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Acipenser sturio and *Acipenser nudiventris* in the Danube – extant or extinct?

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Summary

The presence of Atlantic sturgeon (*Acipenser sturio)* and ship sturgeon (*Acipenser nudiventris*) in the Danube has been known through only occasional, chance sightings; significant uncertainty remains as to whether these species are already extinct or still present in the Danube River basin. In this study, five different statistical methods were applied for assessment of their extinction probability. All methods provided a significant probability that the Atlantic sturgeon is extinct, with extinction having occurred somewhere between 1966 and 1970. Although the applied methods provided different results, all indicated that the ship sturgeon is probably still present, but that extinction may occur within a few decades. Sensitivity analyses of these statistical methods projected that new sightings of ship sturgeon in the coming years would not extend the length of extinction by more than a few years. The best management approach for these two species, given the lack of knowledge on their presence in the Danube River basin, could be to apply all feasible protection measures for the other four Danube sturgeon species. These measures could at the same time provide protection for these two species, presuming they are not already extinct or beyond recovery.

Introduction

It is very difficult to establish how long a certain species has to remain unregistered before it can be declared extinct. According to IUCN (2001), a taxon is presumed extinct when exhaustive surveys in known and / or expected habitat, at appropriate times (diurnal, seasonal, annual), and throughout its historic range have failed to record an individual. Until recently, IUCN and CITES arbitrarily decided on 50 years without sightings as the threshold value (Reed, 1996). According to Solow (2005), a threshold value that implies extinction should be related to previous sighting rates, and for species with a high sighting rate, a relatively short period without sightings would indicate extinction. It is considered critical to increase certainty in inferring species extinction; making the wrong assumption regarding species extirpation may result in a type I or type II statistical error. Following the assumption that a species is extinct, when in fact it is not, inappropriate management actions or the lack thereof may lead to species extinction. The alternative situation may lead to costly and unnecessary sampling activities (Grogan and Boreman, 1998). Current IUCN criteria state that any threat category assigned to a taxon should also reflect a quantitative assessment of the extinction risk (IUCN, 2001). More formal, preferably quantitative, methods would help to ensure that status assessments are scientifically defensible and that resources are efficiently allocated to conservation programs (McCarthy, 1998).

The Danube River was once inhabited by six sturgeon species: beluga (*Huso huso),* Atlantic sturgeon (*Acipenser sturio*), Russian sturgeon (*Acipenser gueldenstaedtii*), ship sturgeon (*Acipenser nudiventris*) stellate sturgeon (*Acipenser stellatus*), and sterlet (*Acipenser ruthenus*). Since ancient times, sturgeons have been important fishery objectives for the high economic value of the caviar and meat (Bemis and Findeis, 1994). However, due to anthropogenic impacts such as water pollution, habitat destruction and over-fishing, sturgeon populations experienced a serious decline during the 20th century, leading to severe stock depletion (Bacalbaşa-Dobrovici, 1997).

A significant lack of knowledge on the current state of sturgeon stocks in the Danube, including their trends of decline and associated extinction risks (Reinartz, 2002; Williot et al., 2002), has hampered the introduction of effective management measures. Regarding the beluga, Russian, stellate sturgeon and sterlet, all still present in the Danube River basin, some attempts have been made to predict their risk of extinction based on catch data (Lenhardt et al., 2006). Unfortunately, the presence of Atlantic sturgeon and ship sturgeon in the Danube in the 20th century has been known only through occasional, chance sightings; lack of empirical data has prevented any quantitative approach.

In the Danube at the beginning of the 20th century, only a few specimens of Atlantic sturgeon were recorded (Reinartz, 2002); the last recorded sighting was in 1965 (Manea, 1980). The ship sturgeon used to be recorded in the middle Danube upstream to Bratislava, in the lower Danube, and occasionally in the Danube delta (Hensel and Holčik, 1997); in the mid-20th century it became increasingly rare, with only a few specimens noted in the past few decades (Hensel and Holčik, 1997; Guti, 2006).

Thus far, only a 'rule of thumb' approach has been used to determine the status of these two species, which has led to differing opinions regarding their Danube River presence. Various authors have considered the ship sturgeon as likely extirpated (Pinter, 1991), possibly extinct (Kynard et al., 2002; Reinartz, 2002), endangered (Simonović et al., 2005), or critically endangered (Hensel and Holčik, 1997; Guti, 2006). There is stronger agreement regarding the Atlantic sturgeon in the Danube River basin, since most authors designate this species as extinct or probably extinct (Bacalbaşa-Dobrovici and Holčik, 2000; Kynard et al., 2002; Reinartz, 2002; Pikitch et al., 2005).

Developments in the statistical approach in circumstances where data are scarce have resulted in new methods for

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calculation probability that a species is extinct (Burgman et al., 1995). Indirect statistical methods for estimating extinction probability from observation records appear to provide practical means of addressing this concern (Grogan and Boreman, 1998), and can be useful when sightings are the only available data (Akçakaya and Sjögren-Gulve, 2000). The strength of these methods is that they can be applied in situations where management decisions must be based on limited information, which is often the case for endangered species (Grogan and Boreman, 1998).

The present study applied indirect statistical methods for assessment of extinction probabilities of Atlantic sturgeon and ship sturgeon in the Danube. However, appropriate caution is necessary in their use, because acquired probabilities for species presence or extinction should represent more an indicator of the true status of the studied population, than to provide the final conclusion. McCarthy (1998) and Robbirt et al. (2006) suggested that it is prudent to use a number of complementary tests, since each can be sensitive to different characteristics of the collection ⁄ sighting records and their combination enhances the overall ability to detect extinction. Four different tests were employed to estimate extinction probability; an additional test estimated the time remaining to extinction. This study represents the first quantitative approach for the assessment of the presence of Atlantic and ship sturgeon populations in the Danube.

Material and methods

Sighting records

Published sighting records in the Danube River were compiled for the two species under study. Only sightings beginning in the mid-20th century (1948 and 1949 for Atlantic and ship sturgeon, respectively) were used; in the years preceding these dates the quality of data was characterized by less reliable records and sightings. Documented sightings of *A. sturio* and *A. nudiventris* are presented in Table 1.

Table 1
Documented sightings of Atlantic sturgeon (*A. sturio*) and ship sturgeon (*A. nudiventris*)

Atlantic sturgeon	References	Ship sturgeon	References
1948	Ristić (1963) and Manea (1980)	1949	Manea (1980), Vásárhely (1957)
1949	Manea (1980)	1950	Manea (1980)
1950	Ristić (1963) and Manea (1980)	1951	Manea (1980)
1951	Manea (1980)	1952	Manea (1980), Vásárhely (1957)
1952	Ristić (1963) and Manea (1980)	1953	Ristić (1963)
1954	Ristić (1963)	1954	Ristić (1963), Manea (1980)
1960	Manea (1980)	1956	Vásárhely (1957)
1961	Manea (1980)	1957	Vásárhely (1957)
1962	Manea (1980)	1961	Kálmán (1961)
1963	Manea (1980)	1975	Hensel and Holčik (1997)
1964	Manea (1980)	1989	Hensel and Holčik (1997)
1965	Manea (1980)	1992	Guti (2006)
		1998	Harka and Sallai (2004)
		2003	Simonović et al. (2005); Z. Sallai, pers. comm. The 'Nimfea' Environment and Nature Conservation Association, Túrkeve, Hungary
		2005	Guti (2006)

Statistical methods

Five complementary methods based on sighting data for the assessment of extinction probability were applied. An explicit assumption in each of the methods is that all observations of a species are incidental and made independently of each other. It is hence important to note that systematic or deliberate collection of the species cannot be used, as this would violate the underlying statistical assumptions of the methods (Solow, 1993; Burgman et al., 1995). Observations considered as random can be landings by-catch, incidental observations during surveys designed to capture other species, strandings, and records on entrapment and mortality in power plants (Grogan and Boreman, 1998). Data used in this study fulfill these criteria, as all records represent by-catch or accidental observations.

Another important assumption is that the average chance of incidentally collecting or observing a species does not change over time. According to Solow and Roberts (2003), variation in the sighting effort is an important potential source of variation in the sighting rate, but underlying assumptions of these tests may be reasonable if sightings arise from accidental encounters. The Danube River basin has been an object of intensive fishery throughout the entire period of observations (Reinartz, 2002; Williot et al., 2002; Lenhardt et al., 2006), which justifies the assumption that the chance of catching specimens of either Atlantic or ship sturgeon has always been high.

Sighting records were arranged as a series of time units (t) with positive sightings within the observation period (with the first time unit labeled 1 and the last T), ordered from the earliest to the latest, $t_1 < t_2 < \ldots < t_n$. Multiple sightings within one time unit are recorded as a single sighting. The last time unit (T) corresponds to the year 2007. Separate analyses were run in 2008 as the last time unit, in order to test the potential scenario of a lack of new observations in the current year. All equations express the probability of presence (P) of investigated species, and most authors employ a 0.05 probability as the threshold value, below which the species can be considered as extinct (Solow and Roberts, 2003; McInerny et al., 2006; Roberts and Kitchener, 2006; Carpaneto et al., 2007). Several authors (Burgman et al., 1995; Solow and Roberts, 2003) recommend omitting the first record when the time series of incidental observations has no definitive starting point other than the first recorded observation; this was applied in the present study.

The series of time units with sighting records for the Atlantic sturgeon and the ship sturgeon, respectively, are:

1, 2, 3, 4, 6, 12, 13, 14, 15, 16, 17
1, 2, 3, 4, 5, 7, 8, 12, 26, 40, 43, 49, 54, 56

The first method was introduced by Solow (1993), for inferring extinction of a species based on sightings over a continuous series of time units. Using the time of the last sighting (t_n), this equation expresses the probability of presence in relation to the number of time units in which the species was collected (n) within the period, given that sightings are equally likely to occur throughout the observation period (T):

$$\mathrm{P} = \left(\frac{t_n}{T}\right)^n \tag{1}$$

Burgman et al. (1995) developed a very similar equation which, instead of using number of time units with sightings (n), introduces the total number of individuals (k) observed in the

t_n time intervals. This method was not used in the present study because some of the published records did not include the number of individuals.

The second method was a sighting rate probability model developed by McInerny et al. (2006), which gives the probability that another sighting will occur using the previous sighting rate (n/t_n) and the time elapsed from that last observation ($T-t_n$) with the equation:

$$P = \left(1 - \left(\frac{n}{t_n}\right)\right)^{(T-t_n)} \quad (2)$$

A low likelihood value ($P < 0.05$) means a low probability of discovering another record for the species based on the previous sighting rate.

The third method, the Solow/Roberts non-parametric equation (Solow and Roberts, 2003), can be advantageous in some cases because it does not require a complete series of sighting records, as the number of sightings (n) is not required for calculation. Using t_n, T, and the time of the second most recent sighting (t_{n-1}), the equation generates the probability that another sighting will occur:

$$P = \left(\frac{t_n - t_{n-1}}{T - t_{n-1}}\right) \quad (3)$$

Equation 1 can result in a high P value if a single observation of the species was made relatively recently (as in the case of ship sturgeon), regardless of the length of time intervals between previous sightings or of any evidence of population decline during the observation period (Burgman et al., 1995). As population decline is often characterized by longer and longer periods during which the species is not observed, Burgman et al. (1995) applied a method that considers such a development. The fourth method, a so-called 'runs test', calculates the probability that the species will be recorded again during the period that is as long as, or longer than, the longest observed run of absence:

$$P = \binom{T}{n_0}^{-1} \sum_{x=1}^{\lfloor n_0/r \rfloor} (-1)^{x+1} \binom{n_1+1}{x} \binom{T-rx}{n_1} \quad (4)$$

Here, r is the length of the longest run of consecutive time units without records, n_0 the number of time units without records, n_1 the number of time units with records, and $\lfloor\rfloor$ represents the integer part of the given value. Low acquired probability ($P < 0.05$) implies extinction.

Finally, a model that estimates the most probable extinction time (T_E) was employed, following the method developed by Solow (2005). If it is assumed that the species is extinct, this method estimates the time of extinction as:

$$T_E = \frac{n+1}{n} t_n \quad (5)$$

Solow (2005) also gives the estimation of the upper bound (T_E^u) of a $1-\alpha$ confidence interval for T_E:

$$T_E^u = t_n/\alpha^{1/n} \quad (6)$$

All equations were generally analyzed for sensitivity to various future scenarios and possible biases.

Results

Values used in the equations are given in Table 2. Results of equations 1–4, applied to the documented sightings of the Atlantic and ship sturgeon, provided the indices of probability that these species are still present in the Danube River basin (Table 3).

Table 2
Values used in equations for estimating probability of Atlantic sturgeon and ship sturgeon being present in the Danube

Variables	Atlantic sturgeon	Ship sturgeon
T	59	58
n	11	14
t_n	17	56
t_{n-1}	16	54
n_1	11	14
n_0	48	44
r	42	13
α	0.05	0.05

Table 3
Probability (P) that Atlantic sturgeon and ship sturgeon are still present in the Danube, according to the four methods employed

Method	Atlantic sturgeon	Ship sturgeon
Equation 1	0.000	0.612
Equation 2	0.000	0.563
Equation 3	0.023	0.500
Equation 4	0.000	0.242

All equations provided a significant extinction probability for the Atlantic sturgeon ($P < 0.05$), while for the ship sturgeon they produced values that were well above the level of significance. In the case of absence of new records of the ship sturgeon by the end of 2008, equations 1–4 would give the respective probabilities: 0.482, 0.422, 0.400 and 0.264. Regarding the Atlantic sturgeon, the point estimate of extinction time in equation 5 is 1966–1967; equation 6 gives the upper boundary of the 0.95 confidence interval for extinction time as 1970. When applied to the ship sturgeon, the point estimate of extinction time is 2009, with 2018 as the upper boundary of the confidence interval.

Sensitivity analysis and influence of different future scenarios

Sensitivity analysis of equations 1–4 has been discussed in detail by various authors (Burgman et al., 1995; Grogan and Boreman, 1998; Solow and Roberts, 2003; McInerny et al., 2006). Specifically, an increase in time since the last observation is expected to increase the extinction probability. In the absence of ship sturgeon observations in future years, equations 1–3 require a different number of additional years to reach a significant level of probability of extinction ($P < 0.05$). For equations 1–3, an absence of observations lasting until the years 2019, 2016 and 2044, respectively, would produce a likely extinction. In the case of new sightings of ship sturgeon in the near future, the time to extinction would not be extended by more than a few years.

One of the potential biases in sighting records would be observations that were either wrongly identified or not recorded and published. An increase in the number of ship sturgeon sightings during the observation period before the last recorded sighting would lead to increased probability of extinction in equations 1–3. According to Pinter (1991),

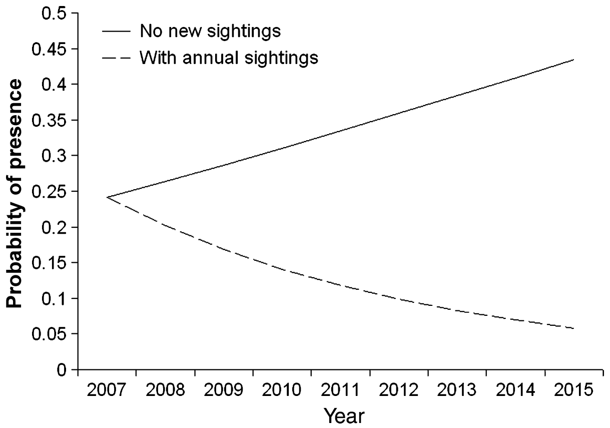

Fig. 1. Probabilities for continued presence of ship sturgeon given by equation 4 in two potential future scenarios: one where *A. nudiventris* is recorded annually over the next seven years and one where there are no new sightings

fishermen did not always distinguish larger ship sturgeon from Russian sturgeon, or smaller ship sturgeon from sterlet. However, this had limited effect regarding adult ship sturgeon upstream from the Iron Gate dams because power plant construction prevented all large anadromous sturgeons from migrating upstream (Reinartz, 2002), and the sterlet, the only sturgeon now found upstream, can never reach the dimensions of an adult ship sturgeon.

Equation 4, which is sensitive to long periods without observations but less so to a short period since the last observation, gave the highest extinction probability for the ship sturgeon. As Fig. 1 shows, when making new observations in the years that follow, this equation would give a greater probability of extinction and a smaller probability without new sightings, given that the longest new run of years without observations is shorter than the longest run recorded thus far ($r = 13$, between the time units 12 and 26, or 26 and 40). Although this might seem counterintuitive, it is caused by the fact that equation 4 is sensitive to the ratio of the longest run of years without sightings to the total period of observations, and not to the time since the last sighting.

Extinction time based on equations 5 and 6 proved to be only moderately sensitive to new sightings, which would extend the extinction time by a few years for each new observation.

Discussion

According to the results of all applied methods, the Atlantic sturgeon in the Danube River is extinct, with the extinction most likely having occurred in 1966–1967, and at the latest in 1970.

For the ship sturgeon, different equations provided different probabilities for the presence of the species, with an average value of 0.479. Although none of the given values were significant, they are certainly alarming. In the absence of new observations in the years to follow, the extinction probability would reach significant levels in two or three decades; even with a few new observations this critical period would not be dramatically extended. According to the method for extinction time estimation (Solow, 2005), the absence of new observations in forthcoming years would imply that the Danube ship sturgeon would become extinct somewhere around 2009, or at the latest in 2018.

Why is there such a dramatic difference in the rate of decline between the Atlantic sturgeon and the ship sturgeon, and why are they both doing worse than the other four sturgeon species in the Danube River? According to historical data, the Atlantic and ship sturgeon have never been abundant in the Danube River, and thus never gained a status of high economic importance (Bacalbaşa-Dobrovici and Holčik, 2000; Reinartz, 2002). Population size *per se* is often considered as the major determinant of population persistence (Reed et al., 2003), and rare species are often much more vulnerable to extinction (Roberts and Hawkins, 1999). Thus, it is possible that a smaller population size of these two species has been the cause of their lower resistance to all anthropogenic pressures and changes in habitat, making them the first to disappear from the Danube River region.

Studies by McInerny et al. (2006) and Robbirt et al. (2006) found significant correlations between estimations based on the probabilistic models used in this study and the ranked IUCN Red list categories. As in McCarthy (1998) and Regan et al. (2000), they have suggested that such indices may not only be used for estimating the probability of species extinction, but also to infer threat and decline in species considered to be still extant. As such, they should be included in the evaluation criteria for all IUCN categories (Robbirt et al., 2006).

As Diamond (1987) suggested, the burden of proof should not be placed on proving that a species is extinct; on the contrary, a species must be presumed extinct or endangered unless shown to be extant and secure. On the other hand, there have been many cases where a species has been recorded as extinct and later been rediscovered (Regan et al., 2000; Roberts and Kitchener, 2006), and species that become increasingly rare before their final extinction may continue to exist unseen for many years (Roberts and Solow, 2003). One example could be the reappearance of *A. sturio* in Estonian waters almost 30 years after the last catch (Paaver, 1999). Reinartz (2002) states that the search for ship sturgeon in the Danube River system should be one of the priorities within sturgeon conservation activities in this region. Grogan and Boreman (1998), who applied some of the methods used in this study on two sturgeon species in US, state that the final determination of extirpation status should be based on the combined use of indirect methods and directed surveys, with the addition of all available ancillary information. Very little experience exists in applying this approach to species with the life history of Acipenseriformes, thus due caution in interpreting results is necessary. This approach was therefore meant to be more scenario-building, rather than providing a final conclusion on the presence or extinction of the studied species.

In conclusion, the methods used in this study indicate that the Atlantic sturgeon can be considered as extinct in the Danube River, with extinction having occurred somewhere between 1966 and 1970. The ship sturgeon is probably still present in the Danube basin, but its extinction could probably occur within the next few decades. In any case, given the current absence of knowledge on their presence in the Danube River basin, the best advice to management authorities on protection of these two species could be to apply all feasible protection measures for the other four Danube sturgeon species. The Action Plan for the Conservation of Sturgeons (Acipenseridae) in the Danube River, adopted in 2005 by the Standing Committee of the Bern Convention, has defined a specific set of actions designed to be relevant simultaneously for the conservation of all Danube sturgeons (Bloesch et al., 2006). As in the case of 'umbrella species', measures aimed at the other four sturgeon species could at the same time provide protection for these two species, if they are not already extinct or beyond recovery. As stipulated in the Action Plan, *ex-situ* measures mainly through aquaculture and restocking programs could provide additional help for recovery of these species, or even represent a last resort in the case of their threatened extinction.

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References

Akçakaya, H. R.; Sjögren-Gulve, P., 2000: Population viability analyses in conservation planning: an overview. Ecol. B. **49,** 9–21.

Bacalbasa-Dobrovici, N., 1997: Endangered migratory sturgeons of the lower Danube River and its delta. Environ. Biol. Fish **48,** 201–207.

Bacalbaşa-Dobrovici, N.; Holčik, J., 2000: Distribution of *Acipenser sturio* L., 1758 in the Black Sea and its watershed. Bol. Instituto Español de Oceanografía **16,** 37–41.

Bemis, W. E.; Findeis, E. K., 1994: The sturgeons' plight. Nature **370,** 602.

Bloesch, J.; Jones, T.; Reinartz, R.; Striebel, B.; Holcik, J.; Kynard, B.; Suciu, R.; Williot, P., 2006: Action plan for the conservation of sturgeons (Acipenseridae) in the Danube River Basin. Nat. Environ. **144,** 121.

Burgman, M. A.; Grimson, R. C.; Ferson, S., 1995: Inferring threat from scientific collections. Conserv. Biol. **9,** 923–928.

Carpaneto, G. M.; Mazziotta, A.; Valerio, L., 2007: Inferring species decline from collection records: roller dung beetles in Italy (Coleoptera, Scarabaeidae). Diversity Distrib. **13,** 903–919.

Diamond, J. M., 1987: Extant unless proven extinct? Or, extinct unless proven extant? Conserv. Biol. **1,** 77–79.

Grogan, C. S.; Boreman, J., 1998: Estimating the probability that historical populations of fish species are extirpated. N. Am. J. Fish. Manag. **18,** 522–529.

Guti, G., 2006: Past and present status of sturgeons in Hungary. Proceedings of 36th International Conference of IAD, 143–147. Austrian Committee on Danube Research / IAD, Vienna.

Harka, A.; Sallai, Z., 2004: Magyarorszag halfaunaja [Fish Fauna of Hungary]. Nimfea Termeszetvedelmi Egyesulet, Szarvas. [In Hungarian].

Hensel, K.; Holčik, J., 1997: Past and current status of sturgeons in the upper and middle Danube River. Environ. Biol. Fish **48,** 185–200.

IUCN, 2001: IUCN red list categories and criteria. Version 3.1. IUCN Species Survival Commission, Gland, Switzerland and Cambridge, UK.

Kálmán, I., 1961: A 23 és fél kilós tok. Magyar Horgász **15,** 1–2. [In Hungarian].

Kynard, B.; Suciu, R.; Horgan, M., 2002: Migration and habitats of diadromous Danube River sturgeons in Romania: 1998–2000. J. Appl. Ichthyol. **18,** 529–535.

Lenhardt, M.; Jaric, I.; Kalauzi, A.; Cvijanovic, G., 2006: Assessment of extinction risk and reasons for decline in sturgeon. Biodivers. Conserv. **15,** 1967–1976.

Manea, G., 1980: Sturgeons; taxonomy, biology, sturgeon rearing and sturgeon rearing ponds. Ed. Ceres, Bucuresti, 243 p. [In Romanian].

McCarthy, M. A., 1998: Identifying declining and threatened species with museum data. Biol. Conserv. **83,** 9–17.

McInerny, G. J.; Roberts, D. L.; Davy, A. J.; Cribb, P. J., 2006: Significance of sighting rate in inferring extinction and threat. Conserv. Biol. **20,** 562–567.

Paaver, T., 1999: Historic and recent records of native and exotic sturgeon species in Estonia. J. Appl. Ichthyol. **15,** 129–132.

Pikitch, E. K.; Doukakis, P.; Lauck, L.; Chakrabarty, P.; Erickson, D. L., 2005: Status, trends and management of sturgeon and paddlefish fisheries. Fish Fish. **6,** 233–265.

Pinter, K., 1991: Sturgeons in Hungary, past and present situation. In: Acipenser, P. Williot (Ed), Cemagref-Dicova, Bordeaux, France. pp. 173–178.

Reed, J. M., 1996: Using statistical probability to increase confidence of inferring species extinction. Conserv. Biol. **10,** 1283–1285.

Reed, D. H.; O'Grady, J. J.; Brook, B. W.; Ballou, J. D.; Frankham, R., 2003: Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. Biol. Conserv. **113,** 23–34.

Regan, H. M.; Colyvan, M.; Burgman, M. A., 2000: A proposal for fuzzy International Union for the Conservation of Nature (IUCN) categories and criteria. Biol. Conserv. **92,** 101–108.

Reinartz, R., 2002: Sturgeons in the Danube River. Biology, status, conservation. literature study. International Association for Danube Research (IAD), Bezirk Oberpfalz, Landesfischereiverband Bayern, e.V.150 p.

Ristić, M. D., 1963: Ribarsko biološka studija. Acipenseridae-a jugoslavenskog dela donjega Dunava [Fishery biological study. Acipenserids of Yugoslavian part of the Lower Danube]. Ribarstvo Jugoslavije [Yugoslavian Fishery] **2,** 48–58. [In Serbian].

Robbirt, K. M.; Roberts, D. L.; Hawkins, J. A., 2006: Comparing IUCN and probabilistic assessments of threat: do IUCN red list criteria conflate rarity and threat? Biodivers. Conserv. **15,** 1903–1912.

Roberts, C. M.; Hawkins, J. P., 1999: Extinction risk in the sea. Trends Ecol. Evol. **14,** 241–246.

Roberts, D. L.; Kitchener, A. C., 2006: Inferring extinction from biological records: were we too quick to write off Miss Waldron's Red Colobus Monkey (*Piliocolobus badius waldronae*)? Biol. Conserv. **128,** 285–287.

Roberts, D. L.; Solow, A. R., 2003: When did the dodo become extinct? Nature **426,** 245.

Simonović, P.; Budakov, L. J.; Nikolić, V.; Marić, S., 2005: Recent record of the ship sturgeon *Acipenser nudiventris* in the middle Danube (Serbia). Biologia **60,** 231–233.

Solow, A. R., 1993: Inferring extinction from sighting data. Ecology **74,** 962–964.

Solow, A. R., 2005: Inferring threat from a sighting record. Math. Biosci. **195,** 47–55.

Solow, A. R.; Roberts, D. L., 2003: A nonparametric test for extinction based on a sighting record. Ecology **84,** 1329–1332.

Vásárhely, I., 1957: Felső-tiszai színtokok – és a Tiszalöki vízilépcsö [Ship sturgeon catches in the upper Tisza River and the Tiszalok water step]. Halászat **4,** 105. [In Hungarian].

Williot, P.; Arlati, G.; Chebanov, M.; Gulyas, T.; Kasimov, R.; Kirschbaum, F.; Patriche, N.; Pavlovskaya, L. P.; Poliakova, L.; Pourkazemi, M.; Kim, Y.; Zhuang, P.; Zholdasova, I. M., 2002: Status and management of Eurasian sturgeon: an overview. Int. Rev. Hydrobiol. **87,** 483–506.

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