Scientometrics
DOI 10.1007/s11192-011-0583-7

Analysis of publications on sturgeon research between 1996 and 2010

I. Jarić · J. Gessner

Received: 27 June 2011

Abstract Sturgeon species are among the commercially most valuable and the most endangered groups of fish. To assess the existing literature published within the field of sturgeon research over the past 15 years (1996–2010) we applied a bibliometric approach, in order to identify patterns and trends of the published research in this field. The analysis was performed based upon articles obtained from the ISI Web of Knowledge online database. The results revealed that although all 27 sturgeon species have been objects of the research, species that are endangered or facing a high probability of extinction have received disproportionately less attention. White sturgeon (*Acipenser transmontanus*) was the most frequently studied species, but it was recently surpassed by Persian sturgeon (*A. persicus*). Early life phases have been among the central objects of the research, and genetics, especially the use of microsatellite DNA, is becoming increasingly popular and had the highest impact. Research related to aquaculture was prominent, while the research related to hybrids (as a commodity of aquaculture production) was decreasing in popularity. Papers dealing with conservation issues were most frequently focused on European sturgeon (*A. sturio*). A steady increase in the number of published articles over time was observed. However, the overall citation rate declined significantly over time. During the period reviewed, the sturgeon research published in peer reviewed journals dominantly originated from the USA and EU. Nevertheless, considering the current trend in output, it is very likely that the Asian countries, mainly Iran and China, will surpass them within the next 5–10 years. International and inter-institutional collaboration both tended to increase the impact of the research. Stimulation and improvement of the international cooperation should be considered as future priorities.

I. Jarić (✉)
Institute for Multidisciplinary Research, Kneza Viseslava 1, 11000 Belgrade, Serbia
e-mail: ijaric@imsi.rs

I. Jarić · J. Gessner
Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany

J. Gessner
Society to Save the Sturgeon, Rostock, Germany

Published online: 16 December 2011

Keywords *Acipenser* · *Huso* · *Scaphirhynchus* · *Pseudoscaphirhynchus* · Bibliometry · Trends

Introduction

Sturgeon species (order Acipenseriformes) are among the commercially most valuable fish. Due to the value of their caviar, they have been an important object of fisheries, as well as of rapidly growing aquaculture production during the last three decades (Bronzi et al. 2011). Due to their vulnerability towards overfishing, habitat degradation and fragmentation, sturgeons are the most endangered group of fish. According to the International Union for Conservation of Nature (IUCN Red List of Threatened Species, Version 2011.1), 17 out of 27 extant species are classified as critically endangered (63%), eight as either near threatened, vulnerable or endangered (30%), while only two are considered to be species of the least concern (7%; www.iucnredlist.org). Several populations became extinct already, starting as early as during the Middle Ages, while the majority was facing crisis during the last century (Ludwig 2006; Jarić et al. 2009).

Sturgeon research has experienced a considerable increase over the last few decades, as a result of the above mentioned drivers. In the early 20th century, main areas of sturgeon research were addressing their biology and systematics as well as fisheries, while the more recent efforts have been increasingly focused on their farming and conservation (Billard and Lecointre 2001). A number of reviews were published within the sturgeon research fields (e.g. Billard and Lecointre 2001; Ludwig 2006; Zhu et al. 2008). However, there were no attempts to provide a more quantitative assessment of the current status and trends of this research thus far. As claimed by Neff and Corley (2009), the bibliometric analysis is a powerful tool that enables the analysis of research priorities across an entire discipline. It has the ability to reveal interesting information about knowledge producers and their interactions (Persson et al. 2000). Therefore, the aim of this study is to assess the published sturgeon research literature over the past 15 years (1996–2010) by applying bibliometric methods, to identify patterns and trends as well as the exchange within the community.

Materials and methods

Publication collection

Articles utilized in this analysis were obtained from the ISI Web of Knowledge online database, published by Thomson Reuters (available at www.isiknowledge.com). To retrieve papers dealing with sturgeon research, the following terms were used as a search query phrase: "sturgeon* OR paddlefish* OR acipenser* OR huso OR scaphirhynch* OR pseudoscaphirhynchus OR psephurus OR polyodon*", to search the titles of referenced publications between 1996 and 2010.

The search resulted in the total number of 1,664 articles. In a second step, the titles were checked manually to identify mismatches (e.g. articles with the toponyms that contain the word "sturgeon", such as "Sturgeon Falls" or "Sturgeon Bay", those containing the last name Sturgeon in the title, those with the term "polyodontia", etc.). The revision excluded 26 articles from further analysis. Within the remaining articles, five lacked the data necessary to perform the analysis (e.g. no available data on authorship) which were thus also excluded from further analysis.

Finally, the analysis was focused on original articles, reviews and proceedings, which in total comprised 92% (1,501) among these publications (1,156 articles, 316 proceeding papers and 29 reviews). The remaining publications, such as meeting abstracts (3.7%; $N = 61$), editorial material (1.7%; 28), news items (1.5%; 24), corrections (0.9%; 14), letters (0.2%; 3) and reprints (0.1%; 2), were excluded from the final analysis.

Data analysis

Each of the publications were analyzed for the authors' names and number of authors, their affiliation(s), publication subject category (ISI journal classification), journal names, citation, and the sturgeon species the studies dealt with. The "whole counting method", according to Gauffriau et al. (2007), was applied as a general counting method. Furthermore, the period studied was separated into three 5-year sub-periods (1996–2000, 2001–2005 and 2006–2010) for comparison, to assess the trends in analyzed variables.

Since the total citation of an article is highly dependent on the time elapsed since publication, only citations during the first 2 years following publication (TC2) were taken into account. This procedure is in line with the approach of Qiu and Chen (2009) to evaluate immediate impact. Based on the TC2, the number of citations per publication (CPP) was defined as the total number of citations over the total number of publications (i.e., it was standardized as citation ratio per publication; Hsieh et al. 2004). CPP was estimated only for the articles published between 1996 and 2008, since the citations for the articles published in 2009 and 2010 were still missing at the time when the analysis was carried out (Qiu and Chen 2009). *H*-index, established by Hirsch (2005), was also used to assess the publication impact. This index, which represents the number of papers (h) of an individual with citation count $\geq h$ (Hirsch 2010), is being increasingly promoted as a suitable tool in measuring journal performance, substituting the commonly used commercial impact factor (Braun et al. 2006).

The analysis was conducted by the combined use of MS Excel and coding made in R programming language. The statistical analyses were performed by standard statistical software (SPSS 15.0). Data were tested for normality by Kolmogorov–Smirnov test. Since most of the data failed normality test, nonparametric inferential statistics were applied. In particular, the initial assessment of the differences among the groups was performed by Kruskal–Wallis H test, which was followed by comparisons of particular pairs by Mann–Whitney U test. The relationships between the analyzed parameters were assessed by Spearman's non-parametric correlation test.

Publication patterns were also compared with the Human Development Index per country (HDI, data for 2010, UNDP 2010) and Gross Domestic Product derived from purchasing power parity (GDP, data for 2010, IMF 2011). To assess overall scientific focus regarding the level of extirpation risk in studied species, species were categorized according to the IUCN red list criteria at the mid-point of the studied period (www.iucnredlist.org), and thereafter compared with publication patterns.

Subject analysis

We attempted to identify the most frequently used words and the trend in their frequency change over the studied period, which should indicate the research priorities within the studied period and main trends within the respective scientific field (Neff and Corley

2009). The titles were used as units of analysis, to avoid controversies when using keywords (Neff and Corley 2009). Following the formation of the basic title word lists, all words devoid of meaning (i.e., “if”, “and”, “with”, etc.) were removed from the list, and the alternate forms of words were grouped together. The occurrence frequency of each word was standardized separately for the total period and the three sub-periods to eliminate the potential bias created by the change in the number of published articles over the studied period. The number of times each word appeared in titles of articles was divided by the number of articles published in the respective period. As such the word occurrence frequency was expressed as a rate of the total number of articles published within the studied period containing a particular word. The change in the frequency over time was calculated by subtracting their frequencies within sub-periods.

Results and discussion

Overall publication activity was characterized by an increase in a number of published articles over time. Number of publications per period increased from 376 articles (25% of total) published during 1996–2000 and 467 articles (31%) during 2001–2005, to 658 articles (44%) published during 2006–2010. The majority of the articles was published in English language, while there were only 13 articles listed in ISI database published in French, eight in Russian, two in Japanese, Arabic and German, and only a single article published in Chinese, Persian and Czech language.

The overall CPP of 1.93 ± 2.66 indicates that the citation frequency of articles dealing with sturgeons was comparably low. Moreover, there was a significant decrease in CPP over time ($p < 0.05$, Kruskal–Wallis test), from 2.21 ± 3.22 in the first period to 1.72 ± 2.28 in the third. Comparison of citation frequency in sturgeon research publications with the publications on other species revealed a much lower citation impact of the former (Table 1). Publications focused on salmonids, shads, eels, aquaculture and cyprinids were retrieved by the use of ISI Web of Knowledge online database, and their trends in CPP were assessed within the same time periods (words “Salmo”, “Oncorhynchus”, “Alosa”, “Anguilla”, “Aquaculture” and “Cyprinus” were used as search phrases within publication titles). As can be observed in Table 1, publications dealing with most of the other diadromous species, such as salmonids and eels, had a significantly higher impact. The same was true for *Cyprinus* spp. as well as for publications focused on aquaculture. The only exception were shads, which had a lower overall citation rate, although their citation rate exceeded that of sturgeons during the last sub-period. Contrasting to sturgeon related publications, the overall citation rate for all other assessed subjects experienced an increase, in some cases even significant.

Possible explanations for the observed negative trend in the citation rate of publications dealing with sturgeon research were assessed. An increase of the citation rate over time is a global trend across all scientific fields, with 2.6 as an average annual rate of increase (Althouse et al. 2009). However, according to the same authors, an increase in the number of publications within a particular scientific field, which was also observed in this study, will not lead by itself to an increase in citation rate. While more articles are being published and thus more citations are being assigned, those citations are still shared among a larger pool of papers (Althouse et al. 2009). Changes in the number of citations within publication reference lists is one of the major causes of a change in citation rate (Asari and Aziz 2005). According to Althouse et al. (2009), the single greatest contributor to citation rate increase across all scientific fields during 1994–2005 has been an increase in the average number of references per paper. Average number of references found in this study

Table 1 Citation impact (CPP) of scientific publications focused on different issues within fish biology and fisheries during 1996–2010

Research focus	1996–2000	2001–2005	2006–2010	Total	Change[a]
Acipenseriformes	2.21	1.90	1.72	1.93	−0.22
Salmo	2.95	3.66	3.73	3.43	0.26
Oncorhynchus	3.19	3.19	3.49	3.27	0.09
Alosa	1.67	1.17	2.00	1.51	0.20
Anguilla	2.36	2.92	3.00	2.75	0.27
Cyprinus	1.97	2.72	2.57	2.44	0.30
Aquaculture	1.37	2.04	2.61	2.06	0.90

CPP citations per publication

[a] Difference between the first and the third subperiod (%)

(31.9) was lower than those found in other scientific fields (e.g. 40 references on average within the field of conservation biology; Liu et al. 2011). This might partly explain a lower citation rate of sturgeon related publications when compared with publications related to other subjects. On the other hand, the average number of references within the field of sturgeon research has increased over time (from 30.3 during 1996–2000 to 32.6 during 2006–2010), which should have resulted in an increase of citation rate over time. According to Althouse et al. (2009), citation rate is also substantially influenced by the fraction of citations that comprise non-indexed literature. Those scientific fields that cite less within ISI databases have lower citation rates. We hypothesize that, with only a limited number of publications listed in the ISI databases, "grey literature" was increasingly referenced among the cited material. Although we have not tested this assumption explicitly, there are some indices that point in that direction. According to Arunachalam and Balaji (2001), majority of fishery science articles from China (87.7%) are being published in non-indexed journals. Therefore, if countries that increasingly contributed to the total scientific output within sturgeon research during the last two sub-periods (China and Iran) tended to refer predominantly to local, non-indexed publications, this would have reduced the overall share of indexed citations in an increasing number of publications. Furthermore, the field of sturgeon research seems to be a relatively small and compact network, being rarely cited by publications that do not belong to this field. This renders the field a net importer of citations (i.e., a scientific field that references more publications each year than the number of times it gets cited; Ma and Stern 2006). This import/export ratio has increased over time, which might indicate the trend of a diminishing interest for sturgeon related publications by other fields of research. According to Said et al. (2008), small and tighter scientific networks can be less useful for their members, since the more open ones are more likely to introduce new ideas and opportunities.

Subject categories

Publications were classified under 53 different ISI subject categories. "Fisheries" was by far the most frequent subject category, throughout the whole study period as well as in each of the sub-periods. This was followed by the category "Marine & Freshwater Biology". The "Fisheries" subject category also experienced a growth in frequency over time, from 47% during 1996–2000 to 58% during 2006–2010. Major subject categories are presented in Table 2.

Table 2 Number of articles, average number of citations per publication and the species that was most frequently studied within major ISI subject categories

Subject category	*N* (%)	CPP	*H*	IC	Major species studied
Fisheries	791 (53%)	1.56	29	0.18	*A. transmontanus*
Marine & Freshwater Biology	623 (42%)	1.61	31	0.24	*A. transmontanus*
Environmental Sciences & Ecology	208 (14%)	2.46	26	0.22	*A. transmontanus*
Biochemistry & Molecular Biology	114 (8%)	2.13	17	0.26	*H. huso*
Zoology	104 (7%)	1.71	17	0.22	*A. baerii*
Physiology	97 (6%)	1.29	15	0.22	*H. huso*
Genetics & Heredity	67 (4%)	3.97	18	0.22	*A. baerii*
Evolutionary Biology	45 (3%)	2.77	12	0.18	*A. persicus/A. stellatus*
Veterinary Sciences	40 (3%)	1.21	8	0.15	*A. transmontanus*
Toxicology	35 (2%)	2.21	11	0.26	*A. transmontanus*
Neurosciences & Neurology	33 (2%)	2.57	12	0.27	*P. spathula*
Agriculture	31 (2%)	0.29	5	0.06	*A. baerii*
Biodiversity & Conservation	31 (2%)	2.73	10	0.10	*A. sturio/A. oxyrinchus/ A. fulvescens*
Life Sciences & Biomedicine—Other Topics	30 (2%)	3.30	11	0.30	*P. spathula*

N number of publications, *CPP* citations per publication, *H* *h*-index, *IC* international co-authorship

“Marine & Freshwater Biology” was the subject category with the highest *h*-index (31), while the highest citation output (CPP) was achieved within Physics (9.50), followed by Developmental Biology (4.50), Reproductive Biology (4.13) and Genetics & Heredity (3.97). Most of the major subject categories experienced a significant decline of citation input over time. Such trend was especially pronounced in subject categories that were not directly related to the fishery science or fish ecology, such as “Life Sciences & Biomedicine—Other Topics”, with a decline in CPP from 6.75 in the first sub-period to 1.60 in the third one. “Evolutionary Biology” declined from 4.67 to 1.92 while “Genetics & Heredity” decreased from 5.35 to 2.43 and “Physiology” from 1.78 to 0.88. The subject category Biodiversity & Conservation also experienced a declining citation trend, from 4.33 to 2.00. The observed trend might be influenced by the already described causal relationship between the reduced participation of indexed articles in reference lists and the decline of the overall citation rate. However, these data might also indicate reduced interest of the scientific community for the mentioned topics regarding sturgeon species. The opposite trend was observed in the category “Environmental Sciences & Ecology” (increase from 2.04 to 2.80), as well as for categories “Toxicology” and “Chemistry”, revealing an increase from 1.58 and 0.50 to 3.00 and 2.67, respectively.

Observed trends in the two most prominent subject categories, “Fisheries” and “Marine & Freshwater Biology”, were compared with the general trends within these two subject categories over the same time period (phrase “fish*” was used to search within publication titles). Both subject categories had higher overall CPP values than those for sturgeon research publications within each respective field, and both categories also experienced a significant citation rate increase over time. The overall CPP within “Fisheries” and “Marine & Freshwater Biology” was 2.29 and 2.86 respectively while their CPP increased over time by 52 and 30%.

Based upon the results presented, the existing set of ISI subject categories seems to be inadequate. On one hand, it is too simple to cover and catalogue a whole range of existing study objectives, and some topics lack adequate subject categories. On the other hand, journals often cover much wider scopes than those defined by subject categories that were initially assigned to them. As a result, one of the implications of this study is the need for a revision of ISI subject categories. Inappropriateness of the ISI set of subject categories was also recognized by other authors (Porter and Rafols 2009).

Authorship

In total, 2604 authors participated in the research, although the actual number is probably somewhat lower, due to a misprinting of last names and initials. The total number of authors publishing sturgeon related papers increased by 250% over the time, from 609 during 1996–2000, and 1,114 during 2001–2005, to 1500 during 2006–2010. 947 were involved in more than one paper (36%), while 1657 (64%) authored only a single paper. Only 1% (27) of the authors produced each more than 1% of the total number of publications (15 papers). Comparison of the total number of publications and the total number of authors within each period indicates that the number of publications per author has decreased over time. This indicates that on average the increase in the number of publications over time was caused by a significantly increased pool of contributing authors, and not by their increased individual productivity.

Over the entire period, there were 3.8 persons coauthoring an article. Comparing the three periods, the average number of authors per publication increased significantly over the time ($p < 0.05$, Mann–Whitney U test), from 3.4 in the first period to 4.0 in the third one. The increase in the number of authors per publication over time is a global trend in science, with as much as 70% of increase over the last 30 years (Porter and Rafols 2009). Although the average number of authors per paper was fairly similar to the one observed in the field of conservation biology (3.7; Liu et al. 2011), it was higher than the one in the field of invasive species research (3.2; Qiu and Chen 2009). On the other hand, it was lower than the average number of authors across different scientific fields (5.5; Abt 2007a). The global trend of the decline of single-authored publications (Abt 2007b) was also observed in this study. The portion of publications that were produced by a single author decreased constantly over time, from 12% during 1996–2000 to only 8% during 2006–2010.

Institutions

Out of 802 institutions that contributed to the research only 352 were involved in more than one paper (44%). Only 4% (31) of institutions produced each more than 1% of the total number of publications. Institutions with the highest number of published articles within the respective field are presented in Table 3. As can be observed in the Table, the most productive institutions were located in USA, followed by Iran and China. Many of the most productive institutions in this field were also among the most productive within the field of conservation biology, such as the Chinese Academy of Sciences, University of California, Davis, and the Russian Academy of Sciences (Liu et al. 2011). University of California, Davis, was also the second most productive institution within invasive species research (Qiu and Chen 2009).

Table 3 The most productive institutions within the field of sturgeon research between 1996 and 2010

	N (%)	CPP	*H*	IC (%)	CA (%)	CPP of CA	Species
University of California, Davis, USA	129 (9%)	2.57	21	26	50	2.56	*A. transmontanus*
US Geological Survey, USA	90 (6%)	2.20	16	11	68	2.08	*A. oxyrinchus*
US Fish & Wildlife Service, USA	82 (5%)	1.75	13	6	80	1.88	*S. albus*
Chinese Academy of Fishery Sciences, China	50 (3%)	1.89	9	38	86	2.08	*A. sinensis*
Cemagref, France	47 (3%)	1.84	14	60	68	2.17	*A. baerii*
Russian Academy of Sciences, Russia	42 (3%)	0.58	7	12	40	0.73	*A. gueldenstaedtii*
International Sturgeon Research Institute, Iran	40 (3%)	1.23	6	28	75	1.43	*A. persicus*
Chinese Academy of Sciences, China	36 (2%)	1.88	10	61	94	1.96	*A. sinensis*
University of Tehran, Iran	34 (2%)	0.92	5	38	100	0.92	*A. persicus*
University of Missouri, USA	32 (2%)	5.50	12	34	56	6.00	*P. spathula*
University of South Bohemia, Czech Republic	31 (2%)	2.18	8	68	84	2.42	*A. baerii/ A. ruthenus*
University Tarbiat Modares, Iran	30 (2%)	1.08	4	23	90	1.08	*A. persicus*

Table includes only the institutions with 2% or more of the total number of publications

N number of publications, *CPP* citations per publication, *H* *h*-index, *IC* international co-authorship, *CA* Inter-institutional collaborated articles, *Species* most frequently studied species

No clear trend was observed with regard to the status of institutions. Both universities and national research centres were among the most prolific institutions. Principal researchers with a focus on sturgeon research do represent the nucleus for research in different institutions. Long-term continuity in research also pays off, since all of the most productive institutions have been involved in sturgeon research for the whole period examined. According to Borsi and Schubert (2011), research within aquaculture and fisheries in EU is dominated by state-owned institutions.

Comparison of the total CPP per institution with the CPP of publications authored by more than one institution (Table 3) shows that, with the exception of some of the most productive institutions, such as the US Geological Survey and University of California, Davis, most institutions did benefit from the established cooperation leading to publications. An increase in the number of collaborating institutions per publication over time has been observed as a general trend in science (Hicks and Katz 1996).

Country of publication

Authors contributing to sturgeon research publications were situated in 52 different countries. Nearly all of the countries involved in sturgeon research were located in Europe, North America and Asia, which is not surprising, considering the circumpolar distribution of sturgeons in the northern hemisphere. Major countries involved in sturgeon research are presented in Fig. 1, and the output per continent in Fig. 2. USA were by far the most productive country throughout the studied period, contributing 49% of all published articles ($N = 732$). Its dominance in the total scientific production was also observed in other

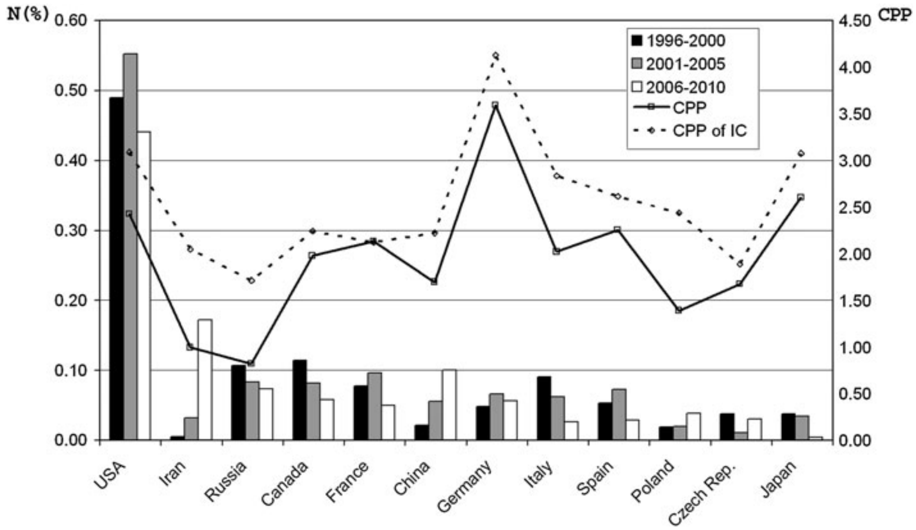

Fig. 1 Publication output of the most productive countries within the field of sturgeon research during 1996–2010. *CPP* citations per publication, *CPP of IC* citations per publication within publications with international collaboration (both calculated as a mean for the entire period)

studies (Soteriades and Falagas 2005; Igami and Saka 2007; Qiu and Chen 2009; Liu et al. 2011). Beside the apparent influence of the larger amount of research funding provided, this is to some extent caused by differences in publication culture among countries. A major impact is also caused by the database utilized, which tends to better represent USA based papers than those from the rest of the world (Holmgren and Schnitzer 2004). There is also a question of units; according to Gauffriau et al. (2008), EU should be considered in analyses as a single unit of comparison, such as USA, and not as a set of individual countries.

However, while the share of USA in the total publication output ranged from 44% to as much as 55% of the total publications among the different sub-periods, this proportion declined over time. The same was also true for Russia, Canada, France, Spain and Italy. Italy experienced the largest relative decline in productivity, which might have been caused by a decreasing number of researchers involved in sturgeon work, following the initial development of aquaculture and the techniques to reestablish the Adriatic sturgeon (*Acipenser naccarii*) in the wild (Bronzi et al. 2011).

Iran was the country with the largest and the most rapid overall growth, increasing from 1% of the total number of publications during 1996–2000 to 17% of the publications during 2006–2010. Such an increase in productivity was partly caused by the publication of the proceedings from the 5th International Symposium on Sturgeons, organized in 2005 in Ramsar, Iran. These proceedings, which were published in 2006 in the Journal of Applied Ichthyology, accounted for 32% of the total number of publications in Iran in the third subperiod. Nevertheless, the boost in productivity in Iran is undeniable, since it would still remain the country with the largest relative growth even without considering the publications included in the proceedings. A comparable significant growth in productivity was also experienced in China. However, it is important to note that some countries, such as USA, France and Russia, while experiencing a relative decline in publication output, revealed an increase in the absolute number of publications. In other words, although the

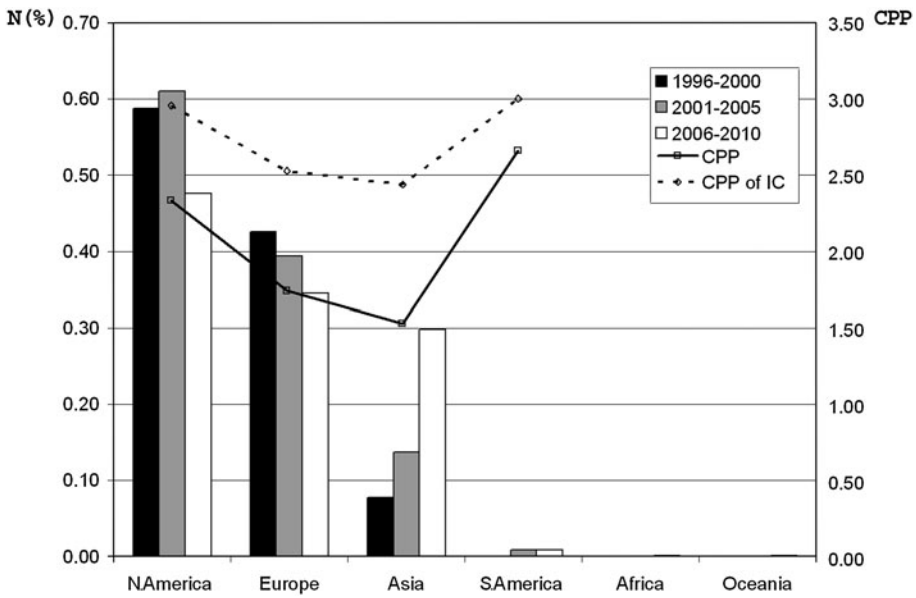

Fig. 2 Publication output per continent within the field of sturgeon research during 1996–2010. *CPP* citations per publication, *CPP of IC* citations per publication within publications with international collaboration (both calculated as a mean for the entire period)

number of publications produced by these countries did increase over time, their relative participation in the total scientific output declined over time. As it was elaborated by Larsen et al. (2008), a relative decline in publication output should not be mistaken for a real decline, and it is to be expected that the relative contribution of the "old scientific countries" to a common stock of scientific knowledge has to decline over time, due to a more rapid increase of output in developing countries.

Moreover, high citation rates of publications from USA and EU also indicate that the scientific production in these countries is stable (Larsen et al. 2008). In this study, USA publication output was greater than the total EU output. In some studies in other fields, a trend of the total EU scientific production surpassing that of USA has been observed (Gauffriau et al. 2008). EU had in total more publications than USA within the fields of aquaculture and fisheries, although USA had a higher citation rate, especially in fisheries (Borsi and Schubert 2011).

The same patterns of publication activity were observed when total outputs were assessed per continent. Both North America and Europe, being the dominant continents with regard to the number of published articles worldwide, experienced a relative decline in productivity. In contrast, Asia experienced a significantly increasing output (Fig. 2). This is in line with an overall trend in scientific publications (Larsen et al. 2008).

Sturgeon research, however, reveals a strong regional focus. Only 15 countries provided more than 1% each of the total number of publications. On the other hand, the number of countries participating in sturgeon research increased over time, from 31 countries during 1996–2000 and 33 countries during 2001–2005 to 43 countries during 2006–2010. Besides the 12 most productive countries presented in Fig. 1, other countries with notable contributions were UK ($N = 21$), Romania (18), Hungary (17), Azerbaijan (13), Serbia (12), Portugal (11), Sweden (10) and Turkey (10). Comparison of the total number of countries also reveals that some countries did drop out from sturgeon research altogether.

The highest overall CPP was observed for Germany (3.58) and the lowest one for Iran (0.99) and Russia (0.81; Fig. 1). North America had the highest CPP (2.35) per continent, followed by Europe (1.77) and Asia (1.56).

The US was the dominant country of authorship within most of the subject categories. Russia was the leading country within the category "Evolutionary Biology", Iran dominated within the subject category "Agriculture", Germany within "Developmental Biology", Spain in "Anatomy & Morphology" and "Cell Biology", while Italy contributed with the majority of articles in "Chemistry" and Czech Republic within "Reproductive Biology". These dominances of specific countries within particular subject categories might be in certain cases a result of the activity of a single research group, and in certain cases by the possible preference of scientists from a particular country for submitting papers in a specific journal.

Country GDP and HDI scores had both a low but significant positive correlation with TC2 ($p < 0.001$, Spearman's non-parametric correlation test), indicating a higher number of citations per publications for the more developed countries. HDI and GDP also had a weak but significant negative correlation with the year of publication, indicating a trend of increasing participation of less developed countries in the total scientific output over time.

International cooperation patterns

International cooperation contributed to 21% of the total number of publications. The ratio of publications with international co-authorship varied over time, from 17% in the first subperiod to 25 and 20% in the second and third one, respectively. The observed level of international cooperation is much lower than in the general field of environmental science (60% across countries; Igami and Saka 2007), as well as in the general field of biology (30.4%; Abt 2007a). Increasing international collaboration over time is a general trend, across all countries and scientific fields (Abt 2007a).

The average CPP of articles that stemmed from international cooperation (2.54) was significantly higher ($p < 0.001$, Mann–Whitney U test) than for those published by authors from a single country (1.78). The same pattern was observed when the impact of international cooperation was analyzed for individual countries and per continent. Most of the countries and all continents had significantly higher CPP ($p < 0.05$, Mann–Whitney U test) for articles with international co-authorship (Figs. 1, 2). This implies that the countries generally benefited from the international research collaboration regarding the publication impact. This result was most pronounced for Russia, Poland and Iran. The exemption was France, which actually had a lower CPP for articles stemming from international collaboration than from national research. The benefit in increased impact of publications based on international cooperation was also confirmed by a weak but significant positive correlation between TC2 and the number of authors per publication, as well as between TC2 and both the number of countries and the number of continents involved in publication authorship ($p < 0.001$, Spearman's non-parametric correlation test). These findings are in accordance with the observations by Persson et al. (2000). On the other hand, Abt (2007a) found only a weak relationship between the international cooperation and the citation rate across different scientific fields.

The strongest international cooperation was established by France and Germany, who had both as much as 64% of papers published through international co-authorship (Table 4). While the authors from USA published articles in cooperation with the majority of the countries that were involved in sturgeon research (33 countries, 63%), the overall ratio of

Table 4 Sturgeon research publications by major species studied per country

Country	IC (%)	Sp. no.	Major species studied			
			Total period	1996–2000	2001–2005	2006–2010
USA	21	26	*A. transmontanus*	*A. transmontanus*	*A. transmontanus*	*S. platorynchus*
Iran	28	8	*A. persicus*	*A. persicus*	*A. persicus*	*A. persicus*
Russia	29	18	*A. gueldenstaedtii*	*A. gueldenstaedtii*	*A. gueldenstaedtii*	*A. baerii*
Canada	38	14	*A. fulvescens*	*A. fulvescens*	*A. transmontanus/ A. brevirostrum/ A. oxyrinchus*	*A. fulvescens*
France	64	16	*A. baerii*	*A. baerii*	*A. baerii*	*A. baerii*
China	41	14	*A. sinensis*	*A. transmontanus*	*A. sinensis*	*A. sinensis*
Germany	64	15	*A. ruthenus*	*A. sturio*	*A. ruthenus/ P. spathula*	*A. oxyrinchus/ A. sturio*
Italy	38	12	*A. naccarii*	*A. naccarii*	*A. naccarii*	*A. naccarii*
Spain	42	13	*A. baerii*	*A. baerii*	*A. baerii*	*A. naccarii*
Poland	37	9	*A. baerii*	*A. fulvescens*	*A. baerii*	*A. baerii*
Czech Rep.	56	9	*A. baerii*	*A. baerii*	*P. spathula*	*A. baerii/ A. ruthenus*
Japan	45	12	*H. huso*[a]	*H. huso/ A. ruthenus*[a]	*H. huso*[a]	*H. huso/ A. ruthenus/ A. sinensis*[a]

IC international co-authorship, *Sp. no.* number of species studied

[a] In Japan, predominant object of studies involving *H. huso* and *A. ruthenus* was bester (hybrid *H. huso* × *A. ruthenus*)

articles published through international cooperation in USA (21%) was low, when compared with other countries. A low level of international cooperation of scientists from USA was also observed in other studies (Igami and Saka 2007; Gauffriau et al. 2008). International cooperation of USA within conservation biology, although much lower than in other countries, was still higher than within sturgeon research (31.5%; Liu et al. 2011). However, as was discussed by Gauffriau et al. (2008), this does not represent a true picture of the level of cooperation in USA, as the cooperation between different institutions within this country and among its states compensates partly for international cooperation. Most of the countries experienced an increase in the ratio of internationally co-authored publications through time, while it drastically declined for Iran, China and Poland. The most frequent cooperation was between USA as a principal partner and Canada, Germany, China and Russia, as well as between France as a principal partner and Germany, Czech Republic and Spain (Table 5).

Journals

There were a total of 279 scientific journals publishing articles related to sturgeon research. The number of journals increased over time, from 116 in the first sub-period to 174 in the third one. However, 51% (142) of the journals only published a single article dealing with sturgeon research during the studied periods. Overall, 95% of journals (266) each published less than 1% of the total number of articles. Major journals and their scientific output are presented in the Table 6. As can be seen in the Table, the journal that most frequently published sturgeon related articles was the Journal of Applied Ichthyology. This is not

Table 5 The most frequent cooperation bonds between country pairs within the field of sturgeon research during 1996–2010

Cooperation pair	*N* (%)	CPP	*H*	Major species studied	Major subject category
USA/Canada	31 (10%)	2.65	9	*A. transmontanus*	Fisheries
USA/Germany	21 (7%)	6.00	11	*P. spathula*	Life Sciences & Biomedicine—Other Topics
USA/China	19 (6%)	1.82	9	*A. sinensis*	Marine & Freshwater Biology
France/Germany	14 (5%)	2.69	7	*A. sturio*	Marine & Freshwater Biology
USA/Russia	14 (5%)	3.15	6	*A. baerii*	Marine & Freshwater Biology
France/Czech Republic	12 (4%)	1.75	7	*P. spathula*	Fisheries
France/Spain	10 (3%)	2.11	6	*A. baerii*	Marine & Freshwater Biology

Table includes only those country pairs that had 10 or more mutual publications

N number of publications (percent of all publications with international co-authorship), *CPP* citations per publication, *H h*-index

surprising, since it represents the official journal of the World Sturgeon Conservation Society (WSCS). Beside the dominant journals listed in the Table 6, there was a number of journals which ranked high within particular sub-periods, such as Folia Zoologica, International Review of Hydrobiology and Iranian Journal of Fisheries Sciences, which were, respectively, ranked among the dominant journals in the first, second and third sub-period.

Certain journals have published proceedings from conferences focusing on sturgeons. These have significantly contributed to the total output of sturgeon related publications. The most important of those were 3rd, 4th and 5th International Symposium on Sturgeons (ISS), published in 1999, 2002 and 2006 in the Journal of Applied Ichthyology (with CPP, respectively, 1.07, 0.71 and 0.34). Very low CPP value for the fifth ISS might be partly explained by a low participation of authors from USA (6% of papers). Relevant proceedings (i.e., those with more than 20 articles recorded in this study) also originated from the "International Conference on Sturgeon Biodiversity and Conservation", held in 1994 in New York, published in 1997 in the Environmental Biology of Fishes (CPP = 2.07), as well as the "Conference on Evolution, Ecology, and Management of Scaphirhynchus", held in 2005 in St. Louis, Missouri, with proceedings published in 2007 in the Journal of Applied Ichthyology (CPP = 2.66). Proceedings of the 6th ISS, which was held in 2009 in Wuhan, China, were not included in this study, since they have been published in the Journal of Applied Ichthyology in 2011, which was out of the time-frame of this study.

The ratio of papers in the conference proceedings declined over time, from 26% of the total number of papers published during 1996–2000 to 18% of those published during 2006–2010. However, it is important to note that the actual share of conference publications within assessed papers was probably somewhat higher. Certain journals publish conference proceedings in regular issues, in which case they are not designated as proceedings papers in the ISI Web of Knowledge database.

Species

All 27 sturgeon species have been the object of scientific research during the study period. The species most frequently studied over the entire period was the white sturgeon (*Acipenser transmontanus*) (13%), followed by the Siberian sturgeon (*A. baerii*) (10%), lake sturgeon (*A. fulvescens*) (9%), paddlefish (*Polyodon spathula*) (9%), beluga (*Huso huso*) (8%), Gulf sturgeon (*A. oxyrinchus*) (8%), Russian sturgeon (*A. gueldenstaedtii*) (7%),

Table 6 Major journals publishing articles within the field of sturgeon research between 1996 and 2010

	N (%)	CPP (Rank)	IF (Rank)	*H* (Rank)	IC (%)	Species
Journal of Applied Ichthyology	321 (21%)	1.08 (11)	1.12 (9)	18 (3)	20	*H. huso/ A. gueldenstaedtii*
Transactions of the American Fisheries Society	94 (6%)	2.68 (4)	1.26 (5)	19 (2)	4	*A. oxyrinchus*
Environmental Biology of Fishes	93 (6%)	2.49 (6)	1.16 (8)	21 (1)	24	*A. medirostris*
Aquaculture	54 (4%)	2.69 (3)	1.93 (4)	18 (3)	37	*A. transmontanus*
North American Journal of Fisheries Management	49 (3%)	1.67 (8)	1.07 (11)	11 (6)	2	*A. fulvescens*
North American Journal of Aquaculture	37 (2%)	1.11 (10)	0.64 (12)	9 (9)	8	*A. oxyrinchus*
Fish Physiology and Biochemistry	36 (2%)	0.78 (12)	1.23 (6)	9 (9)	36	*H. huso*
Journal of Fish Biology	32 (2%)	2.56 (5)	1.23 (7)	12 (5)	28	*A. baerii/H. huso/ P. spathula*
Aquaculture Research	31 (2%)	1.63 (9)	1.10 (10)	5 (12)	23	*A. baerii*
Journal of Evolutionary Biochemistry and Physiology	25 (2%)	0.14 (14)	0.27 (14)	1 (14)	0	*A. persicus*
Canadian Journal of Fisheries and Aquatic Sciences	20 (1%)	2.11 (7)	1.95 (3)	11 (6)	15	*A. fulvescens*
Comparative Biochemistry and Physiology	20 (1%)	2.81 (2)	1.61–2.58 (2)	9 (9)	25	*P. spathula*
General and Comparative Endocrinology	19 (1%)	3.11 (1)	2.73 (1)	10 (8)	21	*A. transmontanus/ S. albus*
Cybium	16 (1%)	0.69 (13)	0.29 (13)	3 (13)	50	*A. sturio*

N number of publications, *CPP* citations per publication, *IF* impact factor (2009), *H* *h*-index, *IC* international co-authorship, *Species* most frequently studied species

sterlet (*A. ruthenus*) (6%) and Persian sturgeon (*A. persicus*) (6%; Fig. 3). While experiencing a significant decline in the frequency over time, *A. transmontanus* still dominated as the most frequently studied species during 1996–2000 (19%) and 2001–2005 (16%). It was exceeded however by *A. persicus* during 2006–2010, which emerged as the most frequently studied species (12%) in that period. On the other hand, the most rarely studied species were Syr-darya shovelnose sturgeon (*Pseudoscaphirhynchus fedtschenkoi*), dwarf sturgeon (*P. hermanni*), false shovelnose sturgeon (*P. kaufmanni*), Sakhalin sturgeon (*A. mikadoi*), Chinese paddlefish (*Psephurus gladius*), Alabama sturgeon (*Scaphirhynchus suttkusi*) and Yangtze sturgeon (*A. dabryanus*) (<1% of the total number of publications).

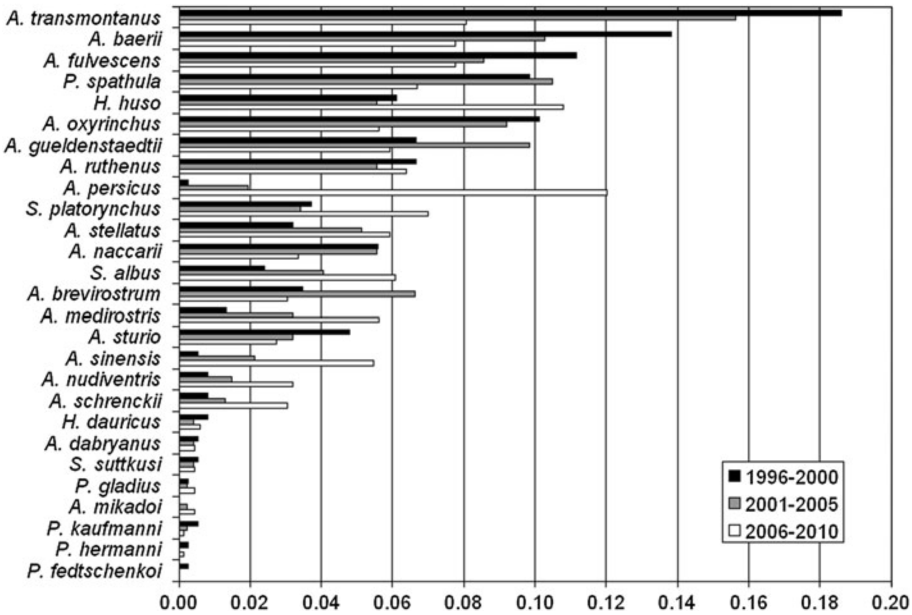

Fig. 3 Publication output per each of the 27 sturgeon species during 1996–2010

These species are among those that are extremely rare and are threatened by extinction. The lack of availability of specimens is hypothesized to strongly influence the low presence in the published research, since conservation is a "hot topic" in sturgeon research (Rosenthal et al. 2006).

Overall, the majority of Eurasian species, such as *A. persicus*, *H. huso*, stellate sturgeon (*A. stellatus*), Chinese sturgeon (*A. sinensis*), ship sturgeon (*A. nudiventris*) and Amur sturgeon (*A. schrenckii*), experienced a significant increase in relative frequency of publications over time. The Eurasian species with a marked decrease in frequency were *A. baerii*, Adriatic sturgeon (*A. naccarii*) and European sturgeon (*A. sturio*). On the other hand, the majority of North American species experienced a significant decline in their relative frequency over time, and this was most pronounced for *A. transmontanus*, *A. fulvescens*, *P. spathula* and *A. oxyrinchus*. While publications focused on *A. transmontanus* were declining in their absolute number (from 70 publications during 1996–2000 to 53 during 2006–2010), the decrease in the relative frequency of other species was caused by a growing number of contributions focused on other species, rather than by a decline in the number of publications focusing upon these species. The opposite trend was observed only for the green sturgeon (*A. medirostris*), which was the North American species revealing the most pronounced increase in frequency of publications (from 1% during 1996–2000 and 3% during 2001–2005 to 6% during 2006-2010), as well as for the shovelnose sturgeon (*S. platorynchus*) and pallid sturgeon (*S. albus*). In all three cases, proceedings of species focused meetings contributed significantly to the increase in publications related to the species. Most frequently studied species in each of the major countries, within the studied period and the sub-periods, are presented in Table 4.

The number of countries involved in the research on a specific species was highest for *A. gueldenstaedtii* (29), followed by *H. huso* (27), *A. ruthenus* (24), *A. stellatus* (22), *A. transmontanus* (21), *A. baerii* (21) and *P. spathula* (20). Aquaculture related research has a strong impact upon the range where particular species is being studied. These six species are also the species with the highest number of countries where their aquaculture is being practiced (Bronzi et al. 2011). *A. transmontanus* was the major species studied in North America, and it was the dominant species in each of the three sub-periods. *A. baerii* was the dominant object of studies in Europe, within the whole study period and within each of the sub-periods as well. Importance of these two species as objects of aquaculture largely contributed to their prominence within the total publication output (Williot et al. 2001). *A. transmontanus* and *A. gueldenstaedtii* were dominant species in Asia during 1996–2000 and 2001–2005, respectively. The reason for such prominence of *A. transmontanus* in Asia during the first sub-period is mostly research conducted on this species in Japan, followed by international cooperation between Institute of Hydrobiology, Chinese Academy of Science, and University of California Davis. However, the actual research in these cases was mainly conducted in USA, in cooperation with visiting scientists from Asia. During the last period (2006–2010), *A. persicus* became the dominant species in Asia, which rendered it also the most prominent species in Asia over the whole investigated period.

When taking the subject categories into consideration, *A. transmontanus* was the most frequently studied species within many of the subject categories. *P. spathula* was the dominant species within the "Neurosciences & Neurology" and "Life Sciences & Biomedicine—Other Topics", and the only sturgeon species listed in "Physics", which is a result of the research focused on *P. spathula* electroreceptors. Dominance of *A. naccarii* within "Anatomy & Morphology" was as a result of the research conducted on its developmental biology and anatomy of the cardio-vascular system. There was no single dominant species within the category "Biodiversity & Conservation", although *A. sturio*, *A. oxyrinchus* and *A. fulvescens* could be distinguished as the most prominent ones.

It is apparent that the North American species had the highest *h*-index values, such as *A. transmontanus* (24), *A. oxyrinchus* (23), *A. fulvescens* (22) and *P. spathula* (20). *A. medirostris* had by far the highest CPP (3.54). Species with a high overall CPP were *P. spathula* (2.61), *S. albus* (2.43) and *S. platorynchus* (2.42). The species with the lowest CPP were predominantly those from Asia, such as *P. fedtschenkoi* (0.00), *P. gladius* (0.67), *A. nudiventris* (0.69) and *A. persicus* (0.75). However, nearly all species experienced a significant decrease of citation rate over time. The exceptions were *S. platorynchus*, *H. dauricus* and *A. naccarii*, which had the opposite citation trend. *A. persicus* and *A. sinensis* had both a pattern of a high CPP during 2001–2005 (2.67 and 2.90, respectively), followed by a large decline of CPP in the third sub-period (1.05 and 0.41, respectively). This might be probably linked with the observed decline in international cooperation in China and Iran, which were the major countries where these two species have been studied, respectively. Moreover, such decline in citation rate could be also probably caused by an increased share of non-indexed publications within reference lists, as was already discussed before.

Conservation related publications

The overall publication output reveals unevenness of the species coverage. Figure 4 presents average publication output per species, according to their IUCN Red List status in 2003, which was the mid-point of the studied period. The mid-point was chosen since that classification, established in 1996, was valid during almost all of the studied period (for most of the species up to 2009). As shown in Fig. 4, the number of publications decreases with increasing Red List status. Although the situation has improved to an extent for

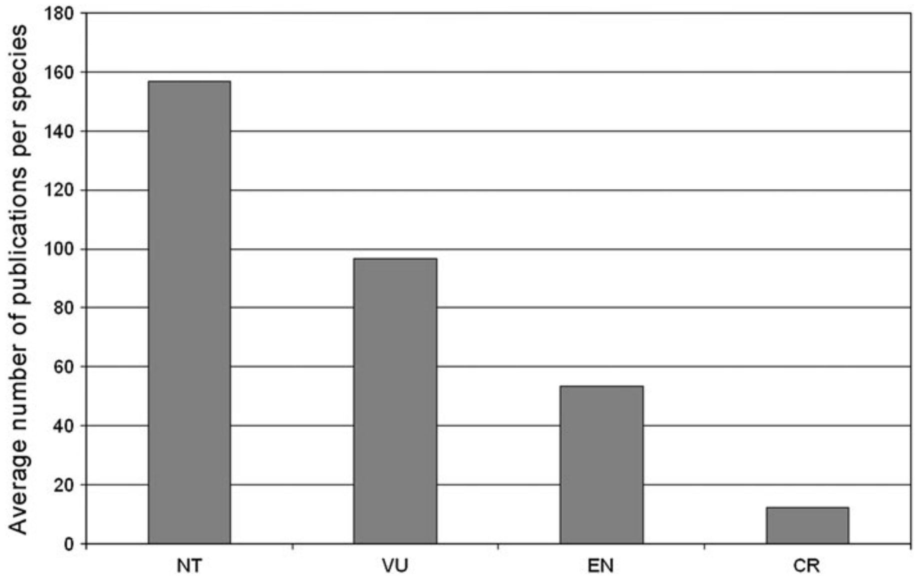

Fig. 4 Average publication output (publications per species) per IUCN Red List classification category (in accordance with the IUCN classification in 2003); *NT* near threatened (2 species), *VU* vulnerable (8 species), *EN* endangered (11 species), *CR* critically endangered (6 species)

endangered species (an increase from 2% per species of the total number of publications in the first sub-period to 5% in the third one), it has remained practically unchanged for those classified as critically endangered. Furthermore, publications dealing with more endangered species in general had a lower impact. This was confirmed by a weak but significant negative correlation between TC2 and the IUCN category of studied species ($p < 0.001$, Spearman's non-parametric correlation test). Probable reasons for such uneven scientific focus might be the economic value, reduced access to specimens, the utilization of model species, as well as the fact that the most important aquaculture species are less endangered. According to Billard and Lecointre (2001), the major reason for a lack of knowledge on critically endangered sturgeon species is a lack of available specimens for research. Accordingly, Pikitch et al. (2005) claimed that a large portion of current research on conservation breeding and supportive stocking is conducted for species that are not under the greatest anthropogenic pressure, which makes knowledge transfer a priority. The pattern of a smaller share of studies on fish species threatened with extinction was observed in other studies as well (Azevedo et al. 2010).

Word analysis

There were a number of words within the titles of the analyzed publications that were both frequent and growing in relative frequency over time. The most prominent one was the word "juvenile", being present in 9.9% articles, and with a 0.9% growth in frequency over time. A number of other words related to early life stages were also frequent, such as "egg", "larvae" and "larval". However, although they all had an increase in frequency over time, they had a relatively low citation rate (CPP ranged from 0.50 to 2.21).

Words related to the research of genetics were both frequent and with the highest citation rates (CPP ranged from 2.50 to 3.51). Words "microsatellite", "genetic" and "gene" experienced a substantial growth in frequency over time, and *A. fulvescens* was the dominant species studied within this field of research. On the other hand, both the word "mitochondrial" and the word "DNA" experienced a considerable decline over time (−2.3 and −1.9%, respectively). For publications with these two words, *A. oxyrinchus* and *A. baerii* were the dominant species. Such trends might indicate that the use of microsatellite DNA is gaining popularity, while the opposite trend appears to exist regarding the use of mitochondrial DNA. Increasing popularity of genetic studies has been observed by other authors as well. As determined by Azevedo et al. (2010), genetic studies were predominant type of research within the field of fish biology in Brazil, with nearly a third of the articles dealing with different issues within genetics. It was also an increasingly popular object of the research within the general field of ecology, with the phrases "microsatellite loci characterization" and "mitochondrial DNA" becoming the major emerging word clusters (Neff and Corley 2009). Moreover, words "DNA" and "microsatellites" belonged to the most frequent words within the field of conservation biology, with the latter one being as well among those with the most intensive growth in frequency over time (Liu et al. 2011). Significant growth in frequency was also observed for words "sex" (2.7%; CPP = 2.08), "protein" (2.6%; CPP = 2.41), and "spawning" (2.5%; CPP = 2.34).

Terminology related to aquaculture production ("cultured" and "reared") had a weak increase over time, and a relatively low citation rate (CPP = 0.95–1.50). *A. transmontanus* was the dominant species studied in aquaculture related publications.

The dominant species within publications containing the word "endangered" in their titles was *A. sturio*. It is however worth noting that no species could be distinguished as the most frequent one for the publications with the word "conservation", since as much as ten different species had equal frequencies in this group of publications. Both of these words increased in frequency over time, and had a similar citation rate (CPP = 2.00–2.27).

The frequency of the word "hybrid" (−2.0%) revealed the most expressed decline over time. This might indicate a reducing interest for using hybrids for aquaculture purposes. Citation rate of those articles was low (CPP = 1.36), and the dominant country in these publications was Japan, which also experienced a severe decline in publication output over time. Substantial declines in frequency were also observed for the words "management" (−1.6%), "feeding" (−1.2%), "caviar" (−0.6%), "behaviour" (−0.6%) and "migration" (−0.8%). The first four words had a low to average citation rate (CPP = 1.33–2.25) and were associated to *A. transmontanus* as a predominantly studied species, while the word "migration" had a higher citation rate (3.11) and *A. oxyrinchus* as the dominant species.

Conclusions

This study detected a steady increase in the number of published articles that are dealing with sturgeon research. This is associated with the growing number of scientists dealing with sturgeon research, and not by the increase of individual productivity. In fact, a decrease in the number of papers per author over time indicates an increasing presence of co-authors with only an ephemeral publishing within this field, by appearing on no more than a single paper.

Sturgeon research publications in ISI during the past 15 years were dominantly originating from the USA, as well as from the EU. Within EU, major countries in this field of research were France, Germany, Italy and Spain. New EU countries, although having substantial sturgeon aquaculture industry and formerly also important sturgeon fishery industry, are still not proportionately represented within the total EU research, as was also observed in other studies (Soteriades and Falagas 2005). Publication policy as well as language command might be partly attributed as reasons for this phenomenon.

Iran was the country with by far the most rapidly growing field of sturgeon research. It has emerged as the second most productive country in this field. A rapid growth of publication output was also experienced by China, which might not be surprising as it has become the largest sturgeon aquaculture producer in the world (Zhu et al. 2008) and actively promoting international cooperation. According to the observed trends, it is very likely that the Asian countries will surpass both North America and Europe within the next 5–10 years by their total publication output. However, it is also likely that both USA and EU will remain dominant in the following years regarding the impact of their research. One should however be aware of a certain level of bias of the existing scientific databases, which are skewed towards representing North American and European publications far more frequently than those of the rest of the world (Costanza et al. 2004; Holmgren and Schnitzer 2004; Igami and Saka 2007). As stated by Stocks et al. (2008), substantial portion of the locally published research remains overlooked at the international level. Some of the inherent flaws of the ISI system have been frequently criticized (e.g. Adam 2002; Zetterström 2002).

Sturgeon research had a comparably low overall impact, and a trend of a decline in the impact has been also detected. This seems to be principally caused by non-indexed publications becoming increasingly cited within sturgeon research publications. Scientists working on sturgeon research increasingly tend to use locally published studies as a base of their research. The situation might be partly improved by the expected future increase in the number of indexed journals from Iran and China, the two countries with the most rapidly growing publication output within this field (Ren and Rousseau 2002). However, low overall impact seems to be also caused by an apparent lack of interest for sturgeons by other fields of research, and this gap also seems to increase over time. Sturgeon research still remains a relatively isolated field, without the "eclectic appeal" that would attract readership from the outside.

All 27 sturgeon species have been objects of the research during the studied period. While the research has been dominated by *A. transmontanus*, *A. persicus* exceeded it during the last few years. The overall trend in the total publication output indicates a certain shift from North American towards Eurasian species. However, species that are endangered or facing a high probability of extinction have received disproportionately less attention. Such disparity, probably influenced to an extent by commercial, aquaculture and fishery related priorities, is certainly alarming when bearing in mind high risks of extinction some sturgeon species are currently faced with.

This study has also detected certain trends in the subjects studied within this field. Early life stages have been one of the central objects of the research. Research related to the genetics is becoming increasingly popular, especially the use of microsatellite DNA, and such publications seem to have been also those with the highest impact. Research related to the aquaculture was also prominent, and such studies were most frequently focused on *A. transmontanus*. On the other hand, research related to hybrids seems to be losing popularity. Papers dealing with the conservation issues were most frequently focused on *A. sturio*.

Results indicate that the establishment of collaboration generally increased the impact of the research. However, although there is a well established cooperation among institutions and countries, it is still comparably lower than in some other fields of research and in science in general. Therefore, there is an expressed need for the improvement of cooperation within this field, both on national and international level, as well as a need for the enhancement of the knowledge and experience exchange efficiency. The major future research priorities should be further expansion of the sturgeon research to cover a broader and a more multidisciplinary scope, and particularly investment of greater efforts on the research of those highly endangered species that have been neglected thus far. As stated by Pikitch et al. (2005), future management activities would be best facilitated through targeted research and monitoring efforts.

Acknowledgments The authors thank the Leibniz-Institute of Freshwater Ecology and Inland Fisheries in Berlin, Germany for its support through the IGB—Fellowship Program in Freshwater Science, the support by the Project No. 173045, funded by the Ministry of Science and Technological Development of Republic Serbia, as well as the support by the German Federal Agency for Nature Conservation under the project grant Az: Z 1.3-892 11-4/09. The authors would also like to thank the anonymous referees for providing helpful comments and suggestions that enhanced the quality of the paper.

References

Abt, H. A. (2007a). The frequencies of multinational papers in various sciences. *Scientometrics, 72*(1), 105–115.

Abt, H. A. (2007b). The future of single-authored papers. *Scientometrics, 73*(3), 353–358.

Adam, D. (2002). The counting house. *Nature, 415*, 726–729.

Althouse, B. M., West, J. D., Bergstrom, T., & Bergstrom, C. T. (2009). Differences in impact factor across fields and over time. *Journal of the American Society for Information Science and Technology, 60*(1), 27–34.

Arunachalam, S., & Balaji, J. (2001). Fish science research in China: How does it compare with fish research in India? *Scientometrics, 52*(1), 13–28.

Asari, M. A., & Aziz, N. (2005). The use, misuse, and misconception of impact factor. *The International Medical Journal, 4*(2), 102–103.

Azevedo, P. G., Mesquita, F. O., & Young, R. J. (2010). Fishing for gaps in science: A bibliographic analysis of Brazilian freshwater ichthyology from 1986 to 2005. *Journal of Fish Biology, 76*, 2177–2193.

Billard, R., & Lecointre, G. (2001). Biology and conservation of sturgeon and paddlefish. *Reviews in Fish Biology and Fisheries, 10*, 355–392.

Borsi, B., & Schubert, A. (2011). Agrifood research in Europe: A global perspective. *Scientometrics, 86*, 133–154.

Braun, T., Glänzel, W., & Schubert, A. (2006). A Hirsch-type index for journals. *Scientometrics, 69*(1), 169–173.

Bronzi, P., Rosenthal, H., & Gessner, J. (2011). Global sturgeon aquaculture production: An overview. *Journal of Applied Ichthyology, 27*, 169–175.

Costanza, R., Stern, D., Fisher, B., He, L., & Chunbo, M. (2004). Influential publications in ecological economics: A citation analysis. *Ecological Economics, 50*, 261–292.

Gauffriau, M., Larsen, P. O., Maye, I., Roulin-Perriard, A., & von Ins, M. (2007). Publication, cooperation and productivity measures in scientific research. *Scientometrics, 73*(2), 175–214.

Gauffriau, M., Larsen, P. O., Maye, I., Roulin-Perriard, A., & von Ins, M. (2008). Comparisons of results of publication counting using different methods. *Scientometrics, 77*(1), 147–176.

Hicks, D. M., & Katz, J. S. (1996). Where is science going? *Science, Technology & Human Values, 21*(4), 379–406.

Hirsch, J. E. (2005). An index to quantify an individual's scientific research output. *PNAS, 102*(46), 16569–16572.

Hirsch, J. E. (2010). An index to quantify an individual's scientific research output that takes into account the effect of multiple coauthorship. *Scientometrics, 85*, 741–754.

Holmgren, M., & Schnitzer, S. A. (2004). Science on the rise in developing countries. *PLoS Biol, 2*(1), 0010–0013.

Hsieh, W. H., Chiu, W. T., Lee, Y. S., & Ho, Y. S. (2004). Bibliometric analysis of patent ductus arteriosus treatments. *Scientometrics, 60*(2), 205–215.

Igami, M., & Saka, A. (2007). Capturing the evolving nature of science, the development of new scientific indicators and the mapping of science. STI working paper 2007/1, Directorate for Science, Technology and Industry, Organisation for Economic Co-operation and Development, Paris, France, 53 pp.

IMF. (2011). Nominal GDP list of countries, April 2011: Data for the year 2010. World Economic Outlook Database, International Monetary Fund. http://www.imf.org/external/pubs/ft/weo/2011/01/weodata/index.aspx. Accessed 31 May 2011.

Jarić, I., Lenhardt, M., Cvijanović, G., & Ebenhard, T. (2009). *Acipenser sturio* and *Acipenser nudiventris* in the Danube—extant or extinct? *Journal of Applied Ichthyology, 25*, 137–141.

Larsen, P. O., Maye, I., & von Ins, M. (2008). Scientific output and impact: Relative positions of China, Europe, India, Japan and the USA. In Kretschmer, H., & Havemann, F. (Eds.), Proceedings of WIS 2008, fourth international conference on webometrics, informetrics and scientometrics & ninth COLLNET meeting, Berlin, 9 pp. http://creativecommons.org/licenses/by/2.0/. Accessed 31 May 2011.

Liu, X., Zhang, L., & Hong, S. (2011). Global biodiversity research during 1900–2009: A bibliometric analysis. *Biodiversity and Conservation, 20*, 807–826.

Ludwig, A. (2006). A sturgeon view on conservation genetics. *European Journal of Wildlife Research, 52*, 3–8.

Ma, C., & Stern, D. I. (2006). Environmental and ecological economics: A citation analysis. *Ecological Economics, 58*, 491–506.

Neff, M. W., & Corley, E. A. (2009). 35 years and 160,000 articles: A bibliometric exploration of the evolution of ecology. *Scientometrics, 80*(3), 657–682.

Persson, O., Luukkonen, T., & Hälikkä, S. (2000). A bibliometric study of Finnish science. Working papers No. 48/00, VTT, group for technology studies, Espoo, Finland, 74 pp. www.vtt.fi/inf/julkaisut/muut/2000/wp48.pdf. Accessed 31 May 2011.

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

Porter, A. L., & Rafols, I. (2009). Is science becoming more interdisciplinary? Measuring and mapping six research fields over time. *Scientometrics, 81*(3), 719–745.

Qiu, H., & Chen, Y. F. (2009). Bibliometric analysis of biological invasions research during the period of 1991 to 2007. *Scientometrics, 81*(3), 601–610.

Ren, S., & Rousseau, R. (2002). International visibility of Chinese scientific journals. *Scientometrics, 53*(3), 389–405.

Rosenthal, H., Pourkazemi, M., & Bruch, R. (2006). The 5th international symposium on sturgeons: A conference with major emphasis on conservation, environmental mitigation and sustainable use of the sturgeon resources. *Journal of Applied Ichthyology, 22*(Suppl. 1), 1–4.

Said, Y. H., Wegman, E. J., Sharabati, W. K., & Rigsby, J. H. (2008). Social networks of author–coauthor relationships. *Computational Statistics & Data Analysis, 52*, 2177–2184.

Soteriades, E. S., & Falagas, M. E. (2005). Comparison of amount of biomedical research originating from the European Union and the United States. *BMJ, 331*, 192–194.

Stocks, G., Seales, L., Panlagua, F., Maehr, E., & Bruna, E. M. (2008). The geographical and institutional distribution of ecological research in the tropics. *Biotropica, 40*(4), 397–404.

UNDP. (2010). Human Development Index and its components. United Nations Development Programme. http://hdr.undp.org/en/media/HDR_2010_EN_Table1.pdf. Accessed 31 May 2011.

Williot, P., Sabeau, L., Gessner, J., Arlati, G., Bronzi, P., Gulyas, T., et al. (2001). Sturgeon farming in Western Europe: Recent developments and perspectives. *Aquatic Living Resources, 14*, 367–374.

Zetterström, R. (2002). Bibliometric data: A disaster for many non-American biomedical journals. *Acta Paediatrica, 91*, 1020–1024.

Zhu, B., Que, Y., Yang, Z., & Chang, J. (2008). A review on genetic studies in sturgeons and their trade control in China. *Journal of Applied Ichthyology, 24*(Suppl. 1), 29–35.