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A bedform morphology hypothesis for spawning areas of Chinese sturgeon

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Abstract Results from previous research suggested that geomorphic characteristics may be important controlling factors among other microhabitat variables for spawning fish. We investigated the bedform morphology of seven spawning areas (five historic and two present spawning areas) of Chinese sturgeon (*Acipenser sinensis*) by analysis of relief maps of the riverbed and by field surveys. We conclude that the topographic characteristics of the spawning areas include rocky or gravelly substrate river bend, large variations in water depth and river width and a slope with moderate length and slope. The turning structure and the adverse slope may be the most important topographic characteristics for the spawning areas. Combined with the reproductive occurrence of the fish in these spawning areas, we tentatively propose a bedform morphology hypothesis for the spawning areas. We consider that a spawning area of *A. sinensis* should consist of three functional areas: Mating area (M), Dispersal area (D) and Incubation area (I). M, D and I are distributed along the water current and their bedform characteristics are clearly different. M is the place for mature fish to mate and spawn. It is usually below a riffle with rolling terrain. D is the place for fertilizing and dispersing fertilized eggs. It is usually in a river bend with sharp variations in terrain, such as deep pools or steep slopes. I is the place for dispersal of fertilized eggs. It is usually in long point bars or broad shallow areas with rocky substrate. This hypothesis could serve as a guideline for improving the present spawning areas or constructing new spawning areas, so as to rehabilitate the wild stock of the sturgeon.

Keywords *Acipenser sinensis* · Natural reproduction · Riverbed topography · Microhabitat · Yangtze River

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Introduction

The Chinese sturgeon (*Acipenser sinensis* Gray), is a large, anadromous species with historical breeding populations in the Yangtze and Pearl rivers (YARSG 1988). In the late 20th Century, the population of *A. sinensis* declined dramatically because of overfishing and habitat degradation (Wei et al. 1997). The species was listed as a First Class Protected Animal by the national government in 1989. The hydroacoustic assessment on the size of spawning cohorts in 2002 indicated only about 200 individuals (Qiao et al. 2006). In addition, the stock assessment on juvenile sturgeons indicated that more than 90% of the juveniles originate from natural reproduction, although more than seven million cultured larvae and juveniles have been released into the Yangtze River for stock restoration since 1983 (Zhu et al. 2002; Wei 2003; Yang et al. 2006). Under these prerequisites, it becomes critically significant how to maintain or even to enhance the natural reproduction and recruitment of this species.

Due to their instinctive behavior, most species of Acipenseriformes have critical requirements for spawning conditions (Billard and Lecointre 2001), and show a homing fidelity to some particular spawning areas (Bemis and Kynard 1997). Sturgeon reproductive success is influenced by many environmental factors, such as water temperature, water level, discharge, current velocity and riverbed substrate (Dettlaff et al. 1993; Billard and Lecointre 2001). Results from previous research have suggested that geomorphic characteristics are likely important in regulating other microhabitat variables (e.g., substrate quality, hyporheic exchange, hydraulic habitat complexity) important to spawning fish (Baxter and Hauer 2000; Keckeis 2001; Moise and Michel 2004; Moir et al. 2006). Therefore the topography of the spawning area maintains a close relationship with the natural reproduction process, such as gonad development, fertilization, dispersal of fertilized eggs and incubation (Knapp et al. 1998; Hauer et al. 2007).

Early studies on spawning areas of *A. sinensis* were reported by Ke and Tian (YARSG 1988). They provided a general description, including the locations and topography of several historic spawning areas as well as hydrological status (water temperature, water level and silt content) in relation to reproduction. Subsequent researchers (Hu et al. 1983, 1985, 1992) investigated the topography of the present spawning area below Gezhouba Dam, and considered it has some similar characteristics to the historic spawning areas. In recent years, a comprehensive investigation has been conducted on abiotic factors in the last regular spawning area (Wei 2003; Yang et al. 2007; Zhang et al. 2007), including water depth, riverbed substrate, current velocities and hydrological status. However, bedform morphology, the key environmental factor that has great influences on spawning activities, is still unclear (Wei 2003; Yang et al. 2006). Therefore, we investigated the topography of seven spawning areas of *A. sinensis*, and tried to explore the relationship with the natural reproduction process of the fish. Based on the findings, we tentatively propose a bedform morphology hypothesis for spawning areas of *A. sinensis*.

Materials and methods

Study area

Historic spawning areas of *A. sinensis*, which have been documented previously (YARSG 1988), were located in the mainstem of the upper Yangtze and the lower Jinsha rivers, covering a stretch of about 600 km river length (Fig. 1). Two potential spawning areas (20 and 21) also have been reported in the Pearl River (Zhang 1987, 1993). Approximately 21 potential historic spawning areas of the species have been reported in its native rivers. However, after the damming of the Yangtze River by the Gezhouba Dam in Yichang on 4 January 1981, the spawning areas for *A. sinensis* were no longer accessible and fish alternatively spawned within a 30 km section below the Dam (Hu et al. 1983, 1985, 1992; Yu et al. 1986). Moreover, only two spawning areas (22 and 23) have been found in the area downstream of the Dam (Wei et al. 1997, 1998). The two spawning areas (20 and 21) in the Pearl River also became dysfunctional in the late 1970s as a result of the decline of the stock (Zhang 1987, 1993).

To ensure the reliability of this study, only the spawning areas where sturgeon eggs were collected were taken into consideration for this study. Thus, we only studied seven out of 23 spawning areas of *A. sinensis* in this paper, including five historic (8–10, 12 and 14) and two present (22 and 23) spawning areas (Figs. 1 and 2). Spawning areas 8–10 were located in the lower Jinsha River. The riverbed of this reach is narrow (~300 m wide), and deeply incised into the valley, which is surrounded by mountains of about 2,000–3,000 m in elevation. The high gradient of the riverbed results in great flow velocity and rocky substrate. Spawning areas 12 and 14 were located in the upper Yangtze River. The physical characteristics of this reach are similar to those of the lower Jinsha

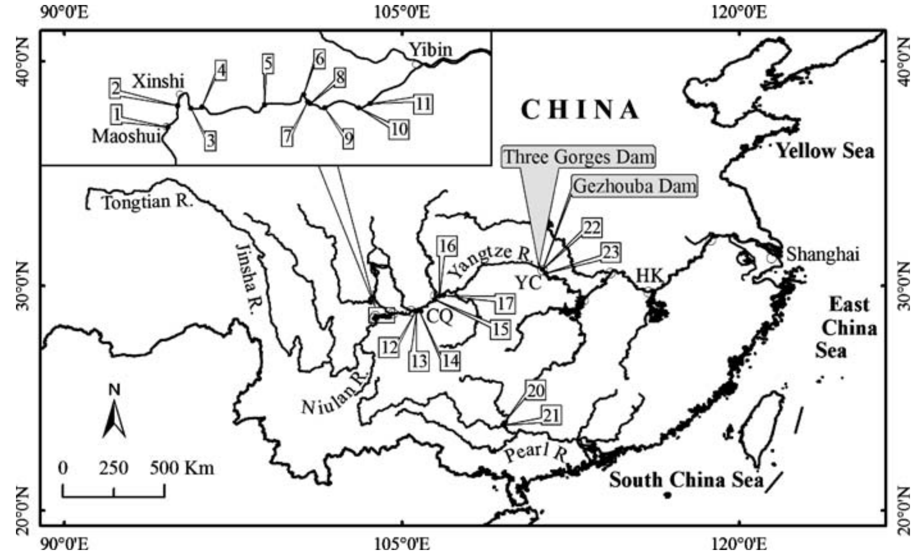


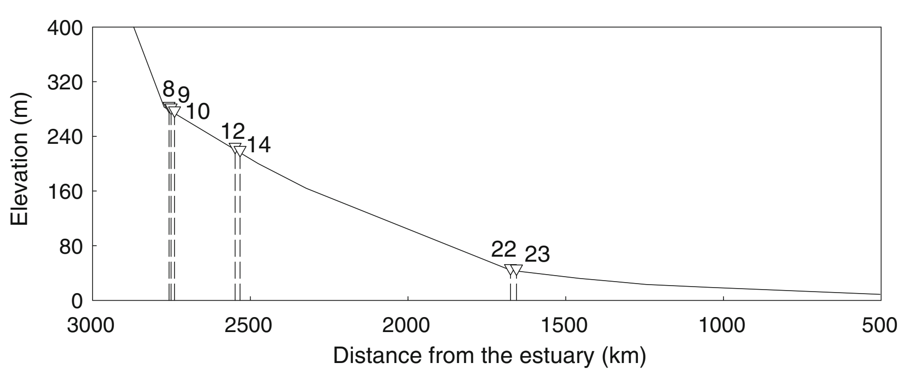
Fig. 1 Distribution of spawning areas of *Acipenser sinensis* in the Yangtze and Pearl basin. *CQ* (Chongqing), *YC* (Yichang), *HK* (Hukou). Those spawning areas that have been reported could be divided into three categories (Zhang 1987; YARSG 1988; Zhang 1993; Wei et al. 1997, 1998; Wei 2003): (a) Confirmed by the previous investigations: Jinduizi (*8*), Pianyanzi (*9*), Sankuaishi (*10*), Tielutan (*12*), Wanglongqi (*14*), Xiba (*22*) and Huyatan (*23*); (b) Reported by the fishermen and very credible: Yaojiatuo–Kuzhutan (*1*), Hongyanzi (*5*), Heibanwan (*6*), Fudui (*17*), Henggucai (*20*) and Yubu (*21*); (c) Reported by the fishermen but status unknown: Hantianba (*2*), Dawotuo (*3*), Guanyindian (*4*), Laziwo (*7*), Erlangtan (*11*), Huanghekou (*13*), Ganqishi (*15*) and Ergoudui (*16*), Shawan (*18*) and Youfangzi (*19*), *18* and *19* are not indicated, they were reported to be located in the reach between Xinshi and Maoshui, but without exact sites

River. However, it has fewer sharp bends, greater river depth and slower flow velocity. Spawning areas 22 and 23 are located in the start of middle Yangtze River, covering a stretch of about 30 km river length. This stretch is a transitional reach from mountainous river to alluvial river.

Reproductive occurrence of *A. sinensis*

The reproduction (timing and locations) of *A. sinensis* in historic spawning areas were obtained from previous research by Ke and Tian (YARSG 1988). Their investigations took place in 1963–1965 and 1970–1975. It is known that in the spawning season (October–November) of these years, fishermen were hired to catch *A. sinensis* using setlines and gill nets. Once in some reaches many pre-spawning sturgeons with running milt or eggs were captured, plenty of drift nets were set in these sites to catch the benthic fishes that predate the sturgeon eggs, such as *Coreius heterodon* Bleeker, *Coreius guichenoti* Savuage et Dabry and *Pelteobagrus fulvidraco* Richardson. Once the sturgeon eggs were discovered in the benthic fish stomachs, frame swingnets were set along the sites to capture the early life stages (ELS = eggs and yolk-sac

Fig. 2 Elevation and distance from the river mouth of the seven designated spawning areas



larvae). By these methods, the spawning locations and the area for dispersal of fertilized eggs can be approximately ascertained.

After the closure of the Gezhouba Dam in 1983–2004, the investigations into reproductive behavior of *A. sinensis* in the present spawning areas were by our research group. The methods mainly included the examination of the stomachs of benthic fishes (1981–2004) (Wei et al. 1997; Wei 2003), tracking the mature sturgeons by ultrasonic tags (1993, 1996–2004) (Kynard et al. 1995; Yang et al. 2006) and captured ELS from the river bottom by D-shaped bottom drift nets (1996–2004) (Wei 2003; Wei et al. in press). For details please see the related literature. By these methods, the spawning locations and the area for dispersal of fertilized eggs can be ascertained precisely.

Topographic investigation of spawning areas

Topographic data of the spawning areas were obtained in a two-step approach: first by utilization of the relief map of the riverbed and secondly the verification of the data obtained by field surveys. The navigation channel charts were utilized as data sources, including the Navigation Channel Chart of the Jinsha River (Xinshi – Yibin, surveyed in 1965 at a scale of 1:8,000), the Navigation Channel Chart of the Upper Yangtze River (Yibin – Chongqing, surveyed in 1992 at a scale of 1:15,000), the Navigation Channel Chart of the Upper Yangtze River (Chongqing – Wanxian, surveyed in 1977 at a scale of 1:12,000) and the Navigation Channel Chart of the Middle Yangtze River (Yichang – Wuhan, surveyed in 1981 at a scale of 1:25,000). In addition, the Three Gorges Hydrological and Water Resources Survey Bureau of the Yangtze Water Resources Commission provided the Underwater Topographic Map from Gezhouba Dam to Huyatan (surveyed in December 1999 at a scale of 1:5,000) and the Electronic Map from Dam Axis to Moji Hill (surveyed between October and December 2003 at a scale of 1:10,000).

Bathymetric data were collected with an HD-17A echo sounder (Hi-Target Surveying Instrument Co., Ltd., China) mounted on the front of a 6.3 m long boat with an 85 hp outboard motor. The precision of the echo sounder data is 2 cm. Navigation base maps were compiled from the corresponding navigation channel charts used above and exported as georeferenced DXF files that could be imported into navigation software. These digital maps were used as the basis for transect design and real-time navigation using South Navigation Software (South Surveying & Mapping Instrument Co., Ltd., China). Lateral transect lines were generated at 50 m intervals along the river centre line. Bathymetric data were georeferenced in the field by an SF-2050G GPS receiver (NavCom Technology, Inc., USA) to sub-meter accuracy. Boat speeds were maintained at around 8 km h^{-1}.

In the spawning season of 2006, riverbed topography was determined for five of the confirmed historic sites (8–10, 12 and 14). With regard to the sedimentation and erosion processes in the river channel, topography research on historic spawning areas mainly relied on the navigation channel charts. However, the on-site data acquisition also took into consideration where the topography was not changed. In the spawning season of 2004, we surveyed the riverbed of two present spawning areas (22 and 23) before the commencement of a large River Regime Regulating Project.

The topographic data were imported into ArcGIS 9.2 software (Environmental Systems Research Institute, Inc., USA) for the purpose of analysis. The riverbed surfaces were interpolated using Inverse Distance Weighted scheme with grid size of 5 m, and the quantitative topographic characteristics of the spawning areas were analyzed by Geostatistical Analyst and 3D Analyst module. According to previous research on reproductive behavior of *A. sinensis* (YARSG 1988; Wei 2003), the extent of the spawning area was confirmed by the start transect and end transect, it is the shortest length of reach that the fish can carry out its spawning activities during the investigation period. Some topographic parameters potentially associated with spawning activities were analyzed, such as river width, water depth, turning angle, slope and their variation extents and degrees (Fig. 3). The actual elevation was converted to the water depth for the convenience of analysis, and the base level is the average water level of the spawning days (YARSG 1988; Yang et al. 2007).

Results

Topography of spawning areas in the lower Jinsha River

Spawning area 8 (S8) was located close to the southern bank (Fig. 4a). According to the riverbed

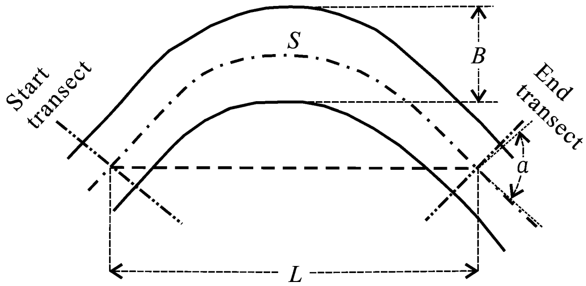


Fig. 3 Geometry criteria of river planar morphology (Yu 1994). *S* is the length of the river centerline between the two transects, *L* is the straight-line distance between the two transects, *B* is the maximal river width between the two transects, and turning angle (α) is the angle between the normal of the two transects

structure, it could be divided into two parts. The upper portion was a riprap (a loose assemblage of broken stones) slope (~400 m long), and the lower portion was Houzi point bar (a low ridge of sediment that forms along the inner bank of a meandering stream) (~1,800 m long). Moreover, this point bar could be divided into three segments based on its materials. These three segments were composed of large cobble, sand and small pebble, with the length about 300 m, 500 m and 1,000 m, respectively.

Spawning area 9 (S9) was located close to the southern bank (Fig. 4b). The length of the riprap slope between Ganzilin point bar and Qingshihao was ~600 m and was longer than that in S8. Below

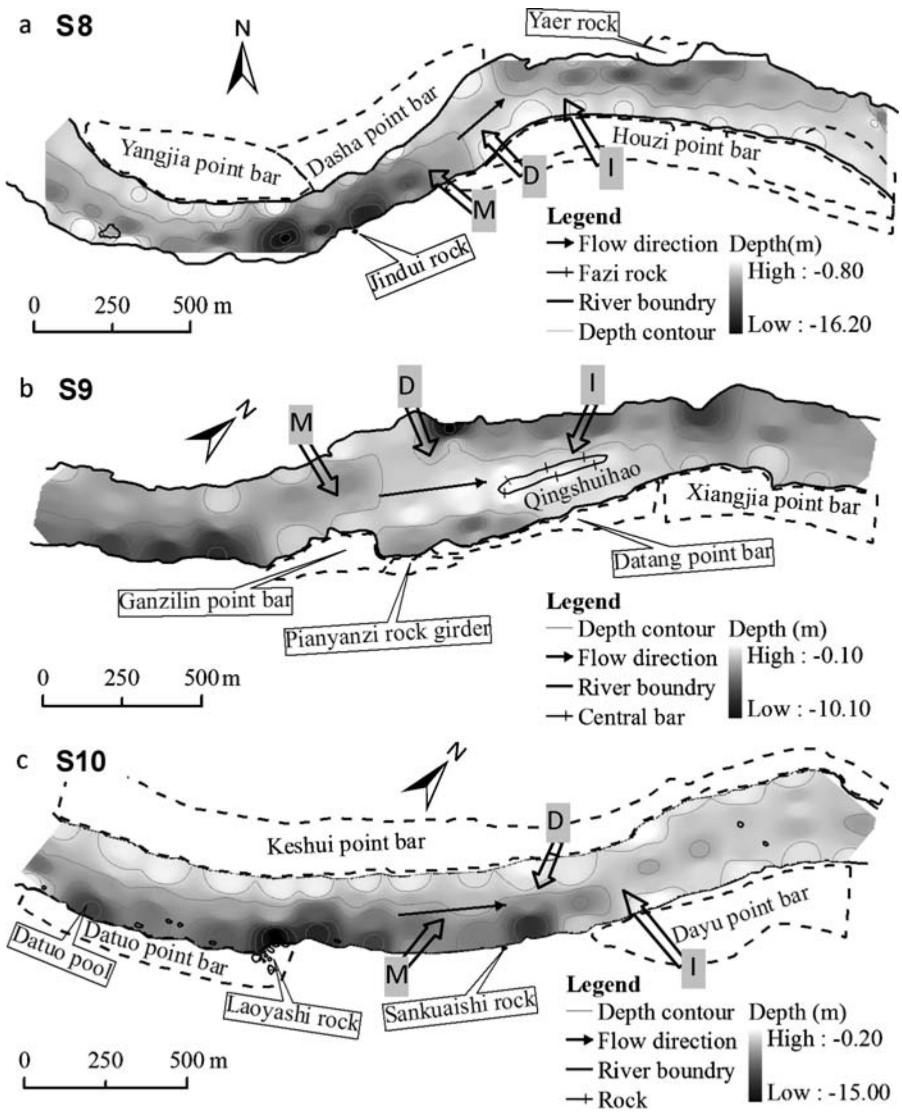


Fig. 4 Topography of spawning area (**a**) 8, (**b**) 9 and (**c**) 10 in the lower Jinsha River. *Arrow* indicates the Mating area (*M*), Dispersal area (*D*) or Incubation area (*I*)

Pianyanzi rock girder, the Datang point bar extended through to the downstream area of Qingshuihao, with a total length more than 1,000 m. The Datang point bar took 70% of the whole river width (~370 m), and the water depth at this point bar was less than 3 m. Moreover, this point bar rose towards Qingshuihao, and at low water levels, its top could be seen at the water surface, like a fish.

Spawning area 10 (S10) was located close to the southern bank (Fig. 4c). On the northern bank of this spawning area, there was Keshui point bar (150 m wide, 2,000 m long) formed by pebble and coarse sand. On the southern bank, there were steep cliffs, but the continued erosion broke them down. Therefore, there was a lot of riprap on the southern bank between Datuo point bar and Sankuaishi rock, and the riverbed of this section was composed of fractured rock formations and riprap. There were three pools from Datuo point bar to Sankuaishi rock: Datuo pool, pool near Laoyashi rock and pool below Sankuaishi rock. Many large cobbles were deposited below Sankuaishi rock and formed a large riffle, where there was a greater river width and higher riverbed gradient.

Topography of spawning areas in the upper Yangtze River

Many central bars formed by riprap were in spawning area 12 (S12) (Fig. 5a), and the top of them emerged perennially. A large rock pile called Jiaotan, composed of fractured rock formations, stretched to the main channel. Above this rock pile, there was a rocky groove, the river width at this groove was ~300 m. Below this rock pile, there was a rocky pool (~20 m deep), and below the pool, the Luogu point bar formed by gravels and pebbles took 50% of the whole river width (~380 m).

In the upper portion of spawning area 14 (Fig. 5b), there was a rock girder called Duiwotan stretched into the river channel vertically. Below the rock girder, a pebble point bar called Wanglongqi took 80% of the whole river width (550 m). The river width of this spawning area was ~500 m. From the rock girder to the head of Wanglongqi point bar, the distance was about 1,500 m. The water depth gradually became shallower in this area, but did not increase to more than 8 m.

Topography of spawning areas in the middle Yangtze River

In spawning area 22 (S22) (Fig. 6a), the abandoned stone materials coming from the construction of the Gezhouba Dam formed two flat riffles (area IB2b and area IC2b) in the tailrace of Dajiang and Erjiang power plants, the water depths in the two riffles were about 8.7 m and 7.3 m, respectively. Below the riffles (at areas IB3c-IIC1a), the riverbed elevation sharply decreased and formed a steep slope. At the right side of the steep slope was a pile of cobble (elevation 35–37 m). In dry seasons, some cobbles (diameter 15–30 cm) usually showed up on the surface. At the left side of the middle cobble pile was a deep pool (areas

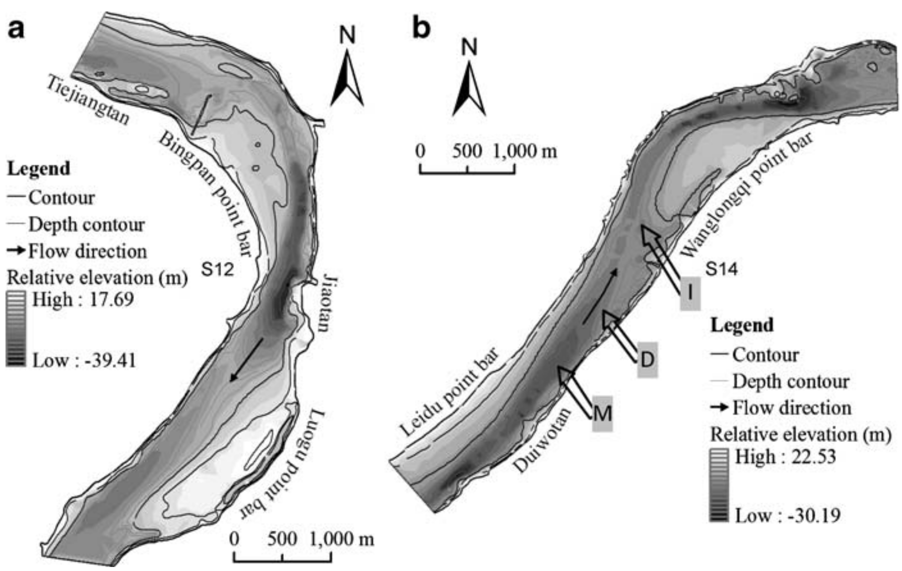


Fig. 5 Topography of spawning area (**a**) 12 and (**b**) 14 in the upper Yangtze River. *Arrow* indicates the Mating area (*M*), Dispersal area (*D*) or Incubation area (*I*)

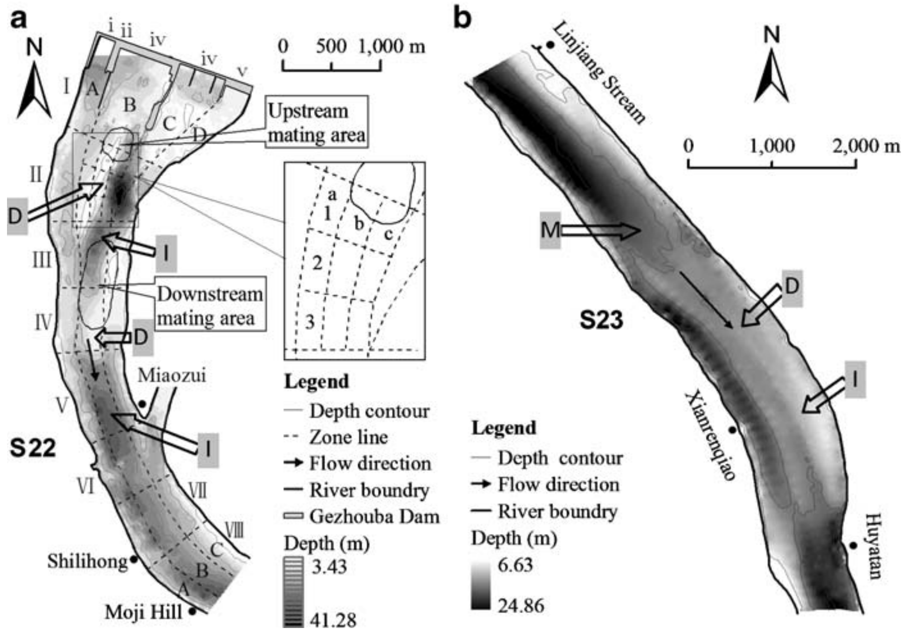


Fig. 6 Topography of two present spawning areas in the middle Yangtze River (December 1999). *Arrow* indicates the Mating area (*M*), Dispersal area (*D*) or Incubation area (*I*). **a** Spawning area 22: (*i*) Flushing sluice, (*ii*) No. 1 ship lock, (*iii*) Dajiang power plant, (*iv*) Erjiang water relief sluice, (*v*) Erjiang power plant; capital Roman numerals (*I–VIII*), letters (*A–D*, *a–c*) and Arabic number (*1–3*) are labels for the subareas. **b** Spawning area 23

IIB2c-IID3b). The water depth here was more than 35 m, its area was about 4.4 km^2. Below the end of the cobble pile (area IIIB1a), the riverbed elevation fluctuated slightly (areas IIIB1a-IVB2c), but ascended gradually on the whole. Lastly, a plain riffle was formed in areas IVB2b-IVB3c. But in areas VB1a-VB1c, the riverbed elevation sharply decreased, and the main channel gradually turned into the southeast.

On the whole, the topography in spawning area 23 (S23) was comparatively smooth (Fig. 6b). From Linjiang Stream to Huyatan (~6,400 m long), the water depth decreased gradually. A shallow area was formed at the river bend, with the water depth ~6 m. The river width of this spawning reach did not have large variation, with the average ~1,060 m. The riverbed there was mainly composed of pebbles, but its percent was affected by the erosion and disposition process of the riverbed.

Common topography of the spawning areas

The analysis of the river regime and morphology of the seven spawning areas suggested that their topography had some similar characteristics (Table 1). They were located in the rocky substrate river bends. Most of the spawning areas were characterized by a turbulent riffle in the upper portion, a deep pool in the middle portion, and an adverse slope in the lower portion. The water depth and river width in the spawning areas had certain variations. Moreover, the slope and length of the adverse slopes seemed to have a negative correlation, because a higher slope seemed to sustain a shorter length (Fig. 7). In addition, the spawning area with higher gradient and longer length of adverse slope seemed to have more excellent reproductive success (based on adult use, embryo numbers and emergent larvae), such as S12. On the assumption that the importance of spawning areas are associated with the reproductive success of *A. sinensis* in them, we assigned reproductive success "+++", "++" and "+" weight 3, 2 and 1, respectively. We could then calculate the weighted means of topographic parameters of the five historic spawning areas (Table 1).

Division of function areas for spawning areas

On spawning days in historic spawning areas, dramatically large numbers of *A. sinensis* could be caught in 1 day in some special areas every year, however, fewer sturgeons can be caught there at other times (YARSG 1988). For instance, in S10 (Fig. 4c), about 10–20 sturgeons could be caught in area M on spawning days, this is much more than the total number of sturgeon caught about half a month before the spawning day (YARSG 1988). These special areas also occurred in the present spawning area. According to the locations of tagged mature *A. sinensis* below Gezhouba Dam during 1996–1998 (Wei 2003; Yang

Table 1 Topographic parameters of 7 designated spawning areas and associated reproductive success of *Acipenser sinensis*

Spawning area	River pattern	*B* (m)	*S* (m)	Turning angle (α, °)	Tortuosity factor (*S/L*)	*B/S*	*B*-minimal width (m)	Adverse slope			Reproductive success[c]
								Altitude difference (AD, m)	Length (LA, m)	Slope (AD/LA, %)	
S8	Straight	240	2,202	34	1.06	0.11	104	12.6	929	1.36	++
S9	Braided	418	1,604	18	1.01	0.26	242	8.8	995	0.88	++
S10	Straight	278	2,574	20	1.03	0.11	94	12.9	879	1.47	+++
S12	Meandering	388	4,920	66	1.13	0.08	164	35.9	1,405	2.56	+++
S14	Straight	554	3,029	18	1.02	0.18	234	14.0	2,674	0.52	++
S22	Straight	1,348	4,696	25	1.05	0.29	781	31.4	1,568	2.00	++
S23	Straight	1,129	–[b]	29	–[b]	–[b]	242	15.4	6,124	0.25	+
Max.[a]		554	4,920	66	1.13	0.26	242	35.9	2,674	2.56	
Min.[a]		240	1,604	18	1.01	0.08	94	8.8	879	0.52	
Mean[a]		376	2,866	31.2	1.05	0.15	167.6	16.8	1,376.4	1.36	
Weighted mean[a]		369	3,013	33.2	1.06	0.14	161.2	18.1	1,337.3	1.47	

[a] Except S22 and S23

[b] Investigation on spawning activities in S23 are rare, little evidence for reproductions exist, limiting the knowledge on the dimensions of the site

[c] "+++", "++" and "+" indicate the reproductive success from excellent to weak.

et al. 2006), the sturgeons had two main distribution areas during their propagation period, labeled upstream mating area and downstream mating area in Fig. 6a.

In historic spawning areas, a few days after spawning, many benthic fishes with stomachs containing *A. sinensis* eggs could be caught in some point bars or broad shallow areas, while in other areas we could rarely catch these fishes. For instance, in S10 (Fig. 4c), about 3 days after spawning, most of the *C. heterodon* were caught in the vicinity of Dayu point bar, while in other areas we rarely caught this fish (YARSG 1988). In the present spawning area below Gezhouba Dam, the same phenomenon occurs, most of the *C. heterodon* are captured in areas IVB and VB in few days after sturgeon spawning (Fig. 6a; Wei 2003). Moreover, according to the sampling of ELS of *A. sinensis* from the river bottom during 1996–2003 (Wei 2003), areas IVB and VB were the main dispersal area for sturgeon eggs (Fig. 6a).

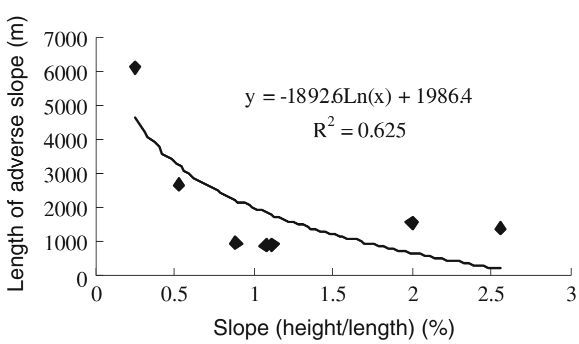


Fig. 7 The negative correlation between slope and length of the adverse slope on the spawning areas (n=7)

Discussion

The selectivity of the behavior of *A. sinensis* on some fixed areas on spawning days may suggest that they need special microhabitats to mate and spawn. To disperse fertilized eggs on some fixed areas may suggest that the fertilized eggs need special areas to develop. Moreover, in both historic and present spawning areas, between the area for mating of the fishes and the area for incubating of the fertilized eggs, another special area exists. This area is often at the turning point of the river channel, for instance, area D in S10 (Fig. 4c) or area D in S22 (Fig. 6a). Generally, the circulating flows are formed in the river bends, together with the longitudinal water current, it makes the main flow proceed with a helical structure (Zhang 1989). This special flow could prolong the contacting time between sperm and eggs and mix them sufficiently, thereby enhancing fertilization rate. Moreover, it also makes the fertilized eggs more evenly distributed in the downstream areas for embryonic development.

Based on the our findings, we tentatively conclude that a functional spawning area of *A. sinensis* should contain three main areas including the Mating area (M), Dispersal area (D) and Incubation area (I) in the direction of the current, respectively. These three parts are indispensable and are locally differentiated. M is habitually the place for the ripe males and females to mate and spawn. It is usually below the riffle and characterized by rolling terrain. D is normally the place for fertilizing and dispersing fertilized eggs. It usually has some sharp variation in terrain, such as deep pools or steep slopes. I is typically the ground for dispersal of fertilized eggs. It is characterized by a wide river bend with rocky or gravel substrate. The purpose of M could serve to also partially serve the functions of the downstream areas (D and I), while D could play some part in embryonic development. According to the reproductive behavior of the fish and bedform morphology of these spawning areas, we can identify them in each spawning areas (Figs. 4, 5, 6).

In the last regular spawning area (S22), in view of adult use and embryo numbers on the riverbed (Wei 2003), the downstream mating area is more effective than the upstream mating area. It is possible that the topography structure near the downstream mating area is more similar to those of the historic spawning areas and thus has more suitable microhabitat for the spawners. Mating and spawning on the upstream mating area also may occur because the size of spawning cohorts is too large, and the downstream mating area cannot provide enough space for them. The natural reproduction of *A. sinensis* rarely occurs at S23 (Wei et al. 1997, 1998), the unsuitable terrain probably is the major reason, which makes the hydrological regime and hydraulic conditions unsuitable to trigger spawning activities. After the shipping channel construction on S9, spawning activities were rarely observed in this spawning area before the closure of the Gezhouba Dam (YARSG 1988). This probably was because some of the functional areas were lost due to the construction of the project.

This study is the first one to compare the topography of present and historic spawning areas in detail, and gives some quantitative characteristics to define these spawning areas. The turning structure and the adverse slope may be the most important topographic characteristics for the spawning areas of *A. sinensis*. Based on the bedform morphology hypothesis, a spawning area with weighted mean topographic parameters in Table 1 could serve as the model of artificial spawning areas. According to this, we can improve the topography of the last spawning area (S22) by some feasible measures. For instance, some large irregular rocks can be set in areas IB and IIC to provide more shelters for the pre-spawning sturgeons, and the adverse slope in areas IVB and VB can be developed into area VC to provide more incubation area.

Although natural reproduction of *A. sinensis* takes place below the Gezhouba Dam every year, it may be an activity imposed by the interception of migration. Currently, the last spawning area is confronted with many new challenges, such as the construction of the River Regime Regulating Project, the improvement of navigation capability and the operation of the Three Gorges Dam (TGD) which is about 40 km above this site. It is essential to prevent effects of changes in temperature regime and reduced turbidity due to the operation of TGD on the reproductive behavior of *A. sinensis* to circumvent limitations in physiological conditions for reproduction. According to research on the lake sturgeon, *Acipenser fulvescens* (Johnson et al. 2006), future studies also should focus on riverbed substrate and flow interactions on the spawning area, because they may influence the reproductive behavior directly. Under these prerequisites, artificial spawning areas are suggested to reduce the associated risk of losing the population. Some side arms with rocky substrate riverbed are the first sites to be considered to build the artificial spawning area. Ultimately, the maintenance of the spawning area is the basis of maintenance of the wild population of the sturgeon, and to improve the spawning environment might be the only effective method to restore the wild stock when recruitment data are considered.

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