ACTA ICHTHYOLOGICA ET PISCATORIA (2008) 38 (2): 103–111 DOI: 10.3750/AIP2008.38.2.04

THE EFFECTIVENESS OF GLASS EEL STOCKING IN THE VISTULA LAGOON, POLAND

Iwona *PSUTY* * and Bohdan *DRAGANIK*

Sea Fisheries Institute in Gdynia, Poland

Psuty I., Draganik B. 2008. The effectiveness of glass eel stocking in the Vistula Lagoon, Poland. Acta Ichthyol. Piscat. 38 (2): 103–111.

Background. Eel recruitment and catches have decreased drastically throughout Europe since the beginning of the 1960s (recruitment) and the 1980s (catches). Until the end of the 1990s, European eel, *Anguilla anguilla*, the highest priced fish, was the basis of the fishery in the Polish part of the Vistula Lagoon. The lagoon was stocked with glass eel from 1970 to 1994 with the aim of enhancing the stock of this species. Due to political and economical changes after 1989, national stocking funds were stopped. The aim of the presently reported study was to estimate the effectiveness of stocking glass eel in the Vistula Lagoon, with regard to the limited reliability of official landings data.
Materials and Methods. Eel catches in the Polish part of the Vistula Lagoon were reconstructed from landings statistics. Corrections of Polish landings were only based on grey literature request; political and socio-economical changes were explained in personal reviews with fishermen and fishery inspectors. The effectiveness of the stocking was estimated with the simplified method of calculating the accumulated biomass of fish from stocking with the assumed, constant coefficients *F* and *M* (fishery and natural mortality, respectively). The sensitivity analysis of F and M was estimated using the input of different parameters.
Results. Changes in human history resulted in different biases in official landings statistics. The change in fishermen cooperative organisation and the martial law in Poland, during the period of 1981–1984, resulted in significant changes of the eel official landings. The reconstructed catches in this period (1980–1985) do not exceed 30% of the total exploitable biomass of the reserve for silver eel escapement, even under intensive exploitation. With assumed *M* and *F*, the exploitable stock biomass increased sharply to the peak value during the 10 years of stocking. Uncertainty concerning M for the first year of stocked eel results in a difference in the estimated biomass as high as 700 t.
Conclusions. Under great uncertainties and lack of "hard data", social science methodologies could help to estimate basic parameters for assessment models. Glass eel stocking at the Vistula Lagoon was effective both for the enhancement of the eel population and maintenance of an intensive eel fishery.

Keywords: transitional waters, transboundary area, *Anguilla anguilla*, stock assessment

INTRODUCTION

European eel, *Anguilla anguilla* (L.), which occurs in the coastal marine and inland waters of Europe, has been a highly valued fish for centuries. Archaeological studies indicate that the inhabitants of the western Baltic Sea coastal region made targeted eel catches as early as 5500 BCE (Schmölcke et al. 2006). Eels still continue to be heavily exploited. The only current official source of the annual eel landings from European inland and marine waters is the fishery statistics published in FAO yearbooks. Although experts (Moriarty and Dekker 1997, Dekker 2003) agree that these data are low-grade, they show that the eel landings have a declining trend. In contrast to fish whose reproductive biology is well known, the causes of declining eel biomass remain subject to hypothesis and conjecture (Knights 2003). For the past 20 years, the number of eel migrating from oceanic waters to the continental Europe has decreased (Dekker 2003), and experts believe that the principle reason for this is anthropogenic stress (namely: overexploitation, hydroengineering and pollutions) that has led to reductions in the silver eel that undertakes spawning migrations (escapement) (for review see among others: Dekker 2003, Wysujack 2007). According to Moriarty (1996), exploitation has practically no impact on reproductive success. Castonguay et al. (1994) postulated the decline in recruitment of both European and American eels is caused by unidentified factors linked to the circulation of oceanic waters.

Polish eel landings reported from marine waters are mostly from the Vistula- and Szczecin lagoons. Landings

* Correspondence: Dr Iwona Psuty, Morski Instytut Rybacki w Gdyni, Kołłątaja 1, 81-332 Gdynia, Poland, phone: +48 58 73 56 218, fax: +48 58 73 56 110, e-mail: *iwcia@mir.gdynia.pl*

have been registered since the end of the nineteenth century. Prior to the First- and Second World Wars, the Vistula Lagoon was stocked with eels from the Elbe estuary in Germany. The mean annual eel landings from the Vistula Lagoon during the 1933–1939 period exceeded 350 t. Exploitation fluctuations occurred when catches in the Polish part of the lagoon increased from 100 t after World War II to 250 t in 1956, after which a decline occurred. This worried the authorities (eel was exported at this time and was one of the sure sources of hard currency) and prompted them to stock these waters. However, the stocking program in the Polish transboundary area was not possible to put in operation until 1970.

Long-term observations by the present authors indicate that registered landings in the statistics differ substantially from the actual eel biomass removed from the population. Available statistical information should be regarded as the minimum catch, which has an undetermined relationship to the actual quantity of annual eel catches.

The aim of the study was to determine the effectiveness of glass eel stocking conducted during the 1970–1994 period.

MATERIALS AND METHODS

Study area. The Vistula Lagoon is a brackish water basin at the southern coast of the Baltic Sea, with a surface area of 838 km^2; 39% of this area is located within the Polish borders (Fig. 1). The physical conditions of the basin for fish assemblage habitats are variable, including salinity (ranging from 0.1 PSU in the south-western part to 4.5 PSU near the Polish–Russian border), intensity of water, bottom sediment mixing, and the content of organic matter in the water (for review, see Pliński 2005). The catchment area of 23 871 km^2 and the volume of water inflowing from the main rivers (Pregoła, Pasłęka, and Elbląg) ensure that water exchange occurs in this basin every six months. The only permanently open passage from the lagoon into the Baltic Sea is the Pilava Strait (approximately 400 m wide). The lagoon's shallowness (mean depth of 2.7 m), polymixing, and variable hydrology render it susceptible to invasions of alien species. In the past two decades, the ecosystem has become host to species such as *Marenzelleria neglecta* in the benthic zone, *Palaemon elegans, Rhithropanopeus harrisii* in the epibenthic zone, and *Cercopagis pengoi* in the plankton (Ezhova and Spirido 2005, Jażdżewski et al. 2005; to name just a few).

Stocking data. The amount and characteristics of stocked eels were taken from SFI (Sea Fishery Institute in Gdynia) archives and cross-referenced with archives from the Regional Sea Fisheries Inspectorate in Gdynia (Table 1).

Catch data. The basis for reconstructing real catches from official landings statistics (Table 2) was field interviews with fishermen from all of the fishing bases in the Polish part of the lagoon and local fisheries inspectors. Using methodology taken from social science, the results were triangulated with other sources of data:

• Open publication in Polish journals, periodicals, and electronic media;

• Presentations and protocols from the Polish–Russian mixed commission on Vistula Lagoon and working groups on fish stock assessments;

• Unpublished annotations of previous lagoon scientists who worked at the Sea Fisheries Institute in Gdynia.

The Russian landings were considered accurate due to the lack of information concerning the nature of bias in that case. Data and additional information on eel fishery were given by FGU (Federal'noe Gosudarstvennoe Uprawlenie= Federal State Agency) Zapbalrybvod in Kaliningrad, in agreement with the Polish–Russian Treaty on the Vistula Lagoon fishery management rules.

Mortality coefficients. The state of fisheries and environmental variables influencing the natural mortality were assumed to be non-variable in the series of years analyzed. The mortality coefficients F and M (fishery and natural mortality, respectively) are constant during an interval of one calendar year with changes in mortality rates between the years. It was assumed that the natural mortality in the first year after the introduction was the highest of glass eel mortality and then decreased to almost negligible. These assumptions were made based on experience and unpublished observation only and should be considered as the "best guess" in the situation due to lack of suitable data. The sensitivity analyses with different values of M were made to show the influence on stocked biomass assessments (Table 3).

Based on knowledge of MLL (minimum landing length) and mean length-at-age data (Table 4), it was assumed that, during the first four years, the stocked eels were not subject to fishery mortality. MLL until 1986 was 45 cm. TL after that year increased to 50 cm. These length classes comprised 75% of 5 to 6 age groups (Tomasz Nermer, unpublished). Then, the fishery coefficients for age groups 5 to 8 were assumed to be ranked by increasing values, according to mean length-at-age and gear selectivity.

The cessation between yellow and silver stage was assumed for the age group 10 (years after introduction). As the eels are known to not mature simultaneously, not all of the silver stage eels are the same age, the fishery mortality coefficient for 10-year-old fish and older was assumed at the level of $F = 0.91$. The analysis was done for 17 age groups after introduction, based on age-readings from fishery catches where 99% of individuals were found to be from 5 to 16 years old. The share of males in the population was assumed to be almost zero. Direct sampling of unsorted catches during the period of 1954–1986 (Jerzy Filuk, unpublished), 1991–2001 (Wladyslaw Borowski, unpublished) and 2006–2007 (Tomasz Nermer, unpublished) confirmed that, in the length class under 27 cm TL, males were found incidentally.

Stock biomass estimation. The relationship between the number of eels stocked in the lagoon in subsequent years and the number of introduced eels that survived until the following calendar year was estimated with the equation

$$N_{t+1} = N_t \cdot e^{-Z}$$

where: N_{t+1}, the number of fish in the population that survived until the end of the year for which estimations were

Table 1

Glass eel stocking data for the Vistula Lagoon (numbers in brackets indicate reared eel)

Year	Weight [kg]	Number of individuals	Mean ind. length [cm]	Mean ind. weight [g]	Comments
1970	1630	4 890 000	6.0	0.33**	Glass eel
1971	800	2 400 000	No data	0.33**	Glass eel
1972	1150	3 450 000	7.0	0.33**	Glass eel
1973	800	2 400 000	No data	0.33**	Glass eel
1974	2140	6 420 000	10.5	0.33**	Glass eel
1975	1600	4 800 000	No data	0.33**	Glass eel
1976	1500	4 500 000	6.6	0.33**	Glass eel
1977	1500	4 500 000	7.5	0.33**	Glass eel
1978	1760	5 280 000	7.2	0.33	Glass eel
1979	2590	7 770 000	7.6	0.39	Glass eel
1980	1050	3 150 000	7.5	0.38	Glass eel
1981	2030	6 090 000	7.9	0.43	Glass eel
1982	1630	4 890 000	7.6	0.4	Glass eel
1983	800	242 000	20.9	13.5	Reared eel import from Italy *
1984	1150	3 450 000	6.0	No data	Glass eel
1985				No stocking	
1986	1880	5 640 000	7.2	0.31	50% mortality during transport
1987	2000	6 000 000	7.3	0.32	Glass eel
1988	1000	3 000 000	6.3	0.27	Glass eel
1989	300	900 000	7.2	0.31	Glass eel
1990				No stocking	
1991	400	1 200 000	No data	0.33**	Glass eel
1992	500	1 500 000	No data	0.33**	Glass eel
1993				No stocking	
1994	300	900 000	No data	0.33**	Glass eel

* 50% 5-year-old and 50% 6-year-old.
** no data on field measurements, mean wieght for model.

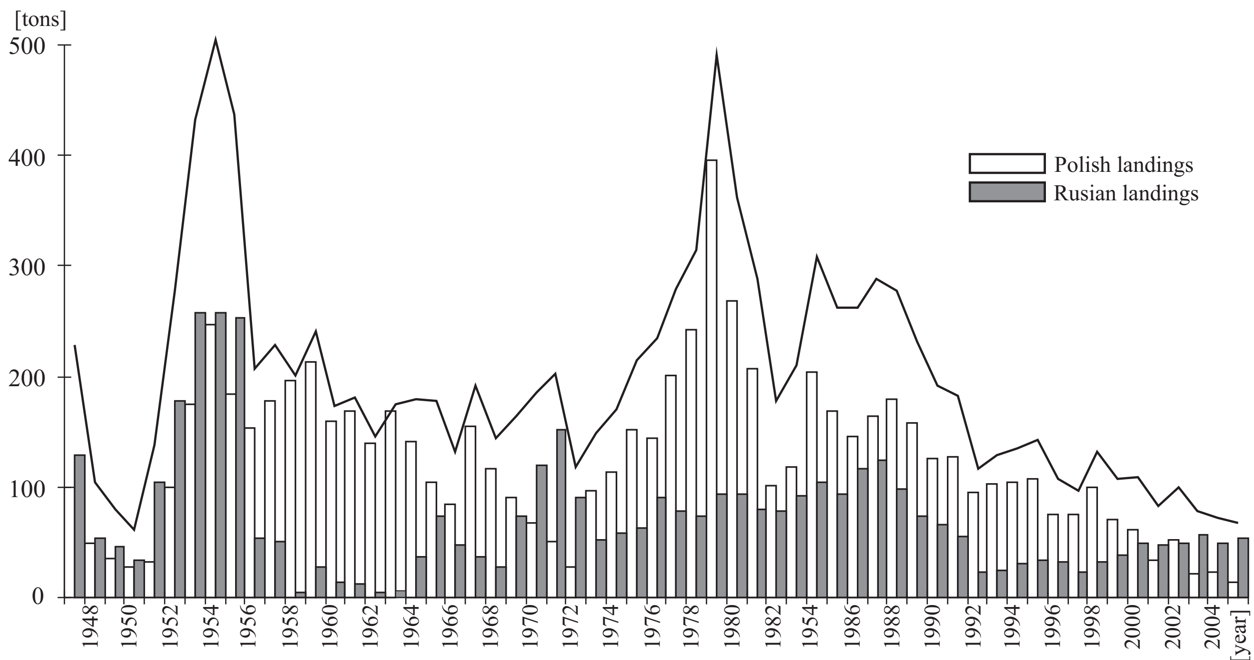

Fig. 2. Official eel landings for the Vistula Lagoon within 1948–2006 (Polish- and Russian data combined)

Table 2

Official and reconstructed eel catches from Polish part of Vistula Lagoon

Year	Official landings	Reconstructed catches	In plus coefficient*
1970	90.4	126.56	0.4
1971	67.0	93.8	0.4
1972	50.3	70.4	0.4
1973	27.9	39.1	0.4
1974	96.0	134.4	0.4
1975	112.8	157.9	0.4
1976	151.7	212.4	0.4
1977	144.2	201.9	0.4
1978	201.3	281.8	0.4
1979	242.0	338.8	0.4
1980	396.1	396.1	0
1981	268.5	350	Fixed value
1982	207.2	350	Fixed value
1983	100.7	350	Fixed value
1984	118.6	350	Fixed value
1985	204.7	327.5	0.6
1986	169.0	270.4	0.6
1987	145.7	233.1	0.6
1988	164.3	262.9	0.6
1989	179.5	287.2	0.6
1990	157.8	252.5	0.6
1991	126.2	201.9	0.6
1992	127.3	203.7	0.6
1993	94.7	151.5	0.6
1994	103.4	165.4	0.6
1995	103.6	165.8	0.6
1996	108.0	172.8	0.6
1997	75.5	120.8	0.6
1998	74.4	119.0	0.6
1999	100.3	160.5	0.6
2000	70.1	112.2	0.6
2001	60.6	96.9	0.6
2002	34.2	54.7	0.6
2003	51.5	82.3	0.6
2004	21.2	34.0	0.6
2005	23.3	37.3	0.6
2006	14.1	22.6	0.6
2007	10.6	17.0	0.6

* coefficient increasing official landings to estimated catch (based on personal reviews).

made; N_t , number of fish in the population at the end of the preceding year for which estimates were made; Z – total mortality ($F + M$).

The mean weight of age groups was taken from data using the von Bertalanffy equation, based on eel sampling during 2006–2007 (Tomasz Nermer, unpublished), (Table 4).

RESULTS

Probably due to its transboundary status the Vistula Lagoon has been treated as the internal marine waters by Polish authorities. This had consequences on special regulations regarding the fisheries work permit issued by the Marine Administration. Another consequence was the lack of funding for eel stocking. The fish stocking was planned centrally by the Ministry of Agriculture and Rural Development. Unfortunately the internal marine waters were at that time under jurisdiction of another Ministry. The inland waters in Poland were stocked as early as 1952, and glass eels were first released into the lagoon in 1970. Due to the currency problems (the Polish złoty was not exchangeable in western Europe), the glass eels were imported with the exchange for adult eels taken from cooperatives catches. The Russian administration never participated in the cost of stocking at the Vistula

Table 3

Coefficients of mortality used for calculations and sensitivity analysis

Year in lagoon	M		F	
	assumed	Used for comparison	assumed	Used after Dekker 2000 for "elsewhere"
1	1.0	1.5/ 2.0/2.3	0	0
2	0.7	–	0	0
3	0.07	–	0	0
4	0.04	0.138	0	0
5	0.04	0.138	0.01	0.10
6	0.04	0.138	0.28	0.10
7	0.04	0.138	0.43	0.10
8	0.04	0.138	0.59	0.10
9	0.04	0.138	0.59	0.10
10	0.04	0.138	0.59	2.87
> 10	0.04	0.138	0.91	2.87

Lagoon. The stocking was continued until 1994, with the exception of 1985, 1990, and 1993 (Table 1). After 1989, the funding rules had to change, and fishermen agreed to take some part in the stocking costs, but not long after, the price for glass eel sharply increased and the stocking stopped definitely.

Eel landings in the Vistula Lagoon showed extensive fluctuations during the post-war period (Fig. 2). The largest landings were recorded in the 1950s, while the smallest were the most-recent ones. A similar decrease in the catches occurred at the end of the 1960s. The sharp increase in the catches started at the next decade with the peak of ~ 400 t in 1980. Stabilisation at the level of 300 t lasted until the beginning of the 1990s, and then the landings showed a decreasing trend until now.

The reliability of official landings data changed during the analysed period. Until 1989, Poland followed the rules of centrally planned economy. This means that most of the landings came from fisheries cooperative units. The management of those cooperatives tended to minimize the landings plans for each worker for each year. In reality, the fishermen treated these plans as an undesirable obligation, because the price of eel was higher in the open market. Usually, the landing plan for eel was fulfilled as soon as possible, after which time landings were not recorded in cooperative statistics. Our interviews estimated the amount of unofficial catch as high as 30%–40% of official landings for the period of 1970–1980 and 70%–100% for the most recent period (1984–present). Another problem with the official landing statistics were some outliers existing within 1980–1984. Extremely high eel landings were recorded in 1980, which may be explained by the concurrent reorganization of the cooperative units and establishment of new cooperative enterprises. It is very likely that the fishermen from those new cooperatives were more interested in achieving good official results. The next four years, during the period of 1981–1984, was a time of martial law in Poland, which was announced after several strikes in state-own enterprises. Although the fishermen enquired about this period did not remember any special restrictions in the transboundary area, it is commonly known that there were limitations with the existing economy rules. The authorities drastically limited bank cash withdrawals and the goods to be bought were very scarce. Foodstuffs such as meat, sugar etc. were rationed (coupons). Food manufacturers or providers were commonly asked to sell their products "under the table" without official statistics. The most unstable political situation was observed in the period of 1981–1984. Finally, by the end of the 1990s the centrally planned economy, managed by the communist party, was forced to yield ground to the free market economy of the democratic society. It is clear that under the circumstances described above the landings from 1981–1984 could not be treated as equally reliable as the values representing preceding- or subsequent years. Based on relative stability of landings after 1984, we assumed the fixed value of 350 t as the Polish landings in the period mentioned above (Table 4).

Table 4

Mean length and weight-at-age in the catches (Nermer, unpublished)

Age group	Mean length	Mean weight
4	47	255
5	51.6	292
6	56	367
7	62.7	528
8	70.1	742
9	76.7	1069
10	80.4	1218
11	82.7	1293
12	83.7	1263
13	87.5	1509
14	91	1821
15	91	1728
16	94.7	1982

The estimated biomass of the eel population from the stocking performed in the 1970–1994 period reached the highest value in the mid 1980s (Fig 3). Based on assumed mortalities (*F* and *M*) values, the peak of "exploitable biomass" (fish 5 years old and older) exceeded 1000 t during the period of 1982–1985. Then, the biomass decreased below 500 t in 1989. After a slight recovery during the period of 1990–1994, the exploitable biomass (resulting from stocking) dropped down to zero in 2007.

The sensitivity analysis using different values of *M* and *F* showed that the model results depended more on assumed *M* values, especially on mortality in the first

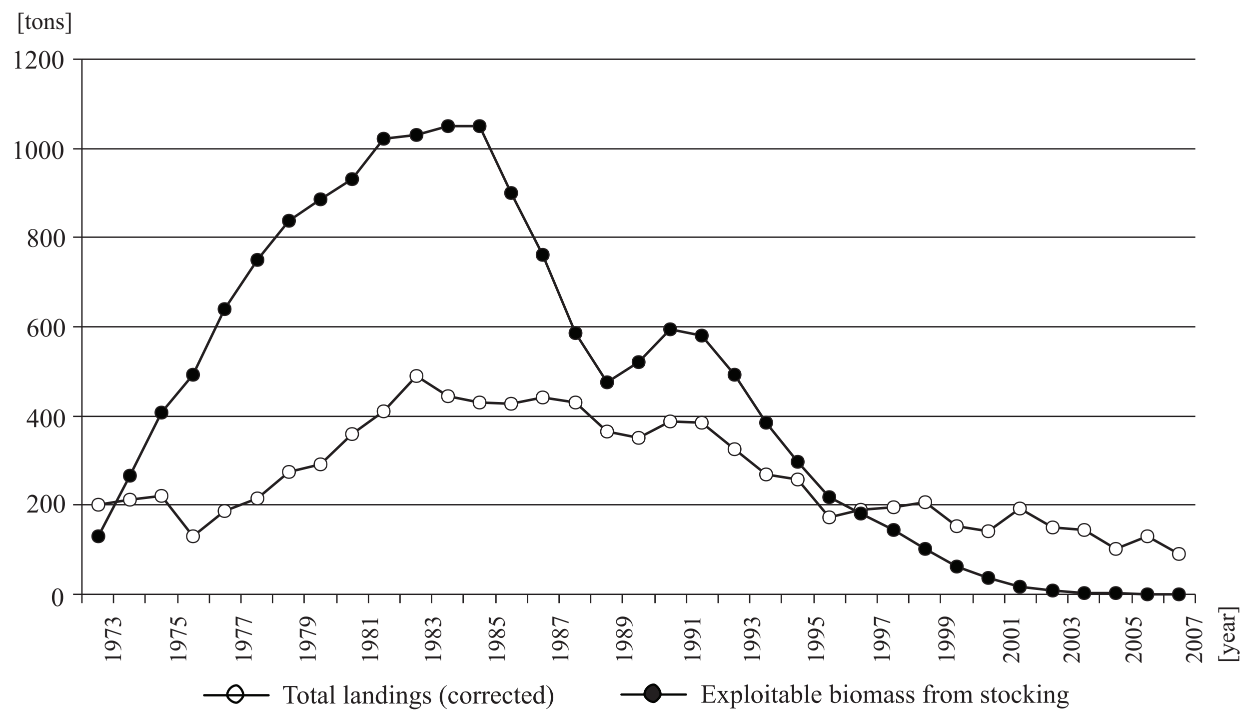

Fig. 3. Biomass estimates of stocked eel and caught eel in the Vistula Lagoon

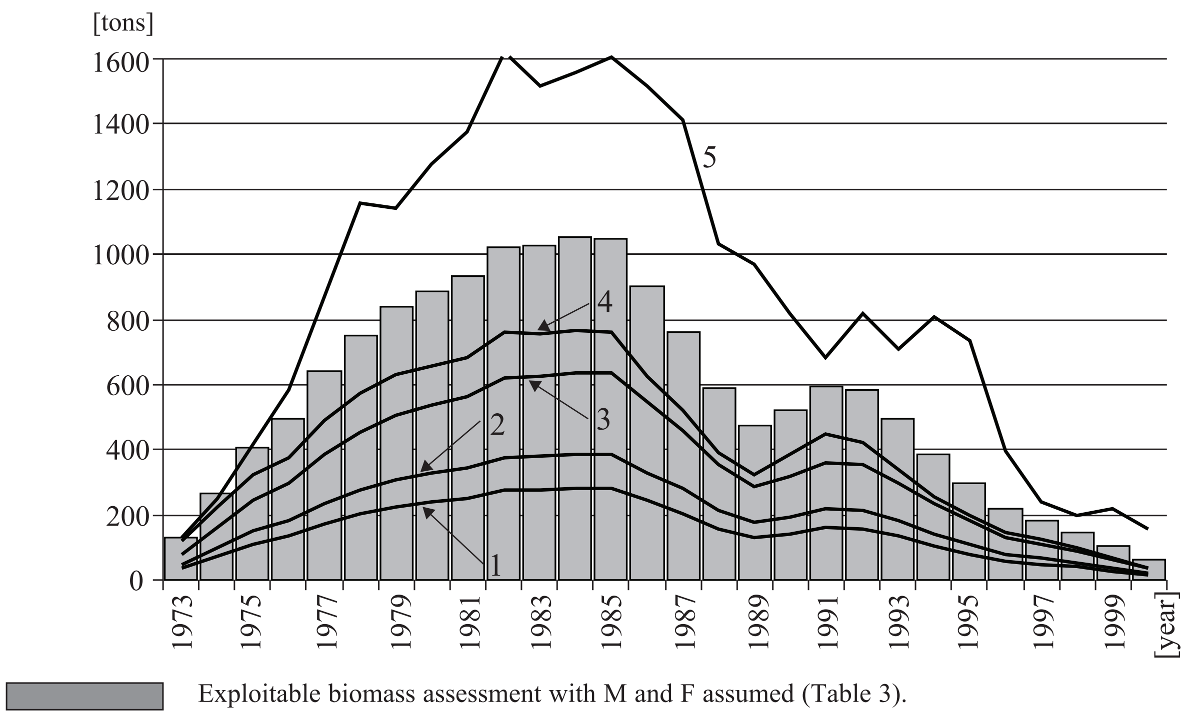

Fig. 4. Sensitivity analysis of exploitable eel biomass for alternative *M* and *F* values

1: M for the first year of life in the lagoon = 2.3; 2: M for the first year of life in the lagoon = 2.0; 3: M for the first year of life in the lagoon = 1.5; 4: M for the fish older than 3.y.o = 0.14; 5: F after Dekker (2000).

year in lagoon. Changes in that parameter (Fig. 4) resulted in major changes in exploitable biomass. The change of M_1 between 1 and 2.3 yielded different estimates below 700 t in 1984. A change in the M value for the fish older than 3 years resulted in a slight decrease in the exploitable biomass. The employment of the F values proposed by Dekker (2000) affected the increase of exploitable biomass to the peak values under 1500 t.

DISCUSSION

The Vistula Lagoon has an impressive eel stocking tradition. In the period prior to the Second World War, the Vistula Lagoon was stocked with eels measuring from 20 to 30 cm TL, obtained from the naturally migrating schools caught in the mouth of the Elbe River (Sakowicz 1930). This stocking program was initiated as early as the beginning of the twentieth century (1910–1915) with 6 t of bootlace eels. Based on the Prussian catch statistics, the effects of stocking were most apparent in the 1920s—landings increased four times after 10 years from the first stocking. During this same period, Polish scientists agreed that the most appropriate eel for stocking Polish inland waters would be the glass eel, mainly due to the high percentage of males in the eel stocks at the Elbe River (Sakowicz 1930). The second stocking action commenced in 1925 and continued until 1941 (Röhler 1929, 1942). The effect of this was apparent until the beginning of the 1960s, when Filuk (1965, 1984) observed a drastic decrease in eel catches. This could also be linked to decreases in the continental recruitment patterns for glass eel via the Danish Straits, as there was no monitoring of recruitment near the Gdańsk Bay area.

According to Filuk and Draganik (1980), economical stocking effectiveness is determined by the proportion of the weight of glass eel introduced into the lagoon compared to the weight of catches made during nine years following the stocking, which was 1 : 120. Comparing the size of annual stocking (number of fish) with the weight of the annual landings after several years had passed, Draganik (1998) concluded that the highest relation between the number of fish introduced into the lagoon and the weight of the landings occurs after six years. The weakness of this approach was that it ignored the effect on subsequent catches of the accumulation of eels that were stocked successively into the lagoon each year.

Reconstructed eel landings from the Vistula Lagoon were coherent with the biomass of the exploitable part of stocked eels with the assumed mortalities coefficients. The balance between exploitable biomass and landings suggests "the wall" in the fishery. It means that the catches were dependant on glass eel stocking, but only to the level of some 400 t per year. Much bigger exploitable biomass estimated during the 1980s did not influence catches. The fishery showed decreasing landing trends only after decreased number of stocked eels and the collapse of stocking in some years.

The eel fishery in the Vistula Lagoon used mainly fykenets in the limited time of the year. The most efficient period was the end of August and September. The physical capacity of the lagoon's area did not allow an increase in fykenet effort beyond some limits. It was the reason to regulate direct locality of each fisher's equipment, especially in the area close to the Russian border. Under assumptions about stability of the mortality coefficients throughout the years of the analysis, results indicated the reserve for preserving eel population and potentially silver eel escapement even under intensive fishery. The very basic condition is to enhance population at the high level of 1.5–2 t of glass eel each year, with its mean under the level of the physical capacity of the fishery fleet.

Not until the 1990s did scientists suggest that glass eels transported from western European waters might be less capable of locating the shortest route to the spawning grounds in the Sargasso Sea (Westin 1998). This would mean that stocking with glass eel may not effect the size of the spawning population; thus, the hypothesis that increasing the glass eel stocking will lead to higher reproductively is doubtful. However, the case of the higher eel biomass originated from glass eel stocking would be the basis for a healthy spawning silver eel population; the way to enhance it should be planned with uncorrupted stocking and, after some 10 years, to regulate the fishery efforts in a peak period of silver eel migration (August–October).

It should be remembered that there is uncertainty with regard to the mortality coefficient in the calculations. The examples of change in mortality coefficients showed that the lack of data concerning natural mortality, especially in the first year of life after stocking, is crucial for assessment. Such observations should be practiced each year when stocking to reach inter-annual variability that is potentially very high. The range of natural mortality given for bigger eels varied considerably among different studies. Based on the tagging study at the Polish part of the Vistula Lagoon, Borowski et al. (1997) estimated mortality at $M = 0.56$ (including migration to the Russian part of the Lagoon, where tag return rates were very weak). According to Sparre (1979), the value for eels from 35 cm to 69 cm in length ranged from 0.1 to 1.33 (including the migration effect). Rassmussen and Therkildsen (1979), recognizing that the value of natural mortality is strongly correlated with mean fish weight, reported that, for fish in the 38–54 cm length class, it is about 0.17. The commonly used value in recent models is $M = 0.14$, as proposed by Dekker (2000), but the same author found that the natural mortality could be negligible (Dekker 1989). We assumed natural mortality for fish older than 3 years was at a low level ($M = 0.04$), but changed for $M = 0.14$, which resulted in rather small assessment changes in comparison with uncertainties concerning the first year of life in the lagoon.

Another question is the ecological capacity of the lagoon's water and its tributaries to provide a food basis for enhancement of the eel population. Eels in the Vistula Lagoon are mainly benthivorous (Hlopnikov 1992), but they could be considered to be omnivorous. The shallowness and polimixia created very good conditions for bottom fauna and mobile epifauna. In the Polish part, some direct observations suggest that eels mainly fed on mobile epifauna, especially on the newly settled, but common and abundant, species, *Rhithropanopeus harrisii* (cf. Jażdżewski et al. 2005). In addition, in the case of bad conditions, eels could settle in thousands of canals built between the Vistula River and its arms (Fig. 1). The Vistula Lagoon ecological capacity to maintain even enormous abundant populations has been demonstrated by a commonly known case of black cormorant breeding colony near Kąty Rybackie. No one could predict the success of the colony initially amounting to some 5000 pairs in 1995 and attaining the level of 12 000 pairs, on the beginning of the 21st century (Kopciewicz et al. 2003). This was possible because of good feeding conditions for ichtchyophagous animals, even in the area with intensive fishery.

The eel population resulting from stocking, capable of maintaining the fishery, definitely ended at the beginning of the 21st century. Some landings, however, still exist. The question is the origin of the present population. There are two potential sources: natural recruitment and eels from inland waters stocking. Unfortunately, it is not possible to monitor the natural recruitment via the Pilava Strait. The monitoring at the rivers of the Polish coast of the southern Baltic Sea confirmed that juvenile eels are entering rivers even under present conditions (Wojciech Pelczarski, personal communication). The Great Masurian Lakes system, which have been stocked for many years, is cut-off by numerous dams without fish passages at the Łyna and Pregoła rivers. The only known stocking program that could influence the Vistula Lagoon waters is provided at Drużno Lake (near Elbląg) and adjacent waters by anglers associations, but the number of eels is not high (5–10 kg of glass eel each year).

The knowledge concerning the real level of catches is more of a social science than a biological one. Until recently, naturalists treated the official landing values as unreliable, though they are the only source of "hard data" about the fishery exploitation. In this situation, the basic data concerning fishery mortality are very uncertain. Eel is a flag species, as there is a lack of suitable "hard data", and economic issues have always influenced its catches and the reliability of landings statistics. With such qualitative data, the models would more accurately reflect real changes in the environment.

REFERENCES

Borowski W., Dąbrowski H., Grzebielec R. 1997. Results of the tagging of eel of the Vistula Lagoon. Bulletin of Sea Fisheries Institute **1997** (141): 33–54.

Castonguay M., Hodson P.V., Moriarty C., Drinkwater K.F., Jessop B.M. 1994. Is there a role of ocean environment in American and European eel decline? Fisheries Oceanography **3**: 197–203.

Hlopnikov [Khlopnikov] M.M. 1992. Piŝevye otnošenia bentosoâdnyh ryb Vislinskogo zaliva. [Trophic interactions among benthivorous fish in Vistula Lagoon.] Pp. 165–188. *In*: Ekologičeskie rybohozâjstvennye issledovania v Vislinskom zalive Baltijskogo morâ. [Ecological investigations on the fisheries management in Vistula Lagoon on the Baltic Sea.] AtlantNIRO, Kaliningrad. [In Russian.]

Dekker W. 1989. Death rate, recapture frequency and changes in size of tagged eels. Journal of Fish Biology **34**: 769–777.

Dekker W. 2000. A Procrustean assessment of the European eel stock. ICES Journal of Marine Science **57**: 938–947.

Dekker W. 2003. Did lack of spawners cause the collapse of the European eel, *Anguilla anguilla*? Fisheries Management and Ecology **10**: 365–376.

Draganik B. 1998. Polish fishery research in the Szczecin and Vistula lagoons. Pp. 60–95. *In*: Proceedings of the Symposium "Freshwater fish and the herring populations in the Baltic coastal lagoons; environment and fisheries". Sea Fisheries Institute, Gdynia.

Ezhova E., Spirido O. 2005. Patterns of spatial and temporal distribution of the *Marenzelleria* cf *viridis* population in the lagoon and marine environment in the southern Baltic Sea. Oceanological and Hydrobiological Studies **34** (Suppl. 1): 209–226.

Filuk J. 1965. Węgorz (*Anguilla anguilla* L.) z Zalewu Wislanego. [Eel (*Anguilla anguilla* L.) from the Vistula Lagoon.] Prace Morskiego Instytutu Rybackiego w Gdyni **A 13**: 101–113. [In Polish.]

Filuk J. 1984. Eel from the Vistula Firth—its past, present and future state. Bulletin of Sea Fisheries Institute **3–6** (83–86): 13–18.

Filuk J., Draganik B. 1980. Ocena efektywnosci zarybiania Zalewu Wiślanego węgorzem szklistym w latach 1970–1978. [The estimation of effectiveness of glass eel stocking in the years 1970–1978.] Studia i Materiały Morskiego Instytutu Rybackiego w Gdyni B **47**: 5–33. [In Polish.]

Jażdżewski K., Konopacka A., Grabowski M. 2005. Native and alien malacostracan Crustacea along the Polish Baltic coast in the twentieth century. Oceanological and Hydrobiological Studies **34** (Suppl. 1): 175–205.

Knights B. 2003. A review of the possible impacts of long-term oceanic and climate changes and fishing mortality on recruitment of anguillid eels of the Northern Hemisphere. The Science of the Total Environment **310**: 237–244.

Kopciewicz P., Stempniewicz L., Nitecki C., Bzoma S., Olszewska A. 2003. Changes in the breeding success of great cormorants *Phalacrocorax carbo sinensis* in the expanding colony at Kąty Rybackie (N Poland), effect of phenology and age of subcolony. Vogelwelt **124**: 127–130.

Moriarty C. 1996. The decline in catches of European elver 1980– 992. Archives of Polish Fisheries **4**: 245–248.

Moriarty C., Dekker W. 1997. Management of the European Eel. Fisheries Bulletin **15**: 1–110.

Pliński M. 2005. The hydrobiological characteristics of the Polish part of the Vistula Lagoon: a review. Oceanological and Hydrobiological Studies **34** (Suppl. 3): 287–294.

Rassmussen G., Therkildsen B. 1979. Food, growth, and production of *Anguilla anguilla* L. in small Danish stream. Rapports et procés-verbaux des réunions, Conseil International pour l'Exploration de la Mer **174**: 32–40.

Röhler E. 1929. Die Aalfangergebnisse in der Küstenfischerei. Fischerei-Zeitung **32** (19): 241–244.

Röhler E. 1942. Die Beschaffung von Aalbesatzmaterial in zwei Kriegsjahren. Fischerei-Zeitung **45** (3): 15.

Sakowicz S. 1930. Węgorz; biologia i produkcja. [Eel, biology and production.] Muzeum Przemysłu i Rolnictwa, Warszawa. [In Polish.]

Schmölcke U., Endtmann E., Klooss S., Meyer M., Michaelis D., Rickert B.-H., Rößler D. 2006. Changes of sea level, landscape and culture: A review of the south-western Baltic area between 8800 and 4000 BC**.** Palaeogeography, Palaeoclimatology, Palaeoecology **240**: 423–438.

Sparre P. 1979. Some necessary adjustments for using the common methods in eel assessment. *In*: Thurow F. (ed.) Eel research and management. Papers presented to an ICES/EIFAC Symposium, Helsinki, 9–11 June 1976. Rapports et procés-verbaux des réunions, Conseil International pour l'Exploration de la Mer **174**: 41–44.

Westin L. 1998. The spawning migration of European silver eel (*Anguilla anguilla* L.) with particular reference to stocked eel in the Baltic. Fisheries Research **38**: 257–270.

Wysujack K. 2007. The precautionary approach and the management of the European eel (*Anguilla anguilla*) – Critical remarks. Informationen aus der Fischereiforschung **54:** 26–33.

Received: 10 April 2008
Accepted: 5 September 2008
Published electronically: 30 November 2008