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Damage to diving beetles (Dytiscidae) from willow traps in Lipetsk oblast (Russia) and features of *Cybister lateralimarginalis* and *Dytiscus circumcinctus* populations in winter

Ущерб для плавунцов (Dytiscidae) от использования кошар в Липецкой области и особенности популяций *Cybister lateralimarginalis* и *Dytiscus circumcinctus* в зимний период

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KEY WORDS: Dytiscidae, *Dytiscus*, *Cybister*, overwintering population, sex ratio, femail morphs, damage.

КЛЮЧЕВЫЕ СЛОВА: Dytiscidae, *Dytiscus*, *Cybister*, зимующие популяции, соотношение полов, морфы самок, ущерб.

ABSTRACT. The amount of damage from the use of willow traps for Dytiscinae in the oxbow lake in Lipetsk Oblast was 400 g/trap-day. The sex ratio (♂/♀) in the winter was 0.60 for *Cybister lateralimarginalis* and 1.73 for *Dytiscus circumcinctus*. The average biomass of *C. lateralimarginalis* females was significantly higher than in males, there were no significant differences for *D. circumcinctus*. The number of reticulate females in comparison with smooth ones was an order larger in the population of *C. lateralimarginalis*, and only 1.6 times larger in *D. circumcinctus*. Probably, the predominance of reticulate females in the *C. lateralimarginalis* population, in comparison with *Dytiscus*, is one of the mechanisms that ensure the expansion of the species range to the north.

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РЕЗЮМЕ. Величина ущерба от использования кошар для Dytiscinae в пойменном озере в Липецкой области составила 400 г/ловушко-сутки. Соотношение полов (♂/♀) в зимний период было 0.60 для *Cybister lateralimarginalis* и 1.73 для *Dytiscus circumcinctus*. Средняя биомасса самок *C. lateralimarginalis* была достоверно выше, чем у самцов, для *D. circumcinctus* достоверных различий не выявлено. Число шагренированных самок по сравнению с гладкими было на порядок больше в популяции *C. lateralimarginalis*, и в 1.6 раз превосходило у *D. circumcinctus*. Возможно, большая доля шагренированных самок в популяции *C. lateralimarginalis*, по сравнению с *Dytiscus*, — одни из механизмов, обеспечивающих расширение ареала вида на север.

Introduction

Willow traps [Russian "koshura"] standing in ice-holes (Fig. 1), are traditionally used in Lipetsk Oblast by fishermen for catching the European weather loach *Misgurnus fossils* (L.) in late winter in oxbow lakes, when oxygen levels in the water are especially low. Many other animals, such as the American mink *Neovison vison* (Schreber), midetteranean water shrew *Neomys anomalus* Cabrera, water scorpions (*Nepa cinerea* L.) and diving beetles, usually fall into those traps attracted by the available oxygen or food. Fishermen shake out these "unnecessary" animals onto the ice as they collect loach from the traps, dooming still living specimens to death from the cold (Figs 2–4).

Estimation the sex ratio, weight and ratio of the females morphs in the samples from the ice made it possible to study the population characteristics of mass species of Dytiscidae in winter season.

Material and methods

Alexander I. Zemlyanukhin studied the damage done by such traps on 17–21 February 2017 in the oxbow lake

Treshchevka in the Voronezh River floodplain, Lipetsk Oblast, 52°16'56" N 39°26'07"E. Three traps on this lake were checked by fishermen twice, on February 19th and 21st. Thus, 12 trap-days were studied.

Four species of Dytiscidae have been recorded: *Colymbetes paykulli* Erichson, 1837, *Cybister lateralimarginalis* (De Geer, 1774), *Dytiscus circumcinctus* Ahrens, 1811 and *D. marginalis* Linnaeus, 1758. Only *Cybister* and *Dytiscus* species were collected and transferred to A. Prokin for studying. Each specimen was weighed on a torsion balance with a precision of 5 mg; the sex and the morph of dimorphic females were recorded.

The specimens are deposited in the collection of the first author in Papanin Institute for Biology of Inland Waters, Borok.

Since the biomass data were normally distributed (Shapiro-Wilk test), the average values in each of the groups were compared by two-way t-test. Logistic regression was used for comparing total number in groups and to construct the models of dependence total number in groups from biomass. All statistical analysis was performed using environment for statistical computing R. In the Tables after + the values of SE are given.

The initial data set and R code can be downloaded here: www.ibiw.ru/upload/staff/267/dytiscidae.zip.

Table 1. Total biomass of Dytiscinae species, mg.
Таблица 1. Общая биомасса представителей Dytiscinae, мг.

Dates	*C. lateralimarginalis*	*D. circumcinctus*	*Dytiscus marginalis*
17–19.02.2017	1079595	296835	—
19–21.02.2017	2172250	1219015	32125
Total	3251845	1515850	32125
	4799820		

Results

A total of 405 specimens were collected near the traps: 67.9% *C. lateralimarginalis*, 32.3% *Dytiscus circumcinctus* and 0.8% *D. marginalis*. The total wet biomass of dead Dytiscinae was about 5 kg (Table 1), in recalculation to one trap-day, the magnitude of the damage was 399,985 mg.

The sex ratio ♂/♀ was 0.60 in *C. lateralimarginalis* and 1.73 in *D. circumcinctus* (Table 2). The average biomasses of *Cybister lateralimarginalis* males (11,300 mg) and females (12,562 mg) (Table 2) were significantly different (t = 7.587, d.f. = 265, $p < 0.001$). The

Figs 1–4. 1 — Willow traps or "koshura"; 2 — European weather loaches, American mink and diving beetles shaken out of a willow trap; 3 — A.I. Zemlyanukhin collecting diving beetles from the ice; 4 — diving beetles around the ice-hole.

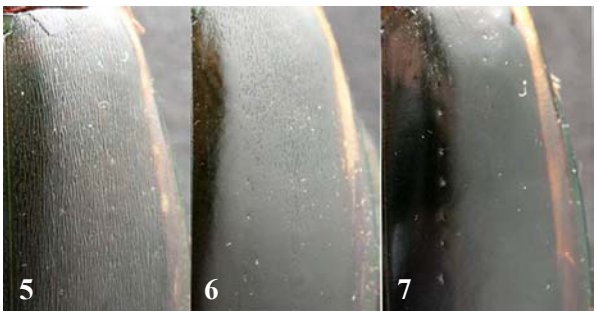
Рис. 1–4. 1 — кошары; 2 — обыкновенный вьюн, американская норка и плавунцы, выброшенные на лёд из кошары; 3 — А.И. Землянухин собирает плавунцов со льда; 4 — плавунцы вокруг лунки.

Table 2. The number of specimens and biomass (*B*) of Dytiscinae species sexes.
Таблица 2. Число экземпляров и биомасса (*B*) полов видов Dytiscinae.

	Cybister lateralimarginalis		*Dytiscus circumcinctus*		*Dytiscus marginalis*	
	♂	♀	♂	♀	♂	♀
number, ex.	102	169	83	48	2	1
B min, mg	7040	8935	9845	9235	9365	10965
B max, mg	13445	16960	13600	13655	11795	
B average, mg	11300 ±106	12563 ± 128	11851 ±102	11576 ±170	10580 ±1,215	

Table 3. Number of specimens and biomass (*B*) of female morphs of *C. lateralimarginalis* and *D. circumcinctus*.
Таблица 3. Число экземпляров и биомасса (*B*) морф самок *C. lateralimarginalis* и *D. circumcinctus*.

♀♀	*Cybister lateralimarginalis*		*Dytiscus circumcinctus*	
	reticulate (striated)	smooth	sulcate	smooth
number, ex.	156	15	30	19
B min, mg	8935	9240	9235	9540
B max, mg	16960	14330	13655	13550
B average, mg	12598 ±135	12370 ±358	11727 ±207	11332 ±292



Figs 5–7. Female morphs of *Cybister lateralimarginalis*: 5 — reticulate, 6 — semi-reticulate, 7 — smooth.
Рис. 5–7. Морфы самок *Cybister lateralimarginalis*: 5 — шагренированная, 6 — полу-шагренированная, 7 — гладкая.

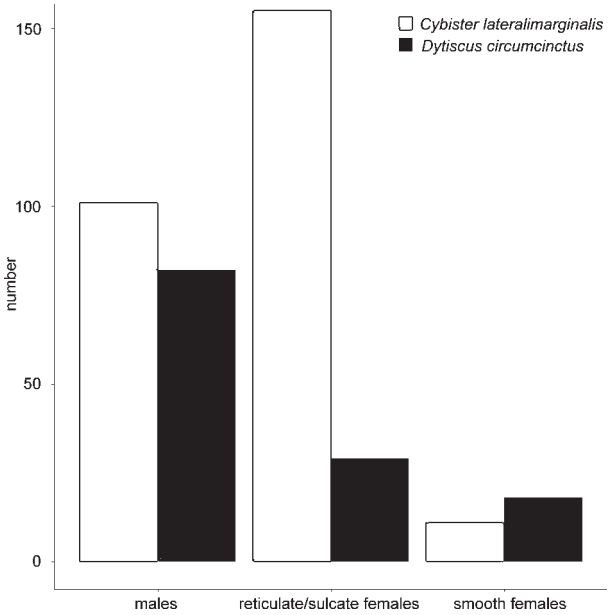


Fig. 8. Number of specimens of males and female morphs in *C. lateralimarginalis* and *D. circumcinctus*.
Рис. 8. Число экземпляров самцов и морф самок *C. lateralimarginalis* и *D. circumcinctus*.

average biomasses of *Dytiscus circumcinctus* males (11,851 mg) and females (11,576 mg) (Table 2) were not significantly different ($t = 1.39$, d.f. = 79, $p = 0.17$).

The total number of reticulate (striated) females was about ten times as great as that of smooth ones in *C. lateralimarginalis*, and the number of sulcate females was only 1.6 times as great as that of smooth in *D. circumcinctus* (Table 3, Fig. 8). Thirteen "semi-reticulate" (Figs 5–7) females of *C. lateralimarginalis* with partly modified elytral surface were recorded and provisionally counted together with the "reticulate" morph.

The average biomass of females with smooth and modified surface of elytra were not significantly different in either species (*C. lateralimarginalis*, $t = 0.59$, d.f. = 13, $p = 0.56$; *D. circumcinctus*, $t = 1.1$, d.f. = 33, $p = 0.28$).

The numbers of male and female specimens in *Cybister lateralimarginalis* were different ($z = -4.04$, $p < 0.001$) and depended on biomass ($z = -6.15$, $p < 0.001$). The numbers of reticulate and smooth females were also different ($z = -8.58$, $p < 0.001$), but it did not depend on biomass ($z = -0.97$, $p = 0.33$). The numbers of male and female specimens in *Dytiscus circumcinctus* was different ($z = 3.04$, $p = 0.002$) and did not depend on biomass ($z = 1.47$, $p = 0.23$). The numbers of ribbed and smooth females did not differ significantly ($z = -1.59$, $p = 0.11$).

Discussion

It is well known that female dorsal surface modifications and suction cups of the male fore legs represent a pronounced co-evolutionary pattern with an "arms race" evolutionary trend in diving beetles [Bergsten et al., 2001; Bergsten, Miller, 2007; etc.]. Females with modified dorsal sculpture are more successful than smooth females in dislodging harassing males that can kill the females by hypoxia resulting from multiple mating and

therefore such females are usually more abundant in natural populations [Bergsten, Miller, 2007].

Therefore, it can be expected that in species with equal biomass of both sexes (such as *D. circumcinctus*) modified females should be more abundant than those with heavier females (*C. lateralimarginalis*). However, we observe the exact opposite: modified females occurred five times as often in *Cybister* as in the *Dytiscus*. The reason of this pattern is probably associated with the more evolutionarily advanced structure of the male palette in *Cybister*, in which it is concave and equipped with smaller and more numerous adhesive cups, compared to *Dytiscus*. This opinion is supported by Nilsson [1986] and Aiken and Khan [1992], who noted that smaller and more numerous discs could be more advantageous for adhesion to a modified (granulate, wrinkled or striated) surface.

The native (primary) range of *C. lateralimarginalis* includes Middle and Southern Europe, North Africa, Western and Central Asia, Mongolia, China, Northern India [Ghosh, Nilsson, 2012; Nilsson, Hájek, 2015]. At present time an expansion of the range of the species to the north are observed.

The most northern record of *Cybister lateralimarginalis* De Geer, 1774 in Russia is known from the Leningrad Oblast': 60.792°N 30.369°E [Litovkin, Sazhnev, 2016]. This record, like the previous ones for the north of the European Russia from Tver and Moscow Oblast's, Chuvashia and Tatarstan [Litovkin, 2012; Petrov, Fedorova, 2013; Petrov et al., 2013] is based on finding adults. The old record for the border area with Finland [Hellen, 1929] is considered doubtful [Kalniò□, 1999]. New record based on the finding of larva in Pskov Oblast' [Prokin, Cherevichko, 2017], confirms the naturalization of the species in the north of the European part of Russia.

In Western Europe, the northern border of the range extends across Denmark, southern Sweden and Latvia [Nilsson, Holmen, 1995; Kalniņš, 1999]. Eastwards in Russia the species is known from the Urals in the Chelyabinsk Oblast' [Litovkin, 2012].

Probably, the structure of the overwintering population of *Cybister* with the predominance of reticulate females, provides this species certain competitive advantages, in comparison with *Dytiscus*, and therefore make possible to expand a native range to the north.

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