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The population size and breeding range of the Scaly-sided Merganser *Mergus squamatus*

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Summary

Based on surveys during 2000–2012 and best available knowledge, we estimate the global population size of the Endangered Scaly-sided Merganser *Mergus squamatus* to be c.1,940 pairs (or c.4,660 birds prior to reproduction). In Russia, surveys identified the breeding range in the Sikhote-Alin mountain range and the area adjoining the lower Amur River. Particular effort was made to define the edge of the range. Breeding densities in the Sikhote-Alin were applied to un-surveyed rivers within the range to estimate overall numbers. The breeding range comprises c.7,800 km of 120 rivers: 6,800 km in Russia, 600 in China and 400 in DPR Korea. In Russia it comprises 88 rivers of both the western and eastern slopes of the Sikhote-Alin Range, and two small isolated areas, one in central Khabarovsk and the other in the Jewish Autonomous Oblast. All known and potential breeding areas were surveyed in China, where the breeding range comprises the western slope of the Changbai Mountains, and one isolated river system in the Lesser Xingan Mountains. Scaly-sided Mergansers are also assumed to breed on the eastern slope of the Changbai Mountains in DPR Korea. No recent surveys have been made there but numbers were estimated by applying densities from China to rivers with apparently suitable habitat. Detailed examination of past records suggests that an earlier claim of breeding Scaly-sided Mergansers on the Dep River was erroneous and we conclude that the breeding range never extended as far west as has been portrayed in most literature. The lack of comparable surveys previously precludes an assessment of change in population range or size, though it seems inevitable that habitat loss in China is likely to have resulted in some loss of range and numbers, particularly in Heilongjiang Province, in recent decades.

Introduction

The Scaly-sided Merganser *Mergus squamatus* is amongst the most threatened sea ducks (Mergini) and is classified as 'Endangered' on the IUCN Red List (http://www.iucnredlist.org). It is listed as 'first rank category' on the List of the Protected Wildlife of National Importance in China, as 'rare' category 3 in the Red Data Book of the Russian Federation, and is included on the Red Lists of the Republic of Korea and Japan. Threats include the loss of large trees (which provide nest cavities) along breeding rivers from logging during the 1940s–1970s, drowning in fishing nets, shooting on the breeding grounds, and major habitat modification to rivers in passage and wintering areas, together with pollution of the rivers in the wintering range. Conservation activities on the breeding grounds include awareness campaigns to address shooting and the use of gill-nets, and an artificial nest-box programme on a number of rivers where logging has removed old trees. There are currently no activities specifically targeted at the conservation of this species on the wintering grounds.

The species favours fast-flowing, clean mountain rivers for breeding. Historically it was known to breed in the south-east of the Russian Far East and north-east China, and it was presumed to breed in the Democratic People's Republic of Korea, based on old literature sources (BirdLife International 2001), although these included records that were undated and without indication of breeding. The distribution map presented by BirdLife International (2001) suggested a recent contraction in range, although there have been no real efforts to delineate the breeding range.

Breeding surveys were chosen as the most reliable method for estimating the global population size of Scaly-sided Merganser. Geolocators fitted to nesting females caught and recaptured on one river in Primorye, Russian Far East, showed that they wintered on freshwater habitats throughout mainland China, straddling an area 830 km east to west and 1,100 km north to south (Barter *et al.* in press). Published records suggest the winter range stretches from Vietnam to DPR Korea, on habitats from rivers to sea coast, a large and diverse area compared with the relatively compact breeding range, where fast-flowing rivers are the only known breeding habitat. Stable isotope analysis of wing feathers confirmed most Scaly-sided Mergansers of both sexes were likely to moult on fresh water (although not necessarily on the breeding rivers), while some males, subadult and failed breeding females may undertake moult migration to brackish and marine waters (Solovyeva *et al.* submitted). Since the species shows no single moult strategy and moulting sites were mostly unknown, a survey of moulting birds was also considered poorly suited for determining population size. The method selected for the Scaly-sided Merganser was survey of breeding rivers within the entire breeding range as suggested by old literature (see list of literature sources in BirdLife International 2001). This method therefore enabled us to determine both the recent breeding range and the population estimate for Russia and China. Estimates have then been added for DPR Korea based on assumptions of numbers and distribution there.

Methods

Selection of survey areas

In Russia, the whole Sikhote-Alin Range and the mountain area to the north of the lower Amur River were assessed. Based on old records of Scaly-sided Merganser, the former breeding area was bounded to the west by the Dep River (53°40′N, 129°11′E; Dymin and Kostin 1977) in the north and the Pompeevka River (48°21′N, 130°48′E; Smirenskiy 1977) in the south (Figure 1). Coordinates for each river represent a point approximately 50 km downstream from its source. A selection of rivers was surveyed within the area 630 km north-south and 650 km west-east between the Dep and Amur. Particular attention was given to the rivers Dep and Pompeevka together with several adjoining rivers to confirm the presence or absence of Scaly-sided Mergansers at the limit of the species' range. In total, c.2,470 km of river were surveyed in Russia. Recent information from nature reserves within this area was also reviewed.

In China c.1,180 km of river were surveyed. This included all rivers in the Changbai Mountains and selected rivers in the Lesser and Greater Xingan Mountains. The Chinese part of the Wusuli (Ussuri in Russian) basin was partially surveyed.

Breeding rivers were mainly between 150 and 450 m asl. They ranged from 20 to 200 m in width and the average current velocity was 6 km h^{-1}. All rivers are situated in the pine-broadleaf forest zone though different logging histories have resulted in different forest quality on their banks.

Survey timing

Surveys were designed to count breeding pairs and started in the month after birds arrived on the breeding rivers. On the majority of rivers, surveys occurred in mid-April in the south of the breeding range and up to mid-May in the north (see arrival dates in Solovyeva *et al.* 2012). Surveys thus occurred when territorial (breeding) pairs were on their territories and before males started to depart breeding rivers in early May in the south and in late May in the north. Some late

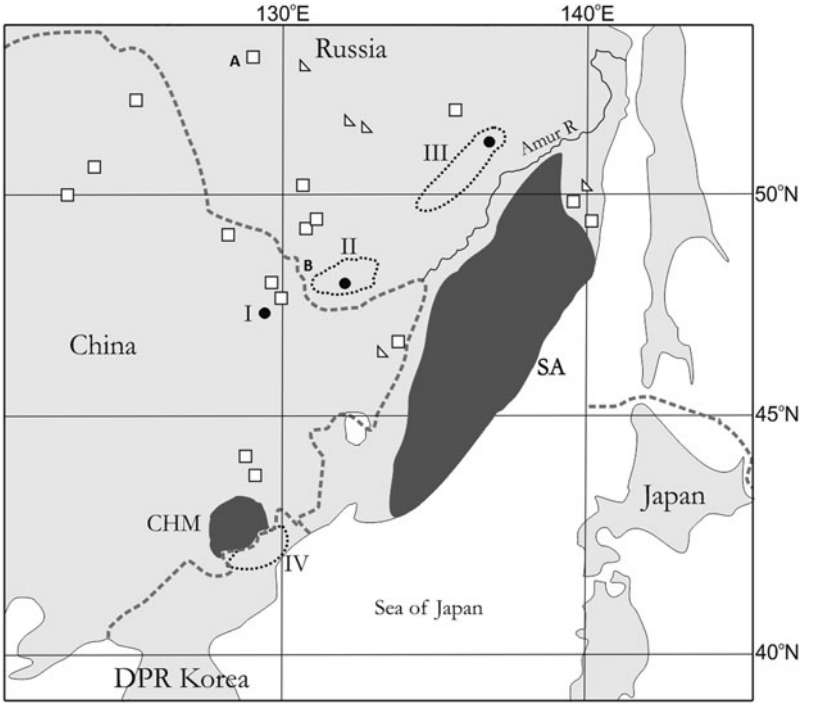

Figure 1. Global breeding range of the Scaly-sided Merganser *Mergus squamatus*. Known breeding populations are shown by solid grey areas (SA = Sikhote-Alin; CHM = Changbai Mountains, China). Presumed breeding populations are shown by dotted contours and Roman numerals (I = Lesser Xingan; II = Jewish Autonomous Oblast; III = Central Khabarovsk; IV = Changbai Mountains, DPR Korea). Recent records of breeding pairs away from the main populations are denoted by black dots. Open symbols represent rivers on which Scaly-sided Merganser breeding pairs were not recorded in recent years: squares represent authors' data, and triangles represent others' data. The Dep River is indicated by the letter 'A' and the Pompeevka River by the letter 'B'. Country borders are shown by grey dashed lines.

arriving pairs and early departing males from early breeding pairs may have been missed during surveys, while some migrating pairs may have been counted as breeding birds on rivers where spring passage occurs.

Survey methods

Combined boat and foot surveys were used (Kolomiytsev 1990). One person undertook surveys on foot, while two persons – a boat driver and observer – surveyed from a rubber boat. Motor boats were employed on the large rivers of Khabarovsk. Birds were only counted once they had been passed by the boat or walker. The following groups were distinguished during each survey: breeding pair, single male or female, flock of subadults, flock of unknown sex and age. Subadults were identified by plumage details; see Liu *et al.* 2010. Trios (one male and two or rarely three females) were considered a breeding pair during spring surveys. Single males were also considered as a pair (the female assumed to be incubating), and single females were considered as a breeding pair if no single male was recorded within a 5-km stretch, though single females with single males nearby were not recognised as breeding (based on the assumption that a paired male will stay close to the nest site when the female is incubating or with the female when off the nest;

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and that he will have excluded other males from a 5-km territory). In many, but not in all, cases we distinguished between adult and subadult males; a subadult male with a female was still considered a breeding pair. Flocks of more than four birds of any sex and age were considered as non-breeders.

Breeding density was estimated as the number of breeding pairs per kilometre of river. We surveyed only the main channel of each river and not side channels or oxbows as Scaly-sided Mergansers are rarely encountered on side channels in spring (Kolomiytsev 1990 and our observations), though it is possible some birds feeding in side channels were missed. Survey length varied from seven to 350 km (mostly 20–40 km) and we surveyed the middle reaches of rivers 100–300 km long and the upper reaches of longer rivers. Scaly-sided Merganser density was found to be the highest in the middle reaches of small rivers (Solovieva *et al.* 2006) and the duck is known not to use the upper 30–40 km of rivers (Kolomiytsev 1990). Some rivers were surveyed by a single survey and others were surveyed several times between 2000 and 2012.

Delineation of breeding range

The margins of the breeding range for each population were the subject of special attention during this study. We surveyed river by river from the area where Scaly-sided Mergansers were absent until breeding birds were found. We considered all rivers with suitable nesting habitats for Scaly-sided Merganser within the limits of the breeding range to be occupied. We were unable to survey rivers in DPR Korea due to political inaccessibility.

Estimating density on unsurveyed rivers

Breeding pair density depends on a number of local factors in each river and is difficult to predict. Adjacent rivers with seemingly similar conditions may support Scaly-sided Merganser densities differing by an order or magnitude (Solovieva *et al.* 2006). We assigned densities to un-surveyed rivers as follows: (1) where a single survey provided a density for a river within a basin or isolated breeding area, this density was used for other rivers in that basin or area; (2) 0.15 pairs/km was used for all small rivers less than 60 km in length; (3) 0.4 pairs/km for all large rivers of the Sikhote-Alin populated by humans; (4) 0.6 pairs/km (the maximum density in Russia) to large pristine rivers of the east slope of the Sikhote-Alin; and (5) 0.27 pairs/km for rivers on the DPR Korean side of the Changbai Mountains (this is the average density on rivers on the Chinese side).

Estimating the number of pairs

Suitable habitats for breeding Scaly-sided Mergansers are clean fast-flowing mountain rivers fringed by mainly broadleaf forest. The upper 40 km of each river were considered unsuitable, as were the lower parts of rivers if situated on a plain below 30 m asl. The length of suitable habitats in Russia was calculated from the total river length according to the State Water Register (http://textual.ru/gvr/index.php?card) and using Google Earth. Google Earth was used to calculate the length of suitable habitats on rivers in China and DPR Korea. Stretches of rivers below dams in DPR Korea were excluded from the calculations where, based on Google Earth images, the habitat appeared unsuitable. We multiplied known or suggested pair density by the length of suitable habitats for each river and then rounded up to the nearest whole number.

Results

Recent breeding range

A total of 143 rivers were assessed: 105, 27 and 11 in Russia, China and DPR Korea, respectively. In total, 7,833 km on 120 rivers were considered suitable breeding habitat for Scaly-sided

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Mergansers: 6,795 km on 93 rivers in Russia, 611 km on 16 rivers in China and 427 km on 11 rivers in DPR Korea.

The breeding range in Russia includes 88 medium-sized and large rivers (longer than 45 km) in the Sikhote-Alin Range, east of the lower Amur River. The northern limit is the Gur River (west slope; 50°20′N, 138°22′E) and Koppi River (east slope; N48°31′N, 139 °10′E) and the southern limit is the upper Ussuri River (west slope; 44°01′N, 133°55′E) and Partizanskaya River (east slope; 43°15′N, 133°17′E). The Sikhote-Alin area represents by far the largest part of the breeding range (Figure 1). Scaly-sided Mergansers were not found on the rivers to the north of these limits, where we recorded only breeding Goosander *Mergus merganser*, as was also the case in 1991 (S. Surmach pers. comm. 2010). Two small breeding populations occurred to the north of the lower Amur River in the 2000s. These were the Jewish Autonomous Oblast population on the rivers Bidgan, Bira and probably Pompeevka (script II in Figure 1) and the Central Khabarovsk population (script III in Figure 1). We found Scaly-sided Merganser pairs only on the River Gorin (51°02′N, 136 °08′E) in the last area, though we suspect it may also breed on the nearby Kur River (Roslyakov 1981, Shibnev 1989, Solovyeva *et al.* submitted).

Two breeding populations occur in China: in Changbai and the Lesser Xingan (scripts CHM and I, respectively, in Figure 1). The Changbai population occupies the middle reaches of 13 rivers falling from Changbai Mountain itself on the Chinese side. Only four apparently suitable rivers in the Changbai Mountains were not occupied by Scaly-sided Mergansers. Only one river – the Tangwanghe (47°26′N, 129°22′E) and its tributary Bishui – was found to support breeding Scaly-sided Mergansers in the Lesser Xingan (script I in Figure 1).

It is reasonable to suggest that Scaly-sided Merganser also breeds on the DPR Korean side of the Changbai Mountains (script IV in Figure 1), although no information on breeding is available from this area. We suggest 11 rivers, with a total length of 427 km of suitable habitats, may hold breeding Scaly-sided Mergansers.

Scaly-sided Mergansers were absent on the River Dep (white square A in Figure 1) and along all rivers surveyed in the area between Rivers Dep and Gorin in Russia (Gorin is the black point within the dashed contour, script III, Figure 1). This area was inhabited by Goosander pairs and broods both during our surveys and according to information for the Nora River (Kolbin 2003; O. Smagina unpubl. photos 2011), the Amgun River (Pronkevich *et al.* 2011), the Levaya Bureya and Pravaya Bureya Rivers (T. Atrokhova pers. comm. 2011). Scaly-sided Mergansers were not found in the Chinese part of the Wusuli basin and are not mentioned in other sources (T. Dahmer unpubl. report and Liu *et al.* 1998) or on the rivers of the Greater Xingan Mountains in China (Table S2 in the online Supplementary Material). Riverine forest, the only known suitable breeding habitat of Scaly-sided Merganser, was absent along all the rivers of the Wusuli basin and the Greater Xingan where agricultural landscapes and settlements now predominate.

Breeding densities

Pair densities (Table S1) were highest on the Fuerhe River in the Chinese Changbai Mountains (0.918 pairs/km) and the Pavlovka River in the Sikhote-Alin (0.63 pairs/km). The lowest densities were 0.006 pairs/km on the Bidjan River, Jewish Autonomous Oblast; 0.007 pairs/km on the Gorin River, Central Khabarovsk, Russia; and 0.025 pairs/km on the Tangwanghe River in the Lesser Xingan, China. Mean breeding pair densities did not differ between Russia and China (0.259 pairs/km and 0.269 pairs/km, respectively; Mann-Whitney U Test, $U = 171$, $P = 0.75$).

Population size

Densities of Scaly-sided Merganser breeding pairs within the recent breeding range were assessed by survey on 40 rivers and estimated for 68 rivers (Table 1). The number of breeding pairs in the Bikin River basin, a catchment with 12 rivers, was taken from Hughes and Bocharnikov (1992).

Table 1. Estimates of the contemporary numbers of Scaly-sided Mergansers *Mergus squamatus* breeding in Russia, China and DPR Korea (breeding pairs), based on surveys, best available knowledge and literature searches, 2000–2012.

Basin, region	Rivers surveyed	Rivers where numbers were estimated	Pairs on rivers surveyed	Pairs on rivers estimated	Total pairs
RUSSIA					**1,654**
Total Sikhote-Alin range (SA)					*1,643*
Sea of Japan, Khabarovsk	1	3	10	7	17
Sea of Japan, Primorye	12	18	117	314	431
Amur basin	1	6	17	21	38
Anuy basin	2	4	195	64	259
Khor basin	1	7	88	128	216
Bikin basin*					200
Bolshaya Ussurka basin	4	9	159	172	331
Upper Ussuri basin	4	4	106	45	151
Total North of Amur River					*11*
Jewish AO (II)	1	2	2	3	5
Central Khabarovsk (III)	1	1	3	3	6
CHINA					**166**
Changbai Mountains (CHM)	11	2	152	3	155
Lesser Xingan (I)	2	1	8	3	11
DPR KOREA					**116**
Changbai Mountains (IV)	0	11	0	116	116
TOTAL	40	68	857	1,079	1,936

*estimate of pairs for 12 rivers in the Bikin basin from Hughes and Bocharnikov (1992).

Although now rather old, we believe this estimate is a valid minimum given no marked habitat changes, less disturbance and the establishment of protected areas since the early 1990s.

The population is estimated to be 1,936 breeding pairs, comprising 1,654 pairs in Russia, 166 pairs in China and 116 pairs in DPR Korea (Table 1).

The largest breeding unit is the Sikhote-Alin metapopulation, with its 1,643 pairs representing 84.9% of the global total. The Changbai metapopulation, combining the Chinese and Korean sites, numbers 271 pairs, 14.0% of the total. Combined, the three small isolated populations elsewhere account for just over 1% of the world population: 11 pairs in the Lesser Xingan (script I in Figure 1), five pairs in the Jewish Autonomous Oblast (script II) and six pairs in Central Khabarovsk (script III). Breeding evidence (nests or non-flying young) was not confirmed for the last two populations, either historically or recently, but we have employed the same approach for all observations, treating pairs in suitable habitats during the early breeding season as breeding pairs.

Trios (a male with two females) accounted for 11.4% of breeding 'pairs' in the Sikhote-Alin population (2003–2012) and 13.7% of 'pairs' in the Changbai population (2008–2009). The total of 1,654 breeding pairs in Russia therefore amount to 3,497 adult birds, and in China and DPR Korea 282 breeding pairs comprise 603 adult birds. Scaly-sided Mergansers in flocks (mainly subadult birds) observed during spring surveys comprised 11.8% of the population in the Sikhote-Alin and 24.7% in Changbai. Applying these proportions to the totals for Russia and China with DPR Korea gives 413 and 149 additional birds, respectively. The total number of Scaly-sided Mergansers is thus 4,662 birds prior to reproduction. Although a proportion of subadults might remain on the wintering grounds during spring and summer, we suggest this number to be negligible because (1) 11.8–24.7% subadult birds in spring is a reasonably high proportion for seaduck; (2) winter habitats used in China are generally highly disturbed rivers with low water transparency, so it seems a reasonable assumption that Scaly-sided Mergansers would be unlikely to remain there during the eight months when the clean fast-flowing rivers of the breeding grounds are ice-free (Solovyeva *et al.* 2012).

Changes in numbers

The only annual monitoring of breeding numbers has been in the Kievka basin, Sikhote-Alin Range (Figure 2). The first breeding pairs were recorded there in 1960 and 1962 (Litvinenko and Shibaev 1965), following the construction of a road alongside the river enabling easy access. Numbers reached 8–12 pairs in 1980–1985 and 11–17 pairs in 1986–1988 (Kolomiytsev 1986, 1992); and we counted 27–78 pairs in 2000–2012, with the peak in 2006 and the minimum in 2012 (Figure 2). There is no doubt that numbers increased in the Kievka basin between the 1980s and the 2000s. Synchronous annual counts during 2001–2012 on the Avvakumovka River (Figure 3), 200 km from Kievka, demonstrated no correlation between the two catchments (Spearman R = 0.132; $P = 0.7$). Scaly-sided Merganser populations in adjacent catchments can likely therefore be considered independent. The densities differed significantly between the two catchments, with densities in the Kievka higher than in the Avvakumovka in all years (Mann Whitney U test, $U = 2.000$, $P = 0.0001$).

Discussion

Current breeding range

The global breeding range of Scaly-sided Merganser is effectively limited to two main areas: the Sikhote-Alin Range and the Changbai Mountains. The first is much the larger, covering both the west and east slopes of the mountains and extending roughly 1,000 km from southern Primorsky Krai into south-east Khabarovsk Krai. We assumed that Scaly-sided Mergansers were present on all 88 suitable rivers within this range. The second area straddles the border between China and DPR Korea, to the north and east of Changbai (or Baekdu) Mountain itself. This range is roughly circular, around 175 km in diameter, contained within Jilin Province, China, and within Ryanggang and North Hamgyong Provinces, in DPR Korea. It comprises some 24 rivers, 13 in China and 11 in DPR Korea.

Given extensive surveys during the period (see Tables SA and SB and also Liu *et al.* 2010), and with particular effort focused on determining which rivers were occupied at the edges of the range and in formerly occupied areas, we are confident in mapping the extent of these ranges with reasonable accuracy in Russia and China (Figure 1); the distribution in DPR Korea is, however, largely speculative.

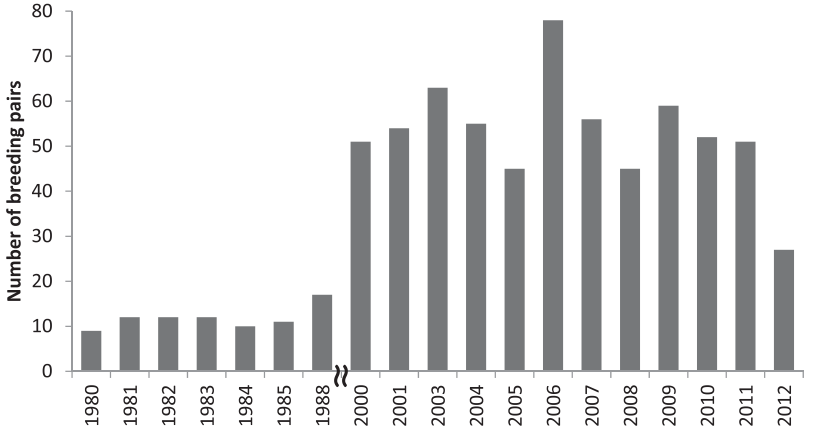

Figure 2. Numbers of Scaly-sided Merganser *Mergus squamatus* breeding in the Kievka River catchment, Primorye, 1980–1988 (based on Kolomiytsev 1992) and 2000–2012 (our data).

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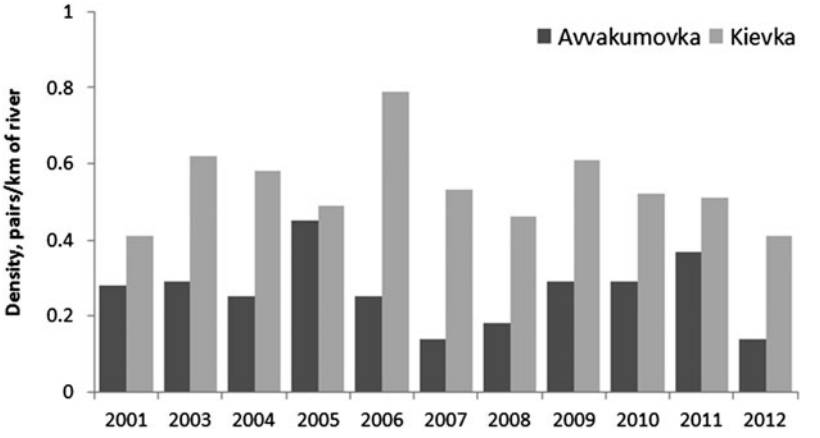

Figure 3. Changes in Scaly-sided Merganser *Mergus squamatus* breeding pair density on the Avvakumovka and Kievka rivers, South Sikhote-Alin Range, Russia, 2001–2012.

We suggest there are also three very small, disjunct and isolated breeding areas: one at the south-western limit of the Bureinsky Range in the Jewish Autonomous Oblast, one in the Badjalskiy Range in central Khabarovsk, both in Russia, and in the south-east Lesser Xingan Mountains of Heilongjiang Province, China.

In Central Khabarovsk (script III on Figure 1), we suggest a small population of a few pairs may occur on the rivers Gorin and Kur to the west of the Amur River. A pair and three males were recorded when travelling up the Gorin River, and a pair and 12 males recorded on the descending survey of 138 km in May 2012. It is, however, possible that the pair were non-breeders and our suggestion of breeding there is thus not confirmed. A Scaly-sided Merganser was collected from the Kur River in August 1910 (Buturlin 1910, cited in Birdlife International 2001), and data from a geolocator fitted to a female indicated its presence there during summer and wing moult in June to early November 2007 (Solovyeva *et al.* submitted).

In the Jewish Autonomous Oblast, there is a single old record (from August 1976) of breeding Scaly-sided Mergansers on the river Pompeevka, north of the Amur River close to the border between Russia and China (Smirenskiy 1977). Eight broods were observed along 12 km of river, a relatively high density (0.66 broods/km) compared with rivers in the core breeding area. Yakhontov (1973) reported Goosanders on the rivers of the Lesser Xingan and Pompeevskiy Ranges in Russia in the late 1960s and early 1970s, but not Scaly-sided Mergansers. In 1988 and 1992, merganser broods, thought to be Scaly-sided, were reported on the Pompeevka (Averin and Voronov 2004). During our surveys of the Pompeevka in August 2008 and in April 2011 (when 97 km were covered), just four mergansers were observed, all females: one Goosander and three not identified to species. A single male Scaly-sided Merganser was reported during a 160-km survey of the Bijan River in May 2011 (Table S1) and a single male was observed on the Bira River in May 2012 (Averin and Kapitonova 2012).

It is possible that the 1976 record on the Pompeevka may have been a Goosander (a confusion we suggest occurred on the Dep River in 1976; see below). It may now be impossible to know which species was involved, or to reconcile the contradictory observations of Yakhontov (1973) and Smirenskiy (1977). Nevertheless, given the positive records in the 1980s and 1990s and subsequent records of single birds in 2011 and 2012, we suggest that a small breeding population might still exist in the Jewish Autonomous Oblast (script II in Figure 1).

A small isolated breeding population of Scaly-sided Merganser exists in the Lesser Xingan Mountains of Heilongjiang Province, China (script I in Figure 1). Breeding pairs were recorded on

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the rivers Tangwanghe and Bishui in 2011, and we suggest that breeding also occurs on the Shuangfen.

Changes in breeding range

Dymin and Kostin (1977) include a record of two juvenile Scaly-sided Mergansers shot and identified in the hand on the Dep River, 750 km to the north-west of the Sikhote-Alin, on 23 August 1976. Based on this record, later literature drew the breeding range of the species extending west of the Amur River to the Dep (Roslyakov 1981, 1985, Birdlife International 2001). We have obtained the field notebook of B. Kostin in which he describes the juvenile merganser obtained in 1976. The description (white throat, culmen length of 78 mm and weight of 1,100 g) categorically indicates, however, that this was a Goosander. We suggest, therefore, that the species' occurrence there has never been satisfactorily proven and that the breeding range never extended as far west as has been portrayed in most literature.

Roslyakov (1981) reported the species as a "rare breeder" on the Amgun, Urmi, Kharpi and Kur rivers, although no data on breeding pairs in spring or broods in summer were provided for these rivers and, apart from the Kur River, there were no records or skins of non-breeders. In his later paper, Roslyakov (1985) did not mention Scaly-sided Merganser as a breeding bird on the Amgun River. Our surveys of the Dep, Ulma and Amgun rivers, as well as recent observations on the Nora River and both major tributaries of the Bureya River (the Levaya Bureya and Pravaya Bureya), did not find any Scaly-sided Mergansers (Table S2), though high densities of Goosanders were recorded. We therefore suggest that most records from this region are likely to have been erroneous. The distribution in Russia shown in Figure 1 therefore indicates a revision, rather than a contraction, of the breeding range of Scaly-sided Merganser.

It is difficult to compare our results with published information from surveys during 1976–1991 in China (Zhao *et al.* 1993, 1994), as only some of the rivers were visited previously and the survey method was different (walking along the river bank). The Chinese part of Wusuli (Ussuri) River valley and the Wusuli River itself were not occupied by Scaly-sided Mergansers in the 2000s. No Scaly-sided Mergansers were found in the Daxing'anling (Greater Xingan Mountains) in Heilongjiang Province during our surveys in 2011, or during surveys in 1984–1985 and 1987–1988, although specimens were collected there in 1956 and 1979 (Zhao *et al.* 1994).

Almost all mountain areas in Heilongjiang Province now have little or no suitable habitat for breeding Scaly-sided Mergansers. There are few old forests left (young secondary forests do not provide nesting cavities for the Scaly-Sided Merganser) and Scaly-sided Mergansers in the Lesser Xingan are found in seemingly the only remaining suitable patch of forest. Some old records were, however, from sites apparently unsuitable for the species, such as wetlands on plains, though these could be attributable to non-breeding birds during their migration or moult (Zhao *et al.* 1994). The species was anecdotally reported to occur at four of six reserves on the Sanjiang plain previously (date unknown, from an unpublished report, T. Dahmer *in litt.*).

Consequently, we suggest that the species' range has contracted to some extent outside the core areas in the two coastal mountain ranges in recent times. We believe, however, that the Scaly-sided Merganser probably never occurred over an extensive area west and north of the Amur River, as suggested in the previous literature. The small numbers on the western and southern fringes of the Bureinsky and Badjalskiy Ranges perhaps simply represent an overspill from the core breeding area of the Sikhote-Alin and historically the species may never have been much more numerous or extensive in Russia than at present.

It seems there has been a contraction in range in north-east China. There are many 20th century records from sites throughout Heilongjiang and Jilin Provinces (see BirdLife International 2001), yet our surveys revealed the current distribution to be very restricted. There seem insufficient past records to suggest that areas away from the Changbai held Scaly-sided Mergansers in comparable numbers or density to the current core breeding range, though the difficulties in accessing suitable habitat, the need for specialist surveys at the right time of year (males are present on the

breeding sites for only a short period), and the potential confusion of females and young birds with Goosanders may be responsible for underestimating the past status. Conversely, it remains possible that some records, as with the case of the Dep, were erroneous and a detailed inspection of past isolated records at the limit of the range may be instructive. Nevertheless, given the extent of mountain forest logging and the development of agriculture, it seems inevitable that there have been losses in the Lesser and Greater Xingan and the Wusuli basin to a greater or lesser extent.

We suggest that the extent of the breeding distribution in the Sikhote-Alin Range has been stable in recent times. Given the high densities found there, it seems likely that the range in the Sikhote-Alin is determined by natural features, namely the absence of mountain rivers of suitable size in the south and perhaps the absence of broadleaf forest along riversides in the north.

Although not quantified, our impression during surveys in Russia was that there is no appreciable overlap of Goosanders and Scaly-sided Mergansers. Although Goosanders were found on some Scaly-sided Merganser breeding rivers, the former were there seemingly restricted to the uppermost stretches. Outside Scaly-sided Merganser breeding range, rivers whose physical characteristics would otherwise appear suitable for that species were often occupied by Goosanders. The nature and causes of this distribution merit further investigation and may help to inform conservation efforts.

The current breeding range in the Changbai seems to be larger than before, as a result of the discovery of an important site, the Fuerhe River. It is, however, possible that this stretch may also have been populated by Scaly-sided Mergansers in earlier years. It is also possible that deforestation in Heilongjiang may have encroached upon the Changbai, and it is possible that the core breeding area was previously more extensive within this mountain range.

Population estimate

We believe the global population estimate of c.1,940 pairs, or c.4,660 birds prior to reproduction, is the most accurate to date. It falls between two previous estimates, based on a small sample size and an unclear breeding range, of 2,500 birds (Birdlife International 2001) and 10,000 birds (Solovieva *et al.* 2006). During the 10 years of our surveys, we covered 44 of the 120 rivers that comprise the species' breeding range. We calculated 857 pairs on rivers that were surveyed, and a further 1,079 pairs were estimated to occur on unsurveyed rivers within the breeding range (Table 1). All rivers with breeding Scaly-sided Mergansers were surveyed in China in both the Changbai and Lesser Xingan populations, and thus we believe the number for China represents a full census. We believe our estimates for unsurveyed rivers in Russia are robust for a number of reasons: (1) all unsurveyed rivers are inside the limits of the breeding range, and these limits were confirmed precisely through surveys; (2) casual observations confirmed the presence of Scaly-sided Merganser during the breeding season on 22 of these unsurveyed rivers (rivers marked * and + in Table S1); (3) the densities used to calculate numbers are based on observed densities for similar habitats and catchments; and (4) although there are annual fluctuations in numbers during the ten years of our survey, there have been no marked changes or obvious trends in densities on rivers surveyed regularly throughout the period (Figure 3). We believe it is unlikely that there are any significant additional unknown populations of Scaly-sided Mergansers in Russia or China.

Our estimate for numbers of Scaly-sided Mergansers breeding in DPR Korea is rather speculative. We have assumed that rivers here are broadly similar in character to those on the Chinese side of the Changbai and have applied the average density from surveyed rivers in Jilin to stretches of river that seem suitable from Google Earth in the area immediately adjacent to the Chinese breeding range. Naturally, it is impossible to verify this approach without visits to the rivers to confirm the nature of the habitat or their extent. Our estimate of 116 pairs compares reasonably favourably with the figure of 200 proposed by Chong and Morishita (1996), though we have been unable to confirm the methods used by these authors.

Detailed historical survey data are lacking for both Russian and Chinese breeding grounds, such that it is not possible to suggest any changes in long-term population dynamics. It seems that there was a decline in the Sikhote-Alin breeding population during the 1960s and 1970s (Shibnev 1976, Yakhontov1976, Isakov 1985) followed by a recovery during the 1980s and 1990s (Kolomiytsev 1992, Bocharnikov and Shibnev 1994, Surmach and Zaykin 1994, our data).

Supplementary Material

The supplementary materials for this article can be found at journals.cambridge.org/bci

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