individual because he is finding out new ideas, because he is departing from an old pattern of action, and because he is contributing facts and ideas of great interest to many other people. The men we visited in Europe are working on these aspects of birds and animals because they are interested in them. If they are so much interested in this sort of study, it is only reasonable that many Americans would find these areas equally interesting.

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THE USE OF MIST NETS IN POPULATION STUDIES OF WINTER FRINGILLIDS ON THE AEC SAVANNAH RIVER AREA[1]

BY EUGENE P. ODUM AND GORDON L. HIGHT

In this paper data are presented illustrating the key role that Japanese mist nets may play in intensive studies of the population ecology of birds. In this case the net technic was used not because it was novel, or catches birds, but because it efficiently sampled a specific ecological group under investigation on study areas selected with an overall purpose in mind. We feel that in their enthusiasm for a new method banders may be tempted to overuse, if not misuse nets. Certainly, very little of real value can result from the wholesale capture and banding of miscellaneous small birds when the chance of returns is small. Furthermore, the overuse of nets in a specific area can certainly disrupt the very population structure which the bander wishes to study.

Since the establishment of the AEC Savannah River Plant in 1951 and the consequent retirement of a large acreage of land from cultivation a student-faculty team of the University of Georgia has been engaged in studies of ecological changes oriented towards functional analysis of total systems in nature and the effects which radioactive waste disposal may have on such systems. Because of the unusual opportunities provided, the "old-field" ecosystem has been a point of emphasis. Seasonal changes in the major plant and animal populations, as well as net primary and secondary productivity, are being studied over a period of years. On the southeastern Coastal Plain, as on the Piedmont, birds are relatively unimportant components of the early stages of vegetative succession during the summer but become quite abundant and important as "harvesters" of the seed crops in winter (Johnston and Odum, 1956). Fringillids, many migrating from more northern summer ranges, make up a large part of the winter population of

[1]This work supported by a grant from the U. S. Atomic Energy Commission (Contract No. AT (07-2)- 10 with the University of Georgia)

pioneer communities which develop on abandoned fields. Consequently, we wanted to know as much as possible about this component.

From the ecological viewpoint the winter fringillids of old fields may be divided into two groups: (1) "herb sparrows," or those species which do not require woody vegetation but may find all their food and habitat requirements in herbaceous vegetation (forbs and grasses); (2) "bush sparrows," or those species which require woody vegetation, or at least a rank growth of tall weeds, as part of their winter habitat. The former species may use bushes, hedgerows, etc., for perching or for escape cover where such woody vegetation is adjacent to the primary habitat, but they are completely at home in the middle of large open fields. On the other hand, the bush sparrows, such as Song Sparrow, Field Sparrow, Chipping Sparrow, White-throated Sparrow, etc., are not found in the middle of large open fields except casually. In this paper we are concerned only with the first ecologic group. On the sandy lands of the Savannah River Plant Area abandoned fields, especially large ones, have remained essentially without woody invaders for five years and have provided winter habitat for four species of herb sparrows as follows: Savannah Sparrow *(Passerculus sandwichensis)*, Vesper Sparrow *(Poecetes gramineus)*, Grasshopper Sparrow *(Ammodramus savannarium)*, and LeConte's Sparrow *(Passerherbulus caudacutus)*. A fifth species, the Henslow's Sparrow *(P. henslowii)*, is a potential member of this group in the region but was not encountered. The Savannah Sparrow was by far the most abundant species.

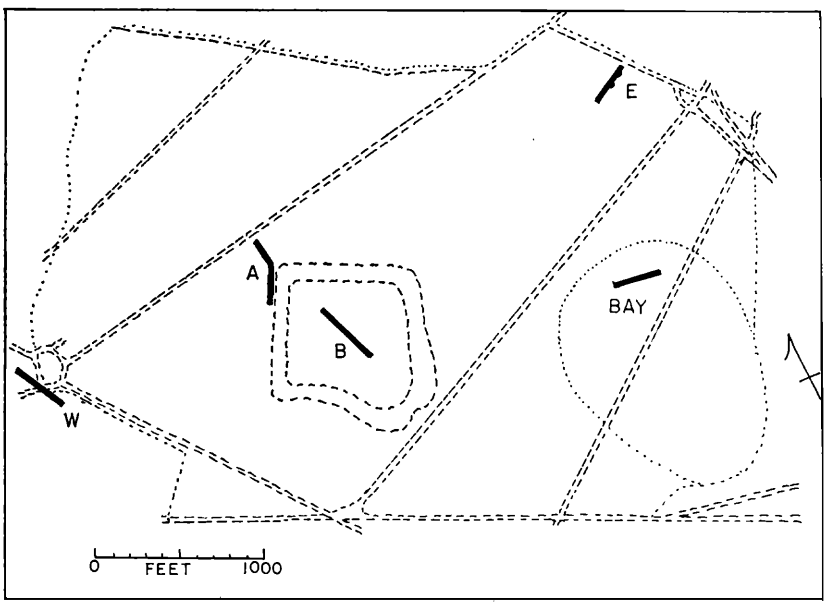

Figure 1. Sketch map of Field 3-412 showing five locations (black bars) where net sampling was done. Broken lines indicate roads and other bare areas; dotted lines show boundaries of the field and of the "Carolina Bay."

During the winter of 1956 and 1957 our net sampling was coordinated with intensive observations on behavior, density and subspecific composition of Savannah Sparrow populations made by Dr. Robert A. Norris. These observations, which will be reported on in full in other papers, were invaluable in interpreting the banding data summarized in this paper. In 1955 Dr. David W. Johnston carried out a preliminary study of subspecific composition (Johnston, 1956). Mr. Karl Herde, Radiation Control Branch of SRP, took an active part in arrangements for sampling. We are very grateful to the following for aiding in various "drives": Dr. W. R. Boss of Washington AEC office, Chandler Robbins, Fish and Wildlife Service, Dr. J. Fred Denton, of Augusta, John B. Hatcher, Project Forester of SRP, William Dupre, of Rome, T. P. Haines, of Mercer College; and the following graduate students: J. B. Gentry, William Cross, Alfred Smalley, Henry Robert, Clyde E. Connell, Larry D. Caldwell, John Barrow, and Herbert Kale.

STUDY AREAS AND METHODS

Nets were used to sample populations of herb sparrows during the three successive winters of 1954-55, 1955-56 and 1956-57. During the first winter several different habitats were studied, while during the next two winters the work was concentrated in one of these areas, 3-412, a very large field which has been the site of our most intensive study of other biotic components as well. A brief description of the principal study areas follows: *Field 3-412.* A large, level field of about 150 acres as shown in Figure 1. A number of roadways cross the area and a small "Carolina Bay," an oval depression filled with water and marsh vegetation, lies along one side. The soil, Cahaba Loamy Sand,

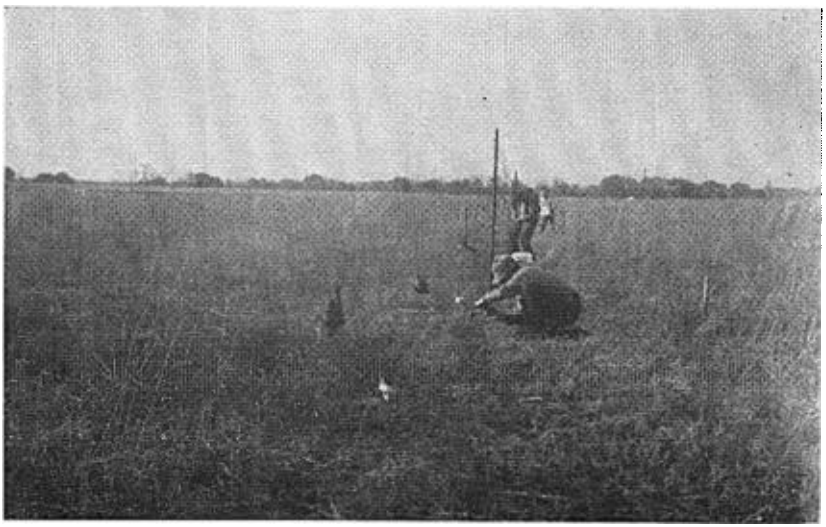

Figure 2. Removing Savannah Sparrows from line of nets at end of a "drive" in field 3-412. Note that vegetation consists of "overstory" forbs and "understory" crabgrass.

is fertile and produced good crops of cotton and corn until abandoned in 1951. Winter vegetation (see Fig. 2) during the period of study consisted of a rather uniform stand of the dead stalks of tall annual forbs, principally yellow aster *(Haplopappus divaricatus)* and camphorweed *(Heterotheca subaxillaris)*, with an understory of lesser forbs, sedges and grasses, especially carbgrass *(Digitaria sanguinalis)*, the main source of seeds utilized by herb sparrows.

Field 3-409. A former watermelon field of about 30 acres on the "sandhills" or Aiken Plateau physiographic subregion. The soil, Lakeland Sand, is very sandy and relatively sterile. In contrast to the above "forby" field this one is "grassy" with *Leptiloma, Aristida, Eragrostris* and other tall grasses intermixed with crabgrass and other low species.

Bay 11-1. This large "Carolina Bay" normally has a shallow pond in the center, concentric zone of dense maiden cane *(Panicum hemitomon)* and broomsedge *(Andropogen)*, and provides but limited habitat for species considered in this paper. However, following the dry summer of 1954, the pond was greatly reduced leaving a 5-acre moist area on which a dense mat of *Paspalum* grass grew between the water and tall vegetation. A very large concentration of Savannah Sparrows wintered here in 1954-55. The birds feed on the abundant *Paspalum* seeds and used the surrounding tall vegetation for escape cover. During the following two winters the water levels were higher and few sparrows were found.

The technic of netting was similar for all areas. A single line of metal fence posts was set into the soil and the 42-foot nets stretched as shown in figure 2. Usually 8-12 nets were set up. A line of men would then slowly drive birds into the nets, first in one direction and then in the other. About 2-4 acres were usually covered in a drive. Where less than 5 "drivers" were available a long rope was used. The two hours after dawn and a similar period before sunset was found to be the most effective time for sampling. It was found that birds tended to fly low at such time and allowed themselves to be driven in the desired directions without seemingly becoming alarmed on repeated flushing. Birds were immediately removed from the nets and placed in darkened gathering cages to be examined and banded after the series of drives had been completed.

A given study area was usually worked intensively several times over a 2- or 3-day period and then left completely undisturbed for at least 3 or 4 weeks before the population was again sampled. Nets and posts were always taken down after each effort. So far as we could determine there was no evidence of birds "remembering" the nets: thus, the probability of capture of previously banded birds was assumed to be the same as that of unbanded birds. Certainly, judicious use of nets provides a much more random sample than do traps. Most of the netting was done in January and February when other studies indicated populations were maximum in size and relatively stable.

In field 3-412 netting was concentrated where density was greatest, namely, in areas A and B as shown in figure 1. Smaller number of birds were banded at three peripheral areas, E, W, and "Bay," as an aid in determining home range movements.

During the three winters something over 1,600 herb sparrows were banded, about 1,500 of which were Savannah Sparrows. In the intensively worked 3-412 field 1,063 birds were banded with 101 repeats and 112 returns being recorded.

RESULTS

Habitat Selection and Relative Abundance.—The results of netting operations in four different habitats in 1955, as shown in table 1, supplemented by general observations provide clues to habitat selection by winter fringillids. As is often the case with a group of related species, the dominant species, the Savannah Sparrow, was found abundantly in various types of the basic "grassland" habitat while the less common species showed more specific preferences. Vesper Sparrows, for example, were most common in open, sparsely vegetated areas, such as along roadways, or in fields where tall overstory vegetation was absent or sparse. Grasshopper Sparrows, on the other hand, preferred dense grassy areas. The relatively rare LeConte Sparrow was found mostly in the one area and was apparently quite local in occurrence. This species flushed less readily and seemed to prefer tall, dense vegetation. In fact, we did not discover its presence until we began using nets. Thus, species of herb sparrows were found to occupy somewhat different niches in winter as well as during the breeding season. On the intraspecific level, however, Johnston (1956) and Norris and Hight (1957) found no evidence that the five distinct races of Savannah Sparrows were segregated as to habitat on the winter grounds.

TABLE 1

Winter Habitat Selection by "Herb Sparrows" as Indicated by Total Numbers Captured with Mist Nets Using Comparable Technic in Four Types of Open Field Habitat in 1956

Habitat (see text for details)	Area Number	Years Since Cultivation	Soil Type	Savannah Sparrow	Vesper Sparrow	Grasshopper Sparrow	LeConte Sparrow
Center of Upland Forb-Crabgrass Field	3-412A & B	4	Cahaba Loamy Sand	211	3	1	9
Edges of above field bordering roadways	3-412E & W	4	Cahaba Loamy Sand	71	28	4	0
Upland grassy field	3-409	4	Lakeland Sand	160	0	9	1
Moist pond margin with matted *Paspalum*	Bay 11-1	*	*	431	10	0	0
Totals				883	41	14	10

*Uncultivated area located in the center of a large "Carolina Bay" with poorly drained high organic content soil having a blue clay subsoil.

In table 2 the relative midwinter density in field 3-412 is indicated by rate of capture per unit of effort. LeConte Sparrows apparently disappeared completely after the first winter since none were observed or captured in 1956 and 1957. While the differences are not statistically significant, an increase in Savannah Sparrows during 1956 and 1957 is suggested, as is also indicated by marking-recapture experiments to be described below. During the three-year period there was a small decrease in the density of overstory forb vegetation and an increase in crabgrass. These vegetation changes, though not great, would seem to favor an increase in Savannah Sparrows. During all three winters, density remained relatively constant during January and February but declined appreciably in March (see Norris and Hight, 1957). In 1955, this decline was evident by February 26.

Marking-Recapture Experiments. Since mist nets apparently provide a relatively unbiased sample, estimates of the total population size may be calculated from marking-recapture ratios, the so-called "Petersen or Lincoln Index" method. By this method a sample from the population is marked, released, then allowed to mix again with unmarked individuals; subsequently, a second sample is taken (in this case 3-4 weeks later) and density determined from the ratio of marked to unmarked. Schaefer (1951) gives a good history and explanation of this technic together with suggestions for appropriate statistical analysis; his paper should be consulted by bird banders who wish to employ this method.

In table 3 estimates of midwinter populations of Savannah Sparrows are given for all cases where two samples should be obtained in a comparable manner. Confidence limits are indicated calculated according to the method suggested by Schaefer (1951). It should be pointed out that density estimates are valid only if mortality of banded birds is not greater than that of unbanded ones and if immigration and emigration are minimum. These two assumptions appear to be valid for the midwinter period. Finally, it is important to note that marking-recapture experiments estimate the number of birds "in potential contact with nets" and do not in themselves indicate density in terms of a unit of area unless, (1) home range is known, or (2) the population is definitely limited by physical boundaries and it is certain that the samples taken are from the entire population within the area.

TABLE 2

Relative January-February Density as Indicated by Birds* Netted per Hour of Drives within the Same 20-Acre Center Area of a Large Forb Field (3-412A & B)

Species	1955		1956		1957	
	total	no./hr.	total	no./hr.	total	no./hr.
Savannah Sparrow	233	24.5	325	34.2	304	38.0
LeConte Sparrow	10	1.05	0	0	0	0
Grasshopper Sparrow	1	—	1	—	2	—
Vesper Sparrow	4	—	0	0	6	—

*Numbers include repeats.

TABLE 3

January-February Savannah Sparrow Populations (N) "in Contact with Nets*" as Calculated from Marking-Recapture Ratios

		First Sample		Second Sample			Calculation of Density		
Year	Area	Date	Number Banded (T)	Date	Number Captured (n)	Number Banded (t)	Recapture ratio t/n	Population Density N = nT/t	Confidence limits (2σ)
1955	Bay 11-1	Feb. 4	207	Feb. 26	266	46	0.173	1197	967-1569
1955	3-412A	Jan. 15	108	Feb. 5	71	31	0.183	590	401-1113
1956	3-412A	Jan. 20	77	Feb. 11	54	9	0.167	462	294-1069
1956	3-412B	Jan. 21	154	Feb. 12	125	26	0.208	740	562-1085
1956	3-412A-B	Jan. 20-1	231	Feb. 11-2	186	40**	0.215	1074	855-1444
1957	3-412B	Jan. 19	136	Feb. 22	150	22	0.147	927	680-1376

*Each sample obtained with a single line of nets 300-500 ft. long with late afternoon and early morning drives (about 4 hours total) covering 2.5 acres on each side of net (total 5-7 acres).

**Includes 5 repeats which "crossed over" between A and B and hence are not included when A and B are considered separately.

The most ideal situation encountered during this study was in Bay 11-1 where it was evident that all birds were obtaining their food from five acres. In this case birds would move around and around the pond as one drove them, only reluctantly flying into the surrounding tall *Panicum*. Nets set across their path soon obtained a large sample (table 3). Thus, in this case we could say that about 1,200 birds or 250 per acre utilized this feeding ground. An unknown amount of additional habitat was undoubtedly utilized for roosting and escape cover. This was obviously an unusual situation representing an abnormally dense population.

In field 3-412 where the population was higher than average for abandoned fields but more normally distributed than in the Bay it was not so easy to estimate density in terms of area. As previously indicated other types of observations must be made before the results of the net samples can be interpreted. A total of 92 Savannah Sparrows were banded in peripheral areas E, W, and "Bay" (see fig. 1). Only one (from "Bay") of these ever repeated in the same winter in the center A and B area where large numbers of birds were caught. However, five additional individuals banded in peripheral areas returned to A and B, that is, were captured there in a subsequent winter. It would seem, therefore, that during a given midwinter period the nets in the center area did not sample the whole 150 acres. It was likewise obvious that nets sampled more than were present within the actual area of drives which was 15 acres or less. During both 1956 and 1957 Dr. Norris made repeated strip and quadrat counts finding density at any one time to be between 10 and 20 birds per acre in the center area and about half of this or less for the field as a whole. Yet during both 1956 and 1957 almost 300 individuals were captured within 15 acres and recapture ratios indicated a population of about 1,000 in "contact with nets." Thus, it is evident that during a period of 3 or 4 weeks birds range over an area larger than 15 acres but perhaps not as large as 150 acres. If we take 100 acres as a reasonble "order of magnitude" estimate of area sampled with lines of nets in "A" and "B" then there were about 1,000 birds in this area in 1956. During the same period Norris estimated on the basis of strip censuses that there were about 700 birds in the same area. As indicated in table 3, confidence limits of marking-recapture estimates are rather wide so that the two estimates are actually not so far apart. It seems likely that strip censuses might underestimate and recapture ratios overestimate density. In any event it is highly desirable in all ecological work to utilize more than one method in estimating population density; reasonable agreement gives confidence in the results.

During the three-winter period there was a slight shift in the center of abundance of Savannah Sparrows in 3-412. In 1955 birds were concentrated in A, in 1956 they were equally abundant in A and B while in 1957 they were centered in B. Thus, for all practical purposes estimates for A in 1955, A plus B in 1956 and B in 1957 may be taken as estimates for the over-all population in 3-412. These estimates as shown in figure 3 indicate, as did the data in table 2, that birds were more abundant in 1956 and 1957. However, differences are not signifi-

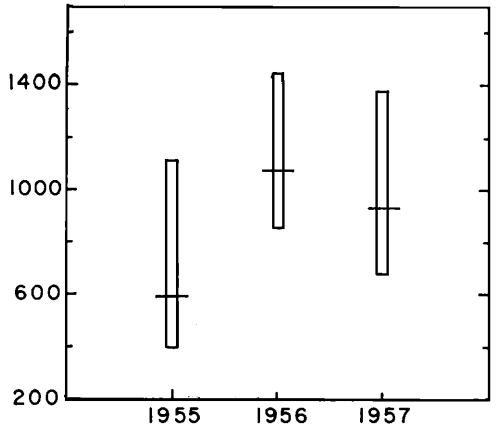

Figure 3. Estimated number of Savannah Sparrows "in contact with nets" in 3-412 during three winters as calculated from marking-recapture ratios. The bars indicate confidence limits at the 95% level (2 σ).

cant at the 95% level. Using the graphic method of Hubbs and Hubbs (1953) there is a 6 to 1 chance that the difference between 1955 and 1956 is not due to chance ("T" = 1.5; p = 0.13). We consider this to be reasonable odds for ecological data of this type. More interesting than possible differences, however, was the fact that the density of Savannah Sparrows remained roughly the same for three successive years.

Returns.—As expected, a large number of returns were recorded in field 3-412, verifying the well-known tendency of winter fringillids to return to the same area on successive migrations. Except for the five individuals previously mentioned which returned to a different part of the field all of the 100 or so returns were captured in the same portion of field (considering A and B as the same area) where banded. When dealing with a large fluid population as represented by the loosely organized flocks of Savannah Sparrows, expressing returns as a percentage of the number banded the previous year is meaningless because it is evident that only a portion of the birds actually returning can be caught. However, having an estimate of total population and knowing the ratio

TABLE 4

Returns of Winter Resident Savannah Sparrows for One and Two Year Intervals to Field 3-412 as calculated from Population Samples.

Time Interval	Banded First Year (A)	Captured Subsequent Year			Estimated Populations of Subsequent Year		
		Total	Number Marked	% Marked (B)	Total T	Number Marked B x T=C	% Return C/A
1955-1956	196	379	26	6.9	1074	74	37.8
1956-1957	379	349	62	16.8	927	156	41.2
1955-1957	196	349	19	5.4	927	50	25.5

of returns to new birds the total number of returns may be estimated as shown in table 4. Here again we see that population density must be known if the number of returns is properly interpreted, a point often overlooked by banders. Thus, while only 26 returns were captured in 1956 we estimate that there must have been 74 birds which returned, or nearly 40%. The fact that a number of birds banded in 1955 were not recorded again until 1957 shows that there were indeed many returns in 1956 that did not happen to be caught that year.

If we assume that birds will return to the field if alive then we may construct a brief "life table" as follows: Out of 100 birds present on the wintering grounds about 40 may be expected to survive and return a second winter and 25 may be expected to survive yet another trip to the northern breeding grounds and return. Since birds may be aged by skull or feather characters in early winter a much more interesting life table could be construed if only one-year birds were included. Unfortunately we did not undertake the aging of birds in the present study until 1957 so that these estimates will have to wait for the future.

SUMMARY

1. Winter fringillids inhabiting the abandoned fields of the AEC Savannah River Plant area may be divided into two ecologic groups: "herb sparrows" and "bush sparrows." Japanese mist nets proved effective for sampling populations of the former group which consisted of the abundant Savannah Sparrow and the less common Vesper Sparrow, Grasshopper Sparrow and LeConte Sparrow.

2. About 1600 "herb sparrows" were banded during a three-winter period, 1955-57, over 1000 of these in a single large field which was intensively studied during successive years; about 100 repeats and 112 returns were recorded in this field.

3. The dominant species, Savannah Sparrow, was found in both "forby" and "grassy" fields with both dense and sparse cover while the less common species exhibited distinct habitat preferences resulting in different proportions of species in different areas. On the intraspecific level there was no evidence that the five subspecies of Savannah Sparrows (which breed in widely different geographical areas) were segregated into different habitats during the winter.

4. In the intensively studied field, No. 3-412, LeConte Sparrows were present only in 1955 and Savannah Sparrows increased somewhat in numbers in 1956 and 1957 as indicated by rate-of-capture indices and marking-recapture estimates.

5. Density estimates with appropriate confidence limits were calculated for 3-412 and one other area by the use of marking-recapture ratios, and the results in 3-412 checked with strip and quadrat counts made by Dr. Norris with reasonable agreement resulting. In a small five-acre area of concentrated food in a "Carolina Bay" 1200 birds wintered, while about 1000 birds were estimated to utilize about 100 acres of field 3-412. In the latter area birds concentrated their activities in a center portion where crabgrass was most common.

6. "True return" percentage as calculated from the actual number of returns and the estimated size of population "in contact with nets" was 38% in 1956, 41% in 1957 and 26% for the two-year span, 1955-57. Thus, out of 100 birds wintering about 40 returned the next year and 26 of these survived to the third winter.

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MIST-NETS versus HELIGOLAND TRAPS

BY KENNETH WILLIAMSON

Some experimental use of Japanese mist-nets was made at Fair Isle Bird Observatory during the field-season of 1956. In addition to two large nets kindly donated by Mr. Alexander Bergstrom, three smaller ones from another source were also available. The purpose of this article is to report on the potentialities of this technique in ornithological studies on remote islands, and consider the relative merits of the nets and the permanent wire-netting traps on the Heligoland model which are standard equipment at all British bird observatories. The article has been stimulated by the appraisal of the various techniques and the results to be obtained from them given by Bergstrom and Drury (1956),—and especially by their statement: "We do not know of any full-scale Heligoland traps in use on this side of the Atlantic, and it is unlikely that any will be built as an alternative to mist-nets."

GEOGRAPHICAL SITUATION

Fair Isle is a rather small island (3½ x 1¼ miles) between the Orkney and Shetland archipelagos north of Scotland, and it is 25 miles from each. It therefore commands an extensive arc of seascape between northeast and south on the European side, and between southwest and north on the Atlantic fringe. It is treeless and lacking in any sort of cover except at the cultivated southern end, where there are small plots or "riggs" of oats, turnips, potatoes, and a few enclosed cabbage-