Chapter 35

Productivity of Marbled Murrelets in California from Observations of Young at Sea

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Abstract: We designed and tested an intensive survey method in 1993 to identify juvenile Marbled Murrelets (*Brachyramphus marmoratus*) at sea. From this, we used the percent of juveniles seen in the sample as an index of productivity of murrelets along the California coast. We found 2.2 percent of the population sampled were juveniles, similar to our estimates in 1989—1992 of 3 percent from less stringent survey methods in this area. Percent of juveniles in the 1993 sample ranged from almost 6 percent in late June to none in mid-August and September. Juveniles were as often alone as in a group with 1 or 2 adults, and showed a similar distribution in distance from shore as adults. We found that some adults were molting into basic plumage as early as 21 June, with three-fourths in molt by mid-August. Therefore, during September, most birds were unidentifiable to age since most appeared to be in basic plumage unless they flapped their wings to expose molting primaries or markings on the lower breast or belly.

One of the vital components of making a demographic model of any species is a measure of that species' productivity. In the case of the Marbled Murrelet (*Brachyramphus marmoratus*), virtually all measures that would go into a demographic model (Beissinger, this volume) are conjecture, based upon studies of other species. Many of these species have only fleeting similarities to the life history of the Marbled Murrelet. The percent of young birds found at sea in the summer is one of many potential estimators of productivity, and is the one part of the demographic life history that could be based on actual numbers. Since murrelets are often difficult to observe closely, this quantity has previously only been estimated. We describe our efforts to put this vital parameter on a firm, quantitative foundation.

We have conducted offshore population surveys during 1989-1992 in California. During these surveys, we determined the proportion of murrelets in juvenal plumage as they occurred in late July and early August. However, the proportion of birds in juvenal plumage was exceedingly small, usually less than 3 percent. During these offshore surveys (Ralph and Miller, this volume), we made a concerted attempt to determine the age of all birds not in obvious breeding plumage.

Other investigators have found similar low proportions in recent years. During the 1992 offshore Oregon surveys, Strong and others (1993) found the proportion of juveniles to be 2.7 percent. At three points on the Oregon coast over a four year span (1988-91), Nelson and Hardin (*in* Beissinger, this volume) found that juveniles made up 2, 4, 2, and 5 percent of the population, respectively. If these estimates of reproduction are accurate, this low rate of recruitment indicates one of three possibilities: a markedly declining population, one whose low reproduction must be offset by years of much higher production; or the species has to be extremely long-lived.

These low figures prompted a reevaluation of our methods for the 1993 breeding season. We felt that it was possible that our measure of productivity might be misidentifying some juveniles. Therefore, we designed an intensive survey method to identify juvenile birds at sea and report here on the surveys used to test the new method and to assess its accuracy.

Molt Sequence

The molt sequence has been investigated by Carter and Stein (this volume), and the information below is largely taken from their paper. The breeding plumage is dark overall, with the entire breast, belly, and sides covered with blotches of dark color, each blotch taking up about half of each feather. During the fall pre-basic molt, the back color changes from the rich brownish black to a duller grey black, but this is difficult to see in the field. Mated pairs may often stay together and molt fairly synchronously. In adults, the timing of the change into winter plumage is poorly documented. It seems generally to be underway by late July, and probably takes 6 to 8 weeks. Failed or non-breeders may molt much earlier. The pre-basic molt begins in the throat area, as the dark feathers are replaced by white, then spreads to the breast, belly, sides, and lower belly. At approximately mid-molt, the first six primaries are lost almost simultaneously. This leaves the bird flightless, with a conspicuous gap in the wings, and thus distinguishable from young when the birds flap their wings. The remaining primaries are lost shortly thereafter. As the bird molts to winter plumage, the dark blotches gradually become fewer in number, but generally remain as identifiable blotches until the breast and belly become white.

Fledglings are seen on the water as early as the second week in June, but the majority will not appear until July. Fledging of young from North American nests begins in early June, reaching a plateau from early July through late August (Hamer and Nelson, this volume a). When first fledged, they resemble winter adults, dark above, and light below. However, in contrast to the clean, white breast and belly of the winter-plumaged adult, the neck and breast of the young will have a highly variable pattern of fine markings or tiny dots on the outer edge of some of the feathers. This

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forms a vermiculation pattern, in contrast to the larger blotches of the adult. As the season progresses, the markings on the edges of the feathers are lost, apparently by wear or molt. Another character for identifying young is the egg tooth, which sometimes can be seen into the fall. While this is rarely seen in the field (Carter and Stein, this volume), it has been seen from shore (Strachan, pers. comm.). Finally, fledglings can often be separated from adults by size. When first on the water, young are about 70 percent the size of an adult.

Methods

Survey Method

We conducted productivity surveys in various areas of California during 1993, near Crescent City, Trinidad, Eureka, and Santa Cruz, both at sea and from shore. Surveys began 21 June and continued until 1 October. This was the period when young were leaving the nest, continuing until large numbers of adult birds were molting into winter plumage.

Surveys at sea followed the general survey methods contained in Ralph and others (1990) for offshore surveys. We conducted both intensive and extensive surveys (Ralph and others 1992; Ralph and Miller, this volume), with additional surveys conducted at 200-m intervals from the coastline out to 2000 m. The boat moved as close as possible to each bird seen, giving the observer an opportunity to record data on the plumage and behavior. The time for each observation varied, depending on the ability of the observer to get an adequate view of the bird to assess the plumage, or until the bird left the area. Consideration was also given to minimizing the disturbance to the birds. For example, if a bird was observed to continually dive, apparently to avoid the boat, the observation was terminated. We often found that many of the birds were easily flushed by the boats, making it difficult to get close enough to see identifying criteria such as fine plumage markings and egg tooth of the juveniles. The driver aided in observations when possible.

Several surveys were conducted from shore using a 40-power spotting scope in a few areas where murrelets occur close to shore, mostly in the Santa Cruz area. Observers scanned the ocean from sites located within 50 m of the water's edge and recorded the plumage of each murrelet seen. Data were recorded on all birds seen within 400 m of the observers.

Data Taken

The location of the bird was recorded, including the depth of the water and the distance to shore.

The information recorded for each bird enabled determination of age by both an assessment of the quality of the observation and then by close examination of the plumage information. The quality of the observation was a subjective evaluation of the ability of the observer to see the plumage of the bird, based on the light level and direction, closest distance to the bird, and what feather tracts were seen. We also recorded the length of time over which what we termed the "best view" of the bird was obtained. For example, a bird might be in view for several minutes, but the best view might only be the 20 seconds when the observer could see the breast area of the bird while it was facing into the light. The quality of the observation could well be marginal, despite a long view. Specific information used to determine the observation quality was:

(1) Total time of best viewing.—Time for the best view as determined by the information below.
(2) Light on the bird.—Determination if light from the sky was on the front, back, or side of the bird, from the observer's view.
(3) Light level on the bird.—We estimated three categories of light, relatively high, medium, or low levels. A high level would be a sunny day, while a medium level would be high overcast or bright fog. Low levels would include a dense, low overcast, very dense fog, or just at dawn or dusk.
(4) View of bird, as to either the front, side, and/or back.
(5) Distance to bird at the best view.

A description of the bird and its plumage was recorded for the entire observation, and was not limited to information gained from the time of best view. The description of the bird included:

(1) Bill details.—Bill color, and presence or absence of an egg tooth.
(2) Size of bird.—As compared to others in the group.
(3) Type of plumage.—The feather tracts of principal concern were the breast, belly, and sides. We recorded the percent area of dark color, seen as dark blotches or fine markings, versus the area that was white. The total for a feather tract would always be 100 percent. If birds stretched their wings, we noted any missing flight feathers.

Behavior was also recorded to evaluate the possibility of juvenile behavior, with an indication of numbers of birds involved in a group. Behaviors recorded were position of birds in a group, begging, feeding of another bird, and vocalizations. Other information, such as condition of primaries, was included as notes.

Evaluation of Productivity Data

We separated observations into five categories to designate the age of the birds as: definite adult, probable adult, unknown, probable juvenile, and definite juvenile. In determining the category, we subjectively considered the quality of the observation from data given by the observer during the best view of the bird, as described above, to determine if the bird should be rated as a definite, probable, or unknown plumage. For example, the bird was assigned to the category of 'probable' if the observation was of poor quality due to low light levels, distance, or view. The combination of length of best view and light levels was a critical factor. We felt that at least 15 seconds were required for a good quality observation under good light conditions, longer if the lighting was poor (e.g., low levels or back-lighting). Distance to the bird was also a

major factor, with under 40 meters considered good under most conditions. Distances as far as 50 m, with a longer viewing time and high light levels, were also considered good observations. Beyond 50 m, observations were usually of poorer quality and were usually qualified as probable or unknown. Observations from shore with a telescope were used if the bird was less than 400 m from the observer and other criteria above were met.

Plumage was the primary criterion used for determining the age category, since no egg teeth were seen. Any bird in breeding plumage or in the process of molting out of breeding plumage was a definite adult. Black-and-white birds with missing flight feathers were also categorized as adult. Black-and-white birds with no information on flight feathers were categorized in part by the date of observation, as during the molt period it was difficult to distinguish adults in winter plumage from juveniles. In this regard, Carter found all birds to be in alternate plumage from early May to late July (Carter and Stein, this volume). However, by late July, some adults might begin to molt if they were failed breeders, and take possibly as little as 6 weeks to complete enough of the molt to appear black and white. Therefore, we considered any black-and-white birds seen before 15 August as juveniles. After that date, birds were not considered juveniles unless other criteria were noted. Other potential criteria for identifying juveniles were the presence of the fine breast markings, relative size, and behavior. Black-and-white birds accompanied by an adult and less than 90 percent of the size of the adult were also categorized as juveniles. There were no observations of what we would have considered juvenile behaviors, such as begging from an adult. After 15 August, all winter-plumaged birds were categorized as unknown in the absence of other identifying criteria.

Results

We attempted to determine the age of 1,174 murrelets (*table 1*). We successfully aged by the above criteria 1,084 birds and had only 103 birds of unknown age. Only 23 birds (2.2 percent overall) were juveniles, when the probable and definite categories were combined. If we excluded the probable observations, then the estimate of juveniles was much smaller at only 0.6 percent.

We found that juveniles occurred equally as often alone (n = 12) as in groups with 1 or 2 other murrelets of either adult or unknown plumages (n = 11) (*table 2*). We did not find juveniles in groups with other known juveniles.

We analyzed the distribution of adults versus juveniles relative to the distance from shore, based on boat surveys alone to eliminate the bias from on-shore surveys. We found no significant difference (χ^2, $P > 0.05$) in distribution out to 1600 m (*table 3*).

The percentage of juveniles by area was: Crescent City 0.6 percent (n = 2 juveniles), Trinidad 4.0 percent (n = 12), Eureka 1.1 percent (n = 3), and Santa Cruz 3.4 percent (n = 6). With so few birds in juvenal plumage, we did not consider the differences between areas to be biologically significant.

We divided the 1993 study period into 10-day periods (*table 1*). In June and early July, nearly 6 percent of the known-aged birds observed were juveniles. This percent varied through early September with 2.9 percent juveniles recorded. No juveniles were identified after mid-September. If only the data before 9 September were included (which excluded the time when juveniles were difficult to identify), the overall proportion of juveniles did not change.

The first juvenile was seen on the second survey of the study on 26 June in Crescent City. The first juveniles for

Table 1—Classification of plumages of Marbled Murrelets seen off the California coast by 10–day periods in 1993. All birds with identifiable plumages are categorized as definite or probable adult, definite or probable juvenile, or unknown age bird in basic plumage. Percentage of adults and juveniles are calculated based on the total number of known ages, while percentage of unknown ages is calculated as a percentage of all birds with identified plumages

	Adult				Juvenile				Known age	Unknown age		Total
Period	Definite	Probable	Total	Percent	Definite	Probable	Total	Percent	total	Total	Percent	
6/21–7/30	14	2	16	94.1	0	1	1	5.9	17	0	0	17
7/1–7/10	60	24	84	94.4	1	4	5	5.6	89	0	0	89
7/11–7/20	157	16	173	98.3	2	1	3	1.6	176	0	0	176
7/21–7/30	186	35	221	98.3	1	3	4	1.7	225	0	0	225
7/31–8/9	44	7	51	96.2	0	2	2	3.8	53	0	0	53
8/10–8/19	150	6	156	100.0	0	0	0	0	156	2	1.3	158
8/20–8/29	55	11	66	98.5	1	0	1	1.5	67	3	4.3	70
8/30–9/8	221	14	235	97.5	1	6	7	2.5	241	28	10.4	269
9/9–9/18	42	13	55	100.0	0	0	0	0	55	19	25.7	74
9/19–9/28	2	0	2	100.0	0	0	0	0	2	21	91.3	23
9/29–10/8	0	2	2	100.0	0	0	0	0	2	17	89.5	19
Total	931	130	1,061	7.8	6	17	23	2.2	1,084	90	7.7	1,174

Table 2—Grouping of juveniles and adults off the coast of California in four areas. Both defininte and probable categories of age are included. Groups are broken down by number of birds in group of each age, and number of each group type[1]. For groups containing more than three birds, the range of group size is also shown

	Number of birds in group																
	1			2						3							>3
Juvenile	1	—	—	1	1	2	—	—	—	1	1	1	—	—	—	—	—
Adult	—	1	—	1	—	—	1	2	—	2	1	—	1	2	3	—	≥1
Unknown	—	—	1	—	1	—	1	—	2	—	1	2	2	1	—	3	≥1
Area	Number of groups																
Crescent City	1	48	3	0	0	0	10	123	6	1	0	0	0	0	4	2	6; range 4–8
Trinidad	5	36	5	3	2	0	14	80	3	1	1	0	1	2	4	3	7; range 4–7
Eureka	1	40	0	2	0	0	18	76	10	0	0	0	0	2	4	1	8; range 4–8
Santa Cruz	5	33	1	0	0	0	19	41	0	1	0	0	0	1	6	0	9; range 4–12
Totals	12	157	9	5	2	0	61	320	19	3	1	0	1	5	18	7	30; range 4–12
Total number of groups:																	
With juveniles			12						7							4	0
Without juveniles			166						400							29	30
Grand totals			178						407							35	30

[1] For example, in Trinidad there were 14 groups of 2 birds, consisting of 1 adult and 1 unknown age individual, 80 groups of 2 birds consisting of 2 adults, etc.

Table 3—Distribution of adult and juvenile Marbled Murrelets according to distance from shore off the coast of California, from boat surveys only

Distance from shore (m)	Adults		Juveniles		Total Number
	Number	Percent[1]	Number	Percent[2]	
0– 200	52	5.7	3	15.0	55
201– 400	161	17.7	4	20.0	165
401– 600	103	11.3	2	10.0	105
601– 800	339	37.2	5	25.0	344
801–1000	102	11.2	3	15.0	105
1001–1200	32	3.5	1	5.0	33
1201–1400	105	11.5	2	10.0	107
1401–1600	17	1.9	0	0.0	17
Total	911		20		931

[1]Percent of total adults
[2]Percent of total juveniles

other areas were: Trinidad 18 July; Eureka 17 July; and Santa Cruz 8 July. The last two juveniles that were identifiable to age were observed on 8 September near Trinidad.

The percent of the adult population in molt, including both definite and probable categories, was fairly constant from late June until mid-August (*fig. 1*). A bird was considered to be in molt if there was a patch of basic plumage on its breast, side, or belly. Even at the beginning of the study period in late June, 25 percent of the 16 birds observed were molting, though in the larger sample (n = 84) for the next period had only 10 percent molting. However, from 11 July onward, we found no appreciable change in the proportion of molting birds until 20-29 August, when a sharp increase to 75 percent was recorded. By 9 September, 95 percent of the birds were molting.

There was also a marked increase of birds with the appearance of basic plumage (while sitting on the water), including both juveniles and molting adults, during the 9-18 September period (*fig. 2*). Along with the birds of unknown age in basic plumage, we included those molting adults in

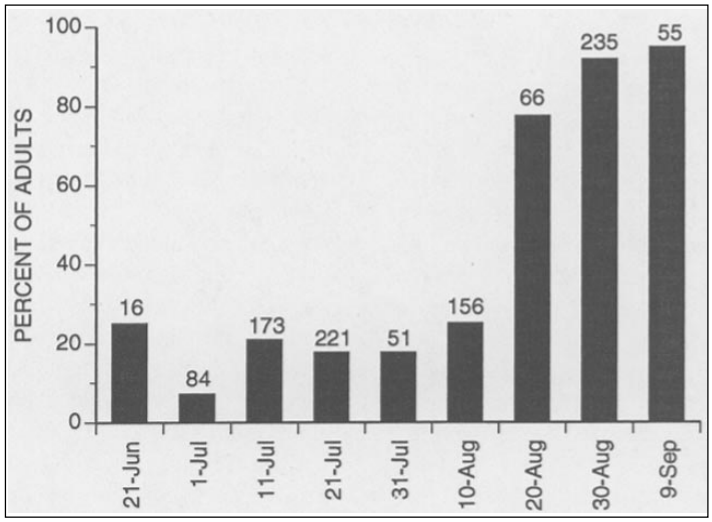

Figure 1—Percent of known adults in molt by 10-day periods. Date indicates the first day of each period. Total number of birds identified as adults (definite and probable) for each period is indicated on the top of each bar.

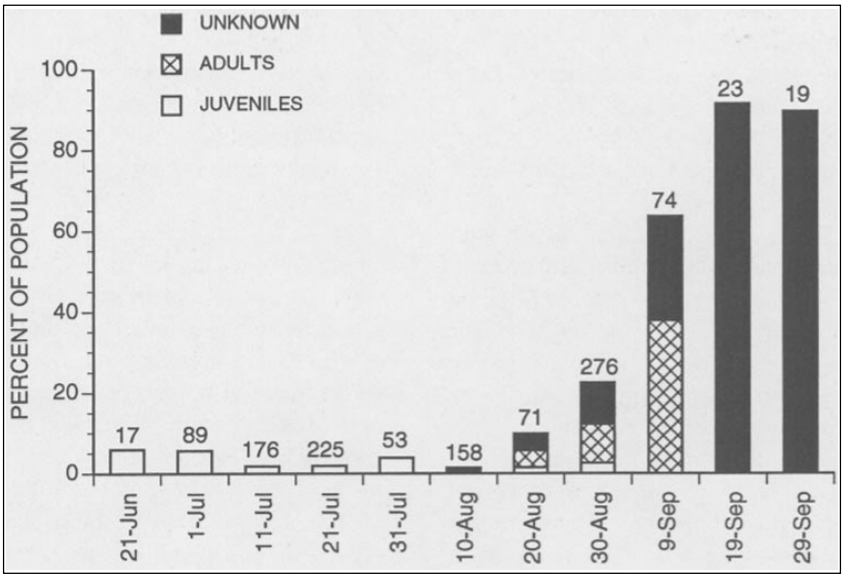

Figure 2—Percent of the total population with black-and-white plumage (both adults and juveniles) by 10-day periods. Remaining birds are adults in alternate (breeding) plumage. Columns show percent of black-and-white birds which were juveniles, adults, and of unknown age. Definite and probable categories for juveniles and adults were combined. Date indicates the first day of each period. Total number of murrelets observed for each period is indicated on the top of each bar.

basic-like plumage that we aged by missing primaries or molting areas on the belly, neither of which would be seen unless the bird flapped its wings. A substantial number of adults were classified as birds of unknown age during this period. Obviously, most of these were actually adults. By 19 September, 90 percent of the population was in basic or near-basic plumage.

Discussion

Our results, using more rigorous methods than previously employed, confirmed productivity estimates from California over the previous five years of under 3 percent. Such a low productivity may indicate a population with a very low reproductive rate. However, we may also be missing some of the juveniles in our surveys if they are distributed differently on the ocean than the adults. In our experience, single birds are usually more difficult to detect from boats. Varoujean (pers. comm.) found during aerial surveys that many juveniles were alone. In British Columbia, Sealy (1974) found about 64 percent of juveniles were seen alone, 20 percent were seen with adults, 14 percent were with another juvenile, and 4 percent were in a group of three or more juveniles. We also found as many juveniles alone as in groups, similar to that found by Sealy, though none were with other known juveniles as in his study. Therefore, we may have missed single juveniles.

There may also be a difference in habitat use by each age group. There is evidence that murrelets as well as other seabirds tend to be distributed in clumps at sea (Harrison 1982, Sealy 1973b). Strong and others (1993) found adult murrelets tended to switch foraging areas between July and August, perhaps in response to prey resources. They also found a patchy distribution of juveniles, with concentrations in three areas on the Oregon coast, which may have been similar to the distribution of adults.

Another aspect of habitat selection is distance from shore. Sealy (1975a) and McAllister (pers. comm.) both found juveniles congregated in nearshore kelp beds in British Columbia and Alaska, while more adults were offshore. Kaiser and others (1991) in Malaspina Inlet and Desolation Sound, British Columbia also found a similar distribution between the young and adults in early August. If there is a difference in distribution between ages in respect to distance from shore, then the use of telescopes from land for determining age ratios may skew the data towards more juveniles. In our study, we did find 35 percent of the juveniles seen from boats were within 400 m of the coast where they would be easily seen from shore (*table 3*). However, we found no difference in the distribution of juveniles versus adults relative to distance from shore, so this would not likely skew the results, at least in our data. More research on the behavioral differences of adults versus juveniles will be an integral part of estimating murrelet productivity.

The highest percentages of juveniles were found in the earliest periods of the study in June and July (6 percent). This estimate may be the most accurate, as compared to late August, since juveniles were difficult to identify when some adults were well into the molt (Carter and Stein, this volume). By early August, about 75 percent of the birds have probably fledged (Hamer and Nelson, this volume a). Unless the primaries were seen, many black-and-white birds were classified as unknown. Thus, the decline in the percent of juveniles in late August may reflect this. The slight increase in juveniles in early September may be a result of the small sample, or indicate a second breeding attempt, as suggested by Hamer and Nelson (this volume a).

We found that some adults on the California coast started molt at least as early as 21 June (*fig. 1*), and by mid-August, three-fourths of the adults were in molt. This is earlier than previously reported (e.g., 20 July in British Columbia [Sealy 1975a]). If it takes about 2-3 months for the entire molt to be completed (see Carter and Stein, this volume), these birds might have been in basic plumage by late August. Indeed, about 10 percent of the sample of adults had a substantial basic plumage in the 20-29 August period (*fig. 2*). The remainder of the adults still retained much of their breeding plumage and were distinguishable from juveniles. Therefore, it appears that August 15 is a conservative date for considering a black-and-white plumaged bird as a juvenile. We are thus relatively confident that our identification prior to this date is accurate. This date will lead to some underestimate of juveniles, since approximately 15 percent of the juveniles have not fledged until after mid-August (Hamer and Nelson, this volume a). By late August, this has decreased to less than 5 percent.

These estimates of production, however, do not take into account the numbers of non-breeders in the population. Since there are no good estimates of proportions of non-breeders for this bird, we must look to other species. Other small alcids do not breed until about 3 years of age. Examples are Ancient Murrelets (*Synthliboramphus antiquus*), and Crested (*Aethia cristatella*), Least (*Aethia pusilla*), and Cassin's (*Ptychoramphus aleuticus*) auklets (De Santo and Nelson, this volume; Gaston 1992) which live about 5-10 years. Thus, if we assume that they breed at 3 years, and the average life span is 7.5 years, then 2 years out of an average of 6.5 years (or 2/6.5 = 30.7 percent) of an adult's life are spent as a non-breeder. So, almost one-third of the 1,061 adults in our sample, or 326 birds, may not be breeding, leaving only 735 breeders sampled. Also, we may assume that early in the season when the first fledglings are coming off the nest, a breeding pair that is still feeding young may sometimes not be on the water at the same time, therefore only one of a breeding pair is counted. If we make a conservative estimate that a fourth of the birds seen on the water represent one member of a nesting pair, we would add another 185 birds for a total of 920 potential adult breeding adults, or 460 pairs, of the 1,061 adults. Consequently, a revised estimate of production would be 26 chicks/460 pairs or 5.0 percent, which is still quite low.

There is a difference in the method of evaluation of plumages between our field study and Carter and Stein's (this volume) analysis of study skins. In their method, they

used a grid placed over the skin to derive an average ratio of dark:light overall coloration. In adults, for example, this resulted in an overall ratio of 90:10 dark:light. We feel that it is more informative to break the data down by areas of the body, since different feather tracts molt at different rates (Carter and Stein, this volume).

Characterization of plumage is a very valuable tool for the murrelet biologist, and, given the limitations we discuss, a fairly accurate measure of productivity. Since it is also the *only* measure we have at present of productivity, we would suggest that investigators take ample data to enable them to evaluate, as we did, the quality of their observations.

Also, we would suggest that some additional data be taken, such as percentage of molt on the back of the neck (the only area of early molt possible to see if the bird is swimming away), the wing shape as pointed versus rounded or "stubby" (see Carter and Stein, this volume), and black versus rusty color on the back.

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PART

V

Trends and Status of Population