Application of Remote Sensing to benthic marine algae Monitoring

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-------Abstract-------

Benthic marine alge are very important for fisheries resouses and coastal enviroment. And these management or monitoring are noticed. Aerial color photographs have derived much usefull information in assessing shallow water zone. In this papper, photographic image enhancement and mapping of benthic marine algae from the aerial color photographs are discussed.

Introduction

In Japan, benthic marine algae such as Laminariales, Undaria, Hizikia bsijorme, Porphyra and so on, have been used as food since Code Marked Potry era (about 2,000-10,000 B.P.). As the evidence, many species names of algae can be found on WAKAs (Japanese poem consisted by 31 words) in Man-you-syu which is the oldest poetry in Japan, published on Nara era. Even modern times, these algae can also be utlized for foods, medicines, and housing materials.

Also, benthic marine algae's zone are very important for coastal enviroment. Especialy, these zone are fish's spawn places and also breezing places for young fishes, shrimps, and other micro creatures. Then, management and/or monitoring of benthic marine algae are comming into noticeable.

A conventional method of monitoring benthic marine algae used to be site investigation with a glass box from the boat. But this is not economical method in wide areas. So recently, color aerial photographs have been utlized.

It is often defficult to identify the boundary of benthic marine algae from the sea bottom on the color aerial photographs. Especialy, the algae growing up beneath the sea deeper than 7-10 meters, is not able to recognize by human eyes. So, the authors applied analogue image processing (masking method)for delineating the bundary benthic marine algaes from the sea bottoms.

Optical charactristics of algaes and waters

Fig.1. shows the spectral reflectivity of benthic marine alge which was carried out by the authers with a spectrometer. The reflectivity spectrum of algae has a small peak around 560-600 n.m., and in near infra-red band, it has a high platoe the reflectivity of which reaches up 60-70 %.

At first, discrimination depth of algae on the color aerial photograph should be considered for photography. Generaly, relation-ship between correct exposure and luminance of the objects are given at eq(1) as follows.

$$2^{Ev} = \frac{A^2}{T} = \frac{B \cdot Sx}{K} \quad (1)$$

Where Sx is film sensitivity by ASA, Ev is exposure index, A is F value of lens, T is ahutter speed (sec), B is avarage luminance of the objects (cd/m^2), and k is constant (11.4 lux)

The other hand, each wave length of light transmitted within the ocean are strongly scattered and absorpted selectively, according to the concentration of organisms and particulate substance present.

When $I_0(\lambda)$is the illuminance of incident ray during to taken a photograohy, and $I(\lambda)$ is the illuminance of reflected ray which is comming back from the ocean. A portion of them included the ray that the incident ray traveled into the ocean and a part of them reflected on the algae exsisted at depth Z. The relation-ship between both of illuminances are described eq(2) as follws.

$$I(\lambda)=I_0(\lambda) \cdot e^{[-2 \cdot \alpha(\lambda) \cdot Z]} \quad (2)$$

Where α is attenuation coefficient, λ is wave length of light.

Fig. 2. shows spectral attenuation coefficient of various types of water. The average attenuation coefficients are calculated from fig. 2. The results shows that 0.37 m^{-1} in coastal water and 0.67 m^{-1} in river-mouth water. And also, from fig. 1, average reflectance of algaes can be calculated. The result of calculation shows that Ulva pertusa has 9.7%, Ecklonia kurome has 7.7%, Sargassum thunbergii has 7.3%, and Zostera bed has 6.2%.

Fig. 3. shows relation between sun-elevations and illuminances. On the assumption that the photograpies are taken during sun elevation is 35°, the illuminance of incident ray at water surface can be estimated from this figure. And these values obtained above, put into eq. (1) & (2) The discrimination depth of benthic marine algae on the color aerial photograph can be estimated.

The result shows that algaes exsist shallow water rather than 4m. depth, are recorded at linear portions of charactristic curve of film. Also, algaes growing deeper than 4m. depth, are recorded at toe portions of charactristic curve of film. Accordingly, recorded algaes at toe portions of charactristic curv, offtenly deficult to identify the boundary of its from the sea bottom on the color aerial photographs. So, image enhancement are needed.

Interpretation of algae and its enhancement

Classfication of algaes on the color aerial photographs are based on photo-interpretation by human eyes with mirror stereoscope. Because, human eyes and brain combinations are superior any other digital computer processing. Even digital computer processing is difficult to detect very small color and scene differnces on the photographs, the processing by combinations of human eyes and brain are possible in immdiately.

Table 1. shows photo-interpretation keys. By this table, a different interpreters try to classfied algaes used a color aerial photograph, the result will be lead to same classfications. Moreover, an interpreters difficult to classfied algaes, the portions are remained and marked on the photographs with a grease pencil. After, this un-knowen portions identified through the field survey recognition.

Although, it is often defficult to identify the boundary of benthic marine algae from the sea bottom on the color aerial photographs. Especialy, the algae growing up beneath the sea deeper than 7-10m. is not able to recognize by human eyes. So, the authors applied analogue image processing (masking method)for delineating the bundary benthic marine algaes from the sea bottoms.

The masking methods are discliminant analisys with the masks which are reproduced photographic processing, and used over a print or negative to obscure a part of the image. these are devided into two metods as follows, Which are intruduced by Dr.D.S.Ross.

1) One is employed very high contrast photographic film to copy with the band pass filter. The contrast of reproduction film is so high that essentialy all intermediate tones on the gray scale are lost, and the image is black and white. A reproducted positive recorded a slightly higher density level contained in original color films. Consequentry, density levels which can seperate interested algae from the others are choosen the obtained image are enhanced interested algae as solid black and othes failed to record clear film.

2) The other one employed photographic masking which is simmply registering a positive transparency with muching negative or different spectral positive, and printing the combination to produce a new image. By controlling the exposure, density, and contrast of positiv mask, the shadow, highlights and/or middle tones of the original films can be altered in density and contrast, or even turned from negative to positve values. Information of the interested algae can be enhanced, while other data can be suppressed.

The actual process are showen in Fig.4 as flow-chart. The several key points are discribed along this flow-chart as follows.

1. Photography was taken 750 meters high from the sea level with an aerial camera, Wild RC-10 (photo scale is 1/5000). If the flight hight taken more low, the high accuracy can be get. Although, the photograpies increase.

2. At the same time to make color positive films, multi spectral black and white negatives were made from the original color films The films for reproductin were used riss pancro film HP-100 (Fuji film industry Co.) and the filters were used Ratten number 47B, 57A, and 25 band-pass filters (Kodak Co.) to produce a series of negatives.

3. The measurement of photo-density for each colors (Red, Green, and Blue) of each classfied algae on the original color films was done by using PDA-65 photo densitometer(Konisiroku film Co.).

4. Fig.5.(1) shows distributions of algae's photo-density for each colors. Fig.5.(2)～(4). shows distributions of calculated photo-density which are obtained with each functions (subtrcting, additioning, and ratioing) using data measured above.

5. It is an important to find a most effective function and/or com-

binations of functions for enhancement of interested algae, compareing these figures. Fig.6. shows most effective function tree (combinations of functions)for enhanced and classfied of algaes.

6. However, this figure (Fig.6)is not perpetualy. Because, Photographic conditions are changeable depending on seasons, time, sea conditions, species of growing algaes, and others.

7. A processing to make mask layers were used CLS-500 (Durst Co.) as color enlarger, KG-30 (Karr Zeiss) as printer, and Merik 25 (Rokuo syoji Co.) as automatic film developer. And films for mask layer were applied copy-line HDU1P type 2 (Agfa Gevaert Co.).

8. At last, color enhanced maps of benthic marine algae are succeded to repeat each enhanced mask layers muching with simply registering on color aerial photograph, and scrubing color dyes which are attached with cromatec process, on the photograph. (photo.1-4)

Disscussion

The succeeded maps of benthic marine algae shows more typical fine detailes algae rather than maps manufactured through the photo interpretation and delineate the boundaries of benthic marine algae by hands.

Therefore, the interesed algae's area can also be measured precisely using enhanced mask layers of interested algae with photo-electric planimeter.

So, if the data of algae's weigt are given, The standing stocks can be estimated by following equation.

$$G = A * g \qquad (3)$$

where G is the standing stocks, A is the area measured using enhanced mask layers with planimeter, and g is avarage wet weight of algae which are obtained through the site invetigations by quadrat method (50×50 cm. size of quadrat were used by the authers).

In addition, to detect the seasonal changings of algae's distributions is also available. This is done by easily compering two different tranceperency positives (enhanced mask layers) of same algae muching with each others.

The problem of this method is some times occuring halation on the phtographs depending on relation with an angle of sun elevation and direction of camera axis. Even the camera axis directed toword the vertical, angle of sun elevation increas beyond 35 degree, the halations apear on the photograph, and influenced density. Avoiding this despitable influence, photographs shoud be taken a time during sun angle is low. The photography already was taken and included halation, the density should be measured using a portions of film evaded the halations.

Conclusion

It is concluded that this method is the most practical method for producing algae's distribution maps. The reasons are (1) the cost is much lower than the one by degital method, (2) the masking method enable to clarify the boundaries between benthic marine algae and the sea bottoms, which are usuary difficult to recognize the boundary by human eye's interpretation on original color aerial photographs.

In addition, this method is available for following analisys.

1) measuring the area of each algae distributions.
2) estimation of algae's standing stocks with data obtained 1) and sea-truth data.
3) detecting the seasonal changings of algae's distributions.

Reference

1) American Standards Association(1961)

2) D.S.Ross (1969) "Color Enhancement for Ocean Cartography" pp.50-63 Oceans from space, Gulf publishing Co.,

3) Mitunori Saito (1978) "Under water Photography" Manual of Photographic Technique.

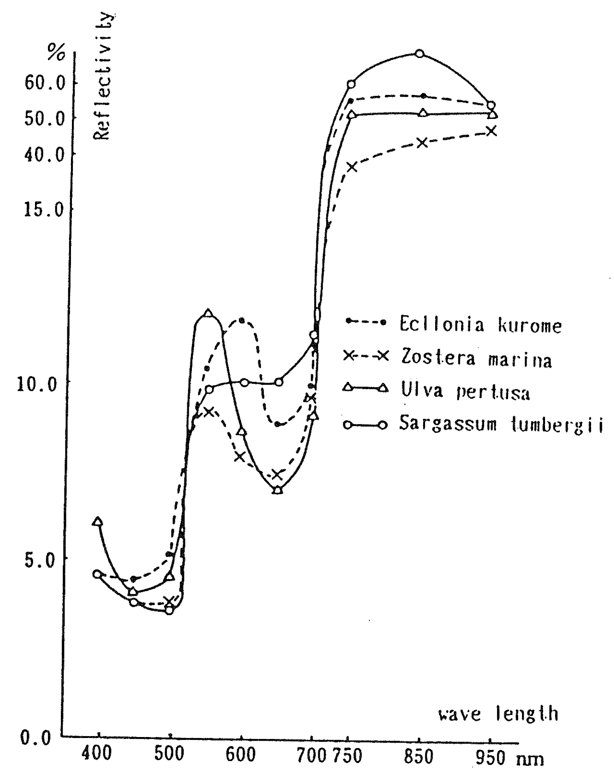


Fig.1 Spectral Reflectivity from algae

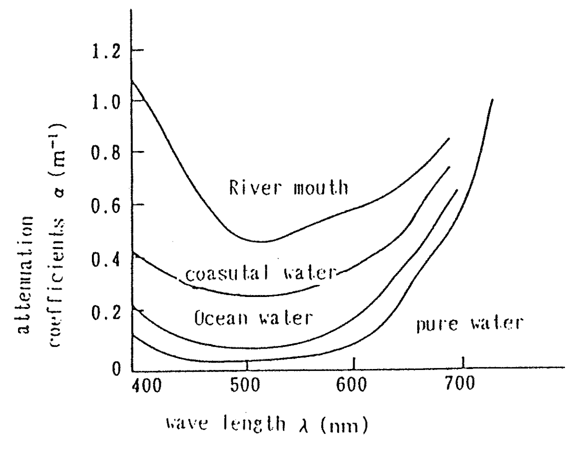


Fig.2 Spectral attenuation coefficients

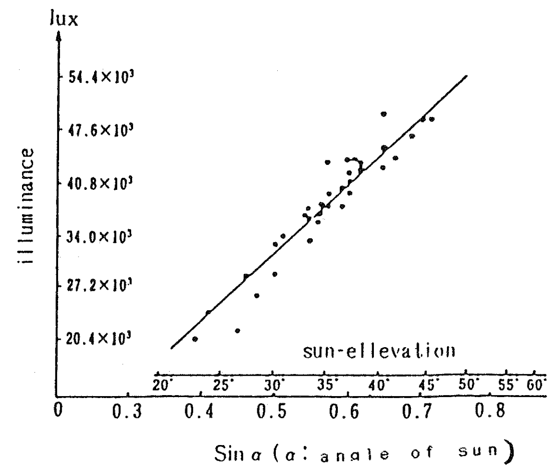


Fig.3 Relation-ship between sun elevations

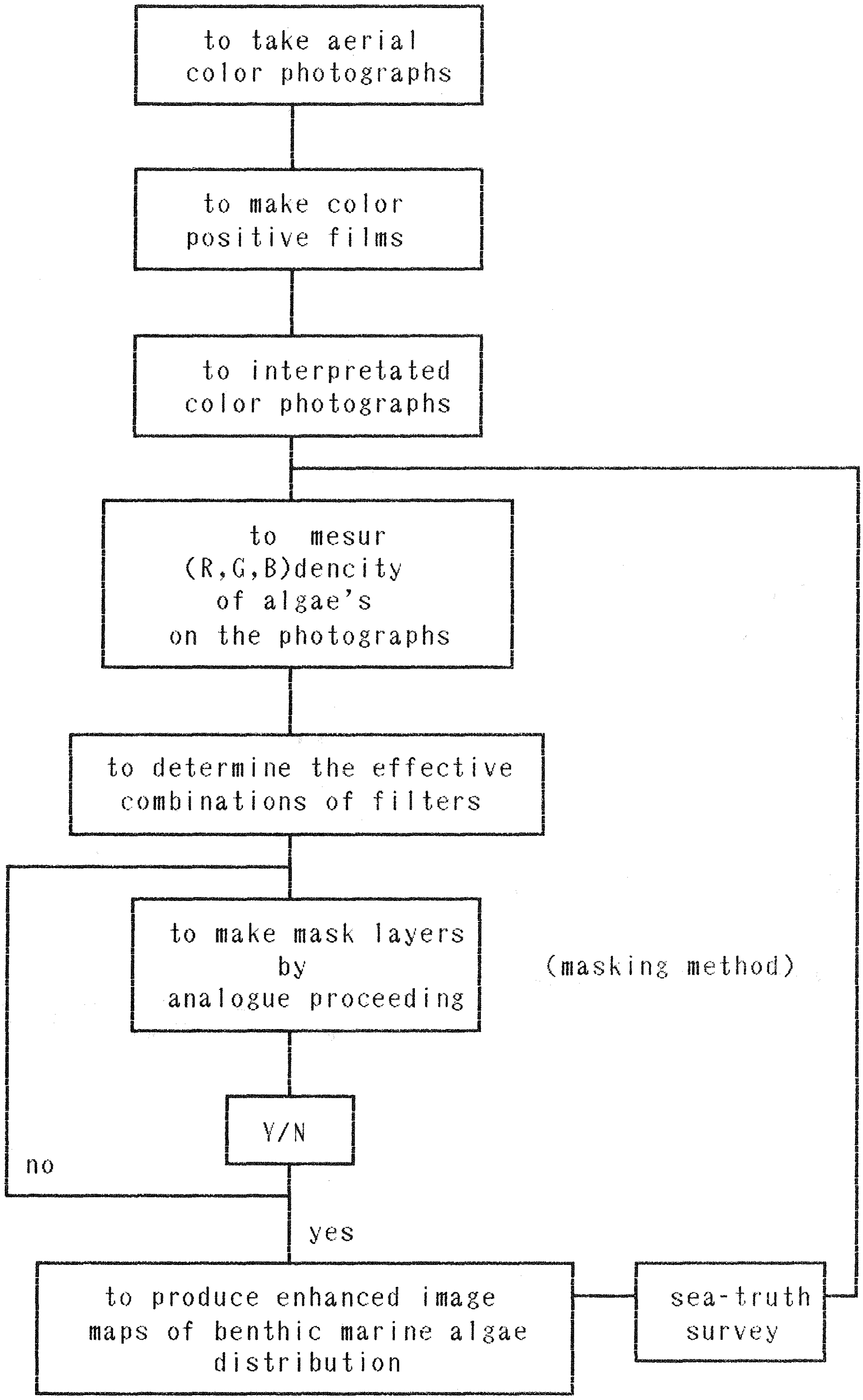
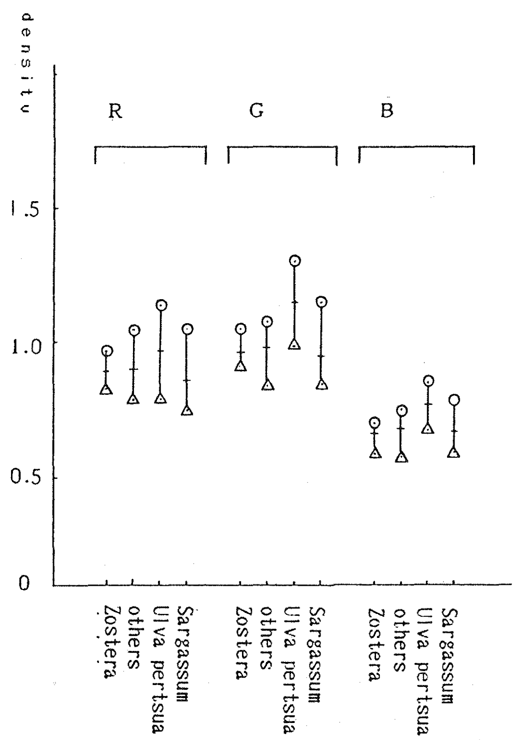
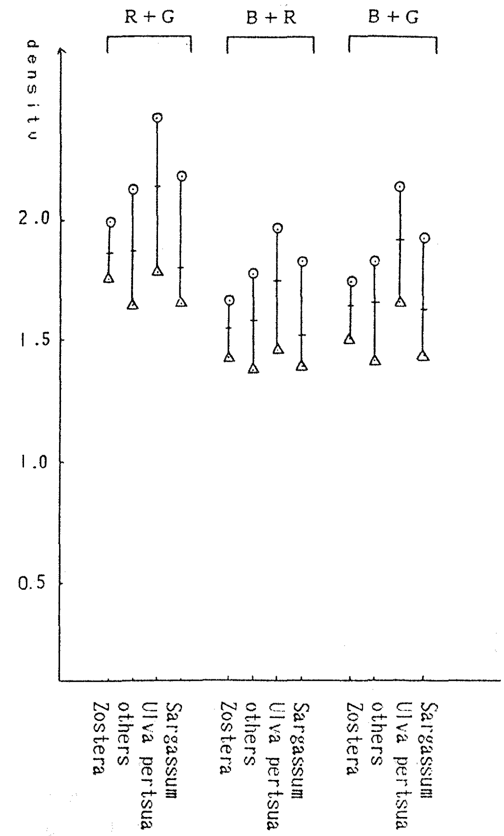


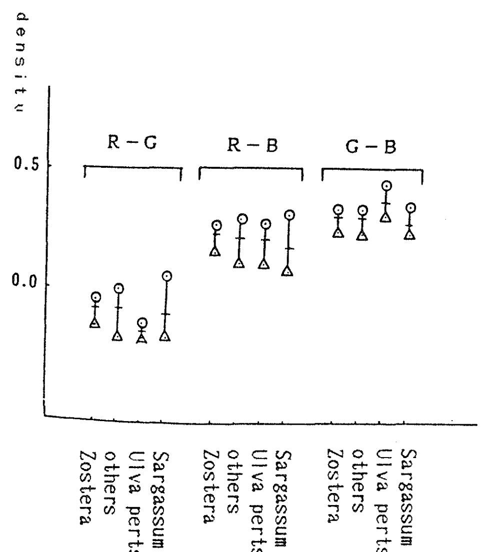
Fig.4 flow chart of analogue analysis for benthic marine algae monitoring



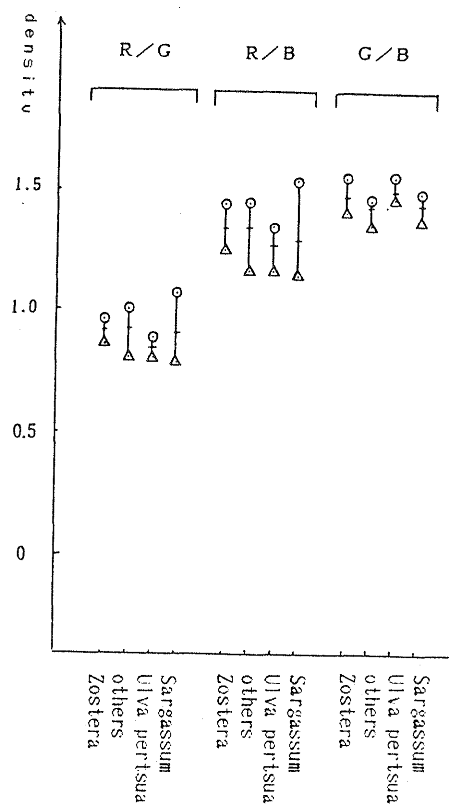
(1) measurment photo density



(2) calculating density by additioning



(3) calculating density by subtracting



(4) calculating density by ratioing

Fig. 5. Distribution of algae's photo density for each colors

Table 1. Photo interpretation keys

CLASS	TONE	TEXTURE	BOTTOM CONDITION	PATTERN
Zostera bed	light greenish brown	fine	sand and mudd	high denesity and widely distribution
Z.japonica (Z.nana)	deep green or bluelish green	very fine	sand and mudd	patch
sargassum (Eisenia bicyclis) (Ecklonia)	dark brown or redish brown	rough	rock grabel	belt zone anlong the coast
Ulva pertusa	uncovers of water yellowish green	smooth	sand and mudd grabel rock	carlm water such as bay
others	redish brown	very smooth	sand	

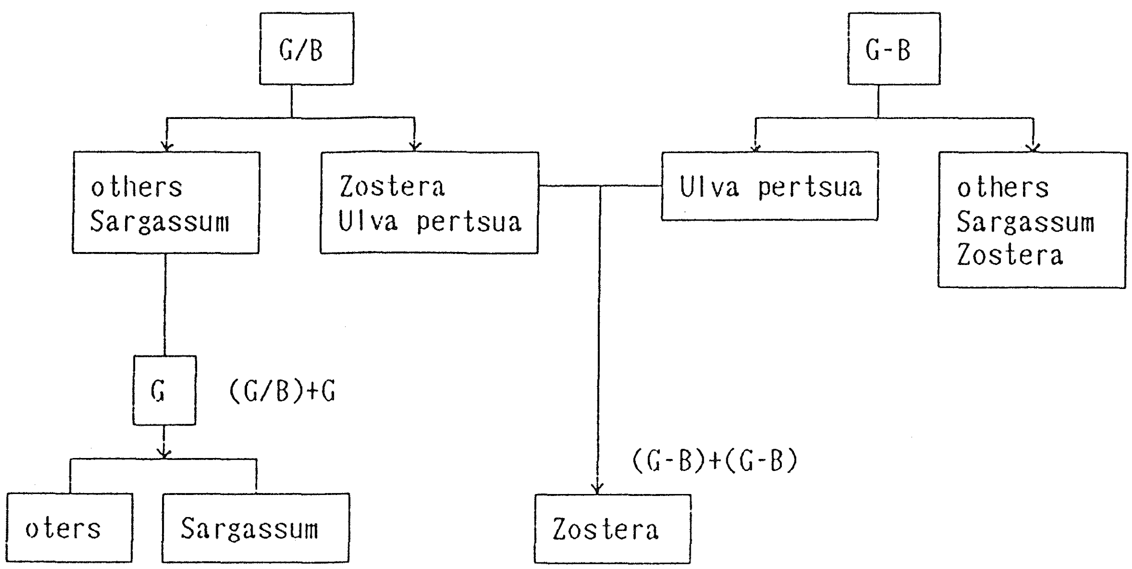


Fig. 6 Most effective function tree (combinations of functions) for enhanced each algae

Photo.1 An aerial color photograph at Gima-coast, Shimane Pref.,in Japan. Scale is 1/8,000

Photo.2 A color enhanced map of benthic marin algae distribution. Blue: Eisenia, Yellow: Surgassam, Green: small algae bicyclis

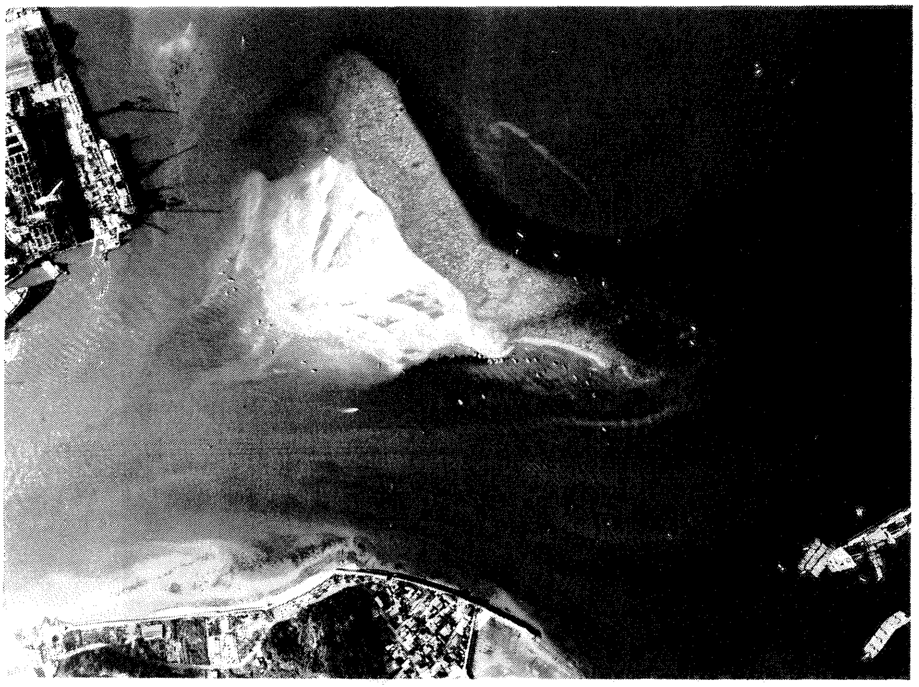


Photo.3 An aerial color photograph at bay of Matsunaga,Hiroshima Pref.,in Japan. Scale is 1/10,000

Photo.4 A mask layer (original is transperency positiv) enhanced Zostera marina