Andrzej KOMPOWSKI, Carlos ROJAS

Fish biology
Stock monitoring

**ON SOME BIOLOGICAL CHARACTERS OF *PARACHAENICHTHYS*
GEORGIANUS (FISCHER, 1885) (*PISCES*, *NOTOTHENIOIDEI*,
BATHYDRACONIDAE) FROM THE SHELF WATERS
OF SOUTH GEORGIA (ANTARCTICA)***

**O NIEKTÓRYCH CECHACH BIOLOGICZNYCH *PARACHAENICHTHYS*
GEORGIANUS (FISCHER, 1885) (*PISCES*, *NOTOTHENIOIDEI*,
BATHYDRACONIDAE) Z WÓD SZELFOWYCH
POŁUDNIOWEJ GEORGII (ANTARKTYKA)**

Department of Biological Marine Resources, Agricultural University of Szczecin, Poland

The present paper evaluates the relevance of otoliths, vertebrae and other osseous elements to the age determinations; the age composition of stock, growth rate, length-weight relationship, condition, stage of gonads maturity as well as the age at first maturity were investigated, too.

INTRODUCTION

Pretty numerous examinations of fish from the suborder *Notothenioidae* have included mainly fishes of commercial importance, being focused first of all on members of two families: *Nototheniidae* and *Channichthyidae*. The remaining families from this suborder, among them *Bathydraconidae*, are still poorly known. *Parachaenichthys georgianus* is the most common species from this family in the region of South Georgia, therefore deserves the more detailed investigations.

The paper demonstrated is the third one dealing with the species discussed - being performed in the Department of Biological Marine Resources in the Agricultural University of Szczecin. The former works: Kompowski 1992, and Rojas and Kompowski 1994, dealt with the food and feeding as well as morphology and osteology, respectively. The objective

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of present paper is to examine, basing on fairly large material, the age composition of stock, growth rate, length-weight relationship, condition and length at first maturity of *Parachaenichthys georgianus* off South Georgia. Moreover, some data on *Parachaenichthys charcoti* (Vaillant 1906) from the shelf waters of King George Island and Elephant Island are presented, too.

MATERIALS AND METHODS

Fishes be studied were captured by the bottom trawl of R/V „Profesor Siedlecki” during the antarctic summer 1987/88. The sites of catches were distributed pretty regularly on the shelf of island - their depths were ranging within 72-420 m. A total of 788 individuals sampled at random were measured to 1 mm (total length). 314 specimens were analyzed in details, involving the weight estimation with the accuracy to 1 g, using the rolling-resistant scale, collecting the otoliths and sex determination as well as the determination of gonads maturity stage, according to 8-stage Maier's scale. Additionally, 141 specimens were frozen for further study in the laboratory on land. Age of 314 individuals has already been determined on the vessel in the period of 3-4 weeks after the capture. Next otoliths were collected from the frozen specimens in Poland, moreover different osseus elements were made for scientific use in order to compare the age determination (vertebrae, opercular bones, frontals, bones of pectoral girdle and hyoid arch). All these anatomical parts were whitened by H₂O₂.

The age determination from otoliths and bones were being performed under the stereo microscope in various magnifications - against the dry background or in water (sometimes with the addition of glycerine). The objects were scanned in the transmitted or incident light - in this case against the black background. Attempts were made to increase the readability of structures studied through alizarin-staining (also other dyes were used) or through heating with a burner. However no effects were obtained. Otoliths read on the vessel were under examination on the land again. The age was determined in a total of 451 specimens.

When classifying fishes to the length classes, their length was made even - to the nearest full number of centimetres.

Additionally, age of 29 out of 30 specimens *Parachaenichthys charcoti* collected in the shelf waters of King George Island and Elephant Island in the period on 5-11 February, 1988 at the depth of 91-279 m, were determined using the otoliths.

RESULTS

Age determination

Length of fish studied

Fig. 1* presents length of *Parachaenichthys georgianus* occurring in the catches performed by bottom trawl in the shelf of South Georgia in Dec.1987/Jan.1988. Fish of length ranging from 11.8 to 59.9 cm were observed. Some groups of fish of similar length could be

Fig. 1. Length frequency distribution of *Parachaenichthys georgianus* caught at the different depth zones of the South Georgia shelf waters

clearly separated. The first group, including specimens 12-19 cm long was characterized by distinct, very sharply expressed modal value, amounted to 16 cm. Next one, being clearly distinguished, too, possessed two modes: 24 and 27 cm. The successive group consisted of individuals 28-36 cm long with mode of 33 cm. Fourth group was also possible to separate - slighter distinctly than former ones. The modal value of this group amounted to 41 cm. Bigger specimens were represented in small numbers with any mode being found out.

The description above concerned the summary curve including fish from all depths they were being captured. More detailed analysis was based on classification of fish sampled according to 3 depths zones: 150 m, 150-250 m and 250 m showed that the small-

* The figure was employed also in the A. Kompowski's paper: Food and feeding behaviour of *Parachaenichthys georgianus* (Fischer 1885) and *Parachaenichthys charcoti* (Vaillant 1906) (Pisces, Bathydraconidae). Acta Ichth. Pisc., 22,1, 1992 : 15-29.

est fish (12-19 cm) occurred mainly in the shallower waters since 150 m, as well - although less numerous, in the zone of 150-250 m. Big fish of length over 45 cm were found, too, first of all in the shallowest and moderately deep waters. At the largest depths medium-sized (20-40 cm) fish were observed almost exclusively.

Over a half of fish examined were captured in the shallowest zone - 150m.

The analysis above allowed to draw a conclusion on existing four age groups of average lengths equal to the modal lengths demonstrated above.

Fig. 2. Otoliths and bones of *Parachaenichthys georgianus* with the visible zones of growth
A - otolith (external side), total length of fish - 33.9 cm; B - Segment of front vertebra,
total length of fish - 41.7 cm; hyaline zones recognized as annual marked by small crosses;
additional zone marked by ring; C - operculum; D - quadratum.

Observation on otoliths

The exterior of most otoliths possesses grooves running parallel to the margins, particularly well visible in the dorsal lobe of otolith (Fig. 2A). The grooves were especially easy to observe in the inclined light, without a submersion in water. After being submerged after some minutes - in the place of grooves, zones built by hyaline substance were revealed. Fish from the first length group (12-19 cm) possessed two such zones; individuals from the second one (22-28 cm) - three; specimens from the third group - four zones and from fourth group - five zones. In the otoliths of fish bigger than 45 cm, 5-11 hyaline zones were stated. The best readability was found in otoliths being just sampled from fish (on the vessel). Several years of otoliths dry storage markedly made their readability decrease - being subjected to numerous cracks. It was presumably resulted from the low content of mineral substances (CaCO_3) in the otoliths and high content of organic substances - shrinking when dried.

Observation on other skeletal elements

Vertebrae. Vertebrae from the frontal and back part of the vertebral column were examined. The surface of vertebrae trunks is biconcave, with pretty large crevice. It made the stereo microscope scanning more difficult, because the object of observation was never seen sharply as a whole. Therefore bigger vertebrae were cut longitudinally (Fig. 2B). Both on the frontal and back surface of otoliths trunks hyaline and opaque zones were detected. Number of hyaline zones in vertebrae in general was convergent with their number on otoliths. The additional hyaline zones made the readings difficult. The readability of vertebrae was improved temporarily by moistening with water.

The width of annual increments in vertebrae often increased along with the distance from the centre (instead of decrease) - what could be a reason of some confusion. The similar phenomenon was found out on the flat bones studied (Fig. 2B, C and D).

Other skeletal elements. Among being examined: operculum, interoperculum, hyomandibulare, coracoideum, matapterygoideum, frontale and quadratum - the most readable were operculum and quadratum (Fig. 2C and D). On the flat surfaces of these bones the hyaline and opaque zones were legible pretty clearly - the closer to the edge of bones the more distinct they were. However in the central part of the bones being thick and spongy, zones of growth were illegible. Thus they could not be employed in the age determination.

Interpretation of observations of otoliths and other elements of skeleton

The comparative review of different elements recording seasonal biological rhythms of *Parachaenichthys georgianus* revealed almost always the existence of hyaline zone on their margins. The comparison of the width of this hyaline zone and adherent from the inside the opaque zone with the width of previous zones indicated for the lack of „pseudohyaline margins” in understanding of North 1988b. It is particularly well illustrated in the pictures

demonstrating otolith, operculum and quadratum (Fig. 2A, 2C and 2D). In the picture of vertebra (Fig. 2B) it is not seen, as a matter of fact, the distinct hyaline zone on the margin, however the last increment, consisted of opaque substance, is very wide.

Therefore the conclusion may be drawn that hyaline zone on the otoliths margins as well as on other structures of *Parachaenichthys georgianus* was set up in the period directly previous to the date of capture - performed in December/ January. Thus the hyaline zones was set up in the species studied in the antarctic spring (October, November, December). It seems to be in close agreement with results obtained by North (1988b), carried out his studies on seven species from the families *Nototheniidae* and *Harpagiferidae*, as well as with examinations on *Notothenia rossi* by Barrera-Oro and Casaux (1992).

The spawning of *Parachaenichthys georgianus* takes place in April and first larvae occur in the end of May (Burchett 1983; Burchett et al. 1983). Therefore it seems to be reasonable to accept as a „date of birth”, according to rules generally assumed for the south hemisphere, as the 1, July.

Thus fish from the first length group (Fig. 1) 12-19 cm long in the moment of capture were not fully two years old - notwithstanding two hyaline zones possessed on the otoliths. Considering that fact they were classified to the first age group. Similarly the remaining fish examined were treated - it means when classifying to particular age groups the first hyaline zone situated in the central part of otolith, was disregarded. Fairly large distance of this zone from the centre indicates for presumably later setting up comparing to next hyaline zones, and its formation may be associated with the change of life style from pelagic - being characteristic for larvae and postlarvae (Efremenko 1983; North 1988a; North and Ward 1989; North and Murray 1992) into benthic one characteristic for older fish (Kompowski 1992). It is of interest, that Ślósarczyk (1987) observed in otoliths of postlarvae of five species from the family *Channichthyidae*, occurring as a by-catch in the krill catches performed in Scotia Sea during the antarctic summer, the hyaline zone has not been set up yet.

Age composition of stock and rate of linear growth

Table 1 presents the age composition of population studied, obtained from otoliths examination. The age estimations were broaden, converting them proportionally into all 788 specimens measured.

Young specimens were predominating in the stock. Individuals from the first age group were the most abundant (35.6%). Specimens from II and III age group contributed 19.7 and 27.5% to the whole sample, respectively. The number of older age groups were considerably lower. The oldest fish, 57.0 cm long belonged to X age group.

Table 1

Age composition and mean length of age groups, annual increments of length and mean weights of age groups of *Parachaenichthys georgianus* captured in the shelf waters of South Georgia during the antarctic summer 1987/88

×		Age groups										
		I	II	III	IV	V	VI	VII	VIII	IX	X	Total
Age composition	n*	280 (102)	155 (118)	217 (149)	87 (46)	21 (13)	12 (10)	10 (8)	4 (3)	1 (1)	1 (1)	788 (451)
	%	35.6	19.7	27.5	11.0	2.7	1.5	1.3	0.5	0.1	0.1	100.0
Mean length of fish in age groups (cm)	×	16.12	25.39	32.65	40.37	48.14	53.83	55.90	56.50	55.00	57.00	×
±σ	×	1.28	1.47	2.11	2.30	2.68	4.28	2.02	-	-	-	×
Annual increments (cm)	×	16.12	9.27	7.26	7.22	7.77	5.69	2.07	0.60	-	-	×
Mean weights of fish in age groups (g)	×	10.8	52.6	126.1	264.0	487.1	718.6	819.4	850.4	-	-	×

* in brackets the real number of otoliths read is given.

Table 1 demonstrates also the mean length of individuals in particular age groups. The average length of I group was amounted to 16.2 cm, what is convergent with the length occurring in the first apex (peak) of the curve in Fig. 1. The mean length of the II age group - 25.4 cm - occurs in the medial part of slightly two-apex the second peak. The average lengths of III and IV age groups as well are pretty precisely convergent with the corresponding modal length on the curve. It seems to be interesting that annual increments till the VI age group decrease rather feebly and only the difference between mean length of VI and VII age groups is markedly lower than difference between mean lengths of V and VI age group (Fig. 1).

Such course of growth excludes the use of von Bertalanffy model because it assumes the exponential decreasing of annual increments along with the age.

Length-weight relationship, condition and rate of weight growth

The relationship between total length and total weight of *Parachaenichthys georgianus* is presented in Fig. 3. It can be expressed by the following formula: $w = 0.00068 \cdot L^{3.48}$, where w = weight of full fish in g; L = total length in cm. If in the formula described instead of

L the mean length of age groups are placed, weights corresponding to them will be obtained (Table 1).

The Fulton's coefficient of condition demonstrates another way of the presentation the weight-length relationship. It is calculated by the following formula:

$$k = \frac{w100}{L^3}$$

where k = condition coefficient; w = total weight of fish; L = total length of fish in cm. In order to find out if the condition coefficient changes along with the fish length, it was calculated separately for 272 individuals of different length.

Fig. 3. Length-weight relationship of *Parachaenichthys georgianus* from the South Georgia shelf waters.

Fig. 4. Dependence of condition coefficient (by Fulton) on total length of *Parachaenichthys georgianus* from the South Georgia shelf waters

As can be seen from the Fig. 4, condition coefficient increases along with the length of fish investigated, with the lowest found k value of 0.183 and the highest one - 0.517. The condition coefficient length relationship can be expressed as follows: $k = 0.0655 L^{0.486}$, where L - total length, k - condition coefficient.

Sex and maturity

Table 2 presents the occurrence of specimens with gonads at different stages of development, according to Maier's scale, among the *Parachaenichthys georgianus* captured. Sex and stage of maturity determination was broadened, converted them proportionally into all 788 specimens measured. The most of fish studied - as much as 90.1% - there are juveniles with gonads being still at I stage of maturity. Their sex has not been possible to determine yet. Among the remaining fish males contributed 4.3% and females - 5.6% to the whole sample. Almost 40% of them consisted of individuals with gonads at II stage of maturity. The remaining fishes at III - V stage of maturity undoubtedly would have been able to take a part in the spawning in approaching season (if they had not been caught). Therefore the population studied consisted mostly of juveniles.

Table 2

Number of *Parachaenichthys georgianus* specimens with gonads at different stages of maturity according to Maier's scale in the catches of R/V „Profesor Siedlecki” in the region of South Georgia during the antarctic summer 1987/88

Sex		Stages of gonads maturity					Total
		I	II	III	IV	V	
Males	n*	-	15 (7)	6 (3)	13 (6)	-	34 (16)
	%	-	43.7	18.8	37.5	-	100.0
Females	n*	-	15 (9)	10 (6)	17 (10)	2 (1)	44 (26)
	%	-	34.6	23.1	38.5	3.8	100.0
Immature	n*	710 (196)	-	-	-	-	710 (196)
	%	100.0	-	-	-	-	100.0
Total	n*	710 (196)	30 (16)	16 (9)	30 (16)	2 (1)	788 (238)
	%	90.1	3.8	2.0	3.8	0.3	100.0

* in the brackets the real number of fish investigated is given

Fig. 5. Contribution of immature specimens, males and females in particular length classes of *Parachaenichthys georgianus* from the South Georgia shelf waters

Certain research workers (among others Kock 1981; 1986; 1989) assume conventionally the length at first maturity as such a length of fish at which 50% of specimens has already been mature and 50% - being still immature. If we assume that these individuals of *Parachaenichthys georgianus* with sex not being possible to determine (I stage of maturity) are immature, whereas all remaining

fishes are mature, therefore the length at getting mature is likely to be estimated (Fig. 5). The smallest male identified was in the length class of 38.0 - 39.9 cm, while the smallest female identified - in 40.0 - 41.1 cm class. In the 40.0 - 41.9 cm length class immature specimens contributed 55.6%, whereas in the next one: 42.0 - 43.9 cm only 47.1% to the all fishes. Thus we can assume 43 cm as an average length at getting maturity by *Parachaenichthys georgianus* from the stock investigated.

Among specimens over 50 cm females predominated, however considering the small number of big fish in the material studied, any conclusion should be drawn on different life span of both sexes.

Some data on *Parachaenichthys charcoti* (Vaillant, 1906)

In the catches performed by bottom trawl in the first half of February in the shelf of islands King George (depth - 91-125 m) and Elephant (105-279 m) few specimens of *Parachaenichthys charcoti* occurred. It was nearly entirely juveniles 12 - 14 cm and 20 - 26 cm long with gonads at I stage of maturity. Their sex was not possible to determine. The sex of one specimen only - the biggest one 40 cm long - was determined, being a male with go-

nads at III stage of maturity according to Maier's scale.

Table 3

Number of *Parachaenichthys charcoti* specimens in particular length classes and age groups. King George Island and Elephant Island shelf. February 1988

Total length (cm)	Age groups				
	I		II		V
	King George Is.	Elephant Is.	King George Is.	Elephant Is.	King George Is.
12		2			
13	2	3			
14		3			
...					
20			2	1	
21			2	2	
22			6	1	
23			1	1	
24			1		
25					
26				1	
...					
40					1
Total	2	8	12	6	1

Otoliths of these fish, slightly different in shape from otoliths of *Parachaenichthys georgianus*, have become fairly readable after several minutes' soaking in the water. Employing similar rules as in the *Parachaenichthys georgianus* treatment, individuals of *Parachaenichthys charcoti* of length ranging within 12 - 14 cm were classified to the I age group, specimens 20 - 26 cm long - to II one. The biggest individual 40 cm long belonged to V age group (Table 3) (Food of these fishes is presented in Kompowski's work, 1992).

DISCUSSION

Parachaenichthys georgianus is a pretty common species off South Georgia, however being of hard commercial importance. In the period of materials collecting, e.i. in the end of December, 1987 and in the beginning of January, 1988 in the experimental catches of R/V „Profesor Siedlecki” being performed by the bottom trawl in the shelf of South Georgia, *Parachaenichthys georgianus* contributed only 0.51% to the total weight of all fish

captured, taking the 9th place in catches (Kompowski 1988). In the fiord of Cumberland East Bay the species discussed is much more common during the summer in the south hemisphere. As Burchett, 1983, states in the catches performed by nearshore setting up trammel nets, *Parachaenichthys georgianus* was on the second position in the respect of frequency of occurrence and on the fourth when the biomass was concerning (following *Notothenia rossi* juv., *Chaenocephalus aceratus* and *Notothenia neglecta*). *Parachaenichthys georgianus* occurred in the catches by the trammel nets in the Cumberland East Bay fiord from October to March - with peak of catches falling on February - then being followed by rapidly decrease (Burchett 1983). The most specimens of *Parachaenichthys georgianus* caught by the cited author were mature - and because the spawning takes place in April, so the author concludes that adults of *Parachaenichthys georgianus* gather at first in the shallow waters of fiords, then migrate to the deeper waters for spawning. These observations by Burchett are in agreement with ours which showed that the biggest fishes were found mainly in the shallowest and moderate - deep waters. Their feeble contribution in the catches performed by R/V „Profesor Siedlecki” in the open sea can be explained by fact of gathering in summer mature specimens of *Parachaenichthys georgianus* in the fiords and shallow waters of shelf.

Examinations of Burchett et al., 1983 indicated for April as a period of *Parachaenichthys georgianus* spawning, with the mature females ready for spawning (IV stage in Everson's scale) being found from February to April. Mature males (IV stage) were met from January to May. According to Permitin (1973) eggs of *Parachaenichthys georgianus* is benthic with a synchronous development. The egg diameter, according to Burchett et al., 1983, was amounted to 3.9 mm. The first larvae according to these authors, have already occurred in the end of May. In the end of antarctic winter (September - November) in the Cumberland East Bay fiord, the length of these larvae ranged within 11 - 35 mm of SL (North 1988a; North and Murray 1992). The main food in the winter period of larvae 11 - 17 mm long was *Copepoda* (North and Ward 1989). Efremenko (1983) recorded the length of larvae (being described by him) caught as 18.5 - 55.5 mm of SL, in the period from August to January in the Scotia Sea, close to South Georgia. According to Kock 1981, in January and February northwards from Joinville Island and Elephant Island *Parachaenichthys charcoti* 47 - 54 mm of SL long were captured. Considering the above information, age of specimens examined by us from the length class 12 - 19 mm of T.L. (mode - 16 mm) corresponds to ca 10 - 14 cm cm of S.L. - see Rojas and Kompowski 1994), basing on otoliths study, were classified to the I age group, amounted to ca 19 months in the period of catch (December - January) - counting from the date of hatch in the end of May and ca 18 months if we conventionally assume as a „date of birth” the date of 1, July. As was mentioned before, hyaline zones - called often as „winter” zones or rings, occurred

on the otoliths of *Parachaenichthys georgianus* not in winter - but in spring - what is confirmed by study carried out by North (1988b) on other species of the antarctic fish.

Parachaenichthys georgianus is a fish of pretty fast growth, reminding in the growth rate in some first years *Chaenocephalus aceratus* and *Pseudochaenichthys georgianus* (compare in: Gubsch 1980; Kock 1981; Chojnacki and Palczewski 1981; Kompowski 1990 a and b).

Length-weight relationship being obtained in the present paper, is markedly different in the dimension of exponent when comparing to Burchett's et al., 1983. It could result from materials they investigated including mainly big mature fish over 40 cm long, whereas our materials constituted mainly immature fish - less than 40 cm long. As can be seen from unit 3.3. the condition coefficient grows along with the length of *Parachaenichthys georgianus* - what confirms the change of relationship length-weight along with the length.

The interesting question is the ratio of length at which *Parachaenichthys georgianus* matures, to the maximum length attained by this species. Kock (1989) made the detailed analysis of this question in fishes from the suborder *Notothenioidei*, the length at first maturity (defined like in unit 3.4.) expressed as a percent of the maximum length - so the highest length observed in fishes of this species. In the summary given by Kock, length at first maturity (L_{50}) constituted from 33.9% (females of *Champscephalus gunnari*, South Georgia) to 79.3% (males of *Chaenocephalus aceratus*, South Georgia) of maximum length. If we assume $L_{max} = 59.5$ cm based on Burchett et al., 1983 results (recorded as maximum observed length of *Parachaenichthys georgianus* as 59.1 cm) as well as on our own observations (59.5 cm), therefore the length at maturity (43 cm) will be constituted 72.3% of L_{max} - thus *Parachaenichthys georgianus* is similar in this view to *Chaenocephalus aceratus*, *Chionodraco rastrospinosus* and *Gobionothus gibberifrons* from different regions of Antarctica.

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Andrzej KOMPOWSKI, Carlos ROJAS

O NIEKTÓRYCH CECHACH BIOLOGICZNYCH *PARACHANNICHTHYS GEORGIANUS* (FISCHER, 1885) (PISCES, NOTOTHENIOIDEI, BATHYDRACONIDAE) Z WÓD SZELFOWYCH POŁUDNIOWEJ GEORGII (ANTARKTYKA)

STRESZCZENIE

Badane ryby zostały pobrane losowo z połowów włokiem dennym przeprowadzonych przez r.v. „Profesor Siedlecki” na szelfie Południowej Georgii podczas lata antarktycznego 1987/88.

W celu zbadania składu wiekowego i szybkości wzrostu populacji przeanalizowano krzywą Petersena (rys. 1), dokonano obserwacji pod binokulem otolitów, kręgów oraz niektórych kości płaskich (rys. 2). Do odczytów wieku najlepsze są otolity i kręgi. Strefy szkliste na tych strukturach składają się nie podczas zimy antarktycznej, ale wiosną (październik, listopad, grudzień).

W stadzie dominowały młode, niedojrzałe osobniki z I, II i III grupy wieku (tab. 1 i 2). Szybkość wzrostu badanego gatunku jest dość znaczna (tab. 1) - porównywalna z szybkością wzrostu *Chaenocephalus aceratus* i *Pseudochaenichthys georgianus*. Zależność długość-masa wyraża się wzorem $w = 0.00068 L^{3.48}$ (rys. 3). Współczynnik kondycji (Fultona) wzrasta znacznie wraz z długością ryby (rys. 4). Ryby z badanej populacji osiągają dojrzałość płciową przeciętnie przy długości 43 cm (rys. 5).

Wyniki odczytów wieku z otolitów 29 osobników *P. charcoti* z rejonu Elephant Is. i King George Is. podano w tabeli 3.

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Author's address:

Prof. Tit. D.Sc. Andrzej Kompowski, Ph.D. Carlos Rojas
Department of Biological Marine Resources
Agricultural University of Szczecin
Kazimierza Królewicza 4, 71-550 Szczecin Poland