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Proper gravel management may counteract population decline of the Collared Sand Martin *Riparia riparia*

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ABSTRACT

Riparian habitats have gone through major structural changes, and related bird populations had to suffer the consequences or adapt to the newfound conditions. Here, we present the results of the analysis of the river and quarry evolution, in relation to a long-term monitoring (1970-2016) of a Sand Martins population nesting along the River Po in northern Italy. During the course of the study, the population changed breeding site, preferring more anthropogenic sites in the surrounding quarries to the natural river banks. The alteration of the river dynamic and linearization of the course, alongside the development of the sand quarries, may have caused this change. We conclude with a consideration on the ways to support the survival of populations of riparian birds. Functional nesting habitat along the river should be better preserved, and potential nesting areas in the surrounding quarries should be protected with long term restoration projects. Sand quarries are not free of threats, and cooperation among stakeholders has proven to be of the utmost importance to ensure the success of the population breeding in the area.

Keywords: nest site selection; river dynamic; *Riparia riparia*; quarry restoration.

INTRODUCTION

Habitat loss, due to destruction and alteration, is one of the most important anthropogenic impacts on animal populations (Newton 1998, Baillie et al. 2004, Curry Lindahl 1972). Among the most affected habitats, riparian ecosystems have been deeply altered with radical changes to their courses, flow and dynamics. The regulation of the flow and course forces rivers to become more and more linear, losing their meanders and changing the erosion of river banks (Brookes 1988). Changes in the riparian system can affect many aquatic animals, and have proven to affect the structure of breeding bird communities (Figarski & Kajtoch 2015, Girvetz 2010).

The Collared Sand Martin (*Riparia riparia*; hereafter "Sand Martin") is a riparian species particularly specialised in nesting habitat (Moffatt et al. 2005). This colonial species usually excavates nest holes in sandy banks, normally in the vicinity of water bodies, such as the eroding banks of meandering rivers and streams, but also in artificial sand deposits (Cramp 1988). The most recent IUCN assessment of the global trend categorized Sand Martin populations as decreasing (BirdLife International 2016). According to the most recent population assessment published by BirdLife International in 2015, Sand Martin populations are decreasing in many European countries, including Italy (Brichetti & Fracasso 2007, Campedelli et al. 2012). This trend appears even more concerning since the species has also experienced large scale population declines since the early 1960s (Cowley 1979, Jones 1987a).

Climate change has often been considered as the major driver behind Sand Martin population changes and this trans-Saharan migrant has been well studied in terms of the influence that climatic factors in the African wintering quarters have on its survival (Cowley 1979, Svensson 1986, Persson 1987a, Szép 1995, Norman & Peach 2013). In more recent years, there has not been any strong drought in the Sahel region (Evan et al. 2014, Sanogo et al. 2015) that might have driven the global decrease in Sand Martin population sizes. Habitat change might therefore be the cause behind more recent declines. However, despite it being recognised as a cause of population decline (Garrison 1999, del Hoyo et al. 2004), few papers have analysed habitat alteration on the breeding grounds. In

California, where the species population is declining mainly due to habitat alteration, Moffatt and colleagues (2005) studied the importance of riparian systems and the effects of different restoration strategies on the species. Sand martins were reported to breed in sandy quarry complexes all over Europe (Alves 1997, Cowley & Siriwardena 2005, Heneberg 2007, Jones 1987b, Krištofík et al. 1994, Kitowski et al. 2015, Morgan 1979, Norman & Peach 2013, Persson 1987b, 1987a). Some of the eastern populations of Sand Martin, however, were still recently found breeding in natural sites in Poland (Figarski & Kajtoch 2015) and, in large numbers, along the banks of the Tisza River in Hungary (Szép 1995, Szép et al. 2003). Despite this important change in the selection of breeding sites in some areas, to our knowledge there are no studies that have analysed the causes behind this phenomenon.

In this paper, we have analysed survey data, collected over 45 years, of a Sand Martin population in north-western Italy. The monitored population did not present signs of decline during the study, and its fluctuations in numbers appeared to have no correlation with climate (Masoero et al. 2016). We have also studied the river dynamic of the past 68 years and the evolution of the quarry complexes, from 1960 until the present, in the nesting area of the Sand Martins. Our aim was to understand the relationship between Sand Martins and their nesting habitat and how the modifications of the river and of the quarries could affect them.

METHODS

Study area and the quarries

The study area included about 25 km of the River Po South of the city of Turin, Italy (from 44.971 N 7.693 E to 44.832 N 7.636 E) and all the 15 surrounding quarries, nine active during the study and six already restored to a more natural state (Fig. 1). The area is located in the River Po Torinese Regional Park. The River Po and its tributaries transported and deposited materials during the Middle Pleistocene and the Holocene creating the river channel deposits that currently constitute this area of the Po plain. The sediments at the top layer are 25-100 m thick and are exploited by quarries complexes (Castiglioni et al. 1999). The raw materials, such as sand and gravel, are excavated from the ground to be used as construction aggregates. After the extraction from the ground, sand and gravel are separated in a range of sizes and stored into stockpiles, creating heaps and banks in which the Sand Martins can build their nests (Fig. 2). The quarries are usually worked in progressive phases, in order to minimise the exposed areas. This method also ensures timely restoration of the already excavated sites while the work is still ongoing. The Park oversees the work of the quarries under its jurisdiction and controls the restoration of the excavated banks and surfaces.

We georeferenced seven different maps of the River Po (from Casalgrasso 44.830 N 7.634 E to Moncalieri 45.008 N 7.679 E) from the years 1922, 1948, 1955, 1963, 1978, 1991 and 2008. To assess river dynamism, we calculated the sinuosity index, i.e. the measures of the degree of sinuosity of meandering rivers calculated as the ratio of the length of the midline of the channel and the air-line distance (Friend & Sinha 1993, Alabyan & Chalov 1998). Values of the sinuosity index close to or equal to 1 correspond to a linear river, whereas higher values correspond to a more winding river.

Data concerning the changes in the quarries were obtained from the databases on extraction activities of the Italian Ministry of Industry and of the Piedmont Region. From 1960 to 1985, the Italian Ministry of Industry collected the data on the amount of extracted construction aggregates for the whole region of Piedmont. After 1982, the Piedmont Region started collecting the data regarding the quarries, obtaining therefore more precise data and we could retrieve data concerning the situation in the 15 quarries located in the study area. We decided to use the amount of extracted material as an index of the quarry activity, and therefore of the amount of potential available nesting habitat because of two main reasons. First, the studied quarries are authorised to extract materials also going below the level of the aquifer, i.e. sand and gravel can still be extracted with the surface of the active quarry remaining stable. Second, sand martins often colonised the sand heaps of extracted materials and seldom the excavated cliffs.

Census of breeding colonies and data analysis

From 1970 up to 2016 the riverbanks and the sand quarries were surveyed each year to identify breeding sites and their location. The census of the colonies with an exhaustive count of all active nests started in 2000, whereas in earlier years (i.e, since 1970), the monitoring of the river was not conducted quantitatively, due to the difficulty to reach every area of the river. From the end of April to July all the possible breeding sites were checked during multiple occasions, both along the river Po and in active and abandoned quarries, and all active nests were counted. Almost every year there was a change in the nesting location chosen by the population, which sometimes split among two or more quarries if the nesting cliffs were not wide enough.

We used generalized additive models (GAMs; Hastie & Tibshirani 1990) to test for the effects of year on the number of nests in riverbanks assuming a Poisson data distribution. GAMs were performed using R 3.3.1 (R Core Team 2017), with the package mgcv (Wood 2011). The default cubic smoothing spline method with fours degrees of freedom was used to smooth the year component. We also evaluated Collared Sand Martin population trends between 2002 and 2016 (years with a complete census of the population) using the software TRIM (Trend & Indices for Monitoring data, TRIM 3.54; Pannekoek & Van Strien 2006). TRIM estimates annual indices and evaluates trends in these indices implementing log-linear models, an approach commonly employed in temporal series analysis. We also tested for a linear relationship between the number of nests in riverbanks and quarries and the amount of gravel and sand extracted from gravel pits using a generalized linear model, specifying a Poisson data distribution.

RESULTS

River dynamic and quarry evolution

The River Po course changed markedly in the study area from 1922 until 1978 (Fig. 3), after which it remained largely unchanged. The sinuosity index of the River Po decreased from a value of 2.19 in 1922, to a minimum of 1.59 calculated in 2008 (Fig. 4), showing that the river had become increasingly linear. Two large floods happened in 2000 and 2016, and created a few suitable nesting areas that were not colonised by Sand Martins. The new nesting cliffs were nevertheless very limited compared to the previous floods, the bank defences did not allow more substantial changes.

From the 1960-1985 data from the Italian Minister of Industry it emerged that until 1966 the production of construction materials in Piedmont region was low, and always below 3 Mm^3. In the subsequent 10 years it grew steeply, reaching a maximum of 14 Mm^3 in 1976. It started then to decrease, but always maintaining values above the 6 Mm^3 (Fig. 5a). After 1982, more precise data from the Piedmont Region are available and it was possible to look in detail at the situation in the 15 quarries present in the study area (Fig. 5b). During the years from 1982 to 2007, the amount of extracted construction aggregates presented a fluctuating trend, ranging from a minimum of 110000 m^3 in 1995 and a maximum of 1.71 Mm^3 in 1983. After 2007, the production almost constantly declined.

Census of breeding colonies

The size of colonies along the riverbanks varied from a maximum of 244 active nests recorded in 1973 to a minimum of 30 nests in 1983 (Fig. 4). No active nests were recorded after 2002. A Generalized Additive Model of the number of nests in riverbanks against year revealed a significant non-linear negative relationship ($\chi^2_{7.058} = 276.5$, $p < 0.001$, deviance explained = 79%). We cannot assert that the population breeding along the river was smaller than the actual population, due to incomplete surveys carried on in the last century, but we can assert that after 2002 all the colonies are breeding in the quarries. Colonies in sand quarries were detected the first time in 1983 with 50 active nests and were found always in active quarries. The number of active nests varied from a minimum of 20 nests in 1993 to a maximum of 934 nests in 2007 (Fig. 4). A Generalized Additive Model of the number of nests in sand quarries against year revealed a significant non-linear positive relationship ($\chi^2_{8.108} = 3960$, $p < 0.001$, deviance explained = 93%). Using TRIM, the population trend from 2002-2016 is uncertain (multiplicative overall slope model: 1.0067 ± 0.0349 SE). The number of nests counted in sand quarries were positively related with the amount of construction aggregates extracted in the study area (intercept: 6.02 ± 0.01 SE, beta: 0.40 ± 0.01 SE; $F_{1,19}$: 6.07, p = 0.023; here we used the standardized amount of construction aggregates as predictor).

DISCUSSION

In this paper we analysed breeding observations of Sand Martins along a section of the river Po and the surrounding quarries. At the same time, we looked into detailed data regarding the river course and the development of the quarries. Overall, we think this provides a reasonable explanation to the change in breeding sites and to the lack of decrease in size previously shown by the studied population (Masoero et al. 2016).

River and quarries

By looking at the maps of the River Po courses along the years and at the values of the sinuosity index we can notice a few things. First, a decrease in the river dynamism in the study area, i.e. the river changed its course markedly until 1978 and after that, the course remained largely unchanged, even after two flooding events in the last 15 years. Second, the low values of the index in the later years show a linearization of the river when compared to the earlier values. The fixed course of the river and the lower sinuosity index indicates a decrease in river dynamism, and as a consequence, a decrease in river functionality (Fehér et al. 2012, Yu et al. 2015). The history behind these changes, both regarding the river and the surrounding quarries, is quite complex and has to be told alongside. Between the 1960s and the 1980s, Italy experienced an economic boom. As the surrounding plain became more anthropized, towns grew. An increasing number of flood protections were built around the surrounding cities, houses, crops and poplar plantations. Without any space left to change its course, the river assumed a more fixed and linear path. In the meanwhile, the amount of construction aggregates excavated was also following the market needs. Up until 1960 the extraction took place mainly inside the river with limited volumes. In the early 1960s, the demand for aggregates slowly started to grow and the quantity of sand and gravel extracted from the riverbed was no longer sufficient and the quarry companies started exploiting the sediments present along the river course and the first lakes created by gravel excavations appeared in the alluvial plain. After 1966, the economic boom lead to a strong increase in the volumes of excavated materials. In the 1970s, the excavation of the riverbed started to decrease, due to more severe environmental laws, until it came to a stop. From the 1980s the extraction of construction aggregates continued along the river in quarries outside of the riverbed. The existing quarries expanded both in area and depth and the amount of extracted construction aggregates presented a fluctuating trend, following the marked needs. Around 2007, the economic crisis hit the construction market. Some quarries were closed and the active ones started extract less sand and gravel. Inactive quarries are currently under a restoration process coordinated by the River Po Torinese Regional Park. A small increase in the extracted material in 2016 might be the sign of a mild economic recovery.

Sand martins and breeding habitat

The evolution of the river habitat and of its quarries had a deep impact on Sand Martins. The population investigated in our study, as other studied populations in many European countries (Cowley & Siriwardena 2005, Norman & Peach 2013), has shown a change in the selection of breeding sites, although the general area remained unchanged. It was not possible to obtain overall population trends for the study area because the census on the riverbanks were not always performed with the same methodology. Despite we reckon this may be a limit for previous years, we still believe that we were able to identify (qualitatively) the magnitude of the reduction of the nests in the riverbanks, and correctly censused the nests since 2000. In the early years, the population was exclusively breeding in the banks of the River Po. It then began to progressively colonize the adjacent sand quarry complexes, and in 2003 the change had become permanent as the traditional riverbank sites were definitively abandoned. This could be explained by considering the decrease in river dynamism (Moffatt et al. 2005). Lower dynamism means less bank erosion, so new sand cliffs are not created and the old ones, remaining undisturbed, start to become covered in vegetation. At the same time, the river became more linear, determining a change in the river regime, and as a consequence, faster and more destructive floods that could have had an impact on the population survival and breeding success. In the meanwhile, the need for construction aggregates grew because of the economic boom, and new sand and gravel pits began to spread along the course of the river. Sand quarries offered clear sand cliffs, free of vegetation, apparently the perfect substitute to the traditional breeding sites. Nevertheless, nesting in an active sand quarry presents some potential threats. If the workers are careless or not aware of the presence of a colony, they could destroy it. In Italy, active nests are protected by the law (L. 157/92), but people are often unaware of the law or of the presence of nests. Quarries can therefore turn into an ecological trap, i.e. Sand Martins can start nesting in a good sand cliff and the nests can be destroyed. Another problem can follow from the quarry management which can change following the market needs. In the quarry environment, a good management, alongside the protection and the monitoring of the colonies, is crucial, because such quarries act as surrogates for riverbanks not only for the Sand Martin, but also for other species such as the European Bee-eater (*Merops apiaster*) and the Common Kingfisher (*Alcedo atthis*). With simple initiatives (i.e. leaving undisturbed the sand heaps with active nests during May, June and July) that have very low impact on quarry management, it is possible to combine economic interests with nature conservation. All of the above has been possible in the study area thanks to a positive interaction between the people in charge of wildlife protection and those working in the quarries. The River Po Torinese Regional Park is actively protecting the colonies having these sand quarries under its jurisdiction, and it is also monitoring them. In 2000, the Park staff have also started to raise awareness among the gravel diggers about the presence and the importance of Sand Martins, and thus, the nests in the gravel pits have been left undisturbed allowing Sand Martins to successfully fledge.

After the quarry exploitation, it is important that the restoration plan allows the Sand Martins to nest for many years to come. Quarry restoration is indeed necessary because of the extensive land disturbances and negative impacts in terms of both safety and environment (Milgrom 2008, Zuquette et al. 2002). Reclamation techniques often try to address this issues by creating a safe environment with more natural slopes and by creating of appropriate surfaces for the establishment of vegetation (Down & Stocks 1978, Haywood 1979, Gunn & Bailey 1993, Legwaila et al. 2015, Muzzi & Mongardi 2016). Nowadays, the fact that colonies were never found in inactive quarries suggests that the sites are not restored in a way that provides suitable nesting habitat. In fact, the sand cliffs and heaps of active quarries used as breeding sites are no longer available after the restoration process.

Concluding remarks

Diversity and abundance of riparian birds is usually increased by a renaturalisation of the river channels often favoured by floods (Kajtoch & Figarski 2013). In most industrialised countries, rivers have been showing signs of decrease in dynamism and functionality, which has led to loss in suitable nesting habitat for the Sand Martins (Moffatt et al. 2005). Not finding suitable habitat along the river, the studied population of Sand Martins probably started nesting in the adjacent sand quarries, which have increased their activity around the same years (Figs. 4 and 5). After 2007, fewer and fewer building materials were needed by the building industry, and many of the quarries present in the area began to close and being reclaimed. The population already lost the traditional nesting sites along the river: what will happen when all the currently active quarries will be closed and restored?

A thorough analysis of the available literature lead to the conclusion that there are two possible alternatives: to leave sand cliffs close to the water available to the Sand Martins to build their nests, or to build artificial breeding cliffs (Gulickx et al. 2007, Bachmann et al. 2008). The first solution can last a few years, but the cliff can collapse or the vegetation can soon invade it. In any case, it has to be managed throughout the years. The second seems a more stable solution, but comes with another type of problem: ectoparasites. Parasites that infest nest holes include different species, including the tick *Ixodes lividus* (Szép & Møller 1999). Newly formed nest sites do not present high levels of infestation by ectoparasites, but as colonies get older the prevalence can approach 100% (e.g. Szép

& Møller 1999). In the traditional breeding sites and in the quarries the colony is usually used for only a year since it is destroyed after the nesting season by floods or by quarry activities, and the parasite load does not approach such high levels. Artificial nests are used from one year to another and can therefore develop very high concentrations of ectoparasites. In a colony of nests artificially excavated in the limestone in the UK, all the nest holes were washed out using a water hose (Gulickx et al. 2007), but the effectiveness of this measure remains to be proven.

A better management of rivers and of the riverbanks in particular should be promoted to help the Sand Martins in their breeding grounds, and it would be beneficial also for many other species of birds (Jankowiak & Ławicki 2014; Figarski & Kajtoch 2015). In areas where the Sand Martins are present and already nesting in quarries, restoration projects should consider the creation of artificial colonies (as in Bachmann et al. 2008). Moreover, active quarries hosting Sand Martin colonies should provide cliffs that should remain untouched during the whole breeding season, and create new ones every year. This management could help preserving a large number of nests over a long period of time as happened in our study.

Figures

Figure 1. Location of the study area, showing the River Po, and the active (circles) and abandoned (squares) quarries.

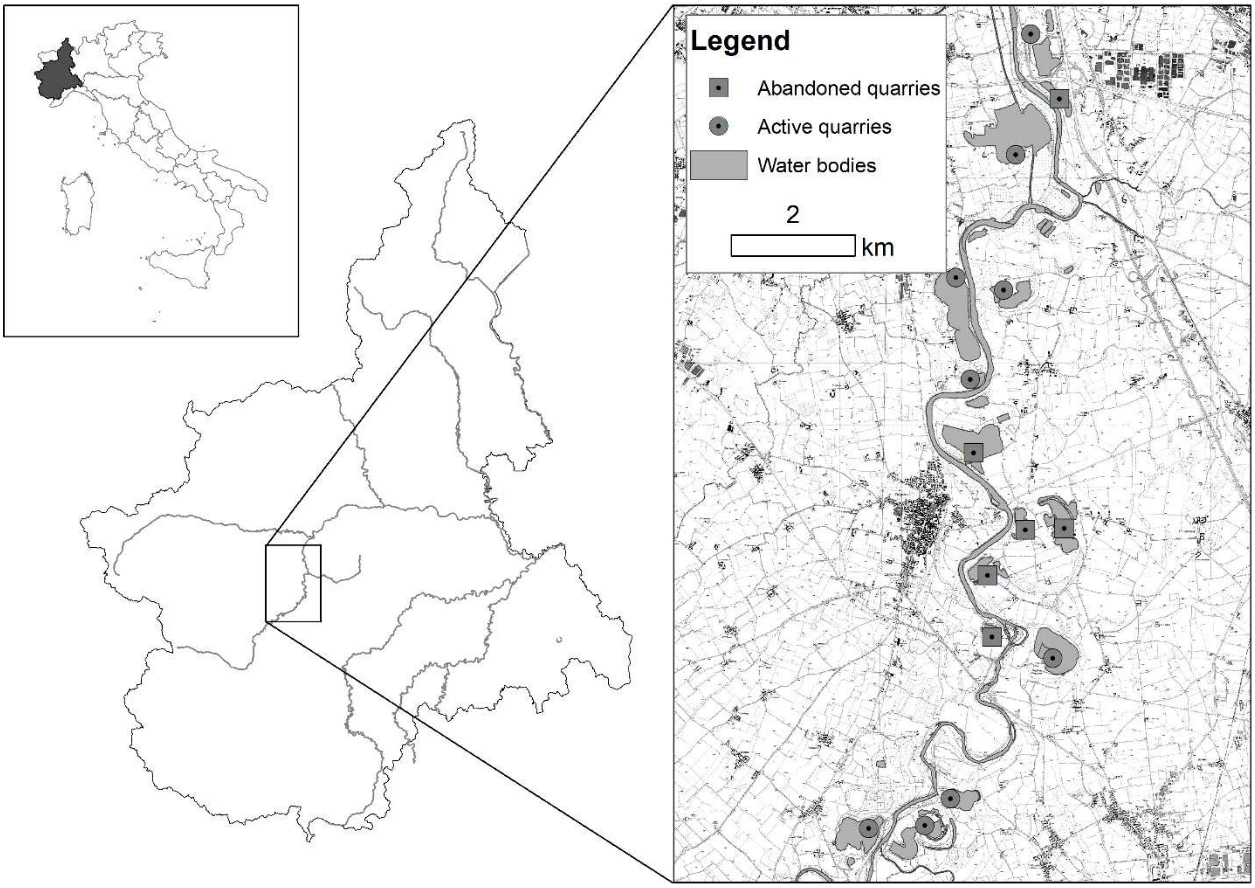


Figure 2. Breeding sites of Sand Martins in the quarries.

Figure 3. Changes in the course of the River Po from 1922 to 2008. Size of lines is for representational purposes only (i.e. it is not related to channel width).

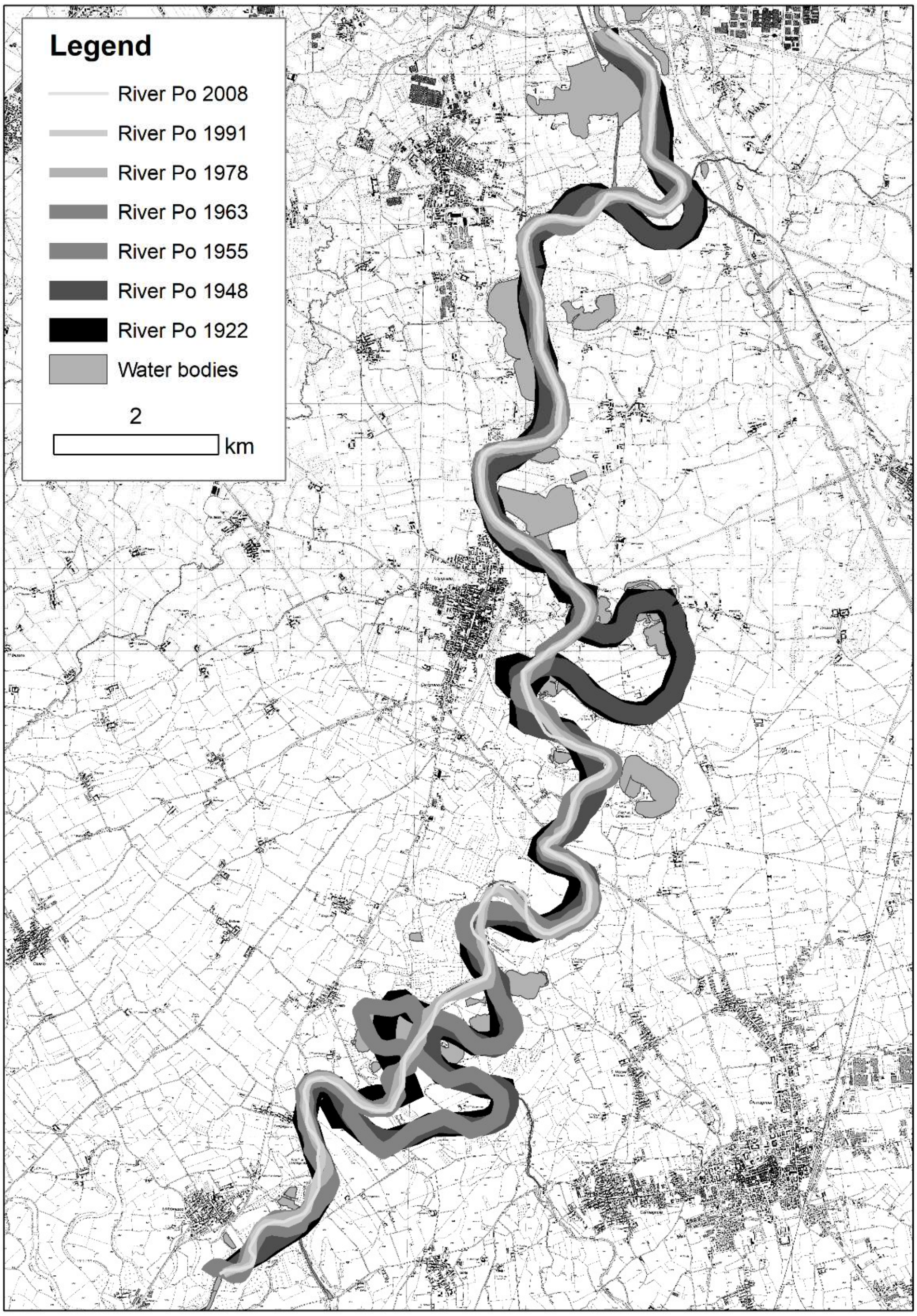


Figure 4. Number of nests per year from 1970 to 2016 counted during the censuses of the breeding colonies in riverbanks (light grey) and in quarries (dark grey) in relation to the amount of sand and gravel extracted from quarries from 1980 and 2016 (dashed) and to the trend of the sinuosity index of the River Po course from 1922 to 2008 (thick solid line). The sinuosity index was calculated for the River Po courses in the years 1922, 1948, 1955, 1963, 1978, 1991 and 2008. The solid lines (light grey for riverbanks and dark for quarries) are smooths (edf = 7.06 and 8.11 respectively) fitted from a GAM specifying a Poisson data distribution, and broken lines are the 95% confidence interval around the smoothed trend. Note that the census of the colonies with an exhaustive count of all active nests started in 2000.

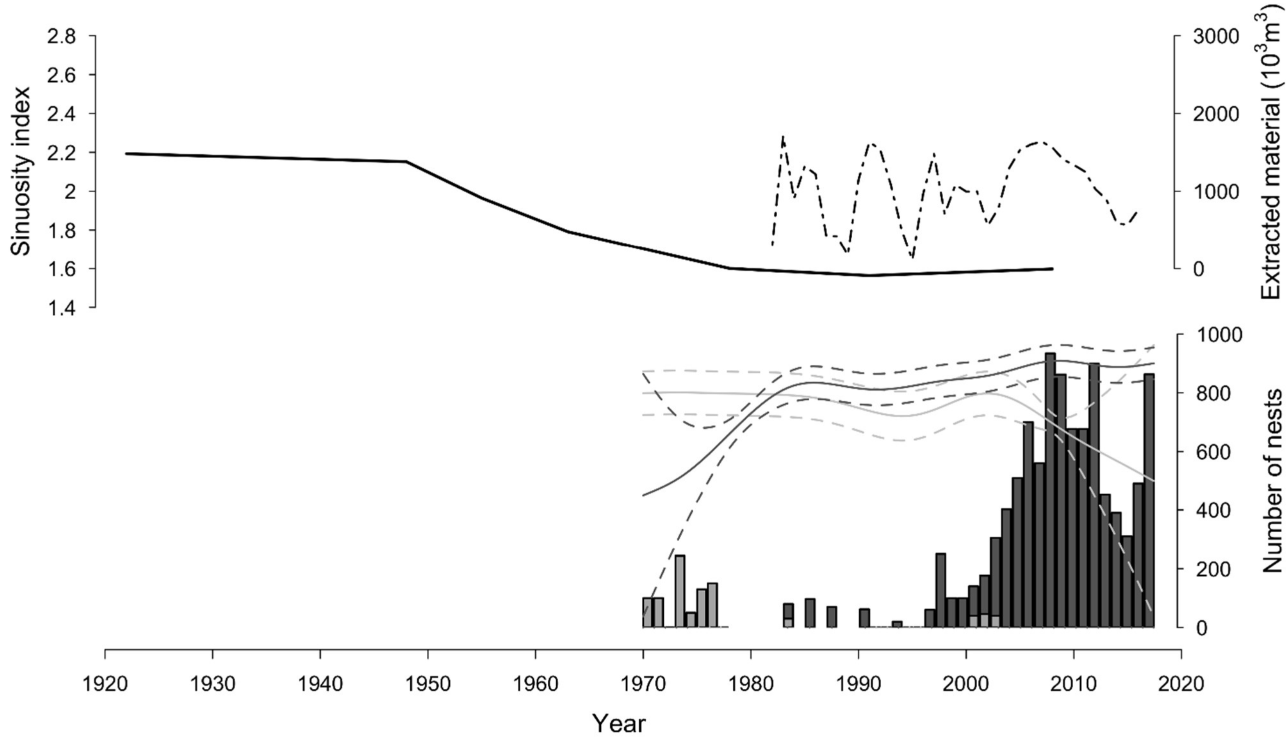
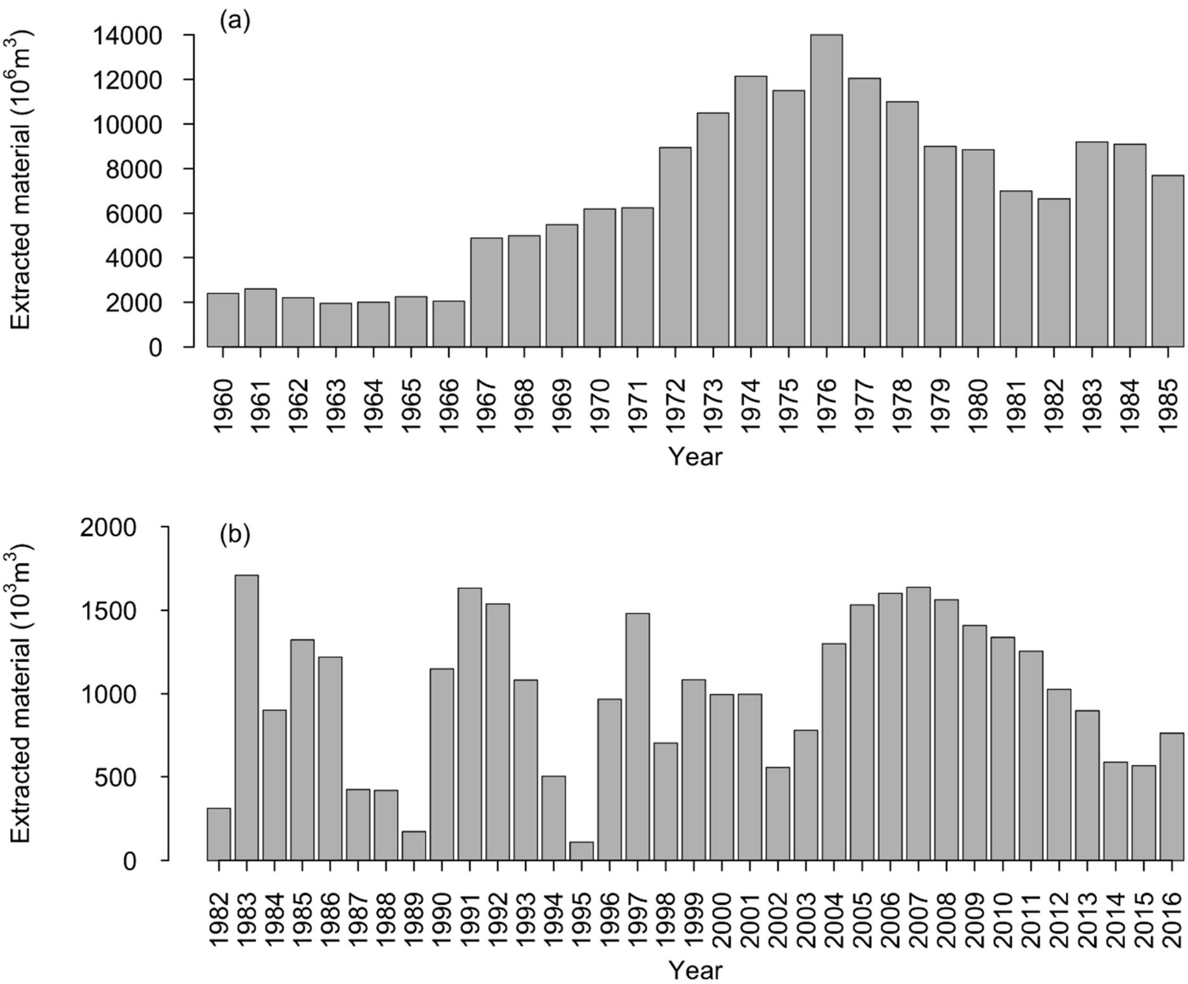


Figure 5. (a) Millions of m³ (Mm³) of extracted construction aggregates in Piedmont from 1960 to 1985 (source: Regione Piemonte - Documento di programmazione delle attività estrattive I Stralcio – Relazione – http://www.regione.piemonte.it/industria/cave/dpae_1.htm accessed on 27 October 2016). (b) Thousands of m³ of extracted construction aggregates in the 15 quarries of the study area from 1982 to 2016 (data from the Piemonte Region's database).



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