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An evaluation of waterfowl sampling methods for the national census on river and dam lake environments

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Abstract : A national census of river and dam lake environments (NCRE) conducted by the Ministry of Construction of Japan has been underway since 1991. Information on the variation in number and habitat use of waterfowl is important in determining the optimum sampling effort necessary for accurately estimating the population density. However, this variation is not sufficiently considered in the census methods used in the NCRE. In this paper, we report the variation in number and habitat use of waterfowl, especially ducks, over short and long temporal scales (daily and monthly changes, respectively) at Takayama dam lake in central Japan. Between December 1998 and March 1999, we counted wintering waterfowl from a small boat and from the lake shore, and analysed the results in relation to the valid range of census methods adopted by the NCRE. General results of the field observations were: (1) the waterfowl assemblage was stable in January and February; (2) the waterfowl assemblage was stable on any given day and only slightly varied during five consecutive days; (3) the locations of ducks on the dam lake remained almost the same during both short and long temporal scales; and (4) terrestrial observations were not useful for counting mandarin ducks and green-winged teals resting on the surface of the dam lake. These results suggest the following: (1) the winter waterfowl census in central Japan should be conducted in January or February; (2) the area surveyed in the census should be large enough to encompass the large home ranges seen in several waterfowl species (e.g. common cormorants, mallards and European wigeons); (3) routes for line transect and positions for point counts should be chosen carefully when observers count waterfowl on land; and (4) boat-based observations are recommended for waterfowl censuses.

Key words : census methods, dam lake, habitat preference, short and long temporal variations, waterfowl assemblage

Introduction

Rivers and waterfronts are intricately related to human life, and citizens are becoming increasingly concerned that the waterfront environment is

managed appropriately (Technology Research Center for Riverfront Development 1994). Since 1991 the Ministry of Construction of Japan (MOC), which is in charge of developing and maintaining water resources in Japan, has conducted a "National Census on River and Dam Lake Environments (NCRE)", with the objective of conserving and providing safe, aesth-

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etically pleasing and natural waterfronts. In these censuses, biological information of plants, insects, benthos, fish, amphibians, reptiles, birds, and mammals in and around rivers and dam lakes has been collected.

The sampling season and methods for counting waterfowl used in NCRE are based on a manual, "Manual for the national census on dam lake environments" (The Ministry of Construction of Japan 1994). According to this manual, for example, bird censuses for the NCRE should be conducted (1) at least in all four seasons in a year, (2) using line transect and point count methods, and using a boat, if necessary, and (3) in areas within 300–500 m of dam lakes.

The objective of the bird census is to show how many species and individuals of birds inhabit dam lakes. However, as many authors have pointed out (e. g. Okamoto & Ichida 1990, Bibby et al. 1993), it is not possible to precisely estimate bird populations if the census method does not incorporate detailed information of temporal and spatial variation in the bird counts. For example, temporary bird aggregations can result in the overestimation of population density in censuses which extend over several days. In practice, logistic difficulties mean that it is not uncommon to take several days to census a dam lake. Conversely, it is also possible to underestimate bird populations when the census area (within 300–500 m of the dam lake) is smaller than the home ranges of censused species.

Thus, the methods adopted in the NCRE are prone to over- or underestimate the number of wintering birds. The majority of birds observed at dam lakes in winter are waterfowl, most of which are migratory ducks whose home ranges are large. For woodland birds, census methodology is described in detail in Yui (1977). However, although knowledge of the temporal and spatial variation in waterfowl counts is a prerequisite to accurate population estimation, there has been no study reporting the variation in waterfowl populations at dam lakes. We here report the variation in number and habitat use of waterfowl over short and long temporal scales (daily and monthly changes, respectively) in winter at Takayama dam lake in central Japan. We also suggest some possible improvements in NCRE censusing methods.

Methods

The study was conducted between December 1998 and March 1999 at Takayama dam lake (Fig. 1) which extends into Nara and Mie prefectures in Kinki district, central Japan ($34^{\circ}45'N$, $136^{\circ}00'E$; altitude 168 m above sea level). Three observers (a main observer, a recorder and a pilot) made waterfowl counts from a small boat. The counts were conducted on December 9, 1998, and January 21–25, February 22 and March 17, 1999 (see Table 1 for details). The narrow width of the dam lake enabled us to cover the entire water area of the dam lake in a single survey.

Additionally, in the morning (7:50–12:25) of December 9, 1998, a census of waterfowl on the lake was conducted by an observer on the bank using line transect and point count methods. It took 125 min. to complete three line transects (about 4.5 km in total) and a total of 40 min. for four point counts. Routes and points adopted in this terrestrial observation (Fig. 1) were those used in 1994 by MOC in the NCRE. These routes and points were located about 20–40 m from the shoreline.

Fig. 1. A map of Takayama dam lake, of which the area is subdivided into 36 sections, numbered for reference.

Table 1. Details of surveys conducted in the study.

L→U: The survey started at the dam site and ended at the upper reach of the lake. U→L: The survey started at the upper reach and ended at the dam site.

Date	Start	End	Direction
9 Dec. 1998	8:00	9:30	L → U
21 Jan. 1999	15:30	17:50	L → U
	21:05	24:10	L → U
22 Jan. 1999	8:00	11:25	L → U
	13:40	15:40	U → L
23 Jan. 1999	8:40	11:40	L → U
	14:15	16:35	U → L
24 Jan. 1999	7:50	9:50	L → U
	13:35	16:30	U → L
25 Jan. 1999	8:15	11:15	L → U
22 Feb. 1999	8:20	10:45	U → L
17 Mar. 1999	8:45	11:00	U → L

In the surveys, the area of the dam lake was divided into 36 sections on survey maps (Fig. 1). During censusing, we identified the species and counted individual waterfowl, and plotted their locations on maps. Care was taken not to double-count individual birds.

Common and scientific names of waterfowl considered in the present paper are as follows: mandarin ducks=*Aix galericulata*, pintails=*Anas acuta*, green-winged teals=*A. crecca*, falcated ducks=*A. falcata*, European wigeons=*A. penelope*, mallards=*A. platyrhynchos*, spot-bill ducks=*A. poecilorhyncha*,

gadwalls=*A. strepera*, goosanders=*Mergus merganser*, common cormorants=*Phalacrocorax carbo*, and little grebes=*Tachybaptus ruficollis*.

Results

Variation in species composition of the waterfowl assemblage recorded over short and long temporal scales

During observations conducted for five consecutive days in January, a total of 10 species of waterfowl were recorded (Table 2). Six of the 10 species (mandarin ducks, mallards, green-winged teals, falcated ducks, gadwalls and common cormorants) were observed every day, but four species (European wigeons, pintails, spot-bill ducks and little grebes) were not always present (Table 2). European wigeons showed a large variation, from 0 to over 100 birds. In the six species which were always observed, coefficients of variation for common cormorants (0.898) and mandarin ducks (0.086) were significantly higher and lower, respectively (Miller-Feltz test (Zar 1996), including all six species: $\chi^2=27.6$, $df=5$, $p<0.001$; excluding mandarin ducks: $\chi^2=13.7$, $df=4$, $p<0.01$; excluding common cormorants: $\chi^2=11.0$, $df=4$, $p<0.05$; excluding both mandarin ducks and common cormorants: $\chi^2=2.5$, $df=3$, $0.25<p<0.5$). The coefficient of variation for the total count of ducks always observed was low (0.074).

The species composition of the duck assemblages

Table 2. A summary of daytime waterfowl counts done in January 1999.

Counts were done eight times over five days.

Species	Mean±s.d.	Range	c.v.*	Occurrence
(A) always observed (observed all 8 times)				
Mandarin ducks	129.4±11.1	112-148	0.086	8
Mallards	77.8±25.3	40-124	0.325	8
Green-winged teals	33.1±14.6	9-124	0.441	8
Falcated ducks	31.4± 7.0	21- 45	0.222	8
Gadwalls	15.9± 5.7	8- 25	0.357	8
Common cormorants	61.0±54.8	20-168	0.898	8
(B) sometimes observed (observed <6 times)				
European wigeons	14.3±35.5	0-102	2.491	5
Pintails	1.4± 2.2	0- 6	1.600	3
Spot-bill ducks	0.4± 1.1	0- 3	2.828	1
Little grebes	0.8± 0.7	0- 2	0.943	4

*c.v.: coefficient of variation (=s. d. /mean).

(percentages of mandarin ducks, mallards, green-winged teals, falcated ducks and gadwalls) did not differ between morning and afternoon on any given day ($G=8.3$, $df=4$, $0.05 < p < 0.1$ for January 22, $G=5.6$, $df=4$, $0.2 < p < 0.3$ for January 23 and $G=7.5$, $df=4$, $0.1 < p < 0.2$ for January 24). The ranges of variation in the percentage of each duck species for five consecutive days (January 21-25) were 42.5-53.6 % for mandarin ducks, 19.7-34.7 % for mallards, 3.4-15.4 % for green-winged teals, 3.8-7.9 % for falcated ducks and 5.6-9.9 % for gadwalls. The composition of the duck assemblage varied significantly during five consecutive days (January 21-25) ($G=9.2$, $df=16$, $p < 0.001$), although it did not vary significantly among three of these days (January 22, 23 and 25) ($G=7.7$, $df=8$, $0.4 < p < 0.5$). The proportion of mandarin ducks, falcated ducks and gadwalls in assemblages did not differ significantly during the five consecutive days ($G=9.2$, $df=8$, $0.3 < p < 0.4$). These results suggest that the variation in species composition within the duck assemblage among five consecutive days was probably due to the variation of counts of mallards and green-winged teals, although coefficients of variation for these two ducks were not large.

No waterfowl, except a single pintail, were observed at night on 21 January. Mallards, mandarin ducks and other ducks flew away from the dam lake around 17:00 and returned to the lake around 6:30 the following day. We were unable to assess the location of these ducks at night, but they probably did not stay within 300-500 m of the dam lake.

The three most abundant species recorded through the study period were mandarin ducks, mallards and green-winged teals, and the percentage contribution of these ducks to the total counts in different months were 30.6-40.2 %, 22.4-32.2 % and 11.5-19.4 %, respectively (Fig. 2). The highest census value of waterfowl was that recorded in December (525 birds), and the lowest that in March (134 birds). Numbers recorded in January (331.25 ± 43.4 birds: mean $\pm$ s.d. for four observations in the morning) and February (343 birds) were very similar. There was no difference in the percentages of the three most abundant species in the total count between January and February ($G=3.9$, $df=2$, $0.1 < p < 0.2$), whereas significant differences in this variable were evident among four months ($G=$

Fig. 2. Monthly changes in waterfowl numbers. Values on the bars represent the percentage of each species to the total counts in each month.

15.9, $df=6$, $p=0.01$). The number of waterfowl species observed remained relatively constant throughout the study period (range: 7-10 species).

The variation in distribution of ducks recorded over short and long temporal scales

General features of the variation in habitat use by five duck species (mandarin ducks, mallards, green-winged teals, falcated ducks and gadwalls) between the afternoon of 22 January and the morning of 25 January 1999 were as follows: (1) the locations of ducks observed at the dam lake varied little throughout the study period, (2) although mallards and mandarin ducks were observed mainly in the middle and lower reaches of the lake, they rarely formed mixed species flocks, (3) green-winged teals were observed mainly in the upper reaches of the lake, and (4) gadwalls were observed only near the dam site,

whereas falcated ducks were observed near the dam site and middle reaches of the lake (Fig. 3). These features were found through the study period between December and March (Fig. 4). However, mallards and mandarin ducks were observed in the upper reaches in the same section in December.

Comparison of observation methods

A total count of 201 waterfowl was obtained using line transect and point count methods along the dam lake, whereas observations from a boat recorded 525 birds (Fig. 5). The terrestrial observer counted 70.4 % of the mallards and 80 % of the common cormorants recorded from a boat. However, the terrestrial observer counted only 10.2 % of the mandarin ducks and 27.3 % of the green-winged teals observed from the boat, and recorded none of the 33 European wigeons noted by boat observers.

These discrepancies are partly due to the fact that about 25 % of the dam lake was not visible to the terrestrial observer, and that there were certain number of ducks in these areas (Fig. 6). However, even when the areas that were not visible to the terrestrial observer are excluded, the terrestrial observer still counted only 17.7 % of the mandarin ducks and 30.6 % of the green-winged teals recorded from the boat.

Discussion

In winter, little variation was found in the total number and species composition of waterfowl at the dam lake between January and February. Although the waterfowl number in December was much greater than in January and February, the percentages of the most abundant species did not vary widely among these three months. These findings suggest that the results from the December census may represent actual waterfowl composition, but do not always represent accurately the population of winter waterfowl at the dam lake. The NCRE manual does not specify dates on which the census should be conducted, and censuses in practice are conducted between December and February. We suggest that waterfowl censuses in winter should be conducted in January or February, or during months in which the number of waterfowl, most of which are migratory ducks, is rather stable, unless the water surface is frozen. It should be noted that since 1982 the nationwide water-

fowl count by the Wild Bird Society of Japan has been conducted on 15 January.

No significant variation in the composition of duck species was found between morning and afternoon on any given day but this value did vary among five consecutive days. However, this does not mean that the species composition varied daily. In fact, it was rather stable, and among three of the five days there was no significant variation. The range of variation in waterfowl number over short temporal scales may depend on the species. For example, the number of European wigeons varied between 0 and 100 birds, and the coefficient of variation for common cormorants was also large. The variation in counts of mallards and green-winged teals caused moderate but significant variation in duck composition in assemblages among five consecutive days, although the coefficients of variation of these ducks were not so large. Species which showed significant variation in the count had large home ranges, and this means that home ranges of some species do not always correspond with the area surveyed, resulting in an underestimation. Census design under situations where the variation of birds counts is large has been considered by Okamoto & Ichida (1990). These authors recommend that when the surveyed areas do not cover the entire home ranges of birds and the variation of birds counts is large, the estimated number of a given species should comprise the largest number among those recorded for that taxon. If this is applied to the present study, the general tendency of the results does not change, except for European wigeons, which become the fifth most abundant species despite being recorded on only one occasion during eight surveys made over five consecutive days in January (Table 2). To avoid such bias, census areas should be larger and include the lower and upper reaches of the dam lake.

The locations at which ducks were observed at the dam lake were almost the same throughout the study period. Different locations on the dam lake were species-specific. It is of ecological interest to determine why certain duck species prefer specific locations within the dam lake, but unfortunately, we presently have insufficient information to investigate this question. From a viewpoint of census methodology, which is the scope of the present paper, this

Fig. 3. Distribution of ducks in January. Section numbers are shown in Fig. 1. Left : mallards and mandarin ducks. Right : Green-winged teals, falcated ducks and gadwalls.

Fig. 4. Distribution of ducks between December and March. For the result in January, mean values and standard deviations are shown. Section numbers are shown in Fig. 1.

stable segregation suggests that it would be possible to accurately estimate the number of ducks at a dam lake without double counting, even if the entire survey takes a few days to complete. The above findings also

suggest that if lines and points for survey are chosen adequately, it is not necessary to survey all dam lake areas to accurately estimate duck numbers. The line transect and point count methods used in NCRE are

Fig. 5. Observation methods and counts of waterfowl obtained by each method. Boat : counts on a small boat on the lake. Walk : counts by line transect and point count methods. Both methods were conducted on the morning of December 9, 1998.

appropriate if the locations of the lines and points are chosen adequately. Therefore, if boats are not available for surveys, lines and points should be chosen carefully (Bibby et al. 1993).

The importance of careful choice of lines and points for land-based censusing of waterfowl is demonstrated in this study by the low number (< 40 %) of birds counted by the terrestrial observer in relation to those counted from a boat on the lake. One reason for this difference between observation methods is that the terrestrial observer was unable to see about 25 % of the lake surface, which contained habitats used by mallards and mandarin ducks, whereas observers on the boat succeeded in sampling the whole area of the lake. In the visible area of the lake the terrestrial observer counted 95.2 % of the mallards counted from the boat, and hence if lines and points are chosen carefully, a terrestrial observer could probably count as many mallards as are recorded from a boat.

Fig. 6. Distribution of ducks in December based on two observation methods, boat and walk (see caption of Fig. 5). Section numbers are shown in Fig. 1. Shadow areas (sections 11-17 and 24-25) are areas not visible to an observer on land.

However, even in the visible areas the terrestrial observer counted only 17.7 % of the mandarin ducks and 30.6 % of the green-winged teals recorded from the boat. This indicates that terrestrial observation methods themselves are not suitable for counting some waterfowl species, such as mandarin ducks and green-winged teals. As these are among the numerically dominant duck species at dam lakes in winter, waterfowl counts using a boat should be a standard method to maximize accuracy in dam lake censuses in winter. It should be noted that dam lakes are usually narrow and it is not difficult to survey the entire lake by boat to census waterfowl. Boat-based surveys did not disturb waterfowl distribution significantly, because the composition and distribution of duck species in assemblages did not differ between morning and afternoon surveys on any given day. This fact also indicates that morning and afternoon are equally

suitable times to count ducks in winter (see Yui 1978 for woodland birds).

The underestimation of numbers of mandarin ducks and green-winged teals by a terrestrial observer in the present study is probably due to the fact that these ducks were distributed along and on the bank rather than on the water surface. Boat-based surveys are useful in such cases because birds are easily counted when disturbed by the boat and fly away. In contrast, terrestrial observation was not useful for those species, although it would be useful for counting species such as mallards which distribute on the water surface. This is because the line transect and point count methods are based on the assumption that all birds in the survey area are detectable (Bibby et al. 1993, Yui 1997). It should be noted that terrestrial observation methods are obviously useful for counting birds other than waterfowl.

Another reason for the lower accuracy of terrestrial observation in the present study is the difference in the number of observers. There were three possible observers on the boat, but only one person doing terrestrial sampling. This could have biased our results. However, in practice, boat-based observations were made by only one person at a given time, and the lower accuracy of terrestrial observations cannot be attributed to the smaller number of observers there.

Concurrent, boat-based surveys may affect terrestrial observations by dispersing waterfowl at the lake. However, we noted that waterfowl dispersed by the boat soon returned to the location where they had been before being disturbed. This is confirmed by the fact that the distributions of duck species did not differ between surveys in the morning and afternoon on any one day, and between survey directions (Fig. 3). Thus, considering the longer survey time taken by the terrestrial observer, boating had minimum influence on the accuracy of terrestrial observations in the present study.

The objective of NCRE is to count not only waterfowl species, but also all taxa including terrestrial birds. In this sense, the terrestrial survey methods currently used by NCRE are not entirely useless. For example, the terrestrial observer in the present study observed a peregrine falcon *Falco peregrinus*, which

was not recorded on the boat, and in visible areas counted more common cormorants than did observers on the boat. Thus, if the entire area of a dam lake, including the banks where some species of ducks prefer to stay, is visible, terrestrial observation is an adequate survey method. In conclusion, we suggest the following to improve methods used in NCRE: (1) winter censuses in central Japan should be conducted in January or February; (2) the area surveyed in a census should be increased, because the ranges used by some waterfowl are larger than might be expected; (3) when observers on land count waterfowl at dam lakes, routes for line transect and positions for point counts should be chosen carefully; and (4) boat-based observations are the recommended method of counting waterfowl.

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摘要

ダム湖に生息する鳥類の調査は、建設省による「河川・水辺の国勢調査」によって1991年度から実施されている。この国勢調査の目的はダム湖に生息する鳥類の種数と個体数をできるだけ正確に把握することにあるが、そのためには対象となる種の個体数変動を時間的にも空間的にも把握しておく必要がある。本論文では高山ダム(34°45'N, 136°00'E, 標高168 m)を例にとり、このダム湖での冬季の水鳥群集について、短期間(1月中の連続した数日)と長期間(12-3月)の個体数変動と利用場所の変動を、水上からの小型ボートを用いた観察で明らかにし、陸上からのラインセンサスを主とする国勢調査の方法の改善点を検討した。

水上観察の結果から以下のことがわかった。(1)水鳥の個体数は12月が最大(525羽)で以後は減少し、3月に最少(134羽)になるが、1月(331羽)と2月(343羽)の個体数はほぼ同じで、その種構成も変わらなかった。(2)短期的なスケールでみた水鳥群集の構成は、一日の

午前と午後では変わることはないが、連続5日間では変化した。しかしこの変化は大きいものではなかった。また、種によって個体数変動の程度が違っており、ヒドリガモやカワウでは大きく、オシドリでは小さかった。(3) 水鳥が利用する場所は長期的にも短期的にもほぼ安定しており、その場所は種によって異なっていた。(4) 陸上からのラインセンサスは、オシドリとコガモのカウントには適していなかった。

これらのことから、水禽類における精度の高い個体数推定を行なうためには国勢調査の方法を以下の点で改善することが望ましいと考えられた。(1) 冬季については調査時期を1-2月に設定する。(2) 種毎の個体数変動と行動圏配置を考慮し、調査範囲をダム湖の上・下流に広げる。(3) 陸上から湖面の水鳥をカウントする際には、調査の定線と定点を慎重に設定する。(4) ボートによる調査をつねに併用する。

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