Arch. Pol. Fish. (2012) 20: 11-18
DOI 10.2478/v10086-012-0002-6

RESEARCH ARTICLE

Economic ranking of the importance of fish species to lake fisheries stocking management in Poland

Maciej Mickiewicz, Arkadiusz Wołos

Received – 21 October 2011/Accepted – 10 February 2012. Published online: 31 March 2012;
Citation: Mickiewicz M., Wołos A. 2012 – Economic ranking of the importance of fish species to lake fisheries stocking management in Poland – Arch. Pol. Fish. 20: 11-18.

Abstract. This paper analyzes commercial fish stocking and catches in lakes in the 2001-2007 period. The eleven fish species that are stocked most intensely were analyzed. Rank scaling was used to compare the parameter values of the analyzed fish species. This permitted ranking all of the species from the most to the least important to lake fisheries management. Pike, *Esox lucius* L.; eel, *Anguilla anguilla* (L.); vendace, *Coregonus albula* (L.); and carp, *Cyprinus carpio* L were the highest ranked species. These were followed by tench, *Tinca tinca* (L.), and pikeperch, *Sander lucioperca* (L.), as well as whitefish, *Coregonus lavaretus* (L.), and common Crucian carp, *Carassius carassius* (L.), and Prussian carp, *Carassius gibelio* (Bloch). The following were of marginal significance: bighead carp, *Aristichthys nobilis* Rich.; silver carp, *Hypophthalmichthys molitrix* (Val.), wels catfish, *Silurus glanis* (L.), and grass carp, *Ctenopharyngodon idella* Val.

Keywords: economic importance, fisheries management, lakes stocking

Introduction

Inland fisheries are dynamic and very diverse and are based on a range of ecosystems whose fish communities respond very differently to internal (fisheries-based) and external (natural- and human ecosystem-based) drivers (Welcomme et al. 2010). As economies evolve, the nature of inland fisheries changes (Arlinghaus et al. 2002). Fisheries enterprises can prevent the adverse effects of lake eutrophication through the application of management measures. Of these, the most frequently applied include regulating catches, adjusting fisheries exploitation to the actual state of fish populations, implementing appropriate fish population protection measures, and stocking lakes (Cowx and Gerdeaux 2004). The significance and intensity of such management measures shifts as the rate of eutrophication increases (Bnińska 1985, Leopold et al. 1986). Stocking is most significant in lakes that are moderately to strongly degraded or are threatened with degradation, and the majority of lakes in Poland fall into these categories (Bnińska 1996). Factors influencing lake stocking management include worsening ecosystem health because of eutrophication and the necessity of managing lakes sustainably (Leopold and Bnińska 1992), but another very important factor was added to these in Poland in the early 1990s – the ownership transformation in lake fisheries that required lake fisheries enterprises to operate within the free-market economy.

Currently, public inland flowing waters, including lakes, rivers, and dam reservoirs, are owned by the Polish State Treasury and managed by the National

M. Mickiewicz [✉], A. Wołos
Department of Fisheries Bioeconomics
Inland Fisheries Institute in Olsztyn
Oczapowskiego 10, 10-719 Olsztyn, Poland
Tel. +48 89 524 10 65; e-mail: mmickiewicz@infish.com.pl

Water Management Authority. Lakes, rivers, and dam reservoirs are exploited by legal persons, primarily limited liability companies established by former employees of state fisheries enterprises and the Polish Angling Association, and by physical persons such as individual farmers or fishers. Enterprises exploiting public waters are required by contract to allocate funds to perform stocking with appropriate materials of a contractually declared value, which compels them to implement suitable stocking measures.

Transformations in the political and economic system in Poland in the early 1990s led to changes in the centralized data collection system. This included, among other things, data on lake fisheries management, and especially information regarding the size of catches and stocking. These studies were performed by surveying newly-established enterprises exploiting lakes beginning in the early 1990s, and they have been conducted systematically since 1995 with the results being presented at conferences focused on the management of fish populations in Polish inland waters (Mickiewicz 2000a, 2001, 2006a, 2006b). The aim of the current study was to determine the intensity of lake stocking management policy by specific species following the fisheries ownership transformation within a selected group of lake fisheries enterprises and long-term survey data on catches made and stocking performed by them. This study is an economic analysis that includes as much information as possible on lake fisheries stocking management, including the impact it has had on commercial catches.

Materials and methods

The analysis was performed using data on the sizes of fish catches in lakes exploited by fisheries from the 2001-2007 period (Table 1). Data on quantities of stocking material, surface areas of lakes stocked with various species, and the value of the stocking material of different species were analyzed. These data were collected by conducting annual questionnaire surveys among enterprises exploiting lakes throughout Poland. The questionnaires were mailed to the enterprises. Information was also gathered regarding wholesale prices for commercial fish set by lake fisheries enterprises in 2005 (Mickiewicz 2010). In 2005, the mean annual exchange rate for the zloty to the US dollar was 3.2348 pln = 1 USD, and for the euro 4.0254 pln = 1 EURO. The value of the stocking material was calculated using information from survey questionnaires collected in the 2001-2007 period. In order that the data remain comparable, the 2005 commercial fish prices were used for the entire period analyzed. The mean wholesale prices of fish were calculated based on information on wholesale prices set by fisheries enterprises in 2005 (Mickiewicz 2010). The value of catches and stocking were analyzed using the financial value of catches that was calculated based on mean wholesale prices for different species of commercial fish. The financial values obtained were analyzed in terms of the surface areas of the lakes studied.

The thirteen species of fish that were the most intensely stocked during the 2001-2007 period were analyzed (Mickiewicz 2006a, 2006b). Crucian carp, *Carassius carassius* (L.), and Prussian carp, *Carassius gibelio* (Bloch), catches and stocking were analyzed together. The same refers to bighead carp, *Hypophthalmichthys nobilis* Rich., and silver carp, *Hypophthalmichthys molitrix* (Val.). In order to determine differences in stocking intensity among the different species of fish in the 2001-2007 period, the following indexes were calculated:

- the share of enterprises stocking a given species – the quotient of the number of lake fisheries enterprises stocking a given species in relation to the total number of enterprises;
- the share of lake surface area stocked – the lake surface area stocked with a given species in relation to the total lake surface area analyzed;
- value (pln ha^{-1}) of stocking lake surface area with a given species;
- value (pln ha^{-1}) of stocking for the entire lake surface area analyzed;
- value (pln ha^{-1}) of catches for the entire lake surface area analyzed.

Table 1
Number of enterprises returning completed survey questionnaires on stocking and the number and surface area of lakes exploited by them in each year of the 2001-2007 period analyzed

Year	Number of enterprises (n)	Number of lakes exploited (n)	Combined surface area of exploited lakes (ha)
2001	50	2450	149246
2002	54	2436	192305
2003	47	2417	169628
2004	55	2408	204022
2005	88	2447	220347
2006	90	2431	224396
2007	104	2583	235784
Annual mean	70	2453	199390

The mean annual values of the preceding indexes, standard deviations (SD), and coefficients of variation (V%) were calculated for each year of the period analyzed from 2001 to 2007. The values of these indexes were used in further calculations of differences in stocking intensity for individual species in the 2001-2007 using scale ranking. All of the species were then ranked from the most to least significant in lake fisheries stocking in Poland in the period analyzed. The analyzed species were ranked according to the index assigned to each species from the highest value for each index of 11 to the lowest of 1. The ranks were summed for all of the indexes, and then the percentage share (%) for each species was calculated with the total sum of all ranks of all species as 100%.

Results

Pike, *Esox lucius* L., was the most frequently stocked species among the analyzed fisheries enterprises (Table 2). In excess of 85% of fisheries enterprises declared having stocked lakes with this species. More than half of the enterprises analyzed stocked carp, *Cyprinus carpio* L. and tench, *Tinca tinca* (L.), slightly fewer than 50% stocked eel, *Anguilla anguilla* (L.), vendace, *Coregonus albula* (L.), and pikeperch, *Sander lucioperca* (L.). Pike also dominated the share of stocked surface area, followed by eel, tench, vendace, and pikeperch (Table 2).

The highest expenditures for a single species were for carp (38.40 pln ha^{-1}), but with relatively high fluctuations (Table 2). The next highest expenditures were for stocking vendace, pike, whitefish, and eel; the coefficients of variation did not exceed 50% for the expenditures for stocking these species. Pike dominated expenditures for stocking the entire surface area analyzed at 9.31 pln ha^{-1}, followed by eel (6.60 pln ha^{-1}), carp (5.78 pln ha^{-1}), and vendace (4.98 pln ha^{-1}). The standard deviations and coefficients of variation for these values indicated highly stable values for the stocking of the total surface area analyzed for these species. In terms of the value of catches from the total lake surface area analyzed, eel dominated at 21.00 pln ha^{-1} and was followed by pike, vendace, pikeperch, and tench (Table 2). The standard deviations and coefficients of variation for all of these species indicated high stability of the index of the mean annual value of catches for the entire lake surface area analyzed in the 2001-2007 period.

Table 3 presents the mean annual values of the indexes described above and compares the values of each species analyzed using the rank scaling method.

Classifications based on the rank assigned to each species permits ranking them and determining their significance in terms of the number of enterprises performing stocking, the surface area of the

Table 2
Mean annual values of selected coefficients that describe lake stocking management in 2001-2007

Coefficient / statistical measure	Species										
	eel	vendace	whitefish	pike	pikeperch	wels catfish	tench	Crucian carp	carp	grass carp	silver carp
Share of enterprises stocking (%)	49.14	48.29	31.57	86.57	48.29	24.71	53.57	38.57	55.57	11.57	8.71
Standard deviation (SD)	6.99	9.23	8.64	3.95	5.44	4.35	5.65	2.15	3.10	3.46	3.73
Coefficient of variation (V%)	14.22	19.12	27.36	4.57	11.26	17.59	10.55	5.57	5.58	29.88	42.79
Share of surface area stocked (%)	55.96	18.56	14.21	67.44	18.51	7.29	23.77	11.86	13.63	1.29	1.13
Standard deviation (SD)	10.40	1.78	2.70	4.55	3,53	3.12	3.88	3.36	4.01	0.61	0.61
Coefficient of variation (V%)	18.59	9.57	19.02	6.74	19.07	42.79	16.33	28.34	29.39	47.19	53.83
Stocking value of a given species by surface area (pln ha^{-1})	12.05	24.24	13.47	13.54	11.27	7.50	7.39	8.63	38.40	11.39	11.95
Standard deviation (SD)	2.31	4.25	4.16	0.84	3.78	1.97	2.07	2.10	12.57	5.43	5.51
Coefficient of variation (V%)	19.20	17.54	30.90	6.21	33.54	26.33	28.03	24.37	32.74	47.70	46.13
Stocking value for the entire surface area analyzed (pln ha^{-1})	6.60	4.98	1.24	9.31	2.07	0.46	2.23	1.49	5.78	0.17	0.17
Standard deviation (SD)	1.14	1.00	0.53	1.64	0.45	0.12	0.73	0.46	0.61	0.08	0.14
Coefficient of variation (V%)	17.31	20.07	42.75	17.65	21.54	25.29	32.89	31.13	10.58	47.23	84.61
Value of catches for the entire surface area analyzed (pln ha^{-1})	21.00	10.20	0.49	10.55	6.97	0.07	4.43	1.15	1.09	0.07	2.18
Standard deviation (SD)	4.08	1.72	0.07	0.84	0.73	0.02	0.59	0.20	0.14	0.02	0.65
Coefficient of variation (V%)	19.43	16.90	14.60	8.00	10.43	29.68	13.29	17.43	13.27	23.47	29.91

Table 3
Mean annual values of selected coefficients characterizing lake stocking management in 2001-2007 by species and their distribution by rank scaling

Species	Share of enterprises stocking (%)	Rank	Share of surface area stocked (%)	Rank	Value of stocking in pln ha^{-1} of surface area stocked with given species	Rank	Value of stocking in pln ha^{-1} of the entire surface area analyzed	Rank	Value of catches in pln ha^{-1} of the entire surface area analyzed	Rank	Rank sum	% of rank sum
pike	86.57	11	67.44	11	13.54	9	9.31	11	10.55	10	52	15.62
eel	49.14	8	55.96	10	12.05	7	6.60	10	21.00	11	46	13.81
vendace	48.29	7	18.56	8	24.24	10	4.98	8	10.20	9	42	12.61
carp	55.57	10	13.63	5	38.40	11	5.78	9	1.09	4	39	11.71
tench	53.57	9	23.77	9	7.39	1	2.23	7	4.43	7	33	9.91
pikeperch	48.29	7	18.51	7	11.27	4	2.07	6	6.97	8	32	9.61
whitefish	31.57	4	14.21	6	13.47	8	1.24	4	0.49	3	25	7.51
Crucian carp	38.57	5	11.86	4	8.63	3	1.49	5	1.15	5	22	6.61
silver carp	8.71	1	1.13	1	11.95	6	0.17	2	2.18	6	16	4.80
wels catfish	24.71	3	7.29	3	7.50	2	0.46	3	0.07	2	13	3.90
grass carp	11.57	2	1.29	2	11.39	5	0.17	2	0.07	2	13	3.90

lakes stocked, the financial expenditures, and the value of catches. The highest ranked species were pike, eel, vendace, and carp, followed by tench, pikeperch, whitefish, and Crucian carp. Silver carp, wels catfish, and grass carp were of marginal significance in the economic ranking of stocking. The greatest differences between neighboring species in the ranking, measured in percentage points for the sum rank, was for pikeperch and whitefish at 2.0 percentage points, and the lowest between tench and pikeperch at 0.30 percentage points. No differences were noted between silver carp and grass carp, while those for the remaining neighboring species in the ranking ranged from 0.90 to 1.81 percentage points.

Discussion

The analysis of the intensity of stocking management in the 2001-2007 period highlighted the arbitrarily designated management and economic indexes used to characterize stocking with different species. These indexes were calculated as the mean annual values in the 2001-2007 period, and above all they were chosen because of the simplicity of their calculation. The reservation must be made that these indexes are not as significant for individual lake fisheries enterprises as they are for the illustration of the systematic lake fisheries stocking performed in Poland. They do permit ranking the different species according to the hierarchy of their importance to lake stocking.

The rank scaling method applied in the current study was used previously to analyze fisheries management stocking in Poland (Bnińska 1998). Usually, rank scaling is recognized as an evaluation method that is not expressed monetarily, is based on subjective assessment, and is characterized by non-comparability (Bnińska 1997). While the economic indexes chosen subjectively and arbitrarily characterize the stocking of individual species, their magnitudes of these indexes are expressed in concrete values, which means that rank scaling can be applied to any given group of lakes or lake fisheries enterprises to effectively obtain comparable results.

Pike distinctly dominated the lake fisheries stocking conducted in Poland during the 2001-2007 period, as it did in previously analyzed periods (Bnińska 1999, Mickiewicz 2000b). In addition to pike, the other basic species stocked in lakes included eel, vendace, carp, tench, and pikeperch. Whitefish and Prussian carp can be considered to be incidental species, while silver carp, wels catfish, and grass carp were only stocked by a few fisheries enterprises and at low intensity. It can be concluded that in the lake fisheries stocking management of the 2001-2007 period, the group of the first six species were of the greatest significance, followed by that of whitefish and Crucian carp, while stocking of the last three species was only of incidental importance.

The ranking of carp is somewhat of a surprise, especially since it is a cultured species that is typical of pond fisheries in Poland and Central Europe (Turkowski and Lirski 2010). In light of the enormous popularity of recreational carp fishing (Arlinghaus and Mehner 2003, Aprahamian et al. 2010), it is difficult to speak about the high effectiveness of stocking Polish lakes with this species and significant recreational catches (Wołos 2000, Wołos et al. 2005, 2009). It is possible, thus, to postulate that the high ranking of carp among fish species stocked in lakes as part of fisheries management is because, in addition to its attractiveness to recreational fishers, carp stocking material is widely available at a relatively low price in Poland.

In summation, the species hierarchy from their ranking in the lake fisheries stocking management can be compared to the ranking of species according to the economic effectiveness index from lake stocking performed in Poland in the 1995-2007 period (Mickiewicz 2010). With the exception of silver carp, the ranking of which in each of the classifications was completely different because of incidentally high effectiveness in one of the years of the studied period, it is notable that the different ranking in the two classifications of individual species could result from reasons linked to the analyzed values of stocking and catches. Presumably, this is the effect of natural spawning, which undoubtedly had the greatest impact on pikeperch and tench rankings, as well as on

the values of recreational catches, which were most notable with regard to carp and pike. While high-value recreational pike catches have been confirmed by studies of recreational lake fisheries, the very high ranking of carp in lake stocking management and its very low ranking regarding stocking effectiveness remains ambiguous. It is likely that social, administrative and legal, and macroeconomic factors linked to, among other things, contracts for leasing lakes for fisheries exploitation, as well as laws and regulations governing lake fisheries.

Acknowledgments. The authors would like to thank Ms. Hanna Draszkiewicz-Mioduszewska for her assistance in collecting materials, and also all respondents from lake fisheries enterprises for their long-term cooperation in supplying wide-ranging information regarding the management of their businesses. The study was supported with funding from Project S-014 of the Inland Fisheries Institute in Olsztyn, Poland.

Author contributions. M.M. and A.W. conceived of and designed the research, M.M. performed the research, M.M. and A.W. interpreted the data, M.M. wrote the paper, and A.W. critical reviewed the article.

References

Aprahamian M. W., Hickley P., Shields B.A., Mawle G.W. 2010 – Examining changes in participation in recreational fisheries in England and Wales – Fisheries Manag. Ecol. 17: 93-105.

Arlinghaus R., Mehner T., Cowx I. G. 2002 – Reconciling traditional inland fisheries management and sustainability in industrialised countries, with emphasis on Europe – Fish Fish. 3: 261-316.

Arlinghaus R., Mehner T. 2003 – Socio-economic characterisation of specialised common carp (*Cyprinus carpio* L.) anglers in Germany, and implications for inland fisheries management and eutrophication control – Fish. Res. 61:19-33.

Bnińska M. 1985 – The possibilities of improving catchable fish stocks in lakes undergoing eutrophication – J. Fish Biol. 27: 253-261.

Bnińska M. 1996 – Principles for fisheries management in lakes with rapidly progressing eutrophication – In: Pikeperch, fisheries management, eutrophication (Ed.) A. Wołos, Wyd IRS, Olsztyn: 13-22 (in Polish).

Bnińska M. 1997 – Value of fisheries management other than from production – In: Lake fisheries. Significance and management (Ed.) A. Wołos, Wyd IRS, Olsztyn: 7-16 (in Polish).

Bnińska M. 1998 – Analysis of factors disrupting the functioning and development of lake fisheries – In: Lake fisheries. Development, changes, challenges (Ed.) A. Wołos, Wyd. IRS, Olsztyn: 105-119 (in Polish).

Bnińska M. 1999 – Remarks on the effectiveness of stocking and perspectives for pike management – In: Lake fisheries (Ed.) A. Wołos, Wyd. IRS, Olsztyn: 33-42 (in Polish).

Cowx I.G., Gerdeaux D. 2004 – The effects of fisheries management practises on freshwater ecosystems – Fisheries Manag. Ecol. 11: 145-151.

Leopold M., Bnińska M. 1992 – Fisheries management and sustainability – Zesz. Prob. Post. Nauk Rol. 401: 73-79 (in Polish).

Leopold M., Bnińska M., Nowak W. 1986 – Commercial fish catches as an index of lake eutrophication – Arch. Hydrobiol. 106: 513-524.

Mickiewicz M. 2000a – Stocking management – In: State of lake fisheries in 1999. Impact of other lake users on the environment and fisheries management (Ed.) A. Wołos, Wyd. IRS, Olsztyn: 25-33 (in Polish).

Mickiewicz M. 2000b – Pike in lake fisheries stocking management policy in 1995-1998 – Komun. Ryb. 2: 3-7 (in Polish).

Mickiewicz M. 2001 – Values of commercial fish catches and lake stocking – In: Selected aspects of commercial and recreational fisheries under conditions of progressing eutrophication (Ed.) A. Wołos, Wyd. IRS, Olsztyn: 10-18 (in Polish).

Mickiewicz M. 2006a – Stocking management as an element of the sustainable development of inland fisheries – In: Fisheries, angling, sustainability (Ed.) A. Wołos, Wyd. IRS, Olsztyn: 191-204 (in Polish).

Mickiewicz M. 2006b – Shifts in exploitation intensity and stocking policy following ownership transformation based on the example of the Great Mazurian Lake System – In: Fisheries, angling, sustainability (Ed.) A. Wołos, Wyd. IRS, Olsztyn: 179-189 (in Polish).

Mickiewicz M. 2010 – Intensity and effectiveness of stocking lakes following the period of ownership transformation in fisheries – PhD Thesis, Inland Fisheries Institute, Olsztyn, 112 p. (in Polish).

Turkowski K., Lirski A. 2010 – The economics of carp farms in Poland – Acta Ichthyol. Piscat. 40: 137-144.

Welcomme R.L., Cowx .IG., Coates D., Béné C., Funge-Smith S., Halls A., Lorenzen K. 2010 – Inland capture fisheries – Philos. Trans. R. Soc. B-Biol. Sci. 365: 2881-2896.

Wołos A. 2000 – Size and structure of recreational catches – In: The state of lake fisheries in 1999. Impact of other lake users on the environment and fisheries management (Ed.) A. Wołos, Wyd. IRS, Olsztyn: 20-25 (in Polish).

Wołos A., Mioduszewska H., Chmielewski H. 2005 – Size and structure of recreational catches and their impact on overall lake production – In: The state of lake fisheries in 2004 (Ed.) A. Wołos, Wyd. IRS, Olsztyn: 17-30 (in Polish).

Wołos A., Draszkiewicz-Mioduszewska H., Chmielewski H., Grzegorczyk J., Miętus A. 2009 – Recreational catches in the waters of the Toruń branch of the Polish Angling Association in 2007 – Wyd. Edycja, Olsztyn: 126 p. (in Polish).