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The Food Effects of Three Unicellular Algae for Larval Oyster *Ostrea edulis* L. in the Laboratory*

Keiji TAKEDA**

Abstract: The author carried out investigation to know about the growth of European flat oyster (*Ostrea edulis* L.) fed with three species of unicellular algae and the spat growth in open sea from July 7 to November 4, 1966.

Chaetoceros calcitrans f. *pumilus* of a marine centric diatom and *Monochrpsis lutheri* of a marine Chrysophyta as foods for the oyster larvae were produced with Umebayashi's modified Pl solution, and *Chlorella ellipsoidea* of a freshwater green algae was produced with a simple medium containing some nutrients per one liter of freshwater (spring water) as follows:

50 mg-Na_2HPO_4 $12H_2O$, 100 mg-KNO_3, 6.5 mg-$MnSO_4$ $6H_2O$, 6.0 mg-$MgSO_4$ $7H_2O$, 5 mg-$FeCl_3$ $6H_2O$, 4 mg-Na_2EDTA, 2 m*l* of 5% Tris buffer solution of 7.4-7.5 in pH value.

Chaetoceros and *Monochrysis* cells were suitable as single food for larvae, but it seemed that the food effect of *Chaetoceros* cells for the increasing of shell length of larvae was a little better than that of *Monochrysis* cells. On the other hand, the larvae fed with *Monochrysis* cells attached on collectors in the smaller stage in shell length than those fed with *Chaetoceros* cells. And, in addition, the setting force (setting function) just after the larvae fed with *Monochrysis* cells attached on collectors was stronger than that of those fed with *Chaetoceros* cells.

Chlorella cells were eaten well by larvae, but could not be digested in the digestive organs. Therefore, the growth effect of larvae was not observed at all.

The survival rate of larvae in all vessels was 88.89% and more just before attaching on collectors. Perhaps this good survival rate might be brought about by the complete exchange of rearing water, test vessels and the washing of larvae with filtered seawater on cleaning net just before feeding every morning.

After the larvae attached on collectors were kept quiet for several days in a big tank filled with seawater containing several ten-thousand cells per milliliter of mixed phytoplankton cells (*Monochrysis* and *Chaetoceros*), they were replaced from the tank to the shallow sea in Ashizaki Inlet for culture on July 24, 1966. And they grew to the oysters of 3 to 5 cm shell height on November 4 in the same year.

1. Introduction

There are many studies on the artificial spawning and collection of sea bivalves in Japan as shown in Table 1. The author also devoted himself exclusively to the studies on the artificial collection of a scallop and a European flat oyster, etc. in the laboratory. An European flat oyster (*Ostrea edulis*) is a well-known sea bivalve a laviparous shell, and the new-born planktonic larvae are very big (185-190 μ shell height). Therefore, the mass rearing and collection of them in the commercial scale are not difficult.

This time, the author wishes to report on the growth of the oyster larvae fed with three unicellular algae in the laboratory.

2. Materials and methods

1. Species of phytoplanktons as food for larvae
   1) *Chaetoceros calcitrans* f. *pumilus* (a marine centric diatom)
   2) *Monochrysis lutheri* (a marine flagellata:

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Table 1. Marine shells used for artificial spawning, rearing or collection of planktonic larvae in Japan.

Species of marine shells	Names of workers
Crassostrea gigas	SATO *et al.* (1943)
Ostrea edulis	SATO *et al.* (1970-b, 1970-c)
Mytilus edulis	IWATA (1949)
Pinctada martensii	KOBAYASHI *et al.* (1952)
P. maxima	WADA (1942)
Pteria penguin	FUJITA *et al.* (1966, 1967), SHIOMITSU *et al.* (1968), YAMAGUCHI *et al.* (1960), YAMANAKA *et al.* (1970)
Patinopecten yessoensis	YAMAMOTO *et al.* (1943, 1950), SATO *et al.* (1970-d), TAKEDA (1970), TAKEDA *et al.* (1966)
Scapharca broughtonii	KANNO (1963), KANNO *et al.* (1963), ITO *et al.* (1967)
Tapes (Amygdala) phlippinarum	HATANAKA *et al.* (1943), IWATA (1948), SAGARA (1958)
Mactra sulcataria	IWATA (1948), SAGARA (1958)
Spisura sachalinensis	KANNO (1965)
Haliotis discus	SAGARA (1963), KANNO *et al.* (1963), KIKUCHI (1964) SATO *et al.* (1970-a), AOYAMA *et al.* (1972-a, 1972-b)
Turbo cornutus	AI *et al.* (1965)

Chrysophyta)

3) *Chlorella ellipsoidea* (a freshwater green alga)

2. Food phytoplankton productions

Three species of phytoplanktons mentioned above were grown with globular flasks of 2.0 *l* in capacity under the conditions of 20.0-23.0°C of room temperature, 1.0 *l*/*l*/min in aeration volume and 3.0 klux in light intensity (National Hi-light 40 W white fluorescent lamp).

The culture medium for production of *Chaetoceros* and *Monochrysis* cells was Umebayashi's modified Pl solution (UMEBAYASHI, 1961), and that for production of *Chlorella* cells was the simple freshwater medium as follows:

a)	KNO_3	100.0 mg
b)	$Na_2HPO_4\,12H_2O$	50.0 mg
c)	$MnSO_4\,7H_2O$	6.5 mg
d)	$MgSO_4\,7H_2O$	6.0 mg
e)	Na_2EDTA	4.0 mg
f)	$FeCl_3\,6H_2O$	5.0 mg

* Spring freshwater (1,000 m*l*)+(a, , c, d, e) → heating (100°C) → +(b, f) cooling

3. Larvae rearing

Four round-shaped styrol vessels of 10 *l* in capacity used for the trial were filled with 5-liter of filtered seawater with 1,000 larvae per liter, and set under the light intensity of 80-200 lux in the culture room (19.0-23.0°C in temperature). For the rearing of larvae, about 100-bubble in aeration volume were sent to each vessel with a glass pipe of 3 mm in inside diameter. Also the larvae for these trials were individually hatched out in water of about 17°C in temperature.

The quantities (cells/m*l*) of phytoplankton cells per day as a single food fed to larvae were as follows:

1) *Chaetoceros* cells of 10,000 cells/m*l*/day were fed to the larvae in Vessel A, and *Monochrysis* cells of 10,000 cells/m*l*/day were fed to the larvae in Vessels B from the first to the last day of the trial.

2) *Chlorella* cells of 40,000 cells/m*l*/day were fed to the larvae in Vessels C and D from the first to the 4th day of the trial. But the author did not have the growth effect of *Chlorella* cells at all, therefore the cells were exchanged to *Chaetoceros* cells in Vessel C or *Monochrysis* cells in Vessel D from the 5th day of the trial.

But 10,000 or 40,000 cells/m*l*/day of each species of phytoplankton as food for larvae were equally divided in two and fed twice a day.

The seawater and each vessel for larvae rearing were completely renewed and the larvae

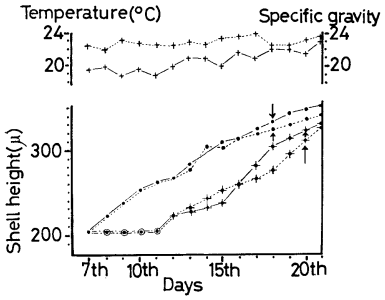

Fig. 1. Rearing records of larvae.
+···: specific gravity of rearing water, -+-: temperature of rearing water, —●—: rough shell length of larvae fed with *Chaetoceros* cells (Vessel A), --●--: fed with *Monochrysis* cells (Vessel B), ⊙: fed with *Chlorella* cells (Vessels C, D), —●—: fed with *Chaetoceros* cells (Vessel C), -●···: fed with *Monochrysis* cells (Vessel D), ↑: time of attach of larvae on collectors.

also were cleaned by filtered seawater on a washingnet (mesh: 110×110 μ) just before feeding once a day every morning. The specific gravity (σ_{15}) of rearing water was ranged from 22.00 to 24.00 (Fig. 1).

The spats, on the scallop shells of about 15 cm in diameter as collectors, obtained from the rearing trial were hung from a raft on the shallow sea (about 5 m in depth) in Ashizaki Inlet of Mutsu Bay of Aomori Prefecture from July 24 to next year. But the author only reports on the variations of seawater temperature, specific gravity of the surface water at the culture place from July 24 to the last of October and the rough shell size on November 4 in the same year. The author used the shell length for measuring the planktonic larvae and the shell height for measuring the small oysters on the collectors in the sea.

3. Results

1. Food effects of phytoplanktons for increasing shell height of planktonic larvae (Fig. 1)

Chaetoceros cells were ranked as the most effective food among three species of phytoplanktons from the results of rearings in Vessels A and C, and *Monochrysis* cells were in the second rank in Vessels B and D. *Chlorella* cells also were eaten by the larvae. However, *Chlorella* cells were not digested in the digestive organs and the larvae did not grow at all in Vessels C and D for the first three days. Then, the trial (Vessels C and D) using *Chlorella* cells was changed to that using *Chaetoceros* cells (Vessel C) and using *Monochrysis* cells (Vessel D) from four days after the beginning of the trial. The larvae in Vessels C and D grew well since then.

Table 2. Survival rate of planktonic larvae in each vessel till just before attaching on collectors.
A: survival rate of larvae fed with *Chaetoceros* cells all through the rearing, B: those fed with *Monochrysis* cells all through the rearing, C: those fed with *Chlorella* cells for the first four days and fed with *Chaetoceros* cells from the 5th day of the rearing, D: those fed with *Chlorella* cells for the first four days and fed with *Monochrysis* cells from the 5th day of the rearing.

Test vessel \ Observed date	July in 1966			
	7th	14th	17th	19th
A	100 %	100 %	94.84 %	— %
B	100 〃	100 〃	93.07 〃	— 〃
C	100 〃	100 〃	— 〃	88.89 〃
D	100 〃	100 〃	— 〃	90.65 〃

2. Difference of growth in shell length of larvae fed *Chaetoceros* or *Monochrysis* cells (Fig. 1)

The author found that the shell length of the larvae fed with *Monochrysis* cells in Vessel B was about 315 μ (262 ± 45.4 μ in mean shell length) and those fed with *Chaetoceros* cells in Vessel A was about 325 μ (276 ± 49.8 μ in mean shell length) just befor setting on the collectors. The same difference was obtained in the trials of Vessels C and D.

3. Survival rate for planktonic larval stage (Table 2)

The survival rate of larvae in all vessels was 100 % from the beginning to the 14th day. But it dropped to 94.84 % in Vessel A, 93.07 % in Vessel B, 88.89 % in Vessel C and 90.65 % in Vessel D just before their setting on the collectors.

4. Discussion

LOOSANOFF *et al.* (1963) showed that *Mono-*

chrysis lutheri, *Isochrysis galbana*, *Platymonas* sp. and *Dunaliella* sp. are useful foods, and *Monochrysis* or *Isochrysis* is good as a single food for many kinds of sea bivalve larvae. They also said that the mixed food of these phytoplanktons has an excellent effect for the larvae growth in shell height. DAVIS *et al.* (1958) also attained the same results from their trials. And WALNE (1965) reared oyster larvae (*Ostrea edulis*) using *Isochrysis*. On the other hand, SATO *et al.* (1970) reported that the food effect of *Ch. calcitrans* f. *pumilus* is better than that of *Phaeodactylum tricornutum* for the growth in shell length in the planktonic stage of European flat oyster. The author also obtained that *Chaetoceros* cells are eaten well by small scallop larvae (110–150 μ in shell length) and *Phaeodactylum* cells are effective as food for the larvae of about 160 μ and more shell length (TAKEDA, unpublished MS in 1966).

Today, the results from the present rearing trials using *Ch. calcitrans* f. *pumilus*, *M. lutheri* and *C. ellipsoidea* cells cultured in the media as shown in "Materials and methods" are discussed as follows:

It seemed that the food effect (Vessel A) of *Chaetoceros* cells for the growth in shell length of larvae is a little better than that (Vessel B) of *Monochrysis* cells in the later half of the rearing. Namely, the shell length of the larvae fed with *Monochrysis* cells was about 315 μ (but $262 \pm 45.4\ \mu$ in mean shell length) and that of those fed with *Chaetoceros* cells was about 325 μ (but $276 \pm 49.8\ \mu$ in mean shell length) just before setting on the collectors (Fig. 1), and the same difference was observed in the rearing in Vessels C and D.

The feet of larvae fed with *Monochrysis* cells began to develop from the growing stage of about 270 μ in shell length, but those of larvae fed with *chaetoceros* cells began to develop from the growing stage of 285 μ in shell length. In addition, the force of setting on the collectors of the larvae fed with *Chaetoceros* cells was a little weaker than that of larvae fed with *Monochrysis* cells just after the setting on the collectors. Therefore, it was necessary to keep quiet the collectors for the larvae fed with *Chartoceros* cells for several days after setting.

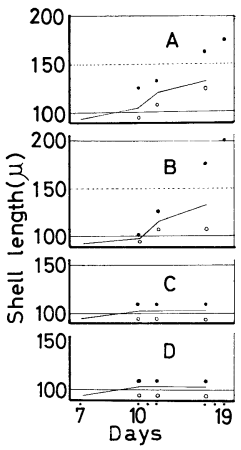

Fig. 2. Growth of ark-shell larvae fed with 10^4 cells/m*l*/day of different phytoplanktons for the first seven days and fed with 2×10^4 cells/m*l*/day from the 8 th day of rearing.
——: Mean shell length, ●: maximum shell length, ○: minimum shell length, A: growth of larvae fed with *Monochrysis* cells, B: those fed with *Chaetoceros* cells, C: those fed with *Phaeodactylum* cells, D: those fed with *Chlorella* cells.

The author could not find out the reason why such difference was brought about in the growing stage, for there was nothing about the analytical data on the nutritive value of phytoplanktons used in the present trials. But *Chaetoceros* was one of the useful foods like *Monochrysis* for the growth of oyster larvae from the view point of the increase of shell length.

On the other hand, *Chlorella* cells were not effective for the growth of larvae, for they could not digest these in their digestive organs, and the same fact was obtained in the author's recent trial on the growth of ark-shell larvae (*Scapharca broughtonii*) (Fig. 2) or scallop larvae (*Patinopecten yessoensis*) (TAKEDA, unpublished MS) fed with *Chlorella* cells. The author shows some results of the trial on the food effect of some kinds of phytoplanktons for ark-shell larvae as follows:

The ark-shell larvae of 93.6 μ in mean shell length fed with *Chaetoceros* cells shewed growth of 143 μ in mean shell length (103 μ in minimum and 203 μ in maximum) (Fig. 2, A), and those fed with *Monochrysis* cells showed growth of

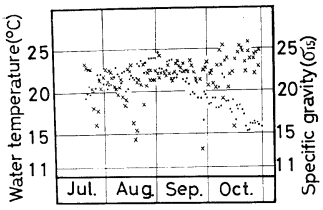

Fig. 3. Temperature and specific gravity of surface water at the culture place in Ashizaki Inlet for the hanging culture from the end of July to the end of October in 1966.
×: specific gravity, ●: water temperature.

133 μ in mean shell length (but 125 μ in minimum and 176 μ in maximum) (Fig. 2, B). But the food effects of *Phaeodactylum* and *Chlorella* for them were not obtained at all. Because *Phaeodactylum* cells were too big as food for ark-shell larvae of 93.6 μ to 105 μ in shell length, and *Chlorella* cells were not digested in their digestive organs (Fig. 2, C and D). However, it was seen that *Chlorella* cells (Lewin's or Gillarud's isolate) used in Davis *et al.*'s work (1958) were slightly effective as food for *Venus Mercenaria* larvae and not effective for *Curassostrea virginica* larvae. Therefore, we cannot use the sorts of *Chlorella* cells as food for the rearing of *Ostrea edulis* and *Scapharca broughtonii* larvae.

The survival rate of the larvae in the present rearing trials was 88.89 % and more just before setting on the collectors in all vessels as shown in Table 2. Perhaps, such good survival rate might be brought about by the effect of the complete renewal of rearing water and rearing vessels or the effect of the washing of larvae with filtered seawater on the net of 110 × 110 μ in mesh before feeding to them every day.

Lastly, the author explains about the treatments of the collectors with spats set in the vessels as follows:

After keeping the collectors of about 15 cm in diameter with 30 to 40 of spats set in a tank (about 6 tons in capacity) filled with seawater containing several ten-thousand cells per milliliter mixed food of *Chaetoceros* and *Monochrysis* cells until the spats set well on the collectors (for several days), these were hung from a raft in Ashizaki Inlet of Mutsu Bay on July 24, 1966. This culture was continued till next year. But hereupon the author reports on specific gravity, temperature of the surface seawater from the end of July to the end of October in 1966 and rough shell size in November 4 in the same year. Namely, the specific gravity sometimes dropped from 25 to 18, 16, 14 or 13 (σ_{15}) by rain fall, but usually the values under the layer (culturing depth) of one meter or more in depth were 20 or more and the maximum value was about 25.1 (σ_{15}). The seawater temperature was ranged from 15°C to 24°C (Fig. 3).

Small oysters of 30 to 40 per sheet of collector were lessened to about 10 at once on the first of September (after a month and a half from the beginning of hanging culture in the sea). And these small oysters on the collectors grew from 3 to 5 cm in shell height on November 4 in the same year.

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ヨーロッパヒラガキの幼生に対する3種の単細胞藻類の餌料効果

武　田　恵　二

要旨: 著者は孵化直後の幼生に，梅林改変 Pl 液で生産した *Chaetoceros calcitrans* f. *pumilus* や *Monochrysis lutheri* 及び著者調整の淡水培養液で生産した *Chlorella ellipsoidea* を単種餌料として与えて餌料効果試験を行った。投与量は3藻の投与量を P.C.V. で定めると，また異なった結果が得られるであろうが，今回は一応投与量を細胞数で取扱い次のとおりの結果を得た。

1) 800～200 lux のもとで 10 *l* 容量スチロール円型水槽を用い，幼生数を 1,000/m*l* とし，毎朝水槽と飼育水の全交換，幼生の洗浄を行った後，朝夕2回 *Chaetoceros* や *Monochrysis* を 5,000 cells/m*l*, あるいは *Chlorella* を 20,000 cell/m*l* 投与した。 2) 同期間での浮遊幼生の殻長増大効果は *Monochrysis* よりも *Chaetoceros* の方が幾分優れていた。3) 逆に *Monochrysis* を与えた方の幼生の足の発達は *Chaetoceros* によった幼生より早い小型（270 μ）の時期に始った。4) *Monochrysis* を与えた幼生は，当初から強く採苗器に固着する傾向が認められた。5) *Chaetoceros* を与えた幼生の付着力が弱い向があるので，付着後は餌料生物を加えた海水タンクで数日間安静養生後，野外養殖場に移すのが肝要であろう。6) *Chlorella* はよく摂取されるが，全く消化されずに排泄されて成長効果は皆無であった。7) 付着直前でも 88.89% 以上の高い生存率を得たのは，毎朝の投餌直前での水槽，飼育水の全交換及びろ過海水による幼生の洗浄処理がもたらした効果と見てよい。8) 実験で得た付着稚貝を6月下旬に海面に移して養殖したところ，同年の11月4日に殻高は約 3～5 cm に達した。

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Halophilism of Microorganisms in the Eutrophied Bay of Tokyo at the End of Summer Stagnation Period*

Humitake SEKI**, Jun-ichi MATSUO***, Mitsuji YAMASHITA***
and Haruo NUMANOI***

Abstract: The halophilism spectrum of the natural microflora in seawater of Tokyo Bay was shown to be one by the mixed microbial florae of the freshwater (non-halophiles) and the oceanic (slight halophiles) environments, although precise shapes of the spectra were various in different samples collected from different watermasses at different collection times. From statistical analyses it was shown that non-halophilic heterotrophic bacteria could inhabit predominantly in water of Tokyo Bay having up to such a high salinity as 30.96‰, whereas non-halophilic yeasts inhabited predominantly in most water samples (salinities: 26.609-33.340 ‰) throughout the watercolumn.

1. Introduction

We have reported *status quo* of the eutrophication in Tokyo Bay (TSUJI *et al.*, 1974) and the possible main mechanism of the formation of microaerobic zone in the bottom layer of the bay (Fig. 1) during summer stagnation period, *i.e.*, phytodetritus and fecal pellets produced by copepod grazing on flagellates of the red tide in the surface layer were shown to form major fraction of organic debris which was used by microorganisms for the consumption of dissolved oxygen in the bottom layer (SEKI *et al.*, 1974a and b). Thus, the destruction of natural environment of Tokyo Bay is most serious during summer stagnation period.

During this period the microorganisms associated with the phytodetritus and the fecal pellets in the surface layer might be composed of freshwater microorganisms (non-halophiles) as well as marine microorganisms (slight halophiles), as seawater of the surface layer was less saline as strongly influenced by the freshwater inflow of sewage and industrial wastes. On the other hand, the microorganisms in seawater of the bottom layer must be chiefly composed of marine microorganisms because the layer was then affected little by the fresh water inflow but greatly by the seawater inflow along the bottom from the outside of the bay, as was indicated by high salinity of seawater of the bottom layer (Fig. 2). From microbial halophilism point of view, therefore, predominant microorganisms responsible for the decomposition of phytodetritus and fecal pellets might interchange while they are sedimenting through the watermasses.

Rapid self-purification process for the organic matter was observed within a few months from summer stagnation to fall overturn (TSUJI *et al.*, 1974), when microorganisms in every watermass were exposed to salinity change of the ambient water. From microbial halophilism point of view, again, predominant microorganisms responsible for this self-purification process should be studied.

2. Materials and methods

Hydrographic observations and water sampling were made from August 9 to September 28, 1973, at Station 1 (Fig. 1).

Water temperature, salinity, dissolved oxygen, pH, Eh, light intensity, microbial respiration, particulate organic carbon, particulate organic nitrogen, chlorophyll *a*, carotenoids and total number of bacteria were determined by the methods described in SEKI *et al.* (1974b).

Numbers of heterotrophic bacteria and yeasts

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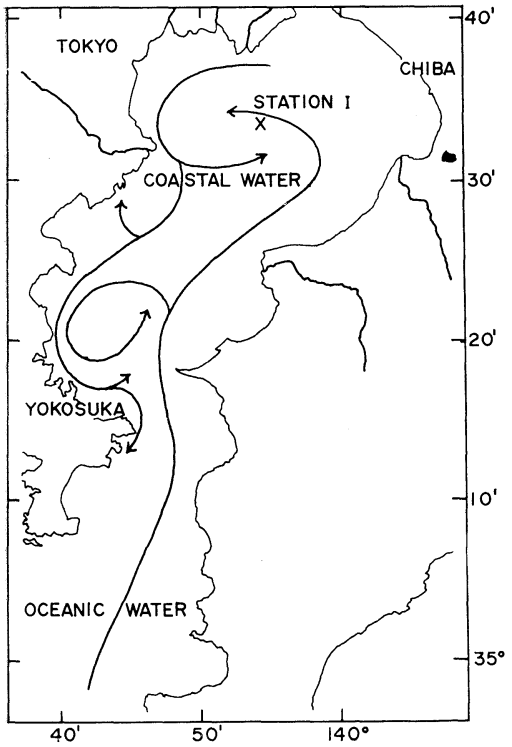

Fig. 1. Station location and general hydrography in Tokyo Bay.
Station 1 (35°31.6'N, 139°53.9'E)

were counted by the agar poured plate method. The media used for the colony count had the following composition:

Freshwater medium for heterotrophic bacteria

Bacto-peptone:	1 g
Bacto-agar:	15 g
Distilled water:	1,000 m*l*

pH adjusted to 7.0

Seawater medium for heterotrophic bacteria

Bacto-peptone:	1 g
Bacto-agar:	15 g
NaCl:	35 g
Distilled water:	1,000 m*l*

pH adjusted to 4.5 with lactic acid.

Freshwater medium for yeasts

Glucose:	10 g
Bacto-peptone:	1 g
Bacto-yeast extract:	1 g
Bacto-agar:	15 g
Distilled water:	1,000 m*l*

pH adjusted to 4.5 with lactic acid.

Seawater medium for yeasts

Glucose:	10 g
Bacto-peptone:	1 g
Bacto-yeast extract:	1 g
Bacto-agar:	15 g
NaCl:	35 g
Distilled water:	1,000 m*l*

pH adjusted to 4.5 with lactic acid.

The halophilism spectrum of the natural microflora was measured as the relative activity of glucose uptake by the method described in SEKI *et al.* (1969).

3. Results

1. Summer stagnation and its degradation

On August 9, watermasses at Station 1 were completely stratified (Fig. 2) as have been observed every summer. Transition from summer stagnation to fall overturn started before August 27, and fall overturn was completely established on September 28 (Fig. 3). The degradation of the stagnation seemed to be accelerated especially with vertical mixing being set up by

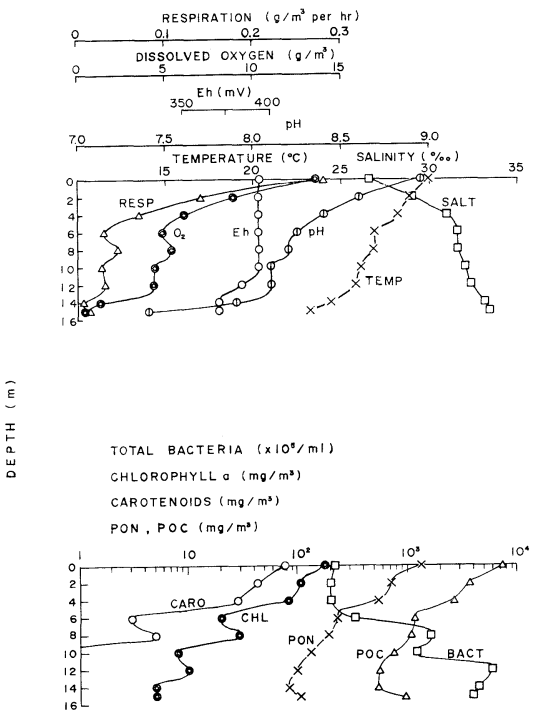

Fig. 2. Vertical distribution of some environmental factors on August 9, 1973.

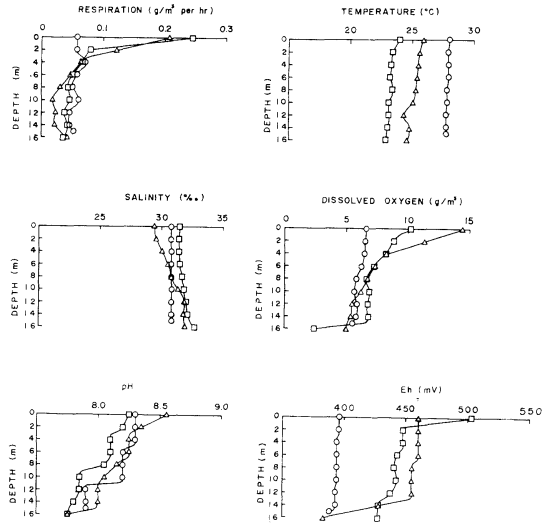

Fig. 3. Fluctuation of some environmental factors during the end of summer stagnation period in 1973.
○: collected on August 27
△: collected on September 12
□: collected on September 28

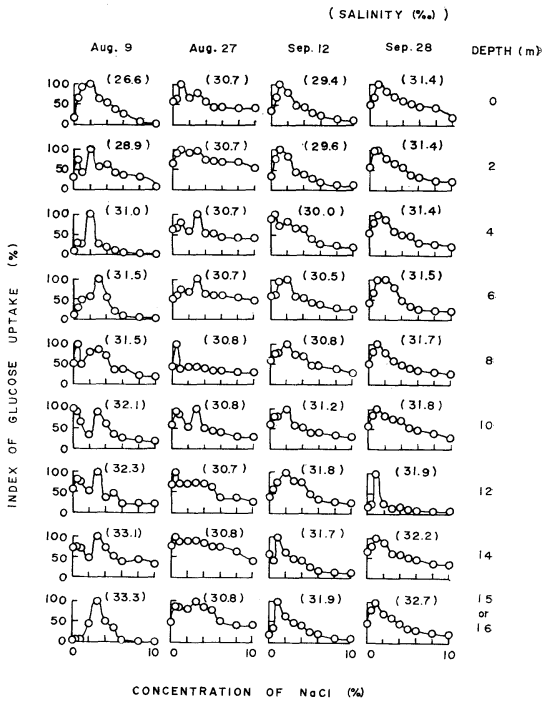

Fig. 4. Glucose uptake by microorganisms in water samples at different concentrations of NaCl.

violent wind which blew for approximately one week until August 26.

2. Halophilism spectrum of natural microflora

The halophilism spectrum of the natural microflora, as indicated by the heterotrophic potentiality of microorganisms, from summer stagnation to fall overturn is shown in Fig. 4.

At the typical summer stagnation period, as observed on August 9, the spectrum in each watermass was different each other. In the surface layer, the maximum microbial activity was measured at 2 % NaCl, and more than 60 % of the maximum activity were observed in the salinity range of 0.5 to 3 %. In the intermediate layer, the microbial activity had two maxima at 0.5 and 3 % NaCl. In the bottom layer, the maximum activity was measured at 3 % NaCl. The microbial activity in deeper layer had more stenohaline characteristics.

During the transition from summer stagnation to fall overturn, the microbial activity had the maximum at 0.5 or 3 % NaCl and the optimum salinity for the activity had no special relation with the depth. At an early stage of the transition, on August 28, the spectrum from every depth had rough shape, whereas at a final stage of the transition, on September 12, the spectrum had very smooth shape: This difference in shapes of the spectra at the different stages must indicate the progress of microbial acclimatization to new salinity environment.

Finally at the fall overturn, on September 28, the microbial activity at every depth had the maximum at 1 % NaCl and more than 80 % of the maximum activity were observed in the salinity range of 0.5 to 2 % NaCl.

3. Halophilism of heterotrophic bacteria and yeasts

The ratio of colonies growing on a freshwater medium to colonies growing on a seawater medium for samples collected from every depth during the observation is shown in Fig. 5 for heterotrophic bacteria and in Fig. 6 for yeasts.

The ratio for heterotrophic bacteria was always higher than 1 for the seawater samples

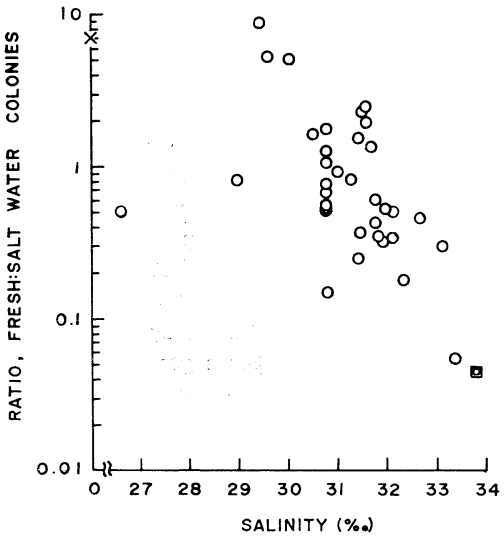

Fig. 5. Relationship between salinity of a water sample and the ratio of the number of bacterial colonies growing on a freshwater medium to the number growing on a saltwater medium.
○: seawater samples collected from Tokyo Bay
⊡: seawater sample collected from the coast of Misaki city at the open sea
×: freshwater sample collected from the Tama river at Mitake city in a mountain free from pollution

Table 1. Regression analysis of fresh and salt water colony ratio to salinity of original sample (data from Fig. 5).

Source of variation	Sum of square	Degree of freedom	Mean square	Fo
Linear regression	3.479	1	3.479	31.333*
Residual	3.537	32	0.111	
Total	7.017	33		

* Probability level F(1, 32; 0.01): 7.50

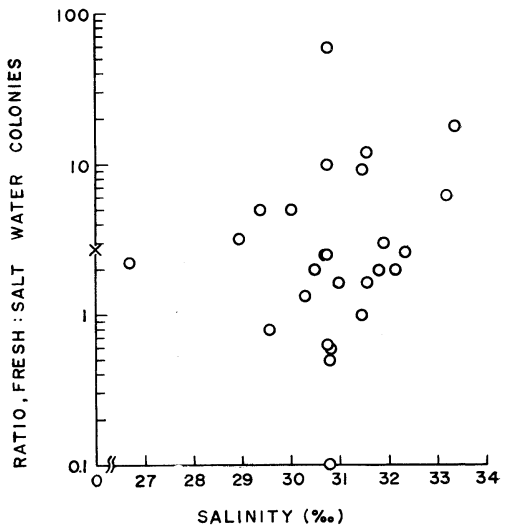

Fig. 6. Relationship between salinity of a water sample and the ratio of the number of yeast colonies growing on a freshwater medium to the number growing on a saltwater medium.
○: seawater samples collected from Tokyo Bay
×: freshwater sample collected from the Tama river at Mitake city in a mountain free from pollution

Table 2. Regression analysis of fresh and salt water colony ratio to salinity of original sample (data from Fig. 6)

Source of variation	Sum of square	Degree of freedom	Mean square	Fo
Linear regression	0.269	1	0.269	0.8433
Residual	7.658	24	0.319	
Total	7.927	25		

Probability level F(1, 24; 0.05): 4.26

from 4 to 8 m, whereas the ratio was between 0.1 and 1 for the seawater samples from other depths. The regression line between the ratio of colonies (y) and the salinity (x) was determined to be

$$y=-0.369\,x+12.426$$

with an unbiased variance $\sqrt{V_{yx}}=0.333$ from a statistical analysis of the data (Table 1). From this analysis, it was shown that *in situ* salinity affects the bacterial halophilism and that the bacteria which grow best in a freshwater medium predominantly inhabited water with salinities of less than 30.96 ‰.

On the other hand, it was impossible to determine the regression line between the ratio of yeast colonies (y) and the salinity (x) from a statistical analysis of the data (Table 2). The ratio was higher than 1 for most seawater samples, which indicates that non-halophilic yeasts were predominant at the investigated region.

4. Discussion

The halophilism spectrum of the natural microflora in seawater of Tokyo Bay at summer stagnation period has shown that the microflora in the surface layer has euryhaline characteristics with the maximum activity at 2 % NaCl, and that the microflora in deeper layer has rather stenohaline characteristics with the maximum activity at 3 %. The spectrum seems to be affected by salinity characteristics of watermasses where the microorganisms inhabit. During transition from summer stagnation to fall overturn, the spectrum changed its shape from rough to smooth as the result of the acclimatization of microorganisms to the degree of mixing of freshwater and seawater throughout the whole watercolumn. Except for the spectrum in the seawater sample from the bottom layer at summer stagnation period, all the spectra showed that non-halophilic microorganisms were responsible to some extent for the heterotrophic potentiality of microorganisms at *in situ* salinity (Fig. 4). It was also shown by the halophilism of heterotrophic bacteria (Fig. 5) and yeasts (Fig. 6) that non-halophilic yeasts were predominant in most samples and that non-halophilic bacteria predominantly inhabit water with salinities of less than 30.96 ‰. These results must indicate that the formation of microaerobic zone in the bottom layer is chiefly carried out by slight halophilic microorganisms and that the self-purification process for the organic matter produced chiefly by red tide during summer (TSUJI *et al.*, 1974) is rapidly carried out by both halophilic and non-halophilic microorganisms at the transition from summer stagnation to fall overturn when *in situ* salinity was from 31.4 to 32.7 ‰ throughout the watercolumn.

The observed fact that the bacteria which grow best in a freshwater medium predominantly inhabit water with salinities of less than 30.96 ‰ in Tokyo Bay, showed a little difference with Larsen's definition (LARSEN, 1962) of non-halophiles being microorganisms which grow best on a medium with less than 2 % NaCl and with our former observation (SEKI *et al.*, 1969) that heterotrophic bacteria which grow best in a freshwater medium inhabit water with a salinity of less than 1.9 % in a non-polluted region. However, the difference can be explained partly by the work of other authors (*e.g.*, JONES, 1964) that the survival of terrestrial bacteria in the marine environment may be enhanced by the presence of organic materials. As a matter of fact, both dissolved and particulate organic materials in seawater at the station have been measured during this period more than 10 times greater than those in seawater at the coastal region in the open sea (TSUJI *et al.*, 1974; SEKI *et al.*, 1974b; Fig. 2 in this paper).

Acknowledgments

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夏季停滞期から秋季循環期の東京湾における微生物の好塩性に関する研究

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要旨: 東京湾における，有機物の自己浄化作用が最も重要な時期である夏季停滞期から秋季循環期において，有機物分解過程に最も重要な役割を果たしている微生物が示す好塩性反応を調査研究した。

海水中の微生物相が示した好塩性反応は，淡水及び海水起源に典型的な微生物による反応の中間的なものであり，それらが生息していた水塊における淡水と海水との混合様式をよく反映しているものと考えられる。

また，非好塩性の有機栄養細菌や酵母の耐塩度は，実験室内環境や自然環境で示される値よりやや高く，東京湾の富栄養化の実体を示しているものと考えられる。

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Salinités de surface caractéristiques du courant équatorial et du contre-courant équatorial nord à 150°-160°E*

J. R. DONGUY** et C. HENIN**

Abstract: Since August 1969, four japanese merchant ships are making regularly, every 60 nautical miles, between New Caledonia and 10°N, surface observations of temperature and salinity. A complete voyage lasts 40 days. The ships cross the equator between 150°E and 160°E.

Contrary to former data, the new observations show high surface salinities (35.0-35.5‰) from 1°N to 3°S and between 150°E and 160°E. This high salinity is associated with East wind and the mean monthly surface temperature is lower at the equator than north and south; the T-S diagrams show also evidence of upwelling near the equator.

Low surface salinities (less than 34.0‰) are observed from 5°N to 10°N at 150°E mainly between August and October, though in summer, the North Equatorial Counter-current is supplied at the same time by waters from the northern hemisphere and by high salinity waters from the southern hemisphere. The maximum rainfall in the Philippines occurs in January; to reach 150°E in August, the diluted water should have a speed of 0.2 knot instead of 1.2 as observed. The low salinities occur with SW winds or in the presence of the Trade Wind Convergence Zone, both bringing rainfalls. The surface salinity charts drawn during EQUAPAC in August 1956 and during a VITYAZ cruise in August 1957 are pointing out several isolated minima between 5°N and 7°N. Thus there are strong evidences for the *in situ* formation of low salinities in the North Equatorial Counter-Current.

1. Introduction

De nombreux minéraliers viennent charger du minerai de nickel en Nouvelle Calédonie et le transportent au Japon. Plusieurs d'entre eux ont bien voulu apporter leur concours à un programme d'échantillonnage superficiel entre la Nouvelle-Calédonie et 10°N. Depuis août 1969, quatre navires en moyenne font régulièrement, tous les 60 milles, des mesures de température et des prélèvements d'eau de mer de surface. Un voyage complet dure 40 jours; les navires, suivant le port de destination, coupent l'équateur entre 150°E et 160°E.

La température a été lue au demi degré près sur un thermomètre placé à l'entrée de la conduite de refroidissement des moteurs, à une profondeur de 5 mètres en moyenne. Un échantillon d'eau prélevé au même moment sur le même circuit, était conservé en bouteille étanche; sa salinité a été mesurée au salinomètre à induction avec une précision de ±0,01 ‰.

* Manuscrit reçu le 9 avril 1974

** Centre ORSTOM (Office de la Recherche Scientifique et Technique Outre-Mer) de Nouméa Nouvelle-Calédonie

2. Salinités de surface du courant équatorial

L'upwelling équatorial, caractérisé en surface par une salinité élevée et une température basse, n'est généralement pas signalé à l'ouest de 160°E. Si la carte produite par REID (1969) pour l'été boréal (mai-octobre) présente des salinités de surface (35,0‰-35,5‰) compatibles avec l'existence d'un upwelling, celle de l'hiver boréal (novembre-avril) (fig. 1) montre que, de 150°E à 160°E, la salinité est inférieure à 35,0‰. Or, les observations des navires marchands pendant cette période présentent des salinités superficielles élevées (de 35,0‰ à 35,5‰) de 1°N à 3°S entre 150°E et 160°E (fig. 2).

Sur la figure 2 ont été groupées:

-la salinité superficielle maximum généralement située entre 1°S et 2°S à 150°E de août 1969 à décembre 1971.

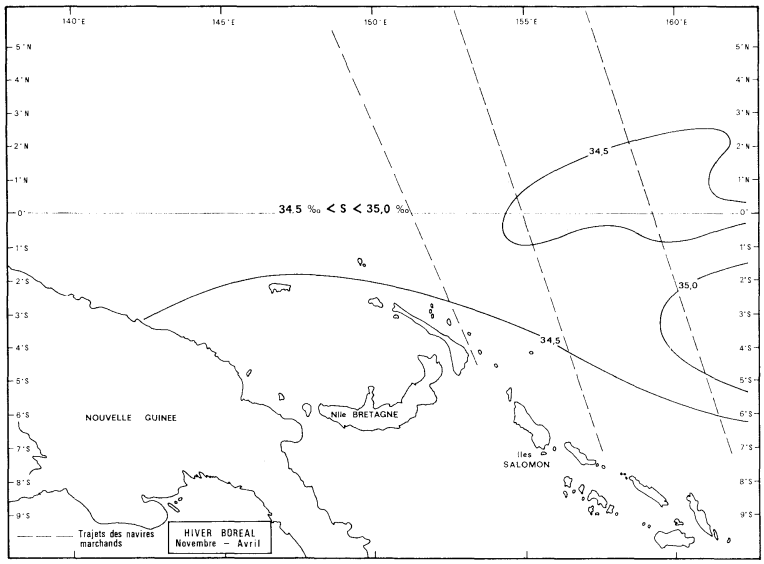


Fig. 1. Salinité de surface pendant l'hiver boréal dans le Pacifique ouest d'après REID (1969).

-les composantes zonale et méridienne du vent moyen à l'île Manus (02°S 147°E) pendant la même période extraites des "Tropical Strip Surface Charts" (National Climatic Center, Asheville, USA).

Les salinités élevées se rencontrent par vent de sud-est capable d'induire un upwelling. D'après CROMWELL (1953), la divergence produite par un tel vent est décalée au sud de l'équateur. Comme, de plus, l'eau subsuperficielle est plus salée au sud de l'équateur qu'à l'équateur lui-même, cela explique les salinités superficielles élevées observées entre 1°S et 2°S pendant la période d'alizés de sud-est, c'est-à-dire de juin à décembre environ.

L'upwelling équatorial peut aussi être mis en évidence par un abaissement de la température de surface. Les moyennes mensuelles de température superficielle entre 20°S et 10°N le long de la route des navires (fig. 3) montrent des variations saisonnières au sud de 5°S et au nord de 5°N. En revanche, les variations de température sur l'équateur semblent moins régulières; à des périodes variées on observe un refroidissement s'étendant sur quelques degrés de latitude qui pourrait être dû à un upwelling. Il convient de remarquer que, malgré la faible amplitude des variations, le refroidissement est significatif puisqu'il ressort de la moyenne des observations de plusieurs navires.

Plusieurs diagrammes T-S de surface (fig. 4) confirment la présence d'upwelling à l'équateur tant à 151°E qu'à 159°E; à l'équateur l'eau est à la fois plus salée et plus froide qu'au nord et au sud.

3. Salinités de surface du contre-courant équatorial nord

En hiver, le contre-courant équatorial nord ne reçoit de l'eau que de l'hémisphère nord. En été, il est alimenté à la fois par des eaux venant de l'hémisphère nord et par des eaux de salinité relativement élevée venant de l'hémisphère sud (HISARD *et al.*, 1969); c'est donc à cette époque qu'il devrait être le plus salé. Or c'est principalement entre août et octobre que les navires marchands ont observé de basses salinités (inférieures à 34,0 ‰) à sa surface, c'est-à-dire entre 5°N et 10°N à 147°E.

Le maximum de précipitation aux Philippines est en janvier (fig. 5); pour arriver en août à 150°E, l'eau dessalée devrait avoir une vitesse de 0,2 noeud au lieu des 1,2 noeuds observés. L'arrivée d'une eau dessalée par advection est donc peu probable et c'est ce que confirme l'étude de la salinité à 7°N et de ses variations en fonction de la situation météorologique.

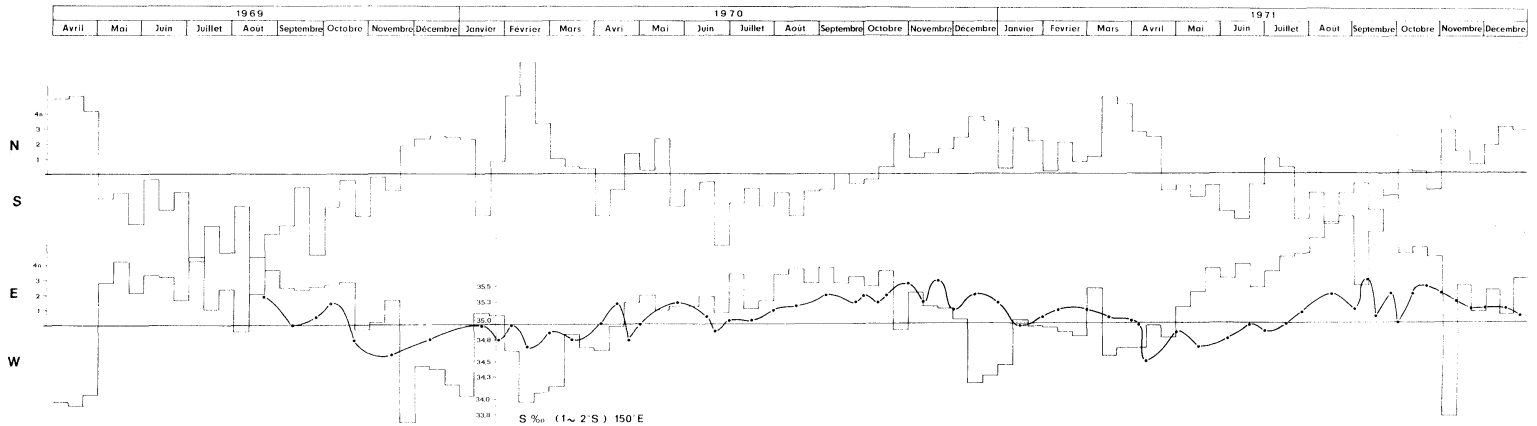


Fig. 2. Maximum superficiel de salinité dans le courant équatorial (trait continu) et composantes zonale et méridienne du vent moyen à l'île Manus (02°S, 147°E).

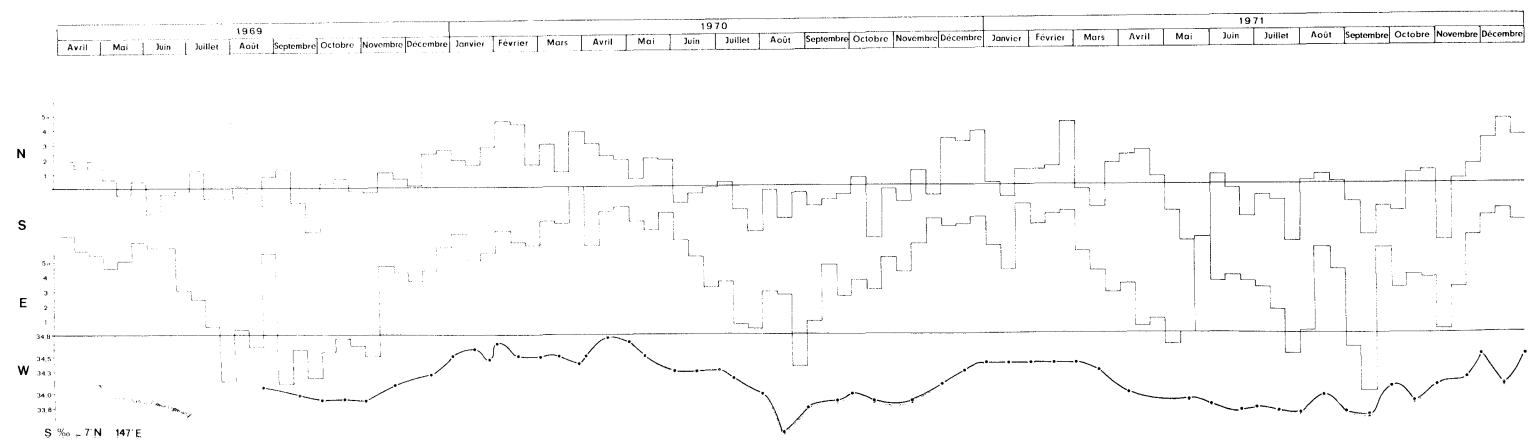


Fig. 6. Minimum superficiel de salinité (trait continu) dans le contre-courant équatorial nord et composantes zonale et méridienne du vent moyen à l'île Woleaï (07°N, 143°E).

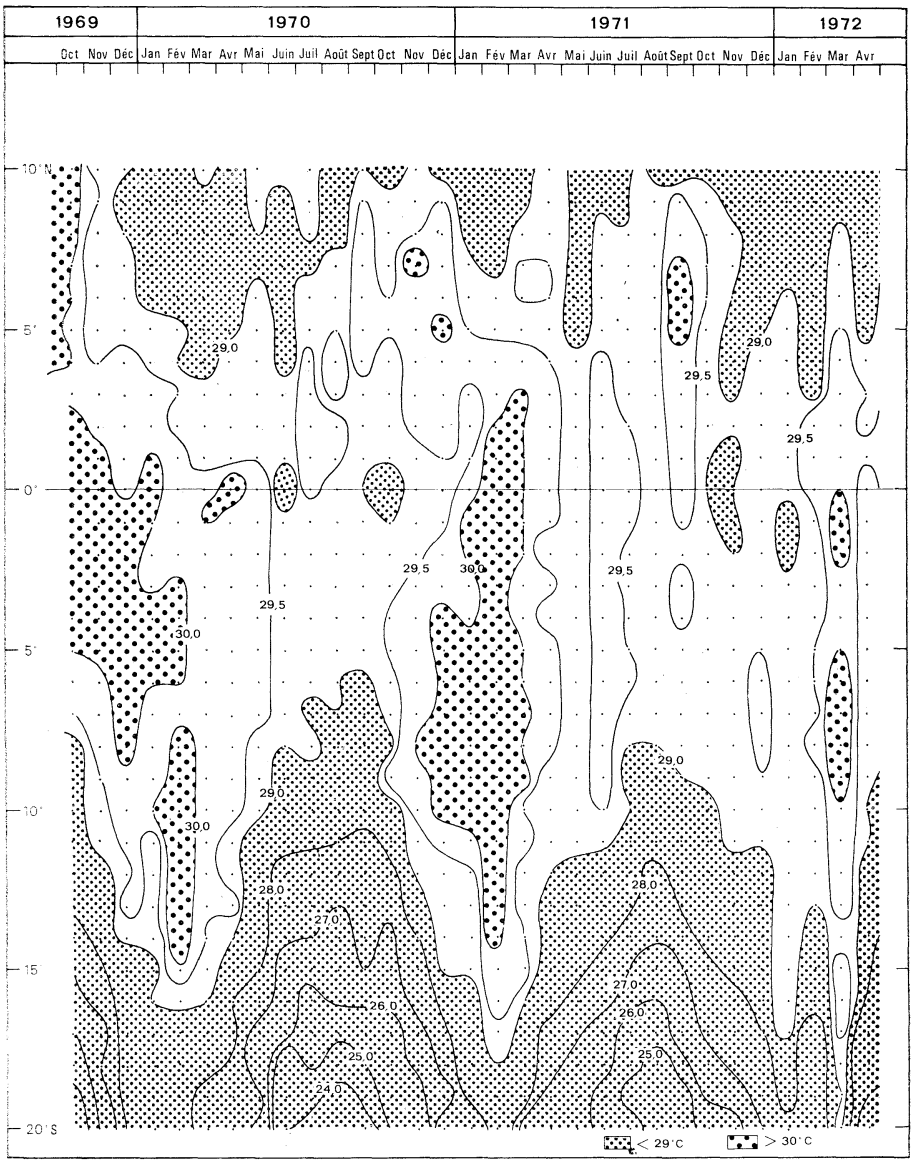


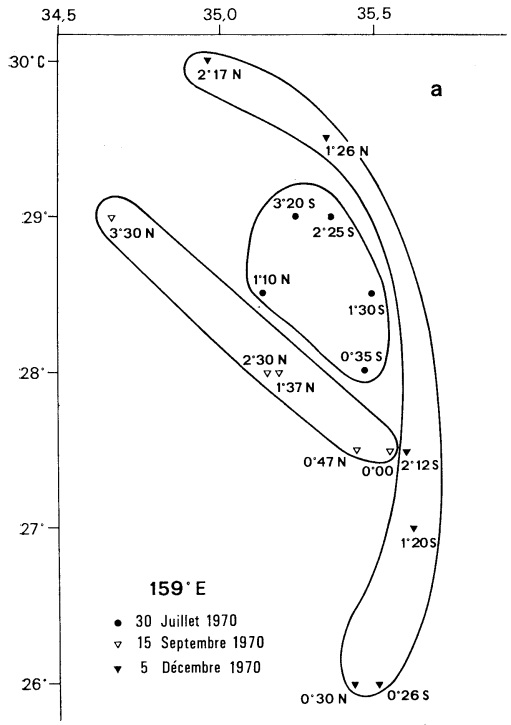
Fig. 3. Moyennes mensuelles de la température superficielle entre 20°S et 10°N le long de la route des navires.

Sur la figure 6 ont été groupées:

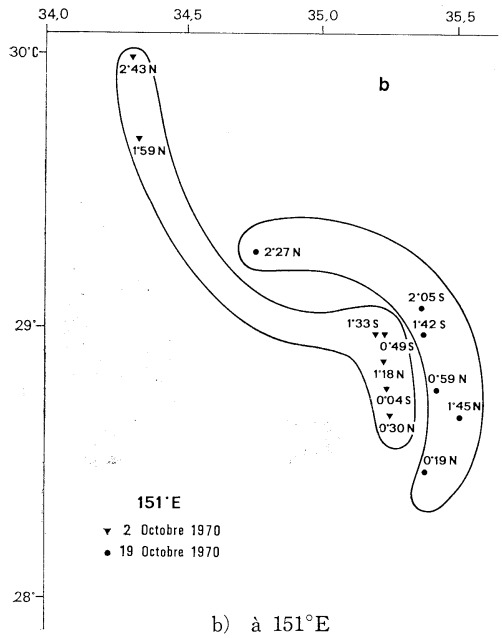
-la salinité superficielle à 7°N, 147°E de août 1969 à décembre 1971.

-les composantes zonale et méridienne du vent moyen à l'île Woleaï (7°N, 143°E) pendant la même période extraites des "Tropical Strip Surface Charts" (National Climatic Center, Asheville, USA).

Les basses salinités superficielles coïncident généralement avec un vent venant du sud-ouest ou encore une absence de vent due à la présence de la zone de convergence des vents. Ces deux phénomènes amènent des précipitations. En 1969 et 1970, les vents de sud-ouest sont apparus d'août à novembre, mais, en 1971, ils ont soufflé d'avril à novembre. La formation de cette eau dessalée serait donc due aux précipitations locales. La salinité de surface (fig. 7) des croisières



a) à 159°E



b) à 151°E

Fig. 4. Diagramme T-S de surface.

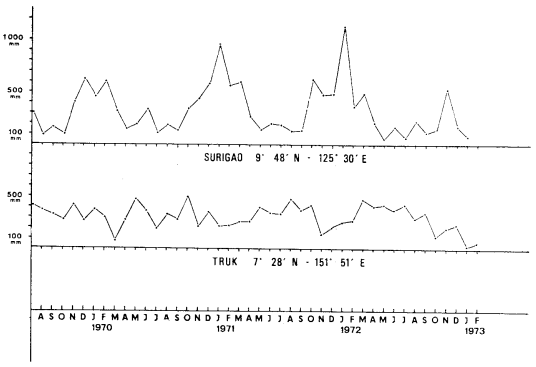


Fig. 5. Précipitation en millimètre à Surigao (Philippines) et à Truk (îles Caroline).

EQUAPAC (août 1956) et VITYAZ 25 (août 1957) le confirme. On y distingue en effet plusieurs minima isolés ($S<34{,}0\,‰$) entre 5°N et 7°N, c'est-à-dire à l'emplacement du contre-courant équatorial nord.

4. Conclusion

Dans le Pacifique occidental, les phénomènes d'advection ne peuvent pas expliquer certaines salinités superficielles observées dans le courant équatorial et dans le contre-courant équatorial nord. Elles sont formées sur place par upwelling dans le courant équatorial, par précipitation dans le contre-courant équatorial nord.

Remerciements

Les auteurs adressent leurs remerciements au commandant et à l'équipage des navires *Gyokuryu maru*, *Horyu maru*, *Koryu maru* de la Compagnie TAIHEIYO KISEN KAISHA, *Koyo maru* de la Compagnie SHINWA KAIUN KAISHA, *Hasshin maru* et *Nanyo maru* de la Compagnie NIPPON YUSEN KAISHA, *Hisashima maru* de la Compagnie KOKUYO KAIUN KAISHA ainsi qu'aux Etablissements BALLANDE, au Groupe P. PENTECOST et à la Société JOHNSTON, consignataires de ces navires. Leur collaboration efficace et sympathique a permis de mener à bien cette étude.

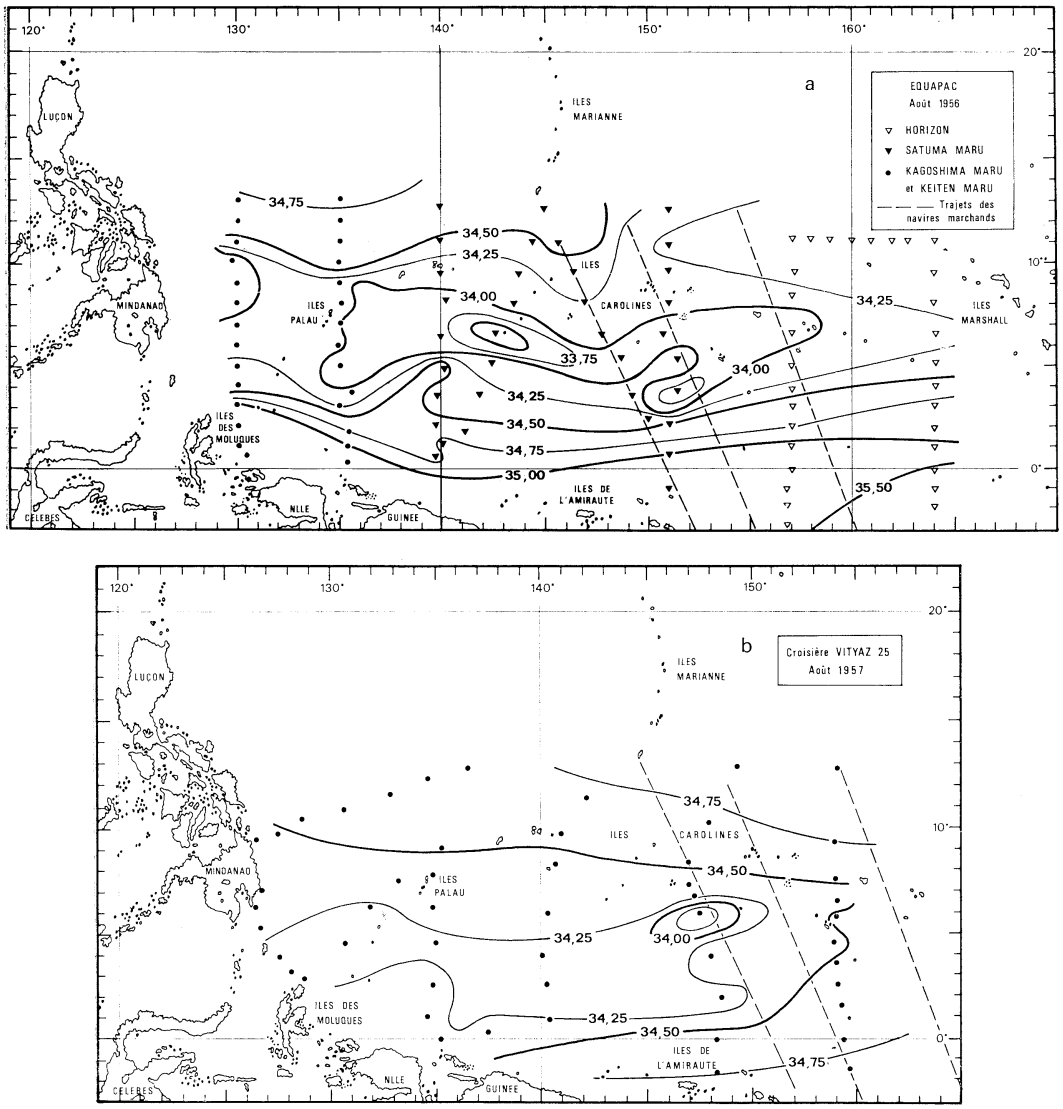


Fig. 7. Salinité de surface pendant
a) la croisière Equapac (août 1956), b) la croisière 25 du Vityaz (août 1957).

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東経 150°～160° 線での赤道海流，北赤道反流を特徴づける表面塩分

J. R. DONGUY et C. HENIN

要旨: 1969年夏から東経 150°～160° 線に沿ってニューカレドニアから北緯 10° まで日本の商船によって表面水温と表面塩分とが観測されてきた。これ以前のデータと違って，南緯 3° から北緯 1° の間に高い塩分（35.0～35.5‰）が見出される。おもに8月から10月まで，北緯 5° と 10° の間に低い塩分（34.0‰以下）がある。フィリピン諸島での最大降水は1月におきるから，この降水でうすめられた海水が8月に 150° 線に達するとすれば，その速度は 0.2 ノットとなり，この海域での観測値 1.2 ノットよりもずっと遅い。この低塩分水は，南西風または貿易風がもたらす降水によるものと思われる。1956年8月の EQUAPAC, 1957年8月の VITYAZ の観測結果も，北赤道反流海域内で低塩分水が生ずることを示しているようである。

なお，太平洋汽船の玉竜丸，宝竜丸，興竜丸，新和海運の光陽丸，大日海運の八新丸，大阪旭海運，東京船舶の南洋丸，国洋海運の久島丸の乗組の方々に感謝する。

La mer (Bulletin de la Société franco-japonaise d'océanographie)
Tome 12, N° 2, pp. 79 à 85. Mai 1974

Natural Stable Sea Foam and its Meteorological Significances*

Tomosaburo ABE** and Naoki FUKUCHI**

Abstract: In the season of prevailing westerly north winds, enormus amounts of stable sea foam are produced at a breaker zone or a certain shoreline of Japan Sea. The examination of the liquid which was obtained when the stable sea foam had decayed showed that it contained enormous amounts of coastal phytoplankton and small fragments of sea weed, then these substances are surface active materials. The foam powder is obtained as residual substance after drying above liquid. By adding of the powder into a seawater, its value of the foaming factor, FF is increased, but h_0 increases little, on the contrary, τ increases very large. When the FF value of a seawater *in situ* becomes 125 mm·sec, stable sea foam is produced. It seems that the concentration of the foam powder contained in a natural seawater is only 0.03 %.

The frequency of occurrence of the foam transport are 3 days every 10 days in the period from November to the next February.

It is most probable that the diameter of the scattered foam masses is 6 cm and its frequency about 27 % at Fukura, Yamagata Prefecture.

And also meteorological consideration are done when the stable sea foam masses are transported there. Practically, 75 % of the number of the foam transport take place at winter monsoon situation. In winter, the foam transport seems to occur when traveling cyclone arrives on the Kuriles, and this cyclone track has northern component after pass through Japan.

1. Introduction

In the season of prevailing westerly north winds, enormus amounts of stable sea foam (*i.e.*, longlived and tenacious ones) are produced at a breaker zone or a certain shoreline of the Japan Sea, and some of accumulated sea foams are scattered in inland direction by wind turbulences. These salty masses become attached many things nearby, and various kinds of disasters are happened (for example, electric current leakage, corrosion of metal, and so on.).

Such phenomena often occurred at the Pacific coastal lines of Japan on the season of the Typhoon and high wind.

It was found by one of the authors (ABE) that the important attribute of the stabilization of a seawater is due to surfactants which extracted from native coastal phytoplankton (mainly a certain kinds of diatom at the Fukura shore, Yamagata Prefecture), sea weeds, etc. when seawater is disturbed violently with wind and wave actions (ABE, 1962, '63).

The various features of stable sea form *in situ* are shown in Figs. 1~5.

2. Effects of the foam powder on the foaming of seawater

What is designated the foam liquid is the one obtained after natural stable sea foam disappeared, its appearance is an opalescent dark brown one (Fukura), and the foam powder (the residual substances obtained after drying above liquid), it appears an opaque, brownish white powder. Then various substances diffused from the powder have apparently the properties for surface active substances which stabilized a sea foam, that is, a sea foam becomes longlived and tenacious one.

When a certain amount of the powder is put into a filtered ordinary seawater and the mixture is shaken, it become stable foaming characteristics as shown in Fig. 6.

* Received April 18, 1974

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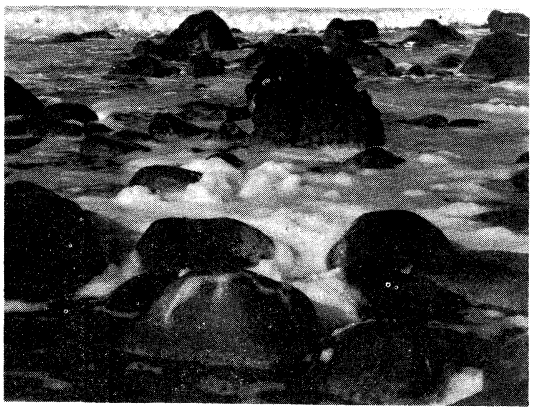

Fig. 1. Production of stable sea foam.

Fig. 2. Accumulation of stable sea foam.

Fig. 3. Flying of stable sea foam by winds. Distance between two black arrows is one meter.

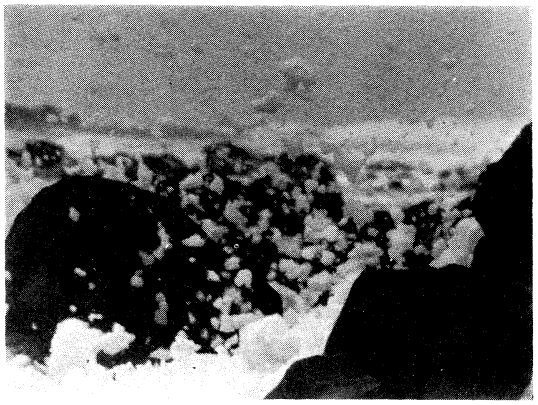

Fig. 4. Flying of stable sea foam by winds.

Fig. 5. Transport of stable sea foam by winds. (Photo by Mr. N. SAKAGUCHI)

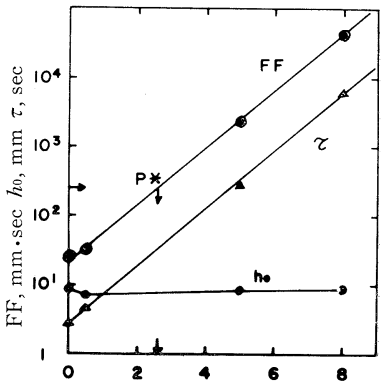

Fig. 6. Effects of the foam powder on the foaming of a seawater.

(Figs. 1~4, photo at Fukura shore, Yamagata Prefecture)

Therefore, values of the foaming factor, FF are increased by addition of the powder, where FF is a certain physical constant which has been previously introduced one of the authors (ABE) to indicate the foam producing ability of a seawater and defined as $h_0\tau$, where h_0 is initial height of foam layer, τ the half life in the decay process of the layer which is supposed to be obeying in exponential law, *i.e.*, $h=h_0\exp(-kt)$, where k is the decay constant, t the time (ABE, 1953, '55, '62). Therefore, we investigate the mechanism of it in detail; by addition of the powder, the h_0 increases little, on the contrary, τ increases very larger, that is, it shown that the foam producing power is almost constant according to the experimental results of the former case (h_0), but the life of foam becomes longer due to be strengthened the membrane of foam according to the experimental results of the latter one (τ).

From Table 1, it can be seen that the foam liquid is about 60 times more viscous than an ordinary seawater, moreover, the membrane of stable sea foam is sufficiently able to resist external forces, and then the membrane is able to become so thinner that pretty interference colors may be appeared momentarily.

Table 1. Physical properties of the foam liquid (Fukura).

	Substance	Value	Notes
Density ($g\cdot ml^{-1}$)	foam liquid	0.977	12.6°C
	foam mass	0.0113	12.0°C
Surface tension ($dyn\cdot cm^{-1}$)	foam liquid	27.34	12°C
	seawater*	74.7	12°C ordinary Cl 19‰
Coefficient of viscosity ($cm^{-1}\cdot sec^{-1}$)	foam liquid	0.63	11.5°C
	seawater*	0.0137	10.0°C ordinary
	freshwater	0.0131	10.0°C
Thermal conductivity $\left(\frac{cal}{cm\cdot sec\cdot deg}\right)$	foam liquid	0.0076	25.0°C
	foam mass	0.0081	20.0°C
	seawater*	0.00135	17.5°C salinity 20‰
Electric specific conductivity ($\times 10\ ohm^{-1}\cdot cm^{-1}$)	foam mass	0.18	12.0°C
	foam mass	0.13	12.0°C one hour later
	foam liquid	2.9	
	seawater*	3.8	

* : see references

Wilson and Collier (1972) discussed experimentally on the production of surfactants by various marine phytoplankton cultures.

Amounts of the foam liquid contained in a stable foam mass is substantially calculated using the ratio of the specific volume of foam mass itself to that of the foam liquid, which is roughly 87 : 1 by our calculation (see Table 1), and then it is seen, volume of 87 times of the stable foam mass as much as that of the foam liquid reduced substantially only one part of the foam liquid. Southward (1953) reported that 500 ml of stable sea foam reduced to 5 ml of an opalescent yellow-brown liquid (Isle of Man, England), that is, it is about the same order in both cases, the Fukura and the Isle Man, though the reduction rate of the case of the former is somewhat less than the latter, and moreover, his microscopical examination of the foam liquid showed the presence of particulate matter of various sizes, some were of obvious planktonic origin, for example, part of copepod cuticle, diatom frustules and green flagellates, however, the majority of the particles were unrecognizable, varying from 0.5 to 1.0 μ in diameter, but mostly about 1 μ (that is, of just colloidal dimensions), and showed a strong tendency to form a layer at air/water interfaces.

How many values are the concentration of surfactants contained in a natural seawater when stable foam is produce? When the FF value of a seawater at the Fukura becomes 125 mm·sec, stable foam is gradually produced, it means that the concentration of surfactants contained in a natural seawater is only 0.03 %, because it is roughly estimated using the value in Fig. 1 (see the place of p_*).

3. The transport of stable foam mass

By means of our observations, the transport of sea foam mass begins to occur and transport in small scale since the middle of November, and then it becomes to increase gradually in the frequency and scale, then it reaches at maximum stage in the end of January, and then decreases gradually since the middle of February. It is rare case that the transport

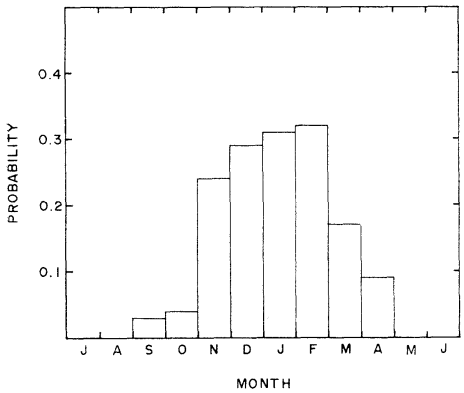

Fig. 7. Monthly mean change of transported stable sea foam masses, 1965-1967 (Fukura).

occurs in August (that is a case accompanied with the typhoon) or in April as shown in Fig. 7. (ABE and FUKUCHI, 1968).

The frequency of occurrence of the transport are 3 days every 10 days, or about every 3 days in the period from November to the next February.

Some of the stable foam masses accumulated at a shore are scattered by gusty winds (mean speed is more than 7 m/sec). Scattered mass is of irregular shape, and so the size of it is represented by the diameter of an ideal sphere of the same volume, then Fig. 8 shows the frequency distribution of the size of stable sea foam which are scattered. It is most probable that the diameter is 6 cm, its frequency about 27 %, and almost sea foams are smaller than 22 cm, and larger ones are few. As previously mentioned, the specific volume ratio of the foam mass to the foam liquid is 87 : 1, then the foam liquid contained in the sphere (6 cm in diameter) of foam mass is 1.30 m*l* roughly. The characteristics of the foam liquid are shown in Table 1.

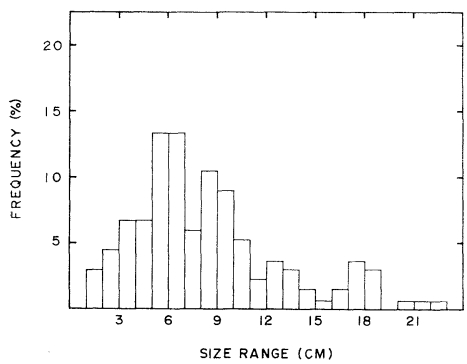

Fig. 8. Size distribution of transported stable sea foam masses (Fukura).

Winds are blowing with the speed more than 7 m/sec, their direction are north north westerly ones, and almost parallel to the Fukura shoreline when many small stable foam masses

Table 2. Plankton observation of the foam liquid.

Station : Fukura beach, Yamagata Prefecture

Date :	Feb. 6, 1962		Feb. 7, 1962	
Diatoms	No. per 10 m*l*	%	No. per 10 m*l*	%
Asterionella japonica	+		160	0.3
Biddulphia auraita	2,880	0.3	—	—
Cocconeis spp.	960	0.1	1,600	2.5
Gramatophora marina	—	—	320	0.5
Licmophora lingbyei	2,240	0.2	320	0.5
Melosira borreri	134,400	14.0	37,440	59.0
Navicula spp.	3,200	0.3	1,600	2.5
N. long. v. *reversa*	640	0.1	160	0.3
Pleurosigma affine	1,920	0.2	160	0.3
Thalassiosira hyalina	2,560	0.3	160	0.3
T. Subtilis	800,000	83.0	20,160	32.0
Pennatae misc.	1,280	0.1	640	1.0
the others		1.4		0.8

Date : Feb. 6-7 1962	Seawater		Stable foam liquid	
Diatoms	No. per 10 m*l*	%	No. per 10 m*l*	%
Asterionella japonica	—	—	2,400	0.4
Cocconeis spp.	4	0.2	52,800	8.7
Denticula marina	16	0.7	4,800	0.8
Eucampia zoodicecers	16	0.4	—	—
Grammatophora marina	—	—	9,600	1.6
Licmophora lingbyei	232	11	57,600	9.4
Fragilaria islandica	388	18	—	—
Melosira borreri	240	11	283,200	46
Narricula spp.	260	12	105,600	17
Nitzochia longissima	4	0.2	—	—
Skeletonema costatum	8	0.4	—	—
Thalassionema nitzschioides	12	0.6	—	—
Thalassiosira decipiens	8	0.4	26,400	4.3
T. hyalina	60	2.8	—	—
T. subtilis	896	42	67,200	11
Pennatae misc.	4	0.2	—	—
Total :	2,140		609,600	

are scattered hard. Then it may be considered that the upwelling produced by the wind in a shore water during the period may be accompanied with movements of certain surfactant particles nearby, but the details on their features and mechanism have to be studied on the basis of may accurate observations *in situ* and in laboratory in the near future.

4. Relation between the foam transports and the meteorological conditions

The transport of the stable sea foam is the result that it is produced due to the turbulence of seawater made by wave action at breaker zone, and the accumulation of it is caused by blowing wind at craggy shore and then the shearing force of wind acts on the foam accumulation. Therefore, it is seemed to be the first cause of the formation how wind blows. This is investigated in respect to weather map and transport during the period from 1965 to 1967. In relating to it when foam transport occur, wind is mainly blowing in the direction of NW-N at Fukura. This atmospheric situation is just satisfied by the winter time monsoon situation. Practically, 75 % of the number of the foam transport take place at this situation. In this situation, the fetch and duration seems to satisfy to stimulate the wind wave at the Japan Sea.

1. Pressure system

As stated above, the foam transport is occurred mainly when atmospheric situation is winter type, that is, this situation is frequent in Japan during winter season, a cyclone is located at the Kuriles and north-westerly monsoon is prevailing in the northern part of Japan. The winter type situation is classified to 3 types relating to atmospheric pressure, that is, A situation is one that the difference of pressure is over 15 mb, A′ situation is 10–15 mb, and B situation is under 10 mb at the area of 130° to 140°E on 35°N line. Both A and A′ situations are strong monsoon cases and B is rather weak one.

Fig. 9 shows a pressure system of A′ situation. Table 3 shows the frequency of occurrence of each pressure system (α) and that of foam transport (β) at Fukura. It is obviously

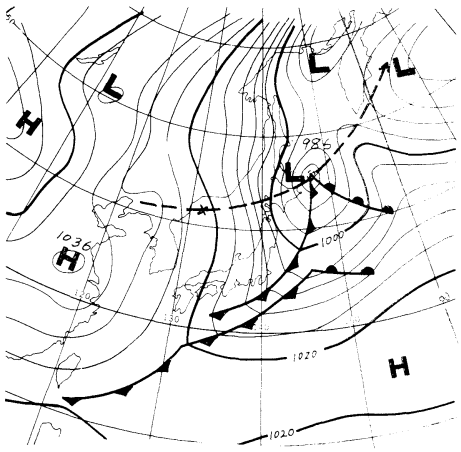

Fig. 9. Pressure system of A′ situation. Broken line shows the cyclone track. (0100 00Z Feb. 1965)

Table 3. Number of day and that of transport in each pressure system, 1965–1967.

Situation	Number of day (α)	Number of transport day (β)	Ratio (β/α) %
A	26	20	77
A′	50	26	52
B	61	23	38

that the ratio β/α is much at strong winter monsoon situation. However, when the pressure system is A′ situation, the ratio is rather little than A situation. The cause of this reduction is seemed to be due to the *satoyuki* situation (snow-fall in the train), and its frequency are 8 times in A′ situation. This pressure system is that northern part of Japan is covered by the atmosphere of which gradient of pressure is slight or by closed isobar. At this situation wind is very slight in the northern part of Japan, and it is snow in the train of a mountain, and the foam transport do not occur at Fukura.

2. Cyclone tracks

The foam formation occur mainly in winter pressure system in Japan. However, at this winter system, the foam transport is not occurred occasionally. Then, examining a weather map, there are some distinction in cyclone tracks. In winter, there are remarkable 4

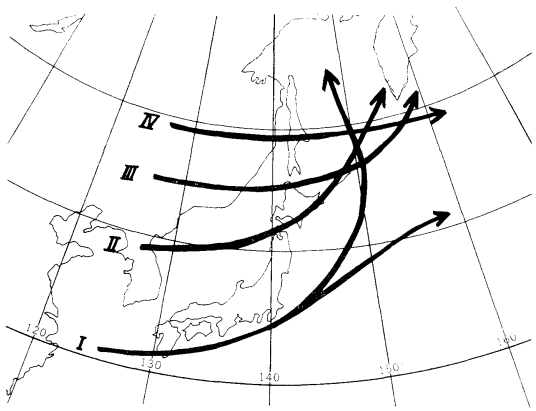

Fig. 10. Typical cyclone tracks in winter.

Table 4. Number of each cyclone track and foam transport, 1965-1967.

Type	Number (n)	Number of transport (m)	Ratio (m/n) %
I	27	9	33
II	49	26	53
III	17	7	41
IV	11	5	45

types in the cyclone tracks as follows:

Type I: A cyclone travels to the east from the Yangtze River and passes along south coast of Japan.

Type II: A cyclone crosses mid Japan sea area about 40°N.

Type III: A cyclone crosses north Japan sea area about 43°-45°N.

Type IV: A cyclone travels to the east from the Amur River.

Fig. 10 shows each type of cyclone track in winter. Table 4 shows the frequency of each cyclone track (n) and the foam transport (m). In this table, the ratio m/n is different slightly in each case. The distinction in the each track whether the foam transport take place or not is as follows:

Type I: Occurrence of transport; a cyclone travels to the north along east coast of Japan and arrives on the Kuriles.
None of occurrence; a cyclone travels to the east alone.

Type II: Occurrence; after pass through Japan, a cyclone arrives on the Kuriles, and then travels to the north.
None; a cyclone travels to the east alone.

Type III: Occurrence; a cyclone track has the northern component on the Kuriles.
None; a cyclone travels to the east alone.

Type IV: The distinction is little.

Therefore, the foam transport seems to occur, when each traveling cyclone arrives on the Kuriles, and above each cyclone track has northern component after pass through Japan. It is obviously that the distinction of the cyclone track is mainly related to track after pass through Japan.

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安定海水泡沫の生成飛散と気象要素との関係

阿部友三郎　福地直樹

要旨: 冬期，季節風卓越時，日本海沿岸において多量の安定な海水泡沫が発生し，飛散するのがしばしば見られる。この泡沫は，沿岸のプランクトン及び海藻類等を源とする表面活性有機物質が海水に溶混入して発生するものと考えられる。この泡沫より乾燥して得た残滓粉末を一般の海水に溶かしこむと，Foaming Factor (F.F.) は指数的に増大する。しかし，h_0 の増大はほとんどなく，τ の増大が主である。これは，現場海水の F. F. の傾向とも一致している。海水の F.F. の値が 125 mm・sec 以上となると，沿岸に安定泡沫が発生することから，現場海水には，0.03 % ほどの残滓粉末量で安定泡沫が発生しえると考えられる。

安定泡沫飛散の現象は，冬期11月から翌年2月にかけては約3日に一度の頻度で見られ，その飛散塊は直径 6 cm が最も多く，27 % を占めている。

又，気象と泡沫飛散の関係を調べたところ，飛散回数の 75 % は，日本が冬型気圧配置の時に起こっている事がわかった。これは，大陸で発生した移動性低気圧が日本を通過後，北に向い千島に到達する場合に，最も泡沫飛散の可能性が強いと考えられる。

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相模湾沿岸における異常高潮位と湾の温度場及び塩分場との関係*

松山優治** 寺本俊彦** 前田明夫**

Abnormal Variations of Sea Level at the Sagami Bay Coast and their Relation to Variations in Offshore Fields of Water Temperature and Salinity

Masaji MATSUYAMA, Toshihiko TERAMOTO and Akio MAEDA

Abstract; Abnormal variations of sea level recorded at Aburatsubo during 1964 to 1971 are analysed in relation to variations of water temperatures measured regularly once a day at the sea surface, 25 m depth and 50 m depth off Iwae and variations of temperature- and salinity-sections between Manazuru and Misaki occupied regularly once a month by Kanagawa Fisheries Experimental Station. The term abnormal variations are used when rises and falls of sea level from its annual mean amount to 10 cm in magnitude and last for more than a week. The sea-level variations are also analysed in reference to variations of daily-mean atmospheric-pressure difference between Oshima and Hachijojima. Most of the abnormal rises of sea level are accompanied with baroclinic variations in the field of water temperature. Abnormal sea-level variations which are of the time scale of a week to two are especially in close correlation to the east-west component of geostrophic wind over the adjacent region. Abnormal, transient sea-level variations magnitudes of which amount to 7 to 15 cm within a day sometimes take place at the coast of the Sagami Bay. Among those variations that occurred during 22nd to 24th of October in 1971 is studied in relation to hydrographic observations which were just conducted before and after the period. This sea-level variation which reaches 15 cm in magnitude is associated with the variation of density field that is suspected to have been caused by upwelling.

1. 序　文

1964年以降1970年末までに日本沿岸の潮位資料を解析した磯崎(1972)[1]は，日平均潮位偏差から考えて，1971年9月の異常高潮位と同程度の顕著な異常高潮位は1966年8月と1968年7月の2回，1971年9月に準ずるものは6回起こっていることを指摘している。彼は異常高潮位とは潮位偏差10 cm以上が1週間以上継続し，数百km以上の水平スケールを持つものと定義している。又，彼は異常高潮位は日本南岸を西に向って2～6 m/secで伝播したことを指摘した。異常高潮位はその伝播方向と位相速度の大きさから考えて，内部ケルビン波(Internal Kelvin Wave)又は陸棚波(Continental Shelf Wave)が沿岸を伝わったことはほぼ間違いないといわれている(吉田，1972)[2]。

われわれは異常潮位変動に関連して，海の内部で密度場がどのように変動したかに特に注目して研究を進めた。変動が一週間以上にわたることから内部モードの現象が起こっている可能性があると考えられるからである。実際には，われわれが取扱おうとする時間スケールの変動の解析に利用しうる海洋内部の変動に関する情報は極めて少なく，わずかに相模湾の一測点における三層で測られた水温記録があるだけである。この論文の前半

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では，この資料に基づいて得られた相模湾における海の内部の変動と潮位変動との関係が論じられている。同時に，潮位変動と陸岸に平行に吹く風との関係も調べられている。著者ら（1973）[3] によると，異常潮位に伴い非常に短期間に急激な潮位変化（8～15 cm/day）が起こる。後半ではこの間に，海水がどのような運動をした可能性があるかについて推測がなされている。

2. データ及びデータ処理

1974年～1971年に起こった異常潮位の内，相模湾沿岸の検潮記録にはっきり現れた1964年5月，1965年6月，1966年8月，1966年10月，1966年12月，1967年9月，1968年8月，1970年10～11月，1971年9月及び1971年10月に起こった10例について解析が行われた。この時期はFig. 4に矢印で示してある。

1. 潮　位

Fig. 1 に示す油壺（35°09.4′N, 139°37.1′E）の日平均潮位が使用された。潮位の気圧補正は横浜の日平均気圧により行われた（網代でも気圧が測定されているが，日平均気圧は両者ではほとんど変らない）。

潮位偏差は，8年間（1964～1971年）の平均潮位 178 cm と平均気圧 1,012 mb を基準にして次のように定義された。

日平均潮位偏差＝（実測潮位－178 cm）

$+\alpha$（日平均気圧－1012 mb）

ただし，気圧 1 mb の変化は潮位 1 cm の変化に対応するとして，$\alpha=1$ cm/mb とされた。以後の潮位変動の議論には，この日平均潮位偏差が用いられる。

2. 地衡風東西成分

陸岸に平行なほぼ東西方向の風を代表するもの

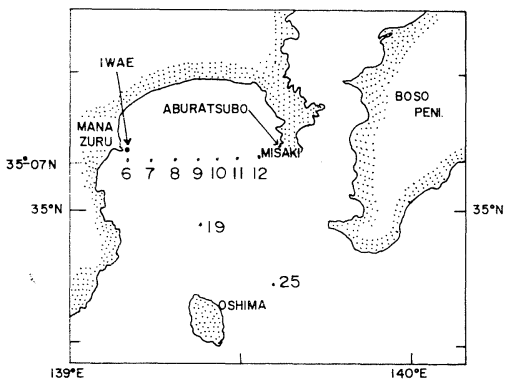

Fig. 1. Location of hydrographic stations occupied regularly once a month by Kanagawa Fisheries Experimental Station (Sts. 6 to 12) and hydrographic stations occupied by R/V *Tansei-maru* before and after abnormal, transient sea-level rise which took place during 22th to 24th of October, 1971.

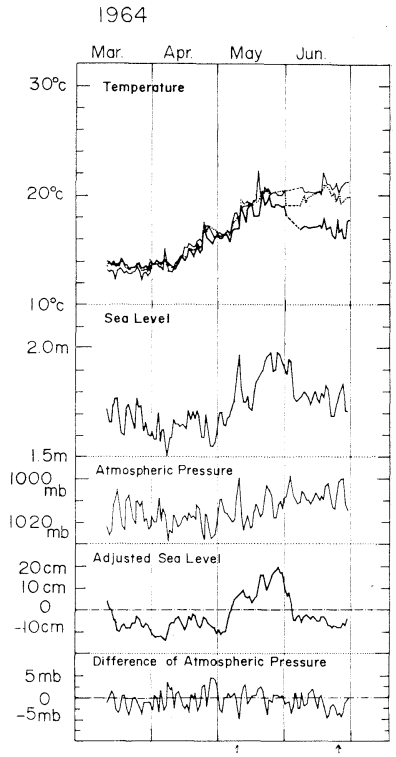

Fig. 2-1. From the top to the bottom, variations of water temperature at the surface (thine line), 25 m depth (dotted line) and 50 m depth (thick line) at Iwae, variations of daily-mean sea-level at Aburatsubo, variations of daily-mean atmospheric-pressure at Yokohama, variations of Aburatsubo daily-mean sea-level from which an atmospheric-pressure effect is eliminated and variations of daily-mean atmospheric-pressure difference between Oshima and Hachijojima are illustrated for the period from March to June, 1964.

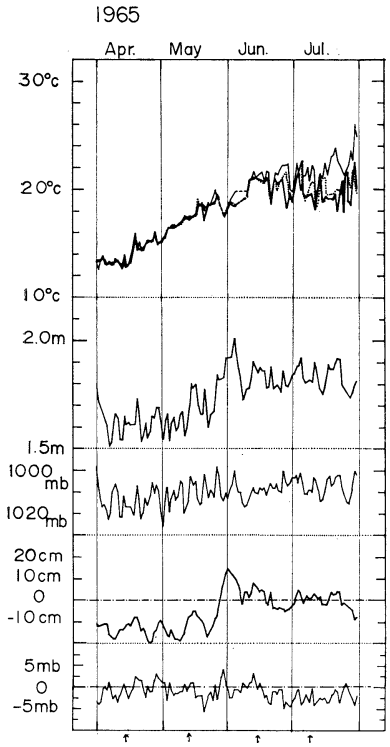

Fig. 2-2. From the top to the bottom, variations of water temperature at the surface (thine line), 25 m depth (dotted line) and 50 m depth (thick line) at Iwae, variations of daily-mean sea-level at Aburatsubo, variations of daily-mean atmospheric-pressure at Yokohama, variations of Aburatsubo daily-mean sea-level from which an atmospheric-pressure effect is eliminated and variations of daily-mean atmospheric-pressure difference between Oshima and Hachijojima are illustrated for the period from April to July, 1965.

として，大島と八丈島との気圧差から次式により求められた地衡風速が用いられた。

$$u=-\frac{1}{\rho_0 f}\frac{\partial P}{\partial y}$$

ここに，ρ_0 は空気の密度，P は大気圧，$f=2\omega\sin\varphi$ はコリオリ・パラメーター（ω は地球自転の角速度，φ は大島と八丈島の平均緯度）である。又，八丈島と大島を結ぶ直線を y 軸とし（八丈島から大島に向う向きをその正方向とする），これに直交して x 軸をとる右手系直角座標が用いられている。この方法で推算すると気圧差 1 mb は地衡風速約 5 m/sec に相当する。一般には，海面上の風は摩擦のため，地衡風から角度にして 10° 前後ずれるが，本文の議論にはそれほど大きな影響を与えないと考え，海面上の風を地衡風として近似的に扱った。

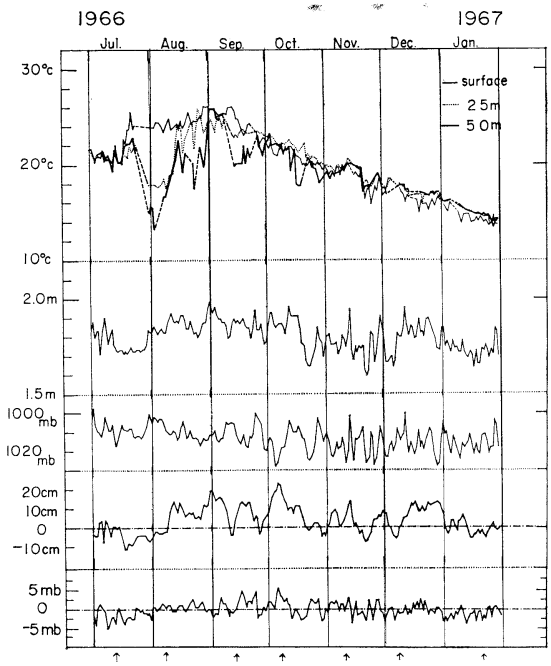

Fig. 2-3. From the top to the bottom, variations of water temperature at the surface (thine line), 25 m depth (dotted line) and 50 m depth (thick line) at Iwae, variations of daily-mean sea-level at Aburatsubo, variations of daily-mean atmospheric-pressure at Yokohama, variations of Aburatsubo daily-mean sea-level from which an atmosyheric-pressure effect is eliminated and variations of daily-mean atmospheric-pressure difference between Oshima and Hachijojima are illustrated for the period from July, 1966 and January, 1967.

3.　一定点における水温

神奈川県真鶴沖，岩江定置網漁場（Fig. 1）では，毎朝揚網時に，表面，25 m 深，50 m 深の三層の水温が 1954 年から約 20 年間継続してとられている。ここで用いられたのはこのデータである。

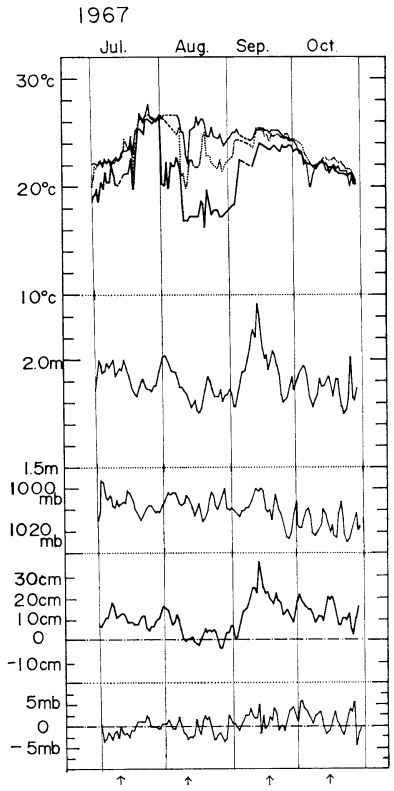

Fig. 2-4. From the top to the bottom, variations of water temperature at the surface (thine line), 25 m depth (dotted line) and 50 m depth (thick line) at Iwae, variations of daily-mean sea-level at Aburatsubo, variations of daily-mean atmospheric-pressure at Yokohama, variations of Aburatsubo daily-mean sea-level from which an atmospheric-pressure effect is eliminated and variations of daily-mean atmospheric-pressure difference between Oshima and Hachijojima are illustrated for the period from July to October, 1967.

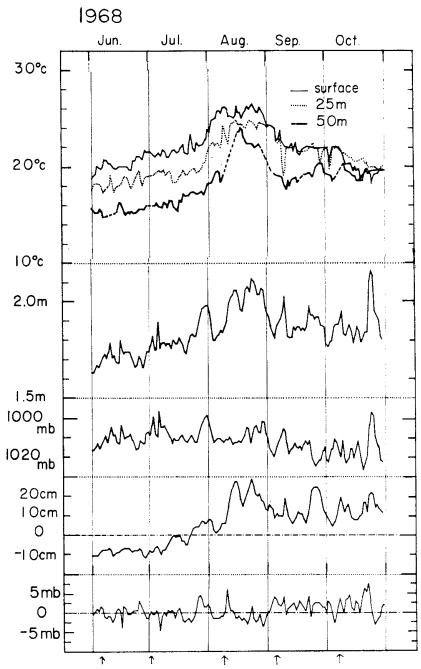

Fig. 2-5. From the top to the bottom, variations of water temperature at the surface (thine line), 25 m depth (dotted line) and 50 m depth (thick line) at Iwae, variations of daily-mean sea-level at Aburatsubo, variations of daily-mean atmospheric-pressure at Yokohama, variations of Aburatsubo daily-mean sea-level from which an atmospheric-pressure effect is eliminated and variations of daily-mean atomospheric-pressure difference between Oshima and Hachijojima are illustrated for the period from June to October, 1968.

4.　相模湾及び相模灘の水温，塩分

神奈川県水産試験場が真鶴と三崎を結ぶ定線(Fig. 1)上で1964年より毎月1回行って来ている海洋観測の結果が用いられている。

3.　異常高潮位の解析とその結果

1964年～1971年に起こった10回の異常高潮位の際の水温（細線，点線，太線はそれぞれ表面，25 m深，50 m深の水温），日平均実測潮位，日平均気圧，日平均潮位偏差，日平均気圧差を Fig. 2-1, 2-2, 2-3, 2-4, 2-5, 2-6, 2-7 に示す。各図の下に示す矢印は，神奈川県水産試験場による定線観測の時期を示す。

1.　潮位変化と水温変化との関係

磯崎(1972)[1] は波浮の表面水温変化と岡田の潮位変化とを比較し，両者の間に正の相関があると述べている。ところが Fig. 2-1 より Fig. 2-7 によると，表面水温の変化と潮位変化については，1968年8月の例にわずかに正の相関がみられる程度で，その他の例ではそれほど明らかな関係は見られない。

ここで，重要なことは，25 m 深と 50 m 深の水温変化が潮位変化との間に一般に正の相関関係

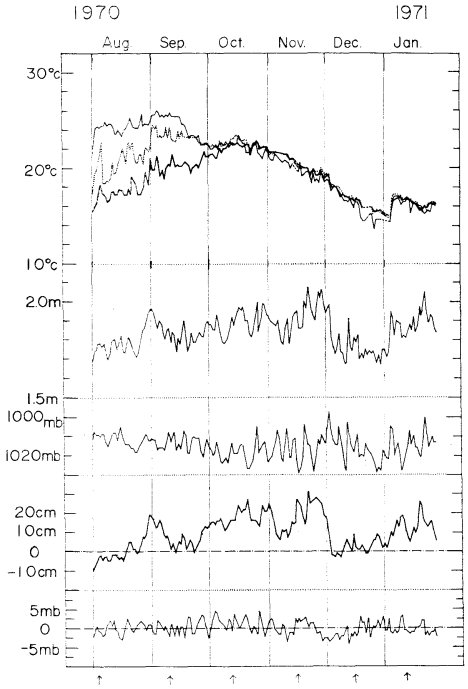

Fig. 2-6. From the top to the bottom, variations of water temperature at the surface (thine line), 25 m depth (dotted line) and 50 m depth (thick line) at Iwae, variations of daily-mean sea-level at Aburatsubo, variations of daily-mean atmospheric-pressure at Yokohama, variations of Aburatsubo daily-mean sea-level from which an atmospheric-pressure effect is eliminated and variations of daily-mean atmospheric-pressure difference between Oshima and Hachijojima are illustrated for the period from August, 1970 to January, 1971.

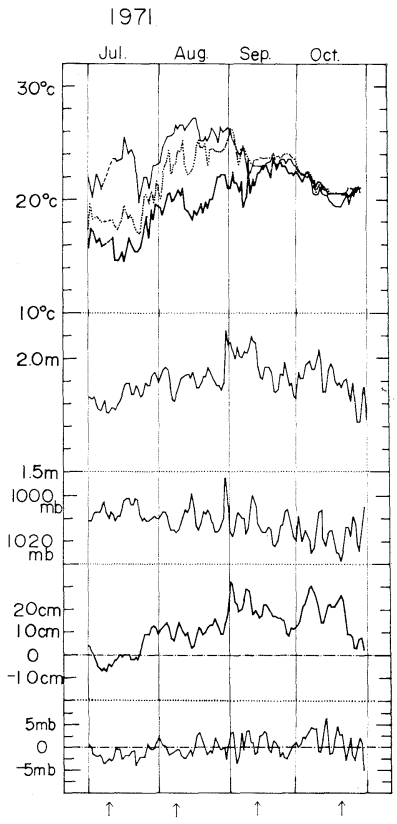

Fig. 2-7. From the top to the bottom, variations of water temperature at the surface (thine line), 25 m depth (dotted line) and 50 m depth (thick line) at Iwae, variations of daily-mean sea-level at Aburatsubo, variations of daily-mean atmospheric-pressure at Yokohama, variations of Aburatsubo daily-mean sea-level from which an atmospheric-pressure effect is eliminated and variations of daily-mean atmospheric-pressure difference between Oshima and Hachijojima are illustrated for the period from July to October, 1971.

をもっていることである。この二層の水温変化と日平均潮位偏差の変化との関係をもう少し詳しくみるために，1968年8月の例を取上げ，それを拡大してFig. 3に示す。図の上部には水温，下部には潮位偏差が示されている。50m 層の水温については，その上昇過程で欠測を生じているので，二層の水温間の位相差は明らかではないが，たかだか2～3日の程度である。異常高潮位10例のうち，7 例において潮位変化に対応してこれら二層の水温が変化している。

1965年5月，1966年10月，1966年12月の3例については，このような潮位と二層水温間の対応関係がみられない。しかしこのことから，これら3例の異常高潮位の力学的機構が他の場合と異なると直ちに断言することは出来ない。何となれば，等温層の上下運動に伴うある深さの水温変化の著しさは，その深さ近傍における水温鉛直勾配に依存する。この深さがこの勾配の大きい水温躍層の中にあるか否かによって，水温変化の著しさは大きく異なる。今取扱われている25m 深，50m 深

の二層が水温鉛直分布の上でどのような位置を占めるかを調べるために，定線観測の資料が用いられた。100 m，150 m，200 m のおのおのの深さについて定線上7測点にわたってとった空間平均水温と，100 m の深さについて7測点にわたってとった空間平均塩分を Fig. 4 に示す。図中の下向きの矢印は，この時に異常高潮位が観測されたことを示す。異常高潮位に伴う 25 m 深，50 m 深の水温変化がみられなかった前述の3例についても，1966年10月，12月の2例では 100 m 深，150 m 深の水温は上昇している。これら2例の起こった時期は表層混合層が厚くなる対流期にあたるため，25 m 深と 50 m 深は水温一様な表層混合層の中にあり，異常高潮位が起きてもこれらの深さの水温は上昇しなかったと考えられる。

以上のように異常高潮位10例のうち9例において潮位変動に伴って，鉛直方向の水温構造，従って密度構造が変化し，潮位が上昇したのに対して水温躍層が下降したと言うバロクリニックな変化であったことを示している。

2. 大島と八丈島の気圧差の変化と油壺の潮位変化との関係

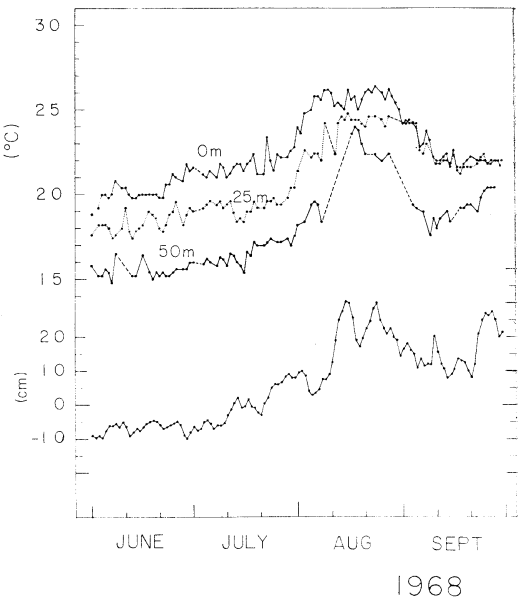

Fig. 3. A detail of water-temperature variations at 0 m, 25 m and 50 m depths measured off Iwae and of daily-mean sea-level variations at Aburatsubo.

この関係は Fig. 2-1 より Fig. 2-7 に示されている。大島と八丈島間の気圧差はそれらの島を結

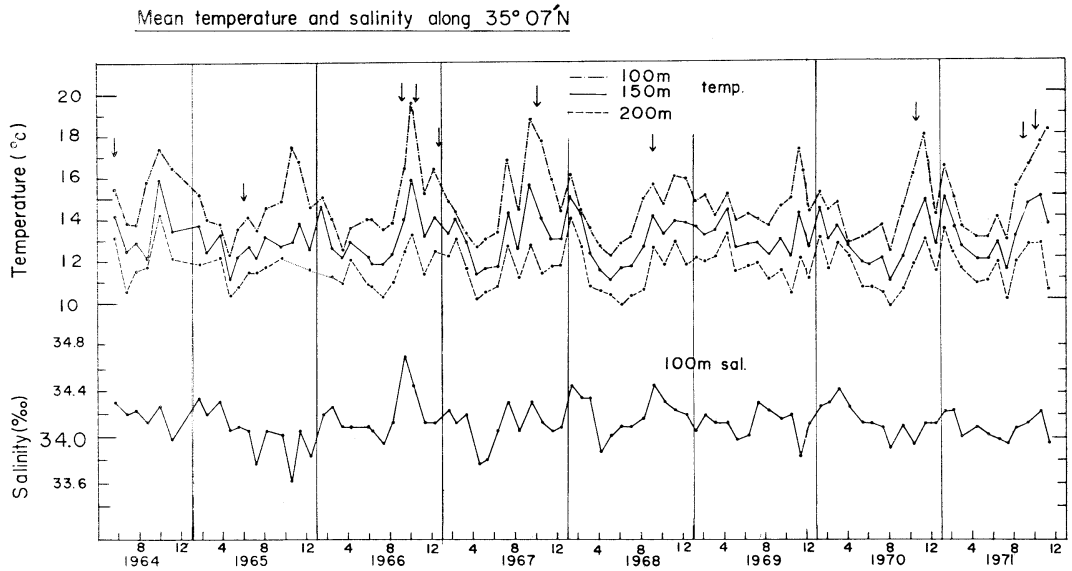

Fig. 4. Temporal variations of spatial-mean water-temperatures over isobars of 100 db, 150 db and 200 db and a spatial-mean salinity over an isobar of 100 db along a hydrographic section at 35°07′N occupied regularly once a month by Kanagawa Fisheries Experimental Station.

ぶ断面に直交する方向の地衡風速に比例する。大島と八丈島を結ぶ線がほぼ南北方向にあることを考えれば，気圧差が正の時，東風成分を示し，負の時，西風成分を示すことが知れる。

今，この関係を更に詳しく調べるために，1971年8月～10月，1968年8月～10月における異常高潮位を例として取上げ，拡大してそれぞれ，Fig. 5, Fig. 6 に画いた。前者では，長周期変動（1か月以上）に関しては潮位と気圧差との間によい相関は見られない。しかし，一週間から十数日周期の変動については，図中に鎖線で結びつきが示されているように，潮位変化と気圧差の変化は非常によく対応している。すなわち，潮位変化にみられる 6～8 個の変動の山はほとんどすべての場合，気圧差にもみられる。両者の位相を比較すると，位相差が Zero か，あるいは気圧差の方が潮位よりわずかに進んでいる。これより短かい周期の変動については，気圧差の変動に潮位変動は追随していない。例えば，10月14日における＋6.2 mb，10月 23日における －3.5 mb のように，気圧差の短期間の変化に対しては，その値が大きくても潮位は対応して変化しない。後者についても，前者について成立の関係は一般に成立っている。しかし，後者に示される1968年8月の異常高潮位においては例外的に気圧差との対応がみられない。この場合，8月10日前後の数日を除けば気圧差は大体負の値，従って西風が吹いていたことを示す。潮位は10日前後に急激に上昇し，以後22～23日に再度高くなり，以後除々に下降している。このような例外は1966年8月，1966年12月，1968年8

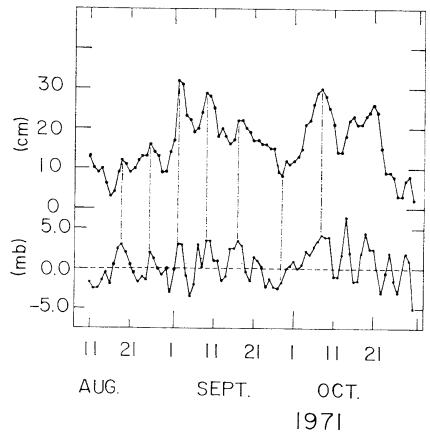

Fig. 5. Correspondence of daily-mean sea-level variations at Aburatsubo (atmospheric-pressure effect being eliminated) to variations of daily-mean atmospheric-pressure difference between Oshima and Hachijojima, for the period from August to October, 1971.

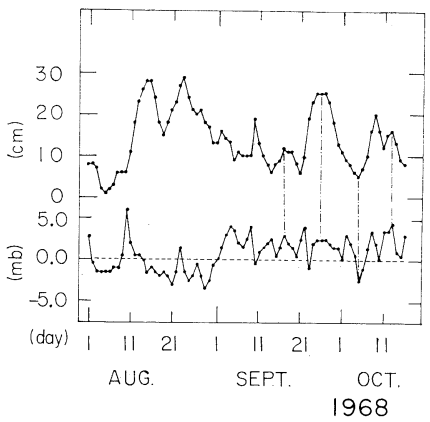

Fig. 6. Correspondence of daily-mean sea-level variations at Aburatsubo (atmospheric-pressure effect being eliminated) to variations of daily-mean atmospheric-pressure difference between Oshima and Hachijojima, for the period from August to October, 1968.

Table 1. The relationships between the abnormal rises of sea-level and the surface layer temperatures (0-50 m depth), the upper layer temperatures (100-200 m depth), the difference of atmosphric-pressures between Oshima and Hachijojima.

Year	Month	Surface layer tempera-tures	Upper layer tempera-tures	Difference of atmos-pheric-pressures
1964	May	○	○	×
1965	June	×	×	○
1966	August	○	○	×
1966	October	×	○	○
1966	December	×	×	○
1967	September	○	○	○
1968	August	○	○	×
1970	October November	○	○	○
1971	September	○	○	○
1971	October	○	○	○

○ : Close correlation　　× : No correlation

月の3例である。一般には,Fig. 2-1 より Fig. 2-7 にみられるとおり，異常潮位時に潮位変化と気圧差の変化とがかなりよく対応している。

3. まとめ

異常高潮位10例について，各々の変化の特徴をまとめたのが Table 1 である。この結果から，異常高潮位は東風と関係していることが多く，且つ，バロクリニック・モードの現象を伴うことが極めて多いことがわかる。

4. 急激な潮位上昇及び下降と海の密度場の変動との関係

上に述べた異常高潮位では，一般に水位は比較的急激に上昇したり，下降したりすることが多い。その程度は，例えば，月平均潮位が1971年9月1日～2日の1日間に15 cm 上昇し，又，1971年10月22日～24日の2日間に 15 cm 下降している。このような比較的短期間に起こる水位の変動に，海洋の水温場あるいは密度場の鉛直構造がどのように対応するであろうか。次に述べる観測の結果は，この問題に対し示唆を与える。

1971年10月，相模湾，相模灘付近の海況変化を知る目的で，東大海洋研究所の「淡青丸」と神奈川水試の「うしお」が共同で前述した相模湾の定線断面を2回にわたり観測した。これらの時期はそれぞれ10月21日と10月28日であり，2日間で水位が 15 cm 下降した10月22日～24日の前後にあたる。この測線のほぼ中央に当る測点（St. 9）の鉛直方向の水温及び塩分分布を Fig. 7 に示した。21日の高潮位時に比べて28日の低潮位時には，水温は 50 m～500 m 深で低くなり塩分は表層から 150 m 深までは高くなり，それより 300 m 深付近までは低くなっている。

Fig. 8 に定線上の St. 7 と St. 9 における10月21日と10月28日の測定結果に基づいて画かれた T-S 曲線を示す。表層 100 m 深以浅を除けば，両曲線はほぼ同一曲線上にある。例えば，高潮位

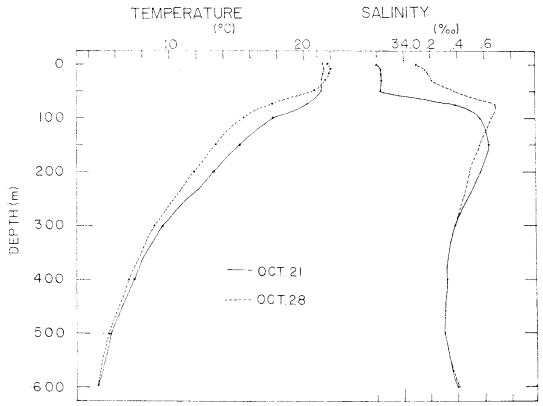

Fig. 7. Variations in vertical profiles to temperature and salinity observed at St. 9 before and after the abnormal sea level variation at Aburatsubo which occurred during 22nd to 24th of October, 1971.

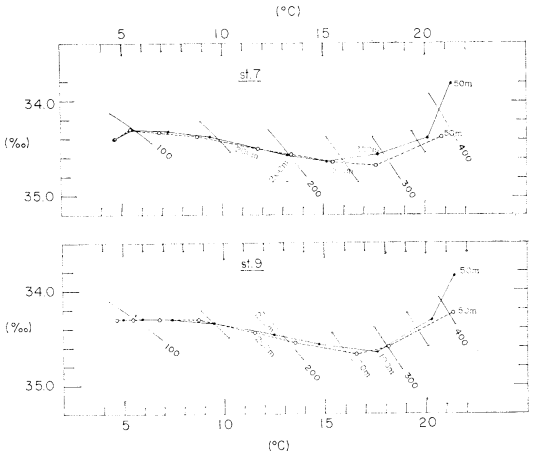

Fig. 8. T-S diagrams for St. 7 (upper panel) and St. 9 (lower panel). Solid lines and dotted lines show the T-S relations before and after the abnormal variation of sea-level at Aburatsubo, which occurred during 22nd to 24th of October, 1971.

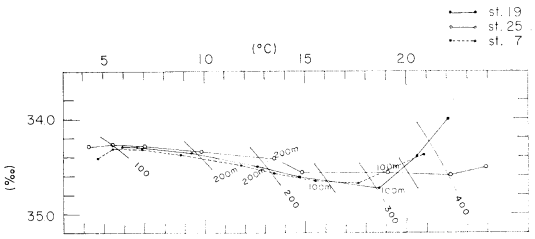

Fig. 9. T-S diagrams for St. 19 and St. 25 which were occupied before the abnormal variation occurred during 22nd to 24th of October, 1971 along with T-S diagram for St. 7 which was occupied after the abnormal variation.

時の 150 m 深の水温及び塩分値は低潮位時の 100 m 深の水温及び塩分値にほぼ一致するように，低潮時のある層の水温，塩分は高潮位時におけるより浅いある層の水温，塩分に等しい。

Fig. 9 は，St. 7 の低潮位時の T-S 曲線と相模湾外の2測点（St. 19, St. 25）における潮位変化前の T-S 曲線を比較したものである。三つの T-S 曲線は，かなり似かよっているが，任意の深さに対する T-S の値はそれぞれの測点で異なっている。以上を要するに，潮位変化に伴った水温場や塩分場の鉛直構造の変化は，海水の水平運動に直接結びついて生ずるのではなく，表層水の水平運動に伴う下層水の湧昇によって生じた可能性があることを示唆している。

5. 結 論

過去の異常高潮位の資料を整理し，潮位変化と水温変化，気圧差（風向，風速）変化との関係を調べた。その結果，

1. 潮位変化と水温変化の関係から大半の場合，異常高潮位はバロクリニック・モードを伴う現象であることがわかった。
2. 一週間から十数日程度の周期については，多くの場合気圧差の変動と潮位変動とは一対一に対応する。両者間の位相差はほとんどないか，あるいは気圧差の方が位相が進んでいる。しかし，1～2日程度と言う短周期については，気圧差変化のピークはその振幅の大小にかかわらず，潮位変化に影響しない。

又，油壺に対する気圧補正済日平均潮位は異常高潮位に関連して，8～15 cm/day という急激な上昇あるいは下降をする。この潮位変化の前後で，鉛直方向の密度分布は大きく変化する。潮位急下降の前後で測定した鉛直密度分布の変化は表層水の運動に伴った湧昇流によって生じた可能性がある。

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Compte rendu

Microbiological Aspects of Petroleum Degradation in the Aquatic Environment*

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1. Introduction

In this decade, increasing attention is being given to the effects and fates of the vast quantities of oil, estimated between 6 and 12 million metric tons annually, that enter the world oceans (MITCHELL, 1972; FREEGARDE, 1972; HEYERDAHL, 1972; BLUMER, 1971). A complete review of the extensive literature dealing with oil spills and microbial degradation of spilled oil is beyond the scope of the current presentation. The excellent reviews of NELSON-SMITH (1968, 1970, 1973), COWELL (1971), ZOBELL (1964, 1969), ATLAS and BARTHA (1973) and the study of HEPPLE (1971) are recommended for complete coverage of the topic. Further, the toxicity of crude oil and its derivatives to animal life has been extensively reported in the literature. Alterations of littoral and sublittoral ecosystems have been well demonstrated, (SMITH, 1968), noting various degrees of toxicity of crude oil as a function of type and quantity, amount of weathering and species of biota involved (CARTHY and ARTHUR, 1968).

Recently, sub-lethal effects of spilled oil have been given serious consideration. MIRONOV (1968) pointed out that the sensitivity of eggs and larval forms was much greater than the adult counterparts, on which most toxicity studies are performed. DAVIS (1971) reported the deleterious effects of pollutants on the reproduction of marine animals. BLUMER (1973) illustrated another subtle implication of the toxicity of crude oil in that, at concentrations of 1:100,000, it could significantly modify the feeding habits and behavior of the lobster, *Homarus americanus*. It has been further suggested that crude oil might interfere with the chemotactic feeding and mating responses of many organisms (TAKAHASHI and KITTREDGE, 1973). Another subtle effect of crude oil is its carcinogenic potential (DEAN, 1968). BLUMER (1971) cited alkylbenzanthracene and 1,2 benzanthracene as significant carcinogens contained in crude oil. In addition, the multinuclear aromatic content of the fraction of crude oil boiling over 390°C suggests potential dangers. EHRHARDT (1971) and BLUMER *et al.* (1970) have also demonstrated that these high-boiling compounds are part of the fraction which is readily absorbed and incorporated into the body fats of oysters. FREEGARDE (1972) presented evidence that copepod members of the plankton ingest and expel fine oil globules. The effects of oil on plankton, however, are largely undetermined.

Increasing attention is being paid to salt marsh ecosystems and its composite vegetation especially the importance of chronic pollution. COWELL (1971a) discussed two types of chronic pollution. In both, recovery of the ecosystem may occur only after the source of pollution is removed. The need to examine oil impact on marshland microbial ecosystems, notably micro-

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bially-induced processes of chitin and cellulose turnover and detrital input into the complex estuarine food web has been stressed (MEYERS *et al.*, 1973). This is all the more important in areas of localized oil production, where danger from spills and blow-outs exists, such as along the upper Gulf of Mexico Coast.

The effect of crude oil on ecosystems is a perplexing problem in view of its being a complex mixture of hydrocarbons and non-hydrocarbon entities containing oxygen, sulphur, nitrogen and many trace metals (DAVIS, 1967; DEAN, 1968). The hydrocarbons in crude oil may be paraffins, alkanes or saturated hydrocarbons, or aromatic hydrocarbons. As a class, crude oil does not usually contain olefins or alkenes, but these compounds may be found in other petroleum products (BLUMER, 1973). The non-hydrocarbon constituents are usually referred to simply as asphaltic material.

ZOBELL (1973a) listed the composition of crude oils as: aliphatics, 15-35 %; cycloparaffins, 30-50 %; aromatics, 5-20 %, and asphaltenes, 2-15 %. Oils from different geographic regions can be very dissimilar chemically and therefore toxicologically. Numerous compounds found in crude oils *i.e.*, benzene, hexane, etc., have well-established toxicities at low concentrations (VAN OVERBEEK and BLONDEAU, 1954). HAVIS (1950) reported that aromatic hydrocarbons are most toxic to plants, with olefins and napthenes ranked next, and alkanes being least toxic. While considerations of actual modes of toxicity is beyond the range of this review, it is well known that most toxic hydrocarbons exhibit narcotic properties in low concentrations. At higher concentrations certain hydrocarbons become markedly toxic due to their being cytolytic, thus bringing about a disruption of cellular organization.

2. Effect of crude oil on the microbial ecosystem

The ability of microorganisms to degrade petroleum and petroleum products has been well known for over 50 years. However, the effect of crude oil intrusion on microbial ecology, or the microbial ecosystem, has received only slight attention.

BALDWIN (1922) noted increases in total heterotrophic bacterial populations in soil from a corn field treated with petroleum. The production of nitrate was decreased in proportion to the amount of oil. A decrease in species diversity was also observed with the addition of crude petroleum, although petroleum application seemed to have little effect on the numbers of anaerobes. Nitrification was also inhibited by crude oil, but the retardation appeared to be overcome after a period of sixty days. Ammonia production was lowered only slightly. The mineralization activity was a reflection of fungal activity. Mold growth was little affected by crude oil, and the types of bacteria favored by crude oil were not able to form ammonia from organic compounds.

In a study of the yeast ecology of an asphalt refinery and its watershed, TURNER and AHEARN (1970) detected several oil-induced changes. An increase in total microbial biomass was noted over control or unaffected areas. In addition, localities with visible hydrocarbon contamination had yeast populations largely composed of *Candida tropicalis*, *C. lipolytica*, *C. guilliermondii*, and *Trichosporon capitatum*. In areas where hydrocarbons had been considerably diluted, *Aureobasidium pullulans* and *Rhodosporidium-Rhodotorula* spp. predominated.

AHEARN and MEYERS (1972) noted a slow increase in yeast populations of marsh plots following oil treatment. There was a concurrent shift in species density from a sporogenous population, dominated by *Pichia* and *Kluyveromyces*, to an asporogenous population with *Rhodotorula* and *Trichosporon* being dominant. CROW (1971), in studies of a large offshore oil spill, noted a similar enrichment of total yeast populations and a shift toward *Rhodotorula-Rhodosporidium* complex.

KINCANNON (1972) reported only slight changes in microbial populations over an 8 month period when crude oil was added to soil. *Flavobacterium*, *Nocardia*, *Pseudomonas*, and *Arthrobacter* were the prominent microbial genera found. Some evidence of ecolog-

ical succession was seen. During the last nine months of the study, *Corynebacterium* increased noticeably, while *Arthrobacter* was seldom prominent. During this time yeasts were predominant in several samples. In laboratory studies, the addition of oil to nutrient agar lowered the total developing populations.

MEYERS *et al.* (1973) observed a microbial succession in experimentally oil-treated plots toward species of hydrocarbonoclastic yeasts. The indigenous yeast flora of the marsh was unable to degrade crude oil to any significant extent. A similar phenomenon was reported by LEPETIT *et al.* (1970) who found hydrocarbon-utilizing yeasts only in littoral waters chronically polluted with refinery pollutants.

COBET and GUARD (1973), in examining beach microflora following contamination by bunker fuel, found no great change in the microbial communities after oil intrusion. There was no significant change in diversity of bacterial genera with time or depth, with major populations of *Achromobacter*, *Alcaligenes*, *Moraxella*, and *Pseudomonas* noted throughout the study.

In addition to the above environmental response, crude oil has been shown to be toxic, or at least inhibitory to a number of microorganisms (BEERSTECHER, 1954). WALSH and MITCHELL (1973) and YOUNG and MITCHELL (1973) showed an inhibition of bacterial chemoreception by a number of purified hydrocarbons and crude oil. Motile bacteria are capable of moving in a non-random fashion to suitable growth substrates. Various hydrocarbons and halogenated hydrocarbons induced random motion even in the presence of intense attractants. The importance of chemoreception in the microbial chemistry of the ecosphere is not clearly established at present.

3. Microbiological aspects of Hydrocarbon degradation

The ability of microorganisms to grow on hydrocarbons was first established by MIYOSHI (1895) who observed growth of the fungus, *Botrytis cinera*, on paraffin. In a series of articles beginning in 1906, SOHNGEN firmly established the field of hydrocarbon microbiology by exploring the ability of microorganisms to utilize various hydrocarbons including kerosene, gasoline, and Russian and American crude oil.

Moreover, the ability to utilize hydrocarbons appears to be widespread among microorganisms. More than 200 species of bacteria, yeasts, and filamentous fungi are able to degrade or metabolize a diversity of hydrocarbons. Seventy genera of organisms comprising 28 bacteria, 30 filamentous fungi, and 12 yeasts have been shown to utilize hydrocarbons (ZOBELL, 1973). To simplify the following review, initial references will be grouped as to type of organism, *i.e.*, bacteria, yeast, filamentous fungi, described by the author.

Yeasts

TAUSSON (1939) reported utilization of hydrocarbons by a number of yeast and yeast-like fungi including those of genera *Debaryomyces*, *Endomyces*, *Hansenula*, *Torulopsis*, and *Monilia*.

KOMAGATA *et al.* (1964) showed that 56 of 498 yeasts could use kerosene as a sole source of carbon and energy. Most of the yeasts were members of the genus *Candida* but representative isolates of *Rhodotorula* and *Hansenula* also exhibited hydrocarbonoclastic activity.

MARKOVETZ and KALLIO (1964) demonstrated that several isolates of *Rhodotorula*, *Trichosporn* and *Candida* were able to assimilate various hydrocarbons of chain length C_{10}–C_{18}. *Candida lipolytica* and *C. pulcherrima* utilized all even-numbered chain 1-alkenes C_{10}–C_{18} as well as all even-numbered alkanes. MILLER *et al.* (1964) showed that growth of an isolate similar to *Candida intermedia* was greater with increased chain length from C_{12}–C_{18}.

SCHEDA and BOS (1966) tested 1,200 yeasts for growth on *n*-hexadecane, *n*-decane and kerosene. Some *Rhodotorula* species utilized all hydrocarbons tested, but growth was comparatively slow. Many isolates of *Pichia*, *Debaryomyces*, *Candida* and *Torulopsis* grew well on all hydrocarbon substrates. OTSUKA *et al.* (1966) examined growth of 10 hydrocarbonoclastic isolates of *Candida*. An isolate of *C. tropicalis* grew better on kerosene than

others studied. Both *C. tropicalis* and *C. cloacae* isolates assimilated numerous pure hydrocarbons from C_{10}–C_{16}. Cell yields increased to a maximum at 15 % light oil.

KLUG and MARKOVETZ (1967a) investigated hydrocarbon assimilation by a number of species of *Candida*. A high percentage of the organisms oxidized many of the *n*-alkanes in the C_9–C_{18} series. Growth on even-chained l-alkene series C_{10}–C_{13} was restricted to a much lower percentage of the yeasts. KLUG and MARKOVETZ (1967b) extensively studied the growth of *Candida lipolytica* (ATCC 8661) in mineral salts-hydrocarbon medium. The conversion of *n*-alkanes and corresponding l-alkenes to fatty acid and alcohols of the same chain length (C_{14}–C_{18}) was observed.

Hydrocarbon assimilation by 66 yeasts within 16 genera was tested by LOWERY *et al.* (1968). Only 11 organisms grew on *n*-alkanes, mostly members of *Candida*, *Rhodotorula* and *Debaryomyces*. None of the yeasts tested were able to assimilate alkanes with less than nine carbons. Several yeasts developed on 2-hexanone and 2-heptanone but none grew on ketones of chain length greater than C_{11}.

AIDA and YAMAGUCHI (1969) noted that growth of *Mycotorula japonica* was improved by dialysis culture. A vessel with two compartments separated by a cellulose dialysis membrane permitted replenishment of nutrients and removal of toxic products from the growth compartment. The dialyzable material depressed the growth of the organism on kerosene medium but not on glucose. The free fatty acid, lauric acid, was responsible for inhibition on *n*-hexadecane.

The oxidation of p-cresol, a phenolic substrate, by yeast was demonstrated by HASHIMOTO (1970). The enzyme system for p-cresol cooxidation was formed when the fungus was incubated with phenol. The organism producted a $C_7H_8O_4$ product, the structure of which could not be completely elucidated, from the cleavage of the benzene ring.

IIDA and IIZUKA (1970) studied the anaerobic conversion of l-decene to *n*-decyl alcohol and decanoic acid. Resting cells of *Candida rugosa* formed 2–3 times as much decyl alcohol under anaerobic conditions, strongly suggesting an initial hydrogenation rather than a direct incorporation of molecular oxygen in this anaerobic hydrocarbon degradation scheme.

BARUA *et al.* (1970) noted utilization of paraffins by *Trichosporon pullulans*. Assimilation of shorter alkanes (C_{10}, C_{11}, C_{12}) was more rapid than longer chain assimilation on mixed hydrocarbon substrates. Larger chains, however, showed increased breakdown rates, suggesting that inducible enzymes may function in this conversion. *T. pullulans* exhibited no growth on the isoalkane fraction of gas oil.

Filamentous fungi

Initial observation of hydrocarbonoclastic activity occurred with filamentous fungi (MIYOSHI, 1895). TAUSSON (1925) demonstrated the ability of *Aspergillus niger* to maintain itself on paraffin wax. HOPKINS and CHIBNALL (1932) described growth of an organism resembling *Aspergillus versicolor* which was able to use both odd and even numbered paraffins to $C_{34}H_{70}$.

PRINCE (1961) reported that representatives of the filamentous fungus, *Cladosporium*, could grow on jet fuel. KRYNITSKY and MCLAREN (1962) noted similar observations with the fungus, *Hormodendrum*.

KESTER (1961) used *n*-tridecane as a sole source of carbon for growth of *Aspergillus alliaceus*, *Cephalosporium roseum*, *Colletotrichum altramentarium*, *Acremonium patronii*, *Fusarium balbigenum* and *Monila bonordenii*. Elsewhere KRAUSE and LANGE (1965) found three species of *Fusarium* were able to grow on various *n*-alkanes C_{11}, C_{20}, C_{22}, C_{23}, C_{28}, C_{32}. In addition, it was noted that 1-octadecene and squalene also could be utilized by the three organisms.

NYNS *et al.* (1968) stated that utilization of hydrocarbons was a property found mainly in the two orders, Mucorales and Moniliales. Genera involved included those of *Fusarium*, *Penicillium*, *Paecilomyces*, *Chloridium*, *Oidiodendron*, and *Scolecobasidium*. Several isolates of *Penicillium* grew well in the presence of numerous pure hydrocarbons, petroleum fractions, and toluene.

LOWERY *et al.* (1968) reported utilization of hydrocarbons, by species of *Aspergillus*, *Cepha-*

losporium, *Dematium*, *Epicoccum*, *Fusarium*, *Gliocladium*, *Graphium*, *Mucor*, *Paecilomyces*, *Penicillum*, and *Trichoderma*. The majority of these organisms grew well on C_{10}–C_{15} normal hydrocarbons, with only a few isolates showing growth on C_8 or shorter chained hydrocarbons. Gaseous alkanes, *i. e.*, ethane, propane and butane, have been found to support the growth of a few hyphomycetes and bacteria (ZAJIC *et al.*, 1969; MCLEE *et al.*, 1972; DAVIES *et al.*, 1973).

MARKOVETZ *et al.*, (1968) described growth of a group of filamentous fungi on selected *n*-alkanes and l-alkenes. Isolates of *Cunninghamella* grew well on all even alkanes C_{10}–C_{18} and on even l-alkenes of 12 carbons and greater. Representatives of *Fusarium*, *Cephalosporium*, and *Spicaria* exhibited good growth on many of the pure compounds tested.

CERNIGLIA and PERRY (1972) demonstrated growth of *Cunninghamella elegans* and a *Penicillium* sp. on a wide range of hydrocarbons. A paraffinic crude appeared much more susceptible to fungal attack than an asphaltic crude.

COFONE *et al.* (1973) examined an isolate of *Cladosporium resinae* for its hydrocarbonoclastic activity. *n*-Alkanes from C_9–C_{19} gave good growth, followed by a decrease in pH. No growth was observed on gaseous hydrocarbons or on paraffin oil containing *n*-alkanes from C_{29}–C_{34}. Alkenes supported lower growth rates than did corresponding alkanes. Shaking cultures gave variable results.

Bacteria

ZOBELL (1946) lists the following bacteria as known hydrocarbon-utilizers: 14 species *Actinomyces*, 13 *Pseudomonas*, 10 *Proactinomyces*, 10 *Mycobacterium*, 5 *Corynebacterium*, 3 *Vibrio*, 2 *Achomobacterium*, and one or more species or isolates of *Desulfovibrio*, *Escherichia*, *Gaffkya*, *Serratia*, and *Spirillum*. The accumulation of data on hydrocarbon-utilizing bacteria is extensive. Most of this material will be reviewed in the ecology of hydrocarbon utilizers and only the references considered most pertinent to further discussion have been included.

SOHNGEN (1913) demonstrated that several mycobacteria and pseudomonads utilized various hydrocarbons, such as paraffin, gasoline, and petroleum as a sole source of carbon and energy. The substrates were oxidized to carbon dioxide and water (mineralization) and traces of organic acids.

TAUSZ and PETER (1919) described several organisms capable of attacking paraffinic hydrocarbons, including *n*-hexane, *n*-octane, di-methyloctane, *n*-hexadecane, triacontane and tetratriacontane. These bacteria, probably pseudomonads, were inactive on cyclic hydrocarbons such as cyclohexane and dimethylcyclohexane.

GRAY and THORNTON (1928) isolated organisms of the genera *Micrococcus*, *Mycobacterium*, *Bacterium*, *Bacillus* and *Spirillum* capable of degrading various aromatic compounds. Isolates were able to utilize naphthalene, toluene, cresol, and phenol.

BUSHNELL and HAAS (1941) demonstrated growth of cultures of *Corynebacterium simplex*, and three unidentified species of the genus in a mineral salt medium with solid paraffin or light oil as a carbon source. *C. simplex* also was able to utilize kerosene for growth. Stock cultures of various *Pseudomonas* species also were tested for their ability to utilize kerosene. The majority of the cultures exhibited good growth on kerosene. *Mycobacterium phlei*, *M. leprae* and *M. smegmatis* grew in mineral salts medium with paraffin or kerosene as substrates. Cultures of *Proteus*, however, failed to grow under similar conditions.

STONE *et al.* (1942) tested oxidation of various oils by a mixed microbial population. In examining organisms growing on crude oil, a preponderance of pseudomonads was noted. Pure culture studies of 250 representative isolates failed to show correlation between particular biochemical morphological traits and growth on any oil or oil fraction. Uniclonal cultures indicated a change in biochemical reactions when placed on hydrocarbons. Oils of very high molecular weight, paraffinic nature and low molecular weight, aromatic composition were most resistant to dissimilation.

WEBLEY (1954) observed good growth of *Nocardia opaca* on *n*-dodecane, *n*-tetradecane, *n*-hexadecane, and *n*-octadecane while heptane, octane and nonane supported little or no

growth.

TRECCANI *et al.* (1955) tested three organisms, an achromobacter, nocardia, and a mycobacterium, for their ability to utilize hydrocarbons. Cultures of nocardia and the mycobacterium utilized numerous compounds from C_3-C_{28} Hydrocarbons of 3-12 carbon chain length were assimilated by the achromobacter.

4. Ecology of hydrocarbon utilizers

Although the ability of microorganisms to degrade hydrocarbons has been well established, the ecological activity and importance of these organisms has only recently attracted considerable interest due to the incidence of major oil accidents. KNEBEL (1946) calculated that the annual production of hydrocarbons through photosynthesis was approximately eighty million barrels of hydrocarbons. This large amount, coupled with the estimated one to two million metric tons added by oil transportation, sewage, and natural seeps, suggests the magnitude of hydrocarbon degradation.

Yeasts

In extensive studies of the microflora of oil fields in Japan, IIZUKA and GOTO (1965) isolated several cultures of red yeasts from oil brines. All yeasts belonged to the genus *Rhodotornla*, except for one strain of *Sporobolomyces japonica*. Organisms were significantly different physiologically from those found in undisturbed soil. The yeasts studied were unable to utilize kerosene. Growth temperatures of 20-30°C also suggested an adaptation to the oil well environment.

VADALKAR *et al.* (1969) isolated yeasts from soil and water samples from natural lakes, oilfields, and oil seeps in India. Of the ten strains that grew well on hydrocarbons, seven were *Candida* species with one each of *Trichosporon*, *Saccharomyces*, and *Pichia*. *Candida lipolytica*, *C. tropicalis*, and *Trichosporon pullulans* grew quite rapidly on gas-oil with generation times as low as 1.14 hours.

LEPETIT *et al.* (1970) isolated yeasts from two littoral areas near Marseille, France. A difference in species composition was noted between polluted and non-polluted areas. Seven species able to utilize gas-oil were isolated, all being representatives of *Candida* or *Torulopsis*, species with known hydrocarbonoclastic ability.

AHEARN *et al.* (1971) isolated yeasts from marine, estuarine, and freshwater environments and tested these for hydrocarbon utilization. Species of *Candida*, *Trichosporon*, *Rhodotorula*, *Rhodosporidium*, *Endomycopsis*, *Pichia* and *Debaryomyces* were able to utilize hydrocarbons. Most rapid hydrocarbon degradation occurred with species of *Candida*. Isolates from non-polluted areas gave less growth on hydrocarbon substrates than similar isololates from polluted areas. Increased concentration of yeasts, particularly hydrocarbon utilizers, was noted in the vicinity of an offshore oil fire, suggesting possible association with *in situ* degradation.

MEYERS and AHEARN (1971) noted rapid growth of *Endomycopsis* (*Candida*) *lipolytica* on most fractions of petroleum. Growth was slightly better in media with seawater as the diluent. Several isolates grow better on yeast nitrogen base and heavy gas oil than on yeast nitrogen base and glucose. Mixed cultures of organisms were able to utilize substrates not used by monotypic cultures. Yeasts were observed growing on the periphery of oil globules with an effect on the surface tension.

AHEARN and MEYERS (1972) discussed the microbiology of artificially oil-treated marsh plots. Yeasts of non-oiled areas were unable to rapidly or extensively degrade Louisiana crude oil. Populations resulting from microbial succession, primarily *Trichosporon* sp. and *Rhodotorula*, exhibited greater hydrocarbonoclastic activity. Examination of yeast biomass in the area of Shell Platform B offshore oil well fire, again showed extensive enrichment of total population in general, and particularly in hydrocarbon utilizers at sites within one-half mile of the fire.

Fungi

PERRY and CERNIGLIA (1973) found that strains of *Cunninghamella elegans* and *Penicillium zonatum* were most effective in degrading crude oil. Strains of *Aspergillus versicolor*, *Cephalosporium acremonium*, and *Penicillium ochro-chlorens* also grew well on hydrocarbons. Reportedly, up to 92% of a paraffinic crude

oil was degraded by selected fungi. Optimum growth temperature for *C. elegans* was 30°C and 37°C for *P. zonatum*. Organisms grew better in seawater which had been enriched with nitrogen and phosphate-containing compounds than in natural seawater.

WALKER *et al.* (1973) studied hydrocarbon-utilization by *Cladosporium resinae*, a prevalent hydrocarbon-degrading fungus. Studies showed that rapid degradation of hydrocarbons was due to mineralization of most of the hydrocarbons rather than assimilation into cellular carbon. Hydrocarbon oxidation was found to proceed in most instances via a constitutive enzyme system in *C. resinae*. Growth on hydrocarbons brought about a decrease in pH in most cases. Data also indicate that *C. resinae* transports alkanes into the cell and then oxidizes these compounds. All these factors suggest a major role for the fungus in the degradation of petroleum in natural environments.

Bacteria

EKZERTSEV (1958) noted formation of gaseous products when crude oil samples were incubated anaerobically. Degradation seems to be enhanced by the natural microflora of the crude oil. Increased oil breakdown was observed when crushed cores from oil-producing zones were added to the oil. Anaerobic breakdown represented the major source of methane in oil deposits.

POLYAKOVA (1963) examined the heavily oil-polluted Neva Bay and estuary for hydrocarbon-utilizers. Microorganisms which could oxidize Solar oil, a Russian crude, were found in large numbers. Organisms capable of degrading benzene, toluene or anthracene were not isolated during the sampling period. Seasonal distribution studies revealed that oil-oxidizers reached a peak during the July-August sampling. Hydrocarbon-utilizing organisms were more numerous at the surface, probably in association with oil slicks. The predominant organisms found were species of *Pseudomonas*, *Mycobacterium* and *Bacterium*.

IIZUKA and KOMAGATA (1964) isolated hydrocarbon-utilizers from oil-brines and soils of Japanese oil fields. Growth on nutrient agar brought about a rapid loss in ability of most pseudomonads to utilize hydrocarbons. Species of *Corynebacterium* and *Brevibacterium*, however, did not lose their ability to degrade hydrocarbons. Loss of enzymatic capacity suggests some essential difference in the mechanism of hydrocarbon utilization between gram-negative and gram-positive microorganisms.

ZOBELL and PROKOP (1966) noted that the oil content (total unsaponifiable, carbon tetrachloride extract) of mud samples from Barataria Bay was generally from 0.001 %–0.1 % of wet weight of samples. Areas of recent pollution gave oil contents of greater than 1 % of the mud. Disappearance of crude oil from water surface was noted with an inoculum of 10 oil-oxidizing bacteria/m*l*. Illumination by sunlight compared with incubation in the dark had no observable effect on the appearance of oil after several months. Disappearance of 0.1 m*l* of crude oil from inoculated containers (141 liter) was observed within a period of one week, and as much as 10 m*l* was removed within 18 weeks with several crude oil chemical types. Field studies illustrated the removal of 100 m*l* of oil from the surface of a 200 liter vessel within 9 weeks. The ability of organisms to quantitatively reduce crude oil under cultured conditions were calculated by gravimetric methods and population measurements. Reduction by as much as 16.3–97.9 % was noted with various crudes. Oil-oxidizers were present in densities as high as 10^6 cells/gram of mud. The ability of sulfate reducers to grow, using mineral oil as sole carbon source, was also demonstrated in laboratory cultures.

GUNKEL (1968), in bacteriological studies of polluted sediments, found increased numbers of hydrocardon-utilizing organisms in all samples containing oil. The occurrence of proteolytic organisms was not deleteriously affected by the presence of oil in any samples. JONES and EDINGTON (1968) examined the microflora of an upland moorland soil and underlying shale for organisms capable of oxidizing hydrocarbons. Samples taken at 20 cm gave the highest proportion of hydrocarbon-utilizers in all samples collected. The addition of hydrocarbons stimulated respiration. Long chain *n*-aliphatics were more rapidly degraded than short-chain *n*-

aliphatics, aromatics, and alicyclic hydrocarbons. In each sample, it was noted that fungi played an important role in degradation of hydrocarbons.

PERRY and SCHELD (1968) reported large numbers of microorganisms in soil were capable of utilizing hydrocarbons as a sole source of carbon and energy. Organisms isolated on an oxygenase-requiring substrate, such as catechol or resorcinol, showed a much higher frequency of hydrocarbon utilization than those isolated on a substrate not requiring an oxygenase. Hydrocarbonoclasts represented from 1-3 % of those organisms capable of growing on nutrient agar. Much greater proportions were found in areas around oil wells.

JONES (1969) studied the effects of adding various hydrocarbons to soil. Increase in microbial activity was noted with addition of *n*-eicosane by buried slide techniques. Further, rates of *n*-eicosane assimilation were lower at environmental temperature (10°C) than at experimental temperatures.

MIRONOV (1969) isolated hydrocarbon utilizers from the Black Sea. It was observed that occurrence of microorganisms was dependent on the content of petroleum products. Organisms isolated were members of the genera *Bacterium*, *Pseudobacterinm*, *Vibrio*, *Achromobacter*, *Micrococcus*, *Bacillus*, *Spirillum* and *Sarcina*. In addition, different species diversities were noted for all four stations. Three near-shore sites, subject to continual petroleum input, gave diversity values of 14, 19 and 24, while a station 10 miles from shore with only slight petroleum contamination had only 11 species. MIRONOV also suggested that self-purification, *i.e*, autochthonous biodegradation of petroleum products, may be inhibited by the introduction of other organic compounds into the system.

MIGET *et al.* (1969) isolated actively oil-degrading cultures from soil and water extensively exposed to hydrocarbons. Two types of growth were noted: 1) that within the oil phase (oil positive) and 2) that within the aqueous phase. Cultures readily oxidized hydrocarbons (paraffins) up to C_{25}. Oxidation of 30-35 % of the crude oil occurred within 60 hours in enriched seawater. In an examination of Cook Inlet, Alaska, KINNEY *et al.* (1969) demonstrated that unsupplemented inlet water could induce crude oil degradation. Approximately 100 organisms per liter were found to be able to degrade oil. It was estimated that biodegradation of crude oil was essentially complete within 1-2 months in Cook Inlet, with almost complete degradation of oil concentrations of 20 mg/*l* within this period.

JOHNSTON (1970) investigated crude oil decomposition in sand columns. Oxygen concentrations throughout the column decreased, with the deepest level becoming anaerobic soon after addition of oil. Slow recovery was noted beginning immediately below the oiled layer, however, recovery was not complete after four months. Removal rates of crude oil in heavily oiled (1.1 kg/m^2) sand was estimated at 0.09 g oil/m^2/day and 0.04 g/m^2/day with a light oiling (12 mg oil/m^2). Amounts of oil greater than 100 g/m^2 would initiate the onset of anaerobic conditions. When normal oxygen profiles were established, crude oil was decreased only 10 % suggesting that large amounts of crude were resistant to degradation in the sand column environment.

MIRONOV (1970) noted that most species of hydrocarbon utilizers were isolated when water temperatures were rather high, *e.g.*, above 20°C. Studies showed that concentrations of organisms capable of growing in mineral media with oil as a carbon source were similar to the normal heterotrophic standing crop. The mere isolation of large numbers of hydrocarbon-utilizing microorganisms only suggests that oil can be degraded in that evironment; this in not *de facto* evidence that degradation occurs. An isolate *Pseudomonas sinosa*, however, was capable of growing well on several crude oils, but only poorly on peptone. Correlations of oil degraders and ability to degrade oil pollutants would seem valid only for areas where "pure" oil pollution occurs without the addition of other organic material.

BRIDIE and BOS (1971) compared rates of oil degradation by natural seawater populations with degradation of a model substrate, *e.g.*, mineral oil. Biodegradation of crude in seawater could be increased significantly by introduction of nitrogen and phosphorus compounds,

suggesting that the limiting factors in crude oil degradation are the availability of nitrogen and phosphorus compounds. The normally low concentrations of nitrogen and phosphorus in seawater limits extensive bacterial reproduction. Areas with large initial populations of oil degraders therefore have rapid degradation rates.

KATOR *et al.* (1971) demonstrated a preferential metabolism of saturated paraffins in Louisiana crude oil. Cells were found predominantly at the oil-water interface after introduction of the microbial culture. Oil "stickiness" was observed to decrease in simulated field studies. In laboratory studies, utilization of C_{12}–C_{30} *n*-paraffins were observed. Indications of a diauxic response *i.e.* two phases of exponential growth, were also detected in the laboratory.

ATLAS and BARTHA (1972a) examined degradation and mineralization of petroleum by two bacterial isolates, *Brevibacterium* sp. and *Flavobacterium* sp. Maximum degradation of crude oil and a model petroleum (C_{16}, C_{18}, C_{19}) occurred within 2 weeks. Crude oil degradation was as much as 60 % with model petroleum degradation as great as 75 %. Compounds to C_{13} disappeared primarily by volatilization; C_{14}–C_{22} were extensively degraded. Degradation appeared to proceed continuously without any diauxic responses.

ATLAS and BARTHA (1972b) demonstrated that the simultaneous addition of nitrate to 10^{-2} M and phosphate to 3.5×10^{-4} M significantly increased the degradation and mineralization of crude oil by natural seawater populations. Mineralization, however, appeared to be much more dependent on concentrations of nitrogen and phosphorus compounds, while degradation appeared to be constant over a range of concentrations. It was therefore suggested that deficiencies of either nitrogen or phosphorus would produce cells with abnormally high lipid stores and low metabolic activity.

SOLI and BENS (1972) isolated strains of *Corynebacterium*, *Arthrobacter*, and *Achromobacter* capable of oxidizing normal paraffins, and aromatic hydrocabons in a synthetic seawater medium. Mixed bacterial cultures utilized as much as 50 % of a Louisiana crude oil within 48 hours. Normal paraffins were more easily attacked.

JOBSON *et al.* (1972) observed degradation of two crude oils at 4 and 30°C by mixed bacterial cultures obtained by enrichment procedures. The initial response was emulsification, followed by an increase in density of the crude oil. Chemically, this was accompanied by a utilization of *n*-alkanes, with longer chains appearing to be slightly more resistant. Degradation of aromatics in crude oil mixtures but not as sole carbon sources suggested that co-oxidation may be the principal mechanism for the rapid removal of those compounds from the environment.

REISFELD *et al.* (1972) isolated a mixed culture capable of emulsifying crude oil in 2–4 days. In studies of dispersal of oil at 32°C by a mixed culture, a decrease in pH from 7.5 to 5.0 was noted during the first 2 days. Populations rapidly increased to maximum levels during the initial 24 hours, and then steadily declined. The mixed culture was found to be composed of several different organisms, only one of which would emulsify oil in pure culture even though all produced colonies on crude oil media and nutrient agar. RAG-1, an *Arthrobacter* isolated from the mixed culture, was capable of dispersing oil in only one day, if grown on oil prior to inoculation. Supernate fluid from cultures of RAG-1 grown on hexadecane was also able to produce dispersion of oil.

SEKI (1973) reported use of a silica gel medium for enumeration of petroleum-degrading microorganisms. Populations of petroleum utilizers were found to be less than 100/100 m*l* of water at several stations in Tokyo Bay.

WALKER and COLWELL (1973) recorded population levels of petroleum degraders in Chesapeake Bay ranging from 5×10^{1} to 9×10^{3} cells per sample. A decrease in pH of hydrocarbon media was noted concurrent with growth of organisms. Microorganisms grew on representative aliphatic and aromatic hydrocarbons. In laboratory studies, culture yield of organisms exposed to oil in the environment was greater than yield of organisms not exposed to oil.

ATLAS and BARTHA (1973 a) enumerated hy-

drocarbon utilizers in Raritan Bay, New Jersey, with populations ranging from a low of 24 cells/*l* to a high of 3,400/*l*. Greater numbers of oil-degraders were found when Sweden crude was used in place of South Louisiana crude in the media. Sweden crude oil is more paraffinic than Louisiana crude. Mineralization of both Louisiana and Sweden crudes by natural populations in seawater collected at several stations was noted. However, it was necessary to add nitrogen and phosphorus compounds to achieve 30–40 % mineralization in 18 days. Populations of oil degraders in a volume of seawater were not useful in predicting rate of disappearance of oil. Populations of all 100 m*l* water samples were able to reduce 1 m*l* of crude oil by 70 % in 18 days.

BLUMER *et al.* (1973) reported the natural history of two oil spills in diverse environments. Light paraffinic crudes spilled near Massachusetts, U. S. A. and Bermuda showed marked persistence over more than a year of sampling. The rates and extent of oil degradation appeared to reflect the presence of nutrients, but even in the presence of decaying seaweed, the degradation of aromatics was insignificant until nearly complete removal of the *n*-alkanes.

5. Pathways and considerations in hydrocarbon degradation

In discussing the mechanisms of hydrocarbon degradation it is simpler to first examine the mechanism of *n*-alkane degradation, since these pathways are well established and are found in a greater number of organisms. Numerous workers (SENEZ and KONOVALTSCHIKOFF-MAZOYER, 1956; THIJSSE and VAN DER LINDEN, 1958; STEWART *et al.*, 1959; KESTER and FOSTER, 1963; LEBAULT *et al.*, 1970; and COONEY and WALKER, 1973), have reported the formation of fatty acids from metabolized hydrocarbons. The intermediates are presumably alcohols together with several other complex metabolites. Terminal (mono-terminal) oxidation appears to be the major pathway for microorganisms, however, evidence for diterminal oxidation has been presented by KESTER and FOSTER (1963). ALLEN *et al.* (1971) and MARKOVETZ (1971) have given evidence for subterminal oxidation via formation of the corresponding alcohol, ketone, and ester.

Cycloparaffin metabolism has not been as extensively studied as has paraffin metabolism, and data on the exact mechanism are scarce. The most extensive work, that of OOYAMA and FOSTER (1965), deals with oxidation of cycloparaffins incapable of supporting growth as a sole source of carbon and energy. Studies showed that cycloalkanes were converted to ketonic substances, usually cyclomonoketones. VAN DER LINDEN and THIJSSE (1965) reported that cycloalkanes with long side chains were degraded. It was not demonstrated whether the cyclic part of the cycloalkane was metabolized.

The mechanisms of degradation of aromatic hydrocarbons have been reviewed by GIBSON (1972). Apparently, initial reactions result in the formation of dioxetanes dy ill-defined processes. However, the complexity of polycyclic hydrocarbons and their constituents found in crude oil makes any generalization of degradation pathways difficult. Benzene, a representative aromatic, undergoes conversion to oxoadipic acid via catechol and muconic acid (VAN DER LINDEN and THIJSSE, 1965).

Hydrocarbons incapable of being utilized as a sole source of carbon or energy may be degraded by another mechanism, *i.e.*, co-metabolism; this occurs when an organism oxidizes a substrate only concomitantly with the oxidation of a utilizable substrate. LEADBETTER and FOSTER (1960) observed the phenomenon with ethane, propane, and butane during growth of *Pseudomonas methanica* on methane, DAVIS and RAYMOND (1961) demonstrated that *Nocardia sp.* could oxidize substituted alkyl-aryl hydrocarbons (such as *p*-isopropyltoluene) in the presence of *n*-hexadecane, but not in its absence, A variety of mono- and dicyclic hydrocarbons which themselves failed to support growth were found to be co-oxidized by pre-grown cells of *Nocardia* (RAYMOND *et al.*, 1967). HORVATH and KOFT (1972) explained the breakdown of alkyl-benzene sulfonates by mixed microbial species as co-metabolism. HORVATH (1972) indicated that co-metabolism is an important degradation mechanism for some complex molecules. How-

ever, the relationship between specific compounds and the co-metabolites of these non-growth hydrocarbons has not yet been established conclusively. Many common compounds, *i.e.*, chitin, cellulose, protein, and their breakdown products may prove suitable co-substrates for many compounds now regarded as recalcitrant.

Among the more important factors in the rapid degradation of crude oil are oxygen, temperature, availability of nutrients, and surface area.

Oxygen.—Established pathways of hydrocarbon metabolism involve the initial action of an oxygenase system. BUSHNELL and HAAS (1941) suggested that organisms might also be able to use combined forms of oxygen such as nitrates or sulfates in oxidation of crude oil. They stated, however, that these alternate oxygen sources were used only when natural free O_2 was in low concentration. The work of NOVELLI and ZOBELL (1944) supported this hypothesis in part. The ability of species of *Desulfovibrio* to assimilate various hydrocarbons from decane to hentriacontane under anaerobic conditions was reported. HANSEN and KALLIO (1957), however, were unable todemonstrate use of nitrate as a terminal oxidant for hydrocarbons. Using oxygenated-homologous substrates it was easily demonstrated that once oxygen was incorporated into the hydrocarbon structure, it could easily be degraded with nitrate and presumably sulfate as the electron acceptor.

LEADBETTER and FOSTER (1959) clearly established the incorporation of molecular oxygen by bacteria utilizing hydrocarbons. Organisms cultured on hydrocarbons in an atmosphere containing oxygen-18 showed an increase in ^{18}O concentrations over organisms grown on non-hydrocarbon substrates. ISHIKURA and FOSTER (1961) noted incorporation of ^{18}O into cells of *Candida lipolytica* grown on hydrocarbons.

Anaerobic hydrocarbon metabolism is still an enigma. EKZERTSEV (1958) indicated that apparent anaerobic decomposition of oil occurred in the presence of fragmented cores from oil productive horizons. Gas formation was observed and the principal gases were identified as methane and carbon dioxide. The microbial agents were not identified, but this activity probably was the result of mixed populations rather than a single organism. The scattered reports which suggest anaerobic biodegradation of hydrocarbons may in fact be attributed to degradation of oil constituents containing molecular oxygen.

ZOBELL and PROKOP (1966) presented evidence that mud samples from Barataria Bay contained organisms capable of anaerobically oxidizing mineral oil. The production of sulfides suggested that sulfates were being reduced in the oxygenation of hydrocarbons, and that *Desulfovibrio* played some role in this anaerobic oxidation of hydrocarbons. Elsewhere, POSTGATE (1959) suggested the inability of most *Desulfovibrio* spp. in pure culture to degrade specific hydrocarbon compounds with sulfate as the electron acceptor. Thus, ZoBell and Prokop's observation might be attributed to the action of a mixed anaerobic microbial flora rather than to a single organism (ZOBELL, 1969).

More recently, IIDA and IIZUKA (1970) demonstrated anaerobic formation of *n*-decyl alcohol from *n*-decene-1 by resting cells of *Candida rugosa*. This and previous observations (IIZUKA *et al.*, 1969; IIZUKA *et al.*, 1968) of *n*-decane-1 as an intermediate in the breakdown of *n*-decane suggests an alternative to aerobic oxidation. A pathway involving dehydrogenation to the alkene and anaerobic oxidation to decyl alcohol was postulated.

Temperature.—Hydrocarbon degradation may occur over a wide range of temperatures. Environmental biodegradation, however, is complicated by a number of non-biological factors, such as evaporation, dispersion, solubility, spreading, and emulsification, all of which may be temperature dependent. Most laboratory studies, however, have been conducted in the 20–30°C range, where rapid degradation does occur. KLUG and MARKOVETZ (1967a) and MATELES *et al.* (1967) have observed the growth of thermotolerant species of *Candida* and *Bacillus* on hydrocarbons at temperatures above 40°C. ZOBELL and AGOSTI (1972) and ZOBELL (1973b) have reported the degradation of hydrocarbons below 0°C. GUNKEL (1967) showed reduced degradation rates at low tem-

peratures.

KINNEY *et al.* (1969) concluded that biodegradation was the major agent in the Cook Inlet, where temperatures rarely reached 5°C. Rates of degradation at 5°C were seven times lower than rates at 10°C. ATLAS and BARTHA (1972c) noted longer lag phases in addition to reduced growth rates at lower temperatures. KATOR *et al.* (1971) found that paraffin oxidation rates doubled with a 10°C rise in temperature.

Nutrients.—Nitrogen and phosphorus seem to be the limiting elements in environmental biodegradation of crude oil. Most other elements K, Mg, Fe, Ca, which might be required are in adequate concentrations in most environments. IMELIK (1948) reported that phosphorus enrichment was necessary for growth of *Pseudomonas aeruginosa* on hydrocarbons. The addition of magnesium also gave beneficial effects.

GUNKEL (1967) reported enhanced biodegradation when cultures were supplemented with phosphates and ammonium chloride. LEPETIT and BARTHELEMY (1968) found similar effects with nitrogen and phosphorus supplementation, with rapid utilization of nitrogen between the second and fifth days, corresponding to the period of maximal oil loss. ATLAS and BARTHA (1972b) extensively studied limitation of oil degradation by nitrogen and phosphorus. Addition of 10^{-2}M nitrate and 3.5×10^{-4} phosphate increased biodegradation from 3 to 70 % and mineralization from 1 to 42 %.

GUNKEL (1967) observed that addition of peptone inhibited degradation of crude oil. When peptone or peptone and yeast extract was added, the initial rate of oil degradation was affected. However, after 8 weeks, the total amount of oil degraded was comparable to that lost in unsupplemented media. LEPETIT and BARTHELEMY (1968) also observed inhibition by peptone. In contrast, GILL and RATLEDGE (1973) found that the addition of alkanes to a culture of *Candida* sp. growing exponentially on glucose resulted in a novel diauxic effect, namely, the inhibition of glucose transport and assimilation. Yet the growth of certain yeasts may be inhibited by aromatic compounds and other constituents of crude oils (AHEARN *et al.*, 1971).

Surface Area.—Water appears to be essential to the degradation of crude oil. HILL (1968) has demonstrated that dry kerosene was lethal to species of *Nocardia* and *Pseudomonas* within a few hours. *Cladosporium resinae*, however, survived well in low water concentrations. COONEY *et al.* (1968) noted that isolates of *Pseudomonas aeruginosa* and a *Hormodendrum* sp. were not able to grow without a water phase. PILPEL (1968) observed that oil in water emulsions and a thin layer of oil on water were more rapidly degraded than water in oil emulsions. Increasing the surface area of oil-water interface can have many beneficial effects, among which are the following:

1) increases leaching of soluble (usually toxic) hydrocarbons
2) increases the availability of nutrients
3) aids penetration of oxygen
4) increases area available for microbial attack
5) increases the removal of toxic or inhibitory metabolic products.

Several studies (AHEARN *et al.*, 1971; SEVERANCE and LAROCK, 1973) have reported oleophilic microorganisms which either penetrate into the oil phase or selectively grow in the oil of a water-oil system. The physicochemical factors governing this type of growth are as yet unknown.

Artificial enhancement of biodegradation.—ZOBELL (1969) suggested that microorganisms might be used to enhance degradation of polluting oils in areas where conventional methods of removal were not feasible. MIGET *et al.* (1969) studied the feasibility of seeding microbial cultures on oil-polluted waters. The limiting factors, as previously mentioned, appeared to be nitrogen and phosphorus concentrations. Most schemes of "seeding" oil spills have provided for some additional sources of these elements. ROBICHAUX and MYRICK (1972) demonstrated that, in addition to mixed microbial inocula, various chemical dispersants could hasten the destruction of oil pollutants. ATLAS and BARTHA (1973b) established the effectiveness of oleophilic nitrogen and phosphorus sources in enhancing biodegradation of

oil. Paraffinized urea and octylphosphates gave greater degradation of oil in environmental simulation tests. It was anticipated that the oleophilic nature of these compounds would not simulate algal blooms; such blooms are a serious problem with water-soluble nitrogen and phosphorus sources.

The effectiveness of oleophilic fertilizers in stimulating oil slick biodegradation is yet to be established in field experiments. Several investigators (JOBSON *et al.*, 1974; ANDERES, 1973) have indicated that sites remote from oil pollution lacked significant populations of hydrocarbonclastic flora. Fertilization of such sites may be ineffective unless a seed inoculum also is added. The application of microbial seed systems to facilitate oil biodegradation may be best suited for specialized environments such as marshes or refinery water treatment systems. Marshes are unsuitable for the use of standard oil spill clean-up procedures and their importance as productivity centers should preclude the use of toxic dispersants or burning procedures. Water treatment systems or shipboard bunkers may be most amenable to seed culture use, since environmental conditions for such facilities may be partially controlled. At present, maximal oil utilization is achieved with mixed culture systems. Factors governing successional development of diverse microorganisms on crude oil are ill defined. Understanding of this complex area will need to be attained before practical application of seed culture systems can be realized.

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学 会 記 事

1. 昭和49年5月24日，東京水産大学において評議員会が開かれた。

1) 会務報告，編集報告が行われた。

2) 昭和48年度の収支決算及び昭和49年度の予算案が審議された。

3) 学会賞受賞候補者推薦委員会の森田委員長から松生洽氏を受賞候補者として推薦した経過について報告があり，松生氏が受賞者と決定した経過が佐々木会長から報告された。

4) 昭和49年度学会賞受賞候補者推薦委員14名を下記のとおり選出した。

有賀祐勝，石野　誠，今村　豊，宇野　寛，草下孝也，久保田　穣，斎藤泰一，佐藤任弘，杉浦吉雄，多賀信夫，高野健三，松生　洽，森田良美，山路　勇
（五十音順）

2. 昭和49年5月30日，日仏会館会議室において第15回総会が開かれ，佐々木会長の挨拶に引き続き次の報告，審議が行われた。

1) 昭和48年度の会務並びに会計報告が行われた。なお，48年度の収支決算（別表）は監事の監査を受けて承認された。

会員異動：48年度の新入会員は正会員12名，賛助会員4社，退会は正会員5名(内死亡1名)，賛助会員2社である。昭和49年3月31日現在の会員数は名誉会員11名，正会員416名，賛助会員56社である。

2) 今村編集委員長から学会誌第11巻の編集経過報告が行われた。

第11巻第1～4号は総ページ数232ページで，その内訳は論文14編（和文5，英文9），寄稿1編（和文），総説2編（和文1，英文1），資料1編（和文），シンポジウム10編，記念講演1編，その他学会記事などである。

なお，第12巻より表紙に色紙を使用せず白色とすることにした。

3) 森田委員長並びに佐々木会長から学会賞受賞候補者選考及び受賞者決定までの経過報告があった。

4) 正会員費の値上げについて審議の結果，現行の1,500円を2,500円に値上げすることが承認された。

5) 昭和48年度の収支決算並びに昭和49年度の予算案について審議の結果，別表のとおり承認された。

昭和48年度収支決算

収　入

項　目	収入額(円)	備　考
前年度繰越金	117,320	
会　費	525,500	
賛助会費	420,000	
学会誌売上	43,720	
広　告　料	195,000	
計	1,301,540	

支　出

項　目	支出額(円)	備　考
学会誌等印刷費	1,005,730	
送料通信費	163,125	
編　集　費	17,195	
事　務　費	21,930	
交　通　費	12,570	
会　議　費	66,500	
次年度繰越金	14,490	
計	1,301,540	

昭和49年度予算案

収　入

項　目	収入額(円)	備　考
前年度繰越金	14,490	
会　費	1,065,000	
賛助会費	535,000	
学会誌売上	80,000	
広　告　料	320,000	
計	2,014,490	

支　出

項　目	支出額(円)	備　考
学会誌等印刷費	1,600,000	
送料通信費	184,000	
編　集　費	20,000	
事　務　費	30,000	
交　通　費	15,000	
会　議　費	50,000	
予　備　費	115,490	
計	2,014,490	

6）昭和49，50年度の評議員が選出された。（日仏海洋学会役員，本誌(58)ページ参照）

7）昭和49年度学会賞受賞候補者推薦委員の選出について報告された。

3. 総会終了後，引き続き学会賞の授与が行われた。

昭和49年度日仏海洋学会賞受賞者：松生洽氏（東京水産大学）

受賞課題：大洋における光学的性質に関する研究（別項「推薦理由書」参照）

佐々木会長から松生洽博士に賞状，メダル及び賞金が授与され，続いて受賞記念講演が行われた。

4. 講演終了後，懇親会が開かれ，多数の参会者を得て盛会であった。

5. 昭和49年5月30日，31日の両日，日仏会館会議室において，昭和49年度「日仏海洋学会学術研究発表会」が次の通り開かれた。

第1日（5月30日）

午前の部

座長：阿部友三郎（東理大・理）

1. 最近の沿岸海洋の潮流調査方法と利用方法
…… 磯　舜也・○盛　敏夫（東京久栄）
2. 瀬戸内海の潮流に関する実験的研究
…… 樋口明生（愛媛大・工）
3. 超音波流速計による波の軌道運動の測定
○平　啓介・石川浩治・三沢信彦（東大・海洋研）
4. 海水安定泡沫の飛散について
阿部友三郎・矢内秋生・○黒沢卓郎（東理大・理）
5. ERTS-1 および SKY-LAB による海況調査
…… 落合弘明（鳥羽商船高）

午後の部

座長：森田良美（東水大）

6. 西之島火山の活動経過と噴出物
…… 小坂丈予（東工大）

座長：永田　豊（東大・理）

7. 台湾周辺海況の一考察…冨永政英（鹿児島大・工）
8. 海洋学の体系…… 星野通平（東海大・海洋）

第15回総会

学会賞授与

学会賞受賞記念講演

座長：岡見　登（理研）

大洋における光学的性質に関する研究
…… 松生　洽（東水大）

第2日（5月31日）

午前の部

座長：石野　誠（東水大）

9. 沿岸水域の汚濁負荷と海水交換についての考察
…… 磯　舜也（東京久栄）
10. 水理模型実験による排水拡散予測の手法に対する二，三の考察
…… 磯　舜也・○今藤　勇（東京久栄）
11. 内湾部の海底地盤地質と岩盤掘削　その1―
伊万里湾―…○原田　暁・古賀真綱（大林組）・常川昌明（日大・工）・松石秀之（大林組）
12. 串本・浦神の潮位変動と海況の変動について（IV）
…… ○小長俊二・西山勝暢（気象研）
13. 日本における17世紀の港湾構築遺跡発見について
…… 大崎映晋（世界水中連盟）

午後の部

座長：高野秀昭（東海区水研）

14. 冬期の西太平洋におけるクロロフィル a とフェオフィチンの分布特性…… 佐野　昭（気象庁）
15. 生物による内湾環境の指標性
…… ○山路　勇・若宮道子（東水大）
16. 真珠稚貝の人工培苗について
○森川吉郎（三井物産）・外海政治（いすず器材）
17. 1）動物性プランクトン“ワムシ”の連続培養装置……細田耕司（三井海洋開発）
2）海面育苗施設（ナーサリバージ）
……徳永栄一（三井海洋開発）
18. 鋼製魚礁の追跡調査……○飯高勇之助・津田良平・森永　勤（近畿大・農・水産）・瀬良　茂・高野幸三・小池　章（中山鋼業）

特別講演

座長：松生　洽（東水大）

西之島新島の地球物理・化学並びに海洋学的災害調査結果について…… 城戸卓夫（東水大）

映　画：西之島新島の記録（16ミリ　カラー）

6. 下記の諸氏が入会された。

正会員

氏　名	所　属	紹介者
結城了伍	北海道立栽培漁業総合センター	宇野　寛
小坂丈予	東京工業大学	佐々木忠義
城戸卓夫	東京水産大学	〃
大槻　忠	三菱総合研究所	〃

小堀　信幸	船の科学館	佐々木忠義
Samuel P. Meyers	Louisiana State University, U.S.A.	関　文威

7. 会員の住所，所属の変更。

氏　名	新住所又は新所属
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川村文三郎	東京都中央区築地 5-3-1 水路部構内 (財)日本水路協会
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長坂　実	仙台市八木山緑町 1-1 仙台電波工業高等専門学校
山本　克巳	東京都千代田区大手町 1-3-4 気象庁海洋気象部海洋課
松本　暁美	横浜市港北区篠原東 3-24-23
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川原田　裕	東京都千代田区大手町 1-3-4 気象庁海洋気象部海洋課
菱田　耕造	清水市折戸1000　東海大学海洋学部

8. 交換及び寄贈図書。

1) 研究実用化報告 **22**(12), **23**(1, 2). (電通研)
2) Science et Pêche, N° 229-231.
3) Preliminary Report of the Hakuhô maru (Ocean Res. Inst.) Jan. 21, Mar. 25 Cruise, 1971.
4) 航海，2月号，49年.
5) 鯨研通信，270，271
6) 神戸海洋気象台沿革誌，2月号，1974年.
7) 海洋産業研究資料，**5**(2, 3).
8) 港湾技術研究所報告，**12**(4).
9) 港湾技研資料，No. 171-175.
10) Ocean Age, **6**(4, 5).
11) 国立科学博物館研究報告，**17**(1).
12) 海洋機器開発，**6**(3, 4).
13) 広島県水産試験場研究報告，第5号.
14) 広島県水産試験場事業報告，昭和47年度.
15) Bulletin de L'association de Géographes Français, N° 411, 412.

日仏海洋学会賞受賞候補者推薦理由書

氏名:　松生　洽（東京水産大学）

題目:　大洋における光学的性質に関する研究

推薦理由: 松生氏は1961年頃から練習船海鷹丸に乗組んで，北太平洋，東部インド洋及び南極洋にわたる広範な光学的観測を行い，従来資料が極めて少なかった大洋の光学的性質に関して多くの新しい事実を見いだした。同氏の研究は，太陽エネルギー分布について天空から海中までを一貫して考察していること，及びほとんど地球全体にわたってグローバルにあつかっていること，の二点で特に高く評価されており，その成果の主なものを要約すれば次の通りである。

(1) 従来深い大洋では海域の違いや水塊構造によってあまり大きな差はないと思われていた海水の光学的性質について，実際にはかなり大きな差があることを広範な観測によって明らかにした。例えば，南極海域，亜南極海域，南極収束線域，黒潮海域，東部インド洋海域は，波長別ろ光特性，放射照度比，波長間強度比の各面から，それぞれ異なった光学的性質をもっていることや，水塊と水塊の接合部では光学的性質にも著しい特異性があることなど，多くの新事実を見いだした。

(2) 従来主に陸上の観測に基づいて研究されていた日射量の分布について，大洋上の観測から検討を加え，可能日射量及び海面日射量を広範囲にわたって算出し，可能日射量は各緯度ともUKRAINTSEVの値より約10%小さいことなどの結果を得た。

(3) これらから海洋生産に関連する海中太陽エネルギーフラックスの分布を計算し，例えば，10 m 深のその年間総量の比は，インド洋赤道域：黒潮：亜南極洋：南極洋：南極収束線域 = 100 : 54 : 44 : 13 : 6 であること等を示した。

以上の成果は海洋物理学の進歩に貢献する所が顕著であるのみならず，海洋の基礎生産や生態学の研究者を稗益する所も大であり，本賞を受けるに十分値する。

学会賞受賞候補者推薦委員会

委員長　森　田　良　美

主要論文

1966: A preliminary report on the primary productivity in the Eastern Indian Ocean in winter—IIOE report on productivity, 1963-1964, Umitaka-maru—Methods of experiments, data, and outlines. J. Tokyo Univ. Fish., Sp. Ed., **8**(1).

1967: Study on the optical characteristics of the waters in the three oceans. Part 1. Optical structure of the Kuroshio (Japan Current) from Lat. 20°N to Lat. 31°N along the meridian of 142°E. J. Tokyo Univ. Fish., **53**(1-2).

1968: The optical characteristics of the waters in the three oceans. Part 2. Optical structure of the Antarctic Ocean from Lat. 45°S to Lat. 70°S to Lat. 70°S and from the meridian of 132°E to 149°W, including the Ross Sea. J. Tokyo Univ. Fish., Sp. Ed., **9**(1).

1969: The optical characteristics of the waters in the three oceans. Part 3. The distribution of solar energy reached to and penetrated in the water of the Antarctic Ocean in the summer and its comparison to other oceans. J. Oceanog. Soc. Japan, **25**(2).

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1973: A study on optical nature in oceanic waters. La mer, **11**(1).

1973: Measurement of insolation and submarine irradiance. Preliminary Report of the Hakuhō Maru Cruise KH-71-3 (IBP Cruise) June 18-July 29, 1971. The Western North Pacific Ogasawara and Kuril Areas. Ocean Research Institute, University of Tokyo.

日仏海洋学会役員

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第15回総会で，昭和49年度から下記のように会費（年額）の改正が承認されましたのでお知らせ致します。

記

正会員費　2,500円

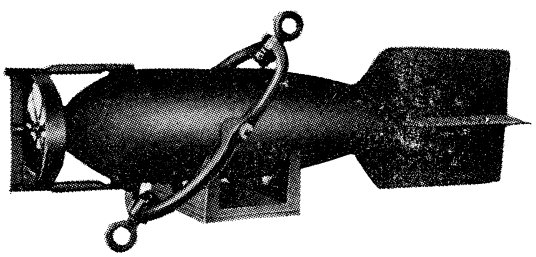
なお，既に49年度正会員費として1,500円をお払込み下された方は，お手数ながら差額1,000円をお払込み下さいますようお願い致します。

日仏海洋学会

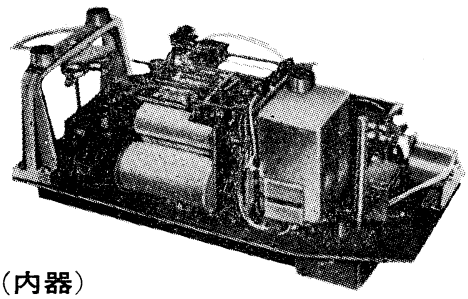
長期捲自記流速計

(NC-Ⅱ)

本流速計は海中に設置し、内蔵した記録器に流速流向を同時に記録するプロペラ型の流速計で約20日間の記録を取る事が出来ます。但し流速は20分毎に3分間の平均流速を又流向は20分毎に一回、共に棒グラフ状に記録しますから読取が非常に簡単なのが特徴となって居ります。



(外器)



(内器)

プロペラはA，B，C三枚一組になって居り

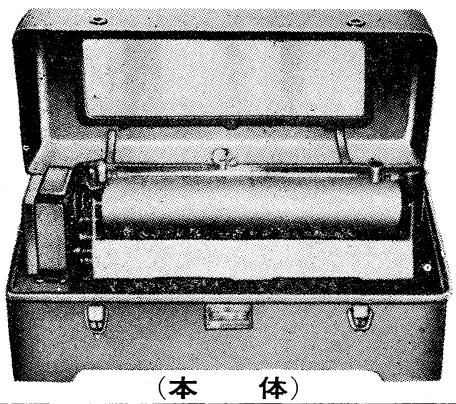
A(弱流用)……1m/sec
B(中流用)……2m/sec
C(強流用)……3m/sec

迄で一枚毎に検定してあります。

弱流ペラーに依る最低速度は約4cm/secです。

フース型長期捲自記検潮器

(LFT-Ⅲ)



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