The use of aerial photographs in studies of marsh vegetation

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Cover photo of the Cessna 195, camera and mapping crew, courtesy of the James W. Sewall Company, Old Town, Maine.

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Foreword

David Olson, who conducted this study for his Master's thesis in wildlife management, had previously served in the United States Air Force for two years as a photo interpretation officer. His interest and skills in photo interpretation were essential to the pursuit of this research project.

This is one of the very first studies to explore the use of air photos for the identification of marsh vegetation in a clear cut scientific manner. It can serve as a guide for future studies of other low growing species that are important in wildlife management.

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Summary and Conclusions

Aerial photographs of marsh habitat in Merrymeeting Bay, Maine, were studied to determine the kind of information relative to marsh vegetation that could be obtained from them, and also to determine the accuracy of the photographic interpretation. Four films were exposed at three altitudes over the same section of the marsh. On the basis of the photographic images, the vegetation on the study area was classified into 11 types: wildrice, river bulrush, round stem bulrush, yellow waterlily, pickerel weed, sweetflag, three-square bulrush, submersed aquatics, mixtures of the above, sand, silt, and high tide zone. Eighty areas representing all of these types were selected for interpretation tests. Each area was identified on the ground and accurately located on the aerial photography. Seven individuals, representing four levels of photo interpretation experience and/or experience iu marshes, interpreted the 80 areas on the aerial photographs. The photo interpretations were compared with the ground identifications. The most important of the results were analysed statistically. The following conclusions may be deduced from this study:

1. The testing procedure appeared to be satisfactory for evaluating film, scales, and interpreters. It also seemed adequate for the classification of vegetation with the exception of three-square bulrush.
2. The classes of vegetation, recognizable on the aerial photographs, are similar to the plant associations that can be recognized on the ground with the exception of plants which usually grow in sparse stands.
3. There were no differences between the relative accuracies of interpretations on the four film materials.
4. With each increase in the scale of photography*, an increase in accuracy of interpretation was obtained. The increase (10 per cent) between scales of 1:20,000 and 1:12,000 was larger than the increase (5 per cent) observed betwen the scales of 1:12,000 and 1:5,000.
5. Biologists who have had experience in ecology of marshes, even though lacking prior training in photo interpretation, were able to interpret aerial photographs of marshes more accurately than experienced photo interpreters who had no experience in marshes.

* The representative fraction is the simplest method of expressing scales of aerial photography, and it is used in this report. At 1:5,000, one unit of measurement on the photograph equals 5,000 of the same units on the ground.

6. Training in the satisfactory use of the stereoscope can be accomplished in two hours or less. Likewise, only three to ten hours of practice in the identification of images on aerial photography (provided training aids and/or instruction are available) will permit interpretation of such aerial photographs with a relatively high degree of accuracy.
7. The images produced on aerial photographs result as much from the physical structure of the plant or stand of vegetation as they do from the color or tone of the plant.
8. Density of the marsh vegetation could not be interpreted accurately from the photographs, regardless of scale.
9. Mixtures of vegetation were interpreted with less accuracy than were pure stands.
10. Photographic penetration of water was less than two feet with the film materials used.
11. Aerial photographs are a useful means of studying marshes. In addition to recognizing the general types of marsh vegetation and the broad ecological zones, many plant species and associations can be recognized with a reasonable degree of accuracy.

THE USE OF AERIAL PHOTOGRAPHS IN STUDIES OF MARSH VEGETATION[1]

DAVID P. OLSON[2]

Introduction

The physical and biological characteristics of a marsh are constantly changing. Some of these changes are slow and may progress for centuries, while others may be comparatively rapid. One of the biological characteristics which may change either slowly or rapidly is plant composition.

The evaluation of marshes for wildlife purposes and the selection of management procedures is dependent upon a knowledge of the variety, quantity, and location of marsh plants. Several methods have been devised to measure the composition of such vegetation. Information from quantitative sampling procedures is accurate, but it is costly as well as time-consuming to obtain. By general observation, less accurate information can be economically obtained, but it is often inadequate for use in management.

Aerial photographs have been used with a high degree of success to obtain quantitative information of certain natural resources, but their use in marsh ecology has been only partially determined. The purpose of this investigation was to further evaluate aerial photography as a means of studying marsh vegetation.

The objectives were:

1. To determine the type of information about marsh plants that may be obtained by studying aerial photographs.
2. To compare four film materials for use in aerial photography of a marsh.
3. To compare three scales of aerial photography of a marsh.
4. To compare interpretations by individuals of varying experience in marsh ecology and/or aerial photography.

Twelve aerial photographic coverages were obtained of a portion of Merrymeeting Bay, Maine, on August 25, 1957. Test areas on these photographs have been interpreted by seven photo interpreters, and the interpretations were checked against the actual stands of vegetation or portions of marsh habitat.

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[1] Contribution from the Maine Cooperative Wildlife Research Unit, Orono, Maine: Maine Department of Inland Fisheries and Game, University of Maine, Wildlife Management Institute, and the Bureau of Sport Fisheries and Wildlife, U. S. Department of the Interior, cooperating.

[2] Currently a member of the faculty at the University of New Hampshire Forestry Department.

Material and Methods

The study area

Merrymeeting Bay is a large, shallow body of water at the junction of the Kennebec and Androscoggin rivers near Bowdoinham, Sagadahoc County, Maine. Its waters are fresh, and it has an average tide of four feet. According to the classification of Shaw and Fredine (1956), it is a combination of shallow fresh coastal and deep fresh coastal marsh.

At low tide a variety of vegetation may be seen. Dense stands of wildrice[3] *(Zizania aquatica)* and yellow waterlily *(Nuphar spp.)* grow in the numerous coves and along five sluggish tidal rivers. Farther out in the bay are large expanses of silt and sand. Clumps of sweetflag *(Acorus Calamus)*, pickerel weed *(Pontederia cordata)*, soft stem bulrush *(Scirpus validus)*, and yellow waterlily are scattered over the silt areas. Various species of submersed aquatics and three-square bulrush *(Scirpus americanus)* also grow on the open areas of silt, but their growth is diffuse. Typical of the sandy areas are large, dense stands of bulrush *(Scirpus validus* and *Scirpus fluviatilis)*. These bulrush stands are called "islands" by residents of the bay.

At high tide, only the tops of the bulrush and wildrice remain above the water, giving the bay the appearance of an expansive lake with scattered, short, emergent vegetation.

An area approximately three miles long and one-half mile wide which contained a variety of marsh vegetation was selected to be photographed (figure 1).

The reasons for choosing Merrymeeting Bay as an area in which to study marsh vegetation were:

1. It contained an excellent abundance and variety of marsh plants.
2. The vegetation could be examined in detail during low tides.
3. Aerial photographs of the area, which were taken in 1956, were available for preliminary study.
4. Merrymeeting Bay is an important waterfowl hunting area.

Photographic films and scales

The four types of film available for this study were two panchromatic films, Kodak Super-XX Aerographic and Kodak Plus-X Aerecon; and two color films, Kodak Ektachrome Aero, High Contrast (a positive color transparency film), and Kodak Ektacolor SO-1185, a color negative film. Black and white prints were made from the panchromatic films, and color prints from the color negative film. The color

[3] Common names of plants are primarily form Hotchkiss (1950). Scientific nomenclature is taken from Fernald (1950).

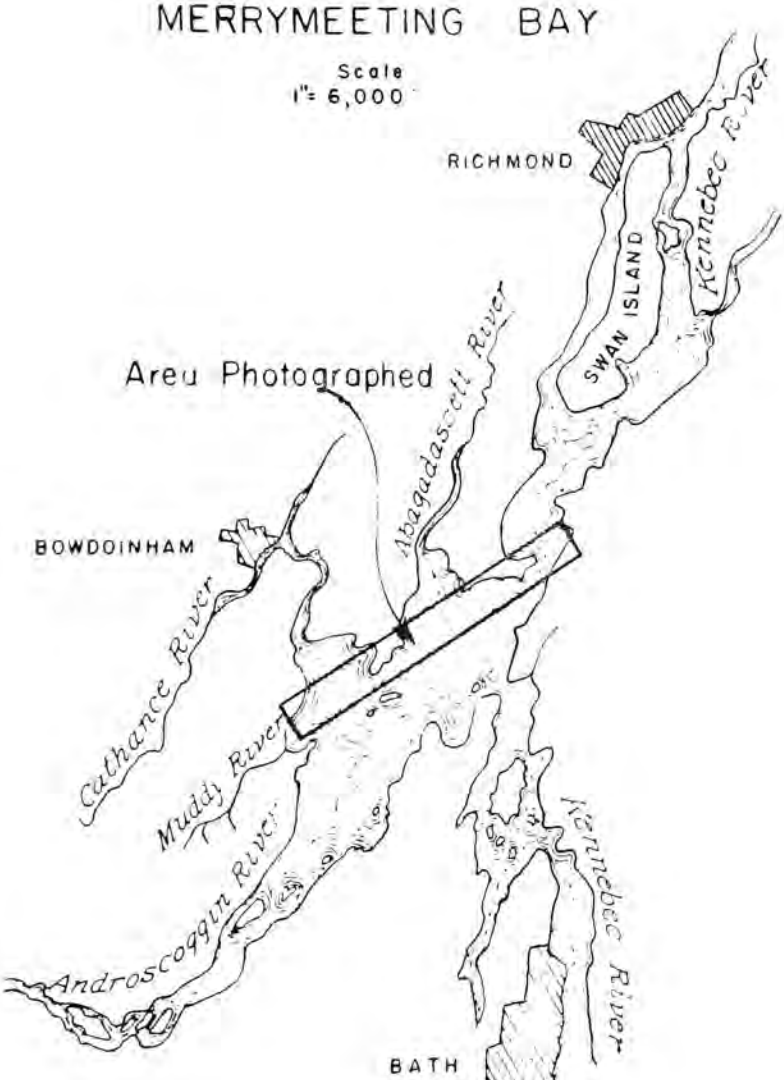

Figure 1

Merrymeeting Bay and the Area Photographed transparencies were placed in cellophane envelopes and studied on a light table.

The films were exposed with filters recommended by the manufacturer. A minus blue (haze and contrast) filter was used with both panchromatic films. The color negative film was exposed through a Wratten 2A (minus ultra violet and blue) filter. Various filters were used in exposing the color transparencies. These were selected by the photographer according to the film manufacturer's instructions, and the haze conditions at the time of photography.

As the scale of aerial photographs increases, the amount of detail in the photographic images increases, and it is possible to distinguish smaller differences in the heights of objects (figure 4). To evaluate the effects of these differences on the interpretation of marsh vegetation, all four films were exposed through an 8.25 inch focal length lens at altitudes of 3,360 feet, 8,250 feet, and 13,750 feet. The resulting scales of photography were 1:5,000, 1:12,000, and 1:20,000.

Photographic conditions

It was decided that photographs would be most useful if taken when the marsh vegetation was at its maximum development. This decision was based primarily on the results obtained from the photographs of Merrymeeting Bay made in 1956, and partially on estimation. Other conditions that were necessary for exposing the films were low tides and clear weather. Morning low tides were preferable since haze and clouds usually developed by early afternoon.

The photographs were taken at low tide on the morning of August 25, 1957. The time of photography extended from one-half hour before low tide until one hour and 45 minutes after. By the time the last 1:20,000 exposures were made, the tide had risen considerably (appendix I). Field observations at the time of photography indicated that the vegetation was slightly beyond maximum growth, as the wild-rice had produced fruit, and the pickerel weed leaves were starting to deteriorate.

Photo interpreters

Studies (although not pertaining to marsh vegetation) have indicated that persons who are most experienced with subjects photographed are the best interpreters of the photographs (DeLancie, 1957). Because of a general lack of familiarity with aerial photographs, many persons feel that special training and experience are necessary to interpret them.

Seven individuals of varying levels of experience in marsh ecology and/or photo interpretation, were selected to ascertain variations in interpretive ability. All seven were given the Moessner Floating Circles Test (Moessner, 1954) to determine if they had normal stereoscopic perception. The experience, occupation, and stereoscopic perception scores of the interpreters are given in table 1. Interpreter A was the most experienced in using aerial photographs of marshes. His experience was obtained in the Delta Marsh, Manitoba, and at Merrymeeting Bay, Maine. Interpreters B and C were wildlife biologists, both of whom have had considerable experience in marshes. They were familiar with the Merrymeeting Bay marsh, but they had not used aerial photographs in the field except to a very limited extent. Interpreters D and E had both used aerial photographs extensively, but little or none of their experience was with marsh vegetation. Interpreters E and F were students in wildlife conservation with little or no experience in marshes or with aerial photographs.

Table 1

Experience, Occupation, and Stereo Perception Scores* of the Photo Interpreters

Intrepreter	Interpretation experience	Marsh experience	Occupation	Stereo perception
A	extensive	extensive	wildlife graduate student	100
B	little	extensive	biologist	96
C	very little	extensive	biologist	96
D	extensive	little	professor of photogrammetry and forestry	96
E	extensive	little	specialist in soil interpretation	96
F	very little	little	wildlife student	88
G	very little	little	wildlife graduate student	96

*Any score of 80 or more is considered good stereo perception.

Young (1956) indicated that the accuracy of photo interpretation varied with a person's interest in the subject and photography. No comparisons of interest between interpreters were made, but it is probably correct to assume that the interest of each was high. All of the test personnel voluntarily spent considerable time interpreting the aerial photography.

Establishment of a classification scheme

Before interpretation of aerial photography can be made, the images on the photographs and their counterparts on the ground must be classified into recognizable groups. The procedure recommended by Young and Stoeckeler (1956) was employed in this study. The steps in this procedure are field reconnaissance, trial interpretations, and field verifications.

Prior to the time the test photographs were taken, field reconnaissance[4] was conducted by utilizing the 1956 aerial photographs. The images on the 1956 photographs were compared with areas in the marsh and a tentative classification was established. Trial interpretations employing the tentative classifications were made and verified in the field, and the classification scheme was modified to permit increased speed and accuracy of interpretation.

The final classification scheme for this study contained 11 types: wildrice, round stem bulrush, river bulrush, yellow waterlily, pickerel weed, sweetflag, submersed aquatics, three-square bulrush, sand, silt, and high tide zone.[5] It was also decided to designate density of vegetation as sparse, medium, or dense. Complete descriptions of each of the 11 types are provided in appendix II.

Initial phase of interpretations

For the initial tests 210 areas of varying tone and color were selected on the 1:5,000 color transparencies. These were then interpreted by interpreter A. Since the color prints were not available at the time, the 210 test areas were interpreted on each of the nine remaining film/scale combinations. The interpreted identity and density were recorded for each area. It is possible that clues to the identity of test areas may be obtained when interpreting one set of aerial photographs and employed while interpreting the next set. To reduce this "carry-over" of information, not more than one photographic coverage was interpreted in any one day; also, for this reason, the coverages which were believed to be most difficult were interpreted first, and the least difficult last. An Abrams, Model CB1, 2-4 lens stereoscope was used for all interpretations in the study.

When the initial phase of photo interpretation was completed, each of the 210 test areas was verified in the field according to the classification scheme. Density and vegetation composition were recorded for each area (table 2). The initial interpretations were compared with field identification with the following results:

1. An average accuracy of 78 per cent was obtained.
2. Little difference in accuracy was noted among the four kinds of photography.

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[4] During the initial studies the author refrained from going into the area which was to be photographed in order to avoid bias in his interpretation.

[5] The type called high tide zone in this study is "coastal shallow fresh marsh", as classified by Shaw and Fredine (1956).

Table 2

Composition of Interpretation Tests in Terms of Vegetative Types and Densities

Type	Initial interpretations (210 areas) Number of areas	Densities attempted sparse	medium	dense	Initial interpretations (80 areas) Number of areas	Densities attempted sparse	medium	dense
wildrice	21	1	—	4	8	1	—	1
yellow waterlily	32	9	15	9	8	2	2	—
pickerel weed	15	1	8	5	6	1	2	1
river bulrush	7	—	—	—	7	—	—	—
round stem bulrush	37	5	13	18	8	2	2	2
sweetflag	24	—	3	13	8	—	2	2
submersed aquatics	9	1	2	2	7	1	2	2
three-square bulrush	7	3	4	—	5	2	2	—
high tide zone	9	—	—	—	5	—	—	—
sand	5	—	—	—	5	—	—	—
silt	8	—	—	—	6	—	—	—
mixtures	28	—	—	—	7	—	—	—
Totals	202*	20	45	51	80	9	12	8

*This figure varies from the original 210 areas selected because 8 areas either were not located on the ground or were eliminated because they were not included in the 11 types listed.

3. More accuracy was obtained on the photographs taken at a scale of 1:12,000 than on the 1:20,000 photographs.
4. Little difference in accuracy was obtained between the 1:12,000 and 1:5,000 scales.
5. Accuracy of interpretation varied with each of the 11 types in the classification.

Photo interpretation tests

To supplement the results of the initial interpretations, as well as to compare interpretations of individuals of varying experience in marsh ecology and/or photo interpretation, a series of photo interpretation tests was conducted. The test consisted of 80 acres selected from the original 210 by stratified random sampling. Each of the 11 classifications was represented between five and eight times, and seven areas of mixed vegetation were also included. Twenty-nine of the 80 areas were designated for interpretation of density.

Each of the interpreters who were to take these tests lacked experience with marsh vegetation and/or aerial photographs. Therefore, a period of orientation and training was necessary, but this training had to be conducted in such a way that no bias would be introduced. To minimize bias in training, each interpreter used the same reference material and the same practice interpretation areas. Also, the interpreter, rather than the instructor, decided when his training would cease.

The wildlife students utilized the most training (approximately ten hours). The experienced photo interpreters trained for the shortest time (two hours), and the biologists' training was intermediate in length. Variations in the amount of time spent in training resulted from personal desires for more or less training and differences in the amount of time which the interpreters could devote to training. An important part of the training program for each interpreter was stereo examination of areas pointed out by the instructor. Practice interpretations were made of areas which were selected during the field checks. The reference materials[6] which were used in training were obtained during the field verification and included the following:

1. A description of each of the 11 types to be interpreted.
2. Photographs of each type taken from the ground and stereo pairs[7] taken from a step ladder.
3. Ecological information for all types including location, soil, and associated types.

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[6] Reference materials are given in appendix II.

[7] Stereo pairs are 2 photographs of the same area which are taken from different positions. When they are viewed with a stereoscope, a 3-dimensional image is obtained.

4. Descriptions of the photographic images (color and panchromatic) for the various types.
5. Examples[8] of each type on the aerial photography.

Due to time limitations, each of the six interpreters did not interpret all sets of aerial photographs. However, the tests were arranged so that an interpreter of each experience level interpreted each film/scale combination (table 8). As in the initial interpretations, precautions were taken to minimize "carry-over" of information. Also, the interpreters were instructed that the 80 test areas contained some of each of the 11 types and some mixtures, but they did not know the number. Instructions to interpret density on 29 of the test areas served as a clue that these areas were vegetative and not sand or silt, but the information gained in this matter was negligible. Scores of the tests were not revealed to the interpreters until all the tests were completed.

At first, the interpreters located the test areas, interpreted them, and recorded their decisions. After about one-third of the interpretation tests were completed, the instructor began pointing out test areas and recording the interpretations. This procedure shortened the time necessary to complete each test, reduced eye strain, and did not affect the interpretation, as judged by subsequent results in comparison with earlier scores.

Photographic penetration of water

During the initial phase of this investigation, several attempts were made to interpret depths of water from the 1956 photographs. In each case the interpretation was very inaccurate. Therefore, it was decided to measure water penetration on the test photography.

Seven markers, approximately ten feet square, were made by sewing strips of burlap and white cloth together. At low tide, immediately before the photographic flight, areas with approximately 1, 2, 3, and 4 feet of water depth were located and marked. One marker was placed on the bottom at each depth, and one marker was floated on the surface beside each bottom marker. During photography, depth readings were taken from a boat at the 4-foot marker. The water depth at each marker was measured immediately before and after photography, and calibrated for the time of photography. By this procedure water depths at four stations on each set of photographs were known within one or two inches. Secci disk readings, which provide an index to the transparency of the water, were taken from the boat when the depth measurements were made.

Each of the 12 sets of photographs was examined by two in-

[8] See aerial photographs of Merrymeeting Bay in Appendix I.

terpreters who recorded whether or not they could see the bottom markers at the stations.

Analytical procedures

Each interpretation was scored "one" when the area was identified correctly. If the interpreter called a single plant type a mixture, and the mixture included the correct type, it was scored "one-half" "One-half" score was also obtained for naming only part of a mixture. The total possible score was 80.

Interpreter C
1:20,000 Aerecon

Total score, 48 of 80 60%
Density, 2 of 29 7%
Mixture, 2 of 7 = 29%

	Interpreted Identity										
Actual Identity	sand	silt	submersed aquatics	three-square bulrush	pickerel weed	yellow waterlily	river bulrush	round stem bulrush	sweetflag	high tide zone	wildrice
sand	4					1					
silt		4	2								
submersed aquatics			4	1				1.5			.5
three-square bulrush			3					2			
pickerel weed					3	1		2			
yellow waterlily				1		6					
river bulrush						1	4	2			
round stem bulrush				1	1			4	2		
sweetflag									4		
high tide zone										5	
wildrice											8
Per cent Correct	100	100	57	0	75	67	100	26	67	100	84

Figure 2
Example of Table Used for Compiling Scores

Densities were scored separately. Since a density designation is meaningless when the vegetative type is not correctly stated, no credit was given for density designations unless the vegetation was identified correctly. Each correct density interpretation was scored "one", and the total possible score was 29.

The most convenient method for compiling these data is a table comparing interpretations with known identities, as used by Young and Stoeckeler (1956). Figure 2 is an example of such a table. It will be noted that the correct interpretations occur in a diagonal row from upper left to lower right. This table also depicts the number and identity of incorrect interpretations. One table was made from each of the 65 test interpretations, and from them, composite tables were compiled for each variable being investigated. The scores on mixture and density interpretations were compiled separately. The data were analyzed statistically, and these calculations are presented in appendix IV.

Results

Identification of marsh vegetation

There was considerable variation in the accuracy of identifying the 11 types of vegetation. In table 3 the total number of times each type was interpreted and the average accuracy of identification are listed. Wildrice, yellow waterlily, river bulrush, high tide zone, and sand were all interpreted with a high degree of accuracy, while pickerel weed, round stem bulrush, submersed aquatics, sweetflag, and silt were identified with an intermediate degree of accuracy. Of the 11 types studied, three-square bulrush alone was identified with an average accuracy of less than 50 per cent. The relative accuracies for the identification of types were the same in all tests regardless of interpreter, film, or scale.

Accuracy of identification in relation to scale

With an increase in the scale of photography, the accuracy of identifying most marsh types increased. However, there were some exceptions. At all scales, accuracy of identifying three-square bulrush stands varied little from what could be obtained by chance. By contrast, accuracy was consistently high for identification of the high tide zone. Table 4 contains the average accuracy for identification of vegetative types on the three scales investigated. The average increase in accuracy was 10 per cent between the 1:12,000 and 1:20,000 scales, and 5 per cent between the 1:12,000 and 1:5,000 scales. These differences are significant at the 99 per cent level (appendix IV).

Table 3

Variation in Accuracy of Identifying Eleven Classifications of Marsh Vegetation (all interpretations)

Marsh type	Number of interpretations	Average per cent accuracy
high tide zone	325	94
wildrice	525	93
sand	325	90
river bulrush	455	86
yellow waterlily	525	82
pickerel weed	390	75
silt	390	66
submersed aquatics	455	65
round stem bulrush	525	57
sweetflag	525	56
three-square bulrush	325	12

Accuracy of identification in relation to type of film

Since the accuracy in identifying the 11 types varied little on the four films tested (table 5), the differences between films were not statistically significant. Pickerel weed was correctly identified more often on the color films than on the panchromatic films. Sweetflag was identified less accurately on the color transparencies than with all other films, but the low accuracy with this plant occurred mainly on the 1:20,000 color transparencies.

Accuracy of identification in relation to experience of the interpreters

As might be expected, interpreters varied in their ability to identify the 11 types of vegetation. Comparison of the average scores as shown

Table 4

Accuracy of Identifying Eleven Classifications of Marsh Vegetation on Three Scales of Photography

Type	Per cent accuracy 1:20,000	1:12,000	1:5,000
high tide zone	94	93	95
wildrice	88	92	98
sand	85	91	93
river bulrush	68	92	99
yellow waterlily	68	84	94
pickerel weed	63	80	82
silt	56	64	78
submersed aquatics	59	66	71
round stem bulrush	47	60	62
sweetflag	48	59	61
three-square bulrush	9	15	12
Average for all types	62	72	77

in table 6 indicated that the interpreters with the most experience with marshes identified the marsh types most accurately. A statistical analysis of the average scores of each interpreter, with the exception of interpreter A, indicated that there was a significant difference between the lowest and highest scores. There were no significant differences between the scores of biologists and students, and, with one exception, none between students and experienced interpreters.

Table 5

Accuracy of Identifying Eleven Classifications of Marsh Vegetation on Four Film Materials

	Per cent accuracy for all scales			
Type	Aereographic	Aerecon	Ektachrome	Ektacolor
high tide zone	90	93	97	96
wildrice	94	93	92	92
sand	90	87	91	90
river bulrush	87	91	88	84
yellow waterlily	82	81	82	84
pickerel weed	65	73	82	82
silt	64	60	67	73
submersed aquatics	68	62	67	65
round stem bulrush	55	58	58	55
sweetflag	61	62	47	58
three-square bulrush	13	11	14	13
Combined average	70	70	71	72

The members of each pair of interpreters (B and C, D and E, and F and G) had similar scores for all scales and film materials. Also, their errors in identification were, for the most part, very similar. Statistical analysis of the scores obtained with the 1:12,000 photographs, on which all interpreters were tested, indicated that the interpreters in each pair did not vary significantly from one another (appendix IV).

Identification of mixed stands

Seven stands of mixed vegetation were included in the 80 test areas. Of these, only two were identified with appreciable accuracy. The seven mixtures and the number of times each was identified wholly correctly or one-half correctly are listed in table 7. Wildrice-round stem bulrush, and wildrice-river bulrush mixtures were recognized much more frequently than the remaining five.

In table 8 the mixture interpretation scores for all seven individuals are listed. Two interpreters obtained higher scores on mixtures than did the other five. As in identification of pure stands, no differences between film materials were noted, but the mixture score was higher with each increase in scale.

Table 6

Comparison of Interpretations—Accuracy in Per Cent of Identifying Marsh Vegetation

Interpreter and experience	Film-scale combination												
	Aereographic Super-XX			Aerecon Plus-X			Ektachrome			Ektacolor			
	1:5	1:12	1:20	1:5	1:12	1:20	1:5	1:12	1:20	1:5	1:12	1:20	Aver
A: Marsh ecology, extensive Photo interpretation, extensive	83	78	74	81	79	73	81	82	75	—	—	—	78
B: Marsh ecology, extensive Photo interpretation, little	76	78	61	—	71	—	74	72	68	—	79	—	72
C: Marsh ecology, extensive Photo interpretation, little	—	69	—	78	76	60	—	78	—	78	78	67	73
D: Marsh ecology, little Photo interpretation, extensive	73	66	59	—	63	—	74	66	66	—	66	—	67
E: Marsh ecology, little Photo interpretation, extensive	—	62	—	74	65	59	—	69	—	72	71	57	66
F: Marsh ecology, little Photo interpretation, little	74	67	65	79	73	58	81	72	57	79	78	52	70
G: Marsh ecology, little Photo interpretation, little	77	71	61	73	73	57	74	64	58	79	74	60	68

Table 7
Interpretations of Seven Stands of Mixed Marsh Vegetation
(all films, scales, interpreters combined)

Composition of stands	Number of completely correct interpretations	Number of half-correct interpretations	Analysis of half-correct interpretations	
three-square bulrush and submersed aquatics	3	50	three-square bulrush	14
			submersed aquatics	36
round stem bulrush and wildrice	40	15	round stem bulrush	13
			wildrice	2
round stem bulrush and sweetflag	0	51	round stem bulrush	50
			sweetflag	1
river bulrush and wildrice	23	26	river bulrush	2
			wildrice	24
river bulrush and sweetflag	0	25	river bulrush	24
			sweetflag	1
yellow waterlily and wildrice	7	21	yellow waterlily	18
			wildrice	3
pickerel weed and round stem bulrush	5	29	pickerel weed	13
			round stem bulrush	16

Table 8

Comparison of Interpretations—Accuracy in Per Cent of Identifying Mixed Marsh Vegetation

Interpreter and experience	Film/scale combination												Aver.
	Aereographic Super-XX			Aerecon Plus-X			Ektachrome			Ektacolor			
	1:5	1:12	1:20	1:5	1:12	1:20	1:5	1:12	1:20	1:5	1:12	1:20	
A: Marsh ecology, extensive; Photo interpretation, extensive	86	59	59	79	71	64	71	71	64	—	—	—	69
B: Marsh ecology, extensive; Photo interpretation, little	64	50	21	—	27	—	57	43	36	—	57	—	44
C: Marsh ecology, extensive; Photo interpretation, little	—	50	—	57	43	29	—	50	—	50	50	38	46
D: Marsh ecology, little; Photo interpretation, extensive	50	43	50	—	50	—	50	43	50	—	43	—	47
E: Marsh ecology, little; Photo interpretation, extensive	—	36	—	50	43	29	—	50	—	57	50	36	44
F: Marsh ecology, little; Photo interpretation, little	43	50	36	50	64	21	57	43	43	57	57	21	45
G: Marsh ecology, little; Photo interpretation, little	64	57	36	64	57	50	71	57	50	71	64	36	56

Table 9

Comparison of Interpretations—Accuracy in Per Cent of Interpreting Density of Marsh Vegetation

	Film/scale combination												
	Aereographic Super-XX			Aerecon Plus-X			Ektachrome			Ektacolor			
	1:5	1:12	1:20	1:5	1:12	1:20	1:5	1:12	1:20	1:5	1:12	1:20	Aver.
A: Marsh ecology, extensive; Photo interpretation, extensive	28	31	24	31	24	17	28	17	21	—	—	—	25
B: Marsh ecology, extensive; Photo interpretation, little	31	31	28	—	21	—	35	21	24	—	10	—	25
C: Marsh ecology, extensive; Photo interpretation, little	—	24	—	28	31	7	—	24	—	35	35	35	27
D: Marsh ecology, little; Photo interpretation, extensive	38	21	17	—	21	—	24	31	28	—	17	—	25
E: Marsh ecology, little; Photo interpretation, extensive	—	24	—	31	14	24	—	10	—	24	21	14	20
F: Marsh ecology, little; Photo interpretation, little	24	17	38	14	28	14	17	24	14	31	3	17	20
G: Marsh ecology, little; Photo interpretation, little	21	17	21	24	31	28	14	17	24	21	17	21	21

Interpretation of vegetation density

The relative accuracies of the interpretations of density for all interpreters and for each of the 12 sets of aerial photographs are listed in table 9. The average accuracy (23 per cent) varies little from what might be obtained by chance. Since there were three classes of density, chance should have yielded 33 per cent accuracy. However, to consider density, the vegetation first had to be identified correctly. Types of vegetation were identified with an average accuracy of 71 per cent. Multiplying the average accuracy of vegetation identification by expected accuracy due to chance (0.71 x 0.33) amounts to 22 per cent. This approximates the accuracy that was obtained.

Photographic penetration of water

The maximum depth at which any bottom marker could be identified on the photographs was 23 inches (table 10). At depths of 24 and 25 inches the two interpreters could detect an object below the surface, but they could not state with certainty that it was a marker. In depths exceeding 27 inches, the markers were not visible. These figures agree with observations made in the field during the reconnaissance phase of the study.

Table 10

Depths of Water at Which Markers Were Visible

Water depth (in inches)	Film	Scale	Marker visible
14	Aerecon Plus-X	1:12,000	yes
14	Aereographic Super-XX	1:5,000	yes
15	Aerecon Plus-X	1:5,000	yes
15	Aereographic Super-XX	1:12,000	yes
15	Ektacolor	1:5,000	yes
17	Ektachrome	1:5,000	yes
18	Ektacolor	1:12,000	yes
20	Ektachrome	1:12,000	yes
24	Aerecon Plus-X	1:5,000	questionable
24	Aerecon Plus-X	1:12,000	questionable
25	Ektacolor	1:5,000	questionable
25	Aerecon Plus-X	1:5,000	questionable
25	Aereographic Super-XX	1:12,000	questionable
27	Ektachrome	1:5,000	no
*			

*Markers were definitely not seen in depths from 27 to 56 inches.

Discussion

The volume and accuracy of information varied between the types of vegetation, the scales of photography, and the experience of the interpreters, but not between the film materials used. A discussion of these factors may indicate some of the reasons for this variation.

Films

Color films have a greater potential for recording detail than panchromatic films because there are many more colors and hues than there are shades of gray (Colwell, 1954, and Ray and Fischer, 1957). Nevertheless, with the 11 types of vegetation studied, the only benefits obtained from the color materials were slight increases in accuracy when identifying pickerel weed stands, and a possible increase in accuracy of identifying silt.

All of the interpreters used the added clue of color when studying the color films, and on many of the color coverages, they stated that they were more certain of their interpretations. However, the scores did not reflect the supposed added certainty.

It is possible to obtain more detail on aerial photographs by using a camera equipped with a device to compensate for movement of the aircraft. Since this equipment was not available, it is quite possible that the full potential of the films was not realized. This is particularly true with the Aerecon film, which is designed to give maximum detail. The prints made from the Aerecon film had greater contrast than those made from Aereographic film. The added contrast seemed to make interpretation more difficult, but only small differences in scores were obtained.

Ektachrome transparencies were slightly over-exposed at the 1:20,000 scale and slightly under-exposed at the 1:5,000 scale. These differences in exposure did not appear to affect interpretation in general, but the low accuracy of identifying sweetflag on the 1:20,000 scale may have resulted from the over-exposure.

Color transparencies were more difficult to use, because extra equipment, such as a light table and a mirror stereoscope, were necessary to view them properly. In this study a simple lens stereoscope was used, but the field of vision was small and considerable manipulation of the photographs was necessary. Since the color transparencies were the original film, they could not be replaced if damaged or destroyed. Therefore, caution was necessary when they were used.

As the color negative film is comparatively new, considerable difficulty was encountered in obtaining prints from it. The results from the interpretations of this material did not vary significantly from those from the other films. However, the accuracy of identifying vegetation types on the 1:12,000 color prints was 4 per cent greater than the accuracy obtained with the other 1:12,000 photography.

Scales and experience of interpreter

Except for differences in accuracy of interpretation associated with plant species or types, the major variables seemed to be the scale and the experience of the interpreter. These two closely related variables are compared in figure 3.

Differences in the overall accuracy of interpretation for the four levels of interpreter experience are apparent. Since the photographic images were relatively easy to memorize, the differences were probably caused by variations in experience with marsh ecology. Interpreters with a greater knowledge of marsh ecology used more deductive reasoning (interpretation) when making their decisions, while the interpreters with less knowledge of marsh ecology relied on identification of photo-

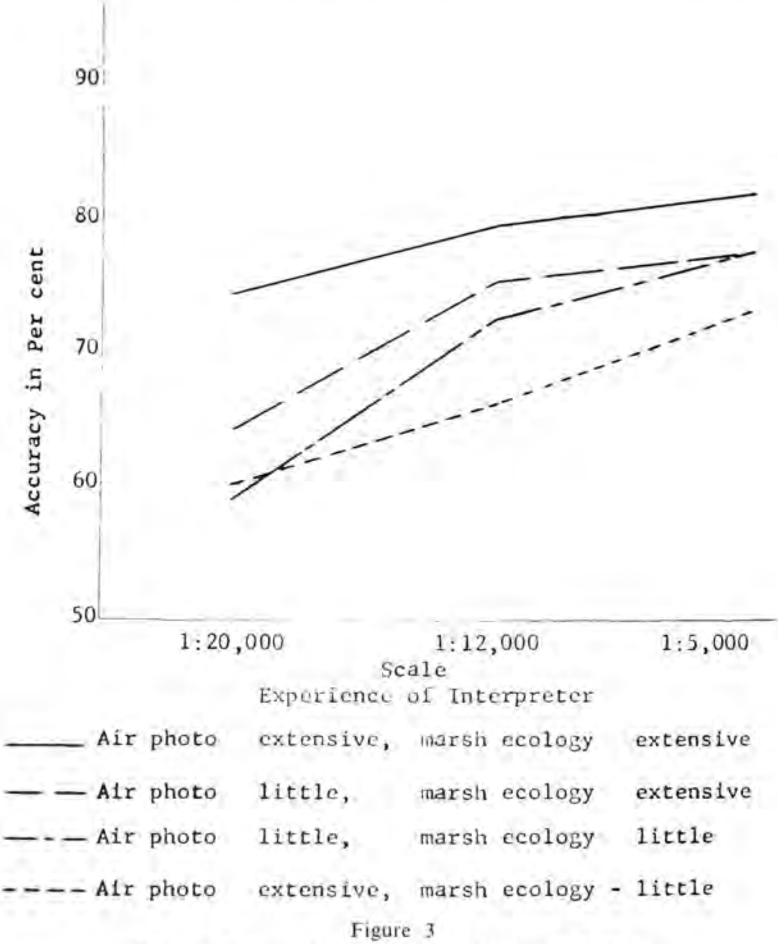

Figure 3

Relation Between Interpreter Experience and Scale in the Identification of Marsh Vegetation graphic images (photo reading). Both student interpreters were able to devote much more time to studying marsh ecology through the training aids than were the experienced interpreters. The higher scores obtained by the students seem to reflect this additional study. The experienced interpreters relied to only a limited extent on ecological information, as obtained in a brief study of the training aids.

While developing the classification system, trial interpretations and field vertification were possible for interpreter A. His higher scores at all scales indicated that these field verifications contributed to accurate interpretation. Interpretations made by the test personnel undoubtedly would have been more accurate had they been able to verify some of them in the field.

The photo interpreters with experience or training in marsh ecology interpreted nearly as accurately on the 1:12,000 photographs as on the 1:5,000 photographs. This indicates that, to some extent, more field experience is necessary to use smaller scales of photography. The wide range of accuracies obtained by the interpreters when using the 1:20,000 photography further supports this premise; also the interpreters without actual field experience stated they were uncertain of many identifications on the 1:20,000 photography.

Smaller differences in height were discernable with each increase in scale. With the exception of round stem bulrush and three-square bulrush, the heights detected in the vegetation corresponded with the calculated heights for each scale (figure 4). Apparently, leaves or inflorescence on the upper parts of the plants are necessary for height perception, and the leaves and/or infloescence of round stem bulrush and three-square bulrush were not sufficient.

Photographic images

The physical structure of the plant is probably as important in producing the photographic images as the tone or color of the plant. The marsh types studied can be discussed in groups by physical structures.

Leafy-topped rushes and grasses

The characteristic images produced by leafy-topped rushes and grasses are medium in tone. The heights of these stands are evident. The stands of river bulrush on the photographs of Merrymeeting Bay (appendix I), and the stands of cane *(Phragmites communis)* on the photographs of the Delta Marsh, Manitoba[9], are examples of such leafy-topped plants. Wildrice stands at maturity may produce images with light tones. Those at Merrymeeting Bay were usually flattened down

9 Aerial photographs of the Delta Marsh, Manitoba are included in appendix I to further illustrate some of the photographic images of marsh plants.

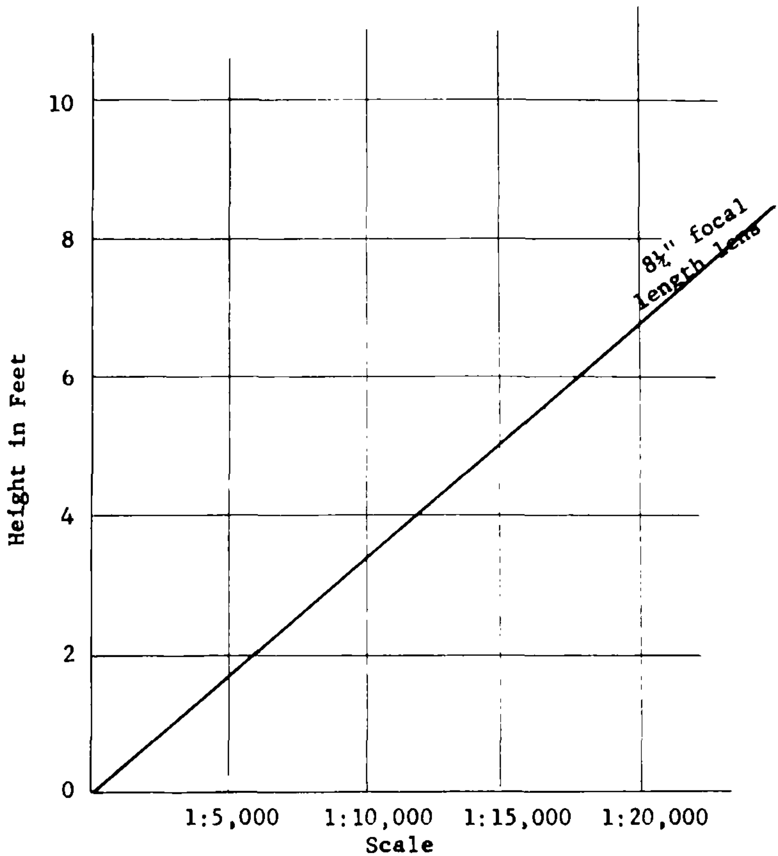

Figure 4

Calculated Height Perception for Photographic Scales Employed in This Study

by wind and tidal action so that no height was obtained from their photographic images.

Bulrushes without leafy tops

The most characteristic feature of the images of round stem bulrush is that height cannot be determined unless the stand is extremely dense or the photography is of very large scale. The edges of the stands are usually indistinct. The tone is dark and the image appears to be formed by the shadows within the stands. The presence of shallow standing water darkens these images considerably; when the water is two feet or more deep, as with hard stem bulrush *(Scirpus acutus)*, the plants frequently cannot be seen. Stands of three-square bulrush produce images which are very diffuse and somewhat reticulated. The denser three-square bulrush stands tend to be confused, in the interpretation, with round stem bulrush; also, due to lack of height perception, both of these types are frequently confused with submersed aquatics.

Plants with sword-shaped leaves

Sweetflag stands have very dark tones (darker than bulrushes) and images with very sharp edges. The flattened, upright leaves produce more shadow than the round stem or three-square bulrushes. The height of these stands is discernible on large scale photography. Cattail *(Typha latifolia* and *Typha angustifolia)* stands which are labeled on the Delta photographs (appendix 1) also have sharp, black images which are uneven in height. Several stands of giant burreed *(Sparganium eurycarpum)* were examined in the field and on the aerial photography. Their images were darker than the round stem bulrush images, but sharp edges were not discernible.

Plants with large flat leaves

Both yellow waterlily and pickerel weed stands produced granular photographic images and tones which were similar to the tone of the individual leaves. The reason probably is that these large-leaved plants reflect more light than most plants with small leaves. The granular image results from clusters of leaves. Height of these stands is evident only on large scale photography. In this study yellow waterlily and pickerel weed could usually be separated by differences in tone and texture.

Submersed aquatic plants

The most characteristic image features of submersed aquatic plants are lack of height and extreme variability in pattern and tone. At Merrymeeting Bay most of the submersed aquatics were exposed at low tide. Their images varied from solid or patchy areas to diffuse reticulations. When reticulations were present they tended to line up with the current or in the direction that the tide receded. Some tone differences were evident on all scales. Beds of submersed linear-leaved arrowhead *(Sagittaria spp.)* were always lighter. On 1:5,000 photographs several tones were evident in beds of submersed aquatics.

The depth to which one can see into water on aerial photographs influences the amount of submersed aquatics that can be observed. Several submersed aquatic beds at Merrymeeting Bay were not visible except on photography made at the lowest stage of tide. Species which grow to the surface are more likely to have discernible images. On the

Delta photography (appendix I), several beds of submersed aquatics with surface growth are labeled. If the three stereo pairs of Delta photographs are examined, it will be noted that the water in certain areas is lighter in tone and that beds of submersed aquatics are easily seen. These differences are due to planktonic algae. A light wind may also indicate beds of submersed aquatics with surface growth, because such growth disrupts the patterns which the wind ripples produce.

Duckweeds and algae

Duckweeds *(Lemna spp.)* have a high light reflectance and produce images with light tones and no height. As duckweeds are not rooted, they are found in places which are protected from the wind. Filamentous algae, which grow at the surface in stagnant waters, also reflect much light. Study of the Delta photography indicated that these duckweeds and algae are likely to be confused. Also, because of their light tones, such areas may be confused with sand and mud flats. Duckweeds are annotated on the aerial photographs of the Delta marsh in appendix I.

Sand and silt

Images of sand are very light in tone and usually have a characteristic pattern. On bars the pattern is rippled and wave-like, and along shore lines the pattern is smooth. Certain areas in this study were elected to test confusion of sand images with those of flattened, dense wildrice. Little confusion was noted.

On the Merrymeeting Bay photographs, silt images were usually medium in tone and with or without a pattern. If a pattern was present it consisted of diffuse reticulations that paralleled the channels or bays. These reticulations resulted from areas of fine sediments on the surface of the silt. Silt or mud flats have a very high light reflectance on some photography; consequently, they appear very light in tone and can be confused with other light-toned images.

Mixed vegetation

Two kinds of mixtures were evaluated in this study. One was a rather coarse mixture of vegetative types, such as round stem bulrush and pickerel weed, and the other was the high tide zone, a finely integrated mixture of many species.

In the mixtures of types the correct identity was stated more often when the tones of the components were dissimilar. Mixtures of similar tones tended to be identified as one of the components.

The high tide zone was composed of many species, none of which could be recognized. The tone and texture were both very even, probably because of the finely integrated nature of the type. The white top sloughs on the Delta photographs are also examples of finely integrated mixtures.

Review of literature

The use of aerial photographs for the study and mapping of wetlands is not new. They have been used to identify these areas and to map the broad ecological zones within various kinds of wetlands. Some of the previous studies have recognized species of plants on aerial photographs as indicators of the ecological zones. However, no quantitative evaluation of such interpretation was found in the literature.

Several workers have described the use of aerial photographs in mapping vegetation of marsh areas. In Massachusetts, MacConnell and Garvin (1956) recognized five types of fresh wetlands and one of salt marsh. Their classification is based in part on the wetlands classification which was set up by Martin, *et al.* (1953). Dalke (1937) stressed the value of aerial maps and ecological principles in mapping vegetation, and described the mapping of ecological zones such as submersed vegetation, floating leafed species, and also rushes and cattail. Nicholson and Van Deusen (1953) recognized six types of coastal marshes in Maryland. However, the aerial photographs were used chiefly for delineating major plant zones, and identification of the plant composition of these zones was made in the field. O'Neill (1953) studied the vegetative types in the Chesapeake Bay area. He constructed a set of keys for interpreting ecological zones in coastal marshes during the four seasons of the year. In the Wetlands Survey of Maine (1954) aerial photographs were used primarily for locating marsh areas. Zohari, *et al.* (1955) studied tone differences on aerial photographs of papyrus stands in the Hula Marshes of Israel. They were unable to find a relation between density of plants and tone of photographic images.

Tundra and range vegetation have some photographic characteristics which may apply to marsh vegetation. Churchill (1951) studied aerial photographs of tundra vegetation. He found considerable variation in the photographic images and was unable to establish the reliability of using aerial photographs of tundra vegetation. The Manual of Photogrammetry (1952) indicates that species composition and density of range vegetation can be mapped by using aerial photographs in part and field identification in part. Colwell (1946, 1948) demonstrated that several kinds of tropical crops and natural low vegetation could be identified on aerial photographs.

Cameron (1950) identified seaweed beds off the coast of Nova Scotia on panchromatic and color photography. He recommended panchromatic film with a green filter for general survey procedure. With this film/filter combination, seaweed beds in water up to four fathoms deep could be mapped. In low-altitude continuous-strip photography he found color transparencies superior to panchromatic prints. Several other comparisons of film material have been made; however, none of these were on photographs of marsh vegetation. Young (1953) counted plots of trees using infra-red prints, infra-red positive transparencies and color transparencies and found no significant differences between films. Shulte (1951) evaluated infra-red prints, panchromatic prints, and color transparencies for identification of tree species in southeastern Canada. He found that infra-red was superior to, and panchromatic about equal to, color transparencies. Spurr and Brown (1946) also found that infra-red was superior to panchromatic and color positive films for tree identification, but that color, when properly processed, was superior to panchromatic.

Young (1953) compared the accuracies of counting trees on several scales of photography and reported a 20 per cent overall increase in accuracy between 1:15,840 and 1:3,500. Spurr (1948) reviewed the scales of photography which are commercially available and recommended 1:15,840 for general forestry work, and larger scales for more detailed interpretation. On the basis of accumulated research information, Stone (1956) suggested that species of brush and grass, and specific crops could be identified at scales larger than 1:10,000.

The military photo interpretation schools recognize that a familiarity with the subject being interpreted is an aid to accurate interpretation (Gardner, 1948). Military photo interpreters are trained in a series of phases, each of which covers one subject. During a particular phase a student learns what the subject looks like on aerial photographs, and he also becomes familiar with it on the ground.

Pomerening and Cline (1953) studied the preparation of soil maps by various persons. They found that if a person had no field experience in the area being mapped his accuracy was lower than that of a person with field experience. They also found that as areas increased in complexity the accuracy of mapping decreased. DeLancie, *et al.* (1957) also evaluated the factor of experience in their study of photo interpretation keys. When interpreting naval vessels and abstract objects, inexperienced photo interpreters scored as well as the experienced photo interpreters, but the experienced photo interpreters had a higher accuracy when interpreting vegetation.

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Appendix I

Aerial Photography

Six stereo pairs of aerial photographs illustrate some of the problems discussed.

The first three sets are panchromatic prints of a portion of the Merrymeeting Bay study area. Some of these areas were used in the interpretation tests.

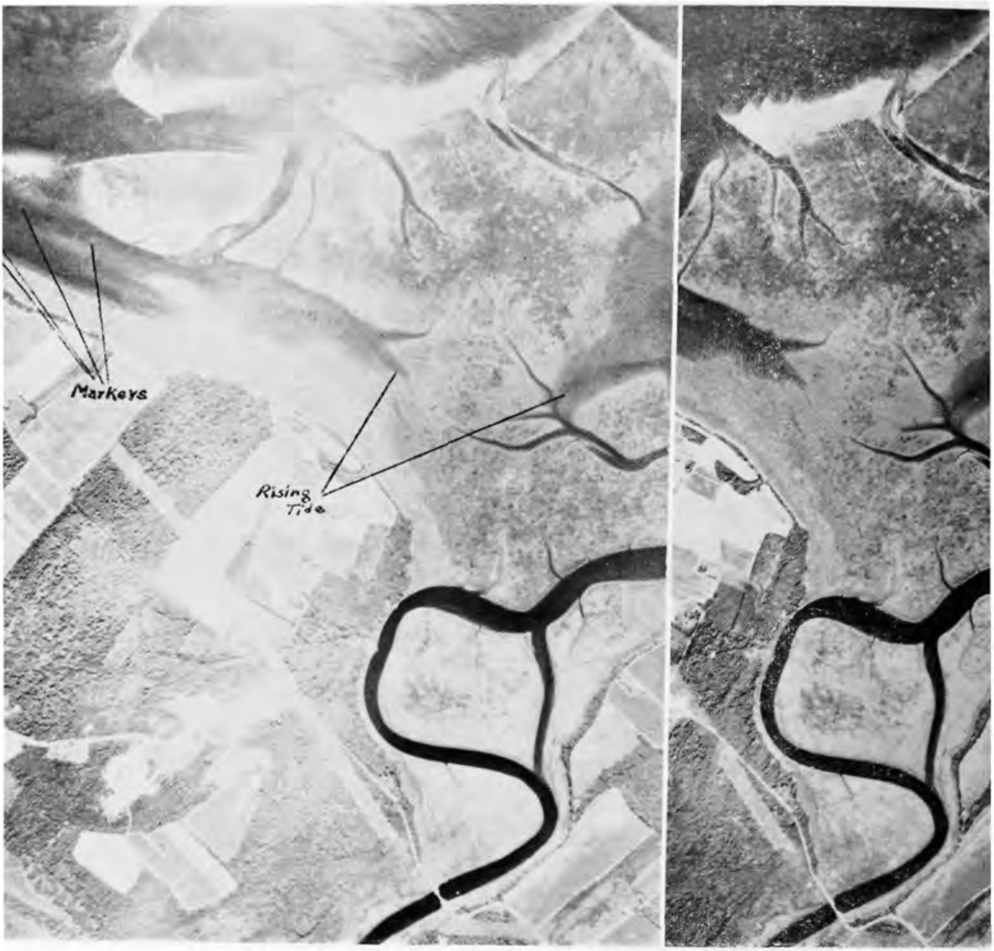
The last three sets are panchromatic prints of the Delta Marsh, Manitoba. While they are not a part of this study, they have been included to supplement the illustrative material. Information concerning these was obtained by the author while assisting S. T. Dillon in field work on the area in 1956.

The photographic images, which are separated by 2⅛ inches, allow stereo vision for the average range of interpupillary distances.

Annotations used on the photography are as follows:

Wildrice — Wr
Round stem bulrush — Rs
River bulrush — Rb
Sweetflag — Sf
Yellow waterlily — Wl
Pickerel weed — Pw
High tide zone — Ht
Three-square bulrush — 3 sq

Submersed aquatics — Sub
Sand — Sand
Silt — Silt
Duckweeds — Du
Phragmites (cane) — Ca
Cattail — Ct
White top sloughs — Wt

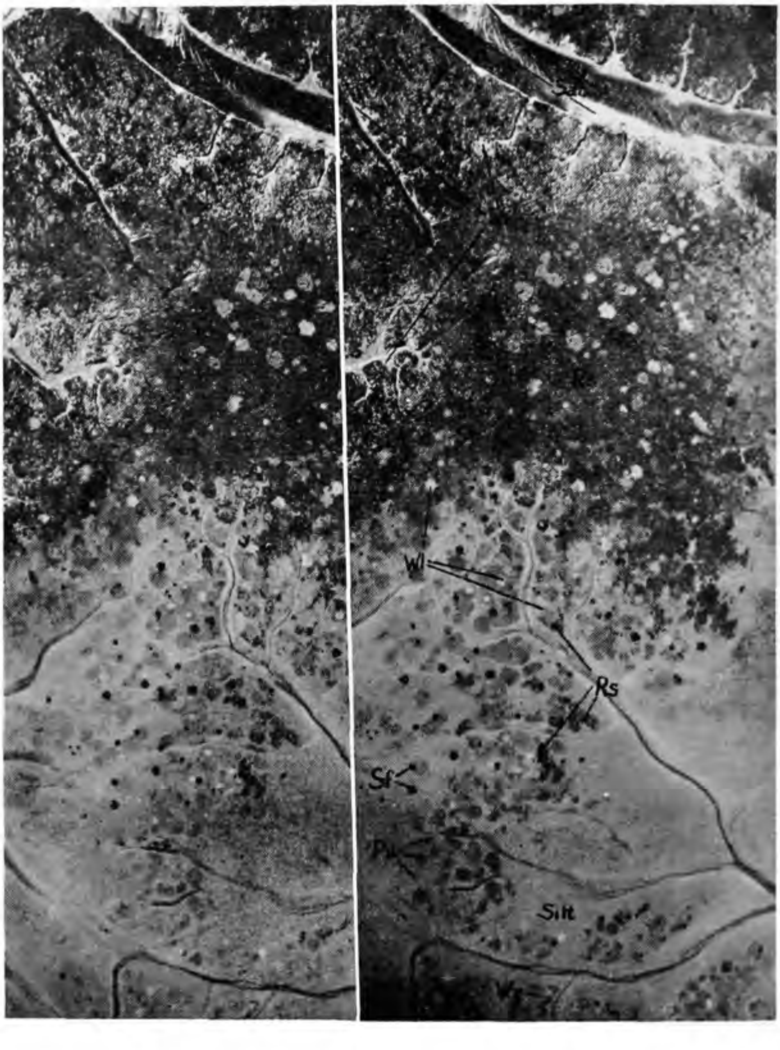


Panchromatic Aerial Photographs of Merrymeeting
Bay, Maine, Scale—1:20,000
Date—August 25, 1957

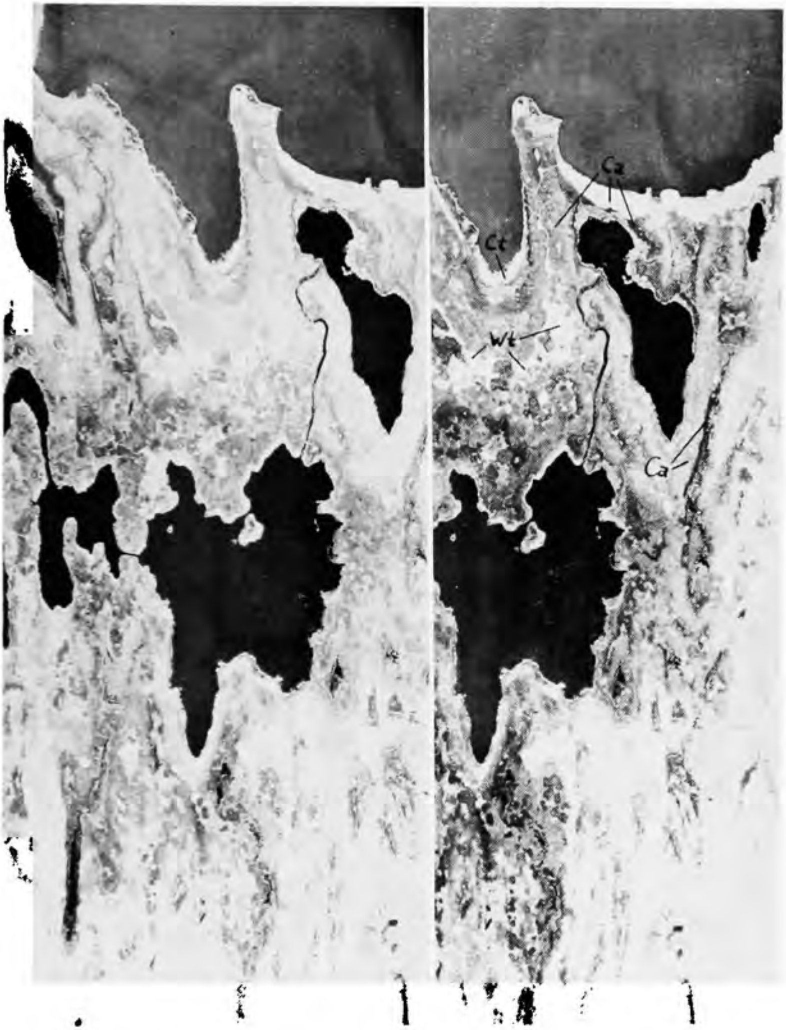
Note:

1. Surface markers of tests for photographic penetration of water.
2. Increase in area covered by water of rising tide as compared to the 1:12,000 and 1:5,000 photographs.

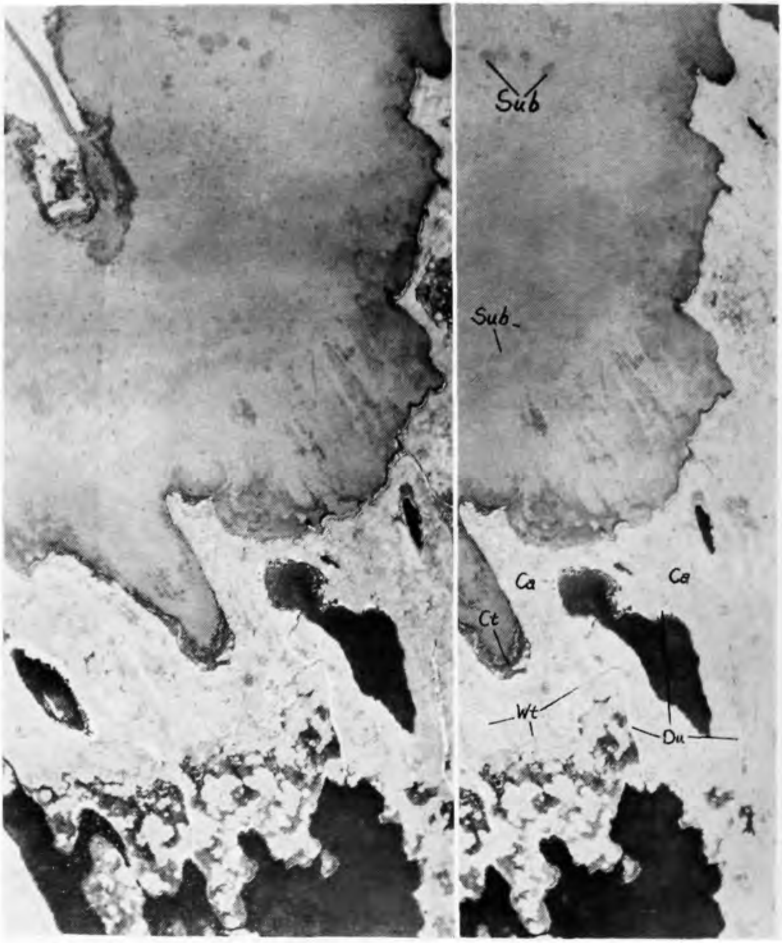
Panchromatic Aerial Photographs of Merrymeeting
Bay, Maine. Scale—1:12,000
Date—August 25, 1957



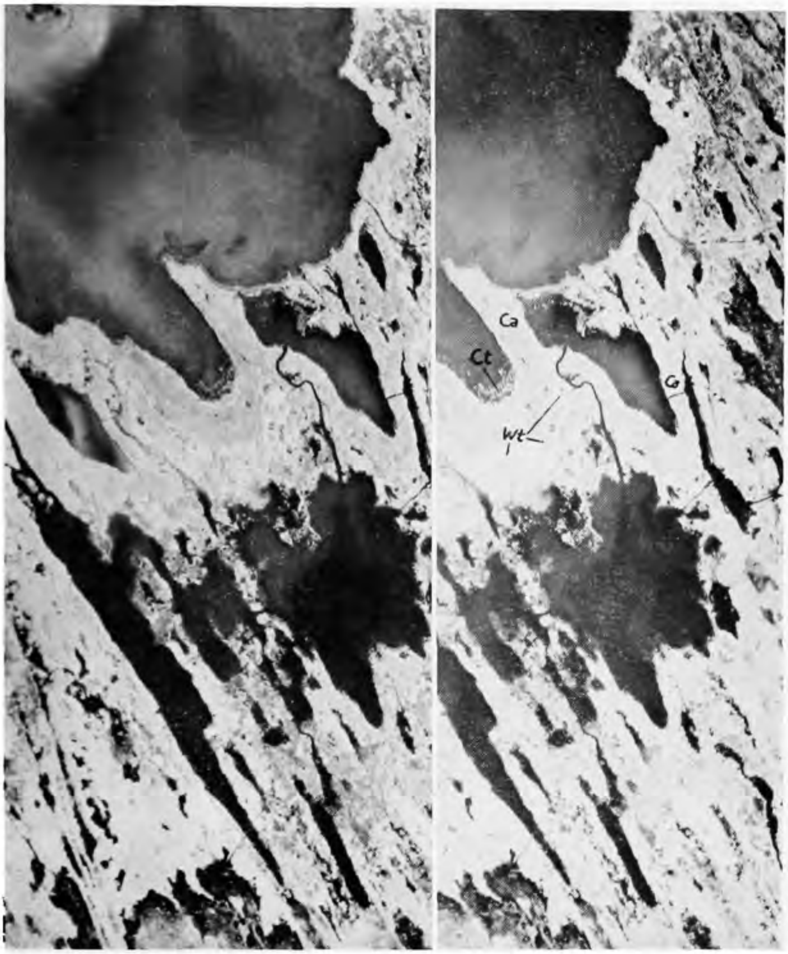
Panchromatic Aerial Photographs of Merrymeeting
Bay, Maine, Scale—1:5,000
Date—August 25, 1957



Aerial Photographs of the Delta Marsh, Manitoba Taken in
Early Spring at Normal Water Level, Scale—1:15,840
Date—May 8, 1946



Aerial Photographs of the Delta Marsh, Manitoba Taken in
Late Summer at Normal Water Level, Scale—1:17,000
Date—September 1, 1948



Aerial Photographs of the Delta Marsh, Manitoba Taken in
Late Summer at High Water Level, Scale—1:20,000
Date—September 3, 1954

Appendix II

Descriptions of the Eleven Classifications of Marsh Vegetation Interpreted

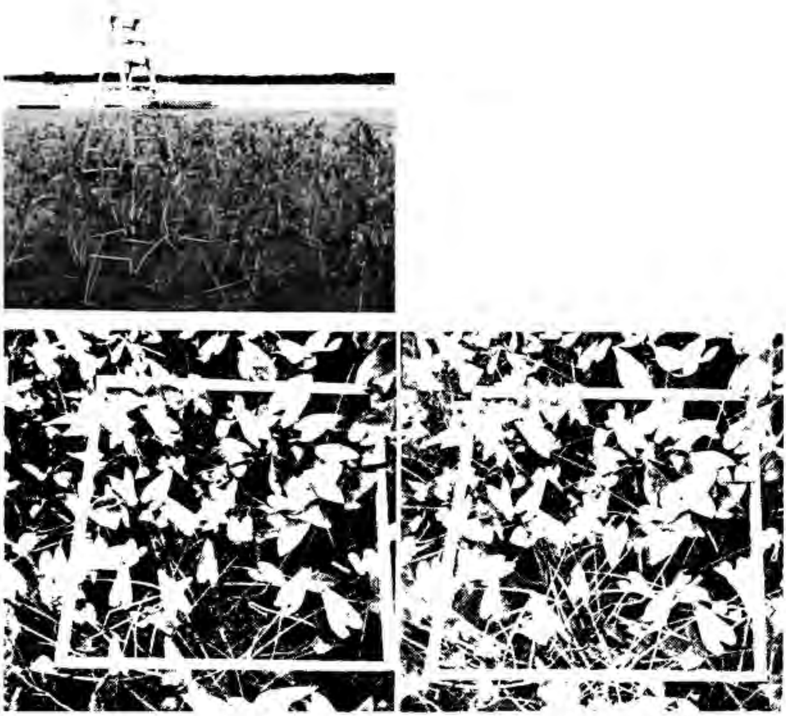
Type: Yellow Waterlily (Wl)

Photographs: A medium-dense stand just as the tide was flooding.

Description: In addition to the waterlily or spatter dock, this type contains occasional stems of round stem bulrush, three-square bulrush, submersed aquatics, and wildrice. It grows in sparse patches on exposed areas, as medium to dense patches in other vegetation, and as extensive beds in protected coves. The soil is usually silt or sandy silt, and it is found in association with all of the types except sand.

Image Characteristics: This type has a very granular image which is green or yellow-green on color films, and a medium gray on panchromatic films. Height is evident only at scales of 1:5,000 and the granular texture may not be noticed at scales of 1:20,000.

Remarks: The round or lobate patches of this type, which occur in most situations, and the large unbroken stands of waterlily suggest that this is a very successful species on the study area.



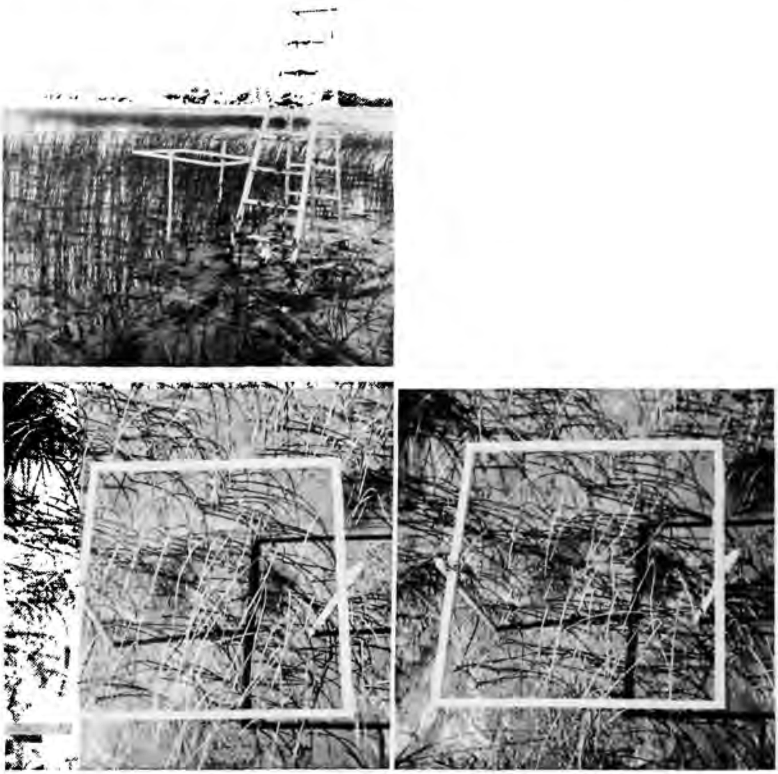
Type: Pickerel Weed (Pw)

Photographs: Sparse stand on silt flat (left). Dense stand (right)

Description: Pickerel weed usually occurs in pure stands, but there may be a few submersed aquatics present. It seems to be a pioneer species, for it grows regularly on open areas of silt as lobate patches and along edges. The soil is usually silt, and it is associated most often with three-square bulrush, submersed aquatics, round stem bulrush, sweetflag, and waterlily.

Image Characteristics: Pickerel weed has a slightly granular image and is usually medium to dark green on color photography, and medium gray on panchromatic photography. The edges of stands are usually distinct.

Remarks: Pickerel weed seems to be a pioneer type, because it is frequently found on open areas of silt or edges, and it is seldom found in dense vegetation.



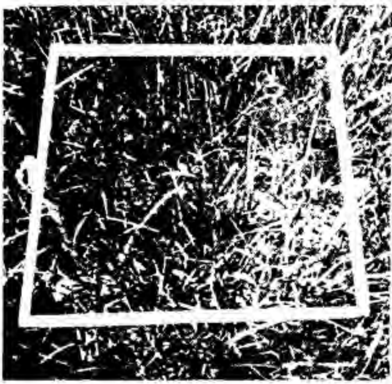
Type: Three-square Bulrush (3 sq)

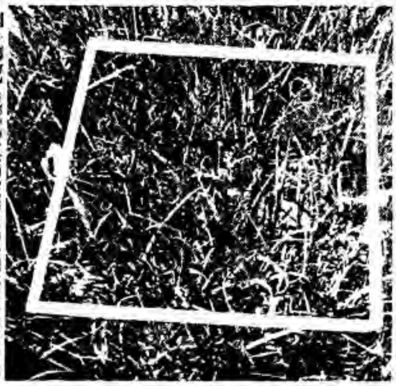
Photographs: Sparse stands of three-square bulrush on silt. Notice submersed aquatics.

Description: Frequently mixed with submersed aquatics and always grows on areas of open silt or along edges. This type does not grow in dense stands.

Image Characteristics: Indistinct pale green areas on color films, and indistinct medium gray areas on panchromatic films. This image is very "fuzzy," but it may be quite distinct in some stands near the high water areas.

Remarks: Very hard to separate from sparse submersed aquatics, or silt.





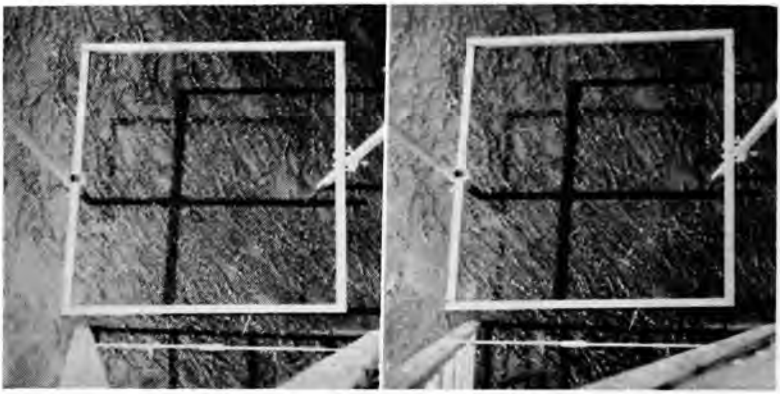
Type: Sweetflag (Sf)

Photographs: A dense clump of sweetflag growing on an open silt area.

Description: Sweetflag usually occurs in dense, pure stands, but occasionally stems of wildrice, round stem bulrush, three-square bulrush, and submersed aquatics are found. It is found most often with silt, pickerel weed, round stem bulrush, and waterlily, and it grows on silty soils.

Image Characteristics: The texture is smooth and the edges of the stand are sharp. This is the darkest image (dark green or black) found on any of the photography. Height is not visible at scales of less than 1:5,000. Stands are mostly round or lobate, but they may be reticulate.

Remarks: Sweetflag grows most thriftily in open areas where its stands are round or lobate. Frequent "doughnut" shaped stands indicate that it creates conditions in the center that are unfit for its own growth. In areas of mixed dense vegetation, sweetflag stands are usually reticulate or irregular in form.



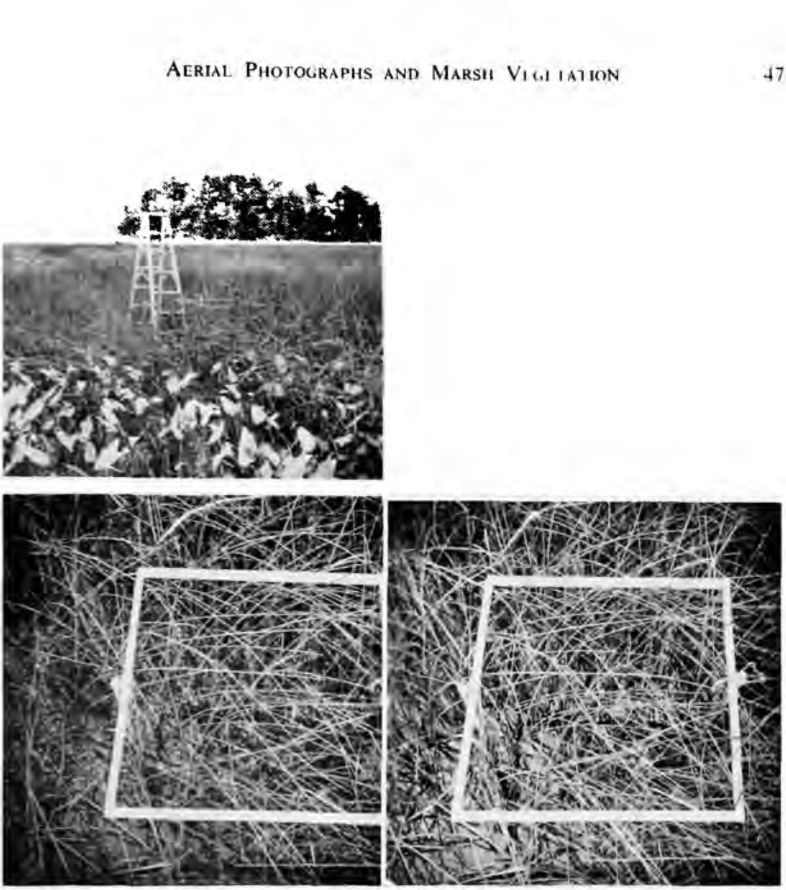
Type: Submersed Aquatics (Sub)

Photographs: Dense beds of claspingleaf pondweed *(Potomageton perfoliatus)*

Description: Submersed aquatics grow on silty soils and are always found in the water or on areas that are exposed the least by low tides. This classification includes all the submersed species found on the study area. The types most frequently found with submersed aquatics are silt, three-square bulrush, and round stem bulrush.

Image Characteristics: Extremely variable. Occur as patches, strings, or solid beds. Color (green) and shades of gray are variable. Frequently there is a reticulate pattern with most lines running in the direction of the tide.

Remarks: Association with water or low tide is a definite aid in interpreting submersed aquatics. Variations in color suggest some species identification may be possible.



Type: Round Stem Bulrush (Rs)

Photographs: Dense stand of round stem bulrush

Description: Occurs mostly as pure dense stands in protected areas and as sparse stands in exposed areas. Frequently stems of wildrice are found in and near round stem bulrush stands. This is the plant at exposed sandy edges. It grows on either sand or silt and is usually associated with wildrice, submersed aquatics, silt, sand, and river bulrush.

Image Characteristics: The most characteristic feature of round stem bulrush images is that height cannot be detected at any of the scales tested. The images are blotchy and dark and have indistinct edges. Dark green on color, and dark gray on panchromatic.

Remarks: Occasionally many plants in a stand will be bent over, and heights of such stands can be seen.

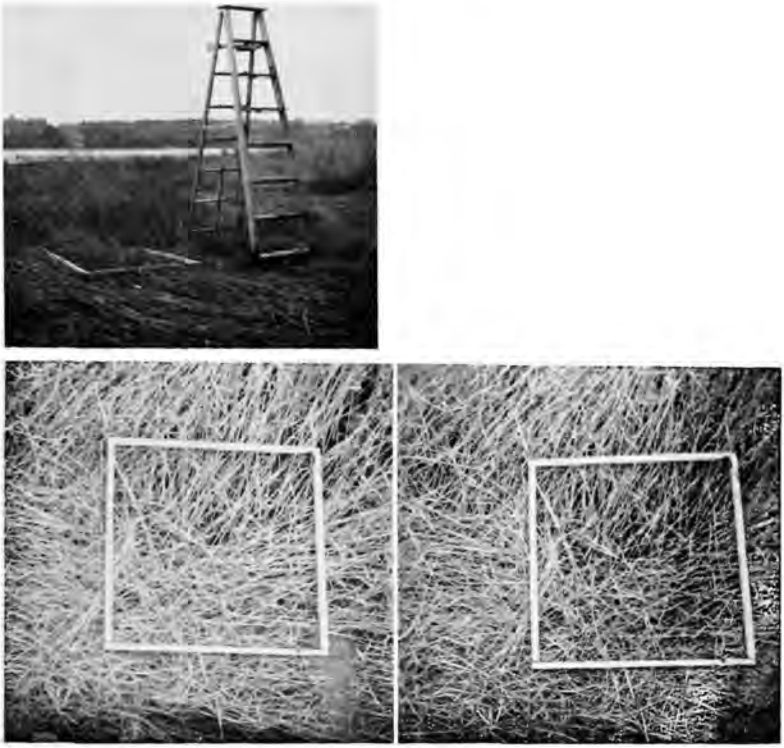
Type: High Tide Zone (Ht)

Photographs: General and detailed views

Descriptions: This type is the "shallow fresh coastal marsh" described by Shaw and Fredine (1956). It always occurs near the high tide limit along shores. Plants composition is variable, but it usually includes scattered wildrice, three-square bulrush, and spike rush (*Eleocaris* spp.). Soil type is either sand or silt.

Image Characteristics: Smooth tones of gray on panchromatic photography, and amber colors on color photography indicate this area.

Remarks: Very easily interpreted because of location and color. Widely different plant compositions in this area produce similar photographic images.



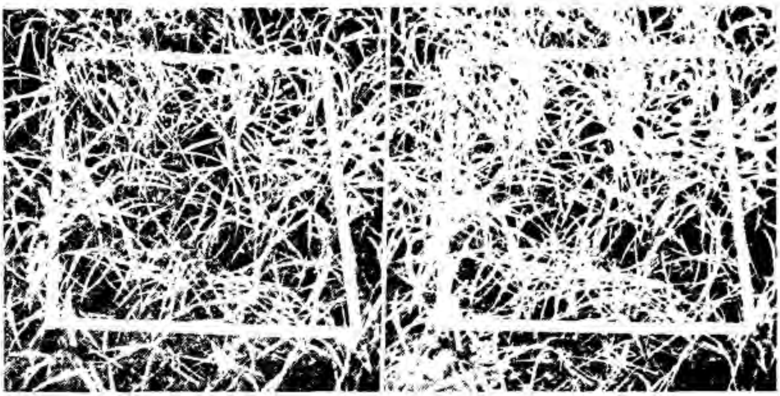
Type: Wildrice (Wr)

Photographs: Dense stands of wildrice (prostrated by the tides).

Description: Usually occurs as pure dense stands and, as on this photography, it is usually prostrate. Typically found in protected coves with soft silt bottoms. The high tide zone and yellow waterlily are most often associated with wildrice.

Image Characteristics: Images usually have no height, or the rice appears to lean on other vegetation. Wildrice appears white on panchromatic photography and yellow-green or yellow on color photography.

Remarks: Some areas of standing wildrice may be present. These areas have light colored, uneven images and the height is evident.



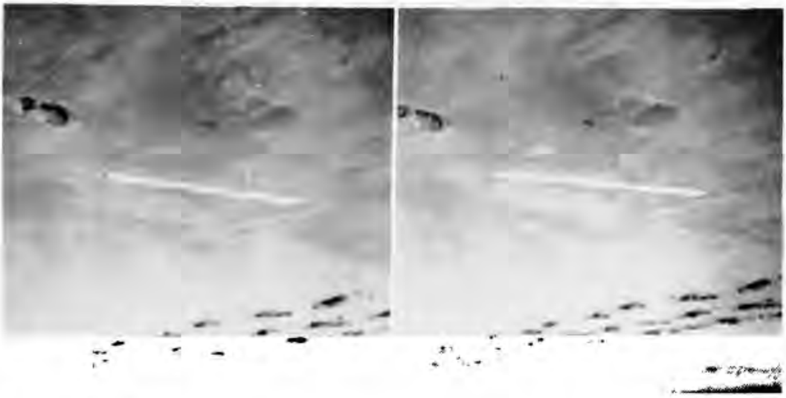
Type: River Bulrush (Rb)

Photographs: A patch of river bulrush within a larger stand of round stem bulrush.

Description: Grows in dense stands. Usually in areas of round stem bulrush, waterlily, and wildrice. Usually the river bulrush stands do not have any other species mixed with them. The soil material is commonly silt.

Image Characteristics: The leaves are primarily at the tops of these plants and they produce a very noticeable height on the photographic image. The texture of the photographic image is smooth with occasional pits.

Remarks: Difficult to see height on 1:20,000 photography, but very definite heights on 1:5,000 and 1:12,000 scales. Always occurs within a vegetated area.



Type: Silt (silt)

Photographs: Stereo pair of a typical silt flat showing blotches or streaks.

Description: This type consists of silt flats barren of vegetation, or with extremely sparse growth. Commonly found near water and with three-square bulrush or submersed aquatics.

Image Characteristics: Smooth in texture. On color silt appears brown or purple-brown, and on panchromatic photography it has a medium gray tone. Reticulations are often present, and they parallel the channels.

Remarks: When silt areas have considerable sand present they may appear very light.

No Photographs Available

Type: Sand (sand)

Photography: None

Description: Areas of granular quartz sand, which support little vegetation except round stem bulrush and three-square bulrush. Usually bare sand is found along the edges of channels or in open water areas where there is considerable wave action.

Image Characteristics: Very light due to large amounts of reflected light. On panchromatic photography the sand areas are usually white, and on color they are pale yellow-brown. Frequently has scalloped surfaces due to wave action.

Remarks: Found only in areas with strong currents.

Appendix III

Description of the Line Intercept Sampling Method

In an attempt to describe accurately the plant composition of the test areas, the following modification of the line intercept sampling procedure was employed.

Materials:

1. One steel rod ten feet long and ⅜-inch in diameter, on which each 1-foot, and each 1/10-foot unit was marked (see photograph, page 53).
2. Two wooden stakes four feet long with adjustable loops to support the ends of the rod.
3. Mimeographed cards on which to record data (see sample card, page 53).

Procedure:

The location of the rod within each area to be samp'ed was selected randomly. The rod was passed through the vegetation, or over it, and supported at both ends by the stakes. Care was taken not to alter the position or composition of the plants prior to recording data.

Each species that occurred above or below a 1/10-foot unit was marked "one. Data were recorded for each 1-foot unit, and totaled for the 10-foot sample. The height of the rod above the ground was adjustable to three feet, but frequently data for taller species had to be estimated. Visual examinations were made in the areas around the samples, and any species not included in the samples were recorded. Estimates of density (sparse, medium, and dense) were also made for each species.

The information obtained was species composition, an approximation of the per cent of ground covered by each species, and an index of frequency.

Advantages of Method:

1. Rapid to use (about five minutes for a 10-foot sample).
2. One person can use it effectively.
3. Suitable for plants of different heights.
4. Does not disturb sample area prior to recording data.
5. Results vary little between observers (five trials of two persons averaged 1 per cent difference).

Disadvantages of Method:

1. Per cent of ground covered is exaggerated for some species which occur sparsely.
2. Per cent of ground cover is exaggerated when species such as wildrice are prostrate.
3. Estimations have to be made for the taller species.

Sampling Rod in Sparse Three-Square Bulrush

Area:	Sample No.				Date
Plant Assoc:	Soil Type:				
Wind:	Foot Number:	C*	T*	D*	Remarks
Species	1 2 3 4 5 6 7 8 9 10				

Other Species found:

C – percent of cover; T – Discernible height; D – Density

Example of Card for Recording Sampling Data

Appendix IV

Statistical Analysis

Analysis of Variance
Photo Interpretation Accuracy in Terms of Films, Scales, and Interpreter Experience for Test Areas on Merrymeeting Bay, Maine

Due to:	Degrees of freedom	Sum of square	Mean square	F ratio	Significance
Film	3	27.063	9.021	0.743	
Scale	2	2053.16	1026.583	84.583	**
Interpreter experience	3	230.230	76.743	6.323	*
Error	39	473.340	12.137		
Total	47	2,783.800			
Correction factor	1	22,945.020			
Grand total	48	232,279			

**Significant at the 99 per cent level.
*Significant at the 95 per cent level.

Analysis of Variance
Photo Interpretation Accuracy in Terms of Films and Interpreter Experience at a Scale of 1:20,000 for Test Areas on Merrymeeting Bay, Maine

Due to:	Degrees of freedom	Sum of square	Mean square	F ratio	Significance
Film	3	40.663	13.554	0.62	
Interpreter experience	3	82.688	27.563	1.27	
Error	9	157.087	21.227		
Total	15	275.438			
Correction factor	1	58,201.562			
Grand total	16	58,477			

Analysis of Variance
Photo Interpretation Accuracy in Terms of Films and Interpreter Experience at a Scale of 1:12,000 for Test Areas on Merrymeeting Bay, Maine

Due to:	Degrees of freedom	Sum of square	Mean square	F ratio	Significance
Film	3	102.792	39.264	2.50	
Interpreter experience	5	350.375	70.075	5.27	*
Error	15	199.458	13.297		
Total	23	652.652			
Correction factor	1	120,550.395			
Grand total	24	121,211.000			

*Significant at the 95 per cent level.

Analysis of Variance
Photo Interpretation Accuracy in Terms of Films and Interpreter Experience at a Scale of 1:5,000 for Test Areas on Merrymeeting Bay, Maine

Due to:	Degrees of freedom	Sum of square	Mean square	F ratio	Significance
Film	3	8.188	2.729		
Interpreter experience	3	52.438	17.479	3.07	
Error	9	51.312	5.701		
Total	15	114.938			
Correction factor	1	92,264.062			
Grand total	16	92,379.000			

Appendix V

Results of a Survey of the Costs of Aerial Photography

Cost of aerial photography is based primarily on the length of time the photographic aircraft is in the air. Other factors which affect cost to a lesser extent are flying weather, work load, season, size of area covered, type of film material, and exactness of specifications.

In January, 1958, a letter-type questionnaire was circulated to 12 aerial photographic concerns in the United States and Canada to obtain general information on costs and capabilities. Seven of these letters were answered and returned. Costs are extremely variable and change particularly with time; the information here presented should be evaluated accordingly.

Estimates of costs for photographing 36 square miles with 1:20,000 panchromatic film varied from $285 to $1,440. Most of the estimates were between $500 minimum and $1,000 maximum.

The costs for photographing one square mile at the same specifications were also requested. These estimates varied from $50 to $350 if flown at the photographer's convenience, and from $75 to $500 if flown at the customer's convenience.

Most of the concerns indicated that costs vary by season, flying weather, and work load.

A general rule has often been stated that "as scale is doubled cost is quadrupled." Two of the concerns agreed with this rule. The other five concerns estimated doubling or tripling of cost as scale doubled. Five of the concerns indicated that they could take aerial photographs on color transparencies, and four indicated that they could expose and process the color print material.

Estimates of the additional costs for color photography varied from a flat rate of $50 to $100, or 20 to 100 per cent more than panchromatic. It should be pointed out that with large flying contracts, the extra cost of color is absorbed by the large size of the job.

In summary, the primary factor in costs of photography is the length of time the aircraft is airborne. Costs can be expected to double, triple, or quadruple for each doubling of scale. Costs for color photography are higher when small amounts of photography are taken.

Information Received on Seven Letter Questionnaires to Aerial Photographic Concerns

1. What is your estimate for flying 36 square miles of stereo coverage with the following specifications?
   a. 1:20,000 scale
   b. panchromatic film
   c. six inch focal length
   d. within 100 mile radius of your airport
   e. normal amount of overlap, number of prints, mosaics, etc.

Maximum price	Minimum price
$1,440	$900
1,200	750
1,000	750
1,000	500
750	500
500	350
285	250

2. What will the cost be to cover one square mile at the above specifications?

At your convenience	At the customer's convenience
$ 75	$100
200	350
350	500
200	500
75	75
100	200
50	110

3. Will the cost vary with work load (yes 5, no 2), season (yes 6, no 1), and flying weather (yes 7, no 0)?

4. A general rule has been stated that as scale is doubled cost is quadrupled. Do you agree with this statement (yes 2, no 5)? If not, can you cite a figure? Doubled 3, Tripled 1, Doubled to tripled 1.

5. Does your firm have the capacity to expose and process the following?
   a. color positive aerial photography, i.e., Ektachrome
      yes 4, no 2, limited 1
   b. color negative materials, i.e., Ektacolor
      yes 4, no 3

6. How much more would the 36 square miles of coverage mentioned in question No. 1 cost if flown in color positive aerial photography?

    Answers:

    no figure available
    20 per cent
    we don't do color photography
    1.5 to 2.0 X
    $50 maximum
    $100 maximum

Appendix VI

Suggestions for Obtaining and Interpreting Air Photos of Marsh Vegetation

Use of existing photography

Practically all of the United States and large portions of Canada have been photographed from the air one or more times; prints of most of this photography are available at prices much below that of new material. When planning to obtain photographs of an area, one should consider these prior coverages. Frequently, the date, season, or scale of prior coverages is unsuitable, but in most cases some information can be obtained and in a few cases prior coverages are very useful. The table on page 62 contains a list of scales commonly available, descriptions of what the photography is used for, and some information as to how extensive it is.

Examination of vegetation

If existing photographic coverages are not available or not useful, new photography may be considered. Before ordering new photography, the structure, color, and tones of the vegetation should be examined in the field. These comparisons may indicate how useful a new photographic coverage would be.

In Merrymeeting Bay, vegetation at distances of 100 yards appeared either as patches of one species or mixtures of many species, which were mostly unidentifiable. On aerial photographs of the same area the "patches of species" could be recognized, but the mixtures could only be recognized as such.

It is doubtful whether areas of very sparse plant growth can be recognized on aerial photographs.

Selection of film

Panchromatic aerial photographs were less expensive, more easily obtained, and as useful for interpretations of this type as the other three films. Based on the results which Cameron (1950) obtained with seaweed, it may be advisable to employ a green filter when areas of submersed aquatics are photographed. Also, it may be advisable not to employ haze filters when water penetration is desired, as they tend to darken images of water.

Selection of scale

When selecting photographic scales, the information desired, the experience of the person who will use the prints, and the costs[10] of the photography should be considered. For mapping or non-quantitative evaluations of marshlands, 1:20,000 photography is adequate. It is an excellent scale for studying the broad ecological relationships within and between marshes, because nearly nine square miles can be viewed on each photograph. Most mapping of wetlands has been with photography of this scale. For detailed identification of plant species, scales of 1:15,000 or larger are advisable. In this study, interpreters who were familiar with marshes interpreted 1:12,000 photographs nearly as well as 1:5,000 photographs. For inexperienced personnel, the largest scale possible should be obtained.

Time of photography

When planning aerial photography of marshlands, or when using existing coverages, the date, time of day, and water level should be considered. The photographs of Merrymeeting Bay were taken at near maximum plant growth in late summer. Although there were no suitable coverages of different dates for comparison, these seemed to provide adequate information. Comparison of the Delta photographs made in spring and late summer (appendix I) indicates that interpretation is much easier with the latter. In the spring, *Phragmites* growth shows three different tones, and in summer it appears as one tone only. Likewise, in the spring, cattail and round stem bulrush stands are very light and hard to separate, and the submersed aquatics have not developed sufficiently to be seen. The white top sloughs, however, are more evident on the spring photographs.

For many purposes aerial photographs are best taken at mid-day. For marshes it is suggested that they be taken in the morning or afternoon. Marsh vegetation does not produce extensive shadows, while those that are produced are useful in interpretation. Also, as the sun's rays approach an angle of 90° the reflectance from water and wet surfaces will increase. Morning photography is preferable, because haze and clouds are usually less.

When photography has to be timed for low tides, and the range is four to six feet, the time of photography should not be more than one hour on either side of low tide.

In this study the presence of water in and around stands of vegetation made interpretation much more difficult. Therefore, it is suggested that aerial photographs of marshes be taken at low water levels. Water level fluctuations which last over considerable periods of time change both the amount of and species composition of the vegetation. While aerial photographs may be an important means of measuring these

[10] In appendix IV the results of a survey concerning costs of aerial photography are presented.

changes, analysis of vegetation on photographic coverages should be made with consideration of water levels and time of photography. A comparison of photographs on pages 40 and 41 illustrates long-term water level changes and their effects.

Interpreter training

An adequately trained interpreter can work more accurately, more rapidly, and will have more confidence in his interpretations than an interpreter with insufficient training. Results of this study indicate that training in the use of a stereoscope can be obtained easily and quickly; also, that some field training, which may be self-acquired, is necessary, regardless of prior experience. Experience and training are usually acquired during the steps in the selection of a satisfactory classification system, but each set of interpretations and field checks adds to this training.

A classification system

Before accurate and efficient interpretation of vegetation can be performed, a satisfactory classification system must be devised. The steps necessary are the same in all photo interpretation studies. They consist of; examination of photographic images and the corresponding objects, selection of a tentative classification, trial interpretations, and field checks. Usually, repetition of these steps is necessary. All of the types in the classification system should be those which can be identified on aerial photographs. The situation with respect to three-square bulrush, described in this study is a good example of a classification which should not be included.

Field verification

Since photo interpretation is an art as well as a science, some errors are unavoidable (Young, 1953). For information obtained by interpretation to be properly assessed, the errors must be quantitatively determined by a series of field samples.

In this study, the true identity of all stands of vegetation was known. Obviously, this cannot be done in practical applications, but a field sample consisting of a number of stands of each type can be identified, and the accuracy of the sample applied to the photo interpretation results.

Scale Equivalents, General Usage, and Availability* of Aerial Photography

Reciprocal fraction	Equivalent	General uses	Availability
1:5,000	1" - 416'	Detailed interpretation. Town planning.	Limited, usually small areas.
1:7,920	1" - 660'	Forestry, detailed interpretation.	Limited, usually forest lands.
1:10,000	1" - 833'	Agriculture - crops.	Limited
1:12,000	1" - 1,000'	Highway planning. Detailed soils studies.	Very limited
1:15,840	1" - 1,320' 4" - 1 mile	Agriculture, forestry mapping.	Extensive of Canada, United States, Alaska
1:20,000	1" - 1,667'	Mapping, Soil Conservation Service. General uses, agriculture.	Most available and widely used civilian photography
1:24,000	1" - 2,000'	Geological Survey Mapping	Available in states with current topographic mapping
1:31,680	1" - 2,640 2" - 1 mile	Mapping, forest inventory	Extensive
1:40,000	1" - 3,333'	Mapping, reconnaissance	Extensive of U. S. usually old photos.
1:50,000	1" - 4,166'	Air Force Reconnaissance	Much of Alaska
1:70,000	1" - 6,333'	Reconnaissance	Parts of Maine

*Information concerning availability of coverages of particular areas is available from the Office of Map Information, U. S. Geological Survey, Washington 25, D. C.