batches of mature *Helix aspersa* subject to alternating electromagnetic field

| Kind of field | Number of egg batches | Egg mass [mg] | | | | |
|---|---|---|---|---|---|---|
| | | Mean | SD | SE | Range | V (%) |
| | | *Helix aspersa maxima* | | | | |
| Control | 14 | 53.0[a. A] | 26.4 | 7.1 | 13.0–93.1 | 49.1 |
| field 50 µT, 50 Hz | 8 | 88.6[b. B] | 15.1 | 5.3 | 56.0–100.0 | 17.1 |
| field 100 µT, 50 Hz | 9 | 67.0 | 35.0 | 11.7 | 6.0–97.3 | 52.2 |
| field 200 µT, 50 Hz | 8 | 64.6 | 29.2 | 10.3 | 9.4–99.2 | 45.3 |
| field 175 µT, 10–100 Hz | 4 | 55.3[a] | 40.1 | 20.1 | 4.6- 86.4 | 79.6 |
| | | *Helix aspersa aspersa* | | | | |
| Control | 14 | 78.1 | 9.9 | 2.6 | 57.7–95.3 | 12.7 |
| field 50 µT, 50 Hz | 13 | 67.9 | 23.5 | 6.5 | 26.7–96.7 | 34.6 |
| field 100 µT, 50 Hz | 7 | 72.0 | 30.6 | 11.5 | 10.1–92.2 | 42.5 |
| field 200 µT, 50 Hz | 12 | 63.6 | 22.2 | 6.4 | 19.2–91.3 | 34.9 |
| field 175 µT, 10–100 Hz | 11 | 73.7 | 22.7 | 6.8 | 22.9–93.8 | 30.8 |

a, b – statistically significant differences (P<0.05)
A, B – highly statistically significant differences (P<0.01)

winter torpor in control groups of *H. aspersa maxima* was greater than in those of *H. aspersa aspersa*. The survival rate from the beginning to the end of reproductive period was higher in control groups of both subspecies, compared to the groups earlier subject to the effect of magnetic fields. The mean egg mass in batches of *H. aspersa maxima* increased, compared to the control group, with the increase in the amplitude of magnetic induction from 50 µT to 200 µT, and was the greatest in the experimental group earlier exposed to magnetic field of alternating frequency of 10–1000 Hz (Fig. 4). In the experimental groups of *H. aspersa maxima* exposed to the field of 200 µT the mean egg mass was statistically significantly (P<0.01) greater than in the control group (Table 1). Likewise, the hatching success in the group exposed to the field of 50 µT was statistically significantly (P<0.01) greater than in the control group (Table 2). The mean egg mass in the batches of this subspecies could be affected by differences in physical condition in the experimental groups, according to the trends shown in Figs 1–2. The hatching success in the control group of *H. aspersa maxima* was smaller, and in *H. aspersa aspersa* greater than in the experimental groups. In the case of *H. aspersa maxima* statistically significant differences (P<0.01)

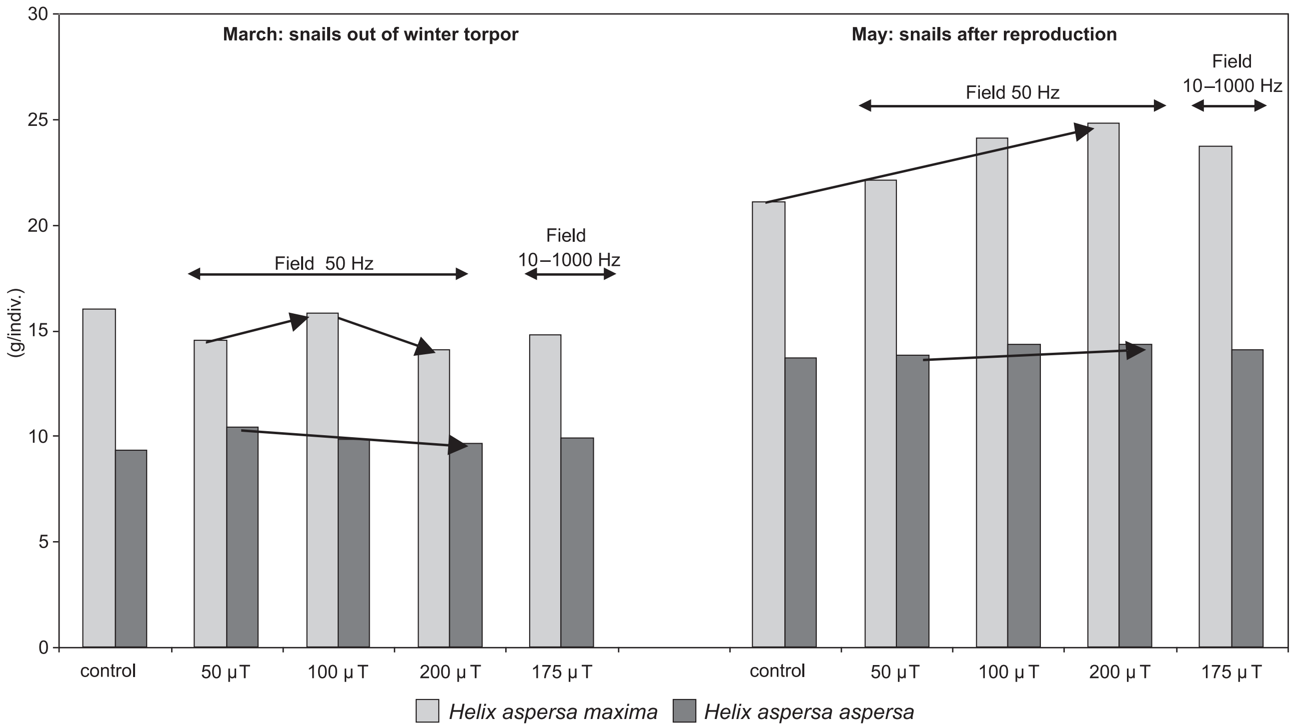


Fig. 1. Body mass of adult *Helix aspersa* exposed to alternating electromagnetic fields during Winter torpor. Mean values

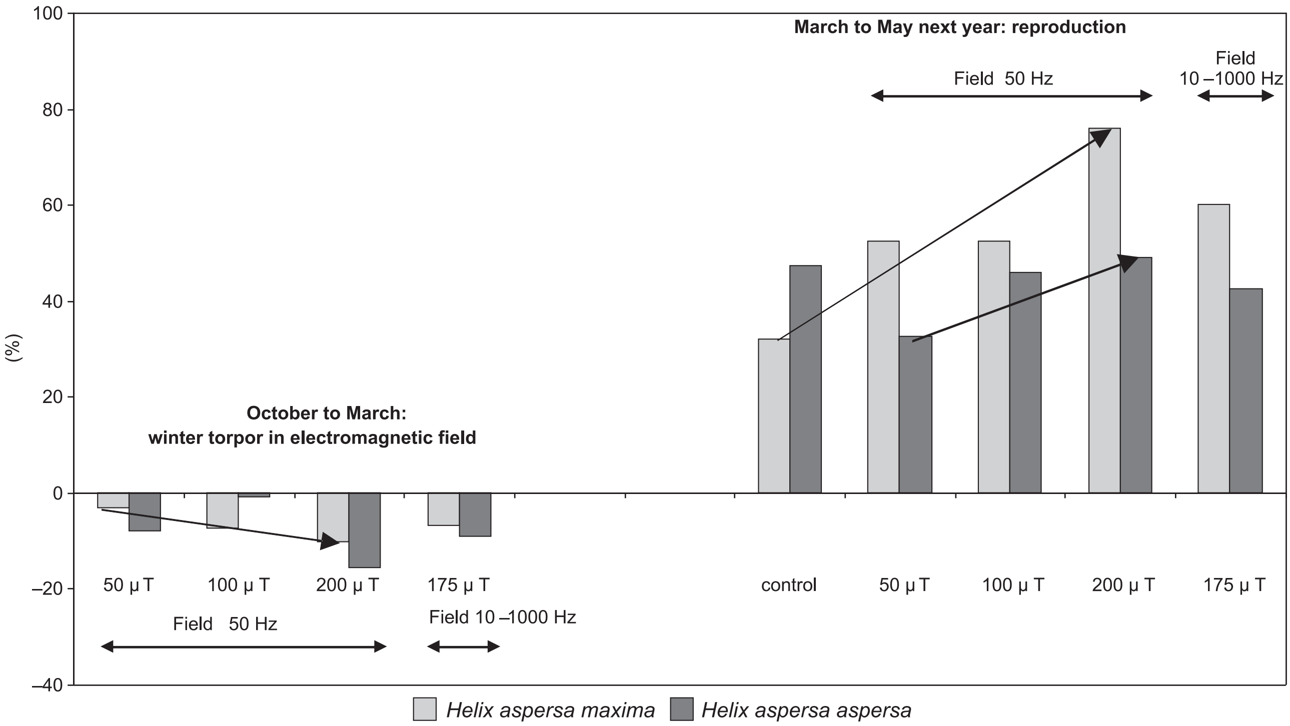


Fig. 2. Percent changes in body mass of adult *Helix aspersa* from the start of winter torpor till the end of next year reproduction

were observed between the control groups and the groups exposed to the field of 50 μT. However, the hatching success in the batches of the first subspecies decreased with the increase of field intensity from 50 μT to 200 μT, and was the smallest in the experimental group exposed to the field of alternating frequency of 10–1000 Hz (Fig. 5). For *H. aspersa aspersa* there was no statistically significant difference in the hatching success between the control and experimental groups (Table 2).

Experiment II

The hatching success of *H. aspersa maxima* and *H. aspersa aspersa* from control groups was up to two

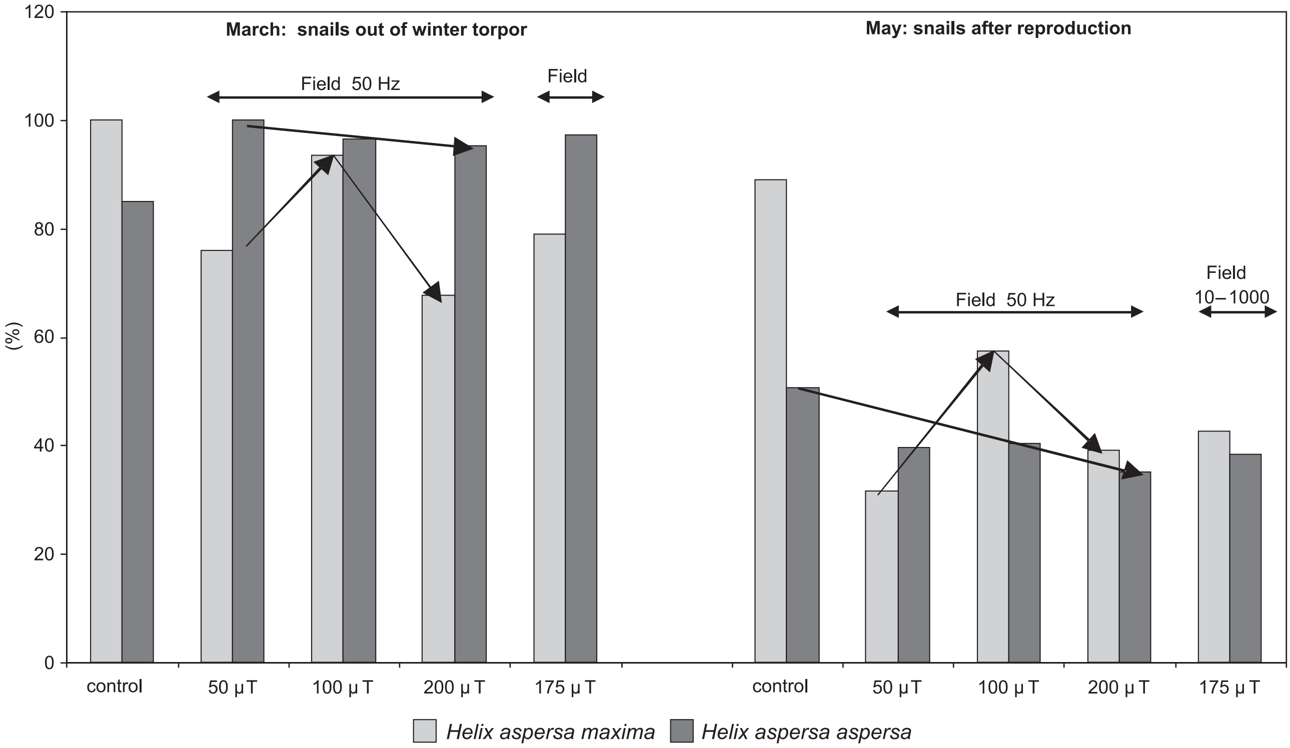


Fig. 3. Survival rate [%] of *Helix aspersa* exposed to alternating electromagnetic field during winter torpor. Mean values

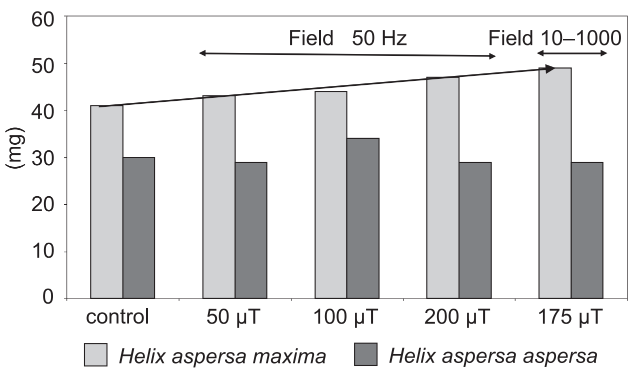


Fig. 4. Mean mass of eggs produced by *Helix aspersa* exposed to alternating electromagnetic field during winter torpor. Mean values

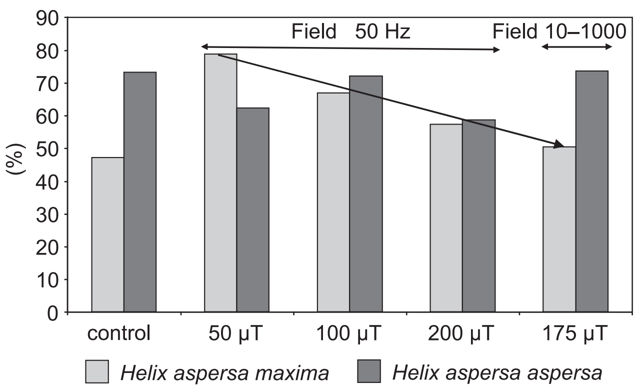


Fig. 5. Percent of hatching from egg batches of *Helix aspersa* exposed to alternating electromagnetic field during winter torpor. Mean values

times higher, compared to the experimental groups exposed during incubation to direct magnetic field or alternating electromagnetic field of intensity by three orders of magnitude greater than that used in experiment I (Fig. 6). The development of eggs of *H. aspersa maxima* was especially negatively affected by direct magnetic fields of intensity of 5 µT to 10 µT; alternating electromagnetic fields of analogous intensity and frequency of 50 Hz were less deleterious. It should be borne in mind that intensity of direct field of 5 µT did not cause a decrease in the hatching success of *H. aspersa aspersa* compared to the control group. The survival rate of 1 month old hatchlings of *H. aspersa maxima* increased, compared to the control group, with increasing intensity of direct magnetic field to which the eggs were exposed during incubation. However, the greatest survival rate was observed in groups exposed to alternating field during incubation. It suggested that the direct magnetic field exerted an earlier selection effect, removing weaker genotypes already during embryonic development. No statistically significant effect of magnetic field on the eggs of *H. aspersa aspersa,* or its later survival rate, was observed. In both subspecies of *H. aspersa*, adults from eggs exposed to the respective experimental fields, in the case of direct field had a greater mean body mass; in the case of alternating fields the body mass was smaller compared to the control groups (Fig. 7), but the differences were mostly statistically insignificant. In the case of *H. aspersa maxima* the mean body mass of particular experimental groups was determined not by the growth rate which was the greatest

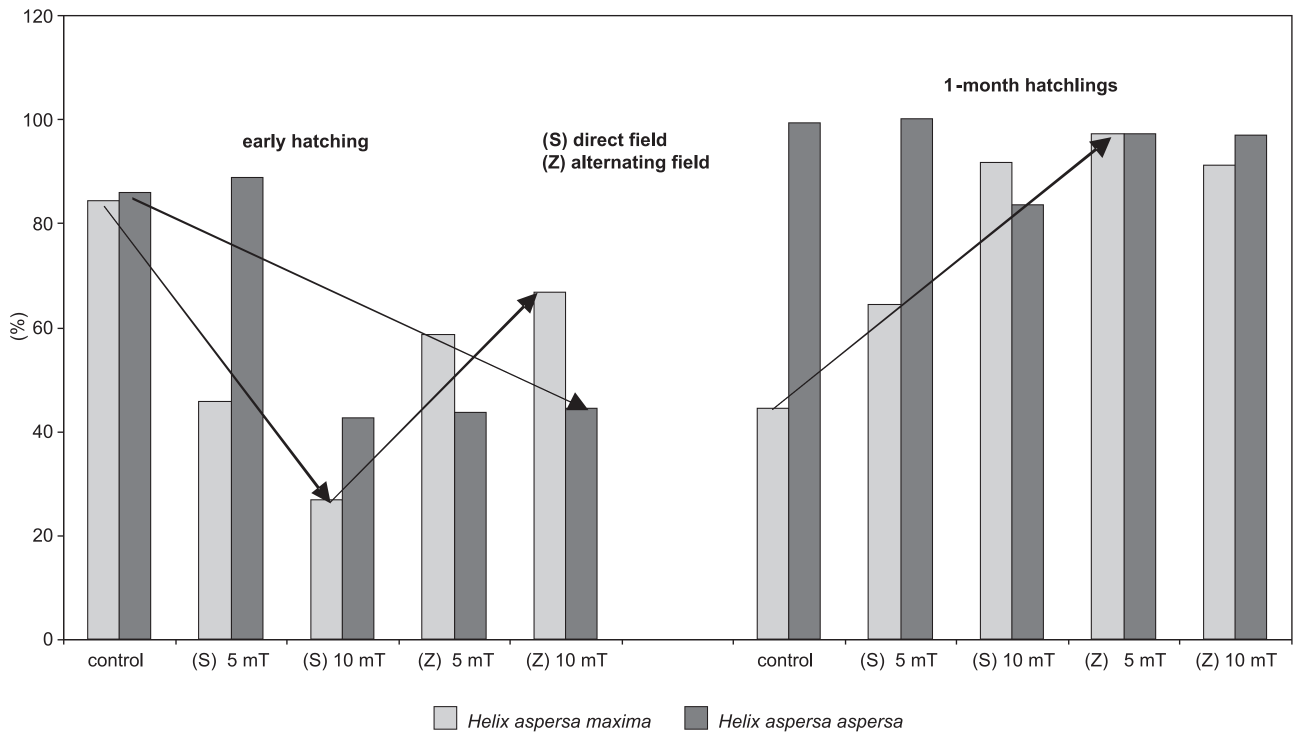


Fig. 6. Percent of early hatching from egg batches of *Helix aspersa* exposed to direct magnetic field and alternating electromagnetic field and percent of survival of hatchlings in relation to early hatchlings. Mean values

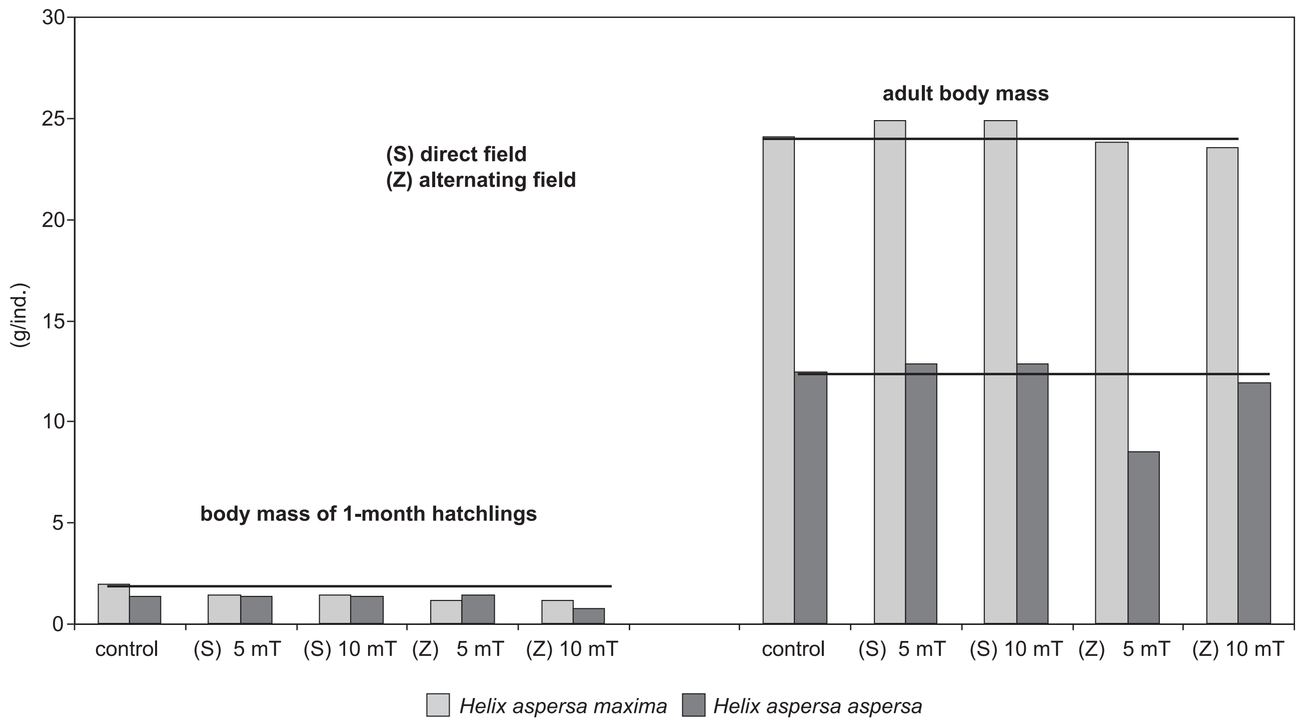


Fig. 7. Body mass of *Helix aspersa* hatched from eggs exposed to direct magnetic field and alternating electromagnetic field. Mean values

in snails hatched from eggs exposed to alternating field (Fig. 8), but the mean body mass of 1 month old hatchlings was slightly but not significantly higher in experimental groups exposed to direct field (Fig. 7). The control group of this subspecies, despite the greatest mean body mass of 1 month old juveniles compared to the experimental groups ($P<0.05$) (Fig. 7), showed a slower growth rate than the hatchlings of *H. aspersa maxima* from groups hatched from eggs exposed to the experimental fields.

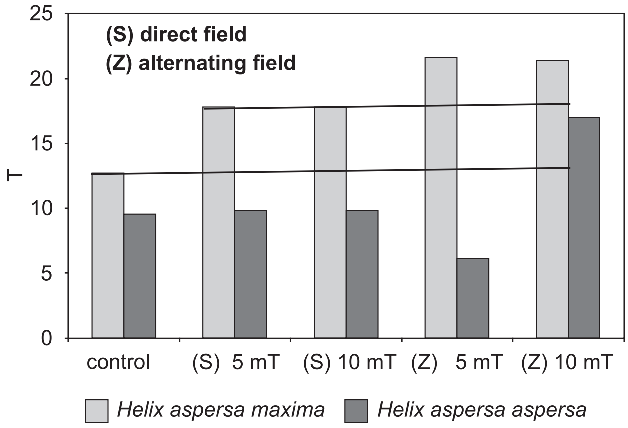


Fig. 8. Body mass increment (expressed as times body mass of 6-week hatchlings) of adult *Helix aspersa* hatched from eggs exposed to direct magnetic field and alternating electromagnetic field. Mean values

## DISCUSSION

The results show that the effect of the magnetic and electromagnetic fields used in the experiments varies not only depending on the stage of life cycle of *H. aspersa*; the reactions differ between the two subspecies: *H. aspersa maxima* and *H. aspersa aspersa*. The reaction of the two subspecies to particular parameters of the experimental fields is shown in Tables 3 and 4. Exposure of hibernating adults to such fields has a largely positive effect on further phases of life and reproductive cycle of *H. aspersa maxima* compared to the control groups. In the case of the respective experimental groups of *H. aspersa aspersa* the effect is mainly negative or none (Table 3). Direct exposure of eggs of the two subspecies to direct magnetic field or alternating electromagnetic field of 5–10 µT has a negative effect compared to the control group,

Table 3. Experiment I: reaction of experimental groups of mature *Helix aspersa* to electromagnetic field compared to control group: + values higher than in control groups for all experimental fields, (+) values higher than in control group for specified induction values of the field, – values lower than in control group for all experimental fields, (–) values lower than in control field for specified induction values of the field, 0 no statistically significant difference or trend of changes compared to control group

| Life cycle parameter | Magnetic field | Subspecies | Reaction |
|---|---|---|---|
| Physical condition of mature snails (body mass, growth rate) | 50–200 µT | *maxima* | + |
| | 50 Hz | *aspersa* | 0 |
| | 175 µT | *maxima* | + |
| | 10–1000 Hz | *aspersa* | 0 |
| Survival rate of mature snails during torpor | 50–200 µT | *maxima* | – |
| | 50 Hz | *aspersa* | + |
| | 175 µT | *maxima* | – |
| | 10–1000 Hz | *aspersa* | + |
| Survival rate of mature snails during reproduction | 50–200 µT | *maxima* | – |
| | 50 Hz | *aspersa* | – |
| | 175 µT | *maxima* | – |
| | 10–1000 Hz | *aspersa* | – |
| Mean mass of egg in batch | 50–200 µT | *maxima* | + |
| | 50 Hz | *aspersa* | (+) |
| | 175 µT | *maxima* | + |
| | 10–1000 Hz | *aspersa* | – |
| Mean percent of hatching from batch | 50–200 µT | *maxima* | + |
| | 50 Hz | *aspersa* | – |
| | 175 µT | *maxima* | + |
| | 10–1000 Hz | *aspersa* | 0 |

Table 4. Experiment II: Effect of exposing egg batches of *Helix aspersa* to direct magnetic and alternating electromagnetic fields on various development stages of hatchlings, compared to control group. For explanations see Table 3.

| Life cycle parameter | Magnetic field | Subspecies | Reaction |
|---|---|---|---|
| Mean percent of hatching from batch | Direct | *maxima* | – |
| | 5–10 μT | *aspersa* | (–) |
| | Alternating | *maxima* | – |
| | 5–10 μT 50Hz | *aspersa* | – |
| Mean survival rate of one month juveniles | Direct | *maxima* | – |
| | 5–10 μT | *aspersa* | + |
| | Alternating | *maxima* | 0 |
| | 5–10 μT 50Hz | *aspersa* | + |
| Growth rate of juveniles (multiplication factor of body mass increment till maturity) | Direct | *maxima* | + |
| | 5–10 μT | *aspersa* | (–) |
| | Alternating | *maxima* | + |
| | 5–10 μT 50Hz | *aspersa* | 0 |
| Body mass of mature snails raised from experimental eggs | Direct | *maxima* | + |
| | 5–10 μT | *aspersa* | + |
| | Alternating | *maxima* | – |
| | 5–10 μT 50Hz | *aspersa* | – |

but the effect on further development varies with the parameters of the field (Table 4). Generally, the effect of alternating field on the survival rate and growth rate of *H. aspersa* is positive or neutral, while the influence of direct field is more negative compared to the control group. Adults of both subspecies hatched from the eggs exposed to direct magnetic field have a greater mean body mass (positive effect) compared to the control groups than the snails hatched from the eggs exposed to alternating field (negative effect). It should be pointed out that the differences are not statistically significant, and only a tendency is observed. The reaction of experimental groups of *H. aspersa* exposed to magnetic and electromagnetic fields of different physical parameters could be affected by genetic differences between the two subspecies, affecting in turn their phenotypic and physiological characters (CHEVALIER 1977, ALBUQUERQUE 1984a, b, DUPONT-NIVET et al. 1997a, b, GOMOT 1998) which evolved in different latitudes (GUILLER et al. 1994). The studied population of *H. aspersa maxima* is of Mediterranean origin (northern Africa – the Atlas foothills) while the population of *H. aspersa aspersa* comes from the Atlantic region of France. It is also possible that natural populations of the two subspecies have evolved in areas with different characteristics of their local geomagnetic fields as a result of different geological structure of the bedrock, but this conjecture requires further studies. The differences in the response to the experimental conditions could also be affected by the fact that farmed *H. aspersa aspersa* reach maturity on average by 4–5 weeks earlier than *H. aspersa maxima,* as well as by the differences in some shell characters, depending on microclimatic conditions (LIGASZEWSKI et al. 2009). The results indicate that adult *H. aspersa maxima* react to the parameters of experimental fields more strongly than *H. aspersa aspersa.* The reaction of the two subspecies to exposure of their eggs to direct magnetic field or alternating electromagnetic field is more uniform. Probably, direct field more than alternating field exerts a selection effect on weaker genotypes at the embryonic stage, resulting in adults with the mean body mass exceeding that in control groups. The conjecture is supported by the studies on fish eggs in which magnetic field, depending on its characteristics, exerted varied effect on the development of cardiac muscles of the embryos at various stages of embryogenesis; these muscles are responsible for later motive function of the organ (HARARY 1962, SMITH & BERNDT 1964, BLOOM 1970, FORMICKI & WINNICKI 1996, FORMICKI et al. 1997, 2001, 2002, 2004b, WINNICKI et al. 2004). This study should be regarded as a preliminary attempt at an estimate of the effect of magnetic field on the farming results of *H. aspersa,* because of the necessity of further modification of the applied fields which should yield more statistically significant data.

## ACKNOWLEDGEMENTS

The study was a part of the project "The effect of parameters of magnetic field on the reproduction and growth of edible snails of the genus *Helix*", No. 2 PO4G 096 29.

## REFERENCES


ALBUQUERQUE DE MATOS R. M. 1984a. Genetics of shell ground colour in *Helix aspersa*. I. Colour locus, uniform and their interaction. Heredity 53: 11–20.

ALBUQUERQUE DE MATOS R. M. 1984b. Genetics of shell ground colour in *Helix aspersa*. II. Albino, its mutations and interactions. Heredity 53: 21–35.

BLOOM S. 1970. Spontaneous rhythmic contraction of separated heart cells. Science 167: 1727–1729.

CHEVALLIER H. 1977. La variabilite de l'Escargot Petit-Gris *Helix aspersa* Müller. Bull. Mus. Nat. Hist. Nat., Zool. 341: 425–436.

DUPONT-NIVET M., GUILLER A., BONNET J.-C. 1997a. Genetic and environmental variability of adult size in some stocks of the edible snail, *Helix aspersa*. J. Zool. 241: 757–765.

DUPONT-NIVET M., MALLARD J., BONNET J.-C., BLANC J. M. 1997b. Quantitative genetics of growth traits in the edible snail, *Helix aspersa* Müller. Genet. Sel. Evol. 29: 571–587.

FORMICKI K., BONISŁAWSKA M., JASIŃSKI M. 1997. Spatial orientation of trout (*Salmo trutta* L.) and rainbow trout (*Oncorhynchus mykiss* Walb.) embryos in natural and artificial magnetic field. Acta Ichthyol. Piscat. 27: 29–40.

FORMICKI K., PERKOWSKI T. 1998. The effect of a magnetic field on the gas exchange in rainbow trout *Oncorhynchus mykiss* embryos (Salmonidae). Italian J. Zool. 65 (Suppl.): 475–477.

FORMICKI K., SADOWSKI M., TAŃSKI A., KORZELECKA-ORKISZ A., WINNICKI A. 2004b. Behaviour of trout (*Salmo trutta* L.) larvae and fry in a constant magnetic field. J. Appl. Ichthyol. 20: 290–294.

FORMICKI K., TAŃSKI A., SADOWSKI M. 2004a. Effects of magnetic field on fyke net performance. J. Appl. Ichthyol. 20: 402–406.

FORMICKI K., TAŃSKI A., SOBOCIŃSKI A. 2001. A directional response of fish to changes in magnetic field in natural environment. Abstracts Tenth European Congress of Ichthyology, Prague, Czech Republic, 3–7 September 2001: 119.

FORMICKI K., TAŃSKI A., WINNICKI A. 2002. Ukierunkowanie przestrzenne rozwijających się zarodków ryb w polu magnetycznym. Abstracts 28th Symposium of the Polish Society of Histo- and Cytochemists and the 3rd Polish Conference of the Developmental Biology Society, Międzyzdroje, 4–7 September 2002: 42.

FORMICKI K., WINNICKI A. 1996. Effects of constant magnetic field on cardiac muscle activity in fish embryos. Publicaciones Especiales Instituto Espanol De Oceanografia 21: 287–292.

GOMOT A. 1998. Biochemical composition of *Helix aspersa*: Influence of genetic and physiological factors. J. Moll. Stud. 64: 173–181.

GUILLER A., MADEC L., DAGUZAN J. 1994. Geographical pattern of differentiation in the landsnail *Helix aspersa* Müller (Gastropoda pulmonata). J. Moll. Stud. 60: 205–221.

HARARY I. 1962. Heart cells in vitro. Scientific American 206: 141–152.

LIGASZEWSKI M., SURÓWKA K., STEKLA J. 2009. The shell features of *Cornu aspersum* (synonym *Helix aspersa*) and *Helix pomatia*: Characteristic and comparison. Amer. Malac. Bull. 27: 173–181.

ŁYSAK A., LIGASZEWSKI M., MACH-PALUSZKIEWICZ Z. 2008. Wpływ pola magnetycznego o różnych parametrach natężenia i częstotliwości na hodowlane populacje ślimaków *Helix aspersa maxima* i *Helix aspersa aspersa*. Streszczenia, XXIV Krajowe Seminarium Malakologiczne. Gdańsk–Gdynia, 2–4 kwietnia 2008: 39.

PERKOWSKI T., FORMICKI K. 1997. Effects of constant magnetic fields on respiration of rainbow trout (*Oncorhynchus mykiss* Walb.) embryos. Acta Ichthiol. Piscat. 27: 41–56.

SMITH T. E. JR., BERNDT W. O. 1964. The establishment of beating myocardial cells in longterm culture in fluid medium. Exp. Cell Res. 36: 179 – 191.

WINNICKI A., KORZELECKA-ORKISZ A., SOBOCIŃSKI A., TAŃSKI A., FORMICKI K. 2004. Effects of the magnetic field on different forms of embryonic locomotor activity of Northern pike, *Esox lucius* L. Acta Ichthyol. Piscat. 34: 193–203.


*Received: October 6th, 2009*
*Accepted: November 24th, 2010*