IUCN-SSC Crocodile Specialist Group Student Research Assistance Scheme, Project 18-3 Report:

Using Local Ecological Knowledge to Assess the Status and Threats of the Critically Endangered Chinese alligator

Introduction

The Chinese alligator *Alligator sinensis* is a small freshwater crocodilian endemic to freshwater wetlands in eastern China. Alligators were formerly distributed across a wide area of the middle-lower Yangtze and Yellow River basins, and were culturally important in Chinese history as manifestations of dragons that could also alert local people to changes in weather and the seasons (Thorbjarnarson & Wang, 2010; Wen, 2018; Wu et al., 2019). However, this region has experienced massive-scale historical conversion to rice agriculture and other human environments (Marks, 2017; Turvey et al., 2017; Pan et al., 2019), and during the past century alligators became restricted to progressively smaller areas of habitat south of the lower Yangtze channel (Huang, 1981; Watanabe, 1982; Chen, 1990; Thorbjarnarson & Wang, 1999, 2002, 2010). The last surviving wild population, comprising c.200 individuals, is distributed across a series of isolated habitat fragments (remnant natural wetlands and ponds in agricultural valleys and hills) within five counties in southeastern Anhui Province (Thorbjarnarson & Wang, 2002, 2010; National Forestry and Grassland Administration, 2019). The species is now one of the rarest and most threatened crocodilians; it is recognised as a global conservation priority on the basis of unique evolutionary history (Gumbs et al., 2018), and is assessed as Critically Endangered by IUCN, with effective monitoring and threat mitigation identified as urgent management needs (Jiang & Wu, 2018). The Chinese alligator has been listed as a Class I Endangered Species under Chinese national legislation since 1972, and the remnant Anhui population was protected in 1982 by designation of the five-county National Chinese Alligator Reserve (NCAR). A large *ex situ* population has also been established through captive breeding, and is being used to reinforce the wild population (Wang et al., 2011; Jiang & Wu, 2018). However, unlike in many Chinese protected areas (Xu et al., 2016), rural communities continue to live alongside wild alligators across the NCAR and utilise the landscape's terrestrial and wetland habitats to support local agricultural economies (Thorbjarnarson & Wang, 2010; Jiang & Wu, 2018).

Agriculture can threaten crocodylians through loss of habitat (e.g. conversion to rice paddies or aquaculture, water extraction for irrigation); disturbance, persecution and exploitation associated with increased contact with people and domestic animals; and direct and indirect effects of environmental contaminants (pesticides, fertilisers) on both crocodylians and their prey base (Manolis and Stevenson, 2010; Tavalieri et al., 2020; Cavalier et al., 2021). All of these factors have been identified as threats to Chinese alligators (Huang, 1981; Watanabe, 1982; Chen, 1990; Thorbjarnarson & Wang, 1999, 2002, 2010). However, the potential impacts of ongoing agricultural activities on wild alligators within the NCAR remain unclear, with little evidence available on the severity or sustainability of different anthropogenic pressures at local or landscape scales in this social-ecological system, and with most recent studies instead focusing on the captive population. Identifying direct and indirect pathways of impact on freshwater crocodylians can be challenging, with threats potentially acting in unexpected ways (Somaweera et al., 2019).

Furthermore, many rural communities are able to coexist with crocodylians within other human-modified systems (Cavalier et al., 2021), making it difficult to infer the relative significance and dynamics of different threats to Chinese alligators in the absence of robust baselines. This knowledge-gap affects the success not only of conservation management of the last wild Chinese alligator population in the NCAR, but also of alligator reintroductions to other human-occupied Chinese landscapes (Wang et al., 2011; Platt et al., 2016).

To address the existing knowledge-gap on status and threats of wild Chinese alligators, an interview survey was conducted of agricultural communities within and around the NCAR. The following was investigated: (1) whether LEK has the potential to act as a monitoring tool for Chinese alligators; and (2) the relationship between different land-use practices and local status of alligators, to identify potentially unsustainable human pressures on the last wild population. Our study provides new insights on the conservation requirements of Chinese alligators, and our findings can be used to guide future management efforts for alligators and threatened wetland landscapes in human-modified systems.

Methods

Interview survey

Interviews were conducted in July-August 2018 in the five counties within the NCAR (Guangde, Jing, Langxi, Nanling, Xuanzhou) and in four counties bordering the NCAR (Fanchang, Ningguo, Sanshan, Wuhu) in Anhui Province. This sampling design aimed to compare respondent knowledge and activities across landscapes that vary in current-day alligator occurrence and histories of local extirpation or persistence, but which had all contained wild alligators within living memory (Huang, 1981; Watanabe, 1982; Thorbjarnarson & Wang, 1999, 2002, 2010). Six villages were randomly selected from each county to survey, with more villages selected in Xuanzhou (six) and Guangde and Langxi (five each) as these are proportionally larger regions. A target of ten interviews was set per village. Respondents were randomly selected by traversing villages on foot. Men and women were interviewed, individuals below the age of 18 were not interviewed, and only one person per household was interviewed to ensure independence of responses. A standard anonymous questionnaire was used for all interviews containing 36 questions, which took approximately 20 minutes to complete. During interviews, respondents' socio-demographic data was first collected, followed by information about their agricultural practices, including land ownership, pesticide and fertiliser use, use of local water resources (irrigation, fish farming), and how many years they had spent farming. Respondents were shown three locally-sourced photographs of wild and captive Chinese alligators in different positions (partially submerged in water, sprawling, resting), and asked them to identify the animal. Respondents who correctly identified the photographs were asked to provide additional diagnostic morphological or ecological attributes to confirm their familiarity with the species (e.g. another known local name; knowledge of its behaviour, habitat, or vocalisations). Respondents who failed to identify photographs were prompted with common local names (*tulong*, *helong*) and guided through the same process. Respondents who could identify alligators from photographs or common names, and who also provided additional morphological or ecological information, were considered to be able to recognise the species; these respondents were then asked further questions about whether and when they had seen wild alligators or their eggs and nests,their perceptions of local alligator population trends compared to historical baselines 20 and 30 years earlier, whether they knew of alligators ever being killed, and their attitudes towards alligator conservation.

Analysis

All analyses were conducted in R version 3.6.1 (R Development Core Team, 2021). Univariate regressions were conducted to assess whether different land-use practices varied across the survey region. The relationships between respondent knowledge, experience and attitudes about alligators and associated socio-demographic and land-use variables across the survey region were investgated using generalised linear models (GLMs) and ordinal logistic regressions (OLRs), using the packages 'dplyr' (Wickham et al*.,* 2019) and 'MASS' (Ripley et al*.,* 2013). A multivariate GLM was conducted using the entire dataset to investigate predictors of whether respondents could recognise alligators, and then conducted further multivariate GLMs on the subset of respondents who recognised them, to investigate predictors of whether they: i) had seen a wild alligator; (ii) had seen wild alligator eggs or nests; iii) perceived wild alligator populations to have been more abundant in the past. All of these GLMs had binomial error structure and logit link, as all responses were binary (yes/no). A multivariate GLM was used with Poisson error structure to investigate predictors of the number of years since respondents reported last seeing a wild alligator.

We ran all univariate regressions and GLMs twice using different geographic frameworks, once using whether respondents lived within the NCAR (binomial regressions; binary predictor in GLMs), and once using county (Poisson regressions; categorical predictor in GLMs). In the latter analyses, data were compared against the county with the highest proportion of the investigated response in each analysis, by setting the intercept to the county with the largest mode. Other predictors included age (continuous), sex (binary), education level (categorical), annual income (continuous), attitude toward alligator reintroduction (ordinal), and a series of indices of habitat modification/usage or potentially harmful activities that might be expected to affect alligators: whether respondent currently grows crops (binary), proportion of lifetime respondent has grown crops (continuous), whether respondent perceived the area they grow crops in to have changed over time (ordinal), pesticide use (binary), count of pesticide types used (continuous), frequency of annual pesticide use (continuous), chemical fertiliser count (continuous), frequency of annual chemical fertiliser use (continuous), number of months/year respondent uses chemical fertilisers (continuous), whether respondent uses local water supply for irrigation (binary), and whether respondent farms fish (binary). Years spent farming were converted into a proportion of respondents' lifetimes to avoid potential collinearity with age data.

To reduce the number of nuisance variables and improve predictive model accuracy and generality (Ginzburg & Jensen, 2004), we first investigated the statistical relationship of each response variable to all candidate predictor variables using a series of exploratory univariate GLMs, and then constructed global models for each analysis which only included predictor variables that were significantly correlated ($p<0.05$) in univariate analyses (Whittingham et al., 2006). We also checked for collinearity between predictor variables using correlation tests (Harrison et al*.,* 2018), and excluded variables with >0.7 collinearity.

We used Akaike's information criterion (AIC) to select the best-fit model in each analysis, with an automated backward stepwise deletion process used to remove the least significant predictor sequentially from each global model (Forstmeier & Schielzeth, 2011). We then selected the optimal model with the smallest AIC value from each set of possible best-fit models (Chowdhury & Turin, 2020). We only report the optimal model results; the best-fit model sets for all analyses are given in.

Results

We interviewed 370 respondents, of whom 225 resided within the NCAR (Fanchang, n=37; Guangde, n=49; Jing, n=38; Langxi, n=48; Nanling, n=40; Ningguo, n=37; Sanshan, n=39; Wuhu, n=32; Xuanzhou, n=50). Mean respondent age was 66.6 years (range: 25-89), 77.3% were men and 22.7% were women, and most (91.6%) had always lived in the same village. Levels of respondent education were low, with 38.6% having received no education, 42.1% having only primary-school education, 16.8% having only junior high/middle-school education, and 2.4% having high-school education (n=368). Mean reported annual income was 15,893 yuan (n=229; equivalent to GBP £1,859; www.xe.com, 27 Dec 2021).

Only 64.1% of respondents reported their occupation as 'farmer', but 95.7% reported growing crops, with 38.4% reported having grown crops in the past; the mean proportion of their lifetime that respondents had grown crops was 0.62±16 SD. In total, 50.8% of respondents (within NCAR, 127/225; outside NCAR, 61/145) reported a decline in their cropland area since they started farming, whereas 38.9% (within NCAR, 78/225; outside NCAR, 66/145) reported no change, and 3.5% (within NCAR, 9/225; outside NCAR, 4/145) reported it had increased. Most respondents (88.4%) used or had previously used pesticides on their crops, on average using two types and/or applying pesticides 2.83±2.27 SD times/year. The most commonly used pesticides were dimehypo (thiosultap disodium: 25.9%) and methamidophos (organophosphate: 12.4%). Respondents also reported usage of three types of chemical fertilisers on average, which were applied for 2.06±1.03 SD months or 2±2.41 SD times/year. Most respondents (77.0%) irrigated agricultural land using the local water supply. Few respondents (11.4%) reported farming fish in local ponds.

Univariate regressions investigating land-use differences within and outside the NCAR showed that respondents within the NCAR were more likely to use pesticides (χ^2=0.874, SE=0.330, p=0.008) and apply more types of fertilisers (χ^2=0.249, SE=0.083, p=0.003), but were less likely to farm fish (χ^2=-1.283, SE=0.347, p<0.005). County-level univariate regressions showed that respondents from different NCAR counties reported higher levels of pesticide and fertiliser usage across several indices compared to respondents from several non-NCAR counties, as well as some other NCAR counties: pesticide use was highest in Guangde (48/49; statistically higher than in Fanchang, Ningguo, Sanshan, Wuhu and Xuanzhou), pesticide count was highest in Jing (mean=2.21; statistically higher than in Ningguo and Xuanzhou), fertiliser count was highest in Nanling (mean=2.25; statistically higher than in Guangde, Sanshan and Wuhu), and frequency of fertiliser use was highest in Xuanzhou (mean=3.77 times per year; statistically higher than in all other counties). Conversely, respondents from different non-NCAR counties reported higher levels of frequency of pesticide use (highest in Wuhu, mean=3.88 times per year; statistically higher than in Fanchang, Guangde, Jing, Langxi, Nanling and Ningguo), irrigation (highest in Fanchang, 36/36; statistically higher than in Jing, Nanling, Sanshan and Wuhu) and fish farming (highest in Sanshan; statistically higher than in Fanchang, Guangde, Jing, Langxi and Xuanzhou).

In total, 43.8% of respondents could recognise alligators. In the optimal binary model (AIC=214.91), recognition likelihood increased if respondents were men (χ^2=-1.384, SE=0.475, p=0.004), had higher annual income (χ^2=0.604, SE=0.201, p=0.003), and lived within the NCAR (within NCAR, 122/225; outside NCAR, 40/145; χ^2=1.964, SE=0.392, p<0.005), and decreased with pesticide count (χ^2=-0.414, SE=0.155 p=0.007). In the optimal county model (AIC=188.84), recognition likelihood increased if respondents were men (χ^2=-1.190, SE=0.558, p=0.033) and decreased with pesticide count (χ^2=-0.483, SE=0.193, p=0.012). At least one respondent from each county recognised alligators, with recognition highest in Xuanzhou (44/50); in the optimal county model, respondents from Xuanzhou were more likely to have seen them compared to respondents from two of four other NCAR counties (*Jing*: 14/38; χ^2=-1.633, SE=0.816, p=0.045; *Nanling*: 9/40;

χ^2=-2.737, SE=0.835, p=0.001) and three of four non-NCAR counties (*Fanchang*: 1/37; χ^2=-5.518, SE=1.213, p<0.001; *Ningguo*: 15/37; χ^2=-3.499, SE=0.803, p<0.001; *Sanshan*: 10/39; χ^2=-3.328, SE=0.852, p<0.001).

Only 15.1% of total respondents (34.6% of respondents who recognised alligators) reported having seen a wild alligator, with sightings reported from all counties except Fanchang. Additional information provided by respondents indicated that all sightings had occurred locally. In the optimal binary model (AIC=198.66), respondents were more likely to have seen alligators if they were older (χ^2=0.047, SE=0.018, p=0.010) and lived within the NCAR (subset of respondents who recognised alligators: within NCAR, 49/122; outside NCAR, 7/40; χ^2=1.255, SE=0.473, p=0.008). In the optimal county model (AIC=198.53), respondents were more likely to have seen alligators if they were older (χ^2=0.059, SE=0.020, p=0.003). Sightings were reported by the greatest proportion of respondents who recognised alligators in Langxi (18/30); in the optimal county model, compared to other counties with reported sightings, respondents from this county were more likely to have seen alligators compared to respondents from three of four other NCAR counties (*Guangde*: 7/25; χ^2=-1.504, SE=0.616, p=0.015; *Jing*: 3/14; χ^2=-1.911, SE=0.776, p=0.014; *Xuanzhou*: 18/44; χ^2=-1.053, SE=0.512, p=0.040), and all three non-NCAR counties with reported sightings (*Ningguo*: 1/15; χ^2=-3.385, SE=1.132, p=0.003; *Sanshan*: 2/10; χ^2=-2.209, SE=0.921, p=0.017; *Wuhu*: 4/14; χ^2=-1.481, SE=0.751, p=0.049).

Mean alligator last-sighting date was 42.36±18.0 SD years ago. Only four sightings dated from the previous decade (youngest = 6 years earlier), and only nine dated from the previous 20 years. In the optimal binary model (AIC=147.05), older sighting date was predicted by increasing respondent age (χ^2=0.074, SE=0.011, p<0.001), proportion of lifetime they have farmed (χ^2=1.161, SE=0.506, p=0.022), increased cropland area over time (χ^2=1.055, SE=0.203, p<0.001), pesticide frequency (χ^2=0.099, SE=0.106, p=0.001), and chemical fertiliser frequency (χ^2=0.316, SE=0.089, p<0.005), and younger sighting date was predicted by whether respondents lived within the NCAR (within NCAR, 41±17.5 SD years ago; outside NCAR, 53±19.2 SD years ago; χ^2=-1.043, SE=0.245, p<0.001) and pesticide count (χ^2=-0.849, SE=0.110, p<0.001). In the optimal county model (AIC=152.16), older sighting date was predicted by increasing respondent age (χ^2=0.094, SE=0.022, p<0.001), proportion of lifetime they have farmed (χ^2=1.217, SE=0.536, p=0.023), increased or consistent cropland area over time (increase, χ^2=2.379, SE=0.798, p=0.003; no change, χ^2=0.521, SE=0.241, p=0.031), and pesticide use (χ^2=2.555, SE=0.982, p=0.009), and younger sighting date was predicted by pesticide count (χ^2=-0.920, SE=0.169, p<0.001). Respondents from Jing reported the most recent sightings (mean last-sighting date = 29±13.5 SD years ago), and in the optimal county model, sightings from this county were significantly younger than those from Wuhu (mean last-sighting date = 63±18.8 SD years ago; χ^2=12.040, SE=5.892, p=0.041).

Only 7.3% of total respondents (16.7% of respondents who recognised alligators) reported having seen wild alligator eggs or nests, with mean last-sighting date 43±18.7 SD years ago. In the optimal binary model (AIC=49.885), sighting likelihood was greater in respondents who felt either negative or positive about alligator reintroduction compared to those who felt neutral (negative, χ^2=2.907, SE=1.021, p=0.004; positive, χ^2=2.388, SE=1.106, p=0.031). In the optimal county model (AIC=52.43), sighting likelihood was greater in respondents who felt negative about alligator reintroduction compared to those who felt neutral (χ^2=2.136, SE=0.924, p=0.021), and increased with frequency of fertiliser use (χ^2=0.362, SE=0.183, p=0.047). Past egg or nest sightings were reported from four of five NCAR counties (Guangde, n=2; Langxi, n=10; Nanling, n=2;

Xuanzhou, n=5) and with single sightings also reported from two of four non-NCAR counties (Sanshan: 1973, Wuhu: 1949); there was no significant difference in sightings between counties.

Only 9.7% of total respondents (22.2% of respondents who recognised alligators) perceived wild alligator abundance to have declined. Declines were perceived in all NCAR counties, but only in three of four non-NCAR counties (Ningguo, n=1; Sanshan, n=1; Wuhu, n=2). In the optimal binary model (AIC=170.41), respondents within the NCAR were more likely to perceive declines (subset of respondents who recognised alligators: within NCAR, 32/122; outside NCAR, 4/40; χ^2=1.163, SE=0.566, p=0.040). In the optimal county model (AIC=171.12), of the subset of respondents who recognised alligators, respondents from Langxi (11/30) were more likely to perceive declines compared to respondents from Guangde (2/25; χ^2=-1.896, SE=0.829, p=0.022). Eleven respondents reported knowing of alligators having been killed by local people; these reports were made by respondents in both NCAR and non-NCAR counties (Langxi, n=1; Sanshan, n=3; Wuhu, n=1; Xuanzhou, n=6), and four were associated with details (dates, locations) of past events that occurred both within and outside the NCAR (Nanling: 1973, killed by hooks for meat; Sanshan: 1988, killed by net; Wuhu: 2017, killed 'nearby').

Discussion

This study provides a new baseline to assess the potential usefulness of social-science methods for complementing standard ecological monitoring approaches for crocodylians, and to understand their likelihood of persistence in relation to differing anthropogenic land-use activities. Some indices of respondents' awareness and experience in the models used herein are correlated with age and sex, socio-demographic parameters that represent known predictors of environmental knowledge acquisition in other systems. This variation is likely to reflect well-understood factors such as age-related shifting baselines in knowledge of declining species that were previously more detectable (Turvey et al., 2010; Kai et al., 2014), and gendered division of labour in rural Chinese communities associated with differences in exposure to wildlife (Lu et al., 2000; Xiao & Hong, 2010; Allendorf & Yang, 2017). However, models that account for these expected patterns of variation also reveal other important conservation-relevant insights on local knowledge-content and likely threats to alligators across their last wild population.

LEK is increasingly recognised as a powerful tool for monitoring wildlife (Anadón et al., 2009; Turvey et al., 2013; Parry & Peres, 2015; Gray et al., 2017), but has only rarely been used to understand the local status of crocodylians (Brackhane et al., 2018; Eniang et al., 2020; Zayonc & Coomes, 2021). Extensive LEK might be expected to exist on Chinese alligators in rural communities within the NCAR, as these animals are easily identifiable, relatively large-bodied, culturally important, and a focal species for regional conservation attention and government policies, all characteristics that increase the likelihood of local awareness (Jones et al., 2008; Turvey et al., 2014). Local knowledge obtained through questionnaire surveys has previously been used to guide ecological surveys of Chinese alligators, but its information-content has not been formally assessed or reported (Ding & Wang, 2004). These results confirm the existence of conservation-relevant LEK on Chinese alligators by demonstrating that respondents living within the NCAR were more likely to recognise alligators, report sightings, and have seen alligators more recently compared to respondents outside the NCAR. More respondents within the NCAR also perceived alligators to have declined in recent decades; we interpret this as another accurate LEK metric, as alligator populations are known to have experienced considerable declines within the NCAR since the 1980s (Thorbjarnarson & Wang, 2002, 2010; Jiang & Wu, 2018), and although

they have declined to extinction in landscapes outside the NCAR, these losses occurred longer ago (Huang, 1981; Watanabe, 1982; Thorbjarnarson & Wang, 1999, 2010).

These data herein also show further variation in indices of respondent awareness and experience of alligators across different NCAR counties. These patterns are harder to assess due to limited independent recent data being available on the local status of wild alligators across different parts of the NCAR, and recent reintroductions of captive-bred alligators (Jiang & Wu, 2018). However, increased levels of alligator recognition in Xuanzhou may reflect the presence of China's largest alligator captive-breeding facility (the Anhui Research Centre for Chinese Alligator Reproduction) and the associated nearby release and monitoring of alligators at the Hongxing conservation site in this county (Wang et al., 2011). The greater proportion of recent sightings in Jing and the greater proportion of respondents perceiving alligator declines in Langxi in the within-NCAR results are also consistent with the tiny surviving local alligator populations in Xuanzhou and Guangde and the particularly severe local alligator decline in Langxi; alligators were only known from a single site in this latter county by 1999 (Thorbjarnarson & Wang, 2002) and have since been locally extirpated (Xiaotong Du, Wildlife Conservation Society, personal communication, January 2022).

However, whereas relative patterns of LEK are consistent with independent baselines on the varying local status of alligators across the survey region, absolute levels of respondent awareness and experience of alligators were low. Less than half of respondents (and only 54.2% within the NCAR) were able to recognise alligators; only 9.7% (and only 14.2% within the NCAR) thought that alligators had declined; only 15.1% (and only 21.8% within the NCAR) had ever seen a wild alligator; and mean last-sighting dates for alligators and their eggs and nests were over 40 years earlier, with only a handful of sightings reported from the previous two decades. The low level of encounters with alligators in the human-modified landscape of the NCAR highlights the perilous status of the species, which now persists as tiny numbers of scattered or single individuals isolated in unconnected habitat fragments (Thorbjarnarson & Wang, 2002, 2010). These findings indicate that further social-science surveys based on random sampling of respondents may be of limited use for understanding Chinese alligator population parameters to inform conservation planning; instead, targeting of specific individuals with known expertise about local wildlife using methods such as snowball sampling may be more appropriate (Newing, 2010). Such an approach could build upon the existing engagement of some local farmers as 'alligator caretakers' within the NCAR (Thorbjarnarson & Wang, 2002, 2010), to establish a more coordinated community-based monitoring network. These results also raise further concerns, because worryingly few people who live alongside wild alligators in the species' last refuge (and inside the protected area established to conserve them) are able to recognise them or are aware of their status. These awareness levels are unfortunately comparable to those seen in some other rural communities with limited access to formal education that live alongside other national-priority threatened species in China (Qian et al., 2021). As alligators likely remain threatened by direct interactions with local people (e.g. disturbance, ingesting poisoned prey; Thorbjarnarson & Wang, 2002, 2010; Jiang & Wu, 2018), these findings highlight the importance of conducting locally-appropriate educational outreach activities in communities across the NCAR as a priority action.

We collected little evidence of recent direct killing of alligators by local people, although our dated reports from non-NCAR counties provide potential evidence of more recent alligator survival in these landscapes than otherwise suspected, as well as raising concerns about possible occasional ongoing exploitation of wild alligators for food. However, in addition to identifying geographic differences in alligator awareness and encounters between the NCAR and

neighbouring counties, our analyses also provide important new insights into specific land-use activities that are statistically correlated with reduced alligator occurrence, thus highlighting these practices as potentially unsustainable for local alligator persistence. Our models show that fewer recent alligator sightings were made by respondents who had maintained or increased their cropland area, and had thus potentially encroached on remaining alligator habitats, compared with those who had reduced the amount of land they farmed over time and thus potentially decreased their direct impact on local habitats. Indeed, whereas only 3.5% of respondents in total reported having increased the amount of land they farmed, this activity influenced alligator sightings sufficiently to be a significant predictor by itself in our binary model. Almost half of respondents in counties outside the NCAR had either maintained or increased their cropland area, but over a third of respondents within the NCAR also reported having done so. These results thus suggest that existing levels of agricultural conversion within the NCAR may be insufficient to support a viable alligator population, with animals now often persisting in unconnected fragments of marginal or unsuitable habitat (e.g. oligotrophic ponds in hilly terrain where burrowing is difficult; Thorbjarnarson & Wang, 2002, 2010), and with ongoing land conversion for agriculture continuing to threaten the last remnant wild population.

In addition to overall levels of land-use change, our models indicate that usage of different environmental contaminants in local agriculture is also associated with reduced awareness or experience of alligators, with reported count of pesticide types used being negatively correlated with alligator recognition, and increased frequency of annual chemical fertiliser use correlated with older alligator sightings. Both pesticides and fertilisers are recognised threats to crocodylians, as they cause sublethal damage to crocodylian reproductive, developmental and immune systems, and can be lethal in higher doses or for younger life stages (Tavalieri et al., 2020). Increased agrochemical use associated with agricultural intensification is also known to have deleterious effects on other biodiversity and human health across China (Huang et al., 2001; Wood et al., 2010; Shapiro, 2016). The two most widely-used pesticides across our survey region, dimehypo and methamidophos, are designated “moderately hazardous” (Class II) and “highly hazardous” (Class IB) by the World Health Organization (2020), respectively. Both pesticides and fertilisers have previously been identified as potential drivers of decline within the NCAR, as they are known to destroy the Chinese alligator prey base and kill juvenile and adult alligators directly, and can pose a particular risk to alligator hatchlings that consume large amounts of small prey items (Huang, 1981; Watanabe, 1982; Chen, 1990; Zhou, 1997; Thorbjarnarson & Wang, 1999, 2002, 2010).

Even more concerningly, although respondents from non-NCAR counties reported higher levels of frequency of pesticide use, other indices of agrochemical use were higher within the NCAR compared to surrounding regions; respondents within the NCAR were more likely to use pesticides and apply more types of fertilisers, and respondents from different NCAR counties reported higher levels of pesticide and fertiliser usage across multiple indices compared to respondents from non-NCAR counties. These findings thus highlight the ongoing prevalence of these potentially unsustainable threats to the last wild Chinese alligator population across the species’ surviving distribution. We note that some of the relationships in our models between respondents’ experience of alligators and agrochemical use appear counterintuitive, with an unexpected negative correlation between recency of alligator sightings and number of pesticides used, and an unexpected positive correlation between likelihood of having seen alligator eggs or nests and frequency of fertiliser use. We interpret these results as possible secondary correlations with other factors rather than primary causations, and potentially attributable to associated differences in respondents’ behaviours that might affect their likelihood of experiencing alligators;

respondents who use more agrochemicals will spend more time applying them on their croplands and therefore have an increased possibility of encountering alligators, and applying fertilisers to soil may be associated with increased likelihood of exposing alligator nests. We acknowledge that our results indicate a complex relationship between agrochemical usage and alligator encounters, and that this relationship requires further investigation. However, overall our results suggest that pesticide and fertiliser use may be associated with decreased local occurrence and earlier disappearance of alligators.

Conversely, our models provide no evidence for relationships between alligator persistence or disappearance and other investigated land-use practices, which did not affect any indices of local awareness or experience of alligators. In particular, utilisation and modification of local water sources for irrigation or fish farming has previously been identified as a threat to Chinese alligators through habitat loss, destruction of nest sites and increased drowning risk, exposure of juveniles to predators, and increased conflict with people (Watanabe, 1982; Thorbjarnarson & Wang, 2002, 2010; Wang et al., 2011). It is possible that a lack of signal for these potential threats in our models was associated with insufficient variation in water-use practices across our sample, with 77.0% of respondents irrigating their cropland using the local water supply and only 11.4% farming fish in local ponds. However, it is also possible that current water modification practices may pose less of a threat to local alligator population survival compared to other land use change and agrochemical use. Indeed, comparisons across the survey region indicate that respondents living alongside the last wild alligator population within the NCAR practice less irrigation and fish farming, and thus have a reduced impact on local wetland habitats required by alligators. These activities might therefore be associated with past alligator disappearance outside the NCAR, but might no longer constitute substantial ongoing threats within the NCAR in comparison to other pressures.

Conclusions

This study demonstrates how investigating the activities of communities living alongside threatened biodiversity can help to identify specific key threats and inform conservation. It is recognised that the indices of respondents' land-use activities used represent relatively crude metrics of local pressures on alligators, and targeted follow-up work using applied methods (e.g. remote sensing analysis of spatiotemporal land use change; ecotoxicological testing to determine agrochemical effects) is needed to elucidate the dynamics and specific impacts of different pressures. However, our analyses still detected several relationships between specific anthropogenic activities and variation in indices of alligator occurrence, thus indicating that our dataset is sufficiently robust to provide insights into anthropogenic correlates of varying alligator occurrence at the local scale. Our findings are alarming, as they suggest that the protected NCAR landscape is continuing to experience negative human pressures that threaten China's last wild alligators. Much needs to be done to ensure the species' continued survival, including establishing more alligator-friendly agricultural landscapes, restoring wetland habitats, and revising management of the NCAR to reduce unsustainable land-use practices within the context of maintaining support for local livelihoods. Our study also has important implications for efforts to reinforce or reintroduce alligator populations, which have largely lacked consideration of the social or ecological dimensions of existing anthropogenic pressures at release sites (Thorbjarnarson & Wang, 2010). It is hoped that these findings can guide *in situ* conservation planning for this highly threatened species, and help to ensure long-term survival of wild alligators in China.

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