OPTIMIZATION MODEL OF FISH GUARD SERVICE IN ORDER TO PROTECT AQUATIC SYSTEMS

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MODEL OPTIMIACIJE RIBOČUVARSKE SLUŽBE U CILJU ZAŠTITE VODENIH SISTEMA

Apstrakt

Važan segment svakog upravljačkog sistema su ljudski resursi i pronalaženje modaliteta da se isti koriste racionalno i ekonomično. Cilj rada je da se na konkretnom primeru određivanja parametara koji utiču na optimalan broj ribočuvara po prvi put prikaže mogućnost primene skalarnog metoda ocenjivanja (SMO) u praktičnom upravljanju ribolovnim vodama. Kombinovanjem metoda SMO sa metodom analitičko hijerarhijskog procesa, moguće je upravljačke odluke na objektivan način valorizovati i učiniti metodološki primenljivim prilikom određivanja optimalnog broja ribočuvarske službe. Objektivnost definisanja kriterijuma i izbor alternativa u odnosu na postavljeni cilj zavise od dostupnih inicijalnih informacija i iskustva donosioca odluka, ali je ovaj nedostatak moguće otkloniti donošenjem alternativnih rešenja zasnovanim na principima višekriterijumske analize i matematičkog modelovanja.

U ovom radu SMO metod je prezentovan na primeru organizovanja ribočuvarske službe i daje mogućnost da se ciljni parametri odrede u kvalitativnom i kvantitativnom pogledu, kroz optimalizaciju broja potrebnih ribočuvara. Rezultati ovog rada ukazuju na potrebu inoviranja postojećih metoda pri donošenju upravljačkih odluka po pitanju organizovanja ribočuvarske službe. Iako na prvi pogled ovaj metod izgleda komplikovan, primenom odgovarajućeg softvera i korišćenjem tabelarnih kalkulatora, ovaj metod postaje izuzetno primenljiv i efikasan u donošenju pravilnih i realnih zaključaka.

Ključne reči: optimalizacija, upravljanje ribolovnim vodama, ribočuvarska služba, skalarni metod ocenjivanja

Keywords: optimalisation, management of fishery waters, fish guard service, scalar evaluation method

INTRODUCTION

A management organization of natural waters becomes complex and dynamic process. An important segment of any management system of resources is to find modalities to use them rationaly and economically. Users of natural waters have difficult task to, on relatively large space organize work of professional and guard services in order to meet contractual and legal obligations with less expenses. The aim of the study is to show, on defined example of determining the parametres which influence optimal number of fish guards, a possibility of applying multi-criteria mathematic modeling. By combining scalar evaluation method (SMO) with method of analytic hierarchy process AHP), management decisions becomes methodologically consistent and objective when making real conclusions.

MATERIAL AND METHODS

As a starting material for this study we used official reports of Ministry of Environment, Mining and Spatial Planning of Republic of Serbia (Table 1). Presented SMO combines inferential statistics methods and multi-criteria analysis (Srđević et al., 2000; Šarčević, 2011). To determine importance and priority in making management decisions we combined SMO with method of analytic hierarchy process (AHP). AHP of problem deciding presents necessary method when solving any complex problems in the field of multi-criteria decision.

Table 1. Annual report data from Ministry, sector of Supervision and Surveillance (2009)

USERS	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Number of issued licenses	2375	431	4600	3528	6322	7847	2484	10736	2090	349
Number of fish guards	17	5	14	5	25	19	10	56	23	6
Number of orders	930	633	1306	616	3300	807	479	3080	2400	790
Number of reports	335	2	18	32	48	16	60	106	44	1

USERS: 1-DOO ''Rivers Guard'' Jagodina; 2-Silver Leik Investment Beograd; 3-OOSR ''Dunavac'' Kostolac; 4- ZSR ''Timočka Krajina'' Zaječar; 5- JP ''Srbijašume'' Beograd; 6- ZOSR 'Južna Morava2' Niš; 7- Asocijacija ''Veternica'' i ''Vlasina; 8- OOSR ''Hristifor Perišić Kićo'', Kraljevo; 9- DOO ''Ekoribarstvo'' Valjevo; 10- OOSR ''Drina'' Ljubovija.

Mutual comparison of elements on each hierarchy level are based on forming the basic matrix, whereby the main diagonal entered values do not compare, and on positions symmetrical to the main diagonal are inverse values. In that way, we have got consistency of comparison and a result of comparison is made by vector of weighting values (Vtv) and determined criteria in relation to objectives. (Saaty, 1980; Jandrić and Srdevic, 2000; Suvočarev and Srdevic, 2007).

Results checking and consistency of pair comparison is calculated with consistency index CI, where λ_{max} is the maximum value of the matrix itself.

$$CI = \frac{(\lambda \max - n)}{(n-1)}$$

Consistency degree is determined by formula CR= CI/ RI, where RI presents random index statistically determined by the rows of the matrix. Using statistical correlation methods four parameters were analyzed, where the value of random index was 0,90. (Saaty, 1980). Forming of matrix criteria comparison is shown in Table 2.

Grade degree for the established criteria (parameters) and relational scalar value were determined based on statistical data analysis of relevant Ministry, using method presented in Šarčević (2011). The way we determine value of grade degree is shown in Table 3. For each grade degree by parametres (criteria), the vector of weighting values (Vtv) values were multiplied with relation scalar of belonging evaluation degree.

Table 2. Diagram of matrix criteria comparison

Criteria	**Parameter 1**	**Parameter 2**	**Parameter 3**
Parameter 1	**1,00**	a_1	A_2
Parameter 2	$1/a_1$	**1,00**	A_4
Parameter 3	$1/a_2$	$1/a_4$	**1,00**
Parameter 4	$1/a_3$	$1/a_5$	$1/a_6$

Table 3. Determining value of grade degree

Criteria	**Vector (Vtv)**	**Grade degree**					
		I	**II**	**III**	**IV**	**V**	**VI**
Parameter 1	**Vtv1**	***Vtv1* A1***	Vtv1* A2	Vtv1* A3	Vtv1* A4	Vtv1* A5	Vtv1* A6
Parameter 2	**Vtv2**	Vtv2* A1	Vtv2* A2	Vtv2* A3	Vtv2* A4	Vtv2* A5	Vtv2* A6
Parameter 3	**Vtv3**	Vtv3* A1	Vtv3* A2	Vtv3* A3	Vtv3* A4	Vtv3* A5	Vtv3* A6
Parameter 4	**Vtv4**	Vtv4* A1	Vtv4* A2	Vtv4* A3	Vtv4* A4	Vtv4* A5	Vtv4* A6
Relation	**scalar**	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**

Using concrete data and comparing them to description of grade degree we performed adequate scalar assessment. Optimal number of fish guards was determined based on number of issued licenses, length of certain water flows, accessibility of terrain, number of issued fish guard orders and submitted reports.

RESULTS AND DISCUSSION

Results of correlation analysis, basic matrix and values of Vtv are shown in tables 4 and 5. During this research we established that there are significant correlations between fish guard's number and number of issued licenses (k = 0,828), as well as between fish guard's number and number of issued orders (k = 0,796). We established insignificant correlation between fish guard's number and number of submitted reports (k = 0,239).

Table 4. Correlation analysis of analyzed parameters

O.N.	Relation	Correlation coefficient	Correlation degree
1	Fish guard-licenses	**0,828**	significant correlation
2	Fish guard - order	**0,796**	significant correlation
3	Fish guard - report	**0,239**	insignificant correlation

Although at the first sight number of submitted reports can be more significant parameter for required number of fish guard's analyses, orders of fish guards are statistically more significant for making decisions about required number of fish guards, that is also logical because orders have preventive role and give better long term results then repressive measures such as submitted reports.

Basic matrix and Vtv, show that consistency rating (CR) was lower than 0,10. According to Saaty-u (1980), tolerant value of CR is 0,10. Vtv for the number of issued licenses is 0,4656, for the length of water flow 0,2772, for the number of orders 0,1885 and for the accessibility of terrain 0,0687. In this research the above vectors which are clearly positioned the determination of the fish guards optimal number.

Table 5. Basic matrix of parameters comparison for defining the number of fish guards and values of the vector of weighting values (Vtv) for basic matrix criteria

Criteria	**Number of issued licenses**	**Number of orders**	**The length of water flow (km)**	**Accessibility of terrain**	**(Vtv)** CR= 0,06
Number of issued licenses	**1,00**	2,00	3,00	5,00	0,4656
Number of orders	1/2	**1,00**	1/2	3,00	0,1885
The length of water flow, km	1/3	2,00	**1,00**	5,00	0,2772
Accessibility of terrain	1/5	1/3	1/5	**1,00**	0,0687
Total					**1,0000**

In tables 6 and 7 we showed data description of scalar grade degree assessment and values of grade degree. Description of scalar grade degree assessment for these parameters are calculated according to existing statistics and specific conditions, and in that way we determined six degrees of the grade. This number is directly dependant on the relational scalar and it was determined based on minimum and maximum number of fish guards, as well as on regression analysis of the most important factor of this research, which is number of sold licenses in relation to the number of fish guards. Data we have got in table 6, show that parameter values ,vector of weighting value and relational scalar, as base for getting values of grade degree caused exponential form of grade degree, as it can be seen in table 7.

Table 6. Description of grade degree for established criteria

Parameter	*Evaluation degree*					
	1	**2**	**3**	**4**	**5**	**6**
Number of sold licenses	0 - 500	501-1500	1501-3750	3751-7500	7501-12500	>12500
Number of orders	0 - 1000	1001- 2000	2001- 3000	3001- 3500	3501- 4000	> 4000
The length of water flow, km	0 - 300	301 - 500	501 - 700	701 - 900	901 - 1200	> 1200
Accessibility of terrain	Flat terrain, little vegetation	Gently sloping terrain, little vegetation	Medium steep terrain, little vegetation	Steep, overgrown vegetation	Steep, densely overgrown vegetation	Partially hardly accessible terrain

Table 7. Values of grade degree

Parameter	**Vector (Vtv)**	**Grade degree**					
		I	**II**	**III**	**IV**	**V**	**VI**
Number of sold licenses	**0,4656**	0,93	2,33	9,31	18,62	27,93	32,59
Number of orders	**0,1885**	0,38	0,94	3,77	7,54	11,31	13,20
The length of water flow, km	**0,2772**	0,55	1,39	5,54	11,09	16,63	19,40
Accessibility of terrain	**0,0687**	0,14	0,34	1,37	2,75	4,12	4,81
Relation scalar		**2**	**5**	**20**	**40**	**60**	**70**

With grade degree formed values we accomplished final optimization of required number of fish guards (Šarčević, 2011), which is shown in tables 8 and 9.

Table 8. Practical example of determining the number of fish guards for 2 users

Users	**Number of issued**		**The length of water flow, km**	**Accessibility of terrain**	**Fish guards (number)**	
	licenses	**orders**			**existing**	**optimal**
I	18,62	7,54	11,09	2,75	25	≈40
II	27,93	7,54	19,40	1,37	56	≈56

USERS: I - PF ''Srbijašume'' Belgrade; II- OOSR ''Hristifor Perišić Kićo'', Kraljevo

Table 9. Review of existing and required number of fish guards

USERS	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	∑
Status	17	5	14	5	25	19	10	56	23	6	180
Required	**17**	**5**	**21**	**10**	**40**	**30**	**12**	**56**	**21**	**6**	**218**

USERS: 1- Doo '' Rivers Guard'' Jagodina; 2-Silver Leik Investment Beograd; 3-OOSR ''Dunavac'' Kostolac; 4- ZSR ''Timočka Krajina'' Zaječar; 5- JP ''Srbijašume'' Beograd; 6- ZOSR 'Južna Morava2' Niš; 7- Asocijacija ''Veternica'' i ''Vlasina; 8- OOSR ''Hristifor Perišić Kićo'', Kraljevo; 9- DOO ''Ekoribarstvo'' Valjevo; 10- OOSR ''Drina'' Ljubovija

The data from table 8., clearly show that the user JP ''Srbijašume'' in relation to OOSR ''Hristifor Perišić Kićo'' issued 69,8% more fishing licenses, had the same number of orders, better accessibility of terrain , it had 73,93% longer length of water flow. Despite that, optimal number of required fish guards was 60 % lower.

In table 9 we showed data for existing and calculated number of guards for fishing waters for 10 users of those waters. Out of ten analyzed users, only four had required number of fish guards and one had more than required, which means that for the protection of aquatic ecosystems in the overall level, is necessary to engage another 38 (218-180=38) fish guard. Based on the research of all users we can conclude that the best results had four users, while the worst results were recorded with users number 5 and number 3.

Applied scalar evaluation method and organization of Fish Guard Service present, in an exact manner, simplicity of optimization for required number of fish guards and for the first time finds possibility of applying in sustainable management of natural waters. So far, it was applies in determining number of game wardens and assessment of generally useful functions of forests (Šarčević, 2011; Šarčević, 2012). A similar mathematic model of multi-parameter analysis in the field of environmental protection, and among other things land waters, indicate the work of Ridgley et al (1997). Practical significance of this method is elimination of two current assumptions, which are: the optimal number of fish guards depends only on number of issued fishing licenses, and the number of submitted reports can have significant influence on determining optimal number of fish guards.

CONCLUSIONS

Results of this study show that there is a need for upgrading of existing methods in making management decisions. Scalar evaluation method (SMO) presented on example of Fish Guard Service organization, gives us the ability to determine the target parameters in both quantitative and qualitative terms, through optimization of required number of fish guards. Although, at the first sight, this method may seem complicated, by applying appropriate software and by using tables, this method becomes very applicable and efficient in making management decisions.

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