Arch. Pol. Fish.	Archives of Polish Fisheries	Vol. 14	Fasc. 1	131-140	2006

Short communication

EVALUATION OF CHANGES IN THE ABUNDANCE OF THREE CATCHABLE CRAYFISH SPECIES IN LAKE POBŁĘDZIE (NORTHERN POLAND)

Tadeusz Krzywosz

Department of Lake Fisheries, The Stanisław Sakowicz Inland Fisheries Institute in Olsztyn, Poland

ABSTRACT. The aim of the study was to learn about the character and dynamics of changes in the abundance of the catchable population of the signal crayfish, *Pacifastacus leniusculus* (Dana), the spiny-cheek crayfish, *Orconectes limosus* (Raf.), and the noble crayfish, *Astacus astacus* (L.), that all inhabit Lake Pobłędzie (northern Poland). During the study period of 1996-2005, the effectivity of crayfish catches conducted with Evo traps in the lake rose from 1.30 to 5.67 specimens trap^{-1} night^{-1}. This indicates that crayfish abundance increased progressively. The noble crayfish was observed only in the 1999-2002 period and succumbed to growing pressure from both of the American species. Studies have excluded the existence of the crayfish “plague” caused by *Aphanomyces astaci* Schikora. The abundance of the signal crayfish, which was introduced in 1992, increased throughout the study period. The abundance of the spiny-cheek crayfish rose from 1999 to 2002. Although a slight decrease was noted in 2003, not until 2004 was a rapid decline noted in this species. A similarly dramatic decline has been noted since 2002 in the abundance of spiny-cheek crayfish in many other Polish waters. This was probably the result of an outbreak of an infectious disease particular to this species. The catch effectivity of signal crayfish (99.5% share of catches) in 2005 was 5.00 specimens trap^{-1} night^{-1} and was higher than the catch effectivity achieved with this species in Californian and Swedish lakes.

Key words: SIGNAL CRAYFISH (*PACIFASTACUS LENIUSCULUS*), SPINY-CHEEK CRAYFISH (*ORCONECTES LIMOSUS*), NOBLE CRAYFISH (*ASTACUS ASTACUS*), CRAYFISH TRAPPING, CATCH EFFECTIVITY

The signal crayfish, *Pacifastacus leniusculus* (Dana), inhabit the waters of the western coast of North America (Laurent 1989). Following preparations for and the development of an introduction program, this species was brought to Sweden in 1960 (Fürst 1977, Brinck 1983). It was successfully introduced to a part of lotic and lentic waters (Abrahamsson 1971, Ahlmer and Karlsson 1980) and cultivated in ponds

CORRESPONDING AUTHOR: Dr hab. Tadeusz Krzywosz, Instytut Rybactwa Śródlądowego w Olsztynie, Zakład Rybactwa Jeziorowego, ul. Rajska 2, 11-500 Giżycko, Tel./Fax: +48 (87) 4283882; e-mail: krzywoszt@infish.com.pl

(Abrahamsson 1972). From Sweden, the crayfish reached most European countries (Westman 1972, Ircing and Prášil 1980, Büttiker 1987, Huner 1987, Cukerzis 1989, Swärdson 1995). Attempts to introduce the signal crayfish to Poland from 1972 to 1979 (Kossakowski et al. 1978, 1983) were not very successful (Gondko and Girsztowtt 1987, Krzywosz et al. 1995). In 2000, a population of signal crayfish was noted in a lake in the Masurian Lake District (northern Poland). It was probably formed by escapees from a nearby cultivation facility, where signal crayfish were kept from 1979 to 1981 (Kossakowski, unpublished data, Krzywosz and Krzywosz 2001).

A second attempt to acclimatize the signal crayfish to Polish waters was undertaken in 1991-1992 when imported young crayfish were reared to maturity and successfully reproduced, and their offspring were reared under pond conditions with good results (Krzywosz 1994). In 1992, a segment of the signal crayfish from this period was introduced to Lake Pobłędzie (northern Poland); the crayfish from this lake are the subject of the study presented in the current paper. The aim of the studies was to establish the course of changes in the abundance of the catchable population of the three crayfish inhabiting the lake and the quantitative relationships among them.

The surface area of Lake Pobłędzie is 57.6 ha. The maximum depth is 15.4 m, and the mean depth is 5.9 m. Emerged vegetation occupies about 10% of the surface area, while relatively ample submerged vegetation grows to a depth of 5 m and occupies 21% of the lake's surface. During the summer period, the layer of well-mixed and oxygenated water that is suitable for crayfish reaches to depths of 5 m (Krzywosz and Krzywosz 2002). The surface area that can support crayfish life was estimated to be about 13.5 ha (Białokoz and Krzywosz, unpublished data).

The noble crayfish, *Astacus astacus* (L.), inhabited Lake Pobłędzie abundantly and was caught commercially until 1989, when, as a result of pesticides used in the direct lake catchment area, the entire population was killed off. In May 1992, 1100 one-year-old signal crayfish were released into the lake. In 1999, fishermen working on the lake reported that in addition to increasing numbers of signal crayfish, single specimens of noble and spiny-cheek, *Orconectes limosus* (Raf.), crayfish were observed. In monitoring catches begun in 1996 the noble and spiny-cheek crayfish were noted from 2000. The circumstances surrounding their appearance in the lake are not fully understood. The spiny-cheek crayfish were probably introduced by anglers, which frequently use this species as bait, or by fishermen who deployed gear in which this species had become entangled when it was used previously in other waters. Noble crayfish could have survived the poisoning incident during a periodic water outflow and then returned to the lake when higher waters returned.

Monitoring catches of the crayfish were conducted annually in the 1996-2005 period (except in 1998) using from 23 to 68 Evo traps baited with dead fish. They were set permanently along the same stretch of lake shore about 600 m in length and from a depth of l to 5 m. The majority of the specimens caught were released back into the lake. In the initial period (1996-2000) crayfish catches were conducted once per season, but catches were conducted from two to five times a year from 2001 (Table 1). The duration of them was from one to five nights. The analysis of changes in the effectivity of catches was based only on the results of catches made on the first night from mid August to the end of September. During this period, all of the species occurring in the lake comprising the catch population have reproduced and molted and have yet to mate again and carry eggs, which could affect their behavior and provoke varied reactions to the bait. Such disturbances were noted during catches conducted in May, June, and November (Table 1). In order to prevent the crayfish from escaping at dawn, all of the traps had to be brought up within the shortest time possible, which rendered it impossible to register the catch effectivity of each trap individually. The combined catches from a given night were divided by species groups, and abundance was determined for each. The STADGRAPHCS PLUS program was used to calculate the catch effectivity of the signal and the spiny-cheek crayfish within the study period.

Table 1 presents data on catch periods, the number of traps deployed and specimens caught, the average quantity of crayfish caught per trap and the percentage of each species in the overall catches. During the decade in which the study was conducted, the effectivity of catches conducted in August and September measured by the number of crayfish caught in each trap in one night increased from 1.30 to 5.67 specimens. The number of specimens caught in individual sampling events ranged from 30 to 329 specimens. The results of catches made in earlier and later months were characterized by decidedly lower catch effectivity and different proportions of the various species (Table 1). The noble crayfish was noted in control catches from 2000 to 2002 when its maximum share was 5.2% of total catches. The spiny-cheek crayfish was noted in the catches beginning in 2000. Its share of the catches increased until 2001, at which time it was close to 20% of the total catches at a catch effectivity of 0.78. In the 2001-2003 period, its share in the catches was similar, but it fell

TABLE 1

Catches of crayfish in Lake Pobłędzie in the 1996-2005 period

Parameter	Catch date																	
	1996	1997	1999	2000		2001			2002			2003			2004			2005
	29/30 August	29/30 August	29/30 August	4/5 Septem-ber	3/4 Septem-ber	25/26 Septem-ber	26/27 November	22/23 May	3/4 Septem-ber	14/15 Septem-ber	9/10 June	22/23 Septem-ber	28/29 May	16/17 June	25/26 August	6/7 Septem-ber	21/22 Septem-ber	7/8 Septem-ber
Trap (pieces)	30	23	28	59	40	60	*68*	*62*	60	60	*58*	50	*40*	*50*	52	58	58	39
Catches (pieces)	42	30	38	136	121	156	*89*	*75*	300	240	*194*	192	*18*	*37*	175	329	300	196
Catch effectiveness (specimens $trap^{-1}$ $night^{-1}$)																		
Signal crayfish	1.40	1.30	1.36	2.08	2.40	1.87	*1.12*	*0.81*	4.08	3.22	*1.05*	3.20	*0.40*	*0.66*	3.31	5.43	4.98	5.00
Noble crayfish	0.0	0.0	0.0	0.12	0.08	0.03	*0.10*	*0.02*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spiny-cheek crayfish	0.0	0.0	0.0	0.10	0.55	0.70	*0.09*	*0.39*	0.92	0.78	*2.29*	0.64	*0.05*	*0.08*	0.06	0.24	0.19	0.03
Total	1.40	1.30	1.36	2.31	3.02	2.60	*1.31*	*1.21*	5.00	4.00	*3.34*	3.84	*0.45*	*0.74*	3.37	5.67	5.17	5.03
Share in catches (%)																		
Signal crayfish	100.0	100.0	100.0	90.4	79.3	71.8	*86.4*	*66.7*	81.7	80.4	*31.4*	83.3	*88.9*	*89.2*	98.3	85.7	96.3	99.5
Noble crayfish	0.0	0.0	0.0	5.2	2.5	1.3	*7.9*	*1.3*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spiny-cheek crayfish	0.0	0.0	0.0	4.4	18.2	26.9	*6.7*	*32.0*	18.3	19.6	*68.6*	16.7	*11.1*	*10.8*	1.7	4.3	3.7	0.5

Figures in italics refer to catches that were omitted in the analysis of catch effectivity drastically (Fig. 1) to less than 5% in 2004 and 0.5% in 2005 along with a decrease in catch effectivity to 0.03 specimens trap^{-1} night^{-1} (Table 1).

The signal crayfish alone inhabited the lake in the 1992-1998 period. From the moment the noble and spiny-cheek crayfish appeared in the lake in 1999 until 2003, its share of the overall catches did not fall below 79%. In 2004, the share of the signal crayfish in the catches rose to more than 95%, and in 2005 it reached 99.5%. The catch effectivity of signal crayfish rose practically throughout the entire observation period and in 2005 it reached a value of 5.00 specimens trap^{-1} night^{-1} (Fig. 2).

Catch effectivity measured by the number of crayfish caught per trap is an approximate measure of the population density in an area inhabited by crayfish (Edsman and Söderbäck 1999). It is necessary that the crayfish compared are caught in similar periods and are in similar physiological states. The still relatively low water temperatures in May and June limit the activity of the indigenous crayfish as well as the signal crayfish. During this period, the females are either still carrying eggs or freshly hatched young and are very cautious, which further limits the catch effectivity of these species (Table 1). During this period, spiny-cheek crayfish exhibit increased activity related to spring mating (Ulikowski and Borkowska 1999) and occur frequently in catches (Table 1). In late fall, when water temperature falls substantially and overall catch effectivity decreases, noble and signal crayfish are far more active than spiny-cheek crayfish. This is probably related to the mating of these crayfish, which is in the final stages or has just concluded (Table 1). This is also why the comparison of the catch effectivity of the various species was made based only on results from late August and September, when all the species inhabiting Lake Pobłędzie have either completed or not yet begun mating and molting, are feeding intensively, and enter the traps in large numbers.

The increasing catch effectivity in Lake Pobłędzie indicates that the habitat conditions are advantageous for the signal crayfish, which was introduced in 1992 (Krzywosz and Krzywosz 2002) and has increased its abundance over time (Table 1). A similar initial increase in the abundance of the spiny-cheek crayfish was noted in the lake from 1999 until 2002 (Table 1). In 2003 the share of spiny-cheek crayfish in the overall catches decreased slightly, but in 2004 the population abundance of this species declined rapidly to an average of a 3.2% share of the overall catches. In 2005 this decrease was even more pronounced. The cause of this rapid decrease in the abundance of the spiny-cheek crayfish has not been identified precisely. Strong pressure

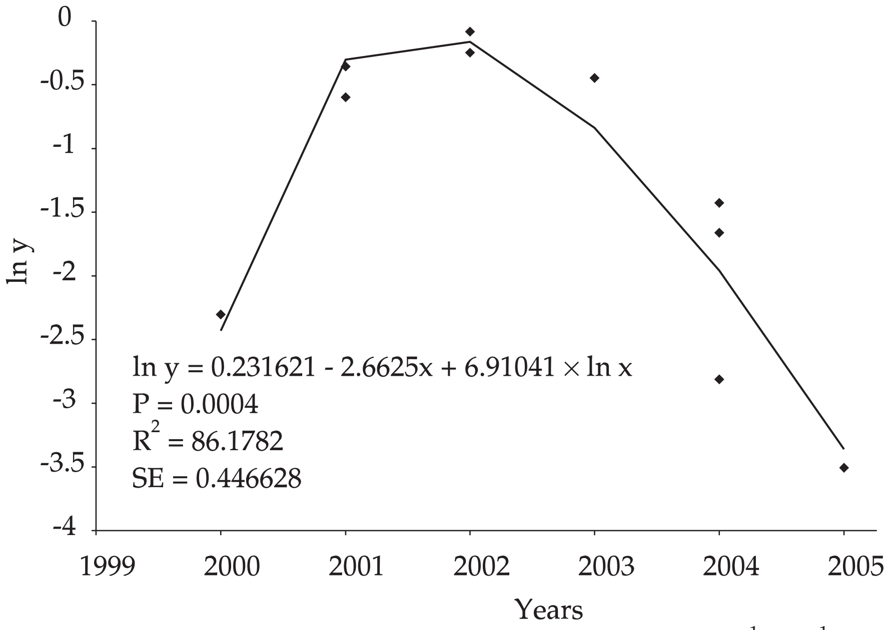

Fig. 1. Catch effectivity of spiny-cheek crayfish in Lake Pobłędzie (y = specimens $trap^{-1}$ $night^{-1}$, x = subsequent years).

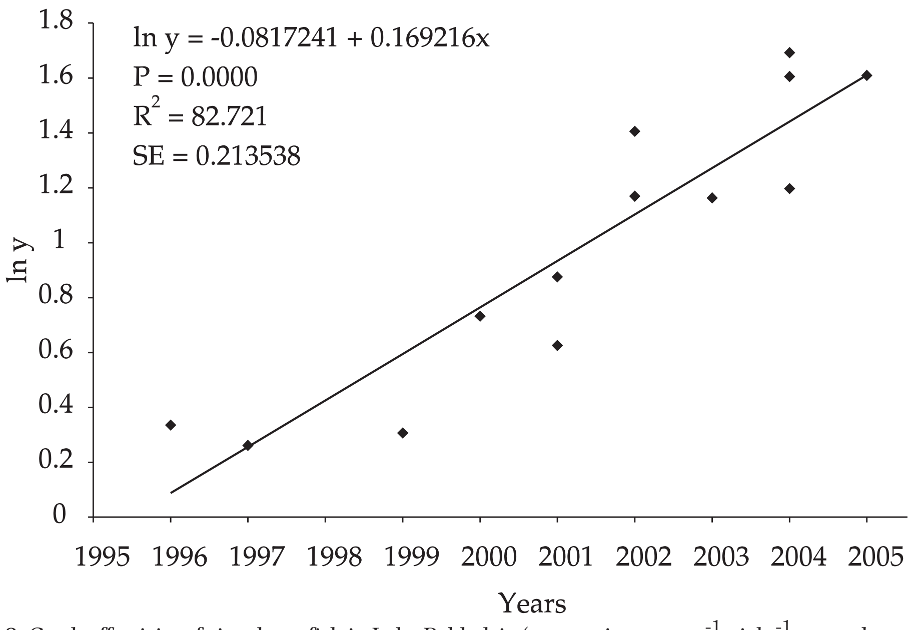

Fig. 2. Catch effectivity of signal crayfish in Lake Pobłędzie (y = specimens $trap^{-1}$ $night^{-1}$, x = subsequent years).

from the signal crayfish is not a possible cause. Until the collapse of the spiny-cheek crayfish population, the number of these two species, which inhabited the same area, was increasing. This indicates that competition between them for territory, food, and hiding places was still not strong. In Poland, widespread deaths of spiny-cheek crayfish were observed from 2002 in many different regions (Krzywosz 2004). The probable cause of this was an infectious disease specific to this species. This is also the most likely cause of the drastic decline in the numbers of the spiny-cheek crayfish population in the studied lake. In the last two years, the substantial decrease in spiny-cheek crayfish has been compensated for by an increase in the number of signal crayfish, the catch effectivity of which was close to a value of 5 specimens trap^{-1} night^{-1}.

The average catch of signal crayfish per trap in Lake Pobłędzie was higher than the results reported for two oligotrophic Californian lakes, where an average of about 3.5 specimens were caught per trap (Goldman and Rundquist 1977) or in Swedish lakes where 0.8-3.5 specimens were caught (Brinck 1977). Lake Pobłędzie is definitely more eutrophic (Krzywosz and Krzywosz 2002) than either the Californian or Swedish lakes. It is possible that the greater abundance of food in the Polish lake is advantageous for the greater density of signal crayfish even though the water quality is poorer, but still tolerated by this species.

Based on the results obtained to date, it is difficult to determine if the increase in the population abundance of the crayfish in the studied lake, particularly with regard to the signal crayfish, will continue. The similar catch effectivity levels obtained in the last two years may indicate that the population sizes of the crayfish that inhabit the lake may be approaching their maximums. This is especially so if the increase in poaching is taken into consideration. It is also difficult to predict the tempo at which the noble crayfish population will regenerate, and, following this possibility, which species will become the dominant or even the only species to inhabit the lake. Observations will be continued in the coming years and may provide some answers to the questions posed above.

Various situations are encountered in practice. In a small post gravel extraction lake in the Masurian Lake Distrct, the signal crayfish that was introduced there in 1979 succumbed after thirteen years under pressure from the spiny-cheek crayfish, which had also been introduced (Krzywosz et al. 1995). The signal crayfish, which has inhabited one of the Masurian District rivers for a quarter of a century, dominates decisively over the spiny-cheek crayfish, which has inhabited this same river for even longer

(Krzywosz and Krzywosz 2001). The co-inhabitation of the Galician, *Astacus leptodactylus*, signal, and spiny-cheek crayfish in Lake Geneva has not led to the decline or limitation of any of these species (Dubois et al. 1999).

The noble crayfish, which was the first species to inhabit the studied lake, was only noted in the study period from 1999 to 2002. In Poland, the phenomenon of the indigenous crayfish species being replaced by the spiny-cheek species was identified many decades ago (Leńkowa 1962, Kossakowski 1966). In Lake Pobłędzie, the noble crayfish also succumbed to pressure from two thriving, expansive species. The reason for this could not have been the crayfish plague caused by *Aphanomyces astaci* Schikora as tests conducted over a two-year period at the Department of Veterinary Hygiene excluded the possibility that the crayfish inhabiting this lake were carriers.

CONCLUSIONS

1. Lakes with trophic states that are not too advanced can provide the noble crayfish with advantageous conditions for living and developing even with the co-occurrence of the spiny-cheek crayfish.
2. The spiny-cheek crayfish population was probably significantly affected by a serious infectious disease. This has called into question the further domination of this species in Poland and also leaves open the issue of the effects of competition between this species and the signal crayfish in Polish lentic waters.
3. The noble crayfish is not able to withstand competition from these two American species even in waters that are free of the crayfish plague.

ACKNOWLEDGEMENTS

This work was conducted as part of project 3P04F 072 23 funded by the State Committee for Scientific Research.

REFERENCES

Abrahamsson S. 1971 – Density, growth and reproduction in population of *Astacus astacus* and *Pacifastacus leniusculus* in an isolated pond – Oikos, Copenhagen 22: 373-380.

Abrahamsson S. 1972 – The crayfish *Astacus astacus* in Sweden and the introduction of American crayfish *Pacifastacus leniusculus* – Freshwater Crayfish 1:27-40.

Ahlmer B., Karlsson A.S. 1980 – Der Signalkrebs im Regierungsbezirk – Jönköping. Mimeo, Sweden, 18 p.

Brinck P. 1977 – Developing crayfish populations – Freshwater Crayfish 3: 211-228.

Brinck P. 1983 – Sture Abrahamsson Memorial Lecture: An ecologist's approach to dealing with the loss of *Astacus astacus* – Freshwater Crayfish 5: 21-37.

Büttiker B. 1987 – Concerning crayfish in Switzerland – Freshwater Crayfish 7: 2-5.

Cukerzis J. 1989 – Rećnyje raki – Monografia, Vilnius, Mokslas.

Dubois J.A., Gillet Ch., Laurent P.? 1999 – Alien crayfish in Lake Geneva – Freshwater Crayfish 12: 801-810.

Edsman L., Söderbäck B. 1999 – Standardized sampling methodology for crayfish – The Swedish protocol – Freshwater Crayfish 12: 705-713.

Fürst M. 1977 – Introduction of *Pacifastacus leniusculus* (Dana) into Sweden: methods, results and management – Freshwater Crayfish 3: 229-247.

Goldman C.R., Rundquist J.C. 1977 – A comparative ecological study of the California crayfish *Pacifastacus leniusculus* (Dana), from two subalpine lakes (Lake Tahoe and Lake Donner) – Freshwater Crayfish 3: 51-80.

Gondko R., Girsztowtt Z. 1987 – A new crayfish species inhabits Polish waters: *Pacifastacus leniusculus* Dana – Kieleckie Studia Biologiczne 4: 133-142 (in Polish).

Huner J.V. 1987 – Status of the crayfish transplantations – Freshwater Crayfish 7: 29-34.

Ircing F., Prášil O. 1980 – *Pacifastacus leniusculus* Dana – Rybářstvi 10: 233.

Kossakowski J. 1966 – Crayfish – PWRiL, Warsaw (in Polish).

Kossakowski J., Mnich M., Kossakowski G. 1978 – The first introduction of the crayfish *Pacifastacus leniusculus* Dana into Polish waters – Freshwater Crayfish 4: 195.

Kossakowski J., Mnich M., Kossakowski G. 1983 – An attempt to raise juvenile crayfish *Pacifastacus leniusculus* Dana – Freshwater Crayfish 5: 555-556.

Krzywosz T. 1994 – The introduction of the crayfish *Pacifastacus leniusculus* Dana into Polish waters – Rocz. Nauk. Pol. Zw. Węd. 7: 81-93 (in Polish).

Krzywosz T. 2004 – It this the retreat of the spiny-cheek crayfish? – Komun. Ryb. 5: 21-23 (in Polish).

Krzywosz T., Chybowski Ł., Ulikowski D. 1995 – *Pacifastacus leniusculus* in Poland – history, current status, and perspectives – Komun. Ryb. 1: 5-8 (in Polish).

Krzywosz T., Krzywosz W. 2001 – Preliminary observations of an American crayfish *Pacifastacus leniusculus* (Dana) population at a new site in the Mazurian Lake District – Arch. Pol. Fish. 9(2): 273-278.

Krzywosz T., Krzywosz W. 2002 – Observations of the crayfish *Pacifastacus leniusculus* (Dana) in a lake in the Eastern Suwałki Lake District – Arch. Pol. Fish. 10(2): 255-267.

Laurent P.J. 1989 – Les crevisses dans le monde – L'Astaciculteur de France 21: 9-17.

Leńkowa A. 1962 – Research on the crayfish *Astacus astacus* (L.), the causes of its disappearance, and the measures for preservation and restitution in connection with the spreading of the American species, *Cambaruas affinis* Say – Ochr. Przyr. 28: 1-38 (in Polish).

Swärdson G. 1995 – The early history of signal crayfish introduction into Europe – Freshwater Crayfish 8: 68-77.

Ulikowski D., Borkowska I. 1999 – Mating of crayfish *Orconectes limosus* Raf. spring or autumn? – Komun. Ryb. 2: 4-6 (in Polish).

Westman K. 1972 – The population of the crayfish *Astacus astacus* in Finland and the introduction of the American crayfish *Pacifastacus leniusculus* Dana – Freshwater Crayfish l: 41-55.

Received – 25 May 2005

Accepted – 10 January 2006

STRESZCZENIE

OCENA ZMIAN LICZEBNOŚCI POPULACJI ŁOWNYCH TRZECH GATUNKÓW RAKÓW W JEZIORZE POBŁĘDZIE (PÓŁNOCNA POLSKA)

Celem badań było poznanie charakteru i dynamiki zmian liczebności populacji łownych raka sygnałowego, *Pacifastacus leniusculus* (Dana), raka pręgowatego, *Orconectes limosus* (Raf.) i raka szlachetnego, *Astacus astacus* (L.), współbytujących w jeziorze Pobłędzie. Połowy kontrolne raków, przy użyciu pułapek typu „Ewo", prowadzono w latach 1996-2005 (tab. 1). Przyjęto, że efektywność połowu mierzona ilością złowionych raków na pułapkę w ciągu nocy może być przybliżoną miarą ich zagęszczenia. Rak pręgowaty do 2002 r. powiększał swoją liczebność, a jego udział w połowach ogólnych sięgał 19,6%. W 2004 r. w jeziorze nastąpił gwałtowny spadek liczebności raka pręgowatego, pogłębiony jeszcze w 2005 r. (rys. 1), co zakłóciło obserwacje wzajemnej konkurencji pomiędzy dwoma amerykańskimi gatunkami.

Rak sygnałowy znalazł w jeziorze dobre warunki i stale powiększał swoją liczebność (rys. 2). W 2005 r. jego udział w połowach ogólnych wynosił 95,5%, a efektywność połowów – 5,0 osobników pułapka^{-1} noc^{-1} i była wyższa od notowanej dla tego gatunku w jeziorach kalifornijskich i szwedzkich. Rak szlachetny występował w latach 1999-2002, a jego maksymalny udział w połowach ogólnych sięgnął 5,2%. Nie sprostał on konkurencji dwóch ekspansywnych gatunków amerykańskich. Badania występujących raków nie wykazały nosicielstwa „dżumy" raczej.