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Review Article

Paweł WRÓBLEWSKI

MONITORING PROPOSAL OF THE RED SWAMP CRAYFISH *PROCAMBARUS CLARKII* (GIRARD, 1852)

Faculty of Animal Breeding, Bioengineering and Conservation, Warsaw University of Life Sciences, Warszawa, Poland

Abstract. Invasive alien species are one of the major problems in Polish fauna and flora. They can displace native species and cause economic losses. Such animals as red swamp crayfish have a wide tolerance to changing living conditions, which means that their range of occurrence increases over time. The current area of red swamp crayfish in Poland includes several locations, but reports indicate that this species inhabits many other reservoirs. It is very important that the red swamp crayfish population is regularly monitored, which may limit the number of this crustacean in Polish waters.

Key words: invasive species, control, aquaculture, crustacean, Cambaridae.

INTRODUCTION

Invasions of alien species have a significant impact on global biodiversity (Naumann and Higgins 2014; Ehrenfeld 2017). In many cases, their populations have potential to spread with a simultaneous, rapid rate of multiplication (Nowak and Szczerbik 2009; Głowaciński et al. 2011). Aquatic ecosystems are among the most susceptible to invasion. They can be easily destabilized and therefore, can be quickly invaded by alien species (Gherardi and Acquistapace 2007; Anufrieva and Shadrin 2017). In addition, global warming and environmental degradation create opportunities for alien species to occupy new areas (Bonk and Bobrek 2021). Some crayfish belong to destructive invasive species, affecting many trophic levels.

One of the most threatening species to fauna and flora is the red swamp crayfish *Procambarus clarkii* (Girard, 1852), originating from North America, which was introduced to Poland as an effect of deliberate introductions by irresponsible keepers. Its first introductions in Europe resulted from the try to replace endangered native crayfish (Gherardi 2006; Cruz and Rebelo 2007). This crayfish is traded and can be purchased for food purposes. Unfortunately, as a result of the lack of responsibility of breeders and large adaptation possibilities, red swamp crayfish colonized other aquatic ecosystems (Śmietana et al. 2018).

Corresponding author: Paweł Wróblewski, Faculty of Animal Breeding, Bioengineering and Conservation, Warsaw University of Life Sciences – SGGW, Jana Ciszewskiego 8, 02-786 Warszawa, Poland, e-mail: wroblewskipawel98@gmail.com.

Crustacean research, particularly invasive alien species, is an important component of aquatic ecosystem research. Information on the inhabited place or the size of a given species is necessary to learn about the expansion of a given population. As a result, it is possible to determine what aspects will be affected by the spread of invasive alien species and how such species can be eliminated.

Fig. 1. Adult red swamp crayfish *Procambarus clarkii* (photo P. Wróblewski)

MATERIALS AND METHODS

I. Information about the species

1. Systematic membership

Family: Cambaridae
Order: Decapoda

2. Status

Invasive alien species – in accordance to Regulation (EU) No 1143/2014 on the prevention and management of the introduction and spread of invasive alien species and Commission Implementing Regulation (EU) 2016/1141 of 13 July 2016 on admission a list of invasive alien species with a Union concern in accordance with Regulation (EU) No 1143/2014 of the European Parliament and the Council.

3. Species description

The red swamp crayfish has a structure typical to decapods. Its body consists of two distinct parts: the cephalothorax and the abdomen. There are five pairs of walking legs on the cephalothorax, the first of which is transformed into large claws. The length of the entire body of an adult individual may exceed 13 cm. There are many varieties, including orange, red, white and blue (Fig. 2). Under proper conditions, they reach sexual maturity after about 3 months, and life expectancy is up to 5 years (Karaban and Stęplowski 2018).

Fig. 2. Red swamp crayfish in three color varieties (photo P. Wróblewski)

Currently, 6 species of crayfish have been found in Polish inland waters. Two species recognized as native are the narrow-clawed crayfish, and the noble crayfish (Strużyński 2007). Another 4, including marbled crayfish, signal crayfish, spiny-cheek crayfish, and red swamp crayfish, are invasive alien species (Wiśniewski et al. 2020). The ability to identify species is particularly important in monitoring programs. The absence of a serrated ridge along the center of the rostrum occurs in all invasive alien crayfish species found in Polish waters. In red swamp crayfish, marbled crayfish and spiny-cheek crayfish, the bottom of the rostrum is perfectly smooth (Kaliszewicz et al. 2022). According to the source of the “Alien Hunter” (Maciaszek 2022), non-closing claws and single side slats are the characteristic features presented on (Fig. 3).

Fig. 3. Characteristic non-closing claws in red swamp crayfish (photo P. Wróblewski)

The different colors of red swamp crayfish are the result of inbreeding or crossing individual varieties. The specimens are intensely colored – blue, white, orange, apricot or blue. The color of crayfish depends on breeding and the availability of astaxanthin in the food (Beingesser and Copp 1985).

Cephalothorax

Sensory legs:

- segment I – antennae I pairs are shorter,
- segment II – antennae of the second pair forming a "mustache" set on a triangular base.

Mouth legs:

- segment III – mandibles made of a hard transverse plate, clearly serrated,
- segment IV and V – jaws of I and II pairs, small leafy appendages.

Mouth legs:

- segment VI–VIII – jaw legs of I, II and III pairs, each clearly lamellar.

Walking legs:

- segment IX – crotch legs I pairs – ended with tongs,
- segment X and XIII – step legs II, III, IV and V pairs – the first two pairs ended with small tongs, the last two – claws.

Abdomen

Copulatory legs:

- segment XIV–XV – abdominal legs of I and II pairs in males of a trough-shaped shape in the form of the letter L, in females the first pair in disappearance.

Floating legs:

- segment XVI–XVIII – abdominal legs III, IV and V, small, two-branched pairs play the role of swimming, and in females they act as an egg trailer,
- segment XIX – abdominal legs of VI pairs, two-branched in the form of gills, together with the telson constitute a "caudal fin".

4. Biology of the species

The red swamp crayfish is characterized by omnivorousness, from fish to plants (Alcorlo et al. 2004; Kaliszewicz et al. 2022). Its diet includes the remains of vertebrates and invertebrates (Cruz et al. 2006a). Cannibalism is also observed in relation to their own species and other species (He et al. 2021). The red swamp crayfish prefers habitats with a water temperature of 21°C to 30°C, but is also found in waters with an annual average temperature of 13°C. Due to such a wide range, red swamp crayfish can live in almost all types of water (Karaban and Stęplowski 2018). These crayfish breed both in burrows 10–70 cm deep and in shallow water sediments at a depth of 0.5–4 m. These observations suggest that reproduction is an activity on the lake shore (Oluoch 1990; Cruz and Rebelo 2006b).

The red swamp crayfish is sexually mature in the natural environment with a total body length of 76 mm (Oluoch 1990). The period which it breeds is estimated from August to November in the wild. A large female can lay up to 700 eggs (Fig. 4), which she looks after by about one month wearing them on abdominal legs (Loureiro 2015).

Fig. 4. A huge number of red swamp crayfish caught from one reservoir in Poland (photo P. Wróblewski)

5. Origin

Red swamp crayfish is native to North America, where it occurs naturally in Mexico and the south-central United States (Aquiloni et al. 2011).

6. Habitat requirements

It generally inhabits shallow stagnant waters, drainage ditches, ponds, lakes, rivers, dam reservoirs, rice fields, etc. It can form permanent populations in periodically drying reservoirs (Foster and Harper 2007). It uses various hiding places available in the water as a shelter, but mainly burrows, that act as shelters (Scalici et al. 2010; Śmietana et al. 2018). In Poland, this crayfish lives in many types of reservoirs. It uses hiding places in the form of roots. During periods of reduced oxygen in water, it is able to go ashore (own observation). Crayfish density should have a negative impact on their survival and growth rate of young specimens. The presence of other crayfishes causes stress and greater energy losses (Karaban and Stęplowski 2018). Males are submissive and prone to courtship towards females, while males are extremely aggressive towards males (Issa et al. 1999). Global warming may conducive to the expansion of the red swamp crayfish population, which in interaction with high ecological plasticity may enable the expansion of this species (Hellmann et al. 2008; Frelich and Reich 2009; Lee and Park 2019).

7. Distribution of the species in Poland

A known case of this species was recorded in the Żerań Canal and Krasiński Garden in 2019. In the Dąbski pond in Kraków (Fig. 5), 4 individuals of red swamp crayfish were observed (Maciaszek et al. 2019). The reports of local residents also point to the Greater Poland Voivodeship.

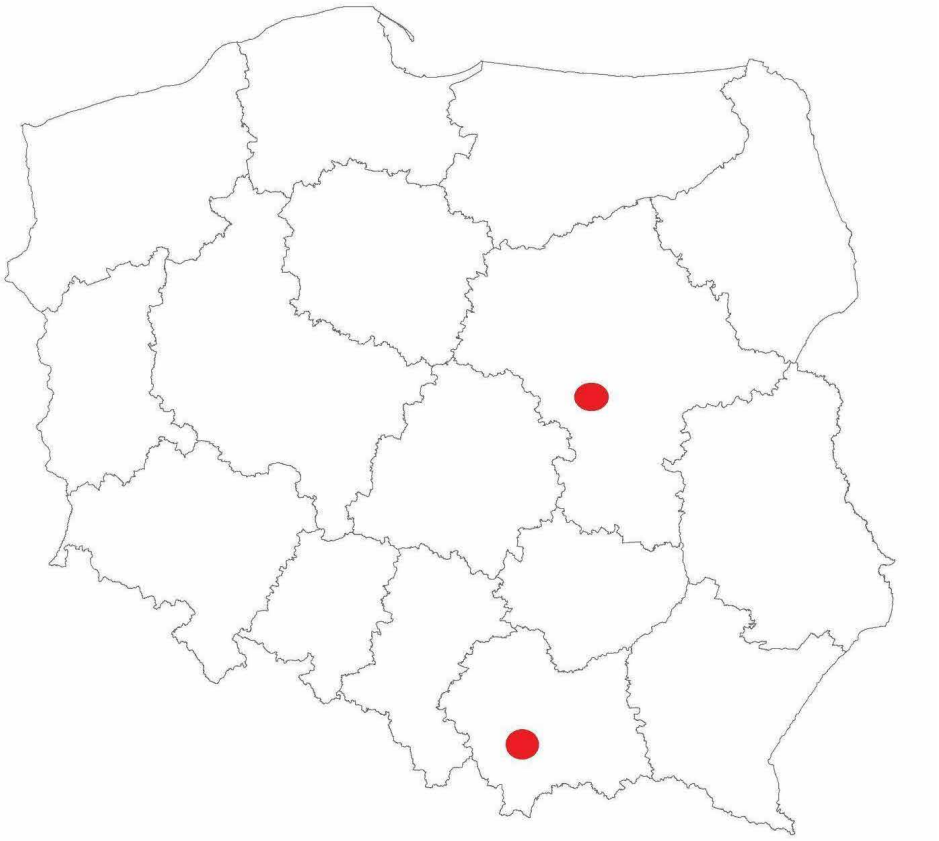

Fig. 5. Red swamp crayfish distribution map

8. Invasiveness

The ways of spreading

Deliberate introductions.
Unintentional introduction of individuals with fishing gear.
Independent movement of the species.

Impact on the natural environment

Red swamp crayfish is a very invasive species and can strongly affect on noble crayfish by transmitting crayfish plague and invading its habitat (Parrino et al. 2020). Moreover, it causes the displacement of amphibians (Perez et al. 2013; Saura-Mas and Benejam 2019). Red swamp crayfish has a negative effect on ichthyofauna by eating eggs and smaller fishes. Due to the reported breeding male red swamp crayfish with female noble crayfish, there is some probability that there will be a large impact on its reproductive success also from the red swamp crayfish. For the same reasons, it may also adversely affect another crayfish species protected in Poland – narrow-clawed crayfish (Śmietana et al. 2018). Digging burrows can cause sediment floating and, as a result, eutrophication of the reservoir (Rodríguez et al. 2003).

Species for which it may be a threat

1. *Astacus astacus* – species endangered with extinction VU, under partial protection.
2. *Pontastacus leptodactylus* – species of least concern LC, under partial protection.

3. *Unio crassus* – species endangered with extinction EN, strictly protected.
4. *Anodonta cygnea* – a species of the least concern LC, under partial protection.
5. *Rhodeus sericeus* (Fig. 6) – a lower risk species of LC, under partial protection.
6. *Misgurnus fossilis* – a species of lower risk LC, under partial protection.
7. *Eupallasella percnurus* – a lower risk species of LC, strictly protected.
8. *Triturus cristatus* – a species of lower risk LC, strictly protected.
9. *Mareca strepera* – a species of lower risk LC, under strict protection.
10. *Spatula querquedula* – a species of lower risk LC, under strict protection.
11. *Trapa natans* – endangered species VU, under strict protection.
12. *Bufo bufo* – a lower risk species of LC, subject to partial species protection.
13. *Rana temporaria* – a lower risk species of LC, subject to partial species protection.
14. *Rana arvalis* – a species of lower risk LC, under strict protection.

Fig. 6. Amur bitterling caught during the research (photo P. Wróblewski)

Impact on the economy

Red swamp crayfish can injure fish resting on the bottom. There was also an impact on the population of *Cyprinus carpio* (Linnaeus, 1758), with which this species has similar temperature and habitat requirements (Angeler et al. 2001). In addition, transmission of the crayfish plague by red swamp crayfish negatively affects on the breeding of European and other commercial crayfishes (Weber and Traunspurger 2017).

Impact on human health

The specie is the intermediate host for *Paragonimus flukes* (Braun, 1899), which man is the ultimate host. This disease is extremely dangerous because it causes permanent damage to the lungs by the deposition of flukes in the lungs (Palillo et al. 2022). In red swamp crayfish, has been found the bacterium *Vibrio mimicus* (Davis, 1982), which can cause gastroenteritis in humans, after eating uncooked meat of the crayfish (Thune et al. 1991; Wong et al. 2011). Extremely large claws can cause injuries when tightened on the skin. Wounds are not serious, but increase the risk of contamination of wounds with pathogens.

II. Methodology

1. The concept of species monitoring

There is no monitoring of red swamp crayfish in Poland so far. The first observation in our fauna dates in 2014, then in 2019 (Śmietana et al. 2018; Maciaszek et al. 2019). From my own observations and according to the publications about red swamp crayfish, it can be noticed that this crustacean increases the area of its occurrence, which has a negative impact on biodiversity. It is worth noting that initiatives such as the "Alien Hunter" contribute to the control and monitoring of invasive species of alien crayfish in Poland (Maciaszek 2022).

This concept of monitoring of the red swamp crayfish is based on the experience and own data obtained from the catch of invasive alien species on the example of the population in Warsaw.

The proposed method of determining the population and habitat status indicators is simple. The monitoring site is a pond which, according to the current knowledge, is inhabited by red swamp crayfish and spiny-cheek crayfish. The assessment of the population status is based on the numerical data of the caught crayfish and their sex structure obtained from catching with standard landing nets using the "on target" method. The assessment of the condition of the habitat is based on the observation of the environmental elements characteristic of the red swamp crayfish.

The studied site of the red swamp crayfish is a closed reservoir, however, the described methodology is universal for other types of reservoir. It is possible, that in the future it will be necessary to verify the method of valorization in other types of habitats.

Due to the high invasiveness and great interest as an aquarium species, an educational campaign related to invasive alien species of crayfish should be carried out. The best way to present the problem would be workshops for schools and kindergartens and lectures for local residents.

2. Indicators and assessment of the state of the population

Population status indicators

Red swamp crayfish Population Status Indicators are shown in Table 1.

Table 1. red swamp crayfish Population Status Indicators

Indicator	Standard	Measurement method
Abundance	CPUE	Indicator defined as the average number of crayfish caught in 2 hours during night fishing with a landing net during May-December, during high crayfish activity

Valorization of red swamp crayfish Population Status Indicators are shown in Table 2.

Table 2. Valorization of red swamp crayfish Population Status Indicators

Indicator	FV	U1	U2
Abundance	CPUE > 1	1 > CPUE > 0.5	CPUE < 0.5

Cardinal indicators

Not highlighted

Habitat status indicators

Red swamp crayfish Habitat Status Indicators are shown in Table 3.

Table 3. Red swamp crayfish Habitat Status Indicators

Indicator	Standard	Measurement method
An inhabited section of the shoreline	**%**	Determination of what part of the shoreline is occupied by crayfish, in the case of a watercourse on a designated site with a length of 1000 m or a length of 10% of the shoreline for water reservoirs
Type of substrate	descriptive indicator	Determining the type of substrate on the test stand in terms of the availability of hiding places. Also the presence of a substrate enabling digging of burrows or the presence of stones and rock debris
Anthropogenic transformation of the habitat	descriptive indicator	Determining the share of hydrotechnical transformations, including adapting the shore to recreation
Water reaction	pH	Test using a pH meter
Current species of fish and crayfish	descriptive indicator	Identification of all invasive alien fish and crayfish species (catfish, grass, stripe crayfish, marbled crayfish, signal crayfish (and all fish and crayfish recognized as IGO) at the site itself based on environmental interviews with water users and own catches
The presence of amphibians	descriptive indicator	Identification of all amphibian species (spotted salamander, common newt, great crested newt, mountain newt, Carpathian fire-bellied newt, common toad, green toad, grass frog, marsh frog, water frog, lake frog, tree frog)

Valorization indicators of the status of the red swamp crayfish habitat are shown in Table 4.

Table 4. Valorization indicators of the status of the red swamp crayfish habitat

Indicator	FV	U1	U2
A inhabited section of the shoreline	<10%	>10–30%	>30–100%
Type of substrate	>50% of the studied habitat are places that provide hiding places for crayfish or conditions for their formation (root systems, stones)	10–50% of the studied habitat are places that provide hiding places for crayfish or conditions for their formation (root systems, stones)	<10% of the studied habitat are places that provide hiding places for crayfish or conditions for their formation (root systems, stones)
Anthropogenic transformation of the habitat	The natural layout of the habitat	<60% of habitats transformed	>60% of habitat transformed
Water reaction	pH >7.0	pH 6.0–7.0	pH >7
Current species of fish and crayfish	The IGOs listed in Table 3 are present at the crayfish site	No information on the presence of IGOs at the site, but there is a high risk of IGO expansion from nearby (up to 10 km) watercourses or reservoirs inhabited with invasive alien species listed in Table 3	No information about the presence of IGOs at the site and in the nearby waters
The presence of amphibians	There is no information about the presence of amphibians at the site and in the nearby waters	There is no information about the presence of amphibians at the site, but they are present in nearby ponds and watercourses	The site includes the amphibians listed in Table 3

Cardinal indicators
Not highlighted
FV – proper condition, U1 – unsatisfactory condition, U2 – bad condition
Assessment of the state of the population
The assessment of the population status is determined by the assessment of the indicator "number".

Habitat condition assessment
When assessing the condition of a habitat, all indicators are treated as equal. The assessment of the condition of a habitat is determined by the assessment of the lowest rated indicator.
The perspective of invasiveness
The assessment of the invasive perspective is an expert judgment. It is a population and habitat status forecast for the next 10 years, taking into account the current population status as well as habitats and population control activities. It is important to consider the risk and impact of red swamp crayfish on other animals. The outlook is good (FV) when there are no signs of red swamp crayfish, (U1) is unsatisfactory when we find signs of red swamp crayfish and its effects have a negative impact on the environment. When the current population status increases and we assess the high impact of red swamp crayfish on the ecosystem (U2).
Overall assessment
In accordance with the principles of species monitoring. The general assessment of the conservation status of a species is equivalent to the lowest assessment of the three assessed parameters (population, habitats and conservation prospects).

3. Description of monitoring studies
Selection of monitoring areas and their suggested size
Places selected for monitoring the red swamp crayfish are both watercourses and water reservoirs in which its presence was found as a result of inventory activities. Our research area is the entire reservoir and the shore. In the case of watercourses, the section of the studied will be approximately 1000 meters. The monitoring will include those fragments where the presence of red swamp crayfish has been recorded or there are features of the habitat suitable for crayfish.

This species is characterized by appear in all over positions. It is found both in man-transformed places and in reeds.

To update the knowledge about the red swamp crayfish in Poland, control catches should be carried out using a landing net. The colors of the crayfish and their willingness to go ashore make it possible to catch them using the "targeted" method with high efficiency.

In case of insufficient visibility, it is worth using crayfish net. It is estimated that red swamp crayfish has 4 sites in Poland, but each of them should be monitored due to the high invasiveness of this species.

Test method
According to the methodological assumptions:
- 10% of the coastline (standing waters),
- approx. 1000 m fragment (flowing waters).

Determination of population status indicators
Abundance. On the selected tank, start catching by landing net with a mesh width of 1x1 cm and a landing net rim size of 50 × 50 cm. Check the entire tank and catch crayfish into a bucket. The time we perform a given catch is 2 hours.

Instead of a landing net, you can use a crayfish net with a sea fish bait. Then the traps should be left overnight and collect it after 24 hours.

Because catching is the best at night, it is worth conducting research in a team of two, which also results from the health and safety rules. Depending on the owner of the pond or watercourse, you must obtain their full permission to catch.

After harvesting, the crayfish can remain in the bucket. Red swamp crayfish cannot be returned to the tank after being caught, so it can become part of the food for animals in the bird refuge.

After catching all equipment that has come into contact with crayfish should be thoroughly cleaned with a bactericidal and fungicidal preparation or 70% isopropanol, due to the possibility of transmission of the crayfish plague.

Determination of population status indicators

An inhabited section of the shoreline. The control catches provide the basis for calculating the shoreline colonization by the presence of the red swamp crayfish in a given habitat. The red swamp crayfish inhabits often the sections where it can build a burrow or hide safely in the reeds. In order to determine the population index over a distance of 1000 m, 2-hour night catches are carried out. In the case of showing crayfish over a distance of 500 meters, the indicator will be 50%. The presence of crayfish concerns the observation of a 1000-meter long section. Each 50 meters represents 5% of the settlement. If 1 crayfish was found in 6 sections of 50 meters, the occupancy rate will be 30%.

Type of substrate. Pay attention to the type of substrate present in the tank or watercourse (Fig. 7). Shores can be strewn with water, stones and roots that provide shelter.

Fig. 7. The shore of the pond is diverse in terms of the type of substrate and the shape of the reservoir bowl, sometimes there is silty sand with a gentle descent (a), or a swampy area covered with water plants with a steep bottom (b) (photo P. Wróblewski)

Anthropogenic transformations. When assessing this indicator, the level of shoreline transformation should be taken into account (Fig. 8). Anthropogenic transformations include: bank reinforcements, bridges, drained sections, concrete water outlets). For this type of fragments, the assessment is made on the basis of the length of the transformed fragment in relation to the entire shoreline, or 1000 meters in the case of watercourses (for example, in a 1000 meter stretch, 100 meters are run-offs). Anthropogenic transformations may affect the speed of expansion of the red swamp crayfish. An example is concrete drains through which crayfish can escape from the reservoir and colonize other areas.

Fig. 8. Anthropogenic transformations constitute a good hiding place for crayfish (photo P. Wróblewski)

Water reaction. In the case of the pH parameter, measurements are performed directly on the stand using measuring tools, e.g.(GroLine pH waterproof, Hanna Instruments, Poland) and (TDS & EC meter (hold), TDSmeter, Poland.

Invasive alien species of fish and crayfish. The presence of other invasive alien species is verified by 'entering' these species into traps or by catching together with red swamp crayfish in a landing net. We document all results and observations at the stand in the form of notes and photos.

The presence of amphibians. The presence of amphibians is checked by accidental landing net, vocalization and observation. It is also possible to detect spawn or larvae of amphibians also by observation.

Research deadline

In purpose to correctly demonstrate the status of the red swamp crayfish population, tests should be performed throughout the year.

Test equipment and materials

1. Crayfish net (a tool for catching crayfish, usually made of synthetic mesh. It has several entrances), presented on (Fig. 9).
2. Bucket.
3. Landing net.
4. Waders.
5. Headlamp.
6. Nitrile gloves.
7. pH meter and conductivity meter.
8. Caliper.
9. Tape measure for measuring the lengths of the shoreline to catch crayfish
10. Notebook and pen.
11. Disinfectants.

Fig. 9. Crayfish net with several entrances (photo P. Wróblewski)

An example of a completed species observation sheet at the site are shown in Table 5.

Table 5. An example of a completed species observation sheet at the site

Species observation sheet for the site

The species name	Red swamp crayfish *Procambarus clarkii* (Girard, 1852)
Job title	Name of the monitored workstation ……
Type of position	Research / Reference Research
Protected areas where the position is located	Natura 2000, nature reserves, landscape parks, ecological lands ……
Geographical coordinates	Enter the geographic coordinates of the site XX ° XX′XX ″ N XX ° XX′XX ″ E
Altitude above sea level	Enter the altitude above sea level or the range from to 400 m above sea level
Stand area	Enter the size of the area in ha or m^2 0.3 ha
Characteristics of the species habitat at the site	Brief characteristics of the habitat, taking into account the nature of the water reservoir. The shore is inaccessible from the north-east due to the reeds. Sand bed on the west side at the bathing site A steep bank with numerous aquatic vegetation on the south-west side Perch and bleak dominate in ichthyofauna The reservoir is rich in aquatic vegetation
Information about the species in the position	Information on the occurrence of the species at the site, including when it was found for the first time and other important facts The species was found at the site in 2020. The species has displaced the amphibians
Is monitoring required in subsequent years?	YES/NO with justification why the resignation from the position was proposed YES
Observer	Name of the observer Paweł Wróblewski
Date of observation	Date of observation 07/11/2022

The status of the species at the site are shown in Table 6.

Table 6. The status of the species at the site

Parameter	Indicators	Indicator value and comment	Rating	
Population	abundance	Enter the CPUE value 0.6 6 crayfish were caught	U1	U1
Habitat	the settlement of the coastline	Specify what part of the coastline is inhabited by crayfish at the designated site 50%	FV	U1
	type of substrate	Specify the type of substrate in terms of the availability of hiding places. Numerous aquatic vegetation as well as roots and branches create a large number of hiding places. The type of substrate supports the building of burrows	FV	
	anthropogenic transformation of the habitat	Describe by specifying the percentage share of hydrotechnical transformations in the shoreline and the reservoir basin, including adaptation of reservoirs for recreation. The reservoir has existed for about 90 years, the basin is presumably free from hydrotechnical transformations. 10% are rainwater runoffs, 5% are urban buildings (flooded stairs) and 5% are a bridge connecting the eastern and western banks	FV	
	water reaction	Enter the pH measurement result 8.5	FV	
	alien species of fish and crayfish	List the foreign species of fish and crayfish occurring at the site Streaky crayfish, grassland carp, carp	U1	
	the presence of amphibians	List the amphibians present on the site	FV	
Behavior prospects		Brief forecast of the population and habitat status of the species at the site in the next 10 years in relation to their current condition and the observed processes taking place in the habitat. The condition of the population is satisfactory. Despite the pressure of anglers and other alien species, it can gradually increase its population.		U2
Overall assessment				U2

List of the most important current and anticipated impacts (threats) on the species and its habitat at the site studied are shown in Table 7.

Table 7. List of the most important current and anticipated impacts (threats) on the species and its habitat at the site studied (including the current use, planned investments, planned changes in management and use); impact influence: "+" – positive, "–" – negative, "0" – neutral; impact intensity: A – strong, B – moderate, C – weak

Current impact			
the name of the activity	intensity	influence	synthetic description
Cannibalism	B	–	The larger and stronger crayfish can hunt and kill younger and smaller crayfish of the same species. Strong territorialism
Predation	A	–	Large predators present in the reservoir can deplete the red swamp crayfish population
Pressure from other alien species	B	–	The spiny-cheek crayfish in the reservoir competes with louisiana for a habitat
Threat (future, anticipated impacts)			
the name of the activity	intensity	influence	synthetic description
Cannibalism	B	–	As the population grows, this crayfish can fight itself
Predation	A	–	Presumably it will not change
Pressure from other alien species	B	–	Increasing the number of red swamp crayfish may result in a depletion of the spiny-cheek crayfish population

4. Species with similar ecological requirements for which the developed methodology can be adapted

The prepared methodology can be used to monitor another crayfish species which is an invasive alien species. Mainly marbled crayfish that belongs to the same genus – Procambarus, but it can be useful in catching spiny cheek crayfish (Fig. 10). Most of the invasive species of crayfish are characterized by high plasticity in relation to the environment, therefore they can be very dangerous to the native fauna and flora by occupying new habitats and displacing its inhabitants.

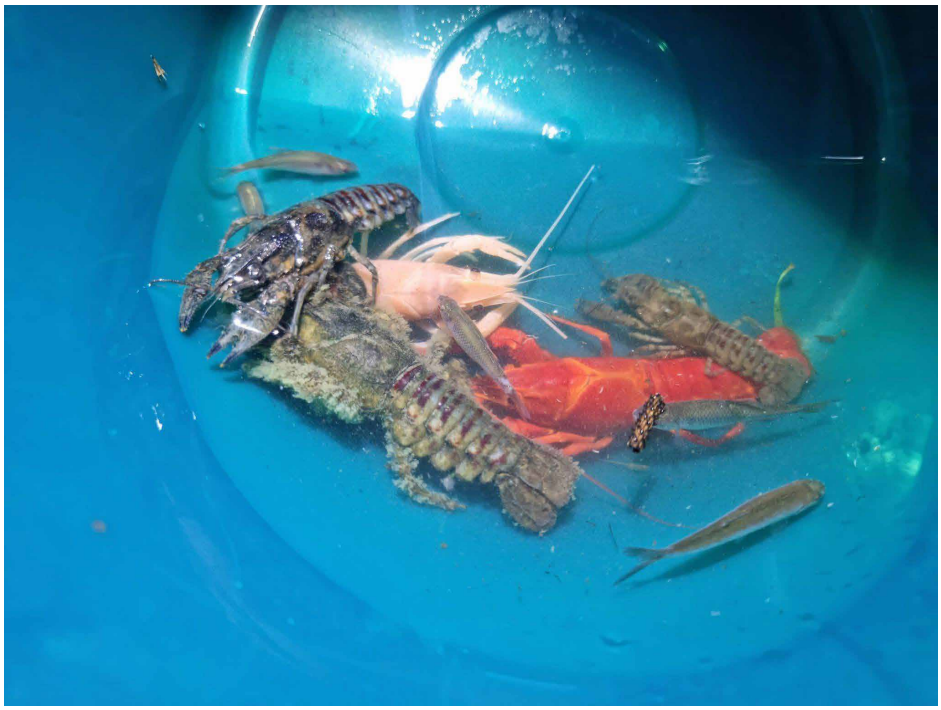

Fig. 10. Some spiny cheek crayfishes noted in the studied reservoir (photo P. Wróblewski)

5. Means of combating

As in the case of other crayfish species, due to the high densities achieved, this species is difficult to eliminate completely. Young, smallest individuals are difficult to catch. Red swamp crayfish can hide in deep burrows. Currently, the best practice is to regularly catch and monitor the red swamp crayfish. The admission of predatory fish is also a good method when there are none of them in the tank. The most invasive solutions are pesticides and insecticides, but they have a negative effect on other organisms (Cecchinelli et al. 2012).

RESULTS

The initial catches show that red swamp crayfish is present in large numbers in the studied reservoir. Cannibalism in red swamp crayfish is causing its decline (He et al. 2021). Nevertheless, catching specimens are in different sizes. Among the caught animals, rosettes and numerous predatory fish were noticed. However, the presence of amphibians was not recorded.

Interview with local residents shows that their knowledge about the presence of invasive alien species in the studied reservoir is still small. In addition, fishermans catch crayfish for hobby purposes in the home aquarium.

This paper is only a proposal for the monitoring of red swamp crayfish. The exact results of field studies for the selected reservoir should be presented in the mentioned observation cards

of the species at the site, together with the observations resulting from the affects on the red swamp crayfish.

DISCUSSION

The high ecological plasticity of the red swamp crayfish in relation to environmental variables increases the invasion potential of this crustacean (Scalici et al. 2010). Therefore, it is likely to settle in reservoirs with favorable water parameters. The harvested young individual may suggest that the red swamp crayfish is able to reproduce in the tank. The presence of red swamp crayfish can adversely affect other aquatic and terrestrial species. It is also likely to exclude native amphibians from their aquatic habitats (Smith et al. 2013). The reservoir is not adjacent to watercourses and ponds, which may limit the further invasion of red swamp crayfish. The anthropogenic transformations along the shore can provide a good shelter, and a substrate suitable for burrowing and makes this crayfish difficult to catch.

In order to limit the increase of the population, effective methods of combating red swamp crayfish should be developed. A very important aspect is educating the local community to stop the spread of the species. During the research, all red swamp crayfish that had been caught in the reservoirs were removed. However, it is strongly recommended to implement regular environmental monitoring and eradication measures in the occupied and surrounding areas.

CONCLUSIONS

Invasive alien species have become one of the main factors adversely affecting the biology of water bodies. Among other things, they contribute to the depletion of the food base of many fish, being their competitors for food. They can also contribute to the disappearance of amphibians in the reservoir.

Based on the initial catches and inspection of the reservoir, it can be assumed that a given location may be conducive to the occurrence of the red swamp crayfish population. This is evidenced by numerous hiding places in the form of reeds, aquatic plants and anthropogenic buildings. The type of substrate helps red swamp crayfish dig their burrows. Adult crayfish show intraspecific aggression, unlike young individuals, so the crayfish can self-eliminate. In reference to the interview with local residents, it appears that many people catch adult specimens due to their attractive coloration, which additionally has a positive effect on the population of this crayfish in the reservoir.

Overall, red swamp crayfish is well adapted to withstand the temperate climatic conditions of an urban area and is likely to continue to expand its range. Its presence could have affected other species in both aquatic and terrestrial environments. This species adversely affects fish species attractive to anglers and may reduce the recreational value of fishing grounds and places of rest. Sensitizing public opinion and local knowledge is essential for the early detection and control of invasive species.

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PROPOZYCJA MONITORINGU RAKA LUIZJAŃSKIEGO *PROCAMBARUS CLARKII* (GIRARD, 1852)

Streszczenie. Inwazyjne gatunki obce są jednym z głównych problemów w polskiej faunie i florze. Mogą one wypierać rodzime gatunki i powodować straty gospodarcze. Takie zwierzęta jak rak luizjański mają szeroką tolerancję na zmieniające się warunki bytowania, przez co z biegiem czasu zwiększa się zasięg ich występowania. Obecnie teren, który kolonizuje rak luizjański w Polsce, obejmuje kilka lokalizacji, jednak doniesienia wskazują na to, że gatunek ten zasiedla wiele innych zbiorników. Bardzo ważne jest więc, aby populacja raka luizjańskiego była regularnie monitorowana w celu ograniczania liczebności tego skorupiaka w polskich wodach.

Słowa kluczowe: inwazyjne gatunki obce, zwalczanie, akwakultura, skorupiak, Cambaridae.