Czech University of Life Sciences Prague

Faculty of Forestry and Wood Sciences

Effect of stream and bank vegetation on Narrow-clawed crayfish (*Pontastacus leptodactylus*)

Bachelor thesis

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BACHELOR THESIS ASSIGNMENT

Andrey Ponomarenko

Forestry

Thesis title

Effect of stream and bank vegetation on Narrow-clawed crayfish (Pontastacus leptodactylus)

Objectives of thesis

The aim of the present thesis is the overview of the relationship of Narrow-clawed crayfish (Pontastacus leptodactylus) and both bank and submerged stream vegetation used as shelters, cover and food.

Methodology

The author will survey scientific publications focused on freshwater crayfish in general and particularly on Narrow-clawed crayfish (Pontastacus leptodactylus) and the relationship with vegetation cover.

The proposed extent of the thesis

30

Keywords

Crustaceans; Habitat; Shelter; Food; Preference

Recommended information sources

Holdich, D. M., & Lowery, R. S. (1988). Freshwater crayfish: biology, management and exploitation.
Kouba, A., Petrusek, A., & Kozák, P. (2014). Continental-wide distribution of crayfish species in Europe: update and maps. Knowledge and Management of Aquatic Ecosystems, 413, 05.
Kozák, P., Ďuriš, Z., Petrusek, A., Buřič, M., Horká, I., Kouba, A., ... & Němečková, K. (2015). Crayfish biology and culture. University of South Bohemia in České Budějovice, Faculty of Fisheries and Protection of Waters.
Souty-Grosset, C., Holdich, D., Noel, P., Reynolds, J. D., & Haffner, P. (2006). Atlas of crayfish in Europe (p. 188). Muséum national d'Histoire naturelle.

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Hereby I declare that I have written Bachelor thesis “Effect of stream and bank vegetation on Narrow-clawed crayfish (*Pontastacus leptodactylus*)” on my own under supervision of Ing. Jiří Patoka, Ph.D., DiS. and I have used only the sources which are marked in the bibliography.

I am aware that by releasing of this bachelor thesis I agree with its publication according to the law number 111/1998 Sb. about universities as amended regardless of the result of it’s defend.

In Prague, April 10th, 2018

Abstract

Freshwater crayfish (Decapoda: Astacidea) inhabit various waterbodies such as rivers, brooks, lakes, estuaries, floodplains, reservoirs, ponds, swamps, and caves. One of the most exploited crayfish species is Narrow-clawed crayfish, *Pontastacus leptodactylus*, from family Astacidae. This species is also endangered in the part of its native range. Surprisingly, its habitat requirements are poorly studied. Therefore, the presented Bachelor thesis summarizes our knowledge about biological and ecological requirements of this species and preferred habitat particularly with regard to associated vegetation (used as shelter, food source, and shadow). As a case of the vegetated environment inhabited by *P*. *leptodactylus* was chosen the Lagutnik river in the region of Rostov, a southern part of the Russian Federation. Important trees and plant species with their brief characteristics were described.

Based on the presented information, it is obvious that well vegetated habitats are important for *P*. *leptodactylus* and this might be of attention of wildlife managers, conservationists, fishermen and other stakeholders who want to repatriate, protect or culture this crayfish in the wild as well as in artificial reservoirs.

Keywords: Crustaceans; Habitat; Shelter; Food; Preference

Content

1 Introduction

The narrow-clawed crayfish *Pontastacus leptodactylus* is naturally and widely distributed in lakes, ponds and rivers throughout of all Europe and some parts of Asia. *Pontastacus leptodactylus* is a widespread species and can be found throughout all Europe, Turkey, Russia, and the Middle East. This species is found in both fresh and brackish waters, including lagoons, estuaries, as well as running freshwater rivers in the Ponto-Caspian Basin. Southern Russia native crayfish includes one crayfish species, *P*. *leptodactylus*. Only *P. leptodactylus* is commonly distributed in South Russian water resources. The ideal environment for living crayfish is a coastal reservoir line with shore, where both submerged and emerged plants grow well and tree roots creating shelters and conveniant environment of the water bottom, attractive for other aquatic species. Therefore, it is necessary to pursue research that will bring new solutions and streamline processes in forestry management related among others with conservation of mentioned crayfish, which is considered endangered. Species of interest by human and protected by conservationsts – knowledge about its habitat requirments is crucial – relationship with vegetation poorly studied – aim of this thesis is to summarize current information about this topic.

2 Goals of the thesis

1. Thesis is the overview of the relationship of Narrow-clawed crayfish (*Pontastacus leptodactylus*) and both bank and submerged stream vegetation used as shelters, cover and food with Rostov region as a case study.

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3 Literary review

3.1 Biological characteristics of crayfish

Scientific classification	
Kingdom:	Animalia
Phylum:	Arthropoda
Subphylum:	Crustacea
Class:	Malacostraca
Order:	Decapoda
Family:	Astacidae
Genus:	Pontastacus
Species:	*Pontastacus leptodactylus*

3.1.1 Morphology

Body length of narrow-clawed crayfish can reach 20 cm, colouration depends on the habitat from greenish - brownish to blue - brown (*Kozlov et al., 1998*).

The body consists from two main divisions (tagme): cephalothorax (Figure 1) and abdomen (pleon). Dorsal cephalothorax is covered by robust carapace bearing on the antennal end a sharp extension known as rostrum. There are some grooves on the the carapace surface: cross-seam neck and two longitudinal suturae known as gill grooves. The lateral sides of the carapace cover gill cavities. The last abdominal segment is terminated by a tail fan (telson and uropodes).

Starobogatov (*1995*) noted that below rostrum are two pairs of sensory appendages: antennae I and antennae II, and compound eyes on movable eyestalks. Mouthparts consist of six pairs of limbs: mandibles (upper jaw), two pairs of maxillae (lower jaw), and three pairs of maxillipeds (*Starobogatov, 1995*).

Abdomen, as well as in other decapod crustaceans, is composed of eight segments and carries eight pairs of legs (pleopods). Cephalothorax bears three pairs associated with the mouthparts (maxillipeds), and five pairs of long legs (pereiopods). The first pair of pereiopods is known as chelipeds. Chelipeds bear robust claws, which are larger in males. The other four have function as walking legs; the first two pairs bear small claws used for body cleaning and catching food. Thoracic legs reach with their extensions (epipodites) modified to gills into the cavity under the lateral carapace *(Kozlov et al., 1998)*.

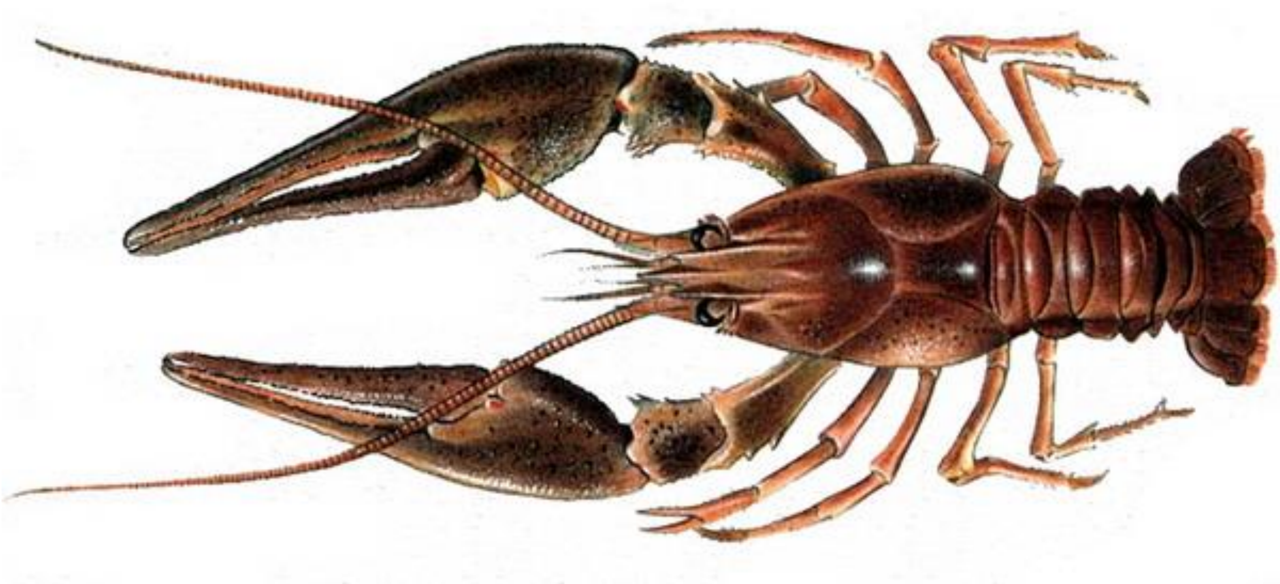


Figure 1 - Pontastacus leptodactylus, adult male (picture was taken from: http://novbu.ru/anapa/dlya-magazina/raki-zhivye-i-varenyerak_676006)

In adult females, this body part is wider than in males. The pleopods of the first segment in males are modified to copulatory legs (*Figure 2b*) and are reduced in females *(Harlioglu et al., 2017)*.

Crustacean integument consists from chitinized cuticle, which lies on the hypodermal layer of epithelium on a bazal membrane. Calcium and other content of carapace, which make it hard, are concentrated in peripheral cuticle layers. The inner layer consists of a soft and elastic chitin. Cuticle forms an exoskeleton (carapace). It protects the body against external influences being a place for the muscles adhesion. Musculature of crustaceans consists of a cross-striped fibers, forming a powerful muscle bundles. Exoskeleton prevents the growth. Therefore, crayfish periodically moult and change the carapace. In stomach, there is formed a pair of lens-shaped balls of calcium carbonate (gastroliths), which make the new carapace to be hard (*Huner et al., 1990*).

3.1.2 Anatomy

Crayfish stomach is divided into two sections: cardiac and pyloric. In the first one, food is grinded with inner chitin teeth, and the second includes filtering apparatus (pyloric mill). Large food particles are removed from the digestion, rest is passed through the filter and continues into the digestive gland, a complex system of midget protuberances, where the digestion and absorption happens. The undigested remnants are being ejected through the anal opening located on telson *(Guner, 2007)*.

Respiratory system includes gills: thin-plate or branched outgrowths of thoracic limbs (pereiopods) in branchial chambers laterally under the carapace (Figure 2a). The second maxilla is the appendage of the fifth head segment and it lies immediately anterior to the first maxilliped (Figure 2b). It generates a water current that pumps water out of the anterior end of the branchial chamber. In small crustacean, gills are absent *(Herrick, 1909)*.

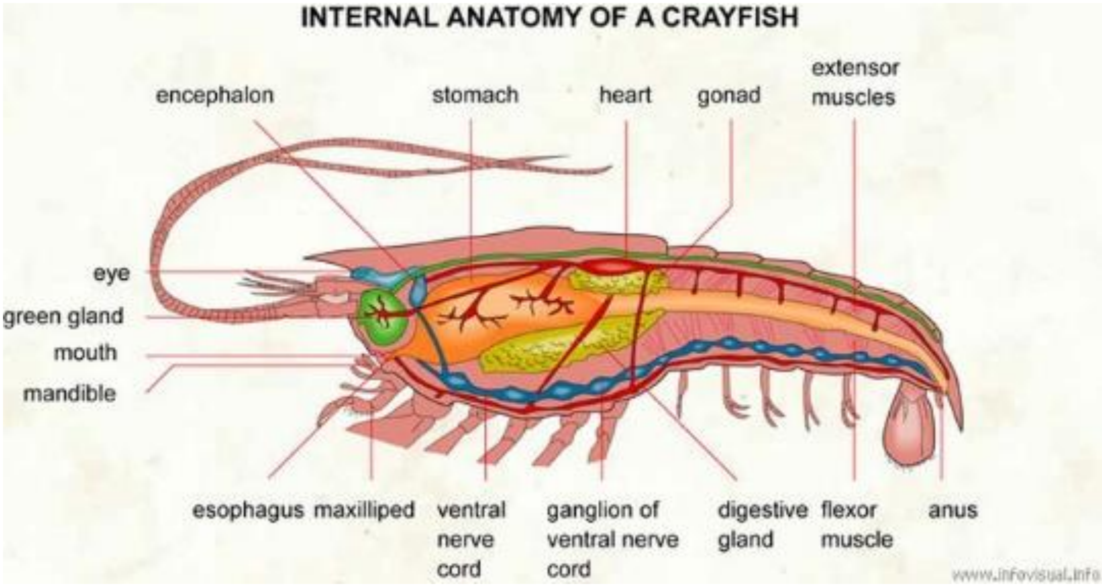


Figure 2a - The internal structure of the crayfish (picture was taken from: www.infovisual.info)

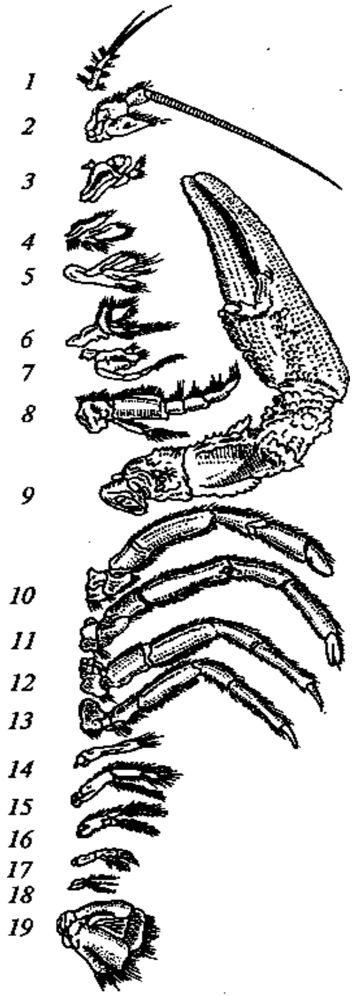


Figure 2b - Legs of the male crayfish: 1 - antennules; 2 - antenna; 3 - mandible; 4 - maxilla I; 5 - maxilla II; 6-8 - maxilliped; 9-13 - walking legs; 14-15 - copulatory apparatus; 16-18 - biarmous abdominal legs; 19 - uropod (picture was taken from: http://3w.su/zoology/83-348.html)

Excretory system is represented by a pair of green glands - secretory organs, modified metanephridia. Every organ composes of three parts: a terminal pouch (coelom portion) extending therefrom with glandular crimped channel walls and bladder. Bladders are opened at the base of antennae II as secretory pores (antennal gland) *(Naumov et al., 1979).* The circulatory system in crayfish is unclosed (Figure 3) *(Herrick, 1909).*

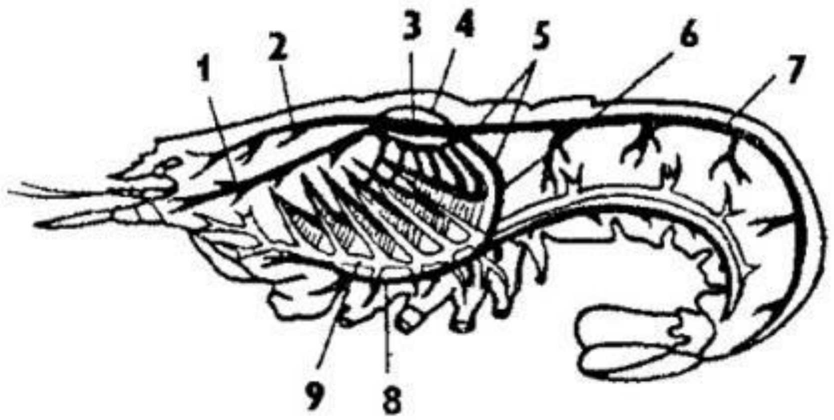
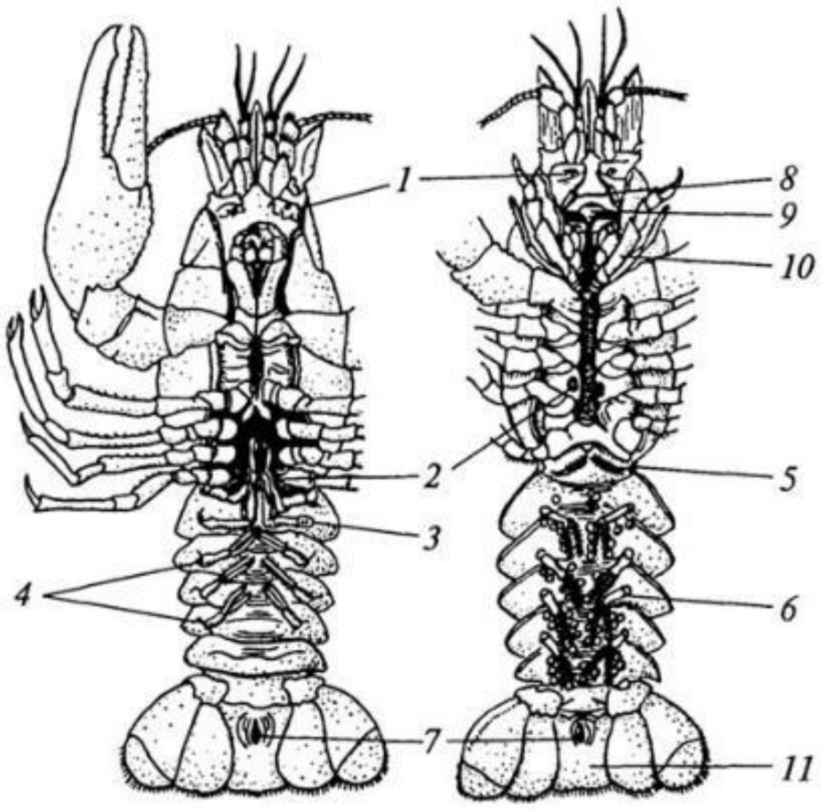


Figure 3 - Circulatory system of crayfish (by Gegenbauer): 1 - antennal artery; 2 - front aorta; 3 - heart; 4 - perikard; 5 - branchial efferent vessels; 6 - descending artery, 7 – posterior (abdominal) artery; 8 - subnerval artery; 9 - abdominal venous vessel;(picture was taken from: http://3w.su/zoology/83-348.html)

The nervous system comprises nerve ganglions and the ventral nerve cord *(Herrick, 1909)*.

3.1.3 Reproduction

Mating takes place either in the autumn (in temperate zone), or at early spring (February - March). In case of the Russian Federation, which is a large country, reproduction perioud depends on the region. Mating of Narrow-clawed crayfish (*P. leptodactylus*) occurs at a temperature of 6 to 8°C, spawning eggs at 4-6°C, Juveniles hatch at 20-21°C, foraging activity starts at 24-26°C *(Cherkashina, 2007).*



A **B**

Figure 4 - Crayfish (ventral view): A-*male;* B-*female; 1-lobe with the excretory opening; 2-genital opening; 3-first and second limbs abdominal male segments; 4-end of the third-fifth abdominal segments of the male; 5-rudimentary female abdominal first limb segment; 6-second limb - fifth abdominal segments of the female eggs; 7-anus; 8-exopod of first maxilliped; 9 -mouth opening (covered maxilla); 10-third pair maxillipeds; 11–telson (picture was taken from: https://otvet.mail.ru/question/12213374)*

The duration of mating is 15-20 days, fertilization is external. The male pursues the female and embracing her legs, pressed against the underside of the female abdomen and through sexual holes spermatophores in the internal reproductive organs of the female. One male can successively fertilize up to 4 females *(Alekhnovich et al., 2014).*

Figure 5 - Ovigerous female with attached eggs (picture was taken from: http://x-trail-club.ru/forums/topic/15022-vostochnyy-kazahstan-ozero-zaysan-mestechko-shakelmes-gory-kiin-kirish-marsianskaya-dolina/)

Crayfish eggs require continuous washing with oxygenated water, therefore, the gravid female frequently fan with abdominal legs where the eggs are attached. In calm water, especially when females stay in their burrows, oxygen level is low and products of metabolism are high. This is one of the reasons why eggs can be lost *(Kozlov et al., 1998).*

In southern areas (46-48° N), Narrow-clawed crayfish reaches maturity and commercial size (total body length = 9 cm) during 2 or 3 years, while in 3 or 4 years in northern areas. Absolute female fertility ranges from 260 to 420 eggs per female in the central part of the distribution range and naturally decreases southward (40° N) and northward (62° N) *(Alekhnovich et al., 2014)*.

3.1.4 Growth and moulting

The growth rate and development of crayfish is positively influenced by water temperature, its chemical parameters, amount and quality of food, as well as by the population density. Thus, the growth rate of crayfish in different waterbodies is different *(Deval, 2007)*.

Within the first year of life, the growth rate of males and females is almost identical. Within the second year, males are considerably bigger than females. By the end of first summer, crayfish reach a body length of over 2 cm, in second summer about 4 cm, and by the end of the third summer reach 5-6 cm or more (*Deval, 2007*). Males of Narrow-clawed crayfish reach 10 cm in total body length in age of 6-7 years, females about one year later (*Deval, 2007*).

In particular conditions favorable for growth and development (optimal water temperature and sufficient oxygen content, pH of the water, amount of food and some others), species can reach commercial size 1-2 years before the term. However, under not favourable conditions, growth rate of individuals slows down significally (*Ulikowski*, *2006)*.

Currently, there is no way to exactly determine the age of crayfish (methods of determining the age of fish are not applicable to crustaceans)(*Deval, 2007*). The lifespan of Narrow-clawed crayfish is usually 10 years – but individuals with age of 20 years were also described (*Kiyashko, 2016*).

Crayfish grow abruptly, usually with moulting - changing the old carapace. During this period, the entire body of the animal varies considerably: changing not only chitinous shell, but also the digestive system, the gills, eyes, etc. *(Taugbol et al, 1992).*

Kiyashko (2016) in the study *"Crayfish culturing in an artificial pond"* indicates that few days before moulting crayfish hide in its hole, but the process of moulting (ecdysis) extends in open water. Process of dropping of chitinous carapace lasts usually not more than 10 minutes, followed by hurry hiding in a hole. About 1-2 weeks it stays there until its new shell hardens. During this period, the crayfish does not come out even for feed (*Kiyashko, 2016*).

Crayfish moult only during the summer months. In the first year of life, crayfish moult 5-7 times, in the second year 3-4 times, in the third year 3 and in the fourth year only twice. Adult males tend to moult 1-2 times, and mature females once for the season. In more northern regions females moult once per two years *(Taugbol et al, 1992).*

3.2 Distribution

Native range of Narrow-clawed crayfish is highlighted in Figure 6. It must be noted that the north-eastern edge of the distribution is very uncertain. The hatched area covers regions where the species is considered widespread but information about specific localities are lacking. Narrow-clawed crayfish was considered widely present around the Caspian Sea, particularly in the eastern coastal areas, but present distribution requires updating (*Kouba et al., 2014*).

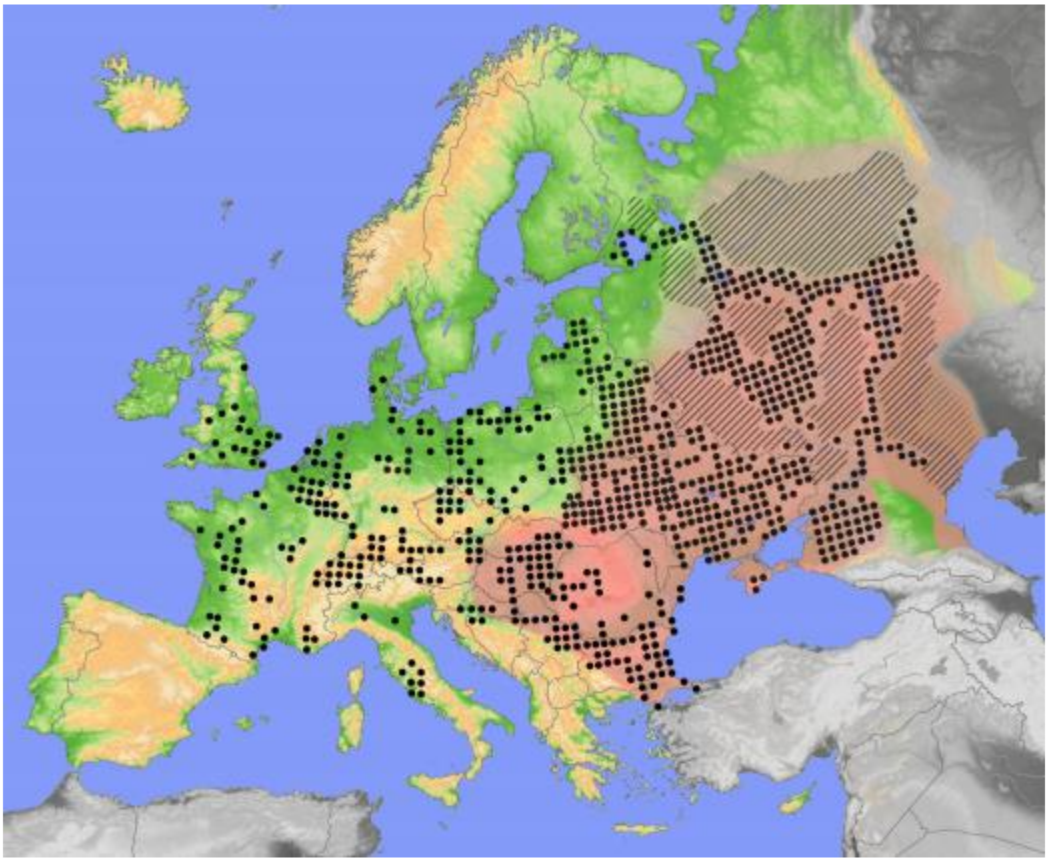


Figure 6 - Distribution of Pontastacus leptodactylus in Europe (picture was taken from: Kouba et al., 2014)

Within the former USSR, crayfish *P. leptodactylus* presence was recorded in the waters of the Caspian basin, the Black and Azov Seas, the Caspian and Azov Seas, as well as Western Siberia rivers and lakes.The latitudinal direction it extends from 45°E - Omsk region to the Atlantic coast of Europe. This species was introduced in Western and Central Europe in 20th century. The southern boundary of the range of this species extends 40° N (Caspian Sea, Turkey). The northern boundary of the main range *P. leptodactylus* corresponds to 57° N (Latvia, Yaroslavl, Tobolsk). However, some populations are found in more northern waters *(Fedotov, 2002).*

3.3 Culture and capture

Pontastacus leptodactylus has a high commercial value and it is especially popular as a food item in the southern part of European Russia (estimated consumption is 0.4 kg of crayfish per person per year) and the Ukraine. In 1940 in the former USSR annual yield of crayfish was 1712 tonnes and in Ukrainian SSR 120 tonnes. In the Ukraine in 1971 the annual yield was approximately 650 tonnes. There is still an abundant and exploited harvest in the Caspian Sea and in many water bodies and rivers of countries bordering the Ponto-Caspian basin. In the Astrakhan region it is estimated that the harvest is 70-110 tonnes per year *(Fedotov, 2002)*. Off the Kazakhstan shore of the Caspian Sea there are considerable crayfish resources of *P. leptodactylus*, as well as in the Bukhtarma and Shulbin reservoirs, and in some other water bodies. During the first eight months of 2003, only 1.1 tonnes of crayfish were harvested from these two reservoirs, while the maximum sustainable yield is estimated at 100 tonnes per year. In the Upper Volga River (Russia), a total yield of 5-10 tonnes was recorded for the period 1977-1980, which is 2-5% of the total catch in the whole of the Volga region. In the Karelia region potential resources of crayfish are estimated at 22 tonnes per year. However, pollution seems to have had an impact on some Russian resources, e.g. the biomass of *P. leptodactylus* in the waterbodies of the lower Don amounts to 140 tonnes. It has decreased 4 times compared to the 1980s; in polluted waterbodies the biomass has dropped 17 times, with the catches coming to only 23-25 tonnes. Crayfish in Russia and Ukraine are also used as the raw material for production of chitosan used in medicine *(Fedotov, 2002).*

Figure 7 - Live crayfish trade in Russia (photo was taken from: www.lemur59.ru)

3.4 Ecology of Narrow-clawed crayfish

3.4.1 Environmental requirements

Narrow-clawed crayfish live in fresh and clean water such as rivers, lakes, ponds, or the rapid flow streams with depth of 3-5 m and with troughs to 7-12 m. In summer water should be warmed to 16-22 °C. Narrow-clawed crayfish is relatively thermophilic: optimal growth temperature is 22-25 °C, the upper limit of temperature is 32 °C. The light regime for Narrow-clawed crayfish is indiferent, it is able to maintain the activity of any daytime (*Udalova, 2012)*.

For Narrow-clawed crayfish, critical pH value for its vital activity is considered 4.6 - 4.7, because at this value of output of Ca^{2+} exceeds their rate of absorption gill epithelial cells from crayfish body. Thus, it can be assumed that Narrow-clawed crayfish in vivo can withstand slightly acidic and neutral active reaction medium (*Udalova, 2012)*.

3.4.2 Habitat

Crayfish prefers a sufficiently dense bottom (sand or clay) with the presence of calcareous rocks, stones and ponds with normal or high salinity of water. If this is not a big lake near the river in your garden, the ground near the bank should be such that they could be able to conveniently construct burrows (they also may be under stones, roots, stumps). Most often, crayfish build its burrows on steep shady shores, where there is little of sunlight pesent. For example, in the Krasnodar region it is necessarily the reeds, where the banks are grown by salix, alnus, populus. Size of the shelter (in average) length - from 10 to 40 cm, width 5-20 cm height - from 3 to 18 cm. In winter holes and shelters are located at the bottom, and in summer - closer to shore, depends on temperature *(Kujawa, 2008).* The presence of dense soils for narrow-clawed - not a requirement of habitat in the pond.

Webber (1976) mentioned that the possible habitat of Narrow-clawed crayfish in reservoirs with muddy bottoms is possible, therefore relatively low dense distribution over the pond bottom. For narrow-clawed crayfish construction of burrows are not necessarily because as a shelter it can use terrain bumps the bottom, the roots of plants.

Crayfish dig their burrows with the help of the legs and tail, resting on the front claws. Tails of crayfish are being used not only for digging holes, but also for swimming. It is very rare that crayfish leaves pools of contaminated water and move on land, that can happen only with purpose of finding better pond to live. In water with an acidic reaction, they usually are not able to survive. The optimum amount of dissolved oxygen in water for crayfish is 7 to 8 mg/L, but it is permissible tepmorary decrease to the level 2-4 mg/L (*Webber, 1976)*.

Crayfish tend to be nocturnal, but if they feels prey, they will strive for it in the afternoon. Female crayfish always sit alone in burrows but males during the winter often gather in groups *(Borisov, 2011).*

Crayfish are dioecious animals. Males reach maturity in the third year with a body length of at least 7-9 cm and long and narrow claws. Females become adult in the fourth year at body length of 6-7 cm. Typically, males are 2-3 times larger than females *(Borisov, 2011).*

3.4.3 Food

Crayfish diet included plants (up to 90%) and meal (worms, insects and their larvae, tadpoles, fish). In summer crayfish feed on algae and freshwater plants (*Elodea*, nettle, lanceleaf, equisetum) or ocassionally fallen leaves. Per meal female consumes more than male, however does it less frequent. Crayfish forage in vicinity of their shelter, but if there is not enough of food, they can migrate up to 100 - 250 meters. Narrow-clawed feed on plants and dead or live animals, stay active during the whole day, however, prefer to hunt at dusk or at night. Crayfish use its sense of smell to locate food, even from some distance away, especially if the bodies of frogs, fish and other animals began to decomose *(Naumov et al, 1979).*

Among the plants the most important role in the diet of European species of crayfish plays higher aquatic and wetland plants, rich of lime: waterweed, some pondweed and stoneworts. The incidence in the stomachs of Narrow-clawed is 14 to 70%. Waterweed in the stromach is 17.7% by weight of the contents. For crayfish quality of charales plants such as stiffness is less important than for the smaller species of crustaceans. The structure of the mouthparts allowing Narrow-clawed crayfish use them along with soft and hard plants. They are very willing to eat the stems and rhizomes of reeds, rushes, and sedges, and crayfish eat all parts of those plants. Their daily ration is approximately 2.5% of actual bodyweight *(Udalova, 2009)*.

Crayfish enemies in nature are predatory fish (e.g. pike, perch, and catfish in some parts), some birds, water rats and foxes *(Udalova, 2009)*.

As with other scavengers, crayfish carriers sometimes can be dangerous to human diseases, such vectors of fever and hepatitis A *(Borisov, 2011).*

According to their way of life, crayfish are typical solitary animals. Each individual has a unique shelter where it hides from other aggressive neighbors. In the daytime crayfish is hiding at the beginning of a hole, closed its input claws. In case of danger crayfish quickly hides deep in the hole *(Borisov, 2011).*

It is believed that Narrow-clawed crayfish is a sedentary species. Recently, however, marked by the ability of populations to migrate *(Schutze*, 1999*)*.

3.4.4 Conservation status

Crayfish plague is usually fatal for this species. Burn spot disease has been reported for *P. leptodactylus*. This disease can be caused by a number of fungal pathogens that are found on *P. leptodactylus*, e.g. *Fusarium solani, F. oxysparum, F. roseum var. eulmorum, Cephalossparium leptodactyli, Saprolegnio parasitica*. Apart from these fungi many other species have been found on the exoskeleton of P. leptodactylus. *Saprolegnia parasitica* isolated from *P. leptodoctylus* was used to challenge *A. astaeus, P. leniusculus* and *P. clarkli*, and caused mortalities in all of them. *Fusarium solani* has been identified as causing brown abdomen disease in cultured *P. leptodactylus*. *(Holdich et al.* 2009) Porcelain disease (*Thelohania contejeani*) is known to affect *P*. *leptodactylus*. Psorospermium sp. sporocysts have been found in muscle tissue from a number of European countries including Russia and Hungary, in Ukrainian populations a cestoid, *Maritrema* sp., and an oligochaete, *Aelosoma markewitschi* were found.

Indigenous crayfish species (ICS) in Europe are considered to be endangered due to several factors, including habitat loss, deteriorating water quality, overfishing and climate change, as well as competition with non-indigenous crayfish species (NICS) and crayfish plague *(Holdich et al. 2009)*. One of the most significant threats is the continued spread of NICS due to their capacity to directly outcompete indigenous crayfish species and, even more importantly, to transmit diseases that are detrimental to native crayfish species *(Kozubíková et al. 2008).*

The degradation of aquatic habitats has increasingly become one of the most important factors influencing the distribution of freshwater species worldwide *(Fitzgerald et al., 2006)*.

Crayfish are very intolerant of pollution and other human-generated fouling of their environment. A rich crayfish population, then, is a very positive index of habitat quality. Crayfish are more abundant in streams that have acidic water. This abundance may be due more to the acid-generated absence of fish which prey on crayfish than to a direct, positive influence of the acid on the crayfish itself *(Fitzgerald et al., 2006)*.

The most important predators of *P*. *leptodactylus* are sturgeon, especially beluga (*Huso huso*) in the Caspian Sea, and pike (*Esox lucius*), catfish (*Silurus glanis*), eel (*Anguilla anguilla*), and perch (*Perea fluviatilis*). The main terrestrial predators are the otter (*Lutra lutra*) and recently the American mink (*Mustela vison*).

Species included in IUCN Red List (VU, ver 2.3, 1994.), Annex II of the Bern Convention, and Annex 5 of the EU Directive on the type and location - habitat. The IUCN data types are in the status of vulnerable protected. Species are at risk of becoming endangered. They need size and reproductive rate monitoring, as well as measures to promote the conservation of their environment a habitat.

4 Detailed characteristics of Narrow-clawed crayfish habitats

Certain previous studies focused in detail on Narrow-clawed crayfish's habitat requirements and bilogical and ecological characteristics. These findings were adopted by wildlife managers. Firstly, a study by *Foster (1993)* compared the size of stones and pebbles on the stream bottom to the body length of crayfish. A positive relationship was found between the surface area of the stone and crayfish size, but not between stone thickness. Moreover, the presence or absence of Narrow-clawed crayfish was determined by the underlying geology, altitude, whereas abundance appeared to be associated with river margins, refuges, and the presence of deciduous trees. Crayfish were captured by kick sampling and found among submerged tree roots and in leaf litter directly beneath the roots. Individuals were absent in localities with sewage fungus although they were present upstream and downstream of affected areas. However, they were abundant below treated sewage outlets. No significant difference was found between sites with or without crayfish with respect to most evaluated parameters. However, seven positive habitat features associated with river margins or refuges were selected based on multiple regression analysis (*Table A*). Another four features (*Table A*) were associated with a lack of refugee and had a negative effect on crayfish abundance.

Parameter	Positive influence	Negative influence
Decidious trees on bank	yes	no
Submerged tree-roots	yes	no
Vegetation cover > 0.5 m	yes	no
Sloping banks	yes	no
Lack of refuge	no	yes
Gravel	no	yes
Sandy bank	no	yes

Table A: Habitat parameters and their influence on crayfish population

In another study, *Smith et al. (1996)* examined conditions in the upper River Wye (country) and River Severn and found a strong positive relationship between crayfish abundance and the proportion of vertical banks the proportion of riverbed covered by vegetation canopy that was more than 0.5 m above the water level, and the proportion of bank height with submerged tree root systems. They also found that once the threshold for a particular chemical parameters was reached, for example concentration of calcium and pH value, consequently, the crayfish abundance was no longer infuenced by water chemistry. The studied areas were characterised by intensive rainfall and relatively impermeable geology leading to a rapid fluctuations in flow. The riverbed architecture, bank vegetation and extension of their roots into the water are crucial habitat parameters providing for food and shelters for the crayfish, and protecting them against strong currents and predators.

Summary of findings of *Smith et al. (1996)*: Strong positive relationship between crayfish abundance and following selected habitat parameters:

- proportion of vertical banks

- proportion of channel width overhung by a plant canopy
- proportion of bank length with root systems projecting into the water.

Naura and Robinson (1998) used river habitat survey data to predict the distribution of crayfish in the wild. They pointed out crucial environmental characteristics crucial for successful crayfish repatriation. They found that the variables most associated with crayfish presence were overhanging tree branches, extensive steep banks, presence of submerged vegetation, boulders/cobbles as a bank substrate, and the tree shading. Certain parameters they found, were not conducive to crayfish presence, for instance the presence of exposed tree roots, eroding rocks, banks poached by cattle, gravel/pebble/sand bank substrate, and reinforced banks. They suggested that as well as giving shade, overhanging vegetation provides an important source of food both directly and indirectly by support for species forming part of the crayfish diet. Below are summarizes some of the finding of *Naura and Robinson (1998).*

Summary of findings of *Naura and Robinson (1998*).
Variables most associated with crayfish presence were:

- overhanging branches,
- extensive steep banks,
- presence of submerged vegetation,
- boulders/cobbles as a substrate,
- amount of tree shading

Variables associated with crayfish absence were:

- presence of liverworts,
- exposed tree roots,
- eroding cliffs,
- banks poached by cattle,
- gravel/pebble/sand substrates,
- reinforced banks

The results of *Naura and Robinson (1998)* were similar to those of *Foster (1995)* and *Smith et al. (1996)* with the exception of the negative correlation between tree roots and crayfish abundance. Although they found a positive relationships between crayfish abundance and a boulder/cobble substrate, when cobbles alone were assessed be a negative parameter. That may be because cobbles and the substrates associated with them, do not provide sufficient cover for crayfish. When crayfish are found in stony substrate, it is probably because boulders and/or vegetation are also present in the locality. Also submerged tree roots are a very suitable habitat for both juveniles and adults. A habitat only mentioned by *Foster (1995)* is that of beds of leaf litter. As with overhanging vegetation, leaf litter can provide a source of food directly, or indirectly by providing support for species forming part of the crayfish diet. Juvenile crayfish in particular may be found in such a habitat. Of course, any object deposited in a water body can provide a suitable shelter for crayfish, e.g. tree trunks, logs, slates, tiles, corrugated roofing sheets, builder‘s rubble, and even supermarket trolleys *(Foster, 1995)*. Many man-made structures also provide suitable habitats for crayfish, in particular submerged stone walls with gaps between the blocks. Adequate sheleters are needed because crayfish are cannibalistic, particularly within the ecdysis (moulting). Crayfish are also very attractive prey for many predators such fish, birds, otters, and even aquatic insects when young *(Smith et al.,1996)*. Narrow-clawed crayfish may occur in lakes with a largely sediment covered bottom, but they not prefer to, unless there are beds of vegetation and rubble to escape into *(Smith et al.,1996)*. If the substrate is sandy, they burrow into the banks *(Naura and Robinson, 1998).*

Based on the naforementioned findings of *Foster (1993), Naura and Robinson (1998)* and *Smith et al. (1996)*, it is obvious that*,* trees, stream bank vegetation and aquatic plants have a great influence on population of Narrow-clawed crayfish. In the next chapter, the typical trees and other species of bank vegetation, which presence have a positive interrelation with prezence of Narrow-clawed crayfish in Rostov region are summarized.

4.1 Typical tree species

4.1.1 Alnus glutinosa

Black alder (*Alnus glutinosa*) grows better on flat areas or even in hollows, and it is one of the most suited tree species for planting on the banks of the lowland rivers, brooks, along ditches, lakes and ponds. The altitudinal distribution ranges from sea level (sometimes even below, in depressions) up to high altitude sites, especially in the mountains located in the south of its range *(Mcvean, 1953).* Black alder may provide a food for crayfish similarly as submerged plants. Black alder affects the water courses by deoxygenating the water and shading out other species *(Van Dijk, 1978)*. Black alder's dense root system is capable of trapping sediment and subsequently altering water flow in wetland ecosystems, which creates a great food source and shelter for crayfish *(Funk, 1990).*

Figure A: Alnus glutinosa and its root system provides an ideal shelter for Narrow-clawed crayfish (photo was taken from: http://xn--e1aaqjt5d.xn--p1ai/articles/derevja/olha.html)

4.1.2 Salix alba

White willow (*Salix alba*) can be found along rivers, lakes, or other natural water sources. This is because they need a large amount of water to sustain themselves *(Sommerville, 1992).* White willow is tolerant of wet soils. Also, they need a large amount of sunlight. The banks of water sources provide a perfect combination of these factors for willow trees. They also have strong capability to adapt to different PH levels in soil *(Kuzovkina, 2005)*. This gives them the ability to survive many different soil types. Species easely invade riverbanks and wetlands. Roots of *Salix alba* spread into beds of watercourses, slowing water flow, reducing aeration and causing flooding and erosion. In Rostov region *S. alba* is one of the most common tree species *(Baldina, 1999). Salix alba* provides not just food and shelter to *P. leptodactylus*, but also shadding, which plays important role in crayfish population presence *(Kujawa et al., 2008).*

Figure B: Salix alba at Lahutnik River, Rostov region (photo was taken from: http://foto-planeta.com/photo/120286.html)

4.1.3 Populus nigra

The black poplar (*Populus nigra*) is a tree species of floodplain forests, growing in riparian mixed forests together with white poplar (*Populus alba*), willow (*Salix*), alder (*Alnus*) *(De Rigo, 2016)*. It is a pioneer tree species, which does not tolerate drought or shade *(Eckenwalder, 1999).* It is an opportunistic species able to colonise new sites after disturbances, and has a good tolerance to high water levels and high temperatures during summer.

The wide spatial distribution of black poplar overlaps with many areas in Europe subject to high erosion rates, including moist slopes with high drainage-area within the European mountain systems. Here, this tree contributes to relevant forest ecosystem services such as soil stabilisation and watershed protection. It has high ecological value in riparian floodplain ecosystems, frequently used as a windbreak or to control erosion along riverbanks *(Praciak, 2013).*

Figure C: Populus nigra at Lower Don river basin (photo was taken from: http://fotokto.ru/photo/view/1610914.html)

4.2 Typical plant species

4.2.1 *Typha latifolia*

Typha latifolia is an "obligate wetland" species, meaning that it is always found in or near water. The species generally grows in flooded areas where the water depth does not exceed 0.8 meters. However, it has also been reported growing in floating mats in slightly deeper water. *Typha latifolia* grows mostly in fresh water but also occurs in slightly brackish marshes *(Lansdown, 2014)*. Rhizomes grow horizontally just below the soil surface. Some indicate that broadleaf cattail produces 2 types of rhizomes; one that is "more superficial", thin, "feathery", and multibranched, and another that is deeper, thicker, and branching at the base *(Rowlatt et al.,1993)*. *Typha latifolia* is a typical shore vegetation species, that are commonly presented at Low Don river basin. This species are very common shelter and food source for Narrow-clawed crayfish in Rostov region.

Figure D: Typha latifolia at Don river (photo was taken from: https://ok.ru/kletskoek/topic/67424247360326)

4.2.2 *Alisma lanceolatum*

Figure E: Alisma lanceolatum (photo was taken from: https://cs.wikipedia.org/wiki/%C5%BDabn%C3%ADk_kopinat%C3%BD#/media/File:Alisma_lanceolatum_Prague_2012_1.jpg)

Lanceleaf water plantain (*Alisma lanceolatum*) is a species of aquatic plant in the water plantain family *(Cother et al., 1994)*.

Water-plantains are wetland plants and found in saturated soils and shallow water as well as marshes, wooded swamps, shrub swamps and flooded farmland *(Cother et al., 1994).* When introduced to an area, water plantain can rapidly reproduce.

This is a perennial herb growing from a caudex in the water or mud. It produces lance-shaped leaves 12 to 20 centimeters long and 4 wide on long petioles; leaves which remain submerged in water are smaller and less prominently veined. The inflorescence is mostly erect and up to half a meter tall *(Rose, 2006)*.

4.2.3 Phragmites australis

Common reed (*Phragmites australis*) commonly forms extensive stands. It can grow in damp ground, in standing water up to 1 metre or so deep, or even as a floating mat *(Van Der Putten, 1997)*. The erect stems grow to 2–6 metres tall, with the tallest plants growing in areas with hot summers and fertile growing conditions. It is a helophyte, especially common in alkaline habitats, and it also tolerates brackish water, and so is often found at the upper edges of estuaries and on other wetlands which are occasionally inundated by the sea. Common reed is suppressed where it is grazed regularly by livestock. Under these conditions it either grows as small shoots within the grassland sward, or it disappears altogether *(Van Der Putten, 1997).*

Figure F: Phragmites australis at Lahutnik river (photo was taken from: https://upload.wikimedia.org/wikipedia/commons/5/5e/%D0%9B%D0%B0%D0%B3%D1%83%D1%82%D0%BD%D0%B8%D0%BA.jpg)

5 Conclusion

- Narrow-clawed crayfish is one of the important crustaceans exploited for human consumption. It has a high commercial value and is rated as a luxury commodity. Chitinous carapace is used also in medicine.
- Narrow-clawed crayfish is considered endangered in many European countries and is protected by laws.
- It prefers well vegetated habitats. Submerged roots of some trees (e.g. *Populus nigra*, *Salix alba*, and *Alnus glutinosa*) provide preffered shelters for this species and inhibite its burrowing aktivity.
- Narrow-clawed crayfish feeds on algae and aquatic plants (e.g. *Phragmites australis*, *Alisma lanceolatum*, *Typha latifolia*) and ocassionally fallen leaves.
- Vegetation cover is also important to shade the waterbody, which is preffered by many crayfish species including the Narrow-clawed crayfish.
- Therefore, the culture or repatriation of the Narrow-clawed crayfish in both natural and artificial waterbodies is recommended only in localities with well developed associated vegetation.

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