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RESEARCH ARTICLE

Economic effectiveness of stocking lakes in Poland

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Abstract. This paper was based on survey data regarding stocking and fish catches from the 1995-2007 period that was collected from enterprises licensed to manage lake fisheries in Poland. An average of 70 questionnaires were collected annually from lake fisheries enterprises exploiting a combined lake surface area of 228,102 ha. The eleven species of fish analyzed were those that were the most intensely stocked. The effectiveness of stocking in Polish lakes in this period was analyzed by calculating the mean annual stocking effectiveness coefficient, i.e, the value in PLN ha^{-1} of catches of a given species per 1 PLN ha^{-1} of stocking this species in a given year. The highest mean annual stocking effectiveness coefficient was noted for pikeperch *Sander lucioperca* (L.) (4.21 PLN ha^{-1}) and bighead carp *Aristichthys noblilis* Rich. together with silver carp *Hypophthalmichthys molitrix* Val. (4.02 PLN ha^{-1}); however, these values were unstable. A similar situation was noted for eel *Anguilla anguilla* (L.), which had the next highest stocking effectiveness coefficient at 2.32 PLN ha^{-1}. The stocking effectiveness coefficient was stable for tench *Tinca tinca* (L.) (2.16 PLN ha^{-1}), vendace *Coregonus albula* (L.) (2.09 PLN ha^{-1}), and pike *Esox lucius* L. (1.31 PLN ha^{-1}). The stocking of whitefish *Coregonus lavaretus* (L.), Wels catfish *Silurus glanis* (L.), crucian carp *Carassius carassius* (L.) together with Prussian carp *Carassius auratus gibelio* Bloch., common carp *Cyprinus carpio* L., and grass carp *Ctenopharyngodon idella* Val., were ineffective economically from the viewpoint of the size of commercial catches.

Keywords: lake fisheries, economics, lake stocking, effectiveness of stocking

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Introduction

Factors that impacted lake management stocking programs in Poland in the 1990s such as progressive degradation of lake ecosystems from eutrophication were compounded by the ownership transformation in lake fisheries that occurred during this period. This factor was significant as it required fisheries enterprises to function under the conditions of a free-market economy. Enterprises exploiting public inland surface waters were required by their leases with the Polish Treasury, the owner of these waters, to earmark a designated portion of their financial resources to perform stocking with suitable material of a value declared in the lease. This obliged these enterprises to implement the planned stocking program.

The political and economic transformation in Poland in the early 1990s and the corresponding ownership transformation in fisheries resulted in the collapse of the former centrally-controlled system of data collection, including data regarding lake fisheries economics, and, above all, information regarding catches and stocking. This prompted the Inland Fisheries Institute in Olsztyn to begin monitoring the lake fisheries economy. These studies conducted by surveying newly-created fisheries enterprises exploiting lakes were initiated in the early 1990s and have been conducted annually from 1995 to the present. The results of these studies, including those pertaining to lake stocking, have been

published annually, and attempts have also been made to analyze stocking over periods of several years (Mickiewicz 2001, 2006a, 2006b).

The present attempt to determine the effectiveness of lake stocking in Poland based on long-term data on catches and stocking of the populations in many lakes with a relatively large combined surface area focused on three species – eel, vendace, and whitefish. There are also reports in the literature of analyses of the stocking of pike (Bnińska 1999) and common carp (Szlażyńska and Wołos 1987). The effectiveness of stocking several species simultaneously into the waters of the same lakes, rivers, or dam reservoirs with large surface areas was also assessed, as was the experimental stocking of pike, pikeperch, and common carp in the waters exploited by a single fisheries enterprise (Nowak 1984, Bnińska 1985). The analyses of coregonid and eel stocking effectiveness was the most thorough, and was based on wide-ranging materials mainly because these species have long been and remain today the economic backbone of the lake fisheries economy (Wołos and Leopold 1999). Publications on eel management usually concentrate mainly on analyzing the effectiveness of stocking lakes with glass eel (Leopold and Bnińska 1985, Moriarty et al. 1990, Leopold and Wołos 2001). Papers addressing the management of coregonids often analyze the effectiveness of stocking depending on environmental factors such as lake morphometry or stocking frequency. They also study the allocation of stocking material and compare the effectiveness of stocking lakes with hatch and reared forms (Wołos et al. 1995, 1998, Bnińska and Wołos 1998, Falkowski 1998, Falkowski and Wołos 1998, Leopold and Wołos 1998a, 1998b, Leopold et al. 1998, Wołos 1998, Wołos and Bnińska 1998).

The economic impact of stocking is also analyzed abroad, primarily as the effectiveness of recreational catches (Pawson 1991, Vostradovský 1991, Rennert and Winkel 1998), while Scandinavian research focuses on assessing both commercial and recreational fisheries (Salojärvi 1992, Raitaniemi et al. 1995, Heikinheimo and Raitaniemi 1998). These studies focus on salmonids, grayling *Thymallus thymallus* (L.), whitefish, and common carp. The effectiveness of stocking other species such as eel, pikeperch, and common carp have also been studied (Linfield 1988, van Densen et al. 1990). The aim of the present work is to determine the economic effectiveness of stocking performed by enterprises licensed to exploit lakes after the period of ownership transformation at the level of selected populations of lake fisheries enterprises and long-term survey data regarding catches made and stocking done by these enterprises. The cognitive aspect of this publication is the presentation of a method for assessing the economic effectiveness of stocking.

Materials and methods

Data utilized in this article were obtained from two sources: lake fish production (catch size of particular fish species) and lake stocking (quantity of stocking material of particular species released) were collected yearly using questionnaires sent by post to enterprises exploiting lakes throughout Poland in the 1995-2007 period (Table 1). More detailed characteristics of the analyzed data (e.g., share of enterprises stocking lakes with given species, share of surface area stocked with particular species, financial value of stocking per surface area, value of stocking per total area of lakes, value of catches of stocked fish per lake area) were presented in a paper by Mickiewicz and Wołos (2012). Information on the prices of commercial lake fish set by lake fisheries enterprises in 2005 was collected via questionnaires in fall of the same year from 31 enterprises exploiting 153,685 ha of the total surface area of lakes located in Poland's largest lake districts in Mazury, Pomerania, and Greater Poland (Mickiewicz 2010).

Only species that had been stocked during the 1995-2007 period were analyzed: eel, whitefish, vendace, pike, pikeperch, Wels catfish, tench, common carp, grass carp, Crucian carp and Prussian carp together, and bighead carp and silver carp together. The survey data were analyzed statistically (catches and stocking) using the financial value

Table 1
Number of enterprises that returned completed questionnaires regarding fish catches and stocking by year in the 1995-2007 period and the lake surface areas these respondents exploited

Year	Number of respondent enterprises (n)	Total combined surface area of exploited lakes (ha)
1995	51	206,783
1996	57	208,643
1997	62	236,902
1998	60	230,594
1999	66	230,328
2000	67	232,980
2001	65	231,454
2002	65	229,080
2003	66	231,352
2004	64	229,681
2005	95	234,082
2006	91	226,495
2007	104	235,784

(PLN) of catches and stocking calculated based on mean wholesale prices of various commercial fish species in 2005 (Mickiewicz 2010). The financial values obtained were analyzed with regard to the surface area of the lakes studied as the index of PLN ha^{-1}. In order to maintain data comparability throughout the entire period analyzed of 1995-2007 the same prices were used from 2005.

The effectiveness of stocking in Polish lakes in this period was analyzed by calculating the mean annual stocking effectiveness coefficient, i.e, the value in PLN ha^{-1} of catches of a given species per 1 PLN ha^{-1} of stocking it in a given year. Using this methodological approach to determine the effectiveness of stocking does not require performing complicated experiments of biological factors such as determining the survival of a given type of stocking material or growth rates for populations of given species. Conducting these types of experiments for such a numerous population of the lake fisheries enterprises analyzed, each of which typically exploits the waters of at least 15 lakes, is unrealistic considering the present capabilities of conducting ichthyobiological studies in Poland. However, the mean annual stocking effectiveness coefficient is the most straightforward way of determining stocking effectiveness for such large populations and surface areas of lakes exploited by the fisheries enterprises analyzed. The mean annual stocking effectiveness coefficient calculated for each species was also described with the basic statistical measures of standard deviation (SD), the coefficient of variation (V%), and maximal and minimal values.

Results

The highest mean annual stocking effectiveness coefficients (Table 2) were noted for pikeperch (4.21 PLN ha^{-1}) and bighead carp (4.02 PLN ha^{-1}). However, their very high standard deviations and coefficients of variation (Table 2) indicate that these values were unstable during the studied period of 1995-2007. A similar situation was noted for eel, which had the next highest stocking effectiveness coefficient at 2.32 PLN ha^{-1}. The stocking effectiveness coefficients were stable for tench (2.16 PLN ha^{-1}), vendace (2.09 PLN ha^{-1}), and pike (1.31 PLN ha^{-1}). The effectiveness of stocking other fish species, i.e., whitefish, Wels catfish, crucian carp, common carp, and grass carp, was ineffective when measured with the size of commercial catches made with fishing gear.

The maximum value of the pikeperch stocking cost effectiveness coefficient (Table 2) was noted in 1996 (15.28 PLN ha^{-1}), while the minimum was noted in 2001 (2.69 PLN ha^{-1}). The maximum values of the stocking effectiveness coefficients for eel and vendace were noted in 1996 and 1999 at 4.93 PLN ha^{-1} and 3.02 PLN ha^{-1}, respectively, as minimal values in 1995 and 2007 (0.77 PLN ha^{-1}, and 1.33 PLN^{-1} respectively).

Changes in the stocking effectiveness coefficients of tench exhibited a decreasing tendency from the maximum in 1995 (3.56 PLN^{-1}) to the minimum in 2002 (1.44 PLN^{-1}). The results for crucian carp and

Table 2
Comparison of mean annual economic effectiveness of stocking fish species in Polish lakes in 1995-2007. Data are means, minimum (min), maximum (max), standard deviation (SD), and coefficient of variability (V%). Economic effectiveness of stocking coefficients are in PLN ha^{-1} of catches of a given species per PLN ha^{-1} of stocking in a given year

Species	mean	min	max	SD	V%
Eel	2.32	0.77	4.93	1.06	45.67
Vendace	2.09	1.33	3.02	0.45	21.68
Whitefish	0.45	0.18	0.93	0.22	49.23
Pike	1.31	0.76	2,09	0.35	26.71
Pikeperch	4.21	2.69	15.28	3.36	79.84
Wels catfish	0.12	0.08	0.31	0.09	76.67
Tench	2.16	1.44	3.56	0.64	29.79
Crucian/Prussian carp	0.85	0.51	1.61	0.39	45.33
Common carp	0.27	0.14	0.79	0.21	79.03
Grass carp	0.34	0.11	1.35	0.31	92.51
Bighead/silver carp	4.02	1.44	98.82	26.13	650.02

Prussian carp were similar with the maximum in 1995 (1.61 PLN^{-1}) and the minimum in 2002 (0.51 PLN^{-1}). The maximum for pike was noted in 1995 (2.09 PLN^{-1}) and the minimum in 2004 (0.76 PLN^{-1}). The maximum of the common carp stocking effectiveness coefficient was noted in 1998 at 0.79 PLN ha^{-1}, while the minimum was noted in 2000 at 0.14 PLN ha^{-1}.

The maximum actual value of the stocking effectiveness coefficient for grass carp was noted in 1995 at 1.35 PLN ha^{-1}, and also for whitefish in 1995 at 0.93 PLN ha^{-1}, while for Wels catfish the actual maximum was noted in 1998 at 0.31 PLN ha^{-1}. The minimal value of the grass carp stocking effectiveness was noted in 1999 (0.11 PLN-1), for whitefish in 2005 (0.18 PLN^{-1}), and for Wels catfish in 2005 (0.08 PLN^{-1}). The bighead carp and silver carp maximum was noted in 2005 (98.82 PLN^{-1}), while the minimum was in 1997 (1.44 PLN^{-1}).

Discussion

The analyses of stocking management following the ownership transformation period in fisheries (i.e., after 1995) led to the conclusion that there are no scientific publications based on wide-ranging data that address this issue, and especially none which employ similar methods to those used in the current study. The methodology applied in this paper, as already mentioned in the introduction, has practical applications. As early as twenty years ago, the necessity of developing such methodology was recognized; to cite Bnińska (1994): “As determined in the report from 1987 prepared by the Working Group of the European Inland Fisheries Advisory Commission of the Food and Agricultural Organization (EIFAC/FAO), it is essential to develop methodology to assess the effectiveness of stocking that is ‘...relatively easy, cost effective, and possible to apply on a large scale in order to assist fish farmers in making appropriate decisions. This is especially pressing since numerous studies of stocking indicate that the effects of stocking vary significantly in different basins.’ Of course, such conditions preclude the application of refined and complex scientific methods including marking methods, which are possible only on very limited scales.”

Presenting the stocking effectiveness in lake fisheries following the ownership transformation through the prism of the many fish species in a population of numerous lakes, means it is impossible not to mention the wide-ranging scientific

analysis presenting the horizontal analysis of the values of catches and stocking from the 1951-1974 period for about 15 fish species in a population of 1050 lakes with a unit surface areas of up to 20 ha (Nowak 1984).

The data presented in the present work include the mean annual stocking effectiveness coefficients for the 1995-2007 period for the species analyzed. The highest of these values was noted for pikeperch at 4.21 PLN ha^{-1}, bighead carp at 4.02 PLN ha^{-1}, and eel at 2.32 PLN ha^{-1}. This means that the annual outlay for stocking these species returned revenues of 321, 302, and 132%, respectively. This is an extremely high rate of return on invested capital that is really only possible to attain on the free market by investing in high risk stocks. However, stocking these species was also high risk as indicated by the highly unstable values of their standard deviations and coefficients of variation. This risk is illustrated by the values of stocking effectiveness coefficients for bighead/silver carp, pikeperch, and common carp in the 1995-2007 period. The high cost of the stocking material of these species means that a high degree of revenue is spent on stocking them. As might be assumed, this refers only to material that is allocated to carefully selected lakes with suitable environmental conditions and under the assumption that exploitation will be sufficiently intensive, climatic conditions will be advantageous in a given season on both micro- (e.g., the production capabilities of a single lake or enterprise, including the possibility of processing caught fish) and macro-scales (e.g., the demand for a given species in a given fishing season, and the supply of a given species and the price of stocking material). It is worthwhile bearing in mind that the very high bighead carp mean annual stocking effectiveness coefficients in the 1995-2007 period was determined by its incidental value in 2005. This is also true of pikeperch with regard to the value in 1996, but certainly not to the same degree. According to Nowak (1984), the effectiveness of stocking small lakes up to a surface area of 20 ha with bighead carp provides no results, while stocking eel produced 2.03 PLN ha^{-1} for a revenue return of 103%, and pikeperch stocking produced 2.06 PLN ha^{-1} for a revenue return of 106%.

The stocking effectiveness coefficients for tench, vendace, and pike were 2.16, 2.09, and 1.31 PLN ha^{-1}, respectively, for annual revenue returns of 116, 109, and 31%, respectively. These were not as high as the values for bighead carp or pikeperch, but the stocking cost effectiveness coefficients for tench, vendace, and pike were much more stable during the period studied as is indicated by the values of standard deviations. This indicates that investing in stocking material of tench, vendace, and pike was less risky than investing in bighead carp, pikeperch, or eel, but it also returned less revenue. While the same range of factors discussed above that can influence the economic effects of stocking also obviously existed, they had less of an impact on tench, vendace, and pike than they did on bighead carp, pikeperch, and eel. Nowak (1984) reported that stocking lakes with tench was described by a value of 1.25 PLN ha^{-1} at a revenue return rate of 25%, stocking vendace by a value of 1.17 PLN ha^{-1} with a revenue return rate of 17%, and pike at 0.45 PLN ha^{-1}, which was unprofitable. It should be borne in mind that aside from the slightly different method for calculating the effectiveness of stocking and the differing prices for fish and stocking material used, the cited work investigated only lakes with surface areas of under 20 ha and catches made in them during the 1951-1974 period. Yet, the analysis of stocking effectiveness presented in the present paper refers to highly varied lakes ranging from basins of just a few hectares to lake complexes with surface areas exceeding 10,000 ha and to fisheries management conducted in the 1995-2007 period, which means that the management systems varied hugely, even if only with regard to the ownership transformation in Polish fisheries.

In returning to the mean annual stocking effectiveness coefficients in the 1995-2007 period, it still must be underscored that the results of these analyses indicated that for whitefish, Wels catfish, crucian carp, common carp, and grass carp the values of these coefficients were less than zero. This means that stocking these species was economically ineffective in terms of the the value of fisheries catches. As is conclusively demonstrated in the individual years analyzed from 1995 to 2007, while high stocking effectiveness

coefficients were noted for crucian carp (1.61 PLN ha^{-1} in 1995) and grass carp (1.35 PLN ha^{-1} in 1995), the coefficients for the stocking effectiveness of whitefish, common carp, and Wels catfish were never higher than a value of 1 PLN ha^{-1} during the period analyzed.

When analyzing the stocking effectiveness coefficients presented in the present paper, one must not forget that while the value of stocking stems only from the quantity and price of the stocking material released, the value of the catches with most of the analyzed species stems not only from stocking, but also from the effects of natural spawning. One more significant fact related to the value of catches must be underscored: the present study only analyzed the values of commercial catches made with fishing gear by professional fishers. However, in order to discuss the full value of fish catches, the value of fish caught through so-called "natural consumption" by recreational fishers must be included. Although currently underscoring the role of recreational fisheries in lake fisheries management is a truism as it was identified and quantified long ago, what must be underscored is the high economic value of these fish, which, under the current conditions in Poland, are mostly destined for consumption. The actual value of fish caught by recreational fishers in lakes in 1998 was estimated to be approximately 173 PLN ha^{-1} (Wołos 2000), while in 2003 it was 184 PLN ha^{-1} (Wołos et al. 2004). In 2008, recreational fishery fees paid to enterprises licensed to operate lake fisheries was 53.51 PLN ha^{-1}, while the value of lake fish production was 81.01 PLN ha^{-1} (Wołos et al. 2009), which is a combined value of 134.52 PLN ha^{-1}. The facts presented above lead to a very important conclusion: the assessments of the economic effectiveness of stocking must also include the value of fish caught by recreational fishers.

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